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Preparing the City of Chelsea, Massachusetts to Better Adapt to Climate Change

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Abstract

The City of Chelsea is susceptible to climate change and its impacts due to the increased risk of flooding, increased storm severity, and increased number of extreme heat events. Our team provided, created, and validated a set of guidance documents for the City of Chelsea's Planning Board, Zoning Board, and Conservation Commission with the support of the Massachusetts Institute of Technology Sea Grant College Program. These documents were designed to inform the boards about climate change and its impacts, provide a list of physical and socioeconomic vulnerabilities of the city, provide questions to ask developers, and highlight mitigation and adaptation strategies that could be implemented in the Everett Avenue area. We analyzed geographic data and conducted interviews in order to help create these guidance documents. These guidance documents are a first step for expanding climate change considerations to all buildings and areas of Chelsea. Our recommendations addressed the effective use of the guidance documents and the steps that should be taken in the future to expand upon this project to further address climate change on a city and state level.

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Executive Summary

Chelsea Massachusetts is a small coastal city across the river from Boston, measuring only 1.8 square miles. Chelsea is a gateway city for immigrants and contains vulnerable populations with over 50 percent minorities and a low medium household income (Vanasse Hangen Brustlin, Inc., 2010).When compared to other regions of the United States, coastal cities are the most at risk from climate change due to a combination of sea level rise, increased severe storms, increased temperature (Climate Nexus, 2012). Along the coast of New England, coastal flooding due to sea level rise and increased severity of storms are hazards that will only get worse (Frumhoff et al., 2007). Chelsea has around 50 percent of its city in a designated flood plain placing it at risk to climate change impacts. The area known as Everett Avenue is slated for several new projects consisting of hotels, office buildings and apartment complexes. This is one of the areas that have been recently added to the floodplain.

Project Goal and Objectives

The goal of our project was to better prepare the City's Planning Board, Zoning Board of Appeals, and Conservation Commission for the impacts of climate change. We focused on the Everett Ave. Urban Renewal District through a set of guidance documents. These documents will aid the boards in better adapting new developments to climate change in the Everett Ave. area. Identifying the information to include in the guidance documents required literature research, interviews with city officials and developers, and analysis of this information. The objectives of this project were to:

i. Identify climate change vulnerabilities and risks in the Everett Avenue area of Chelsea, MA through analysis of existing literature and the creation of geographical maps
ii. Determine the informational needs of the Planning Board, Zoning Board of Appeals and Conservation Commission related to climate change and adaptation
iii. Use the information gathered in first and second objective to create a usable document to provide climate change and adaptation information for the boards

Methodology

This project was completed in a series of tasks to satisfy the three objectives. Our first objective was to identify climate change vulnerabilities and risks in the Everett Avenue area of Chelsea, MA. This objective was completed in two steps. The first step was to develop tables taking into consideration sensitivities, adaptive capacity, vulnerabilities and risks of planning areas related to the redevelopment of the city. Information obtained from review of relevant literature was analyzed and sorted into these tables. The next step was to create a set of geographical maps that identified areas of physical and socioeconomic vulnerability. These maps display the physical and socioeconomic characteristics that we identified as vulnerable to climate change impacts. These maps showed the entire city of Chelsea and highlighted the Everett Ave. area.

The second objective was to determine the informational needs of the Planning Board, Zoning Board of Appeals, and Conservation Commission related to the impacts that climate change could have on the Everett Avenue area. We conducted a series of 8 interviews with both board members and developers in order to understand their concerns regarding climate change, climate change adaptations and which format would be best to present our guidance documents. The interviews followed a semi-structured format. The responses from these interviews were then organized into a table. The table allowed for comparison of the different responses we received. The information was analyzed to identify similarities and differences in responses that would help our team to generate the guidance documents.

The final objective of the project was to generate the guidance documents. Two guidance documents were produced. The primary document was called Climate Change and its Effects: An Informational Guide for Adapting to Climate Change in Chelsea, MA for the City's Zoning Board, Planning Board, and Conservation Commission. The supplemental document was called Potential Concerns and Responses. The first step in creating the primary guidance document was to create a section that can inform boards about climate change facts and impacts. This document would inform board members on why climate change should be taken into consideration. The next step for creating the primary document was to use the information gathered in the first objective to create a section on the main socioeconomic vulnerabilities that board members should be aware of when planning for climate change. The final step in creating this guidance document was to provide a table of adaptation and mitigation strategies that can be implemented in development and the benefits they have. The supplemental guidance document was designed for the Planning and Development Department and presents a list of concerns regarding specific adaptations from the developers we interviewed, and possible responses the board members can provide to developers to encourage them to start incorporating adaptation strategies.

Findings

Based on the geographical analysis completed during objective one, several findings were developed regarding which physical and socioeconomic factors make Chelsea and the Everett Ave. more vulnerable to climate change impacts. Physical vulnerabilities were related to how flooding due to severe storms and sea level rise and extreme heat events could impact the Everett Ave. area. Additionally, our team made considerations about the city's planning area vulnerabilities and how they could be impacted by flooding due to sea level rise, severe storms and extreme heat events. Socioeconomic characteristics that increased the vulnerability of the City and its population were: language barriers, income level, age, disability, ethnicity and education. By learning how the Everett Ave. area is predicted to be impacted physically and how certain socioeconomic characteristics make the area and its residents more vulnerable, we were able to provide recommendations that will help the city better prepare for climate change.

The analysis of our interviews with members of the city's boards and developers led us to identify several findings that helped develop the guidance documents. We learned several concerns that developers had about climate change and adaptation. One observation was that

some of the board members and developers did not regard climate change as a concern; some attributed this to their lack of information about climate change while others noted that climate change was not regulated and therefore was not a main concern for them. Our team also learned that the guidance documents will need to be concise for the board members to review during meetings because board members often have limited time to review information outside of meetings due to the fact that they are volunteers. Additionally, we found that the preferred method of a deliverable was to have a word document so that it was easily distributed to all board members and could be easily updated as more information was gathered after the completion of our project. Lastly, it was also preferred that the guidance documents contain recommendations for developers rather than suggest regulations that should be implemented. Both developers and board members stated that if the regulations were too strict, developers would move to other cities where the cost of developing was less and there were less regulations to follow.

Recommendations and Conclusions

In addition to the guidance documents provided, we also created a set of recommendations for the city and, more specifically, its Planning and Development Department. Our recommendations are that:

- *The Planning Development Department should provide a tutorial to the members of the Planning Board, Zoning Board and Conservation Commission about how to use the guidance documents*: With the limited time that board members have to read the guidance documents, it would be beneficial for someone from the Planning and Development Department present a tutorial of how to use the guidance documents in a meeting with developers and go over each section of the guidance documents with the board members.
- *Board members should use the guidance documents during meetings with developers*: Using our guidance documents during the meetings will allow board members to physically show developers any ideas presented in the guidance documents and aid the discussion.
- *Board members should send sections of the primary guidance document to developers*: Due to the conclusions that some developers do not see climate change as an issue because they feel they are uninformed, it will be beneficial to allow developers to see what the effects of climate and review the adaptation options before meeting with the board members
- *Board members should adopt these guidance documents to be used for the whole city:* Though our guidance documents are for the Everett Ave. area of Chelsea, the maps and adaptations are applicable to the entire city.

- *Board members should continue to update the guidance documents as new information is introduced*: As new concerns from developers are brought up in meetings we recommend that these concerns are added to the guidance documents for future use.
- *Board members or other city officials should consider updating and adapting other areas of the city's infrastructure and emergency planning:* Due to the time limitations and the scope of our project we were not able to look into all areas of infrastructure or planning. However, we feel that looking into these areas in important if the city is going to address climate change as an issue.
- *The city should asses the cost and benefits of requiring developers to adapt to climate change and then create zoning ordinances to enforce these requirements*: While board members and developers prefer recommendations to regulations, it is important to ensure that some changes are made; as only some developers may choose not to implement the recommended adaptations.
- *MIT Sea Grant College Program and the City of Chelsea or another project group should advocate that regulations for climate change adaptations be set at a state level*: It would be beneficial to implement change at a state level to ensure that all municipalities are following the same regulations.

Climate change's impact on the increased occurrences of flooding, storm severity and extreme heat events have added danger to the City of Chelsea. The increased risk of climate change impacts on the Everett Avenue Urban Renewal District may have severe effects on future developments in that area. Adding provisions to development plans, such as adaptation and mitigation strategies, will not eliminate these impacts but it can help decrease both risk of harm and vulnerabilities. Our team identified the physical and socioeconomic vulnerabilities of Chelsea to show potential concerns in the future. We then generated a structured set of guidance documents for the boards that included information on climate change and adaption and mitigation options for the boards to consider, with a focus on the Everett Ave. Urban Renewal District. These recommendations could better inform the board members and developers of the City of Chelsea and be the first step for further climate change discussions by MIT Sea Grant College Program, The City of Chelsea, and the Commonwealth of Massachusetts.

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1.0 Introduction

Climate change is a problem that is increasingly affecting the globe through changing weather patterns and increased temperatures (Melillo et al., 2014). The global climate has already experienced changes such as: warmer ocean temperatures, higher continental-average temperatures, more temperature extremes, and changes in wind patterns (Kirshen, 2008). Current levels of carbon emissions are predicted to cause large scale changes in temperatures and a rise in sea levels that can dramatically impact natural ecosystems and human populations (Vergano, 2013). Even with major reductions in emissions, climate change will still have an impact on the Earth and its inhabitants.

Although climate change is a global problem, coastal cities are the most at risk from climate change due to a combination of rising sea levels, increasing storm severity, and increasing temperatures (Climate Nexus, 2013). Frumhoff et al. (2007) infers that as sea levels rise, storms, even less severe than ones in the past, may begin to cause greater damages to society. These damages can include loss of wetlands and loss or damage to property. Populations that reside in coastal communities are more prone to be affected when flooding occurs (Frumhoff et al., 2007). The current sea level rise projections for the next 100 years for the mid-Atlantic are minimal, whereas projections for Boston are much higher than previously thought. For Boston, the inferred 2050 rise is 2.4 times higher than the rest of the globe (Boon, 2012). The sea level in Boston has already risen 11 inches over the last 100 years and is predicted to rise as much as 6 feet by 2100 due to the effects of climate change (Melillo et al., 2014)

Climate change is also projected to increase the frequency and severity of storms in the Northeast region. Since 2010, the Commonwealth of Massachusetts has experienced five major

storms, including Superstorm Sandy (Governor of Massachusetts, 2014). Major coastal storms such as hurricanes and nor'easters have a substantial impact on the Northeast and can cause large scale damage to property, including the loss of homes and in severe case these storms can result in loss of life (Frumhoff et al., 2007). Additionally, increases in precipitation can cause outbreaks in waterborne diseases, soil erosion, and flood risks (Frumhoff et al., 2007).

Furthermore, temperatures and the number of extreme heat events are expected to increase as a result of climate change (Melillo et al., 2014). The earth has already experienced an overall increase of temperature or 1 degree. In the Northeast there was an increase of 2 degrees Fahrenheit between 1895 and 2011. While the amount of warming under a higher emissions scenario is projected to be up to 10 °F by the 2080s, even under a lower emissions scenario the increase could reach up to 6 °F (Melillo et al., 2014). The warming will translate in an increase of frequency, intensity and duration of heat waves (Melillo et al., 2014).

Chelsea Massachusetts, a coastal city with coastal lowlands and hills located near Boston, will be subjected to climate change impacts and increased risks of flooding due to sea level rise, increased storm severity and increased numbers of extreme heat events (Daniel, 2013). As a gateway city to Boston, Chelsea has areas of low income and many areas of high immigration (Vanasse Hangen Brustlin, Inc., 2010). Chelsea has many areas that are physically vulnerable to the impacts of climate change, as well as many vulnerable populations that could also be more at risk to these impacts, (DePriest, 2014).

The goal of this project was to better prepare the City of Chelsea's Planning Board, Zoning Board of Appeals, and Conservation Commission for the impacts of climate change in the Everett Avenue Urban Renewal District of Chelsea. In Chelsea's Everett Avenue Urban Renewal District, economic development is highly important (DePriest, 2014). Some of the

development in this urban renewal area includes the development of the Federal Bureau of Investigation (FBI) building and several apartment buildings (City of Chelsea- Everett Ave. Urban Renewal District, n.d.). This area has been recently been added to the proposed FEMA flood insurance maps, which created concern for some members of the city, and is the reason why this is the area the city wanted the project to focus on (DePriest, 2014)

For this project, we generated two guidance documents for these boards to help prepare them to better manage climate change concerns when reviewing and accepting proposed plans from developers who are looking to build in the Everett Ave. area. Our approach included the analysis of geographical information, literature review on climate change, vulnerability, and how to adapt, interviews, and the creation of two guidance documents based on our findings during this process. We analyzed geographical information and reviewed literature in order to identify Chelsea's physical and socioeconomic vulnerabilities. In addition, we conducted interviews and then used our findings to develop the two guidance documents to help board members understand what should be taken into account regarding developments when adapting to climate change. The primary guidance document contained information about climate change in the Northeast and Chelsea, the physical and socioeconomic vulnerabilities of Chelsea, and adaptation and mitigation strategies that developers can use to start addressing climate change. The second guidance document was developed for the Planning and Development Department to share with the board members and included concerns from the developers that we interviewed regarding adaptation and possible incentives that could encourage developers to consider adapting to climate change. It is anticipated that the board members will use these guidance documents when working with developers in the Everett Ave. area, in support of a broader effort

to start incorporating climate change considerations in the city's planning and implementing adaptation and mitigation strategies in the City's urban development.

