



# Climate Change: Ready or Not

Climate Change Impacts, Vulnerability, Risk and Adaptation  
Strategies for the Salem Sound Area of Massachusetts



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## Abstract

This report aims to help six coastal cities located along the Salem Sound in Massachusetts understand the impacts of climate change, the vulnerabilities these populations will face as a result, and strategies they can use in order to effectively adapt to these changes. Background information is provided on the specific projected impacts the region will face in the future. A framework for addressing physical and social vulnerability was identified using Geographic Information System software, highlighting particular populations and spaces susceptible to the impacts of climate change. Finally, key concepts and strategies are reviewed and recommended, providing a starting point for how these communities can incorporate, enhance, and implement adaptation initiatives that will make their communities resilient, safe and sustainable in the long term.

## Executive Summary

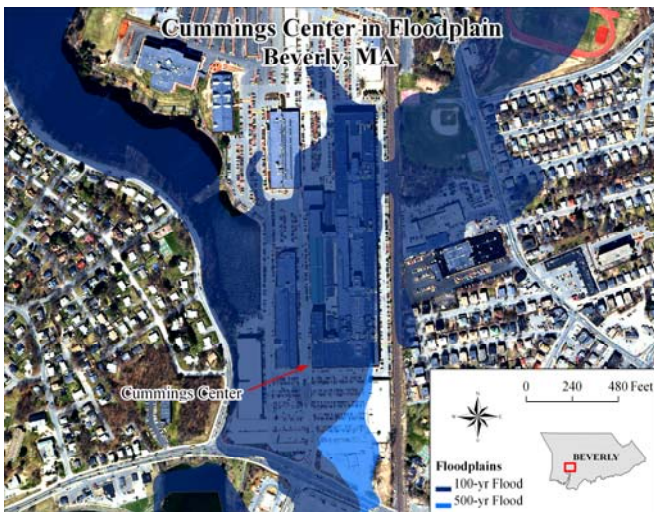
The six communities of Marblehead, Salem, Peabody, Danvers, Beverly and Manchester, which together constitute the Salem Sound area in Massachusetts face increased risk to climate change due in large part to their coastal locations. In order to help ensure that these communities are moving in the direction of increasing their climate change resiliency, Salem Sound Coastwatch (SSCW) partnered with Tufts University UEP students to perform a climate change vulnerability assessment and develop an adaptation strategy.

Based on climate change scenarios the Northeast is experiencing, and expected to experience, the following:

- On average, temperatures in the Northeast have increased about 0.5°F per decade between 1970 and 2000, with average winter temperatures warming even faster at about 1.3°F per decade (Frumhoff 2007, 2).
- By the middle of this century, winter temperatures are projected to increase by 4-5°F or 4-7°F and summer temperatures are projected to increase by 2-5°F or 4-8°F. By late in the 21<sup>st</sup> century, winter temperatures are projected to increase by 5-8°F or 8-12°F and summer temperatures by 3-7°F or 6-14°F, depending on the emissions scenario (Frumhoff 2007, 3).
- Sea-surface temperatures in the U.S. Northeast have risen by 1°F since 1900 and are expected to continue to rise. By 2100 this could mean sea surface temperatures that are 4-5°F or 6-8°F higher (Frumhoff 2007, 12).
- Sea levels have already risen 10 inches over the past 100 years in the Massachusetts area. Part of the relative increase is due to land subsidence, but part is also due to an actual increase in the water level (CHC 2007, 12).
- Sea level is projected to rise anywhere from 7 to 14 inches with lower emissions and from 10 to 23 inches with higher. A more recent analysis even projects a rise of 2 to 4.5 feet with higher emissions (Frumhoff 2007, 12).
- Precipitation is projected to increase by about ten percent, or four inches per year, by the end of the century. However, that increase in precipitation is not expected to be evenly distributed throughout the year (Frumhoff 2007, 8).
- Increased winter precipitation falling as rain will not only cause flooding problems, but will also contribute to droughts later in the year (Frumhoff 2007, 8-9, 63).

It is known with high confidence that even with immediate drastic reductions in greenhouse gasses, climate change effects will still be felt in the Northeast. This creates a need for a process of assessing potential vulnerabilities and risks to climate change in order to plan for and implement effective adaptation strategies that can mesh well with the many other priority planning considerations of municipalities.

In order to accomplish this, vulnerability and risks assessment and mapping were completed using geography information systems (GIS) technology for the Salem Sound communities. This qualitative assessment examined social and physical vulnerabilities and risks. Populations in the Salem Sound area were ranked by their mobility capacity, resource capacity and adaptive capacity, an aggregate of mobility and resource capacity. Place vulnerability analysis was used to examine the connections between physical and social vulnerabilities in the City of Beverly. Potentially vulnerable properties and buildings were identified. Flooding of sensitive land and buildings has the potential to cause costly damage in the area.



Vulnerable Zone	City of Beverly Buildings Value (in dollars)
2-Meter Coastal Zone	101,532,600
3-Meter Coastal Zone	1,033,923,600
4-Meter Coastal Zone	1,222,234,200
100-yr Floodplains	1,104,974,730
500-yr Floodplains	1,356,781,420

Based on the information determined by the completion of the risk assessment and vulnerability mapping a series of adaptation strategies were developed for the Salem Sound communities. The recommendations for Salem Sound communities include:

- Review their hazard mitigation plans and incorporate climate related risks within these plans, and incorporate new and emerging best management strategies.
- Update, review, and strengthen their floodplain overlay district.
- Review their setback laws for coastal and floodplain development, and compare with best management practices across the state of Massachusetts and within other coastal communities.
- Review their wetland preservation and protection laws, and work closely with their conservation commissions to amend and strengthen them.
- Consider the implementation of a rolling easement program.
- Review their land acquisition policies and align them to purchase parcels highly exposed to climate change impacts.
- The six coastal cities should create a master plan for coastal defenses that combine concepts of hard and soft strategies.
- Increase capacity of stormwater collection systems to accommodate projected climate change impacts.
- Salem Sound communities should also work towards developing a Community Rating System that can help lower insurance premiums for residents. Creating National Flood Insurance Program standards for buildings within the 500-year floodplain should also be considered.
- Sound communities should prioritize the establishment of a comprehensive alert system and identify vulnerable groups with respect to each risk.
- Create incentives for developers to relinquish development rights in sensitive areas by offering the right to build in another more suitable area

A natural outcome of this process is the identification of needs for adequately understanding vulnerability and risk to potential climate change impacts. These recommendations represent a starting point for communities and advocates so that they may begin to consider specific local needs, resources and priorities in developing their approach to climate change adaptation.

## Acknowledgements

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## Project Background

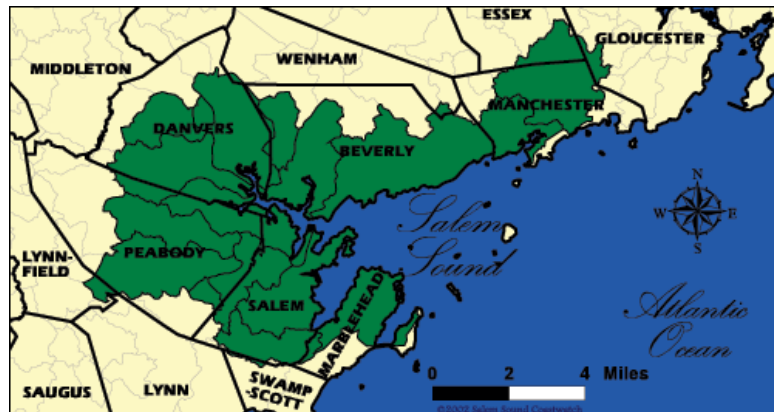
Climate change is occurring and the impacts are already being felt in many regions. It is also widely accepted that, even after introducing significant measures to reduce greenhouse gas emissions, some additional degree of climate change is inevitable and will have economic, social and environmental impacts for communities (Natural Resources Canada, 2007). In order to reduce the potential negative impacts of climate change it is important that communities begin the process of undertaking climate change vulnerability assessments and developing appropriate adaptation strategies.

The six communities of Marblehead, Salem, Peabody, Danvers, Beverly and Manchester, along Salem Sound in Massachusetts, face increased risk of climate change, due in large part to their coastal locations. Salem Sound Coastwatch, a non-profit coastal watershed organization that works cooperatively to protect and enhance environmental quality of the Salem Sound watershed, initiated a project proposal with the Department of Urban and Environmental Policy and Planning at Tufts University to conduct research into climate change adaptation. This project was pursued in order to assist Salem Sound communities in developing a greater understanding of climate change, explain climate change impacts to Northeastern coastal communities, and begin to develop strategies and tools decision makers can use to make their communities more resilient.

# Salem Sound and Climate Change

## Introduction

Climate change is a global phenomenon that will have varying regional impacts. These impacts are projected to intensify as global atmospheric concentrations of greenhouse gases continue to rise. In New England, changes in the region's climate over the next century are likely to have serious impacts on the region's economy, infrastructure (including housing, roads, and utilities), and natural environment. While communities are working hard to implement programs that promote health, safety, and welfare for their populations, there is a critical need to incorporate climate change projections into decision making processes in order create the most resilient communities long into the future. Early adaptation planning and implementation can help communities improve their adaptive capacities and fully prepare for climate change impacts



## Salem Sound

Social and physical characteristics of Salem Sound influence how climate change impacts will be experienced locally. Understanding social and physical resources and their spatial distribution in the area is critical for assessing local effects. Salem Sound is an inlet to the Atlantic Ocean located north of Boston in Massachusetts. It features a primarily rocky coastline with areas of low elevation, high density development that is often built up to the water, commercial districts with historical flooding problems and varying municipal resources. The total population of the six towns was roughly 200,000 in 2000, five percent of which were living below the federal poverty line, and fourteen percent of which were over the age of 65 (U.S. Census Bureau). Additionally, three colleges, major sewage and power infrastructure, a coastal fishing and recreation economy, and coastal wetlands are all present in the area.

Due to their coastal locations, these communities will face challenging impacts as a result of climate change, including rising sea levels, stronger storm surges, possible disruption of the marine ecosystem and increased public health pressures. Though similar impacts will occur across town lines, the adaptive capacity of constituents, infrastructure and natural resources will vary. Adaptive capacity refers to the ability of individuals or natural systems to cope with and recover from climate change



impacts and is a critical factor in assessing local vulnerability to climate change. This is a major theme of this report.

## An Overview of Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC)<sup>1</sup>, it is “unequivocal” that Earth’s climate is warming and “very likely” (a greater than 90 percent certainty) that heat-trapping gases from human activities have caused most of the global warming experienced over the past 50 years. The primary drivers of climate change are the burning of fossil fuels, such as coal and oil, and tropical deforestation. These activities release carbon dioxide (CO<sub>2</sub>) and other heat-trapping, or greenhouse, gases into the atmosphere. Atmospheric CO<sub>2</sub> concentrations have already risen to their highest levels in more than 650,000 years, which has been the primary factor causing average annual temperature in the Northern Hemisphere to increase more than 1.3<sup>0</sup>F over the past century (IPCC Impacts, Adaptation and Vulnerability 2007, 8).

## Climate Change and Uncertainty

Climate change projections are developed using computer-based models of global climate based on scenarios of future greenhouse gas emissions. While computer modeling of climate change has progressed significantly, there is still a significant amount of uncertainty in this science because models cannot fully account for the intricate nature of global climate and ecosystems (Climate Smart Adaptation 2005). Another complication adding to the uncertainty of how communities will be impacted by climate change is the issue of scale. Climate change models are run at a global scale, with grids the size of small countries, making it difficult to accurately pinpoint the impacts a particular community will face. Additionally, it is easier to predict with greater certainty changes in the short-term, rather than the long term.

Although uncertainty in climate change modeling and projections is often a recurring theme and has served as a deterrent in taking action on this issue, it is important to emphasize that the debate is no longer about whether climate change will happen, but to what degree and how severe the impacts will be. Furthermore, uncertainty does not preclude our ability and responsibility to initiate climate adaptation action (Natural Resources Canada, 2007).

## Climate Change Mitigation vs. Adaptation

The response to global climate change can be broken down into two main categories, mitigation and adaptation. Mitigation efforts focus on finding ways to reduce emissions of greenhouse gases while adaptation efforts seek to find ways to make adjustments in response to current or anticipated

<sup>1</sup> The IPCC is comprised of hundreds of experts from around the world. They are responsible for providing comprehensive, objective and up-to-date evaluations of the current state of knowledge about climate change and its impacts on the world. <http://www.ipcc.ch/about/about.htm>

consequences of climate change (The State of Queensland 2005, 9).<sup>2</sup>

While hundreds of municipalities have joined the U.S. Conference of Mayors and the Sierra Club to reduce their carbon footprint, only a few governments have addressed the issue of adapting to climate change and most have not been wide ranging efforts. The City of Revere, Massachusetts and Cape May County, New Jersey have been the subjects of GIS based vulnerability analyses that have examined risk to extreme storms and sea level rise respectively. Additionally, King County, Washington created a climate action plan in 2007, laying out both mitigation and adaptation goals and action items. However, local adaptation planning and implementation has not been widely adopted.



Even with mitigation of greenhouse gas emissions, adaptation will be needed. Even if mitigation targets are achieved, it is likely to take several hundred years to stabilize the effects of past emissions. Under the most optimistic of circumstances, some climate change is inevitable and adaptation to these changes will be essential (UK Ministries of Agriculture, Fisheries, and Food 2001, 19). Additionally, the severity of the impacts from past emissions is likely to intensify due to the long lifetime of many greenhouse gases (Frumhoff 2007, 2).

Mitigation and adaptation efforts are both extremely important and by no means mutually exclusive. However, the scope of this paper is limited to the identification and implementation of appropriate adaptation strategies.

## How to Address Adaptation

When making decisions about how to respond to climate change impacts, governments and local officials need a way to evaluate alternative implementation strategies. This can be accomplished by developing a policy or decision making framework (SMEC 2007, 13). A climate adaptation framework consists of steps that can be used to systematically identify climate change risk and implement adaptation measures in a appropriate and effective manner. There are currently several governments and organizations, locally and internationally, that have developed variations of a climate change adaptation framework. They range from more general three-step approaches to more detailed frameworks that outline nine or more steps. It will be up to each community to review the variety of frameworks that exist and determine which best work for its particular circumstance.

A recent study of six urban regions found that those most successful at implementing climate change adaptation measures utilized frameworks featuring these four elements:

- Measures to increase public awareness of likely climate change impacts and to engage stakeholders in identifying problems and solutions.
- A systematic review of climate trends and projections for the specific urban region and an analysis of where and how major impacts are likely to occur.
- A range of options for reducing vulnerability to climate change, including an assessment of existing programs that create a foundation for an adaptation strategy.

<sup>2</sup> More about local climate mitigation efforts ICLEI (<http://www.iclei.org/>) and City of Seattle, WA (<http://www.seattle.gov/mayor/climate/>) websites.

- A strategy for putting the plan into action (Snover 2007, 2).

Based on the information outlined above, an example of a climate change adaptation framework that we would recommend for the Salem Sound Communities is as follows:

- Identification of climate change impact related risks
- Risk Analysis - by identifying existing management strategies, the likelihood of each risk, the consequence should this likelihood be realized and the level of resulting risk for each climate change impact
- Prioritization of risks requiring further attention by ranking risks by severity and identifying those that require additional analysis
- Establishment of processes to ensure higher priority risks are managed effectively
- Risk Treatment - through the identification and selection of the relevant risk management and/or adaptation options
- Monitoring and evaluation

The framework outlined above is a risk management approach to climate change and is an adaptation of the Australian National Climate Change Adaptation Framework (SMEC 2007, 15). This risk management approach is commonly utilized by communities and countries alike. For example, a similar, but more detailed framework is utilized by New York City to manage climate change risk to its water systems (Rosenzweig 2007, 1391).

## The Need to Adapt Now

Adjustments in planning and policy in response to a variable climate already occur. Most communities already have plans in place to prepare for and adapt to extreme weather events such as drought, hurricanes and floods. These management plans help to mitigate the effects of such climate disruptions when they occur through preparedness. However, current literature on climate change impacts, as well as the analysis in this report conclude that these current measures will not be sufficient to protect infrastructure and natural ecosystems in the long term. Therefore, it is our recommendation that Salem Sound communities act now to adjust planning and management policies and practices to prepare for climate change impacts.

Inaction on the part of a community to plan for climate change now could decrease that community's ability to adapt to climate change in the future, as well as lead to miss-guided investments in infrastructures, and missed opportunities to develop technologies and knowledge (The State of Queensland 2005, 10). For example, land use and building decisions have long-term consequences and, as a result, climate change impacts could eventually have negative implications on those decisions (O'Connell and Hargreaves 2004, 4). By conducting early climate change vulnerability and risk analyses and taking proactive steps now to mitigate vulnerability and risk, communities will increase their resilience and decrease the need for recovery (Clark 1998, 78-80). Additionally, since Salem Sound communities are already working on planning, policy and implementation strategies to address weather related events, incorporating even higher climate change resiliency standards into current management and decision-making frameworks in the Salem Sound area can be smoothly incorporated. Further discussion of adaptation strategies is provided in Chapter 5.

# Projected Climatic Changes and Possible Impacts in the Salem Sound Area

## Projections and Emissions Scenarios

In order to evaluate vulnerability and risk it is necessary to consider the projected nature and magnitude of climatic changes at the most local scale possible. Adaptation strategies will vary based on what changes are most likely in a given area. In order to identify areas to be evaluated for vulnerability and risk, this chapter will provide an overview of projected climatic changes in the coastal Northeastern United States and some of the possible impacts of those changes.

Future conditions are presented as a range of projected changes, based on the emissions scenario being modeled, rather than precise predictions. Atmospheric carbon dioxide (CO<sub>2</sub>) is currently concentrated at about 380 parts per million (ppm). Lower emissions scenarios assume CO<sub>2</sub> concentrations of about 550 ppm (Frumhoff 2007). Higher emissions scenarios vary. When evaluating discrepancies among climate change projections, it is best to rely on projections made within the past 5 years and on those which are derived from multiple models. Some projections, such as changes in temperature, are more certain than others, such as changes in precipitation (Snover 2007, 36).

## Rising Temperatures

### Historical Trends and Projected Changes

Rising temperature is one of the most fundamental effects of global climate change. Historical trends show that warming is already taking place. On average, temperatures in the Northeast have increased about 0.5°F per decade between 1970 and 2000, with winter temperatures warming even faster at about 1.3°F per decade (Frumhoff 2007, 2). Averaging five days per year, Northeastern cities are already experiencing about five days per year over 90°F, twice as many as half a century ago (Frumhoff 2007, 6).

The Northeast United States is expected to experience rising temperatures over the rest of this century. By the middle of this century, winter temperatures are projected to increase by 4-7°F and summer temperatures are projected to increase by 2-8°F. By late in the 21<sup>st</sup> century, winter temperatures are projected to increase by 5-12°F and summer temperatures by 3-14°F (Frumhoff 2007, 3). The range in these temperatures projections is caused by variation in emissions scenarios

When humidity is factored in with ambient air temperature, the summer heat index, or the temperature that the human body will perceive, is projected to increase 12-16°F in the event of higher CO<sub>2</sub>

concentrations (Frumhoff 2007, 6). Cities in the Northeast are projected to experience at least 60 days over 90° F and 14-28 days over 100° F per year (Frumhoff 2007, 6-7) if atmospheric CO<sub>2</sub> concentrations reach 940 ppm (Frumhoff 2007, xi). Even if CO<sub>2</sub> concentrations are stabilized at the lower limit, Northeastern cities could still expect over 30 days over 90°F and 3-9 days over 100°F per year (Frumhoff 2007, 6-7). Additionally, under higher emissions scenarios, winter could be reduced to only a week or two in Massachusetts (Frumhoff 2007, 3).

## Temperature Thresholds

All populations have a heat and cold threshold at which mortality increases sharply. The effects of rising temperatures on vulnerable populations are a serious concern. Especially vulnerable populations include infants, the elderly, the poor, the overweight and people living in urban areas. Heat waves have already proven to be deadly, as evidenced by over 700 deaths in Chicago in July 1995 (Kirshen 2004, 115).

## Disease and Illness

In addition to the direct effects of heat, rising temperatures could increase the prevalence of other conditions and illnesses. Longer summers with higher temperatures and higher CO<sub>2</sub> concentrations will extend the growing season and possibly pollen production, which could exacerbate allergies (Natural Resources Canada, 2007). Higher temperatures and more frequent flooding may also allow certain pests, such as mosquitoes carrying West Nile Virus and malaria, and ticks carrying Lyme disease into the area (Frumhoff 2007, 91, 100-101).

## Air Quality Impacts

Rising temperatures could lead to poorer air quality in the Northeast (Frumhoff 2007, 91). This is especially true for ground level ozone, which is formed by a chemical reaction of nitrogen oxides and volatile organic compounds on hot summer days (Franco 2005, 22). Higher temperatures accelerate the chemical process of ozone formation. Thus the same level of emissions would result in worse air quality, a serious issue in a place like Massachusetts, which has the highest rate of adult asthma in the U.S. (Frumhoff 2007, 91, 97).

## Marine Impacts

Sea-surface temperatures in the U.S. Northeast have risen by 1°F since 1900 and are expected to continue to rise. By 2100 this could mean sea surface temperatures that are 4-5°F or 6-8°F higher (Frumhoff 2007, 12). Warming waters are expected to cause the range for some populations to shift northward. Cod, American plaice, haddock, Atlantic halibut, redbfish, and yellowtail flounder populations could decrease in the Gulf of Maine and New England coastal waters (Field et al. 2001, 479). Meanwhile, other species typically found in warmer southern waters may become more prevalent in the area. These types of changes could effect overall marine diversity in many ways (Frumhoff 2007, 39). For example, it is known that a rise in temperature has already shifted the reproductive cycle of *Calanus finmarchicus*, a primary source of food for young cod, thus endangering cod survival (Frumhoff 2007, 40). Other maladies, such as toxic algal blooms have



been seen to expand with warmer water temperatures causing more red and brown tides, which are harmful to humans and marine life (Boesch et al. 2000, pg 106).

The effects of rising water temperatures on marine life are uncertain, but it is expected that the harvest levels of certain species of fish, such as cod, will be reduced in the Northeast (Natural Resources Canada 2007). Although the lobster and fishing industry is not predominant in the Salem Sound area, a loss of these industries could cause some economic disruption locally.

## Wetland Impacts

Estuaries and wetlands provide food or protection to one third of the commercial fish and shellfish species harvested in the coastal Northeast, making this more than just an ecological concern (Frumhoff 2007, 28). Water temperatures in shallower estuaries rise more rapidly than ocean temperatures. Warmer water temperature causes the solubility of oxygen in water to decrease while simultaneously causing marine animals to consume more oxygen. This ecological process could lead to a worsening of oxygen depletion in many estuaries (Boesch et al. 2000, pg 76-78).

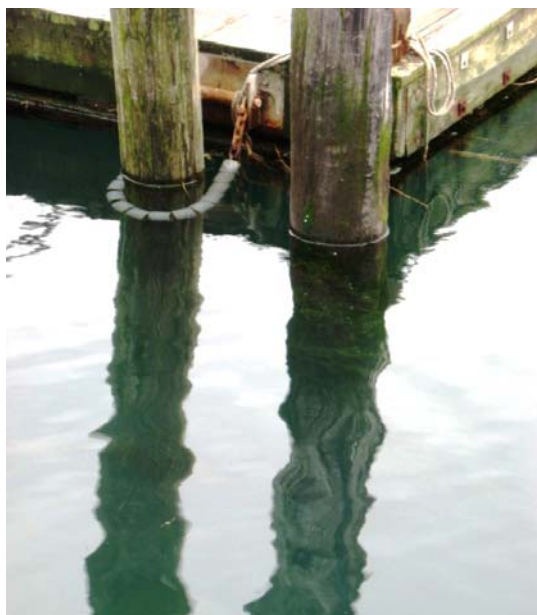
## Rising Sea Levels

### Historic Trends and Projected Changes

Another widely accepted effect of climate change is increasing sea levels. Sea levels have already risen 10 inches over the past 100 years in the Massachusetts area. Part of the relative increase is due to land subsidence, but part is also due to an actual increase in sea level (CHC 2007, 12).

*IPCC projects that global sea levels will rise between 7 and 14 inches under the lower-emissions scenario and between 10 and 23 inches under the higher emissions scenario. A more recent analysis, however, has projected much greater end-of-century sea-level rise: on the order of 2 to 4.5 feet above 2005 levels under the higher-emissions scenario. Even these projections may be conservative in that they do not account for the rapid rate of ice breakup and melting currently being observed in the polar ice sheets (particularly those of Greenland), nor do they assess the potential for further acceleration of this melting. (Frumhoff 2007, 12)*

Even if greenhouse gas emissions are stabilized, sea level will continue to rise for many centuries due to thermal expansion of water molecules (IPCC 2007, 20).



### Inundation and Higher Storm Surge Impacts

Rising sea level is a significant concern, not only because of the potential to permanently inundate low-lying lands, but also from increased storm- surges which can result in severe erosion (Frumhoff 2007, 15). “Storm-surge levels will be affected by sea-level rise, even if the frequency and intensity of storms do not change.” (Najjar et al. 2000, p 221). A strong-storm can temporarily cause

water to rise up to 23 feet above normal levels. Any increase in average sea level will also increase storm surge levels. Storm surges are already the primary cause of insured property damage and beach erosion in the U.S. (Field et al. 2001, 472). This has led to insurance agencies dropping or severely limiting their coverage of coastal properties.