2.0 Background

This chapter first provides an overview of Chelsea, with consideration to the hazards the City faces from flooding, storm damage, and extreme heat along with the duties of the Planning Board, Zoning Board of Appeals, and Conservation Commission. Secondly, the chapter will provide an overview of the impacts of climate change in the Northeast and in coastal communities which may exacerbate the impacts from flooding and extreme heat in this vulnerable coastal community. Third, the chapter will discuss the reasons that the City and its residents are vulnerable. Finally, possible mitigation and adaptation solutions for the city will be discussed.

2.1 Chelsea, Massachusetts

Chelsea, Massachusetts is a small coastal city located in the Northeast. Chelsea is found across the Mystic River from Boston (City of Chelsea-About the City). It was first established in 1624, and now occupies a 1.8 square mile land area in Suffolk County. Demographically, Chelsea contains a diverse population, estimated at 35,080 residents. Chelsea's population has a medium household income of approximately $39,439 (Vanasse Hangen Brustlin, Inc., 2010). The population has a high level of minorities, including a large number of Hispanics. There are more than seventy countries represented by students in schools throughout Chelsea (Madeleine Scammell 2014, personal communication).

The basic topography of Chelsea mainly consists of coastal lowlands along with four areas of higher elevations. *Figure 1* is a topographical map of Chelsea from 1890 (Boston Harbor Association, n.d.). This figure shows areas of Chelsea that were once composed of wetlands. To

increase the area to build on in Chelsea, the City filled in many of these wetlands. Because of this, these areas have a fairly high water table and are more prone to experience flooding.

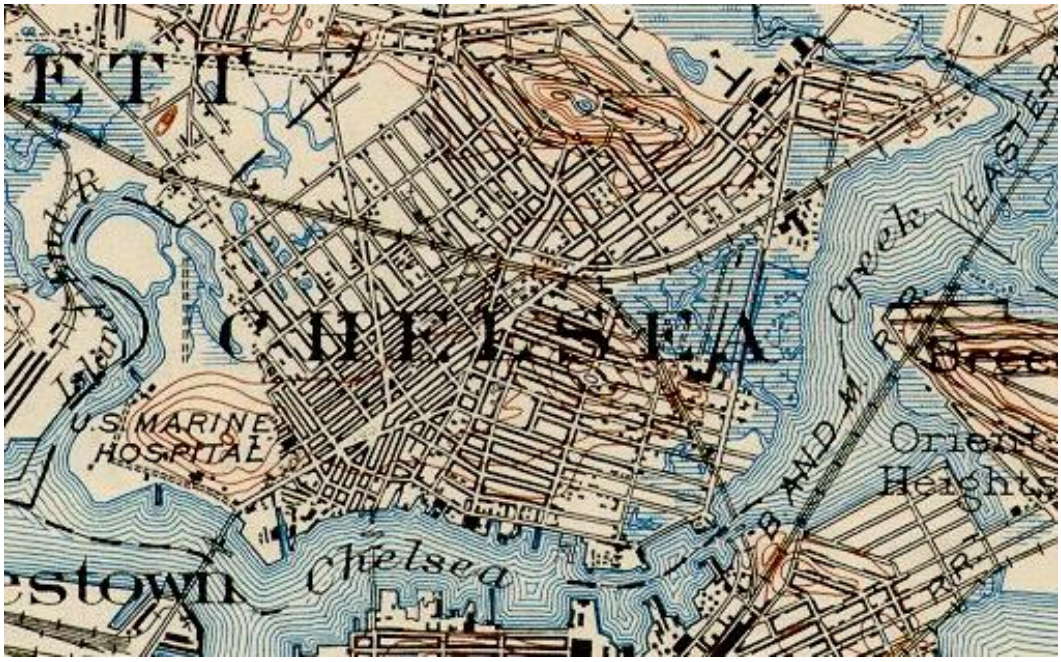

Figure 1: This is a topographical map of Chelsea from 1890 (Boston Harbor Association, n.d.).

2.1.1 The Everett Avenue Urban Renewal District of Chelsea

The City of Chelsea went into receivership in 1991 and was taken over by the state (Fager, 1994). After a charter change in 1995, the City of Chelsea has increased its emphasis on economic development. As an older city, Chelsea has plans in place to continue to develop the city through the process of development and redevelopment; which includes updating the existing infrastructure. Many believe that this development will give the city the jobs, and improve the economy. One main area of focus for this development is in the Everett Avenue Urban Renewal District (Highlighted in *Figure 2)*. This area is one of the areas that was originally composed of wetlands and filled in. This is an area focused on commercial and

residential development for the City with plans to increase local employment opportunities (City of Chelsea- Everett Ave. Urban Renewal District, n.d.).These plans include the development of:

- A 230–unit apartment complex by the Transdel Corporation (DePriest, 2014)
- 250,000 square-foot FBI headquarters (DePriest, 2014)
- A new hotel by XSS Hotel Development Company (DePriest, 2014)

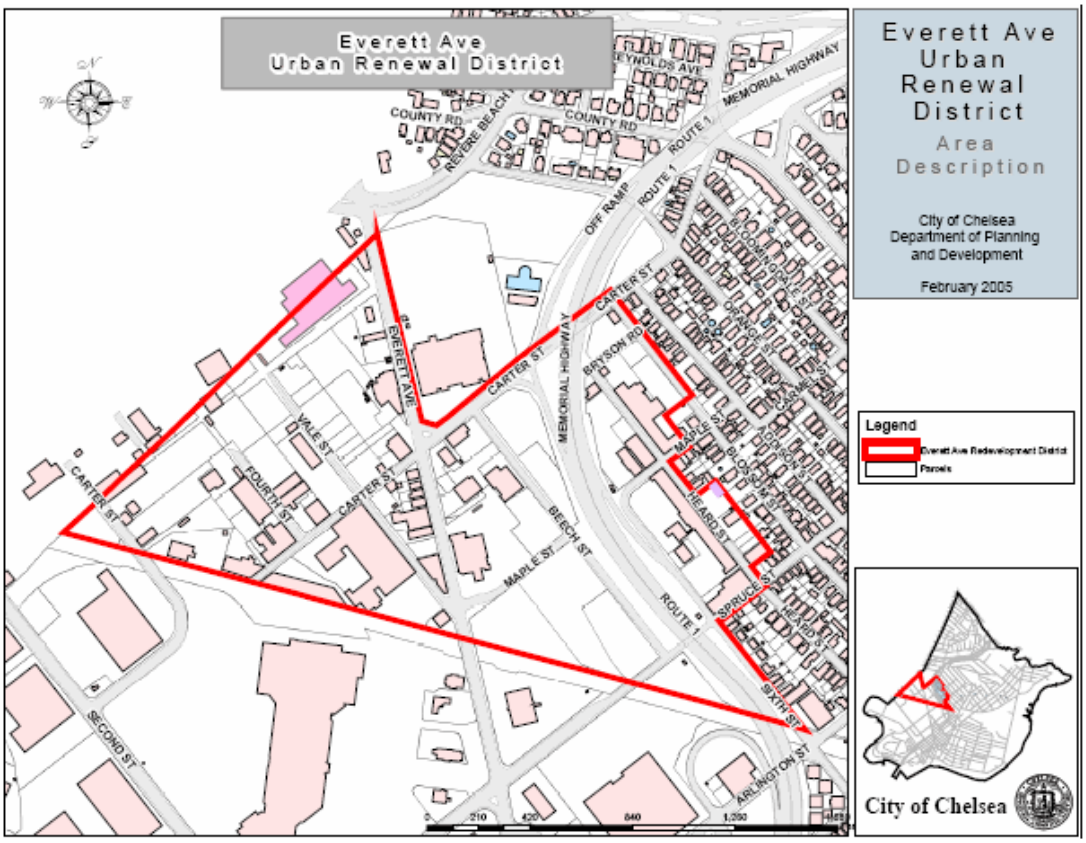

Figure 2: The map of the area of focus, the Everett Ave. Urban Renewal District (City of Chelsea-Everett Ave Urban Renewal District, n.d.)

2.1.2 Planning and Development Process in Chelsea

The Planning and Development Department in Chelsea plans and manages the residential and business aspects of the city. This includes developing the vision, policies and goals of the

physical, environmental, economic, and social growth of the community (City of Chelsea-Planning and Development, n.d.). The Planning and Development Department members work with the members of the Planning Board, Zoning Board of Appeals, and the Conservation Commission who are in charge of approving plans to build in the area presented by developers. This includes approving plans for the development of the Everett Ave. area.

The Planning Board in Chelsea is a nine member board which provides recommendations to the Zoning Board of Appeals on special permit petitions, conducts public hearings, reviews projects requiring major site approval, reviews and approves subdivision plans, provides general planning policy to the city council and makes recommendations on zoning amendments to the city council (City of Chelsea-Planning Board, n.d.). The Planning Board mainly deals with policy and the implementation of that policy through zoning (Conolly, 2014).

In Chelsea, the Zoning Board of Appeals is a three member board which hears and decides individual cases of persons seeking relief from the regulations of the zoning ordinances (City of Chelsea-Zoning Board of Appeals, n.d.). The Zoning Board is a special permit granting authority which hears and decides petitions for special permits, petitions for variances and appeals taken by a person who was unable to obtain a permit or enforcement action from an administrative officer. The Zoning Board does not exercise legislative powers or have the authority to amend zoning regulations or change the boundaries of the districts where they are applicable (Coon, 2005).

The Conservation Commission is a five member board in the City of Chelsea that protects, promotes and enhances the city's natural resources (City of Chelsea-Conservation Commission, n.d.). Like all conservation commissions in Massachusetts, the City of Chelsea's Conservation Commission is in charge of enforcing the Conservation Commission Act, the

Wetlands Protection Act, and the home rule provisions of the state constitution for non-zoning wetlands bylaws (Massachusetts Association of Conservation Commissions, 2014). Most conservation commissions spend the majority of their time hearing wetland cases; however in Chelsea there are limited wetlands, as much of it, as in the case of the Everett Ave. area, has been built over (DePriest, 2014).

Recently, FEMA has proposed updated flood insurance maps, encompassing more regions throughout Chelsea that are now predicted to experience flooding in the event of a 100 year storm. These preliminary maps now include the Everett Ave. area, and their inclusion in the 100 year flood zone may affect many aspects of development there (DePriest, 2014). Now that this area is in a proposed flood zone, the Planning Board, Zoning Board, and Conservation Commission will have to consider these maps when addressing current and future development plans (DePriest 2014, personal communication). Future climate change predictions were not taken into account when creating these maps; however, climate change is expected to make the impacts of flooding even more severe (Melillo et al., 2014).

2.2 Effects of Climate Change in the Chelsea

Due to the location of Chelsea, the City is exposed to impacts from climate change such as: coastal and river flooding, severe storms, and extreme heat days. These factors will present challenges to the social, economic, and environmental systems of the region (Melillo et al., 2014). It is predicted that the impacts of climate change will continue to worsen. Chelsea will be subjected to these increasing risks of flooding occurrences, damaging storms, and increasing temperatures that can disrupt the everyday lives of its citizens.

2.2.1 Climate Change will Increase Chelsea's Vulnerability to Flooding from Sea Level Rise

Chelsea will be subjected to increased amounts of flooding due to sea level rise. Coastal flooding in the Northeast has already increased due to sea level rise (Melillo et al., 2014). This rise of the sea level depends on two major factors: the movement of the local land and the variations in the global average sea level. The sea level has risen approximately eleven inches over the last century due to climate change and land subsidence (Melillo et al., 2014). The global rise of sea level is projected to rise between one and four feet by 2100, which will mainly depend on the West Antarctic Ice Sheets and Greenland's melting (Melillo et al., 2014). Additionally, there is evidence that in the Northeast's coastal areas the sea level is rising faster than the global average due to land subsidence (Frumhoff et al, 2007). Sea level rise is dangerous to Chelsea because a rise of only two feet of the sea level would translate to more than triple the frequency of hazardous coastal flooding throughout the Northeast region (Melillo et al., 2014). Flooding can cause multiple impacts to the community such as loss of life and property damage, as well as, impacting the economy of the area.

2.2.2 Climate Change will Increase Chelsea's Vulnerability to Severe Storms

Chelsea will also experience an increased number of severe storms due to climate change. From these storms, communities face extreme amounts of precipitation over a short period of time. Excessive precipitation, due to storms, can be destructive on homes, public infrastructure and ecosystems. Coastal areas have the highest amounts of precipitation within the Northeast region (Melillo et al., 2014). The average intensity of precipitation is expected to increase from 10 to 15 percent by the end of the century (NECIA, 2006). The 100 year storms (major storms that have a 1 percent chance of occurring, on average, in a given year), are projected to occur

almost annually by the end of the century (IPCC, 2007). Furthermore, the number of severe storms will increase in the future. Studies have found that there could be as much as a 50 percent increase severe storm occurrences over the next century given the current rate of climate change (Dickerson, 2013). Severe storms can cause flooding, damage to property, and threats to public safety. For example, Hurricane Irene and Superstorm Sandy caused 180 casualties and $75 billion in damages mostly in the Northeast (Climate Nexus, 2013).

Chelsea is also predicted to experience added impacts from winter storms such as nor'easters. The National Oceanic and Atmospheric Association (NOAA) defines a nor'easter as a reasonably strong wind that blows from the northeast for an extended period of time. Nor'easters occur more frequently from October to April. Compared to some other regions of the United States, the Northeast is subjected to even more damage from snow storms because of its lower average winter temperatures. The severity of these storms varies from common storms to life-threatening storms that can impact the Northeast region. The major effects of nor'easters include beach erosion and flooding (State of Delaware, 2014).

2.2.3 Climate Change will Increase Chelsea's Vulnerability to Extreme Heat Events

Finally, Chelsea will be subjected to the rising average temperatures that can lead to an increase in the amount of extreme heat events. An overall increase in the temperature of the Earth has been calculated at a full degree Fahrenheit (Dyurgerov & Meier, 2004). One study by Dyurgerov and Meier shows the change in average summer temperatures over the past five decades. As seen in *figure 3*, the average number of "hot" days is increasing when compared to average summer temperatures from 1951-1980 when there was little variation in temperatures (Hansen, et al., 2012). In the Northeast there was an increase of 2 degrees Fahrenheit between

1895 and 2011. The future increases in temperature will be highly dependent on global emissions of heat-trapping gasses. While the amount of warming under a higher emissions scenario is projected to be from 4.5 °F to 10 °F by the 2080s, even under a lower emissions scenario the increase is expected to be from 3 °F to 6 °F (Melillo et al., 2014). This warming may translate to an increase of frequency, intensity and duration of heat waves in Chelsea. With continued increases in emissions, the southern part of the Northeast region is projected to experience more than 60 additional days per year with temperatures above 90 °F in comparison with the end of last century (Melillo et al., 2014). These extreme heat events can be potentially dangerous to human health.

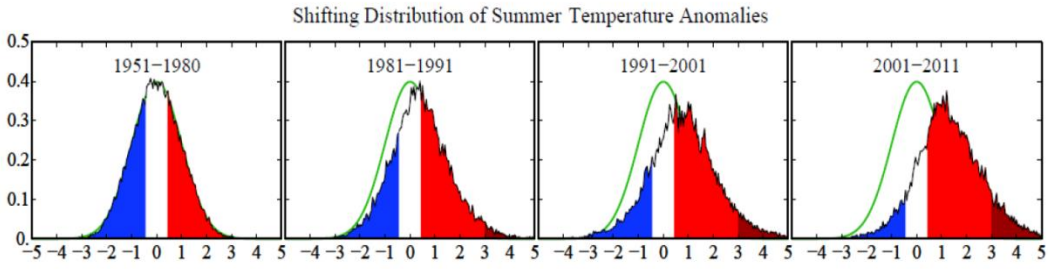

Figure 3: Temperature anomalies from 1951-2011 compared to 1951-1980 data. Blues represents the number of colder than average days and red represents the number of warmer than average days (Hansen, et al., 2012)

2.3 Vulnerability to Climate Change

Chelsea is a city that is vulnerable to climate change impacts (DePriest, 2014). Climate change vulnerability is the degree to which a physical, biological and socioeconomic system is sensitive and unable to accommodate to adverse climate change impacts (Fussel and Klein, 2006). Sensitivity is the degree to which a system is directly or indirectly affected by changes in climate conditions (Fussel & Klein, 2006). Highly sensitive areas are considered to be more

vulnerable to the climate change impacts. In addition to the physical exposure Chelsea has to flooding, storms, and extreme heat mentioned previously, Chelsea's population has several socioeconomic factors that could further increase the City's vulnerability.

2.3.1 Socioeconomic Characteristics Increase Chelsea's Vulnerability to Climate Change Impacts

Specific population groups are more vulnerable to the effects of climate change. Social vulnerability is a product of how sensitive to harm a group is to the impacts of climate change and the group's ability to cope with these hazards (Cutter, 2003). A report conducted by Susan Cutter, Bryan Boruff and Lynn Shirley from the University of South Carolina identifies income level, race, ethnicity, age, education, and gender as some of the variables that influence social vulnerability. For example, income level affects the ability of the population to afford recovery expenses due to lack of insurance, social safety nets and entitlement programs (Cutter, 2003). Chelsea's population has one of the lowest median household incomes in the state of Massachusetts (Vanasse Hangen Brustlin, Inc., 2010). Race and ethnicity are other examples of variables that influence social vulnerability. This is because some ethnicities have a more difficult time accessing post-disaster funding due to cultural and language barriers (Cutter, 2003). In addition, Chelsea is also a city where nearly half of the population is composed of immigrants (Vanasse Hangen Brustlin, Inc., 2010).

2.4 Climate Risks

Climate risk is based upon the interaction of vulnerability and physical exposure (IPCC, 2007). Climate risks are calculated as a function of the consequence of an impact and its probability of occurrence. The consequence of an impact is the known or estimated economic, ecological, social, cultural and legal effects that climate change impacts have on the city. The

probability of a climate impact is the likelihood that an expected impact will occur (Climate Impacts Group, 2014). For example, while flooding may occur in multiple areas, higher risks could be presented in areas that are more socioeconomically vulnerable.

Climate risks can be categorized as acceptable, tolerable and intolerable (Dow, Berkhout and Preston, 2013). Acceptable risks are so low that additional action is not considered necessary. Tolerable risks require adaptation measures to reduce risk within reasonable levels. Intolerable risks affect socially negotiated norms or a value even with adaptive action (Dow, Berkhout and Preston, 2013). However, the lines in between these categories are not clearly defined **(**Dow, Berkhout and Preston, 2013). In order to categorize risk, it is important to consider both the probability of the impact and the consequence of the impact. It is generally encouraged to consider risk in decision making regarding possible strategies to prepare for climate change impacts.

2.5 Potential Solutions for the Impacts of Climate Change

Mitigation and adaptation strategies are often implemented to address the impacts of climate change. There are a number of actions that communities, like Chelsea, can take to address these impacts. Mitigation and adaptation strategies reduce the impacts that climate change can have, and therefore reduce the vulnerability and risks. Mitigation focuses on trying to reduce the emission of greenhouse gases to slow down the progression of climate change, and adaptation focuses on adjusting to the current or anticipated climate change effects (IPCC, 2007). Mitigation and adaptation options should not be seen as alternatives to one another, but rather options that should be employed together to prepare for impending impacts while still reducing

how severe the impacts are in the future. The following section will describe a series of mitigation and adaptation strategies found through research.

2.5.1 Mitigation Strategies

The extent to which climate change is felt by communities, like Chelsea, in the future will be mainly determined by the decisions that society makes regarding greenhouse gas emissions (Melillo et al., 2014). Reducing the amount of greenhouse gases will lessen the severity of impacts and global warming in the future. This can be done through the implementation of various mitigation options that work to improve energy efficiency or use low-carbon energy sources. These options include adopting energy-efficient components into building infrastructure, vehicles, household appliances and more, as well as reducing emissions through the use of renewable energy sources, such as: solar and wind energy.

2.5.2 Adaptation Strategies

Although mitigation will help to prevent more drastic changes in the future, this alone is not enough as it does not erase the damage already caused by current emissions. Adaptation is needed to protect against the future impacts of climate change that are at this moment irreversible.

Adaptation strategies are modifications to natural or human systems to better prepare them for climate change effects (IPCC, 2007). Examples of adaptation strategies include upgrading structures, updating building requirements and codes, routing temporary evacuation plans, adding flood shields, elevating buildings, setting back buildings from wetlands and beaches, redesigning roads and water systems, reducing emissions, and permanent retreat.

Updating older structures protects against the effects of climate change. When developing strategies to improve infrastructure, it is important to consider that structures were built taking into consideration old weather patterns that have now changed (Commonwealth of Massachusetts, 2011). Infrastructure needs to be adapted in consequence of the new information gathered. To reduce the risk and minimize the impact that climate change has on these structures, they need to be upgraded or repaired to become more robust. Feasible strategies are reinforcing the infrastructures, reusing resources, and timely maintenance (Commonwealth of Massachusetts, 2011). For example, for combating the flooding hazards, the city of New York suggests using dry flood-proofing, which means to add flood shields around structures to prevent the water from entering (Burden, 2013). Another way of adapting is creating structures that are resilient to flooding such as: floating development and floodable development; this type of structures integrate the flooding in part of their design (Douglas, Kirshen, & Li, 2013).

There are other adaptation strategies available that are specific towards addressing flooding. The buildings may need a higher elevation, a change in foundation, or a change in construction standards in order to resist debris (Maryland Commission on Climate Change, 2008). This is a preventive measure, considering that the cost of repairing buildings after catastrophe is substantial. Additionally, in order to combat flooding hazards, the Environmental Protection Agency (EPA) recommends to expand setbacks (distance between a structure and the shoreline), to allow wetlands and beaches to push back further inland, reinforce and redesign bridges, roads and storm water systems, and to develop emergency response plans. The EPA additionally suggests incorporating or repairing seawalls, dikes and other structures to protect cities from storms and erosion (EPA, 2014).

According to the comprehensive strategy report completed in Maryland, another useful strategy is to include temporary evacuation plans, and adequately informing the community on how to react in case of an emergency. In case of an extreme event, the population living in susceptible zones need to evacuate and there must be a structured plan in order for this to be effective. For example, the city of Pinole, California is implementing a program to accommodate homeless people and people living the susceptible areas by providing temporary housing and shelter in the event of emergencies (City of Pinole, 2010). Another example is the city of Albuquerque, which has implemented an evacuation plan for the city during times of emergency. Although Albuquerque is not a coastal community, they have developed an evacuation plan to help residents and visitors to understand how to act in times of emergency. Their plan divided the city into different regions and identified specific evacuation routes (City of Albuquerque, 2007).

Finally, for some regions permanent retreat may be necessary. Permanent evacuation or retreat consists of relocating to a different region less susceptible to climate change. Michael Mann, director of the Earth System Science Center at Pennsylvania State University, expressed how even if island nations have decades to adapt to sea level rise, permanent evacuation may be their only option (Confino, 2012). While other adaptation strategies may work for many years, permanent evacuation is the only option in the worst case scenario.

2.6 Summary

Chelsea is a coastal city located in the Northeast region that is vulnerable to climate change impacts. Climate change has become an increasing problem for coastal communities because of impacts such as flooding, increased number of severe storms, and increased numbers of extreme heat events. Identifying climate vulnerabilities and risks in the city is a first step to

start adapting to climate change. There are numerous mitigation and adaptation strategies to address climate change issues and coastal flooding.

The future predictions of climate change in the Northeast will worsen the impacts that the City of Chelsea will face from flooding, storms, and heat. This presents a need for adaptation in order to prepare and preserve the recent and future development in the Everett Ave. area. This requires action from the Planning Board, the Zoning Board of Appeals and the Conservation Commission in partnership with the developers that build in the area to ensure the developments in the area are ready for the future.

3.0 Methodology

The goal of our project was to better prepare the City's Planning Board, Zoning Board of Appeals and Conservation Commission for the impacts of climate change. In order to complete this goal, we provided information about climate change for the Everett Ave. Urban Renewal District through a set of guidance documents. These guidance documents will inform the board members on the effects of climate change by providing climate change facts, explaining how climate change could impact the City of Chelsea, and providing adaptation and mitigations strategies, and presenting developers' concerns.

In order to achieve this goal, we completed the following objectives:

iv. Identify climate change vulnerabilities and risks in the Everett Avenue area of Chelsea, MA through analysis of existing literature and the creation of geographical maps
v. Determine the informational needs of the Planning Board, Zoning Board of Appeals and Conservation Commission related to climate change and adaptation
vi. Use the information gathered in first and second objective to create a usable document to provide climate change and adaptation information for the boards

This chapter will discuss each of these three objectives.

3.1 Identify Climate Change Vulnerabilities and Risks in the Everett Avenue area of Chelsea, MA through analysis of existing literature and maps

The first objective in completing our goal was to identify climate change vulnerabilities and risks in the Everett Ave. area of Chelsea, MA. For this objective we learned the physical and socioeconomic characteristics that make the Everett Ave. area and the city Chelsea more vulnerable to the impacts of climate change. Identifying the area's vulnerabilities and

understanding its climate risks helped us ensure that the delivered guidance documents were effective tools that can be used to help lessen the climate change impacts of flooding, storms and extreme heat events. These guidance documents serve both as an informational tool for the city's board members and propose strategies for the Everett Ave. area to adapt developments to climate change.