*In 2006, Allstate announced that it was dropping coverage for thousands of homeowners along the Mid-Atlantic and Northeast coasts, including Connecticut, New Jersey, and New York City. State Farm itself decided it would no longer write new policies for properties within a mile of the ocean. (Frumhoff 2007, 26).*

Although more rocky coastlines, such as those found in much of the Salem Sound area are less vulnerable than others, even small beaches and coastal marshlands can present areas of localized vulnerability (Burkett et al. 2001, 6.4). Other geologic factors can influence erosion rates as well, making the stability of even rocky coastlines to uncertain (Burkett et al. 2001, 6.42).

### **Flooding and Over- Salinization of Coastal Wetlands**

**R**ising sea level is also projected to impact coastal wetlands through flooding and increasing salinity (Field et al. 2001, 472, Najjar et al. 2000). As the sea level rises, wetlands will be inundated and lost if sediment inputs are not sufficient to counterbalance the rising water, putting areas not fed by rivers at greater risk (Najjar et al. 2000, 221).



Wetlands surrounded by higher elevations or human development will not be able to migrate inland and will be lost as the sea level rises (Field et al. 2001, 476). Ill-designed bridges and culverts can serve to further endanger wetlands in some areas by preventing normal tides from reaching an area or trapping too much water and causing flooding (CHC 2007, 27). Wetlands can serve as important buffer areas from ocean tides and surges, improve water quality and reduce nutrient loads to the ocean and therefore have immense value to society (Wu 2002, 260, Field et al. 2001, 465-466, 475).

### **Saltwater Intrusion**

**A**s sea levels rise, the risk of saltwater intrusion into coastal aquifers increases (Natural Resources Canada, 2007). Saltwater intrusion is a risk when groundwater does not recharge coastal aquifers fast enough to resist the pressure of saltwater from the ocean (Ranjan et al. 2007, 388). This can result in a loss of freshwater resources for a community, especially for those who rely on wells.

# Changes in Precipitation

## Historical Trends and Projected Changes

Average annual precipitation has increased by five to ten percent since 1900, a trend that is expected to continue over the next century. Precipitation is projected to increase by approximately ten percent, or four inches per year, by the end of the century. However, that increase in precipitation is not expected to be evenly distributed throughout the year. Increased precipitation is projected for winter months, while summer precipitation will remain about the same. At the same time, warmer temperatures are projected to cause more winter precipitation to fall in the form of rain, rather than snow (Frumhoff 2007, 8).

## Increased Flooding

Shifting of precipitation patterns to the winter months is projected to increase flooding events (Franco 2005, 19). Precipitation intensity, or the average amount of rain that falls on a day, is projected to increase by eight to ten percent by the middle of the century and by twelve to thirteen percent by the end of the century. The wettest five day period each year is projected to have more total precipitation. With more precipitation falling all at once, soil saturation will be reached sooner increasing runoff. Runoff can lead to flooding and contaminated water (Frumhoff 2007, 31, 63).

## Increased Droughts

Although average annual precipitation is projected to increase and summer precipitation is projected to remain the same, an increase in the number of droughts is projected, especially under higher emissions scenarios. Short-term droughts, lasting one to three months, are projected to occur about once a year in New England by the end of the century. Medium-term droughts of three to six months are also projected to increase in the area. Drought increases are due to the expected reduction in winter snowpack in addition to higher evapotranspiration rates. Snowpack normally stores water to be released slowly in the spring as it melts, but increased winter precipitation in the form of rain will reduce stored moisture (Frumhoff 2007, 8-9, 63).

## Water Quality

Water quality can be severely affected by both heavy precipitation events and droughts. Coastal ecosystems are at risk of excessive nutrient loading and contamination as a result of heavy precipitation events (Field et al. 2001, p 469). Contamination often comes from urban and agricultural runoff (Natural Resources Canada, 2007). However, low water levels in the summer, coupled with higher temperatures may lead to bacterial, nutrient and metal contamination increases (Natural Resources Canada, 2007).



# Understanding Risk & Vulnerability From Climate Change Impacts

## Introduction

Once the projected impacts of climate change are known, the next step is to conduct vulnerability and risk assessments for the systems, people and places that may be affected. The purpose of this chapter is to present a meaningful framework for identifying vulnerabilities and risks from climate change impacts and to distinguish between vulnerability and risk assessments. Although vulnerability and risk are interrelated, they are distinct steps in the planning process. The concept of place vulnerability, in which population vulnerability is assessed relative to exposure to physical vulnerability, is introduced. This approach is used for the identification of priority planning areas. Evaluating the adaptive capacity of individuals is a critical component of understanding social vulnerability within communities.

## Vulnerability Assessment

### Identifying Vulnerability

Vulnerability to climate change is determined by a system's or population's sensitivity to climate and its adaptive capacity, or ability to change in response to changing climate conditions (Snover et al. 2007, 83). Vulnerability can be assessed across the four broad categories of the built environment, societal health and safety, business, institutional and economic vulnerability, and natural resource and ecosystem vulnerability (Heinz Center 2000, Chapter 4). The following questions from *Preparing for Climate Change – A Guidebook for Local, Regional and State Governments* can be used to evaluate the vulnerability of systems to the projected impacts of climate change.

- How exposed is a system to the impacts of climate change?
- Is the system subject to existing stress? Currently stressed systems are more likely to be sensitive to the impacts of climate change.
- What is the impact threshold associated with a system? The capacity of critical infrastructure could be exceeded by climate change impacts. For example, sea walls are built to handle a certain size storm at high tide, with additional buffer factored in. How much additional sea level rise could such infrastructure accommodate? (Snover et al. 2007)



## Built Environment

Vulnerability of the built environment can be assessed through a thorough examination of how well planning and policy can mitigate hazards and potential increases in those hazards due to climate change. Understanding the answers to these questions can help to define the vulnerability of the built environment.



- Where are populations and residential, commercial, and industrial development located with respect to hazards?
- What is the value of at risk property and how much of it is insured?
- What is the exposure of municipal infrastructure to hazards and how does a community's planning address the expansion of this infrastructure?
- Have existing buildings been constructed to withstand coastal forces?
- How resilient are transportation, utility, and communication facilities?
- What are past, present and future hazard mitigation strategies?
- Is there effective land use planning?
- Are coastal hazards and projections of climate change impacts considered in the process of development and infrastructure siting?
- Are building codes strong and well enforced? (Heinz Center 2000, Chapter 4).

## Social Vulnerability

In understanding social vulnerability, the Heinz Center also synthesizes variables, such as income level, age, family structure, disability, and employment status, to a composite for social vulnerability. All risk and vulnerability assessments are subject to intrinsic value judgments, but the Heinz Center highlights the importance of attempting to understand social vulnerability as thoroughly as possible.

*In one sense, it is social vulnerability that turns a coastal storm into a disaster. Any given disaster can be thought of as a failure of the social systems constituting a community to mitigate or adapt to an environmental event. (Heinz Center 2000, 188)*

Several studies have incorporated social vulnerability analysis into hazard risk assessment (Clark et al. 1998, 73) as we have done in the analysis found in Chapter 4.

## Vulnerability of Places

Based on physical vulnerability to a hazard and the social capacity to withstand the damage of a hazard and recover from it, an approach that integrates the two within a specific geographic domain has gained value and has been termed the vulnerability of place (Wu et al. 2002, 265). In this type of analysis, the extent of a hazard is overlaid on a proxy for social vulnerability, and the vulnerability of those that face the greatest risk is conveyed clearly.

## Natural Environment

Evaluating the vulnerability of natural ecosystems is difficult due to their complexity and because the resilience of natural systems is not always well understood. Some species and ecosystems have greater adaptive capacity than others. These factors are best examined by those with biological expertise. However, risk assessment for ecosystems can be even more difficult. Even when the sensitivity and adaptive capacity are well known, the value of a species or ecosystem is often disputed.

# Risk Assessment

## Identifying Risk

Risk assessment has two components. The first part is an evaluation of the magnitude of the consequence of a projected impact. This can include economic, social, cultural, ecological and other results of a projected change (Snover et al. 2007, 87). The second part is the determination of the likelihood of adverse impacts to the social, natural, built, and economic environments. This may be done quantitatively or qualitatively depending on the data available and the purpose of the assessment (Snover et al. 2007, 89).

## Costs and Benefits

Cost-benefit analysis will be a critical step in risk assessment because communities have limited resources to dedicate to adaptive management strategies. The benefits of the adaptation action should strive to outweigh the costs, both economic and social. According to a report conducted by the United Nations Environmental Program Finance Initiative, adaptation efforts can “reduce impacts by a factor of 10 to 100 for often little cost, for example by designing hurricane-resistance into infrastructure and buildings” (UNEP 2006).<sup>3</sup>

## Needs and Recommendations

Adequate planning is constrained by the capacity to understand future vulnerabilities and risks. There are several improvements that would assist local officials in assessing community climate change vulnerability and risk. They include the following suggestions:

- Develop uniform methods for modeling local and regional scale shoreline changes associated with varying degree of sea level rise projections.
- Establish best practices and case studies highlighting the benefits adaptive management.
- Utilize workshops and software tools focused on community-level vulnerability assessments and adaptation planning to support effective action by towns.
- Develop improved modeling to predict migration or vertical accretion of beaches and wetlands. Without this, planning decisions related to flooding vulnerability cannot be properly assessed in terms of cost and benefits.
- Develop a comprehensive needs assessment of social, legal, and economic issues related to sea level, shoreline retreat, armoring, beach nourishment, and “no action” management alternatives.
- Storm surge models must be improved.
- Understanding of flood zone locations needs to be improved.

A well promoted clearinghouse for federal, state, and local programs, research activities, and funding opportunities must be established and utilized by managers and decision-makers

<sup>3</sup> Resources in the form of funding opportunities, and valuable literature describing cost-benefit analysis frameworks can be found in Appendix B.

# Vulnerability and Risk Assessments for Beverly and Salem Sound

## Approach

Qualitative vulnerability and risk assessments were conducted for areas within the City of Beverly and the Salem Sound area that may experience increases in flooding frequency and magnitude based on climate projections for the Northeast. The analyses were conducted using geographic information systems (GIS), specifically the ArcGIS program, and information from an extensive literature review. Populations vulnerable to existing and potentially increasing flood hazards were identified by using a place vulnerability assessment approach as described in Chapter 3. This type of analysis is conducted by evaluating the adaptive capacity of populations residing in areas with higher relative risk to a physical hazard, in this case flooding, in order to identify areas of potentially high planning priority.

## Methodology<sup>4</sup>

### Sensitivity to Flooding

Because flooding events are highly disruptive to the desired use of property, land can be considered highly sensitive to this type of impact. Flooding can deprive people of their homes, businesses, schools, libraries and other services and can minimize or eliminate valuable ecological services provided by wetlands, forests and other habitats. Although flooding can be more or less severe, even minor flooding damage can temporarily dislocate people.

### Likelihood of Flooding

Two types of land vulnerable to flooding were identified in this analysis, coastal land vulnerable to rising sea level and to higher coastal storm surges and all land vulnerable to flooding from heavy precipitation events. Separate analyses were conducted for each of these types of vulnerabilities for the entire Salem Sound area and for the City of Beverly separately.

Three levels of coastal vulnerability were examined. The most vulnerable coastal land was determined by selecting all land at or below two meters elevation that is contiguous to the ocean or an inlet to the ocean, as indicated by the digital elevation model. The second most vulnerable coastal land was determined by selecting all land contiguous to the ocean or an inlet to the ocean that is at or below

<sup>4</sup> A full list of data used in this analysis and a more detailed methodology for data processing and analysis steps can be found in Appendix C.

three meters elevation. The third most vulnerable coastal land was determined by selecting all land contiguous to the ocean or an inlet to the ocean at or below 4 meters elevation. Coastal land at the lowest elevations is most likely to be impacted by rising sea level and increased storm surges, allowing these three selections serve as measures of relative probability of flooding. The probabilities of impacts are not quantified here, but, according to projections, all three selections could be impacted in the next century.

Two levels of land vulnerable to flooding from heavy precipitation and storm events were also analyzed. The highest level of vulnerable land was determined to be all land within the 100-year floodplains and the second level of vulnerable land was determined to be all land within the 500-year floodplain. Again, these areas can be used to evaluate relative probability of flooding.

### **Adaptive Capacity**

Census data were used to identify two categories of populations that are potentially vulnerable in flooding events, those with limited mobility capacity and those with limited resource capacity. Limited mobility capacity was determined by identifying populations that may have trouble evacuating due to lack of resources or limited ability to care for themselves. Limited resource capacity was derived from factors that may limit a population's ability to adequately prepare for or recover from a flooding event or other disaster. Together, mobility capacity and resource capacity form adaptive capacity.

The variables used to determine mobility capacity were:

- percent of households without a vehicle,
- percent of the population living below the federal poverty level,
- percent of the population that is physically disabled,
- percent of the population that is mentally disabled,
- percent of the population that is at 65-years old or over,
- percent of the population that is 65-years old or over and living alone, and
- percent of the population less than five years old.

The variables used to determine resource capacity were:

- percent of the population living at or below the federal poverty level,
- percent of the population that is unemployed,
- percent of the population that has no high school diploma,
- percent of households that do not speak English, and
- percent of households with a single parent.

After each of the mobility capacity variables were independently mapped by Census block group, the population and household percentages for each of the variables were summed to create response capacity, which was also mapped by Census block group. The same was done for the resource capacity variables, resulting in a resource capacity value for each Census block group. This resulted in some values of over 100 for mobility and resource capacity, but all Census block group values were mapped and evaluated relative to one another, not as an actual percent of the population. Adaptive capacity values were derived by adding the mobility and resource capacity values. Because living below the poverty level was used as a variable in both mobility and resource capacity, it is weighted twice in the adaptive capacity values. This weighting of poverty in vulnerability assessments is supported by literature informing other studies (Wu et al. 2002 and Clark et al. 1998, 74)

All three composite values were divided into four classifications based on natural breaks in the data. Mobility, resource and adaptive capacity were mapped by lowest, lower, higher and highest for Census

block groups. Populations with lower and lowest mobility, resource and adaptive capacities would be more vulnerable to increased flooding than those in the higher and highest categories. These classifications are only meaningful relative to each other not to any objective measurement. Acceptable levels of vulnerability are subjective and are best determined at the community level through an inclusive process. This analysis shows relative vulnerability, which can be used to identify planning priority areas in much the same way that the University of Washington's Climate Impacts Group did for the King County, Washington climate action plan (Snover et al. 2007, 65-92).

## **Place Vulnerability**

**I**mpacts to sensitive systems or assets are most pressing when adaptive capacity is limited. In this case, property, which is sensitive to flooding, is examined in relation to populations with varying mobility, resource and adaptive capacities. All physically vulnerable areas were overlaid with the Census block groups coded for mobility, resource and adaptive capacities. This allows priorities to be assessed on a combined basis of physical vulnerability, determined by the exposure of a sensitive asset, and social vulnerability, or adaptive capacity of a population. This is referred to as place vulnerability in this report. In this case, vulnerability analysis for different selections of land also addresses the relative probability of being flooded.

## **Consequences of Flooding**

**A** quantitative risk assessment was beyond the scope of this analysis, but potential losses from flooding damage to buildings were examined for the City of Beverly. In ArcGIS, the building footprint layer was unioned with the parcel layer, which contained building values, and was clipped to include only those buildings at least partially within each of the vulnerable zones. Values of those buildings were then summed for each of the vulnerable zones. Building values were also mapped by the values into four categories according to natural breaks in the data, to provide a visual representation of where the greatest monetary losses could be.

The land use of a potentially flooded area may also determine the importance of protecting that land. Land types are valued differently per acre. Although this study does not attempt to determine which land uses are more or less valuable, the acreage of land, according to land use, in each vulnerable area was calculated. In order to analyze the types of land in vulnerable zones, the land use data was clipped to the 100-year and 500-year floodplains and to the 2-meter, 3-meter and 4-meter coastal elevation areas. Each land use category was selected separately and the area was calculated in acres for each of the vulnerable zones for the Salem Sound area as a whole and for the City of Beverly.

# Results

## Vulnerable Coastal Land

The 2-meter, 3-meter and 4-meter coastal areas are shown on Figure 4.1. If mean tide in the Salem Sound area is 4.7 feet and the tidal range is 8.8 feet on average, then mean high tide averages 4.1 feet above mean tide (NOAA 2008). Since zero elevation in the digital elevation model is based on mean tide, selecting the 2-meter coastal land shows coastal inundation at average high tide if the sea-level rises 22.8 inches. Using the same assumptions, all of the land at or below 3 meters would be vulnerable to inundation at average high tide if sea-level rises 58.8 inches. However, spring tidal range is 10.2 feet, making spring high tide 5.5 feet above mean tide. Therefore, the 3-meter area would be vulnerable to flooding in the spring if sea-level were to rise 46 inches. The 4-meter area would most likely be vulnerable to storm surges, as opposed to permanent or annual inundation. Rising sea-level is projected to strengthen storm surges, causing current 100-year storm levels to occur once every 10 years.

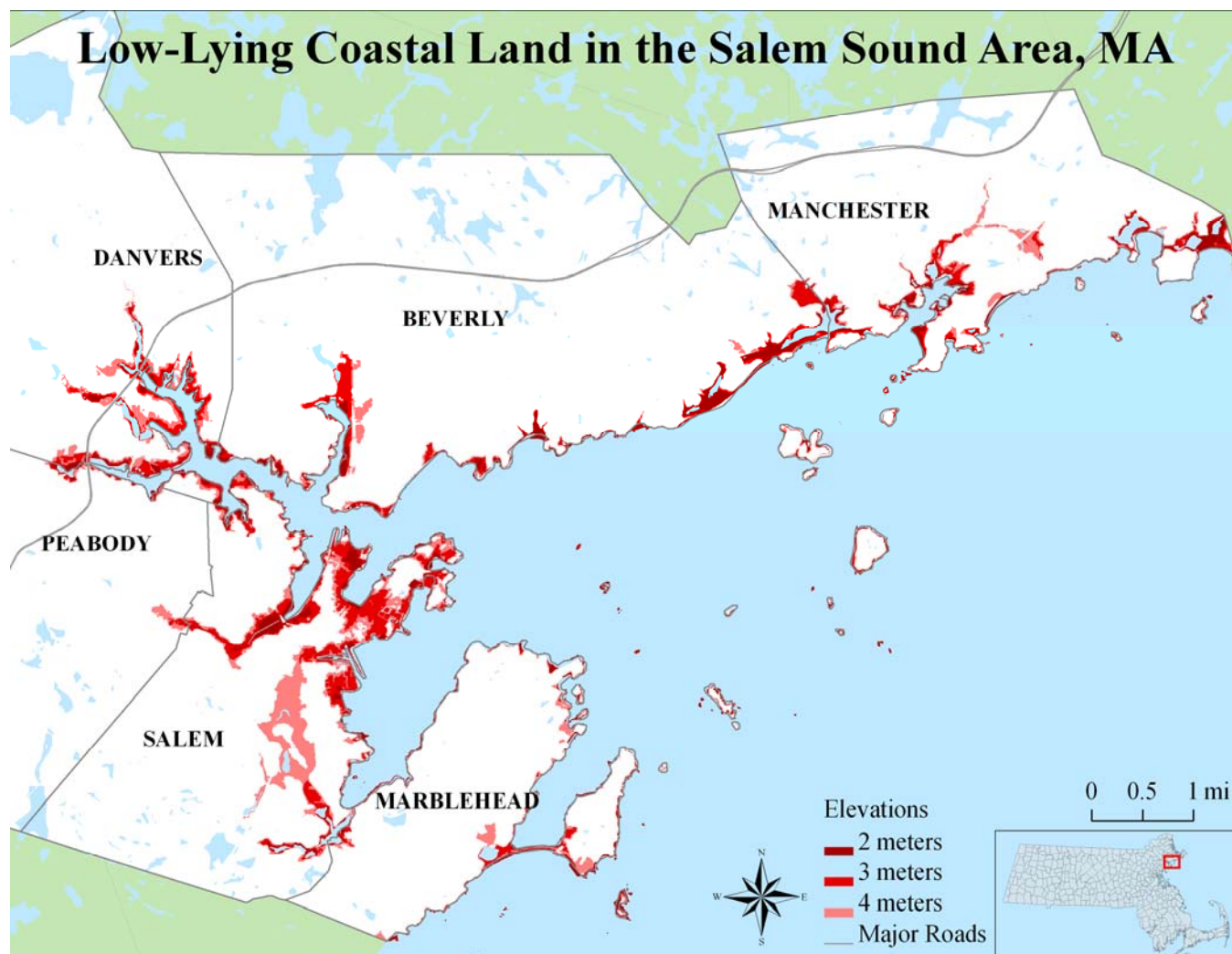


Figure 4.1

## 100-Year and 500-Year Floodplains

Figure 4.2 shows the current 100-year and 500-year floodplains. If projections that the 500-year floodplains will become the 100-year floodplains and the 100-year floodplains will become 10-year floodplains hold true, analysis of what lays within those areas will be important (Kirshen 2008). As discussed later in this chapter, the 100-year and 500-year floodplain data used for this analysis is of questionable accuracy, presenting a challenge to making effective planning decisions. Floodplains need to be re-evaluated and mapped for the entire Salem Sound area. This analysis can best be used to suggest relative exposure to a changing flood frequency and magnitude in the Salem Sound area especially in winter months when the ground may be frozen and unable to absorb as much water.

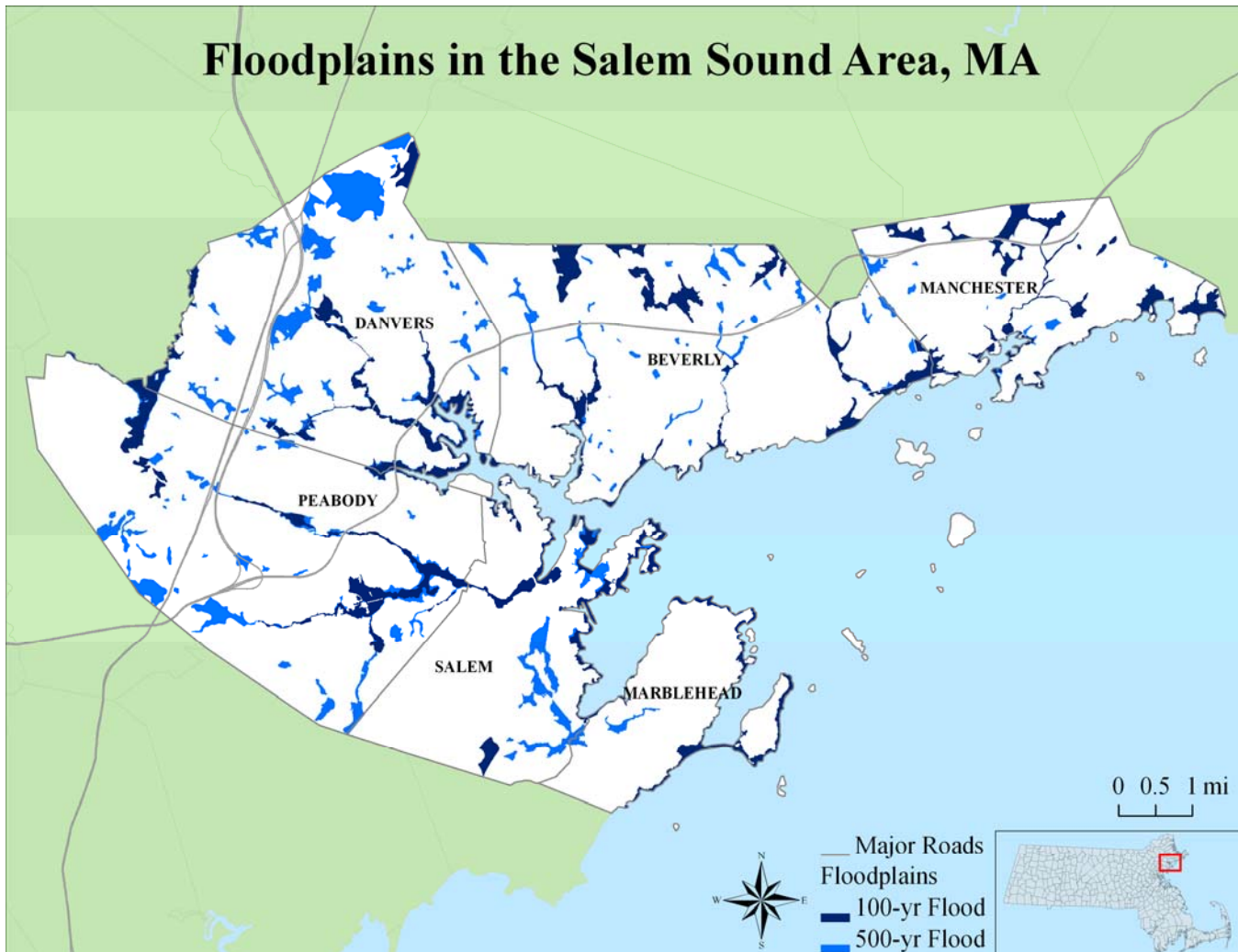


Figure 4.2

## Vulnerable Populations

Figures 4.3, 4.4 and 4.5 depict the three aggregations of Census variables to form mobility capacity, resource capacity and an aggregate of the two, adaptive capacity. The maps indicate that while populations in many block groups within the Salem Sound area and the City of Beverly are not especially vulnerable, some are. These maps may be useful for purposes other than planning for climate change as well.