3.1.1 Identifying Vulnerabilities and Risks due to Physical Climate Change Impacts

Utilizing information gathered in our research about the climate change impacts that affect coastal cities in the Northeast, we identified the climate change physical impacts and socioeconomic variables that were relevant to our project; this information was mostly gathered from the 2014 National Climate Assessment and the EPA. The decision to choose certain variables was then discussed with our sponsors at MIT Sea Grant and the City of Chelsea and our advisors at WPI. For the physical impacts, the scope of our study includes flooding, increasing storm severity and increasing number of extreme heat events because, as a coastal city, Chelsea's development and community will be most impacted by these factors.

We utilized Geographical Information Systems (GIS) maps to better convey the physical characteristics of the City of Chelsea. Our team obtained the following data layers from the Mass GIS database: contour data, major roads, building structures and city boundaries, and obtained the preliminary FEMA flood hazard layer from our sponsors in the Planning and Development Department of the City of Chelsea. These geographical representations were added to our primary guidance document for the board members to better understand the physical implications that climate change could have in their city.

3.1.2 Identifying Vulnerabilities and Risks in the City's Planning Areas

We identified potential planning areas in the city of Chelsea that are susceptible to being affected by climate change, especially focusing on flooding, severe storms and extreme heat events through the analysis of research. Planning areas are the topics in which a government controls, formulates or creates policies that affect the services and activities of built, human and natural systems (Climate Impacts Group, 2014). For this section, we utilized the Climate Impacts Group report completed in association with the International Council for Local Environmental Initiatives (ICLEI) that indicates an approach for local, regional and state governments to adapt to Climate Change to guide our methodology (Climate Impacts Group, 2014).

Our team utilized some of the planning areas proposed in the Climate Impacts Report that are relevant to the City of Chelsea based on vulnerabilities that we identified throughout our literature research. For example, the City of Chelsea has over 70% Combined Sewers which may make it more vulnerable to flooding (City of Chelsea Water and Sewer Department, 2014). The planning areas of our focus are only examples and do not form a comprehensive list. We organized these planning areas in the following sectors: water-related infrastructure, energy, human health and transportation (EPA, n.d.). The scope of our project was to focus on the planning sectors that we found most relevant to the city's development. *Table 1* shows the planning sectors and the planning areas of our focus.

Table 1: Planning sectors and planning areas of our study

Planning Sector	Planning areas
Water-related Infrastructure	Storm water management
Energy	Electricity
	Natural gas
Human Health	Air quality
Transportation	Roads
	Public transportation

After identifying the planning areas of our study, we reviewed the information gathered through our literature research relevant to each of the planning areas of our study, and developed four tables that summarized considerations about the sensitivities, adaptive capacity, vulnerabilities and climate risks for the planning areas.

In order to identify the sensitivities of the different planning areas, we utilized the literature research to better understand how the planning areas are exposed to flooding due to sea level rise and storms, and extreme heat events. We reviewed the 2014 National Climate Assessment and the EPA website as our major sources of information on climate change impacts in the Northeast. We considered the current climate conditions of the Everett Ave. area of Chelsea with regards to flooding, severity of storms and extreme heat events when identifying sensitivities. We utilized the proposed FEMA flood hazard maps and the projections about the severity of storms and extreme heat events gathered in our literature research to determine how climate change may impact the Everett Ave. Urban Renewal District of Chelsea (Climate

Impacts Group, 2014). The information in the FEMA preliminary maps and projections are only an approximation of what could occur in the future. With the information researched in the previous tasks, we created a table adapted from the 2014 Climate Impacts Group report that summarizes the sensitivity for each of the planning areas of our focus. *Table 2* delivers information in a more organized manner and ensured that we cover all of the selected planning areas. The format of the table is the following:

Table 2: Sensitivity Example

Planning Sector	***Planning aspect***	***Current/ Expected Stressors***	***Climate Conditions relevant***	***How are conditions expected to change***	***Impact of changes to the planning aspect***	***Changes in stresses to the planning aspect***

The next task completed in order to identify the climate vulnerabilities and risks was to provide considerations about the adaptive capacity of the planning areas associated with the Everett Ave. area of Chelsea. Generally, the planning areas with a high adaptive capacity are more likely to be capable of withstanding and recovering from climate change impacts (Climate Impacts Group, 2014). In order to provide considerations about the adaptive capacity of the planning areas of our study, we utilized two criterion: the added cost that adaptation would have and the level of disruption that it would cause; we made these considerations based on information gathered through our literature research about the City of Chelsea and about the impacts that climate change could have on these systems. We then provided a table adapted from the Climate Impacts Group report (Climate Impacts Group, 2014). Organizing the information in a table is intended to ensure that we cover the planning areas. *Table 3* includes the following considerations:

Table 3: Adaptive Capacity Example

Sector	***Planning aspect***	***Projected impacts of climate changes minimal disruption or cost***	***Ability of the planning aspect to adapt with minimal disruption or cost***

The information gathered in the previous tasks allowed us to identify vulnerabilities in the planning areas of our focus associated with the Everett Ave. area. Generally, planning areas with higher sensitivity and lower adaptive capacity are considered to be more vulnerable to climate change (Climate Impacts Group, 2014). We then generated a table (see *table* 4) similar to the one in the Climate Impacts Group report with considerations about the different vulnerabilities.

Table 4: Planning Areas' Vulnerabilities Example

Sector	***Planning aspect***	***Is the area sensitive?***	***Ability of the planning aspect to adapt with minimal disruption or cost***	***Vulnerability***

The next task in completing objective one was to identify the risks in the different planning areas. Risks can be expressed as a function of vulnerabilities. The risk of a climate impact is given by its consequence and its probability of occurrence (Climate Impacts Group, 2014). The risk will differ depending on the time frame of the study. Risks that are more likely to happen and that have more severe consequences are considered to be less tolerable (Dow,

Berkhout and Preston, 2013). Presenting the climate risks allowed us to better convey the urgency of some of the issues that the City presents. We used a table to summarize the information in an organized manner. This table, *table 5*, followed the following format:

Table 5: Climate Risks Considerations Example

Sector	***Planning aspect***	***Projected Climate Change Impacts***	***Consequence of the impact***	***Probability of the impact***	***Risk***

3.1.3 Identifying Vulnerabilities and Risks due to Socioeconomic Characteristics

In order to identify the socioeconomic vulnerabilities, our team considered socioeconomic variables utilized in the study conducted by Susan Cutter about socioeconomic vulnerabilities to develop a list of variables that are specific to our project. We worked with the following socioeconomic variables: level of income, language barrier, age, ethnicity, disability, gender, and education. The selected variables incorporate current socioeconomic issues within the Everett Ave. area and common socioeconomic groups found in any city and consider possible future issues that the city's boards might encounter when working with developers in the area. These concerns incorporate present and future considerations about the socioeconomic variables of our study that may worsen or lessen the impacts of flooding, storms or extreme heat events in the area. For instance, a developer that wants to build low income housing in an area susceptible to flooding could create higher risk to the area.

We generated maps for some of the socioeconomic variables previously selected as result of our literature research by utilizing ArcMap. Our team obtained the Environmental Justice and 2010 Census data layers from the Mass GIS database and utilized them to develop a set of maps for displaying the socioeconomic characteristics of the City of Chelsea, this set included maps for the level of income, language barrier, ethnicity and education. Socioeconomic characteristics were presented in addition to physical ones because, while physical hazards on their own can be disastrous, socioeconomic variables can be a deciding factor when determining whether an area is vulnerable or not. For instance, if an area has a school where children attend that is susceptible to flooding, even minimal or moderate flooding would make the area vulnerable. Therefore, by incorporating socioeconomic characteristics and limitations we were able to provide a guidance document that is more appropriate for the current and future population of the Everett Ave. area.

3.2 Determine the Informational Needs of the Planning Board, Zoning Board of Appeals, and Conservation Commission related to Climate Change and Adaptation

The team's second objective was to determine the informational needs of the Planning Board, Zoning Board of Appeals and Conservation Commission with regards to climate change and adaptation. This was done through a series of interviews with members from each board, various developers that the boards have approved site plans for, as well as other Chelsea city staff that work with these boards such as the Department of Public Works (DPW), Emergency Management, Board of Health, and the Planning and Development Department. The purpose of these interviews was to gain a better understanding of the needs of the people we are providing guidance documents to, how climate change specifically impacts their jobs, and what their informational needs are in order for them to better understand the impacts of climate change and what they can do to address them.

Our team scheduled meetings with developers from the Everett Ave. area, and members from Planning Board, Zoning Board and Conservation Commission once we received permission from John Gelcich. John Gelcich, the planner and land use administrator of the Planning and Development Department for Chelsea, MA, provided our team with a list of contacts for both members of the City's boards and a group of developers that have plans to construct new buildings in the Everett Ave. area such as: an FBI building, a hotel and an apartment complex, whom have developed in the City of Chelsea in the past. The members of the three boards that we provided guidance documents for were able to explain how flooding, severe storms, and extreme heat events would impact their work and what they would like included in their guidance documents which will aid them when meeting with developers. We also interviewed the three developers that were mentioned in the list that John Gelcich provided us because they are currently involved in development in the Everett Ave. area. It was important to hear from the developers on what considerations they take into account regarding climate change, as well as their viewpoint on the working relationship they have with the Planning Board, Zoning Board, and Conservation Commission.

For all of the interviews, we chose to conduct semi-standardized interviews. Semi-standardized interviews are when a set of scripted interview questions is created for each interview but allow for unscripted follow up questions during the interviews (Berg and Lune, 2012). This semi-standardized structure allowed our team to gain further detail on any regulations, climate change concerns, or mitigation and adaptation strategies the interviewees mentioned. This structure helped us get a more in depth look into the interviewed boards and also highlight any differences between the developers in more detail. Our team prepared interview questions for the board members and developers that helped us to develop the topics

that were covered in the guidance documents. Based on our background research, our team created a set of questions specific to each board that we spoke with and another set of questions for developers, so we were able to tailor the guidance documents we produced towards the boards. The questions are listed in Appendix B.

Since the main climate change related concerns that we focused on are flooding, severe storms and extreme heat events, we asked each board member and developer how they professionally confront these issues and what their concerns are with them. While we were interested in their general opinions regarding climate change, we wanted to know specifically about regulations and considerations that related to the three impacts of flooding, storms and extreme heat events; therefore, the questions that we asked did not contain the phrase "climate change" for the most part but rather brought up each impact separately. Together the questions and the responses we received showed us what information we needed to put into the guidance documents to inform the boards about climate change and any adaptation and mitigation options that they are not currently aware of.

In order for our team to conduct the interviews, we submitted an Institutional Review Board (IRB) application and received approval. When we conducted these interviews, if given permission, we recorded the conversations, and took detailed minutes throughout the interview. To ensure that we knew what we had permission to record, write down, or quote in our report, we had each individual that we interviewed sign a consent form. The consent form we provided is a part of Appendix B. Recording the interviews allowed the team to ensure that each individual was properly quoted and that the team could then go back and review the interviews at a later time.

Finally, we organized and analyzed the responses from our interviews in a way that allowed us to understand the needs of the board members. To complete this task we organized the responses from our interviews into a table shown in Appendix D. We organized responses to the questions presented in the interview guide into several topics. The table was organized by who we interviewed as well as interview questions. The table displayed the answers in a comparative way; therefore, allowing the reader to understand how responses were similar or different for each of the questions. The format of a table allowed us to represent the information in a clearer and more organized way.

3.3 Using the Information Gathered in the First and Second Objective to create Usable Documents to Provide Climate Change and Adaptation Information for the Boards.

Our third objective was to generate a structured set of guidance documents for the boards that included information on climate change, information on socioeconomic vulnerabilities, and adaption and mitigation options for the boards to consider, with a focus on Everett Ave. area. There was also a separate document created for the City's Planning and Development Department to address any concerns developers may have that did not need to be included for all board members since the Planning and Development Department requested to be the one to introduce these concerns to the other board members.

The first task to complete this objective was to organize the information related to the informational needs of the board members. We organized information about climate change and adaptation strategies obtained through our literature research and geographic data in the form of maps generated from the Mass GIS data layers.

The second task for completing this objective was to decide what format to present the deliverable to the board members. Our team determined what the best format was for this

document from the interviews that our group conducted. The interview questions asked what format the developers and board members prefer when receiving information. Options we considered were a PDF, check list, pamphlet, or even a possible webpage; the format can affect the how much they use the document. The group also did literature review on what types of methods are best absorbed when trying to present guidance document. Some possible methods that the team identified included an interactive document with the front page being highlights of different sections while having links to get more information on each topic; this format could include a document that could be updated when new information is available. For example, if a vulnerability or risk arises that was not previously seen in the Everett Ave. area, the board members could update sections of this document in order to adopt it for future use. Since climate change can be a controversial subject to some, we had to make sure the information was relevant for the city and very objective.

This objective allowed us to learn the informational needs of the board members and other considerations about the format and content of the guidance documents. Board members indicated considerations about the length of the document and the type of information it should include. The information learned from the developers allowed us to understand their perspective about planning and climate change and their expectations of board members. Through completing this objective, we were able to generate two guidance documents that contain climate change information relevant to the board members. The next chapter will present the findings about Chelsea's vulnerabilities to climate change, about the informational needs of the board members, and considerations for the guidance documents.