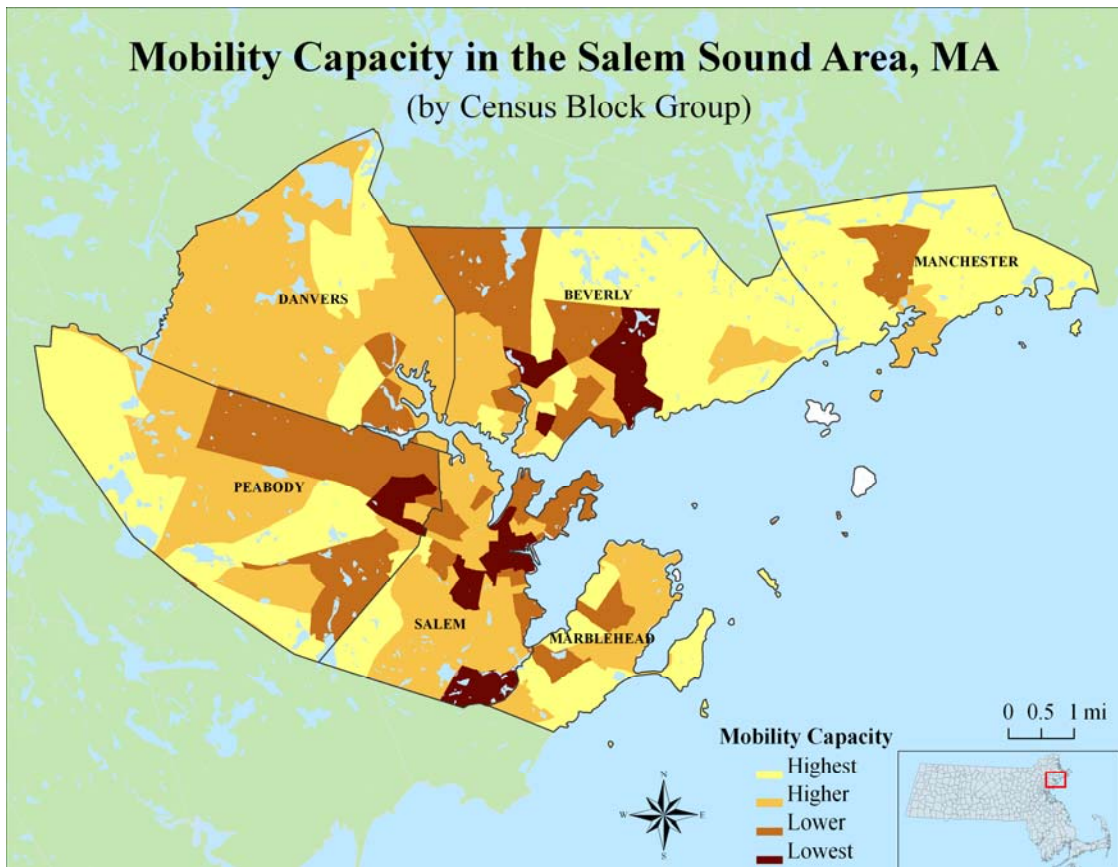


Figure 4.3

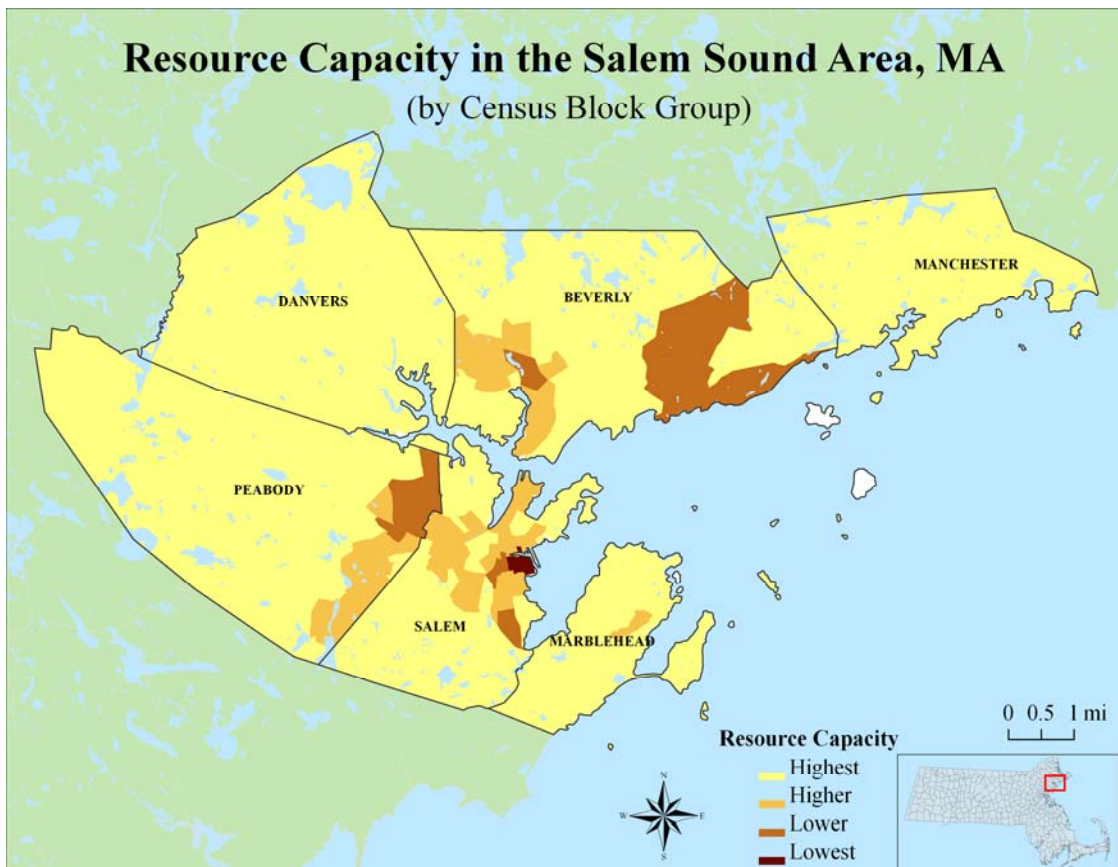


Figure 4.4

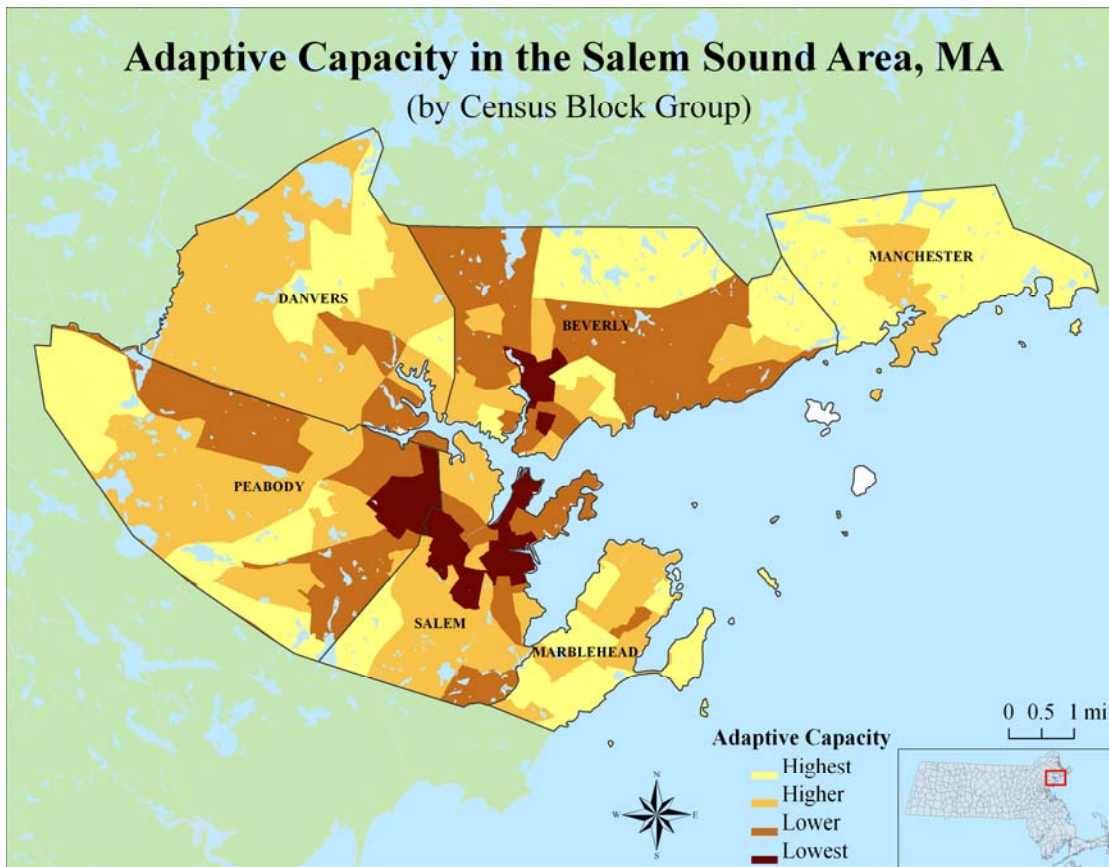


Figure 4.5

### Place Vulnerability

Place vulnerability is simply the coupling of physical vulnerability with social vulnerability. Figure 4.6 is an example of place vulnerability mapping. Adaptive capacity is shown in the 4-meter coastal zone for the City of Beverly. Place vulnerability maps for each of the vulnerable zones in the City of Beverly can be found in Appendix G. Maps showing the distribution of each variable that makes up mobility and resource capacities can also be found in Appendix E. This information can help set planning priorities to mitigate physical vulnerabilities in areas where residents may have more trouble coping with the effects of climate change, specifically increased flooding events.

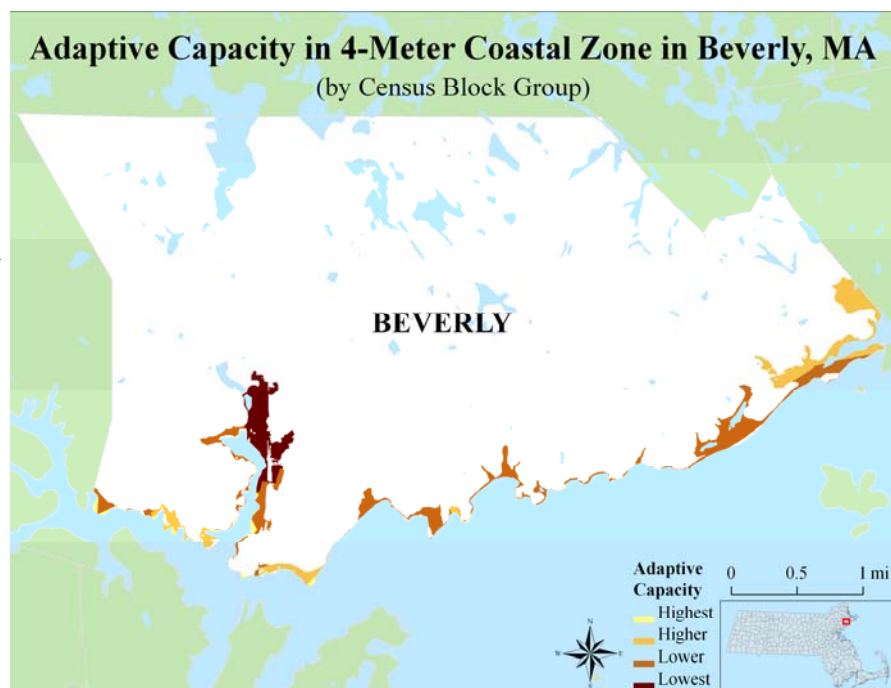


Figure 4.6

## Vulnerable Land by Land Use

The analysis of vulnerable land by land use resulted in the following Table 4.1, which shows the acreage of land by land use that is in each vulnerable zone for the City of Beverly and for the six Salem Sound communities combined. Each type of land use carries a different set of priorities to be considered when planning for climate change. Knowing what types of land are in vulnerable areas is a first step in that planning process.

Vulnerable Zone	Land Use	City of Beverly (Acres)	Salem Sound (Acres)
2-Meter Coastal Zone	Residential	73	197
	Commercial	1	12
	Industrial/Waste Disposal	13	24
	Transportation	0	31
	Parks & Open Space	30	163
	Salt-Water Wetland	29	115
	Fresh-Water Wetland	11	202
	Agricultural	4	5
	Forest	11	39
	<b>Total</b>	<b>172</b>	<b>788</b>
3-Meter Coastal Zone	Residential	118	478
	Commercial	3	75
	Industrial/Waste Disposal	53	133
	Transportation	2	103
	Parks & Open Space	58	333
	Salt-Water Wetland	32	146
	Fresh-Water Wetland	11	229
	Agricultural	4	10
	Forest	40	108
	<b>Total</b>	<b>321</b>	<b>1,615</b>
4-Meter Coastal Zone	Residential	159	859
	Commercial	21	191
	Industrial/Waste Disposal	68	206
	Transportation	6	191
	Parks & Open Space	74	502
	Salt-Water Wetland	32	152
	Fresh-Water Wetland	12	276
	Agricultural	4	15
	Forest	48	177
	<b>Total</b>	<b>424</b>	<b>2,569</b>

Table 4.1

Vulnerable Zone	Land Use	City of Beverly (Acres)	Salem Sound (Acres)
100-yr Floodplain	Residential	153	580
	Commercial	4	103
	Industrial/Waste Disposal	45	165
	Transportation	0	86
	Parks & Open Space	66	406
	Salt-Water Wetland	33	147
	Fresh-Water Wetland	67	377
	Agricultural	13	30
	Forest	138	679
	<b>Total</b>	<b>519</b>	<b>2,573</b>
500-yr Floodplains	Residential	232	892
	Commercial	14	191
	Industrial/Waste Disposal	49	246
	Transportation	2	174
	Parks & Open Space	80	608
	Salt-Water Wetland	31	156
	Fresh-Water Wetland	92	815
	Agricultural	14	49
	Forest	281	1,313
	<b>Total</b>	<b>795</b>	<b>4,444</b>

Table 4.1 (continued)

There are almost twice as much land in the 500-year floodplains as in the 100-year floodplains in the Salem Sound area. Residential land use is more concentrated in the coastal zones. In the 100-yr and 500-yr floodplains, forests make up a larger portion of vulnerable land. These data also indicate that wetland flooding would take place in even the more conservative scenarios. For example, in the Salem Sound area, there are 115 acres of salt-water wetland in the 2-meter coastal zone 146 acres in the 3-meter coastal zone and 152 acres in the 4-meter coastal zone. This shows that the largest portion of salt-water wetland is in the area that is most likely to be impacted, making adaptation measures especially pressing in those areas.

### Value of Vulnerable Buildings

Although flooding of any land can be problematic, flooding of buildings is especially disruptive and costly. Table 4.2 shows the summed values of all buildings at least partially within each of the vulnerable zones in the City of Beverly. Flooding in these areas has the potential to cause substantial losses.

Vulnerable Zone	City of Beverly Buildings Value (in dollars)
2-Meter Coastal Zone	101,532,600
3-Meter Coastal Zone	1,033,923,600
4-Meter Coastal Zone	1,222,234,200
100-yr Floodplains	1,104,974,730
500-yr Floodplains	1,356,781,420

Table 4.2

## Case Studies

The Cummings Center, in Beverly is located in an area vulnerable to flooding (see Figure 4.7). The Cummings Center is a major commercial complex housing 430 business where over 4,000 people are employed (Cummings Properties 2008). According to City of Beverly Mayor Scanlon, the Cummings Center is a major source of new growth and revenue for the City (Scanlon 2008).

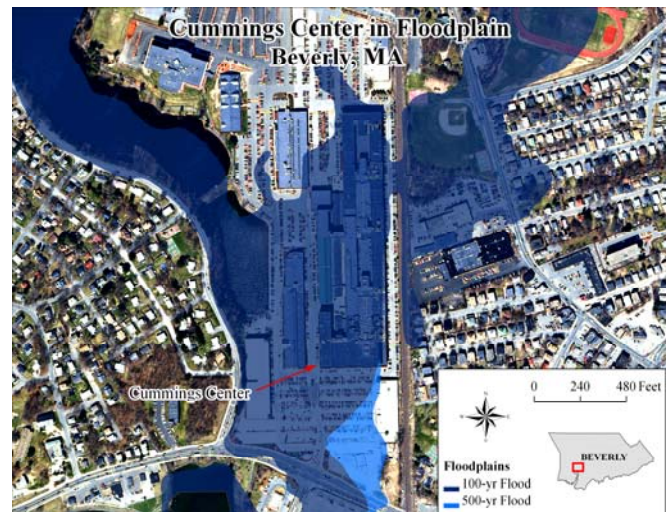


Figure 4.7

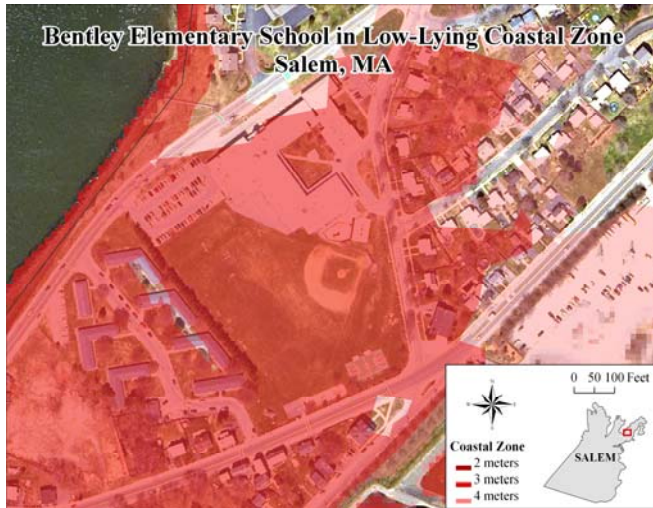


Figure 4.8

Four schools are located in areas that are, or may become vulnerable to flooding. They are the Bentley Elementary School in Salem (shown in Figure 4.8), Riverside Elementary School in Danvers, the Salem Early Childhood Center and the Bright Horizons Children’s Center in Beverly.

Transportation infrastructure in some areas is sited with little regard for flooding risk (see Figure 4.9). Rail service could be interrupted in the area during flooding events and drivers would have to find alternate routes. In some areas this could potentially make evacuation more difficult.

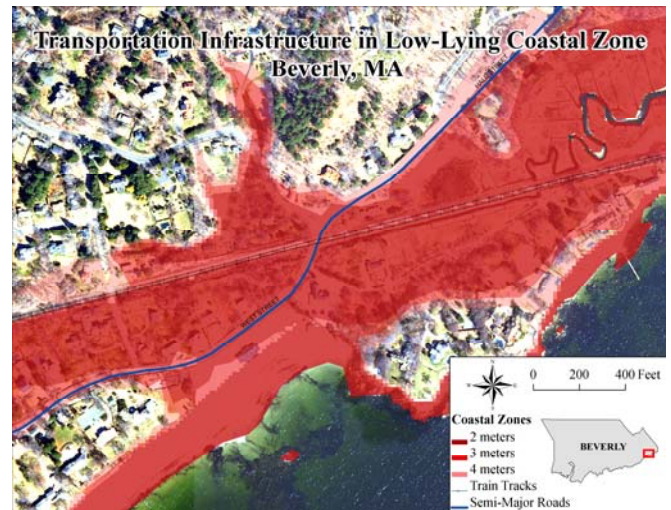


Figure 4.9



Figure 4.10

The Shaughnessy-Kaplan Rehabilitation Hospital is located in an area that may be vulnerable to flooding from storm surge (see Figure 4.10). This hospital provides inpatient and outpatient care to people who have suffered strokes, brain injury, cancer and other medical maladies (Shaughnessy-Kaplan Rehabilitation Hospital 2008). Loss of service from such a facility due to flooding would put an extra burden on the community at a time when resources are needed elsewhere.

Other public infrastructure including libraries, an electric substation, a power-generating facility and a sewage treatment plant are also located in areas that may be vulnerable to flooding in the Salem Sound communities. In addition to interruption of service at these facilities, repair costs from repeated flooding could represent a substantial burden on the communities' budgets.

## Limitations

Although attempts were made to ensure accuracy, some problems with the available data were significant. The most recent Census data (from Census 2000) is eight years old, therefore some block group population and household characteristics will have changed. Also, the approach used to estimate impact from rising sea level based on elevation alone neglects the dynamic nature of the coastline from erosion and land subsidence. Neglecting these factors likely resulted in more conservative estimates of vulnerable zones.

More significantly, however, existing floodplain and elevation data are often inaccurate. The floodplain data is so inaccurate that the Massachusetts Office of Coastal Zone Management (CZM) advises against using it for risk assessment (Haney 2008). A major barrier to accurate depiction of the potential projections of relative sea level rise and its effects on storm surge was the use of different vertical datums, or zero elevation benchmarks across data. Despite understanding that zero elevation is supposed to correlate with mean tide, as defined in the digital elevation data available from Mass GIS, positive elevations do not correlate well with known normal high water marks in the available aerial photography. No accurate data exist that show the coastline at mean high tide or high tide, and consequently, digital elevation data cannot be visually referenced to a known tidal stage. High resolution Light Detection and Ranging (LIDAR) data that have vertical accuracy more appropriate for modeling sea level rise projections does not exist for areas of relevance in Salem Sound.

Adequately addressing these issues of data accuracy and availability is outside the scope of this analysis and will be best addressed by qualified state management and research professionals such as at National Oceanic and Atmospheric Administration (NOAA), CZM, Massachusetts Emergency Management Agency (MEMA), Federal Emergency Management Agency (FEMA), or Massachusetts Department of Environmental Protection (MDEP). Understanding these challenges, we have attempted to show relative risk and possible increases in area of risk.

# Adaptation Strategies

## Introduction

The information given in the previous chapters is the critical precursor to understanding and developing strategies to combat the negative impacts of climate change. Once impacts, vulnerabilities and risks have been identified and prioritized, a town or city can begin to formulate adaptation strategies that reduce vulnerabilities.

While climate change adaptation planning has not been overtly established as its own professional field, it is a part of planning, management, and strategy implementation at the federal, state, and local levels, as well as within the non-profit and private sectors. Municipal departments and government agencies create and manage projects and programs that strive towards maintaining and improving the health, safety, and welfare of local communities. It is within these bureaucratic decision making structures that the need for effective adaptation measures must be emphasized.

This chapter reviews key concepts for successful climate change adaptation, barriers to effective implementation and the potential for mal-adaptive consequences stemming from mere cursory treatment of climate change impacts. It then outlines seven major planning areas affected by climate change and presents general recommendations for how communities can start to incorporate adaptive approaches in the Salem Sound area. Brief case studies are used to provide examples of decisions that are adaptive in nature, but that would be better addressed with a framework that incorporates climate change impacts.

It is evident that climate change impacts will bring increased challenges to Salem Sound communities. In order to cope with these challenges, communities must deliberately integrate climate change impacts into current decision making in order to insure that adaptive measures are effective and far-reaching. This overview of management strategies and the recommendations that follow represent a starting point for building a more robust framework for effective climate change adaptation.

### Criteria for successful adaptation strategies:

**Equity:** Does an effort protect the wellbeing of all people in a community, regardless of their socio-economic background?

**Efficiency:** Can this effort save money, time, and space (land use) in the long-term?

**Effectiveness:** Will this effort eliminate risk or provide amenities to a community? Will it work the way it is supposed to work? Will decision-makers and the community accept it?

**Environmental sensitivity:** Does this effort protect or restore natural ecosystems and habitat? Is this effort in line with wider sustainability efforts?

**Priority:** Is this effort connected to priorities in the community? Does this effort address climate impact vulnerability priorities?

**Practicality:** Is this effort viable from financial and engineering/construction standpoints?  
(Smit et al 2000/ Adger et al. 2005, 238).

# Categorizing Adaptation Strategies

There are several concepts that can guide the implementation of adaptation strategies. These concepts can help communities choose which strategies to use, where and when they get implemented, and who is responsible for implementation and monitoring. In Salem Sound, strategies that specifically address coastal risks will be of particular importance and are therefore emphasized here. However, four additional overarching principles need to be considered as well because they inform approaches to address coastal risks as well as other climate impacts. Coastal considerations and other adaptation categories are discussed in this section.

## Protect, Accommodate, Retreat: Strategies to Address Coastal Risks

There are three general approaches for adaptation to coast risks. First, protective strategies focus on shielding the land from the sea so that existing land uses can continue. Second, accommodation strategies allow for the continuation of existing land uses, but make adjustments, such as elevating buildings, to mitigate impacts. Third, retreat strategies involve no protection of the land from sea level rise and encourage abandonment, as opposed to rebuilding, after buildings have been destroyed. Retreat strategies allow for the natural evolution of the coastline and the inland migration of habitats (Burkett et al. 2001, 367).

In response to sea level rise, communities will have to decide whether to protect, accommodate, or retreat depending on many variables. For example, if a community decides to protect the infrastructure along their coastline using sea walls and jetties, it is probable that these structures will need to be retrofitted periodically. Therefore, retrofitting the coast may be a viable option for areas with high population density or with high income levels that can share the costs or afford to fund adaptation projects outright. On the other hand, retreating or accommodating may be more appropriate in areas of lower population density and with lower incomes that cannot afford to continuously rebuild. Areas that are not already built up and protected by sea walls are better candidates for retreat and accommodation strategies (Gornitz 2001, 33). Sensitive habitats are would also be best served by accommodation policies.