4.0 Findings

In order to provide the city of Chelsea with guidance documents and recommendations for addressing climate change, we conducted a literature review of the climate change data and impacts, adaptation and mitigation strategies and Chelsea's socioeconomic characteristics, and analyzed geographical databases. We also learned the informational needs of the Planning Board, Zoning Board of Appeals, and Conservation commission through interviews. The first set of findings will be about providing findings about Chelsea's physical and socioeconomic vulnerabilities to climate change. We will then discuss the findings about the boards' informational needs obtained through our interviews with board members from the Zoning Board, Planning Board and Conservation Commission and developers.

4.1 Chelsea's Vulnerabilities due to Climate Change

In order to understand the Chelsea's vulnerabilities, we conducted literature and GIS research about its physical and socioeconomic characteristics. The findings in this section were obtained through literature research about climate change impacts, geographical analysis from GIS data layers, and literature research about the key socioeconomic characteristics that make the city more vulnerable to climate change. This section will include findings about the vulnerabilities of physical stressors, planning areas, and socioeconomic characteristics.

4.1.1 Vulnerabilities and Risks due to Physical Climate Change Impacts

Finding: *Severe storms, flooding and extreme heat events are the main climate change impacts that are predicted to affect the Everett Ave. Urban Renewal District*

Our literature research showed that the coastal cities in the Northeast are exposed to sea level rise and severe storms (Melillo et al., 2014). Both sea level rise and severe storms can increase flooding. Additionally, the climate change predictions suggest that coastal cities in the Northeast are also vulnerable to extreme heat events (Melillo et al., 2014). Urban areas experience higher temperatures in comparison to surrounding rural areas because of the urban heat island effect (EPA, n.d.). The Everett Ave. area is especially vulnerable to the extreme heat events because of the large amount of pavement in this development area, which intensifies the local temperature by creating an urban heat island.

Finding: *The Everett Ave. Urban Renewal District is vulnerable to flooding since it is located in the preliminary FEMA flood zone*

The new preliminary FEMA flood map shows that the Everett Ave. Urban Renewal District is in the flood zone (FEMA 2013, *Figure 4*). This map shows the 100 year flood that has, on average, a 1 percent chance of occurring in any given year and takes into consideration historical data until the present. However, this map does not incorporate future climate change considerations (FEMA, 2014). Climate changes are predicted to lead to an increase in the severity of storms and sea level rise (Melillo et al., 2014), and these changes will worsen the flooding in the case that a severe storm occurs. More severe flooding would increase the sensitivity of the Everett Ave. area and would make it more vulnerable. Additionally, more

severe storms would increase the climate risks by worsening the consequence that the impact would have on the Everett Ave. area.

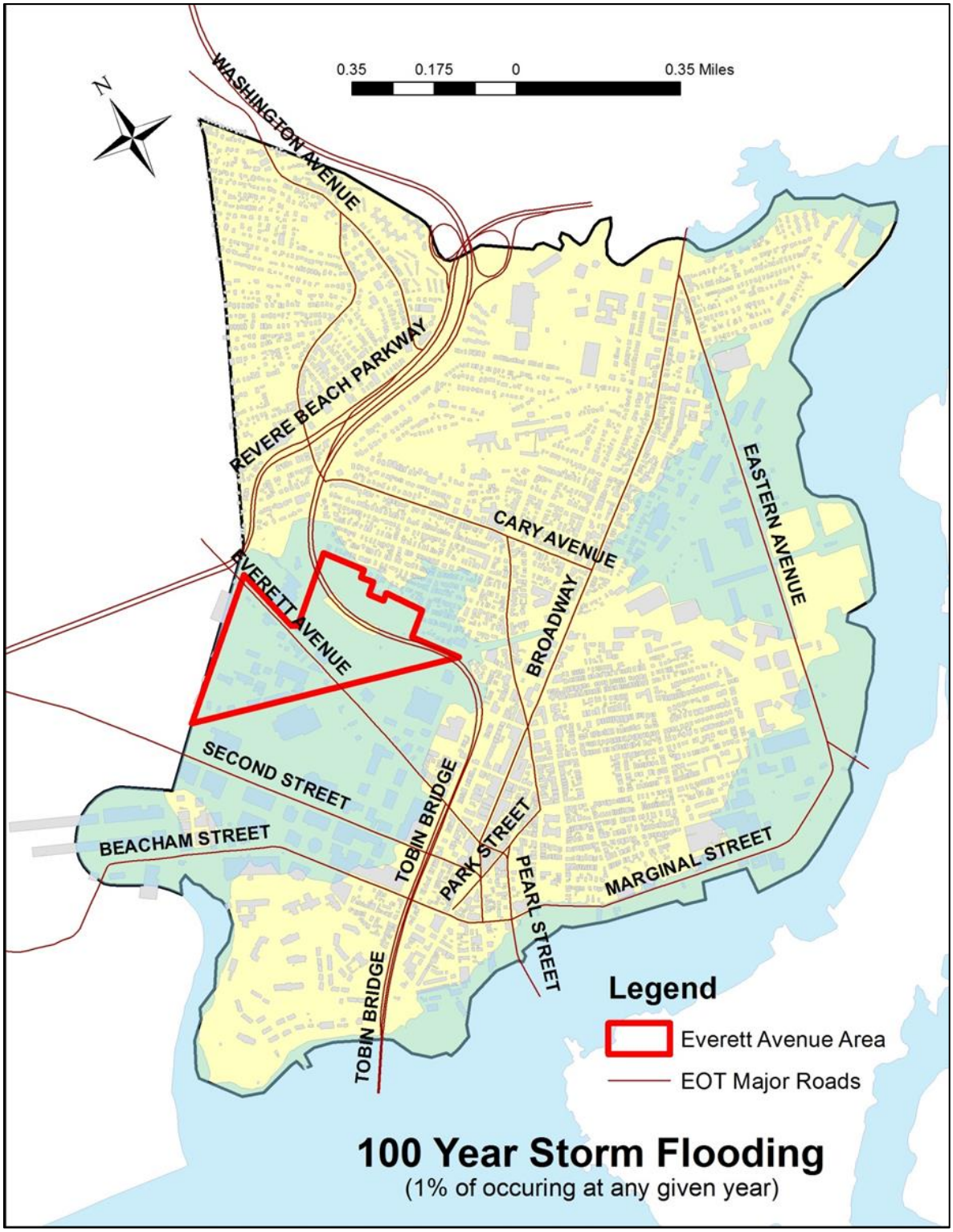

Figure 4: 100 Year Storm Flooding Map of Chelsea, MA.

Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT

Finding: *More areas of the city of Chelsea are likely to be added to the flood zone in the future due to climate change*

As previously stated, the preliminary FEMA flood hazard map does not take into consideration climate change; it shows the flooding caused by 100 year storm. *Figure 5* uses shows the elevation that the 100 year storm flood would reach at up to approximately 9 feet (FEMA, 2013). Sea level rise and more severe storms are projected to increase the flooding levels, which mean that additional areas of the city could be exposed to flooding beyond those that are highlighted in the flood maps. For example, sea levels are projected to rise between 1 and 4 feet by 2100 (Melillo et al., 2014), and therefore the flood levels are projected to increase. According to the Boston Harbor Report, with a sea level rise of 2.5 feet, the coastal storm surge at high tide would be approximately 12.3 feet NAVD (Douglas et al, 2013).

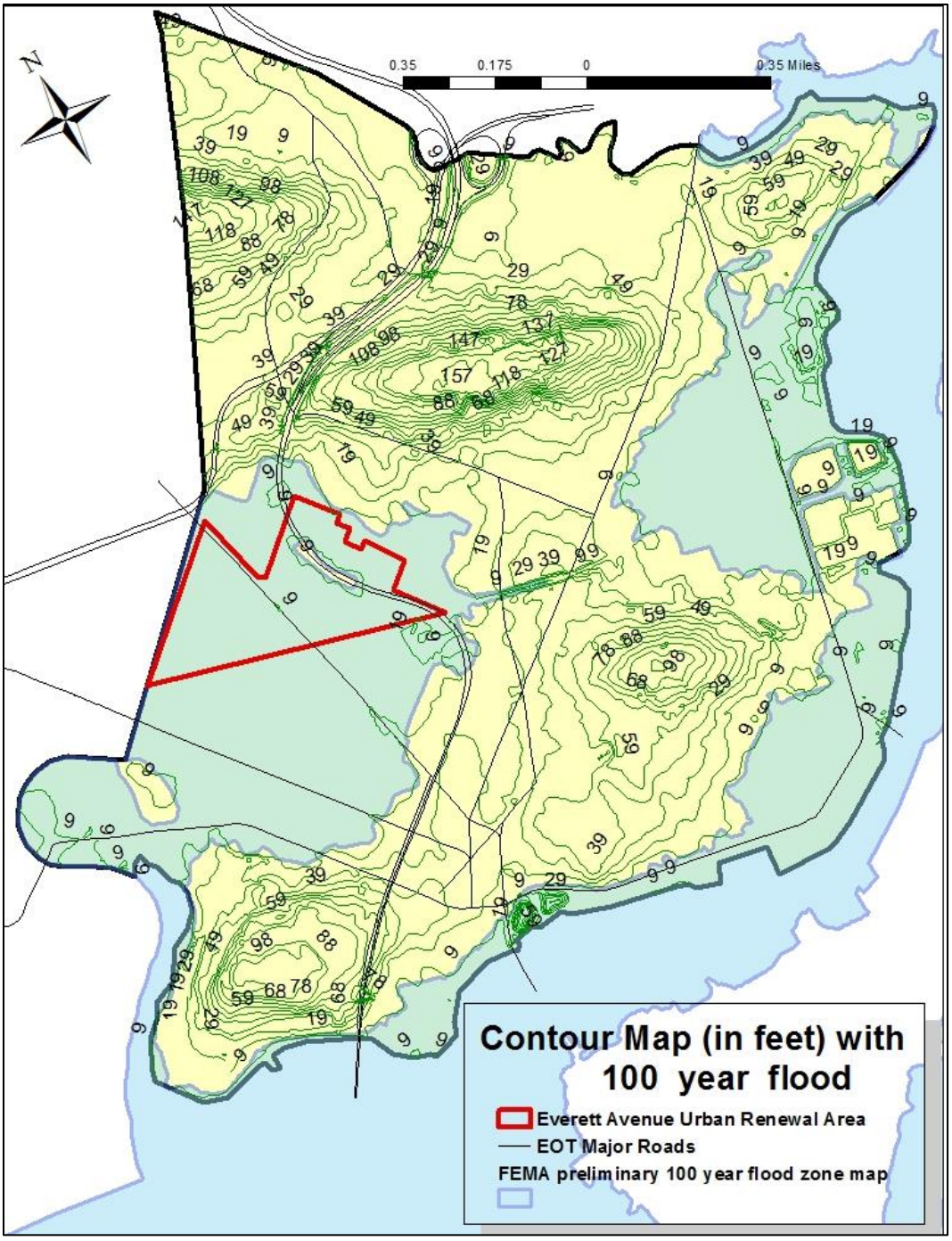

Figure 5: 100 Year Flood Map of Chelsea, MA. with Contour Lines.

Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT

Finding: *All of the major Executive Office of Transportation roads in the Everett Ave. area were added to the preliminary FEMA flood zone*

Figure 4 indicates that the major roads that go through the Everett Ave. area are in the proposed 100 year flood zone. We observed that the major roads that connect the city to the Everett Ave. area are under the FEMA flood hazard zones. These roads are: Beacham Street, Second Street, Everett Avenue, and Tobin Bridge roads. Although we do not have the specific evacuation routes of the area, it is likely that such major roads may be used during evacuations. As the impacts of climate change worsen over time the situation could further disable more roads.

4.1.2 Vulnerabilities and Risks in the City's Planning Areas

From our literature review about the City of Chelsea and climate change, we identified different planning areas of the city found to be especially vulnerable to the impacts of climate change. These include storm water management, electricity, natural gas, air quality, roads and public transportation. In this section, we will discuss the information in different planning sectors such as: public heath, infrastructure, energy and transportation. Applying the concept of planning sectors enabled a more focused analysis of how climate change impacts could affect the City of Chelsea.

Finding: *The storm water management and combined sewer systems in the Everett Ave. area are potentially vulnerable to climate change*

The storm water management system of the city, and of the Everett Ave area, is potentially vulnerable to climate change. The city has over 70 percent combined sewers (City of Chelsea annual report to the EPA, 2014), which in the event of a storm can overflow (Melillo et al., 2014). The combined sewers would worsen the impacts of flooding because their capacity may be exceeded, and they can cause water quality issues could arise when wastewater and debris are untreated (EPA, n.d.). Upgrading the sewer system is very costly and could disrupt the economic development of the area (EPA, 1999).

Finding: *Air quality will worsen due to an overall increase of temperature in the area, an increase of the number extreme heat events, and flooding due to sea level rise and severe storms, leading to increased health risks.*

Air quality is likely to decrease as a result of climate change. With temperatures increasing, more days with unhealthy levels of air pollutants are expected (EPA, n.d.). Additionally, more smog will be present in the air (EPA, n.d.). These pollutants would worsen respiratory diseases and asthma and could cause premature death. For instance, a study found that the changes in temperature would lead to an increase of 50 percent to 91 percent in heat-related deaths in Manhattan by the 2080s in relation to a 1980s baseline (Melillo et al., 2014).