**Rolling easements:** A rolling easement is a strategy that requires humans to yield the right of way, and retreat to naturally migrating shores (Titus 1998, 1377). As sea level encroaches, the easement would allow for all zoned land to move vertically at the same pace as the sea level. Because stabilization structures cannot be built, sediment transport can continue and coastal wetlands and other habitat can migrate naturally. Rolling easements place no restriction on development, therefore, a landowner can build anywhere on their property as long as they do not prevent shoreline erosion or public access to the shore (NOAA 2007). Benefits include the minimization of coastal activity, which would allow for natural erosion without stopping development altogether. Rolling easements could be difficult to implement in highly developed areas because easements may decrease resale values of their property and they may be hard to enforce (Field et al. 2001, 481, NOAA 2007). However, scholars have remarked that restrictions on development will have less than an one percent impact on property values (Titus 1998). Some states that utilize rolling easement policies include Texas, Maryland, and South Carolina (Titus 1998).

## Reactive vs. Proactive (Anticipatory)

Adaptation strategies can further be broken down into reactive and proactive, or anticipatory actions. Reactive adaptations are decisions and strategies implemented in response to climate



change impacts after the fact. On the other hand, proactive, or anticipatory, adaptations are deliberate decisions and actions made in preparation for the potential effects of climate change (Fankhauser et al. 1999, 73).

The IPCC states that “a ‘wait and see’ or reactive approach is often inefficient and could be particularly unsuccessful in addressing irreversible damages, such as species extinction or unrecoverable ecosystem



damages” (Adger and Mirza 2007, 720). It is beneficial for local governments to be proactive for a number of reasons. Planning for the future can also benefit the present; preparing for climate change can serve present complimentary purposes; and local governments are typically on the front line of defense against any disaster or negative impact. While proactive measures may require substantial planning and investments in time, they can drastically reduce long-term costs. Reactive measures can preclude necessary planning and investment and, as a result, can be mal-adaptive and extremely costly in terms of incurred losses that could have been avoided.

### Short-term vs. Long-range Planning Time Frames

The timeframe of strategies is a critical component of climate change adaptation. Short-term decisions should always be made in the context of longer-term goals (Adaptation Network 2007). Choosing strategies that are both effective in the near-term and beneficial in the long-term can help communities in a number of ways. For example, it is often costly to alter existing buildings, infrastructure and land-use patterns in order to compensate for associated risks that are projected to come as a result of climate change, but these issues can be addressed through long-term policies, which can spread the affordability of new construction and zoning over a long period of time (Satterthwaite et al. 2007, 1). Decision-makers and municipalities must be cognizant not to choose strategies simply because they are easier and take less time to implement. Such haste can again lead to mal-adaptive measures and can be more costly over time.

### Mal-adaptation

Adaptation efforts are necessary to alleviate the negative impacts of climate change. However, not all adaptation strategies are good. Adaptation outcomes can sometimes spring from quick, short-sighted decisions that actually “amplify the impacts of climate change by ineffectual and unsustainable anticipatory action,” negatively affecting a community as a whole, or, more likely, having positive impacts for a few people, while creating detrimental situations for many (Adger et al. 2005, 78). For example, mal-adaptations can occur when sea walls and revetments are built to protect certain properties or important infrastructure. While the walls and revetments will protect specified areas they will reflect and diffract wave action and surge to nearby locations (Jolicoeur, S. et al 2007, 295). This can cause flooding to worsen in other areas.

There are many red flags that communities should pay attention to in order to avoid mal-adaptations. These include regulations, policies, practice and procedures that do not provide for regular re-evaluation and adjustment in accordance with changing conditions. Policies that require planning that is based strictly on historical and incomplete data, or pin certain decisions to short-term seasonal patterns, or that reinforce trends that increase vulnerability or reduce adaptive capacity can also be problematic (Snover et al. 2007, 99).

## Cost-Benefit Considerations

The cost-benefit ratio of an adaptation strategy is often the first and most important thing a community will look at when gauging whether to implement policy or action. The benefits of the adaptation action should outweigh the costs, both economic and social. According to a report conducted by the United Nations Environmental Program Finance Initiative, adaptation efforts can “reduce impacts by a factor of 10 to 100 for often little cost, for example by designing hurricane-resistance into infrastructure and buildings” (UNEP 2006, 9). Adaptations in coastal regions are particularly significant and ignoring the potential impacts of climate change could be catastrophic. For example, the Army Corps of Engineers estimated that it would take 20 years and one billion dollars to improve the levee system in New Orleans. However, post Hurricane Katrina, the cost of disaster recovery in New Orleans alone is significantly beyond what it would have cost to prepare ahead of time (UNEP 2006, 10).

## Adaptation Planning, Management, and Strategies

### Introduction

There are many different strategies currently being implemented within Massachusetts and the Salem Sound area that can address climate change impacts including hazard mitigation, hard and soft coastal management strategies, as well as infrastructure development, conservation, and planning efforts. In this section, specific strategies are discussed, case studies are used to highlight specific strategies for climate inclusive planning and recommendations are made for how Salem Sound communities can increase their resiliency to climate change impacts.

### Multi-Hazard/Disaster Mitigation Planning

Hazard mitigation plans aim to reduce impacts from natural hazards, including flooding and strong winds. In October of 2000, the Federal Disaster Mitigation Act of 2000 was signed into law, officially establishing a national program for pre-disaster planning and relief. This program established the national infrastructure for disaster mitigation with oversight and funding to help states and localities along with the process. The program should help prepare states and cities to rapidly and efficiently cope with and recover from natural disasters (Massachusetts Department of Environmental Management 2003, 2-1).

In 2004, the State of Massachusetts developed a comprehensive hazard mitigation plan. That same year, the Salem Sound communities of Beverly, Salem, Peabody and Marblehead, as well as Revere, Winthrop, Lynn, Saugus and Swampscott collaborated with the Metropolitan Area Planning Council to produce the North Shore Regional Multi-Hazard Plan, with specific annex plans for each community. These plans examine current and future development to various types of hazards, as well as develop strategies to cope with existing and potential risks. The goals of these plans are to ensure critical infrastructure sites are protected from hazards; protect residents and businesses from flooding; maintain infrastructure in good condition; enforce existing zoning and regulations; educate the public about zoning and building regulations; collaborate with surrounding communities on hazard mitigation; encourage development outside of hazard prone areas; educate the public about natural hazards; and use public funds for hazard mitigation (MAPC 2004 Hazard Mitigation Plan, 17-18).

Mitigation of certain risks in Beverly has already been instituted through the implementation of municipal projects and state programs that work to enhance the community’s safety and adaptive

capacity. These include coastal defenses, flood reduction projects, a floodplain overlay district discouraging development in hazard areas, hurricane-safe state building codes, wetlands protection, setback regulations from wetlands and other critical areas, and public education about natural hazards. The City is also looking to enhance safety efforts by conducting future efforts such as drainage projects and continued educational efforts (MAPC 2004).

*Recommendations:* Salem Sound communities should review their hazard mitigation plans and incorporate new climate related risks within these plans, as well as incorporate new and emerging best management adaptation strategies. The municipalities should also incorporate issues such as disease, heat stress and air pollution into their hazard mitigation plans.

## Management of the Coastline

The coastline represents the first line of defense against climate change impacts such as sea level rise and storm surge. Therefore the protection and management of coastal ecosystems and infrastructure is paramount to the Salem Sound communities. While the majority of the coastline is rocky and less vulnerable to erosion and flooding, there are significant portions of beach and built coastal defenses that must be maintained on a regular basis. Additionally, most of this coastline is privately owned, which presents a difficult situation for the municipalities who do not have jurisdiction to maintain these coastal areas, but do have the responsibility to keep their constituents safe from harm (Collins 2008).

**Hard Coastal Defenses:** In most cases, adaptation strategies can either be carried out using hard or soft measures. Hard measures refer to engineered strategies erected to protect coastlines and inland structures from sea level rise and storm surge. These structures, often called shoreline armoring, include seawalls, groins, culverts, overflow routes, jetties, bulkheads and breakwaters are put in place along the coastline to protect properties and natural systems from ocean currents, high tides and storm surges, capture the lateral movement of sand by sea currents and stabilize and protect harbors and coves. The increased cost of retrofitting existing structures and armoring new sections of coastline is a significant concern to local communities (Gornitz 2000, 33).



The challenge with hard defenses lies in maintaining and retrofitting current structures, while creating construction standards and methods for new defenses at an affordable cost (Frumhoff et al. 2007, 121). For example, in Beverly, a 2001 storm damaged a sea wall in Lynch Park, which cost \$200,000 to repair. Beverly also noted that a 500-foot section of the Bass River sea wall at Innocenti Park needs immediate repair, which will cost the City an additional \$625,000 (MAPC 2004, 33).

Elevating buildings above the flood level is another hard measure that can be taken to prevent property damage during flooding events. In most cases, raising a building's height above flood levels can be cheaper than moving it. Once landscaping is applied, elevated buildings can have an appealing aesthetic. However, during flooding events, these buildings could be surrounded by water, and thus temporarily uninhabitable (Larson et al. 2003, 60).

**Soft Coastal Defenses:** Soft adaptations promote the conservation, protection, and development of natural ecosystems along the coastline and within coastal communities, as buffers against climate change impacts. Salem Sound has sand and gravel beaches, coastal vegetation such as wetlands and salt marshes and rocky coastline, which can absorb wind or wave energy, making the shoreline much more resistant and flexible to flooding and erosion (Burkett et al. 2001, 356). Thus, these natural features are critical assets to the area.

One method of maintaining existing beaches at existing elevations is beach nourishment, or the process of adding sediment to a beach. Sand and other sediment from dredging projects is sometimes used in these efforts. This practice may become more prevalent as higher storm surges increase coastal erosion. Governments are strongly in favor of beach nourishment and other soft measures like it because they operate similarly to natural processes, are less disruptive to the environment and less expensive than engineered structures (Haney 2007). However, beach nourishment can be resource intensive, especially if sand is hauled to beaches by heavy trucks, which emit considerable amounts of CO<sup>2</sup> and contribute to climate change.

### *Case Study*

#### **South Shore Coastal Infrastructure Inventory Assessment:**

In 2006, the CZM Coastal Hazard Commission Infrastructure Plan Working Group, in collaboration with Bourne Consulting Engineering conducted a pilot program to evaluate coastal structures, and prioritize maintenance and repairs for the entire South Shore coast. This plan focused on the ability of each structure to resist and prevent storm surge, flooding, and erosion. Coastal structures researched and evaluated included municipally owned seawalls, revetments, bulkheads, groins, jetties, breakwaters, and dikes/levees, as well as natural landforms including beaches, dunes, and coastal banks. The evaluation assessed 312 publicly owned coastal structures along the South Shore. Bulkheads and seawalls were the most abundant, with a combined total of 177 (57%). Overall, 49% of the structures were stable and 51% needed moderate to immediate repair (Coastal Hazard Commission 2007, 24). These findings, along with findings from other projects in the remaining coastal regions, will serve as the beginning of a statewide plan for maintenance and/or repair of the Commonwealth's coastal structures. To learn more visit the CZM website at: [http://www.mass.gov/czm/hazards/ss\\_atlas/atlas.htm](http://www.mass.gov/czm/hazards/ss_atlas/atlas.htm).

**Wetlands and Salt Marsh Protection:** Two specific types of natural coastal defenses, and critical assets to Salem Sound's green infrastructure network, are wetlands and salt marshes. While wetlands and salt marsh play a multi-functional role in coastal communities, serving as beautiful natural scenery, breeding grounds for habitat, water and waste filtration systems, and drinking water recharge stations; they also act as a buffer between communities and flooding waters, as well as carbon dioxide sinks. Both the state and local conservation commissions are responsible for protection and maintenance of these ecosystems.

Massachusetts communities must comply with federal, state and local regulations when developing near wetlands areas. The Massachusetts Wetlands Protection Act defines wetlands overlay districts with the state zoning bylaws, and local governments may create stricter laws. For wetlands less than 5,000 square feet, the local conservation commissions or planning boards can grant permission to develop within a wetland zone (EOPSS 2008).

Currently, many Salem Sound communities have put in place a 100-foot setback development buffer from wetlands and salt marsh. This requires developers to go through a rigorous development approval process if they want to build within these zones. Salem Sound cities have also put in place 25 to 50 foot No Disturbance or No Build Zones, preventing building altogether in these specified areas (Cassidy 2008). In general, construction setbacks can increase wetland preservation, open space and other natural habitat amenities, reduce unnecessary and costly hard shoreline control measures, minimize property damage due to erosion and maintain natural shoreline dynamics (NOAA 2007).

*Recommendation:* Salem Sound communities should work with partners such as the CZM office and private contractors to identify and create a master inventory of the condition and capacity of hard and soft coastal defenses that includes climate change projections as part of the assessment. They should identify and prioritize the most vulnerable structures and properties and design and implement best management practices to maintain and enhance these areas in concert with future climate change projections. Specifically, Salem Sound communities should work with partners to understand the variable vulnerability of particular wetlands and salt marsh to sea level rise and review and strengthen their wetland preservation and protection laws (Yenco 2007, 76-78). The communities should also carry out wetlands protection and restoration best management practices and take into account climate change impacts by including available vertical space in setback requirements in addition to lateral buffers.

## Stormwater Management

One way to enhance the resistance, durability and flexibility of the Salem Sound communities is to create an effective stormwater system that can absorb more frequent and more intense amounts of water. Stormwater drainage is currently a problem in certain areas within the Salem Sound area. Particularly, in the City of Peabody, flooding has been a major problem in the downtown area during heavy rain events. Best stormwater management practices and flood prevention techniques are essential in helping communities reach an appropriate adaptive capacity. Stormwater management efforts in the Salem Sound communities include street sweeping, cleaning catch basins yearly to prevent sedimentation, minimal use of sand on streets to reduce siltation, and inlet screen cleaning of culverts and other debris when storms are forecasted (MAPC 2004, 31-32/ Satterthwaite et al. 2007, 1).



The City of Beverly has adopted two sets of stormwater ordinances that require the review of new development or building retrofits in order to ensure the control runoff from the site, as well as an erosion control and materials management ordinance that helps maintain sites during construction (Cassidy 2008).

The drainage improvement projects are also critical, particularly for vulnerable areas in the Salem Sound area. Certain communities have already implemented major drainage efforts including stormwater pump stations and increased storage capacity of catchments. However, other communities do not have these capabilities and have expressed concerns about sea level rise affecting their stormwater outfalls into Salem Sound (Marblehead 2008). These communities may need to consider switching to pump stations and other power based systems rather than gravity-based systems.

*Recommendations:* Salem Sound communities should increase capacity of stormwater collection systems to

accommodate projected climate change impacts. This includes review of zoning laws to make urban stormwater capture a priority for urban landscaping and street design. Curb cuts that channel runoff into a catchbasins to allow for filtration into the ground will reduce stress on drainage systems (Rickards 2006). Preparation of maps that identify high-risk areas and implementation of alternative stormwater programs such as permeable pavements, green roofs, and low impact development will have lower costs than large-scale infrastructure projects and should be considered no-regrets options.

### Case Study

#### City of Beverly Drainage Projects/ Flood Plain Management Plan:

The City of Beverly has been dealing with flooding in various part of the City for decades. In 1970, the City commissioned a report to evaluate critical drainage problems and outline strategies to address flooding. No action was taken until the late 1990s when this report was re-evaluated, updated, and strategies began to be implemented. The City has spent approximately \$15 million dollars over the past 12 years on four major drainage projects in and around Chase Street/Margin Street, Lawrence Street Brook, Chubb's Brook, and Raymond Farms. These projects have employed different techniques, dramatically reducing susceptibility to flooding. The City continues to do work at these sites and plans to make further improvements at other areas. (CDM 1970, 12-23, MAPC 2004, 32, Collins 2008).

Drainage infrastructure must be comprehensively evaluated, especially where sea level rise could impede outfall functionality. Communities should analyze the long-term costs and benefits of drainage infrastructure limitations and projected climate impacts.

### Floodplain Management

The major floodplain management system in the United States is the National Flood Insurance Program (NFIP) administered by the Federal Emergency Management Agency (FEMA), which maps floodplains and provides flood insurance to property owners in local communities. The NFIP establishes minimum floodplain management requirements for participating communities, and in turn the communities have to establish specific requirements in their zoning and other land use ordinances and building codes, or adopt a separate floodplain management ordinance altogether (Larson et al. 2003, 39-40). Currently, all communities within the Salem Sound area are linked into the NFIP system. Salem Sound communities have discouraged development and human habitation within the floodplain, although it is not prohibited.

Floodplains are commonly defined within the municipal laws as areas that will flood significantly based the 100-year flood projection, which is considered a community's base flood elevation (City of Beverly 1985). However the State of Maine restricts development within a 500-year floodplain level (Maine DEP 1998). New buildings developed within the flood zone must be protected from damage by the base flood. In riverine floodplains, the lowest floor of residential buildings must be elevated to or above the base flood elevation (BFE). Non-residential buildings must be either elevated or flood-proofed to the BFE. In coastal areas, the bottom of the lowest horizontal structure of a building must be at or above the BFE (Larson et al. 2003, 39-40). Most Salem Sound communities established floodplain districts in the mid-1980s. The City of



Beverly's floodplain was designated in 1985, which requires development proposals to go through a more intensive process for approval within the floodplain zone. While there is some prevention of development, most buildings are approved by the local zoning board. The effectiveness of current floodplain standards in the Salem Sound area comes into question particularly if one considers the implications of the 100-year storm occurring in much more frequent successions (Kirshen 2004, 59).

*Recommendation:* Salem Sound communities should update, review, and strengthen their floodplain overlay districts to align with future storm and flooding projections. Floodplain overlay districts should also be incorporated as a key component into larger hazard mitigation and climate adaptation plans. More specifically, at a minimum, observed extent of floodwaters, erosion rates and sea-level rise rates should also be incorporated into hazard mitigation or adaptation strategies. Communities should apply for floodplain updating from FEMA regarding specific new development and should use the 500-year floodplain as a more appropriate indicator of exposure to flood hazard.

## Development

There are already many tools in place that can be utilized to further inform how and where to build, how to manage growth properly and which areas to protect in the Salem Sound area. It is the management and improvement of these strategies and systems that will help communities build more climate flexible and resistant communities.

*Building codes:* The Massachusetts State Building Code 780 CMR requires developers to acquire building permits before construction (City of Beverly 2007). All Salem Sound communities have adopted the Massachusetts building code standards, which focus on where and how residential and commercial buildings can be constructed, including measures that require buildings to be able to withstand extreme weather events. In response to Hurricane Katrina, Massachusetts strengthened its code, mandating that newly installed windows meet higher wind load thresholds (Cassidy 2008).



Developers who want to build in the floodplain must obtain a special permit, following the National Flood Insurance Program (NFIP) building requirements, if a municipality does not already have even stricter standards. The voluntary Community Rating System (CRS) encourages communities to exceed the minimum NFIP floodplain management standards. Communities which are able to maintain records of floodplain development, publicize the flood hazard, improve flood data, and maintain open space have a chance to gain credits and reduce flood insurance premiums paid by policyholders.

Communities can also gain additional credit under CRS by developing a flood mitigation plan (Commonwealth of Massachusetts 2004, 5-30).

Enforcing these regulations can have positive measurable effects on flood losses. The NFIP has stated that buildings following its standard suffer 70% less damage than unprotected buildings, which has saved over \$1 billion per year in flood damages. However, these buildings can still suffer significant damage during extreme weather events; therefore, it is encouraged that even higher standards should be sought (Larson et al. 2003, 40).

*Recommendations:* Salem Sound communities should strictly enforce that all development within the stated floodplain follow NFIP standards. Salem Sound communities should also work towards

developing a CRS that can help lower insurance premiums for residents. Creating NFIP standards for buildings within the 500-year floodplain should also be considered.

*Smart Growth:* Smart Growth development emphasizes the mixing of land uses, increases the availability of a range of housing types in neighborhoods, takes advantage of compact design and provides a variety of transportation choices (MA Smartgrowth 2008). There are several benefits produced by this type of development that increases a community's climate change resiliency. For example preservation of open space and density development decrease impervious surface, which will also lead to a decrease in heat-island effect and flooding, along with an increase in groundwater recharge. Additionally, climate change will impact certain areas in the Salem Sound area more severely than others, smart growth tools such as Transfer of Development Rights (TDR) could be used to focus growth away from climate change hazard areas. TDR is used by municipalities to create incentives for developers to relinquish development rights in sensitive areas by offering the right to build in another more suitable area (Smart Growth/Smart Energy Toolkit).

*Recommendation:* Salem Sound communities should utilize Smart Growth principles and other zoning strategies such as cluster development and TDR when dealing with climate change adaptation strategies in order to concentrate development away from areas that are deemed to be potentially hazardous to climate change impacts.

### Case Study

**North Shore - Cape Ann Emergency Preparedness Coalition:** This organization was formed in 2004, and is made up of the Board of Health and Health Departments for the six Salem Sound communities, as well as nine other Cities located north of Boston. The purpose of this organization is to enhance collaboration and capacity needs on health issues, and to work together to respond to public health threats. To learn more about this coalition, visit: <https://www.nscalert.org/about.asp>

## Public Health

Increased heat stress and prevalence of mosquito borne diseases, reduced air quality and higher allergen levels all represent potential threats to public health in Salem Sound communities over the next 30 years (Frumhoff 2007, 91-103). These risks must be addressed in Salem Sound communities if adaptive capacity is to keep pace with risk. The most important aspects of mitigating the effects of these stresses are early action and outreach to vulnerable populations. The Massachusetts Department of Public Health's Health Alert Network (HHAN) is an existing tool that can serve to alert towns and is in use by a number of towns, including Marblehead and Salem (Attridge 2008, Scott 2008). Important tools that communities can use to build resiliency include a reverse 911 system that sends phone messages out to the community alerting people of heat extremes and other public health risks and on-the-ground outreach to vulnerable populations, such as those examined in Chapter 4. A detailed municipal response plan for each of the public health risks posed by climate change in the near future would be the best way to ensure that available resources are utilized in order to limit fatalities, costs, and overall suffering from heightened exposure to risks.

*Recommendations:* Salem Sound communities should prioritize the establishment of a comprehensive alert system and identify vulnerable groups with respect to each risk. Local health boards should also research the increased risk to heat, pollution, and disease. Salem Sound communities should seek interdepartmental cooperation as well as collaboration with the academic community, public agencies, the private sector, non-profits, and other communities to share information, enhance understanding of climate change impacts to public health and revise these municipal emergency response plans for health related emergencies.



## Water Supply

The Salem Sound communities draw their drinking water in different ways and from different places. Manchester uses a well system, Marblehead draws from the Quabbin reservoir and Salem, Beverly, Peabody, and Danvers (along with 10 other cities) draw their water from the Ipswich River (Warren 2008). Currently, Massachusetts has abundant water supply during the majority of the year, but climate change impacts bring into question issues such as drought or limited access to water in the future. Given the severity of this issue, standards are used by each Salem Sound community to draw from the Ipswich River in the most sustainable fashion. Ways to reduce water use include water conservation efforts, such as leak detection and efficiency programs, or raising the water use rates for local residents (Olmstead and Stavins 2007, 36).

*Recommendations:* Salem Sound communities should work to understand and share information about the effects of climate change on drinking water supplies in the area. Salem Sound communities should also look at maximizing water reuse systems and policies. Additionally, Salem Sound communities should look at increasing their water rates and establishing water efficiency programs in order to decrease unsustainable use of water.



# Conclusions and Implementation

**S**ome climate change is unavoidable and its impacts will be felt in the Salem Sound area. In order for Salem Sound communities to successfully adapt to these impending impacts, it is imperative that they begin an in-depth processes of understanding local and regional climate change impacts, inventorying their risk and vulnerability, and developing and implementing appropriate adaptive management strategies.

Adapting to climate change before serious impacts affect the area will not be an easy task. Local communities are responsible for funding and implementing a multitude of programs to solve pressing issues, which constrains funds available for instituting adaptation measures. The cost of implementing adaptation strategies is often beyond the immediate budget of a government or organization. Additional barriers often include: the lack of available data on climate science and its projected impacts, often leading to a stalemate on the topic; agencies that are not well equipped to develop or handle adaptation management; and, organizations that are unwilling to accept climate science or who view adaptation strategies as ineffective or risky (UNEP FI Climate Change Working Group 2006).

Decisions being made today directly relate to our ability to adapt and react to climate change in the future. Therefore it is imperative that communities understand and implement risk management strategies in order to develop strong adaptive capacity and management capabilities. Currently, there are a multitude of existing resources and programs in place that communities can utilize to help build their adaptive capacity. Utilizing these existing resources, while also promoting collaboration, within and among, departments at various levels of government, jurisdictions and organizations can help communities create the most effective planning and management process.

This integrative management approach should be supported by the creation of a climate preparedness team. The team should consist of a network of diverse stakeholders representing: emergency preparedness; hazard mitigation; coastal zone management; planning; building; permitting; storm and wastewater management; conservation, parks and recreation; public health; transportation; economic development; environmental protection; and, utilities. It should also include local elected officials, representatives from the private sector, such as insurance agencies and local business, non-profits, neighboring governments, and regional planning entities. This collaborative approach which integrates the priorities, costs, and leadership of multiple interests will support the broadest and most efficient increases in adaptive capacity.

A key component of increasing adaptive capacity is the emergence of a climate change adaptation champion. In order for significant progress to be made and major challenges to be overcome it is critical for strong leaders to emerge and champion climate change adaptation. Creating effective strategies to adapt to the impacts of climate change will be a difficult and often divisive process, particularly when measures challenge the status quo. Therefore a leader, preferably an elected official, who is well respected and well versed in these issues can play an invaluable role in developing policy

recommendations, building coalitions and promoting integrative and best management strategies that differ from present and past modes of operation (Snover 2007, 47).

Educating the public and government officials about climate change through targeted education and training can also help build support and strengthen adaptive capacity. Climate change issues continue to be burdened by misunderstanding, usually stemming from a general lack of climate change knowledge among the general public and continued uncertainty about specific impacts and future scenarios. Therefore, public information sessions, focused trainings, and outreach campaigns offered by experts and mediators can help generate support. These efforts could potentially help create a broad interest in climate preparedness and an integration of new priorities in the decision-making process. Additionally, educating and training municipal officials in climate change science and adaptation strategies can help build management capabilities at the local level.

Effective adaptation to climate change will require a shift away from reactive and towards proactive long-range planning and management. This shift should utilize systems and structures already in place and enhance them to incorporate the projected impacts of climate change. It is up to each individual community within the Salem Sound region to choose which strategies they believe will best build their adaptive capacity and reduce impacts from climate change. If early action is not taken it will become increasingly difficult for these communities to avoid and recover from the impacts of climate change.

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## Appendix B: Resources

### Funding Opportunities

#### **FEMA:**

##### **Hazard Mitigation Grant Program**

Provides grants to States and local governments to implement long-term hazard mitigation measures after a major disaster declaration.

<http://www.fema.gov/government/grant/hmgrp/index.shtm>

##### **Pre-Disaster Mitigation Grant**

Provides funds to states, territories, Indian tribal governments, communities, and universities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event.

<http://www.fema.gov/government/grant/pdm/index.shtm>

##### **Flood Mitigation Assistance**

Provides FMA funds to assist States and communities implement measures that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insurable under the National Flood Insurance Program.

<http://www.fema.gov/government/grant/fma/index.shtm>

##### **Repetitive Flood Claims Program**

The Repetitive Flood Claims (RFC) grant program was authorized by the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004 (P.L. 108–264), which amended the National Flood Insurance Act (NFIA) of 1968 (42 U.S.C. 4001, et al). Up to \$10 million is available annually for FEMA to provide RFC funds to assist States and communities reduce flood damages to insured properties that have had one or more claims to the [National Flood Insurance Program \(NFIP\)](#).

<http://www.fema.gov/government/grant/srl/index.shtm>

#### **Massachusetts Office of Coastal Zone Management:**

##### **CZM clearing house for related grant opportunities**

<http://www.mass.gov/czm/jobsandgrants.htm>

##### **StormSmart Coasts**

This program will target local officials and provide a clearinghouse of valuable resources, a compendium of legally defensible best practices for development and land-use, and workshops for local managers and officials. [www.mass.gov/czm/stormsmart](http://www.mass.gov/czm/stormsmart)

##### **Coastal and Estuarine Land Conservation Program (CELCP)**

CZM expects to release a Request for Responses (RFR) for applications for funding under the Coastal and Estuarine Land Conservation Program (CELCP). CELCP provides state and local governments with matching funds to purchase significant coastal and estuarine lands, or conservation easements on such lands, that are considered important for their ecological, conservation, recreational, historical, or aesthetic values. For more information about CELCP, see the [CZM's CELCP web page](#).

## **NOAA:**

### **Climate Program Office FY2008 Grant Funding Opportunity**

Transition of Research Applications to Climate Services (TRACS) Program will support transition of drought related decision support tools, methods, and processes, particularly those involving working with stakeholders. Full proposals must be submitted through Grants Online by September 24, 2007. [http://www.climate.noaa.gov/index.jsp?pg=/opportunities/opp\\_index.jsp&opp=2008/tracs\\_info.jsp](http://www.climate.noaa.gov/index.jsp?pg=/opportunities/opp_index.jsp&opp=2008/tracs_info.jsp)

## **US Army Corps of Engineers:**

### **(CAP) Continuing Authority Program US Army Corps of Engineers/ Flood Damage Reduction Projects**

Section 205 of the 1948 Flood Control Act authorizes the Corps of Engineers to study, design, and construct small flood control projects in partnership with non-Federal government agencies, such as cities, counties, special authorities, or units of state government.

<http://www.nae.usace.army.mil/pservices/fldrd205.htm>

### **Streambank and Shoreline Protection**

Section 14 of the 1946 Flood Control Act provides the Corps of Engineers authority to construct emergency shoreline and streambank protection works to protect public facilities, such as bridges, roads, public buildings, sewage treatment plants, water wells, and non-profit public facilities, such as churches, hospitals, and schools. <http://www.nae.usace.army.mil/pservices/shore14.htm>

## **U.S. Fish and Wildlife Service:**

### **North American Wetlands Conservation Act Grants**

The North American Wetlands Conservation Act ([NAWCA](#)) provides matching grants to organizations and individuals who have developed partnerships to carry out wetlands conservation projects in the United States, Canada, and Mexico for the benefit of wetlands-associated migratory birds and other wildlife. There is a Standard (awards up to \$1 million) and a Small (awards up to \$75,000) Grants Program. Both are competitive programs and require that grant requests be matched by partner contributions at no less than a 1-to-1 ratio. 2008 deadlines for U.S. Standard Grants are March 7 and August 18. <http://www.fws.gov/birdhabitat/Grants/NAWCA/Act.shtm>

## **Federal and State Agencies Resources**

### **FEMA Mapping Information Platform**

Free online flood hazard mapping tool.

[https://hazards.fema.gov/femaportal/wps/portal!/ut/p/kcxml/04\\_Sj9SPykssy0xPLMnMz0vM0Y\\_QjzKLd4w39DQGSZnFG8QbmpHogk5IkR8PfJzU\\_WD9L31A\\_QLckMjyh0dFQHZr3ie/delta/base64xml/L3dJdyEvd0ZNQUFzQUMvNEIVRS82X0FfMkVB?nID=6 A 1I3&cID=6 A 1I3](https://hazards.fema.gov/femaportal/wps/portal!/ut/p/kcxml/04_Sj9SPykssy0xPLMnMz0vM0Y_QjzKLd4w39DQGSZnFG8QbmpHogk5IkR8PfJzU_WD9L31A_QLckMjyh0dFQHZr3ie/delta/base64xml/L3dJdyEvd0ZNQUFzQUMvNEIVRS82X0FfMkVB?nID=6 A 1I3&cID=6 A 1I3)

### **FEMA HAZUS-MH Software and Training**

Free software for governments and online training and conferences. This is a hazard mapping software

using GIS and a Comprehensive Data Management System CDMS. It includes a patch that allows for inclusion of local GIS data. <http://www.fema.gov/plan/prevent/hazus/>

### **Mass CZM Coastal Smart Workshops**

Provides a forum to illustrate techniques aimed at integration of Low Impact Development/Smart Growth approaches in local planning and development.

[http://www.mass.gov/czm/smartgrowth/tech\\_assist/workshops.htm](http://www.mass.gov/czm/smartgrowth/tech_assist/workshops.htm)

## List of Organizations and Links

Adaptation Network - [www.adaptationnetwork.org](http://www.adaptationnetwork.org)

Association of State Floodplain Managers - <http://www.floods.org/home/default.asp>

DEM Flood Hazard Management Program (FHMP) (for information on the State Hazard Mitigation Plan, and Flood Mitigation Assistance (FMA) program - <http://www.mass.gov/dcr/index.htm>

DEM Office of Natural Resources – ACEC designations, beach management plans, or other land use plans. [www.mass.gov/dem](http://www.mass.gov/dem)

Emergency Management Institute- <http://training.fema.gov/EMIWeb/>

EOEA Conservation Services – open space preservation, conservation restrictions - [www.mass.gov/envir](http://www.mass.gov/envir)

ICLEI- Preparing for Climate Change: A Guidebook for Local, Regional and State Governments - <http://www.iclei.org/index.php?id=7066>

Massachusetts Association of Conservation Commissions- [www.maccweb.org](http://www.maccweb.org)

Massachusetts Coastal Zone Management - <http://www.mass.gov/czm/>

Massachusetts Emergency Management Agency (MEMA) – emergency response plans and disaster preparedness information and news - [www.mass.gov/mema](http://www.mass.gov/mema)

MA Riverways Program – (Massachusetts Department of Fisheries, Wildlife, and Environmental Law Enforcement) – greenway and open space plans, Adopt-A-Stream initiatives - [www.mass.gov](http://www.mass.gov)

U.S. Army Corps of Engineers (USACE) – water resource projects, Section 22 Planning Assistance program, Flood Plain Management Services program - [www.usace.army.mil](http://www.usace.army.mil)

Watershed organizations/Watershed Initiative Basin Teams – watershed plans or activities - [www.state.ma.us/envir/mwi/watersheds.htm](http://www.state.ma.us/envir/mwi/watersheds.htm)

## Appendix C: GIS Data Sources and Methodology

**The following GIS data layers and tabular data sets have been utilized in this analysis:**

1. Digital Elevation Model (DEM) from Mass GIS
2. 100-year and 500-year flood plain layer from Mass GIS
3. Parcel layer for Beverly from the City of Beverly
4. Buildings layer for Beverly from the City of Beverly
5. Census Block Group layer from Mass GIS
6. Census Tract layer from Mass GIS
7. Census Block Group table population\_by\_age\_gender from Mass GIS
8. Census Block Group table households\_by\_age\_family\_children from Mass GIS
9. Census Block Group table education\_attainment\_by\_gender\_age from Mass GIS
10. Census Block Group table employment\_status\_by\_gender from Mass GIS
11. Census Block Group table income\_poverty\_levels\_by\_age from Mass GIS
12. Census Block Group table housing\_amenities\_by\_tenure from Mass GIS
13. Census Block Group table housing\_value from Mass GIS
14. Census Block Group table household\_language\_spoken from Mass GIS
15. Census Block Group table legattrib from Mass GIS
16. Census Tract table mental\_physical\_disabled\_pop\_by\_age from Mass GIS
17. Land-Use layer from Mass GIS
18. School layer from Mass GIS
19. Library layer from Mass GIS
20. Hospital layer from Mass GIS
21. Electric Substations from the City of Beverly
22. Town boundaries from Mass GIS
23. Hydrography layer from Mass GIS
24. Rail layer from Mass GIS
25. Road layer from Mass GIS
26. Orthographic Photos from Mass GIS
27. Ocean mask from Mass GIS

### **Data Processing Steps:**

1. The Flood Plain, Census Block, Census Tracts, Land-Use, School, Library, Hospital and Town Boundaries layers were all clipped to exclude everything outside the boundaries of the six Salem Sound towns, of Marblehead, Salem, Peabody, Danvers, Beverly and Manchester.
2. The DEM was clipped to include only the general extent of the Salem Sound area.
3. Copies of the Town Boundaries layer were also clipped to include only the City of Beverly and then to exclude the City of Beverly, serving as a mask.
4. The layers from the City of Beverly were re-projected into the same coordinate system as all the layers from Mass GIS.
5. In the housing\_amenities\_by\_tenure table, a field was added and the owner-occupied housing units and renter-occupied housing units fields with no vehicle were summed and divided by total occupied housing units to create the Percent Households with No Vehicle field.
6. In the income\_poverty\_levels\_by\_age table, a new field was created and the population below

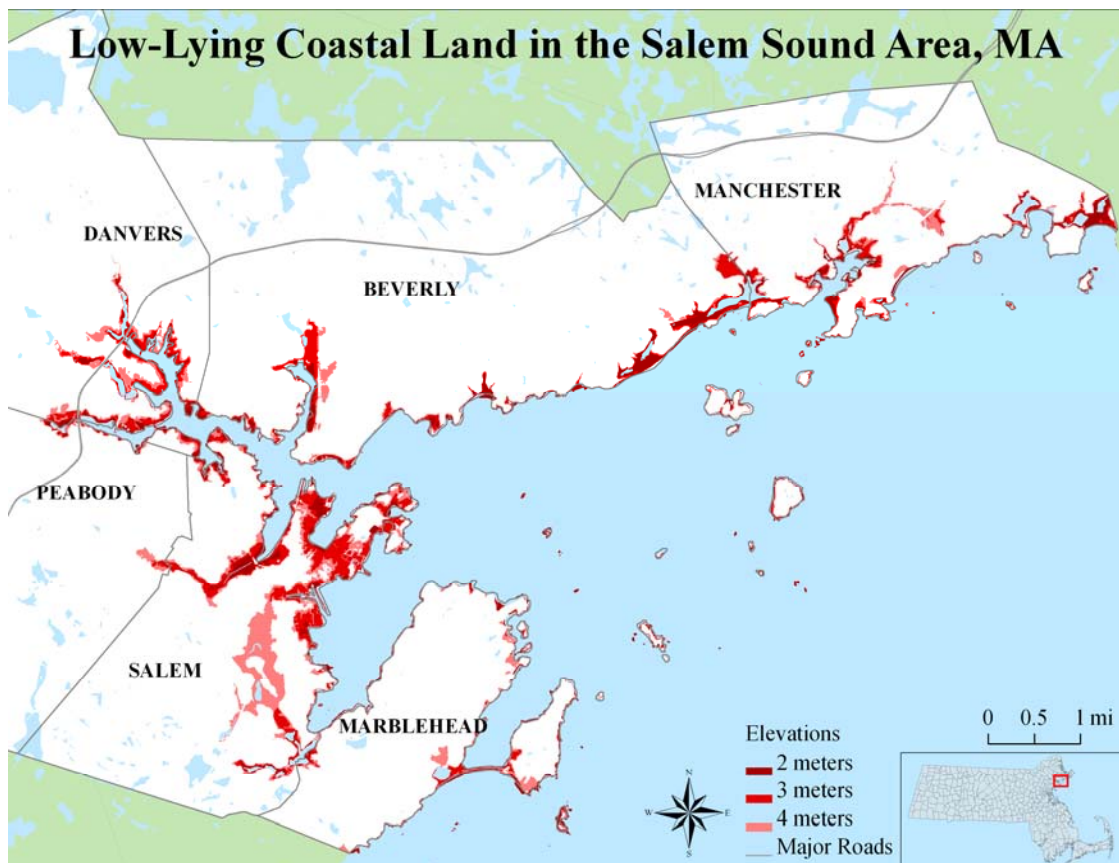
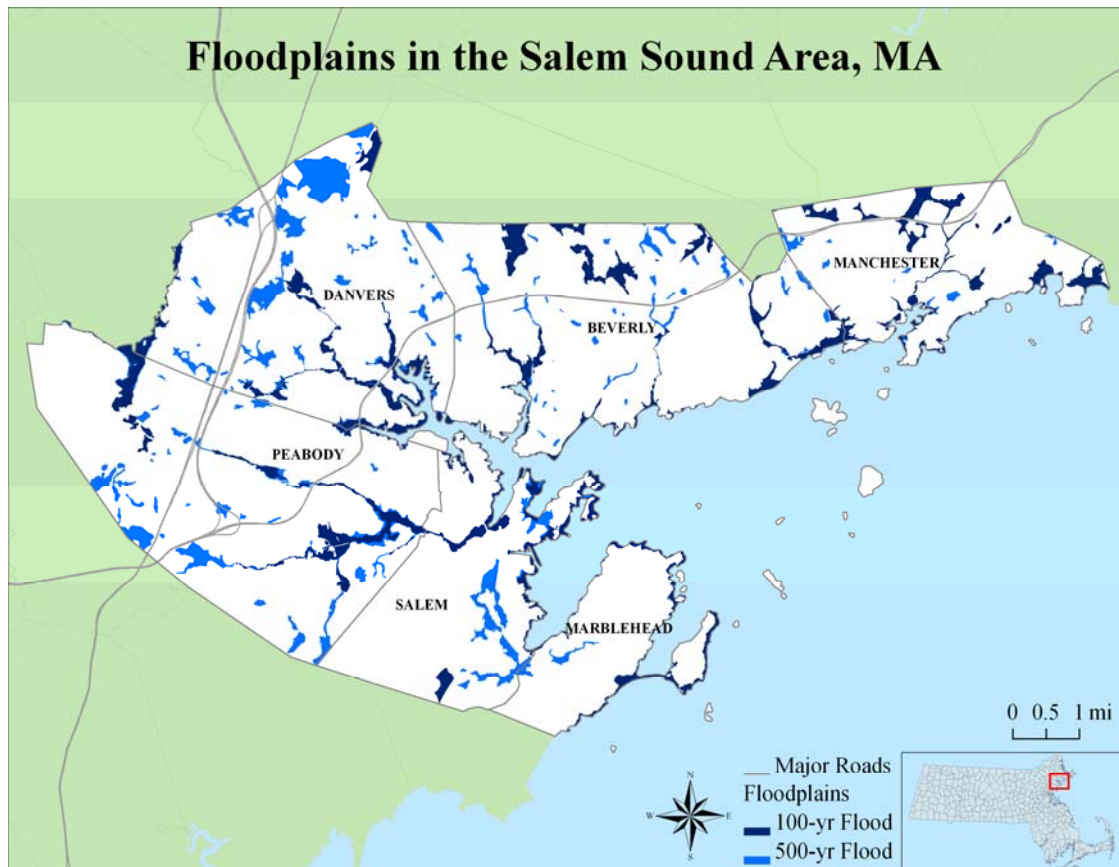
poverty level was divided by the total population for which poverty status was determined to create the Percent Population Below Poverty Level field.

7. In the `mental_physical_disabled_pop_by_age` table, a field was added and the male and female civilian non-institutionalized physically disabled fields of 5 to 15-years old, 16 to 20-years old, 21 to 64-years old, 65 to 74-years old and 75-years old and over were summed and divided by the total population 5-years old and over to create the Percent Population Physically Disabled field.
8. In the `mental_physical_disabled_pop_by_age` table, a field was added and the male and female civilian non-institutionalized mentally disabled fields of 5 to 15-years old, 16 to 20-years old, 21 to 64-years old, 65 to 74-years old and 75-years old and over were summed and divided by the total population 5-years old and over to create the Percent Population Mentally Disabled field.
9. In the `legattrib` table, a field was added and the male and female fields of 65 and 66-years old, 70 to 74-years old, 75 to 79-years old, 80 to 84-years old and 85-years old and over were summed and divided by the total population to create the Percent Population 65-Years Old and Over field.
10. In the `households_by_age_family_children` table, a field was added and 65-years old and over field was divide by the total population to create the Percent Population 65-Years Old and Over and Living Alone field.
11. In the `population_by_age_gender` table, a field was added and the male and female fields of less than 1-year old, 1-year old, 2-years old, 3-years old and 4-years old were summed and divided by the total population to create the Percent Population Under 5-Years Old field.
12. In the `employment_status_by_gender` table, a field was added and the male and female fields for unemployed civilians 16-years old and over were summed and divided by the total population 16-years old and over to create the Percent Population Unemployed field.
13. In the `education_attainment_by_gender_age` table, a field was added and the male and female fields of nursery to 4<sup>th</sup> grade, 5<sup>th</sup> and 6<sup>th</sup> grade, 9<sup>th</sup> grade, 10<sup>th</sup> grade, 11<sup>th</sup> grade and 12<sup>th</sup> grade with no diploma were summed and divided by the total population to create the Percent Population No High School Diploma field.
14. In the `household_language_spoken` table, a field was added and the linguistically isolated Spanish-speaking households, linguistically isolated Indo-European language-speaking households, linguistically isolated Asian/Pacific Islander language-speaking households and linguistically isolated other language-speaking household fields were summed and divided by total households to create the Percent Households No English field.
15. In the `households_by_age_family_children` table, a field was added and male and female fields of 15 to 64-years old and 65-years old and over, children under 18-years old with no spouse present were summed and divided by the total households to create the Percent Households Single Parent field.
16. A field was added to a Census Block Group table and the Percent Households with No Vehicle, Percent Population Below Poverty Level, Percent Population Physically Disabled, Percent Population Mentally Disabled, Percent Population 65-Years Old and Over, Percent Population 65-Years Old and Over and Living Alone and Percent Population Under 5-Years Old fields were summed to create the Mobility Capacity field.
17. A field was added to a Census Block Group table and the Percent Population Below Poverty Level, Percent Population Unemployed, Percent Population No High School Diploma, Percent Households No English and Percent Households Single Parent fields were summed to create the Resource Capacity field.
18. A field was added to a Census Block Group table and the Mobility Capacity and Resource Capacity fields were summed to create the Adaptive Capacity field.

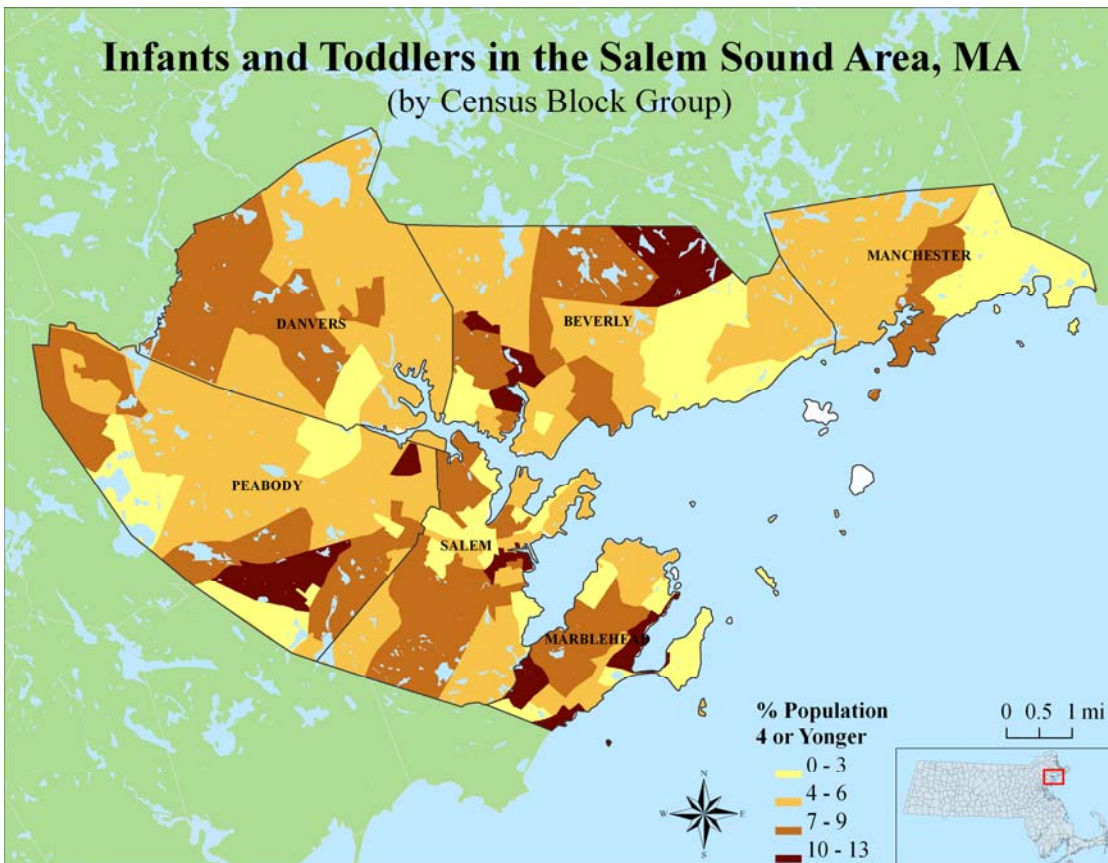
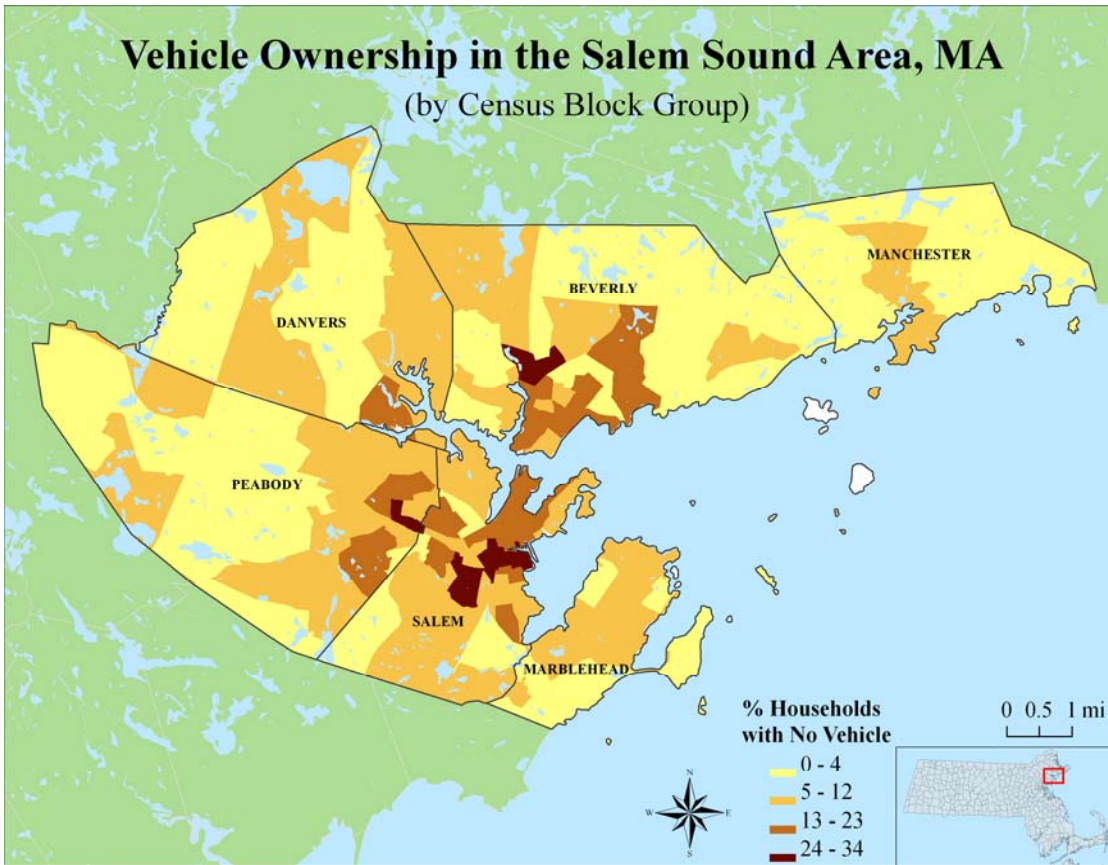
## Analysis Steps

1. The spatial join was used to connect the population\_by\_age\_gender, households\_by\_age\_family\_children, education\_attainment\_by\_gender\_age, employment\_status\_by\_gender, income\_poverty\_levels\_by\_age, housing\_amenities\_by\_tenure, housing\_value, household\_language\_spoken, and legattrib tables to the Census Block Groups.
2. The spatial join was used to connect the mental\_physical\_disabled\_pop\_by\_age table to the Census Tracts.
3. The spatial join was used to connect the Census Tracts (with the mental\_physical\_disabled\_pop\_by\_age table) to the Census Block Groups.
4. Select by attribute was used to create layers to show all land at 3 elevations, at or below 2 meters, at or below 3 meters and at or below 4 meters.
5. For the 2-meter, 3-meter and 4-meter elevation layers, all areas not contiguous to the ocean or an inlet to the ocean were removed to create 2-meter, 3-meter and 4-meter coastal layers. This was done systematically. To be included in the selections, an area must have either directly touched the coastline or have directly touched other areas that touched the coastline.
6. The Census Block Groups and Land-Use layers were clipped to 2-meter, 3-meter and 4-meter coastal layers to create Vulnerable Coastal Populations/Households and Vulnerable Coastal Land-Use layers.
7. The Census Block Groups and Land-Use layers were clipped to the 100-year and 500-year flood plain layers to create Vulnerable Populations/Households and Vulnerable Land-Use layers.
8. Calculate geometry was used to determine how much land is within the 100-year and 500-year flood plains and within the 2-meter, 3-meter and 4-meter coastal layers.
10. A field was added to each of the Vulnerable Land-Use and Vulnerable Coastal Land Use layers and the calculate geometry function was used to calculate the acres of each vulnerable parcel of land.
11. The summarize function was used to find the sum of acres by land use within each of the Vulnerable Land-Use and Vulnerable Coastal Land-Use layers.
12. The Beverly Building layer was clipped by the 2-meter, 3-meter and 4-meter coastal layers to create Vulnerable Coastal Buildings layers.
13. The Beverly Building layer was clipped by the 100-year and 500-year flood plain layers to create Vulnerable Buildings layers.
14. Building Values were summed for each of the Vulnerable Coastal Buildings and Vulnerable Buildings layers to determine the total value of vulnerable buildings in the City of Beverly.