Flooding is also a concern for human health due to potential contamination in flood water and the potential effects that it may have on the air quality of indoor environments (EPA, 2012). Examples are growth of bacteria, mold and other microorganisms such as viruses; these can

cause disease, continue to damage materials after the flood has occurred and cause allergy reactions (EPA, 2012)

Finding: *Economic development and health of residents of the Everett Ave. area are vulnerable to climate change because of the increased risk of power outages and electric lines damage*

More severe storms and flooding could increase the risk of power outages (EPA, n.d.). More maintenance and repairs to the electric lines would add cost for the city, and power outages are disruptive to the economic development of the area. Power outages can also increase health risks of vulnerable populations during extreme heat events or extreme cold temperatures. The risk for the energy sector is concerning because the impacts will affect the services of the area and hinder the economic development of the area.

Finding: *The energy demand for indoor cooling is expected to increase because of the overall increase of temperature and the increase of extreme heat events*

The energy demand and costs for indoor cooling with air conditioning are predicted to increase because of the overall increase of temperature, especially during the extreme heat days. According to the EPA, the demand in energy would be 5 to 20 percent higher if the nation's climate warms by 1.8 °F, and the demand for heating would decrease by 3 to 15 percent (EPA, n.d.). Temperatures are predicted to increase in the Northeast from 3 to 10 °F by the 2080s depending on the emission of heat-trapping gasses (Melillo et al., 2014). Additionally, The Everett Ave. area and other urban areas are particularly sensitive to the urban heat island effect because of factors such as dark paving materials, dark roofs and increased amount of heat produced by vehicles and air conditioners (EPA, 2006)

Finding: T*raffic delays road closures are expected to increase because of increased flooding and number of extreme heat events*

With the predicted increase in flooding due to severe storms and sea level rise, delays and shutdowns of the roads are expected to increase (EPA, n.d.). Warmer temperatures are predicted to increase the amount of liquid precipitation, which will also damage the roads (EPA, n.d.). *Figure 4* shows how multiple major roads were put in the preliminary FEMA flood zone. Major roads are essential for the economic development of the city and necessary for evacuation. The consequence of flooding due to severe storms and sea level rise could be significant to the economic development of the area, emergency evacuation and access. The number of extreme heat events and the overall temperatures in the Northeast region are expected to increase (Melillo et al., 2014). The increased number of extreme heat events is expected to cause damage to the pavement and roads, and therefore more maintenance will be required. Maintenance or repair to the roads can cause disruptions to the economy and can be costly for the City.

4.1.3 Vulnerabilities and Risks due to Socioeconomic Characteristics

Finding: *The residents of the City of Chelsea are particularly vulnerable to flooding due to sea level rise and severe storms because of their income level, education, disability, gender, age, and ethnicity.*

Lower income levels affect the sensitivity and adaptive capacity of residents since they are less able to prepare for events and to afford recovery costs. As shown in *Figure 7*, the city of Chelsea's median household income in 2010 ranged from $13,000 to $37,000. Low income populations already have limited access to emergency services, employment opportunities and

health services, and therefore face higher climate risks (Keller Jensen, 2009). Low income populations are also less likely to be covered by insurance (Haines, Kovats and Corvalan, 2006). In the case of a severe storm, low income populations can lose their property due to damage and would have less ability to cope with the economic consequences. To provide context to the other maps, *Figure 6*, shows the population distribution for the city of Chelsea. Additionally, the population in the Everett Ave. area is likely to increase because of the increased development, which includes an apartment complex. The increase of the number of residents would lead to more exposure and increase the sensitivity of the population

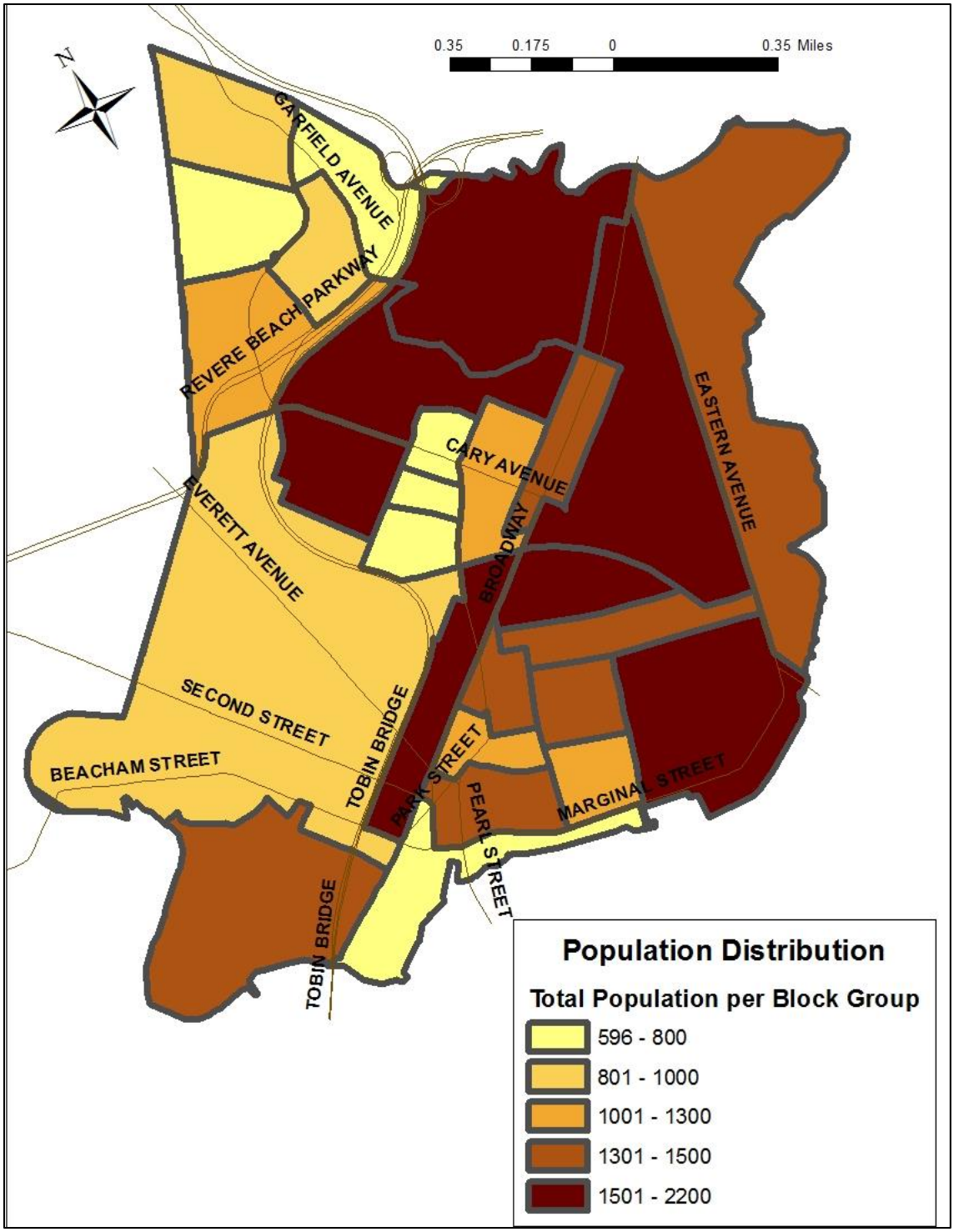

Figure 6: Population Distribution of Chelsea, MA.

Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT

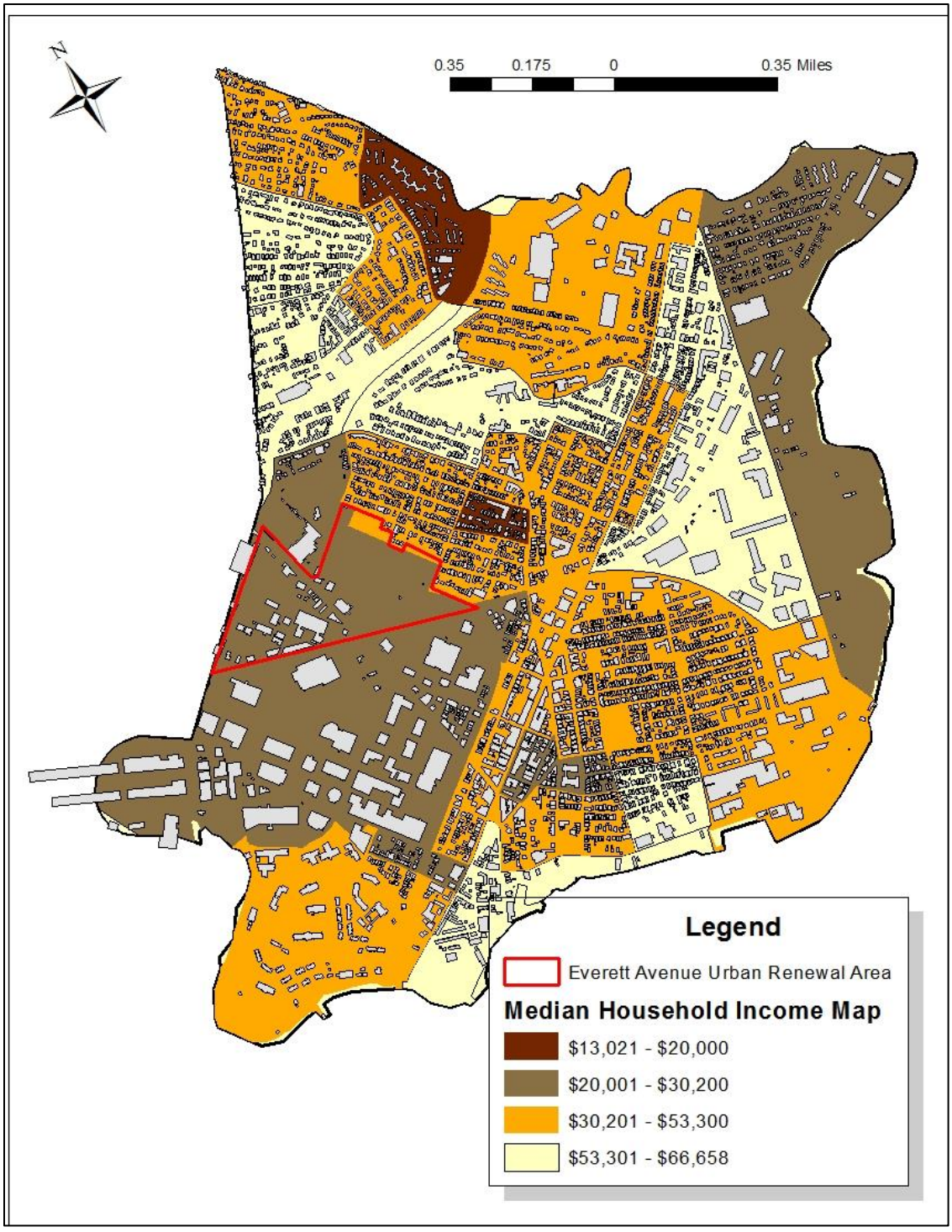

Figure 7: Income Level Distribution of Chelsea, MA.

Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT

People with disabilities are also more vulnerable to climate change impacts due to mobility issues, and dependency on other family relatives. Additionally, people with disabilities have disproportionately higher rates of mortality and morbidity and have difficulties accessing emergency support (Lewis and Ballar, n.d.). This group tends to be overlooked in emergency relief operations, and they might have difficulties moving to safe areas, lose assistive devices or accessing important emergency information (Lewis and Ballar, n.d.). People with disabilities are more sensitive to climate change, and therefore are more vulnerable to the impacts of climate change.

Gender is another factor that can make a city more vulnerable. Women tend to have lower incomes than men making harder for them to recover after disastrous events (Cutter, 2003) Women also generally have more family care responsibilities and are responsible for other members of their family, which can make them more vulnerable as well.

Education level is another factor that may make residents more vulnerable to flooding due to sea level rise. Lower education is linked to a lower socioeconomic status (Cutter, 2003). A lower education level can affect the residents' understanding of warning messages, access to recovery information and climate change issues (Cutter, 2003). Also, lower educational attainment results in less lifetime earnings (Cutter, 2003). *Figure 8* shows that between 50 percent and 64 percent of the residents of the Everett Ave. area do not have a High School diploma. These factors would result in a lower adaptive capacity and higher sensitivity, and therefore higher vulnerability.