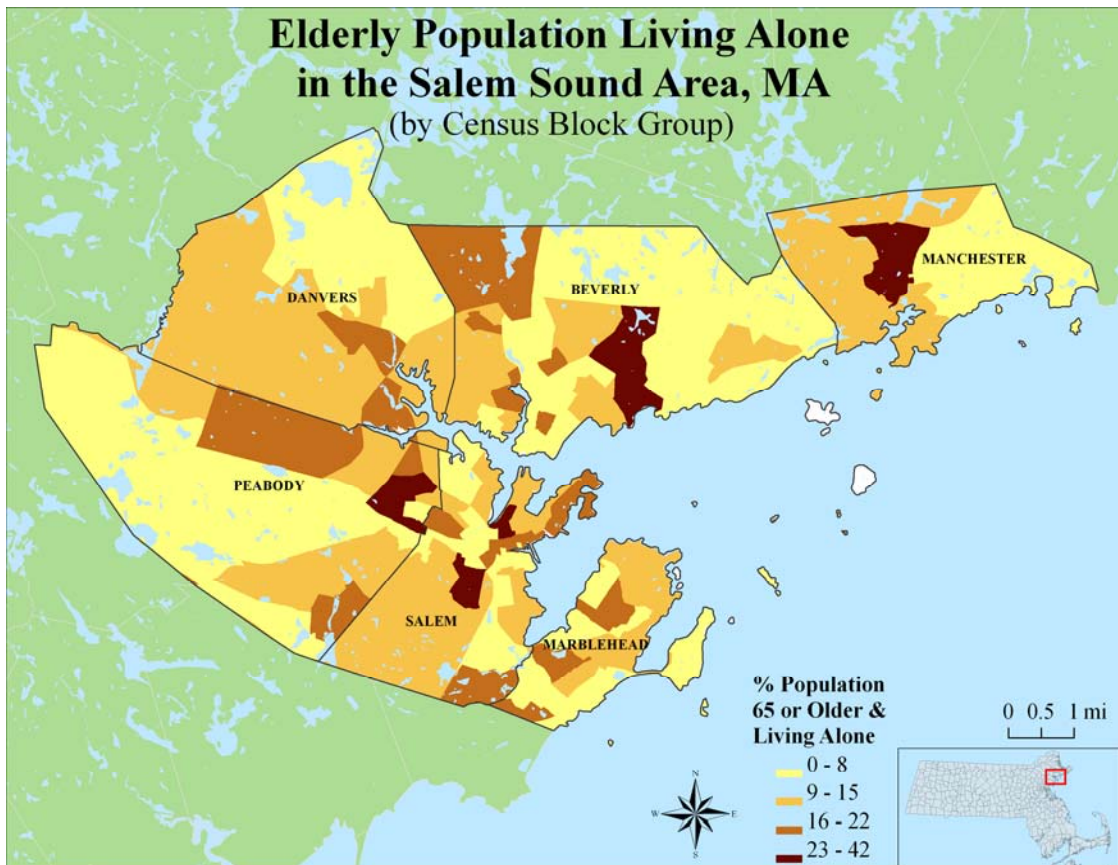
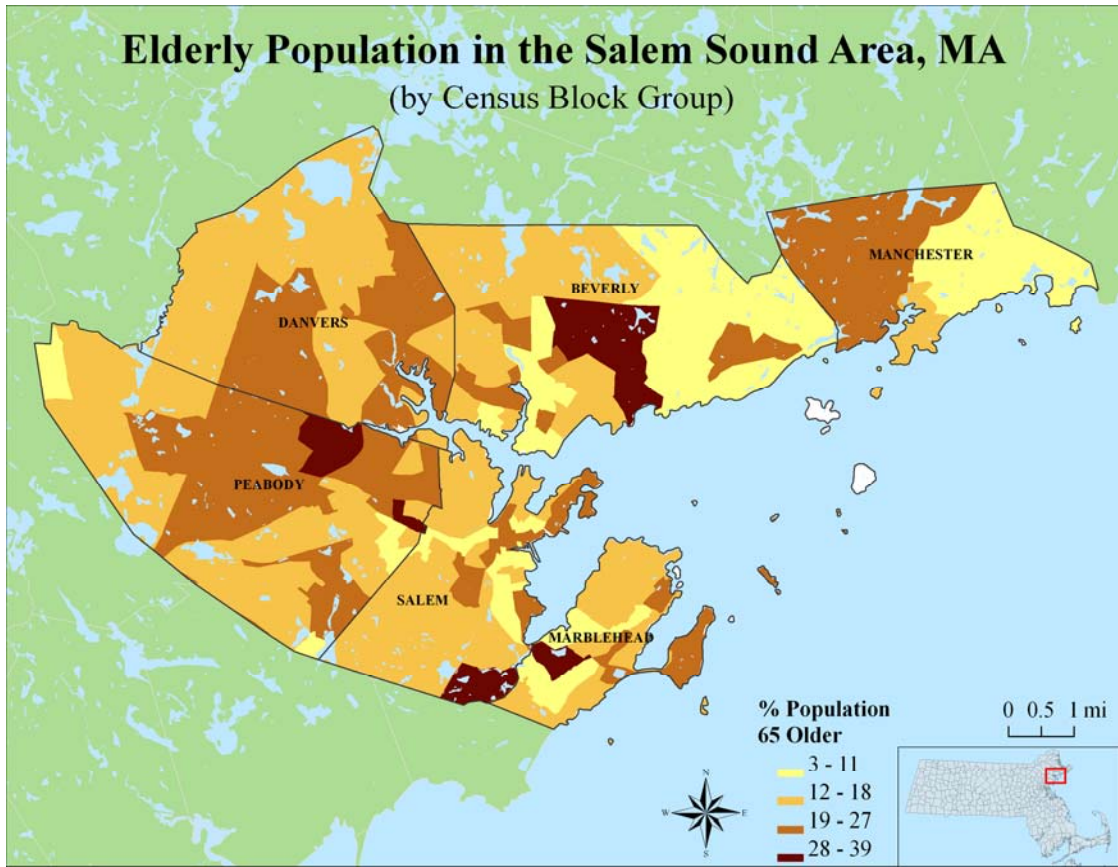
## Appendix D: Flood Zone Maps for Salem Sound, MA



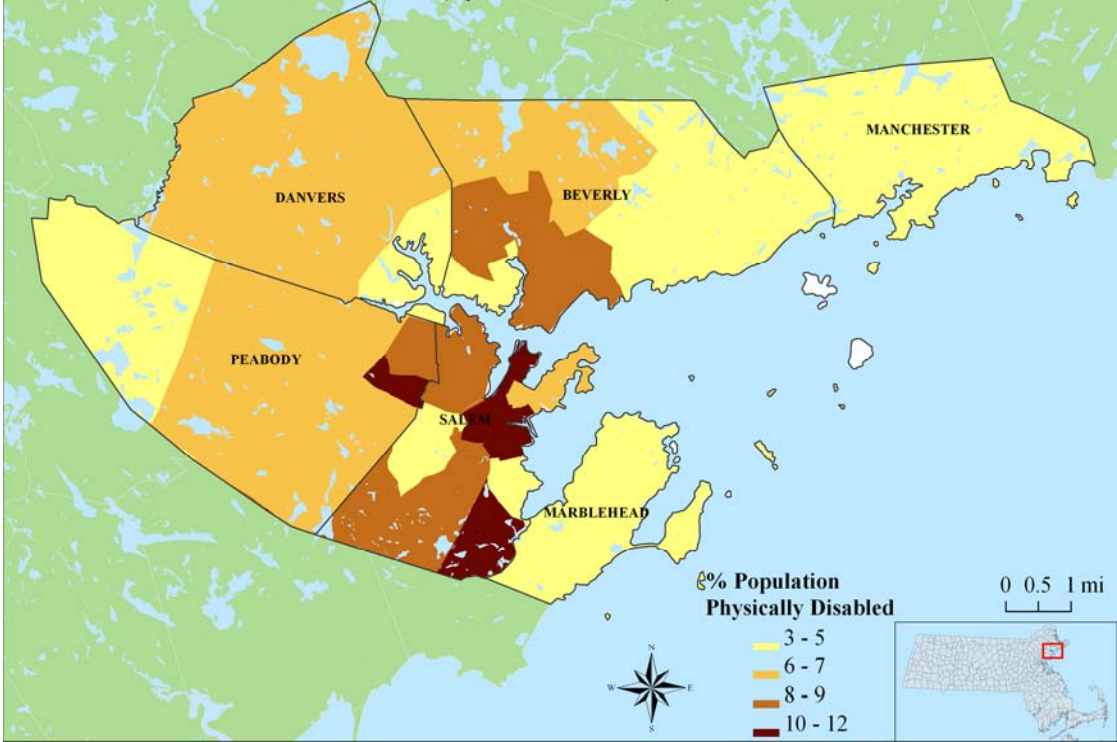
## Appendix E: Census Variable Maps for Salem Sound, MA



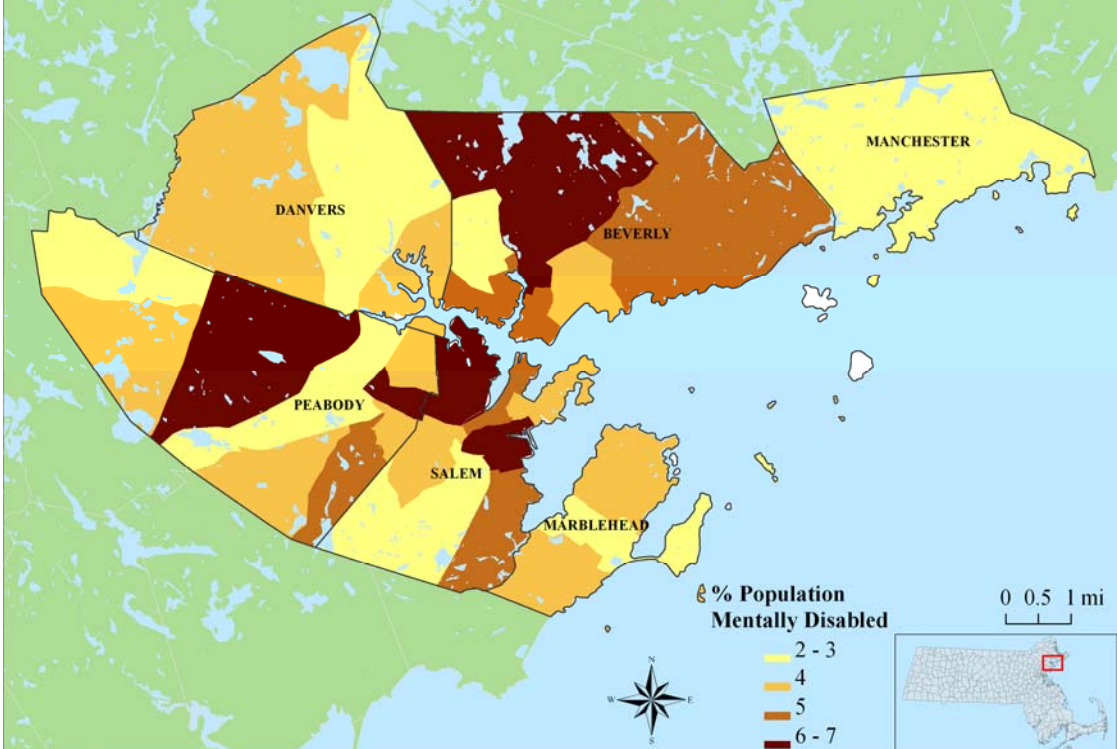


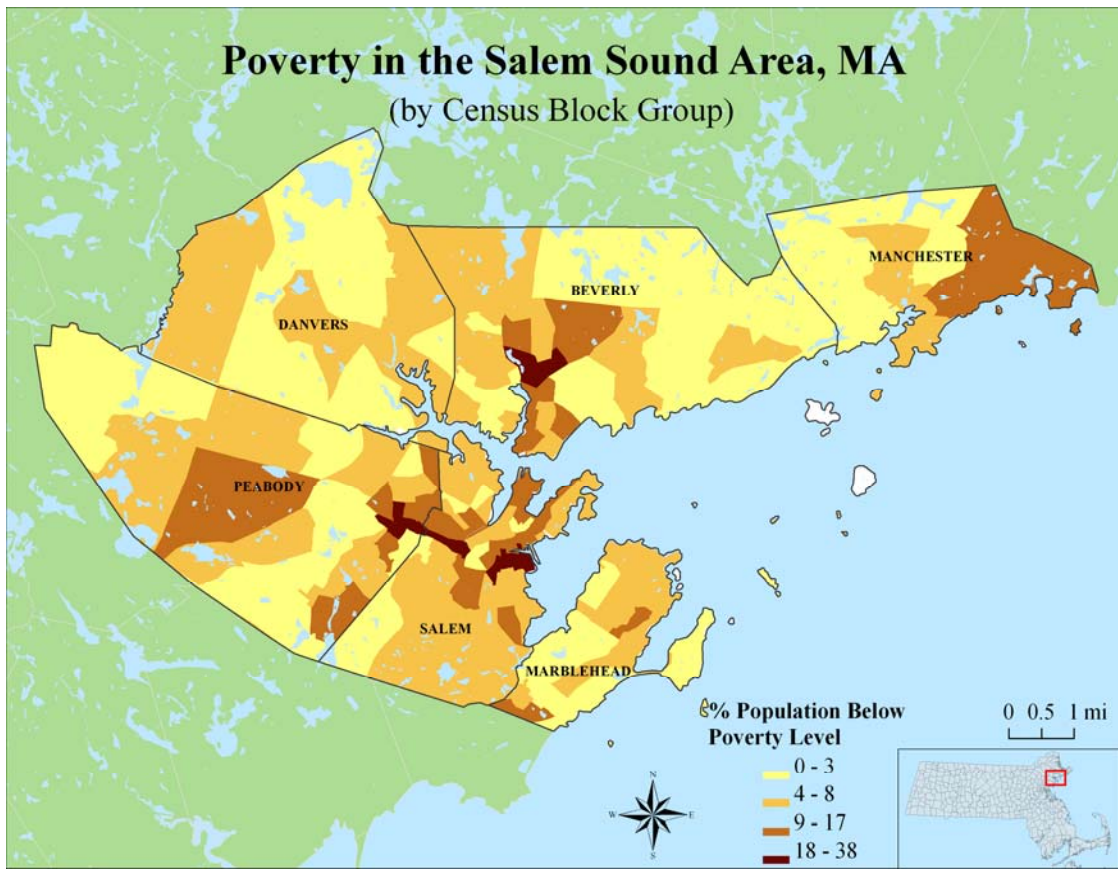


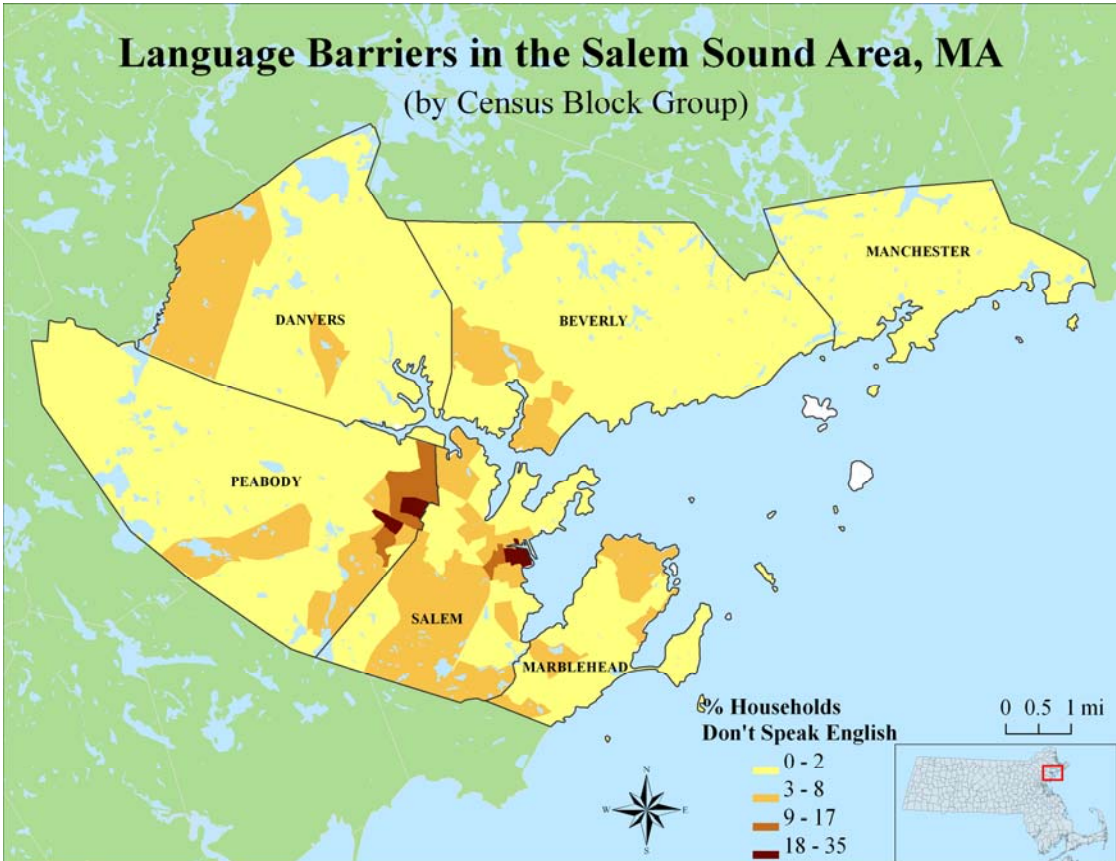
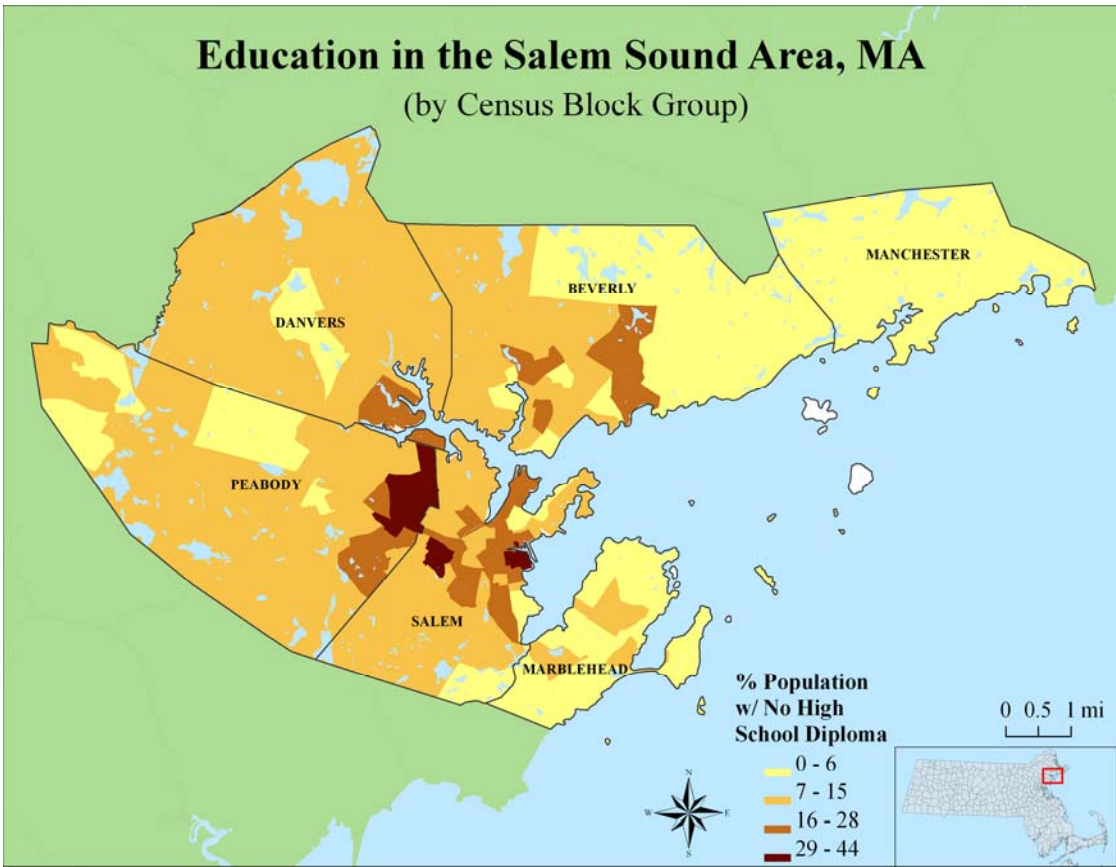
## Physically Disabled Population in the Salem Sound Area, MA (by Census Tract)