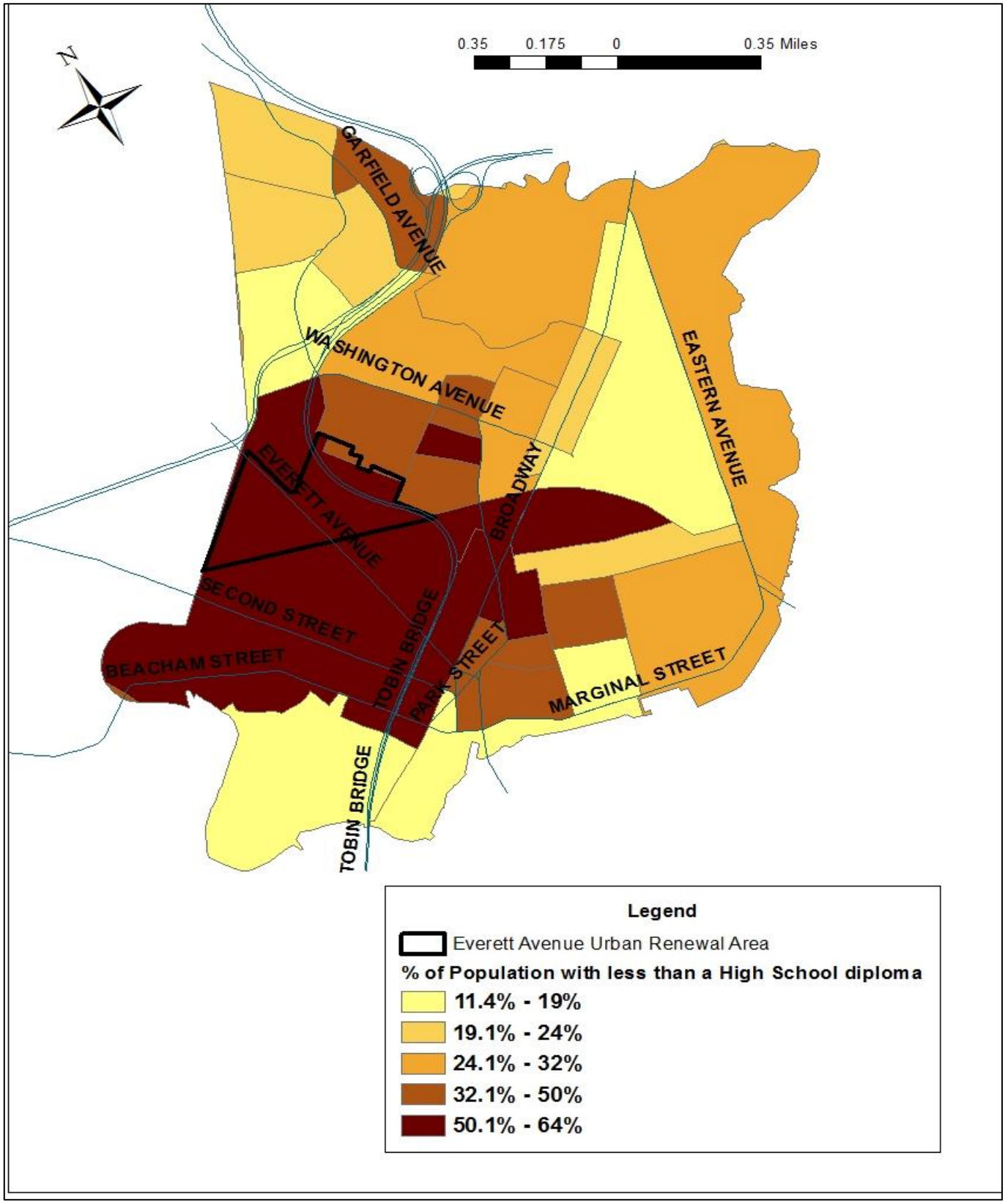

Figure 8: Education Level Distribution of Chelsea, MA.

Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT

The Elderly and young children are more vulnerable to the effects of climate change due to flooding because they have mobility issues. These groups also might depend on family members. 8.9 percent of Chelsea's 2008 population is under five years old and 11.4 percent is over 65 years old. Additionally, the share of US population of adults over 65 is expected to increase from 12 to 21 percent by 2050 (EPA, n.d.), and these shifts may also occur in Chelsea. Elderly people and young children are more sensitive to flooding due to sea level rise and severe storms, and therefore they are more vulnerable.

According to the 2008 Census, 56.1 percent of the city's population is of Hispanic or Latino origin, category which included residents with various racial identities (Vanasse Hangen Brustlin Inc., 2010). *Figure 9* shows the percentage of residents that are considered minority (other than white non-Hispanic) in the City of Chelsea. Minority residents can have lower adaptive capacity because they have difficulty in accessing recovery funds (Cutter, 2013). Additionally, climate change impacts can more severely affect certain groups, such as recent immigrants, particularly if they have language barriers (IPCC, 2007). Minorities that have language barriers are less able to understand warning messages or climate change issues; for example, *Figure 10* shows the percentage of population with limited English ability in the City of Chelsea. Therefore, minorities are more sensitive to the effects of climate change.

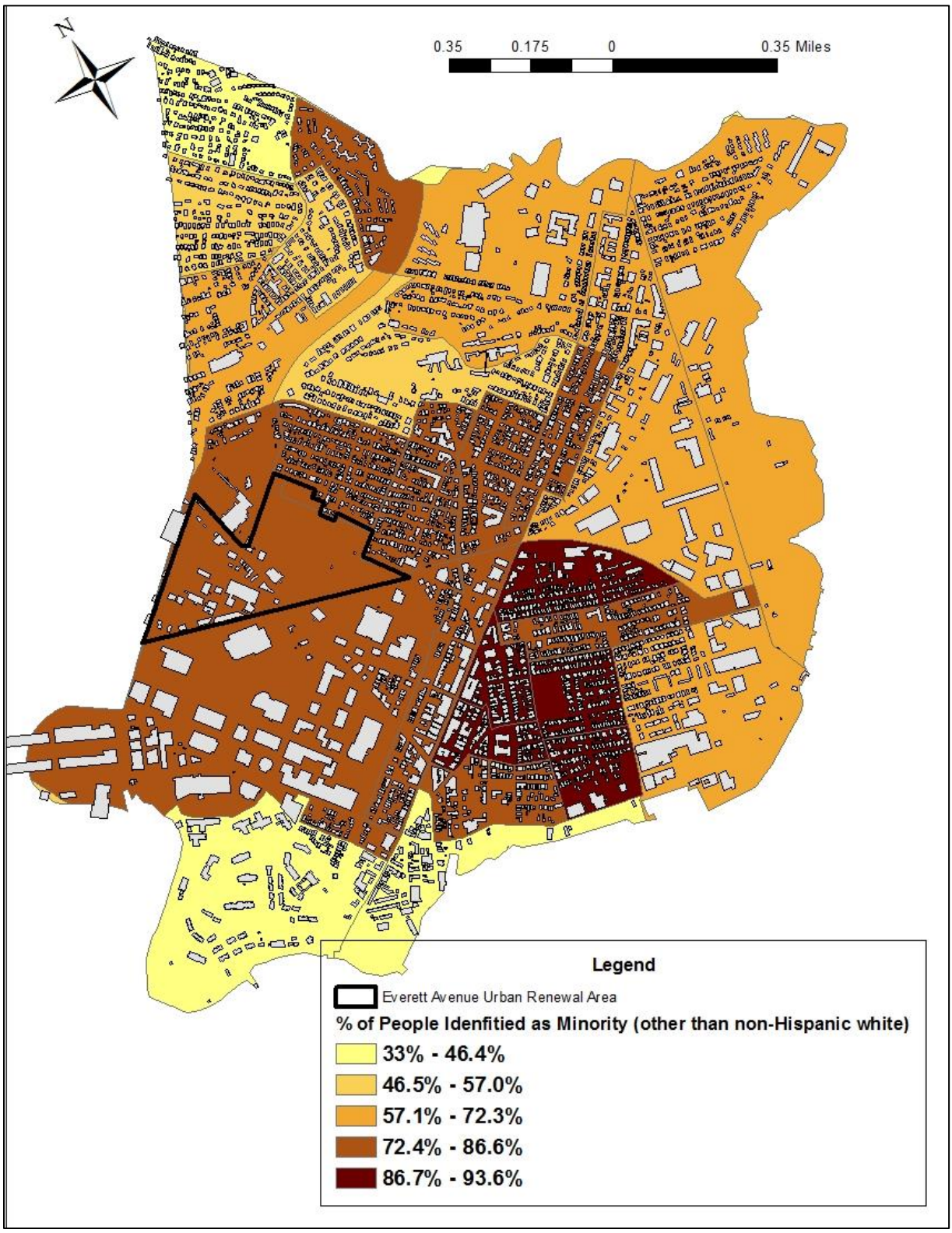

Figure 9: Minority Map

Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT

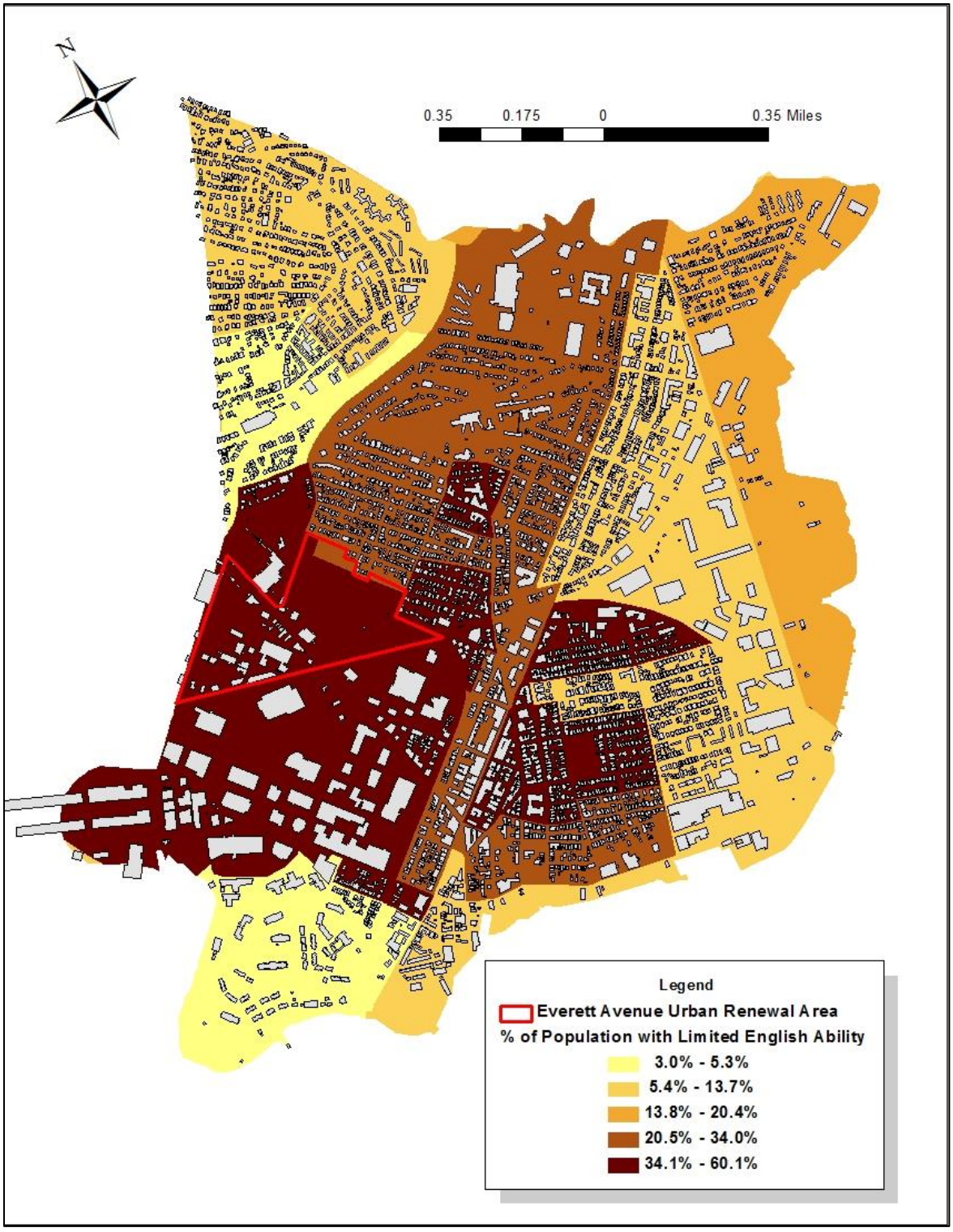

Figure 10: Percentage of Population with Limited English Speaking Ability.

Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT

Findings: *The residents of the City of Chelsea are particularly vulnerable to heat-related illness and death due to extreme heat events due to their income level, age and pre-existing health conditions.*

Income levels and age are factors that make population more sensitive to extreme heat events (EPA, n.d.). The extreme heat events can cause stroke and dehydration, which are the main causes of weather-related deaths. The number of heat related deaths is expected to increase with the increase of extreme heat events, especially in elderly population, young children and low income populations (EPA n.d.). The risk due to extreme heat events is concerning because it is a threat to public health (EPA, n.d.). Low income, elderly people that live in row homes are at even higher risk for heat-related events (EPA, 2006).

The City of Chelsea has low income areas. The Everett Ave. area is an example of an area with low income population, with a median household income in between $20,001 and $30,200. Low income housing usually lacks air conditioning, and even if they have it, residents may not use it to avoid high utility bills (EPA, 2006).