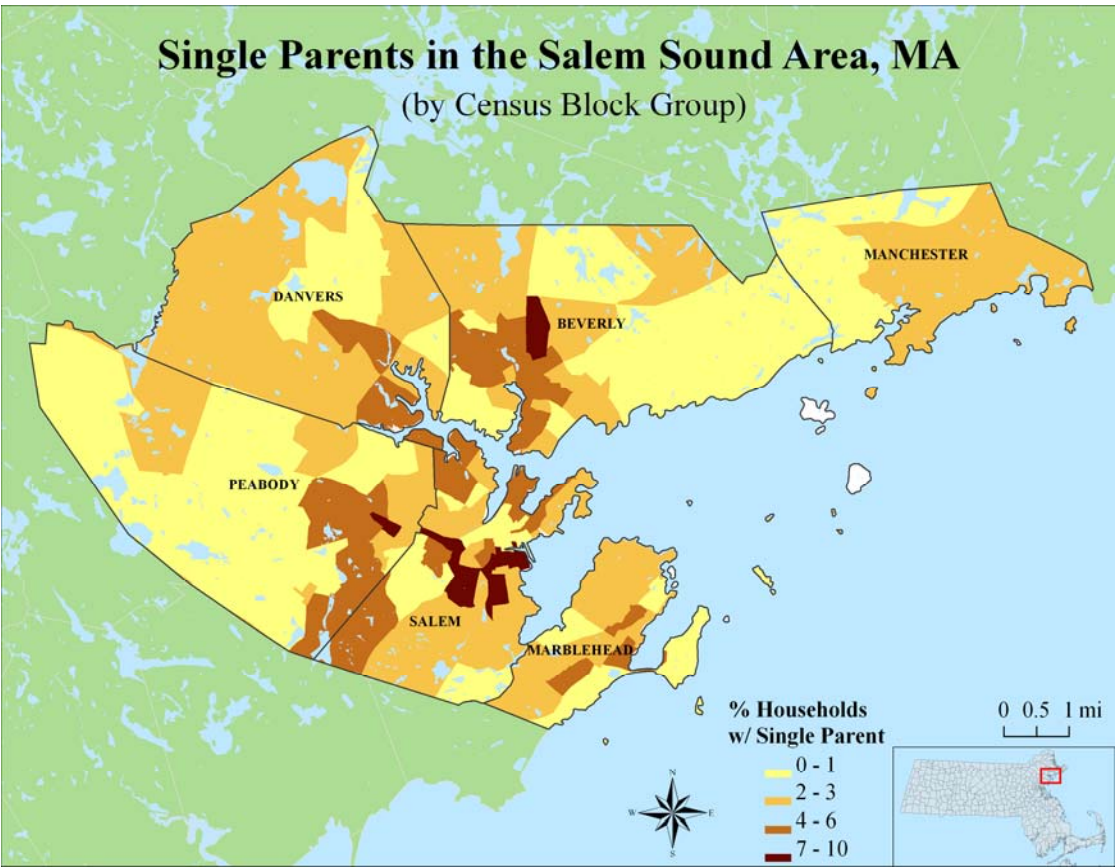


## Mentally Disabled Population in the Salem Sound Area, MA (by Census Tract)

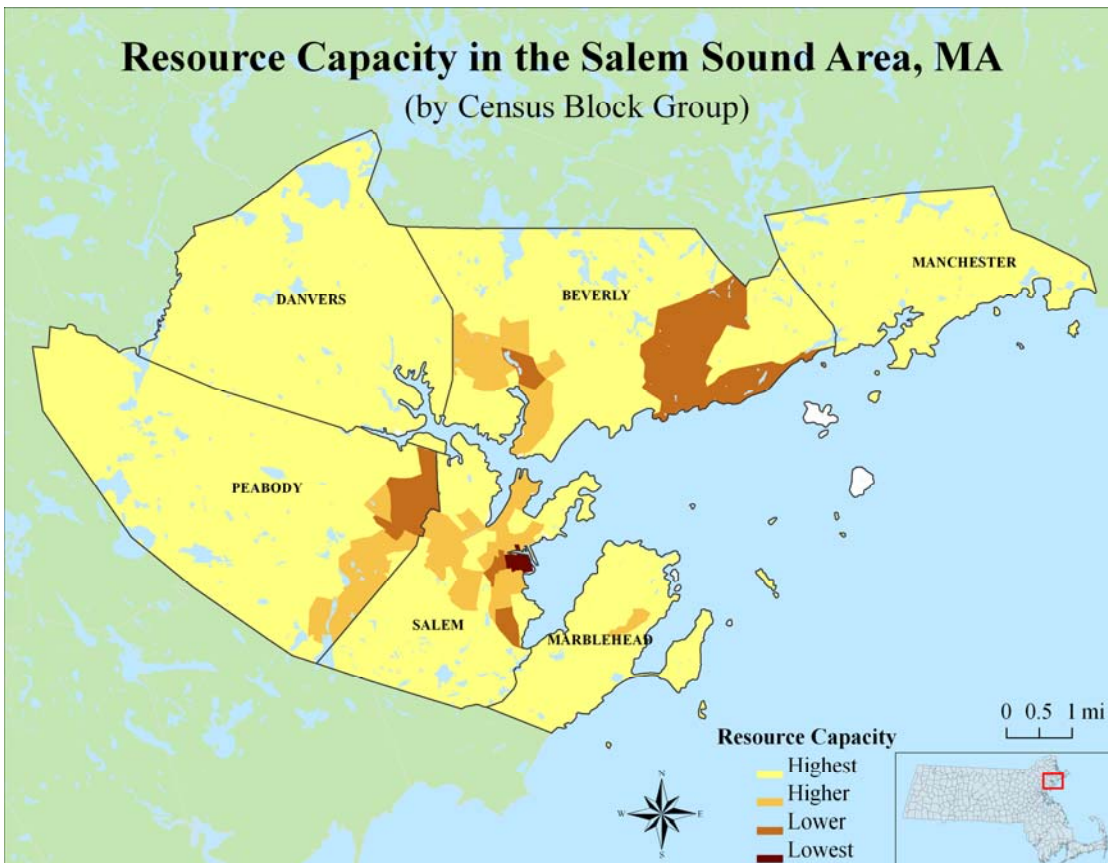
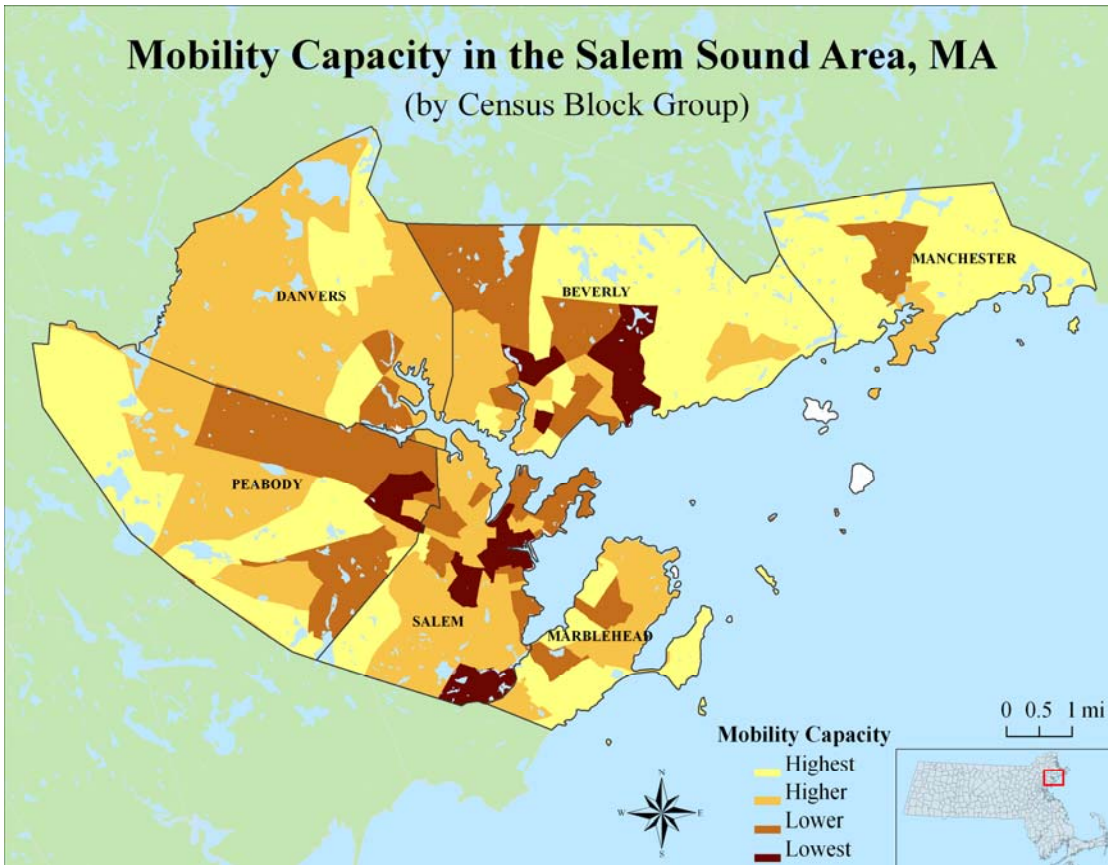


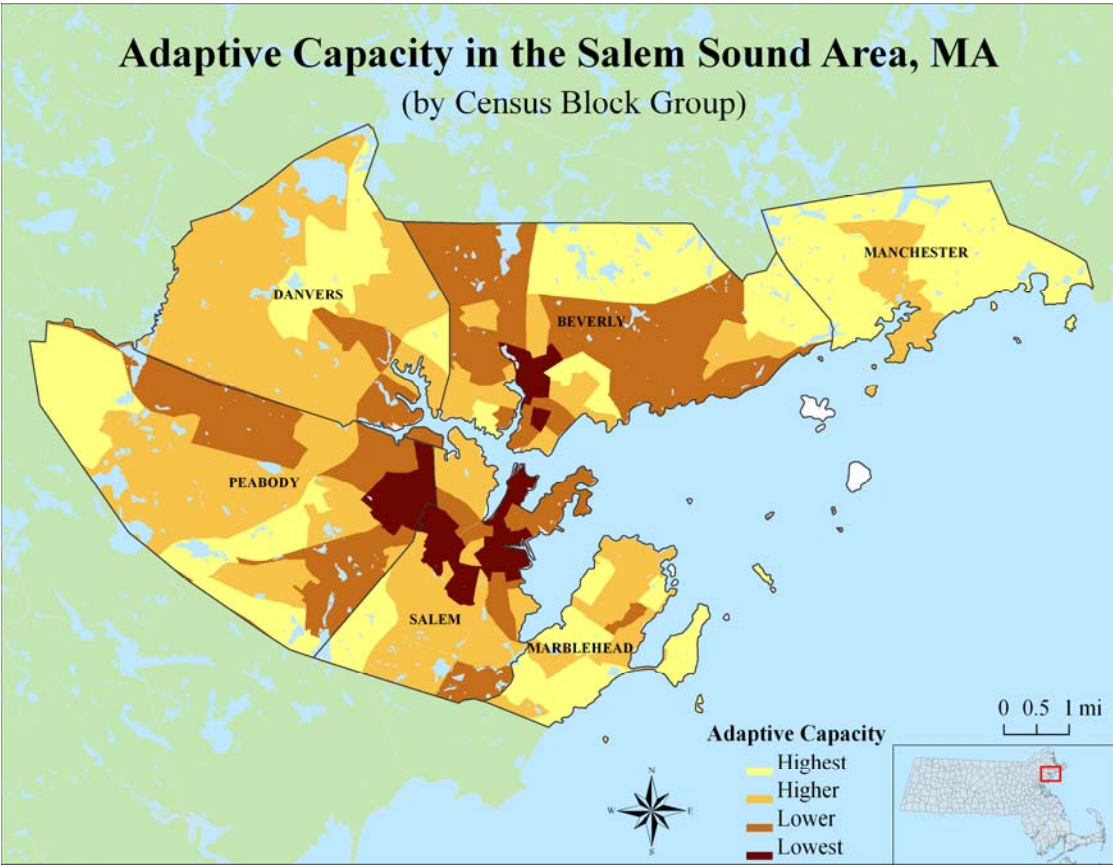




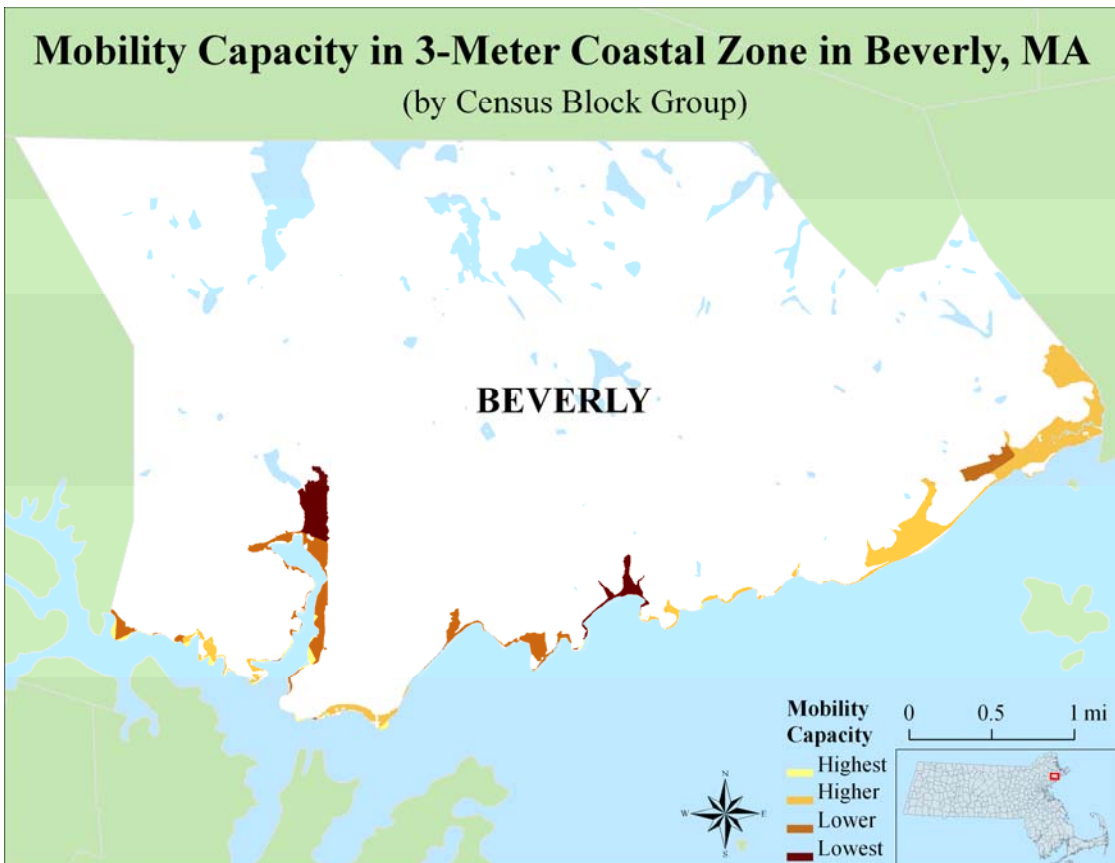
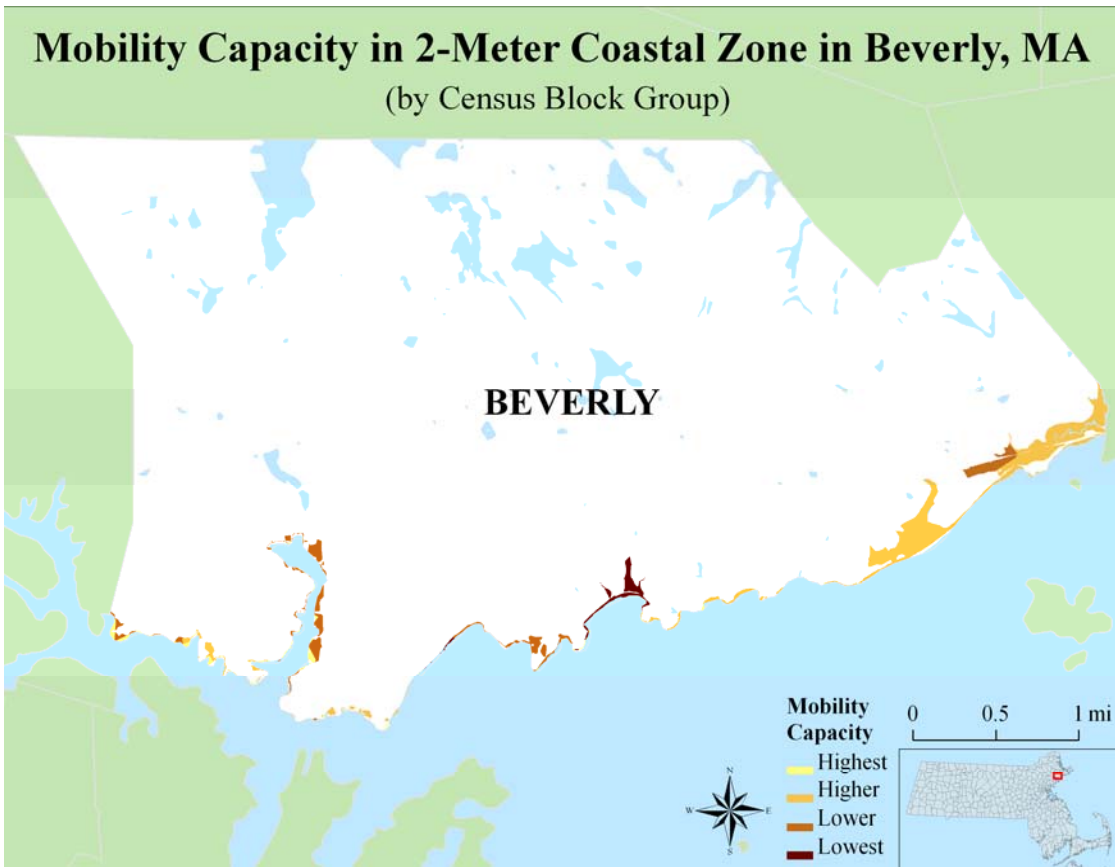


# Appendix F: Adaptive Capacity Maps for Salem Sound, MA

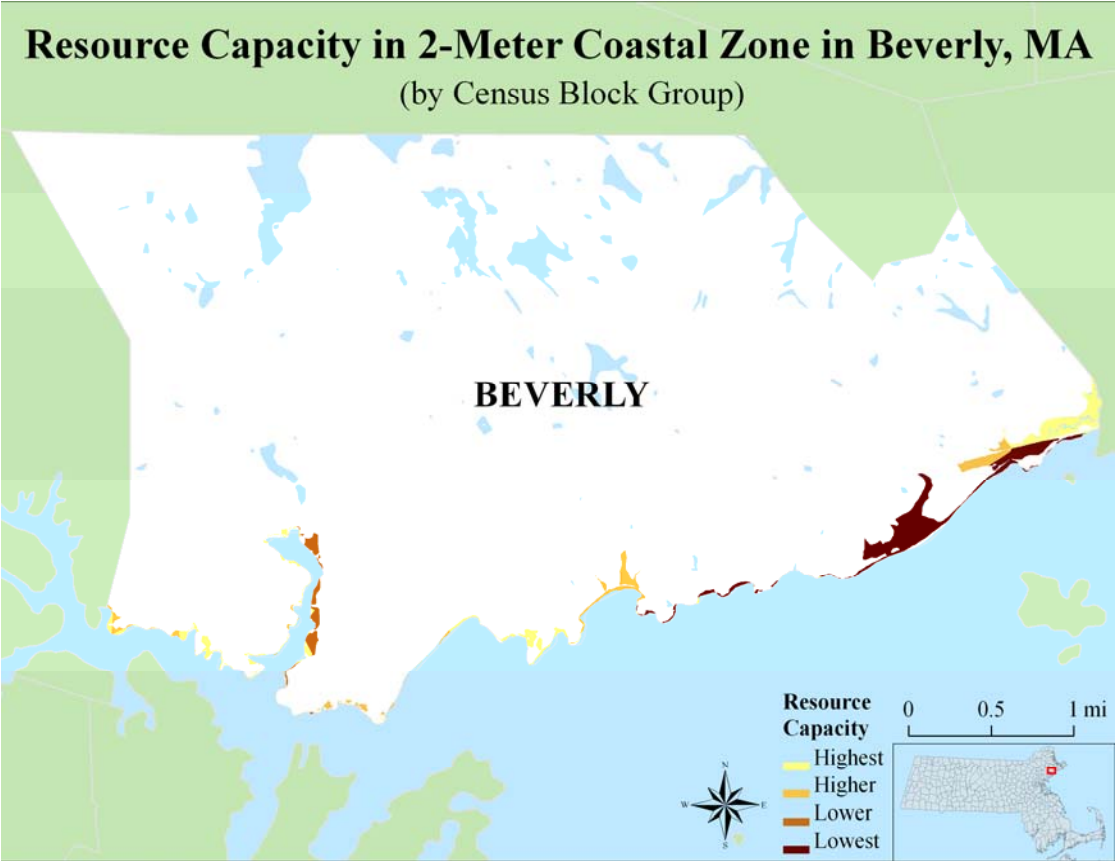
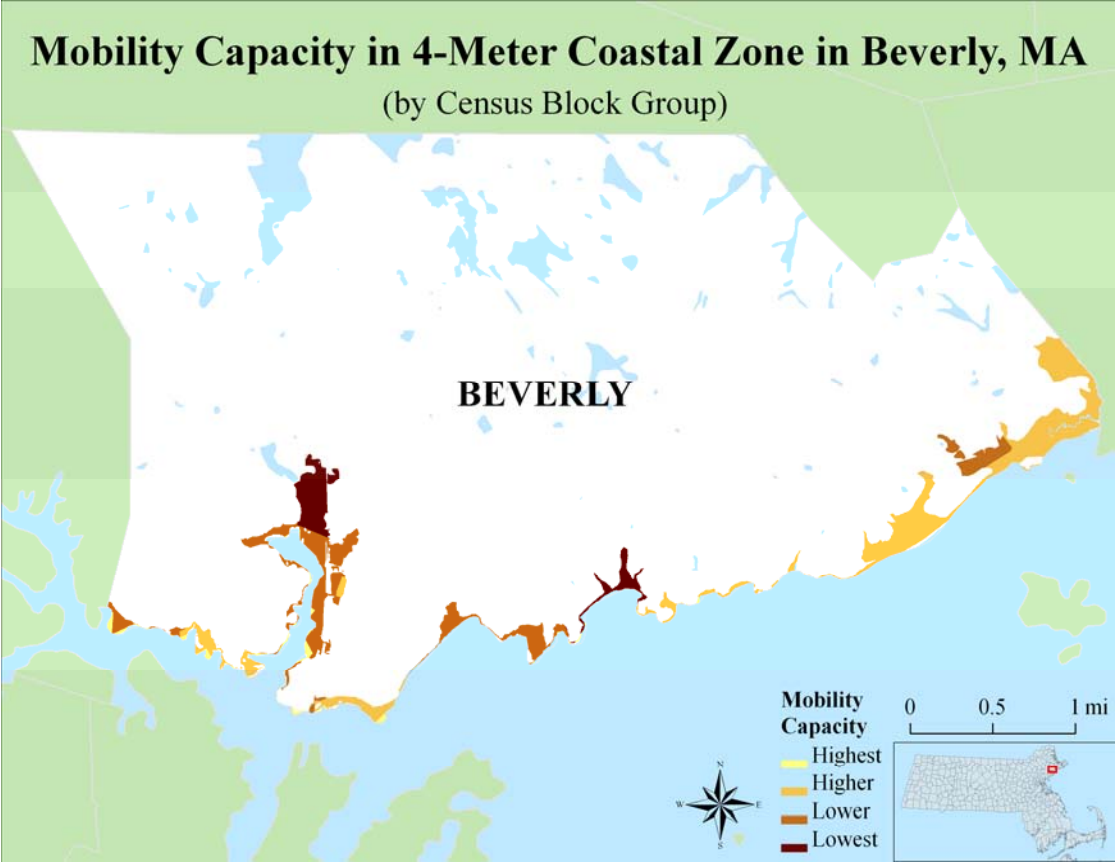




## Appendix G: Place Vulnerability Maps for Beverly, MA





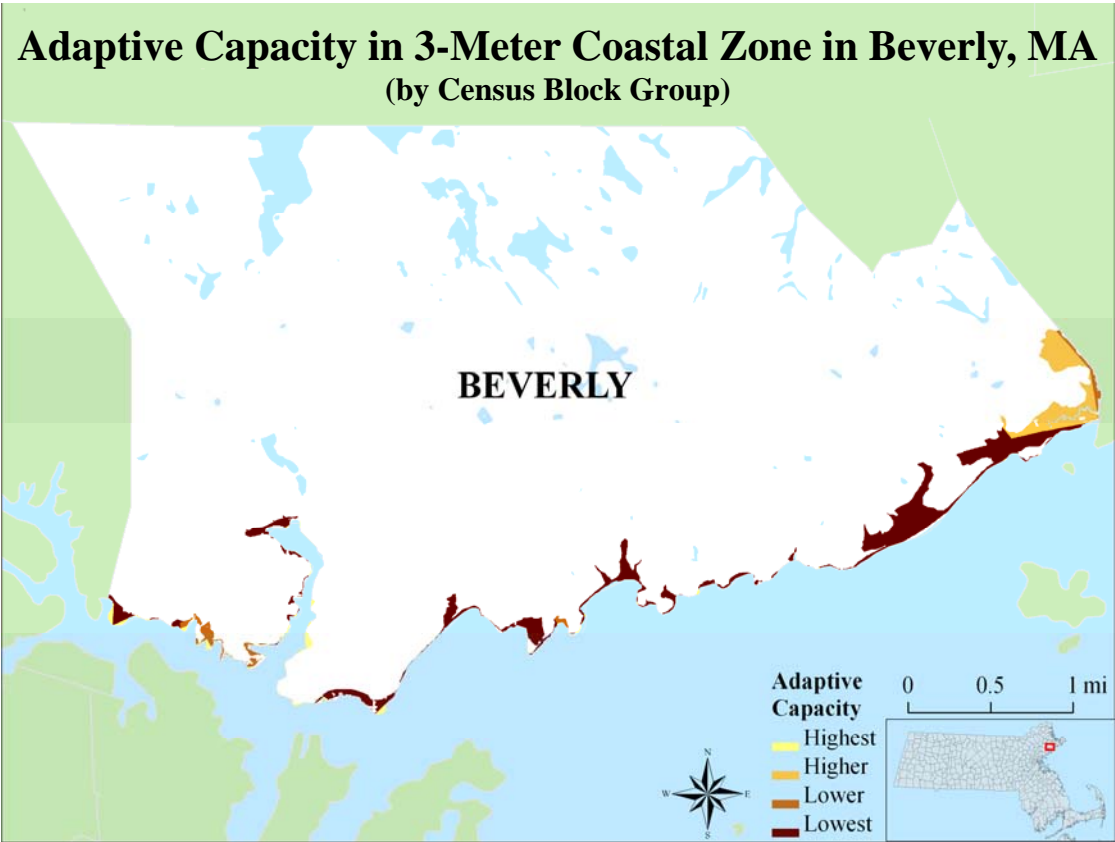
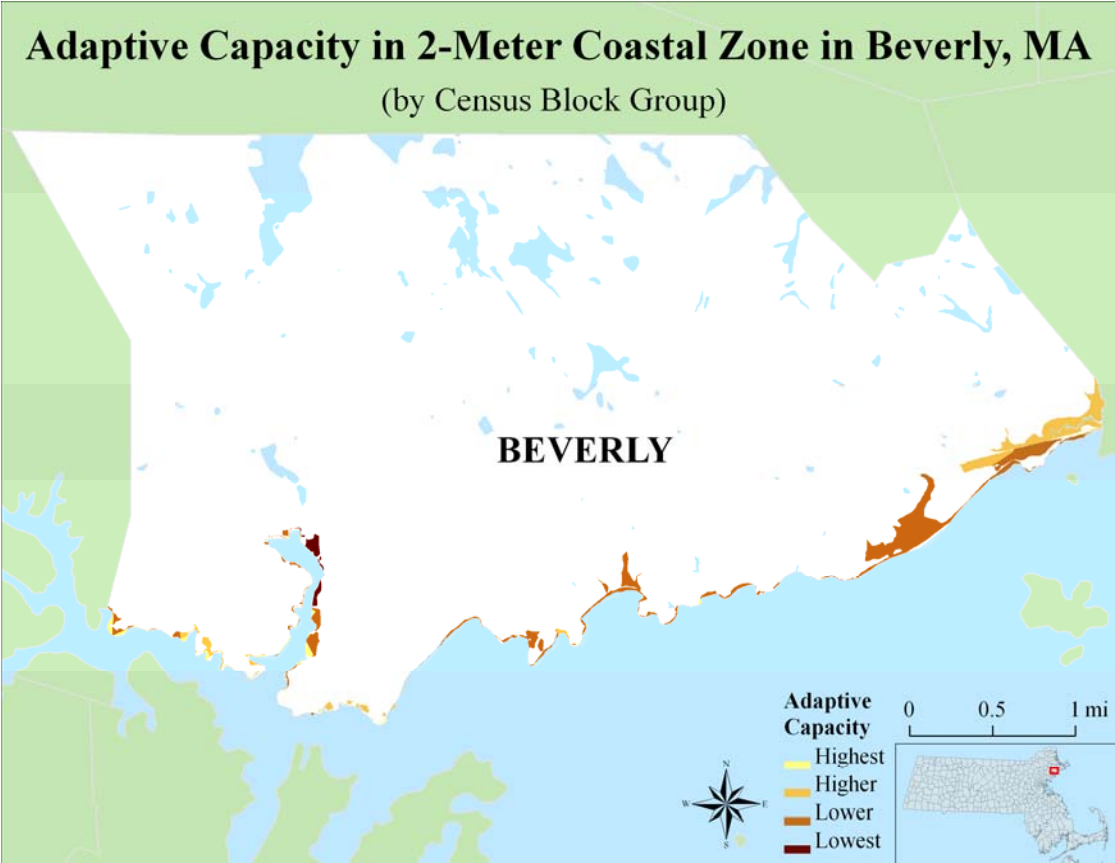


## Resource Capacity in 3-Meter Coastal Zones in Beverly, MA (by Census Block Group)



## Resource Capacity in 4-Meter Coastal Zone in Beverly, MA (by Census Block Group)





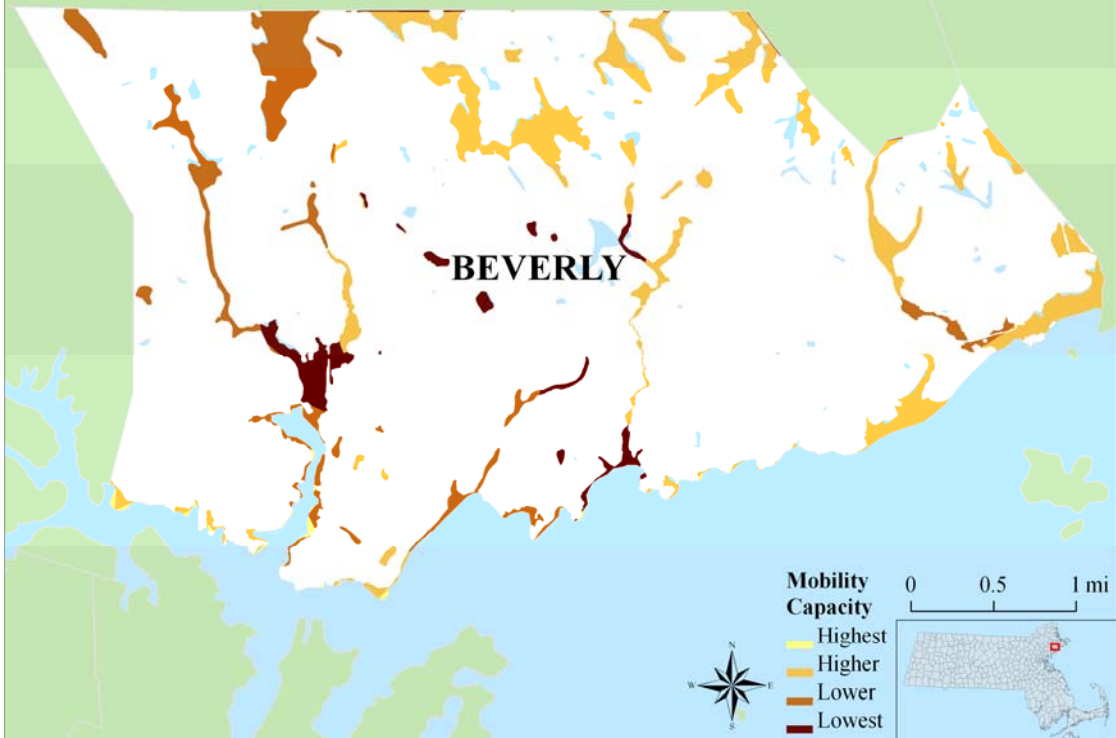
## Adaptive Capacity in 4-Meter Coastal Zone in Beverly, MA (by Census Block Group)



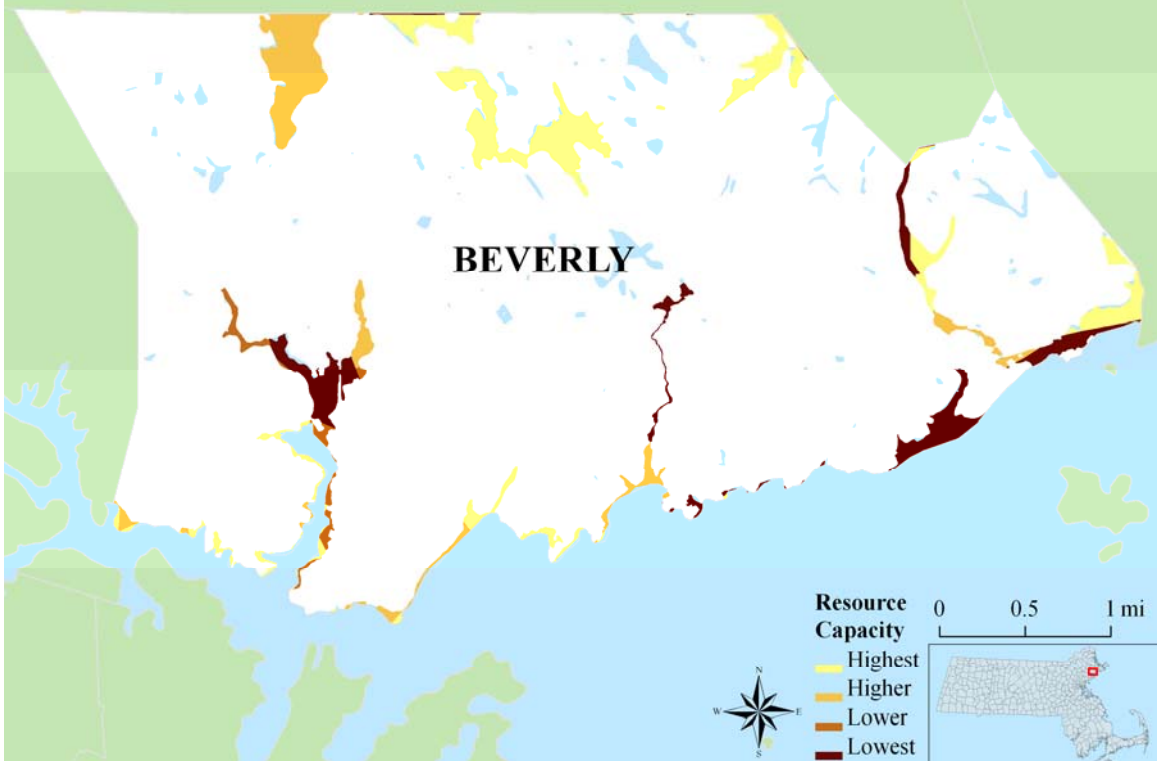
## Mobility Capacity in 100-Year Floodplain in Beverly, MA (by Census Block Group)



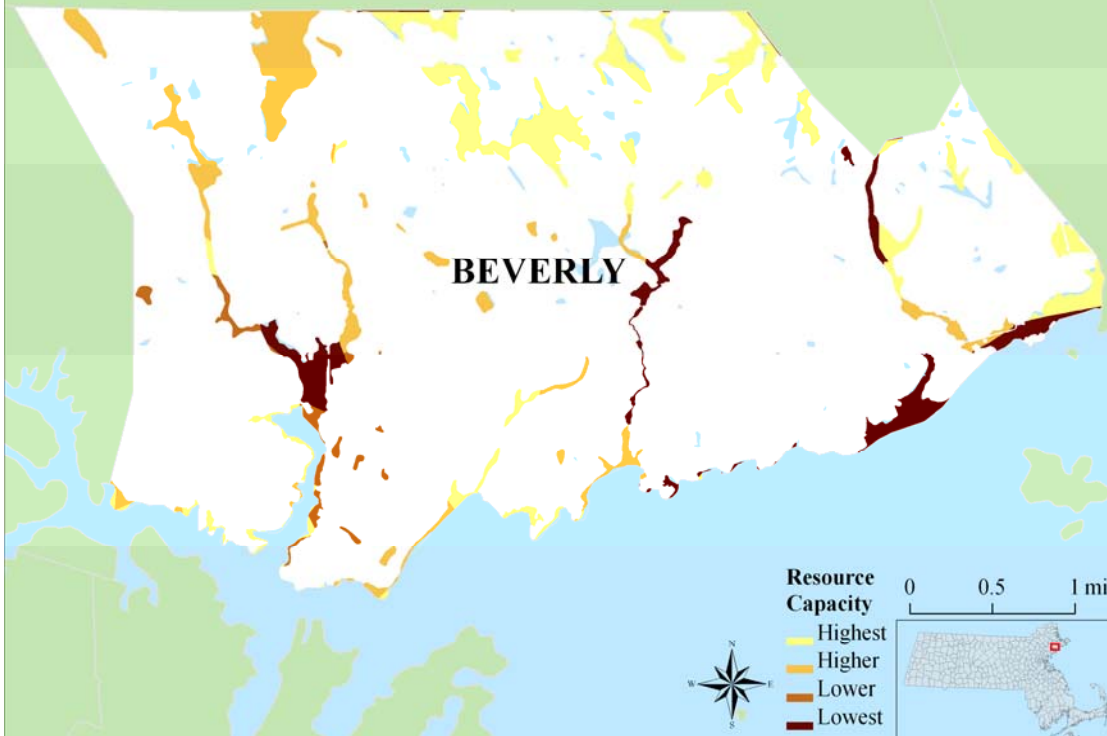
### Mobility Capacity in 500-Year Floodplains in Beverly, MA (by Census Block Group)



### Resource Capacity in 100-Year Floodplains in Beverly, MA (by Census Block Group)

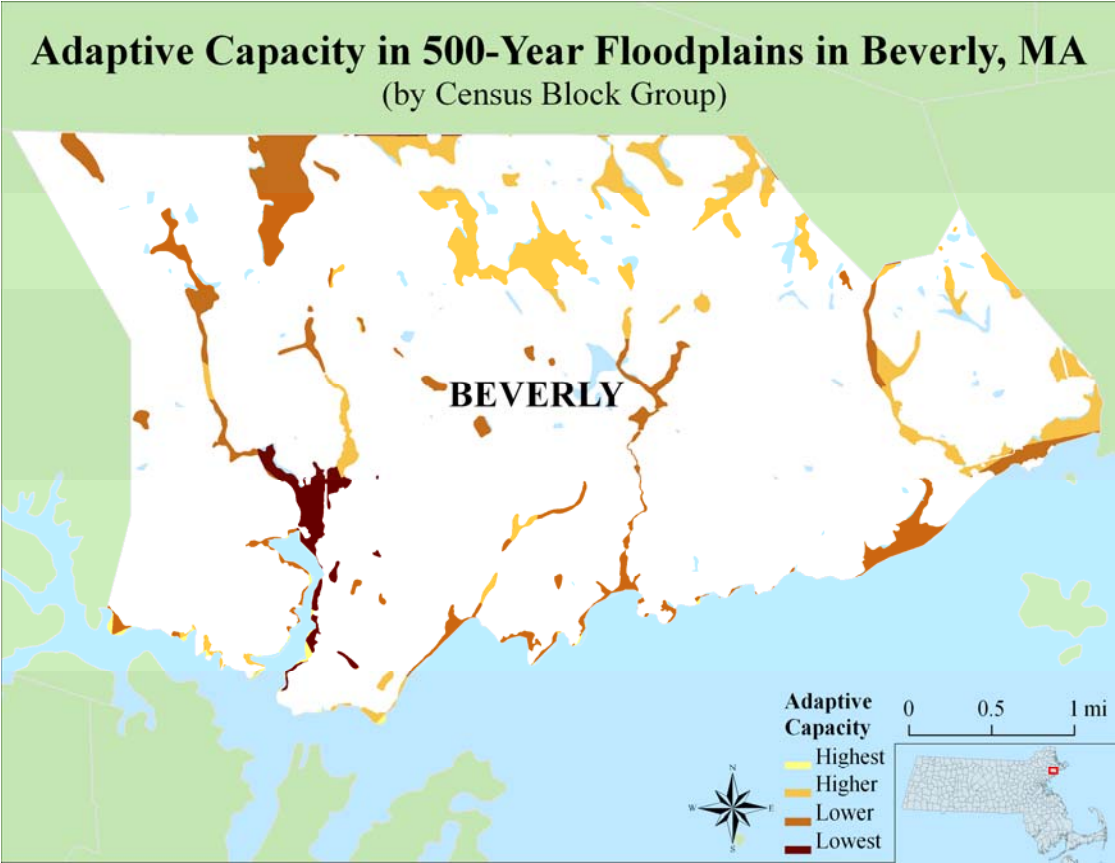


## Resource Capacity in 500-Year Floodplains in Beverly, MA (by Census Block Group)

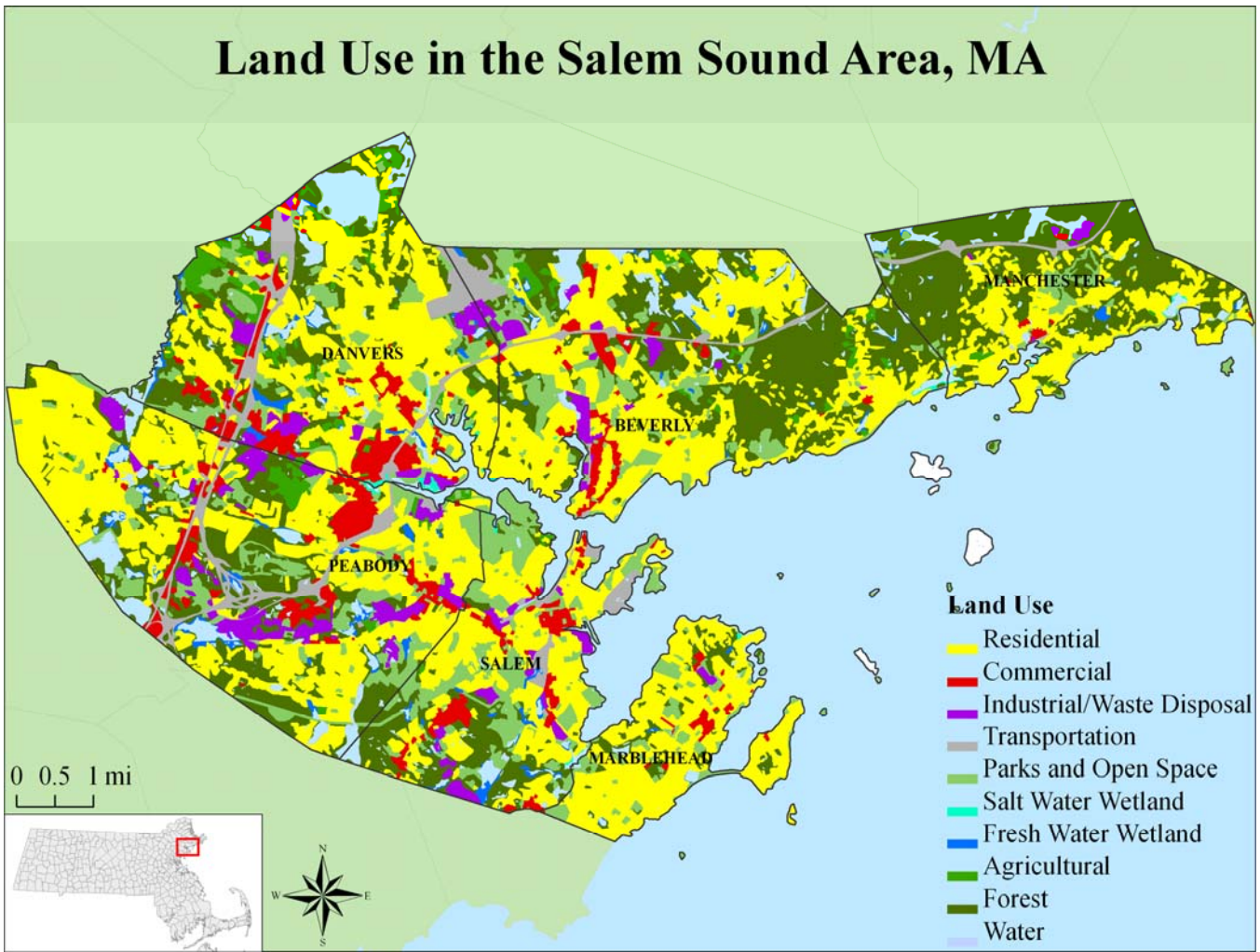


## Adaptive Capacity in 100-Year Floodplains in Beverly, MA (by Census Block Group)





# Appendix H: Land Use Map for Salem Sound, MA





## Appendix I: Memorandum of Understanding

**MEMORANDUM OF UNDERSTANDING**  
**BETWEEN**  
**TUFTS UNIVERSITY FIELD PROJECTS TEAM NO. 9**  
**AND**  
**SALEM SOUND COASTWATCH**

### **I. Introduction**

Project (i.e., team) number: 9

Project title: Salem Sound Coastwatch: Understanding and Managing the Local Impacts of Climate Change

Client: Barbara Warren and the Salem Sound Coastwatch

This Memorandum of Understanding (the “MOU”) summarizes the scope of work, work product(s) and deliverables, timeline, work processes and methods, and lines of authority, supervision and communication relating to the Field Project identified above (the “Project”), as agreed to between (i) the UEP graduate students enrolled in the Field Projects and Planning course (UEP-255) (the “Course”) offered by the Tufts University Department of Urban and Environmental Policy and Planning (“UEP”) who are identified in Paragraph II(1) below (the “Field Projects Team”); (ii) Barbara Warren and the Salem Sound Coastwatch, further identified in Paragraph II(2) below (the “Client”); and (iii) UEP, as represented by a Tufts faculty member directly involved in teaching the Course during the spring 2008 semester.

### **II. Specific Provisions**

(1) The Field Projects Team working on the Project consists of the following individuals:

- |                  |                                     |
|------------------|-------------------------------------|
| 1. Ben Steinberg | email address: brsteinb@yahoo.com   |
| 2. Eric Senecal  | email address: esenecal@gmail.com   |
| 3. Jayme Hamann  | email address: hamanja@aol.com      |
| 4. Kaiba White   | email address: kaibawhite@gmail.com |

(2) The Client's contact information is as follows:

Client name: Salem Sound Coastwatch  
Key contact/supervisor: Barbara G. Warren  
Email address: barbara.warren@salemsound.org  
Telephone number: 978-741-7900  
FAX number: \_\_\_\_\_  
Address: 201 Washington Street, Suite 9, Salem, MA 01970  
Web site: http://www.salemsound.org/

(3) The goal/goals of the Project is/are:

- To raise awareness of climate change and its consequences and affects in the Salem Sound region and specifically the City of Beverly.
- To identify primary types and locations of risks from climate change in Salem Sound.
- To provide educational tools to officials of the Salem Sound region about ways in which they can or will need to adapt to changes in the built and natural environment within their communities, specifically the City of Beverly.

(4) The methods and processes through which the Field Projects Team intends to achieve this goal/these goals is/are:

- Literature Review and analysis
  - Defining categorical risks- social, economic, and ecological
  - Scope of risk and timeframe of impact
  - Cost of risk
  - Review of current adaptation literature
  - Review of policy and management techniques on climate adaptation, adaptive management, risk assessment in Salem Sound region
- Mapping of Vulnerability for Salem Sound and Beverly in particular
  - gray and green infrastructure risks
  - coastal and inland risks
- Interviews
  - Regional, state, local officials
    - public officials and employees
  - Key experts
    - non-profit employees, university employees, and community members

(5) The work products and deliverables of the Project are (this includes any additional presentations for the client):

- Create a climate adaptation report/guidebook for the six coastal communities in the Salem Sound region. The report will focus on risk as well as policy recommendations to deal with these risks. Any available resources or grant opportunities will be included as well.
- Create a PowerPoint presentation for officials in the Salem Sound Coastal region on vulnerability and adaptation issues surrounding the Salem Sound.

(6) The anticipated Project timeline (with dates anticipated for key deliverables) is:

*-Outline- February 27*

*-First Draft- April 4*

*-Final Report- May 2*

*-Presentation in Salem Sound (probably Beverly)- late April (probably)*

(7) The lines of authority, supervision and communication between the Client and the Field Projects Team are (or will be determined as follows):

*-Eric Senecal is the contact person for Barbara Warren*

*-Absence of Eric Senecal presence, the client should feel free to contact any team member. If Eric Senecal is not available, Kaiba will be the secondary contact.*

*-Initial questions and concerns should be directed between client and field project team, and vice versa.*

(8) The understanding with regard to payment/reimbursement by the client to the Field Projects Team of any Project-related expenses is:

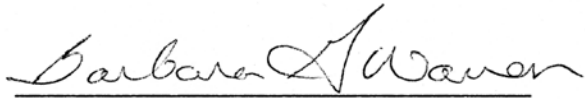
*-No reimbursement is expected unless otherwise discussed between client and the field project group.*

### **III. Additional Representations and Understandings**

- A. The Field Projects Team is undertaking the Course and the Project for academic credit and therefore compensation (other than reimbursement of Project-related expenses) may not be provided to team members
- B. Because the Course and the Project itself are part of an academic program, it is understood that the final work product and deliverables of the Project (the "Work Product") – either in whole or in part – may and most likely will be shared with others inside and beyond the Tufts community. This may include, without limitation, the distribution of the Work Product to other students, faculty and staff, release to community groups or public agencies, general publication, and posting on the Web. Tufts University and the Field Project Team may seek and secure grant funds or similar payment to defray the cost of any such distribution or publication. It is expected that any issues involving Client confidentiality or proprietary information that may arise in connection with a Project will be narrow ones that can be resolved as early in the semester as possible by discussion among the Client, the Field Projects Team and a Tufts instructor directly responsible for the Course (or his or her designee)."
- C. The report can be used by client and field project members for educational purposes. After the final report is completed, if the client wishes to alter the report, the Field Project required notification.
- D. We anticipate exemption from the IRB process, however, it is understood that this Project may require the approval (either through full review or by exemption) of the Tufts Uni-

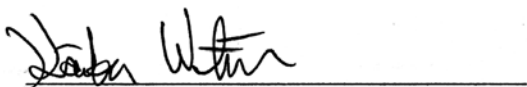
versity Institutional Review Board (IRB). This process is not expected to interfere with timely completion of the project.

#### IV. Signatures




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For Salem Sound Coastwatch  
By: Barbara G. Warren  
Date: January 31, 2008



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Representative of the Field Projects Team  
By: Kaiba White  
Date: January 31, 2008



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Tufts UEP Faculty Representative  
By: Rusty Russell  
Date: February 6, 2008