The elderly population is especially vulnerable to heat-related illness and death. The elderly can suffer from social isolation and physical health issues and may lack neighbors or friends that check on them (EPA, 2006). The elderly may also not hear heat event warnings or recommendations on how to stay safe, and they are physically less prepared to handle heat stress (EPA, 2006). 11.4 percent of Chelsea's 2008 population was over 65 years old. Additionally, according to the EPA, the share of US population of adults over 65 is expected to increase from 12 to 21 percent by 2050.

Air quality is also impacted by the increase in temperature. With temperatures increasing, more days with unhealthy levels of air pollutants are expected and more smog will be present in the air (EPA, n.d.). These pollutants would worsen respiratory diseases and asthma and could case premature death, especially for the elderly and young children (EPA, n.d.).

4.2 Interview Findings

Our group conducted interviews with board members from the Planning Board, Zoning Board of Appeals, and Conservation Commission, the Board of Health and the Department of Public Works as well as three developers who were building sites in the Everett Avenue Urban Renewal District and whom have built in Chelsea in the past. The goal of these interviews was to identify what level of information that board members already had and what would be useful for us to put into the guidance documents or recommend to the board members. All of these interviews were organized into tables found in Appendix D for analysis. The data from the interviews suggest that there are some board members and developers who do not see climate change as an issue, board members will have a limited time to review the document we provide, and that the Planning Board's level of understanding of climate change issues differs from that of the Zoning Board. We also learned from these interviews that the document needs to be short and easy to read and include recommendations rather than regulations. While we were able to interview with at least one representative from each board and three developers, our findings were limited by the small sample size.

4.2.1 Climate Change Awareness

Finding: *A lack of understanding of climate change may lead to a lack of concern or delay in addressing the impacts that climate change will cause.*

During the interviews that our team conducted it was noted that while some board members and developers were starting to take into consideration the impacts of climate change, other board members and developers do not view climate change as a concern and do not take it into account when planning. The lack of concern was noted to be caused by limited information and because of the lack of regulations that incorporate climate change.

- **Board Members' Understanding of Climate Change**

All the board members we interviewed reported that they have not seen any climate change related effects in the Everett Ave. area, and some therefore stated that they do not see a need for change. From our interview with a member of the Planning Board, we learned that some of board members view climate change as a "non-issue" in regards to their board's responsibilities and do not take it into consideration when making decisions. Many of the board members focus on the regulations that they are responsible for and do not focus on issues that are not regulated such as climate change. When asked about the board's concerns regarding flooding, storms and heat days, one member of the planning board replied "In my opinion no attention at all has been paid to that possibility. The concerns, there are none". However, during the interviews with members of the Planning and Development Department who are on the boards, it was discussed that the proposed FEMA flood maps did cause some of the members to begin to think about climate change as a possible issue.

- **Developers' Understanding of Climate Change**

Similar to the information provided from the board members many developers also stated that they had little concern for the impacts of climate change. One issue brought up by one developer was that they need to have concrete proof to make sure that the expense is worth it. When asked about their concerns with climate change the developer replied "I'm not convinced the conditions are going to be that much worse…I mean I could be very not well informed. I am open to that". From this information it can be stated that providing information to the developers may help them to better understand climate change and the effects of climate change. Through an interview with a second developer, our team learned that some developers are starting to consider climate change into their plans. This developer stated that Hurricane Sandy had a large impact on his view of climate change. The other developers did not consider climate change into their plans or they preferred to pay the flood insurance versus building to accommodate climate change. They would rather build their developments for now, and not for the long term, due to how it saves money in the present. The developers all expressed a concern for how climate change adaptation is expensive and that they could only do so much to keep the development worth it and that in order to make the profit some adaptations are not implemented.

4.2.2 Time Limitations

Finding: *Many board members have limited time availability and prefer a short and easy to read document*

Another finding from our interviews was that the board members are busy and often do not have much time to review information. Through our interview with a member of the Planning Board it was stated that it all of the board members were also volunteers. It was also

stated in an interview with a member of the Planning and Developer Department who also serves on the Zoning Board that many board members tend to review information immediately before meetings or even bring the information with them to review during the meeting. The Planning and Development member we spoke with mentioned that many board members do not spend a lot of time looking over reports regardless of the amount of time the report was given in advance.

4.2.3 Communication between Boards

Finding: *There was a different level of understanding among board members that shows a need for more communication*

From the analysis of the interviews will the Planning Board and Zoning Board there was a lack of similarity between answers to certain questions that showed inconsistency in the understanding of information between each board that suggests a need for more communication between them. A member of the Planning Board stated that developers have not been preparing their buildings to address the proposed FEMA flood maps. However other Planning and Development members, who are on the zoning board, stated that there were some developers who have raised their building to be out of the flood zones as well as one developer who had installed a rain garden. These comments suggested that some of the boards were not aware of ongoing efforts.

In our limited number of interviews we also noticed that there is the need for better communication between the city's boards. For example, the members of the Board of Health that we interviewed stated that the Board of Health is often not included in certain plans or situations. They stated that even though "on paper" it may be the Board of Health's responsibility, some of these responsibilities often are handled by other departments.

4.2.4 Guidance documents for the Board Members

Finding: *The preferred method to display the information we are going to present in our guidance documents is through some type of short document that can be easily printed, transferred or emailed out to all of the board members*

During our interviews it was determined that the preferred method to display the information is through some type of short document that can be easily printed, transferred or emailed out to all of the board members. According to a member of the Planning Board the information that the board members receive or seek out comes from the Planning and Development staff. All of the board members are volunteers and trust in the information that the Planning and Development staff provides them with. One member of the Planning Board suggested that having someone present the information from the guidance documents may also be helpful as presentations have been used in the past to present information. During most of our interviews the preferred method for viewing information was visuals and data using percentages will catch the attention of the board members and help them better understand the effects of climate change.

4.2.5 Recommendations are Preferable to Regulations

Finding: *Recommendations are preferred over regulations by board members and developers*

Both board members and developers suggested that providing recommendations for the boards to give to developers would be preferred to regulations that would be recommended for the boards to implement. During our interview with Planning and Development members they stated that they preferred recommendations because recommendations are not as strict and the

board members do not want to deter developers from building in the area due to standards that are stricter than the ones existing in neighboring other areas.

Similarly, interviews with developers suggested that future regulations may keep developers from building in the area due to the higher cost of implementing certain adaptations. For example, one developer stated that if Chelsea made their regulations stricter developers would be forced to move to neighboring towns such as Everett. Other developers expressed that the cost of implementing these adaptations was the main reason they would not want them to be imposed as regulations. Another developer specifically said that if regulations were to be implemented it should be on a state level so that no one city has stricter regulations than the other. All of these comments suggest that developers prefer recommendations to regulations.

Cost was the main concern that developers had when presented with adaptation strategies. One idea that was brought up by developers was having the city offer assistance and incentives for adapting their buildings to meet recommendations. The developer also suggested a soil trade program that would allow different developers to remove soil at no cost while others would be provided the soil needed to raise their buildings. Another developer suggested that the boards could provide discounts to help developers make their buildings Leadership in Energy and Environmental Design (LEED) certified. All of the developers we interviewed stated that cost was the main factor in their decisions, and therefore suggesting reasons why adaptations might save them money will be an important section of the guidance documents.

4.2.6 Short Term and Long Term Development

Finding: *The different types of developers plan their buildings in accordance with the amount of time they plan to keep their building which limits their foresight of future adaptation.*

From our interviews with developers we identified two types of developers: short-term and long-term developers. The short-term developers only hold onto their developments for two to three years before selling the development for profit. From our discussion with one developer, short-term developers are mostly concerned with issues that will affect the building during the time that they own it and future considerations are not looked into. Comparatively, a long-term developer is invested in the growth of city, they hold onto the building longer, use better materials, invest in efforts to make sure that the building is sound, and they care about the city and community. Another developer mentioned that as a longer-term developer he does care about the city and has started to think about the possibility of climate change affecting the buildings that are developed. Presenting the options as a way to save money even for short-term developers is going to be an important part of encouraging developers to take into account the effects of climate change.

5.0 Recommendations and Conclusions

In this chapter we will present the guidance documents that we created, provide recommendations on how to use the guidance documents, and on how these documents could be further expanded to encompass the whole City, and what else could be done to address the future impacts of climate change in the state of Massachusetts. We then present conclusions that were drawn from our findings and how they relate to the creation of our guidance documents for the City of Chelsea's boards. We will also go into detail on why each aspect of the documents was included to address these findings.

5.1 Guidance Documents

The findings presented in the previous chapter provided a basis for developing two documents for the Planning Board, Zoning Board of Appeals, and Conservation Commission about how climate change will affect the city, what can be done to protect against the impacts of climate change, the benefits of these adaptations, and concerns developers of the Everett Ave. area may have about implementing these adaptations. The purposes of these documents are to build climate change awareness and concern, provide examples of adaptation and mitigation strategies, provide possible benefits of these strategies, and concerns developers in the area may have. These guidance documents are included in Appendix E for reference.

To inform the boards about climate change, the primary guidance document starts with facts related to flooding, storm severity and extreme heat events in the Northeast with their relation to Chelsea, Massachusetts. A "Why Care?" section conveys the urgency of the issues. Making sure that the document was brief and it was not full of global facts also helps relate the problem to Chelsea to show that it is relevant to the city. Figures specific to Massachusetts' climate are included to capture the attention of the board members. Adding these figures helps

limit the words on the document and organizes information in quick graphics so the board members do not have to spend time reading a very long document. There are also links to more information in case a board member would like to see the source or get more information on a certain topic. These documents could inform both board members and developers on climate change and help create a sense of concern for climate change impacts.

A second section of the primary guidance document then presents the socioeconomic characteristics that make the Everett Ave. area of the City and its residents more vulnerable. When considering future developments the board members can benefit from awareness of the socioeconomic characteristics of the area that make Chelsea more vulnerable. In the primary guidance document, we provided maps that present socioeconomic characteristics of the City and how they are related to vulnerabilities. A table that explains the how socioeconomic characteristics can make the Everett Ave area more vulnerable to the effects of climate change.

The last section of the primary document contains mitigation and adaptation options to address the impacts of climate change that are most relevant to the Everett Ave. area. These strategies are presented in tables along with the benefits from each potential option. The tables provide the information in an easy to read format. Each adaptation and mitigation option in the table was selected as a feasible option for commercial developments. The tables contain links to more information on each specific option.

The supplemental guidance document contains concerns that developers may have about specific adaptation options. These concerns were drawn from interviews with developers, as well as literature research that highlighted some disadvantages that come with the implementation of these options. This document is intended to be given to the Planning and Development Department separate from the other document so that developers are not provided with concerns

that may have not thought of on their own. The Planning and Development members will then provide the board members with the concerns that apply to the specific situation.

5.2 Recommendations

Based on our team's findings and literature review, we created a set of recommendations that we propose the Planning and Development Department, The City of Chelsea, and MIT Sea Grant implement. Some of the recommendations we have suggested are for how board members should use these guidance documents. Other recommendations are for planning for future climate change on a broader scope.

5.2.1 Recommendations for Using of the Guidance Document

The team proposed that the City of Chelsea's Planning and Development Department use the guidance document in the following manner to get the most out of the documents:

- *The Planning Development Department should provide a tutorial to the members of the Planning Board, Zoning Board and Conservation Commission about how to use the guidance documents*: We found in our interview with the chair of the Planning Board that the boards are composed of volunteers. Because of this, they may not have time outside of their time working on the boards to review the guidance documents. We noted that some board members choose to look at documents briefly before they have a meeting and look to the Planning and Development Department if they need more information. Also, when asked about what may get the attention of board members the most, the chairman of the planning board also mentioned that a presentation could be helpful in connecting the guideline's significance to the boards. Because of this, we recommend that our guidance documents are

first presented to the board members as a tutorial of how to effectively use the document. This may allow the board members to familiarize themselves with what is in the document and the additional links provided within the document. Creating familiarity with the document will allow board members to more easily navigate through the guidance documents and know where in the documents specific sections can be found. This will make the board members more likely to use the document as they will have a working knowledge of what is in it and where to quickly find the information they are looking for.

- *Board members should use the guidance documents during meetings with developers*: In order to begin adapting to climate change impacts within the Everett Ave. area of Chelsea, we recommend that board members use the information in the guidance documents when talking with developers who are proposing plans to build there. In this case, the guidance documents may provide the board members with an outline of what topics to discuss with developers related to climate change adaptation. This will allow the board members to recommend adaptation and mitigation options from the tables and look into how a development will make any area more or less vulnerable. Using the guidance documents, board members can address possible concerns of developers and offer incentives or tradeoffs to developers as they see fit. Having the documents at these meetings with developers will enable board members to present any relevant adaptation ideas they choose to discuss and can also show developers any mapping data that may be relevant.
- *Board members should send sections of the primary guidance document to developers*: Through our interviews with the developers, we found that developers had not looked much into the impacts of climate change in Chelsea. In some cases, this lack of concern was due to a lack of informational background on climate change and its impacts. In our interviews, we

found that the developers we spoke with were willing to discuss climate change. While there had been some precautions taken in developments, overall they had not implemented adaptation and mitigation options into their designs. We suggest that the Planning and Development Department send developers certain sections of the primary guidance document, such as the climate change section and the adaptations section, before meeting with them to give the developers a chance to consider adaptations and why action needs to be taken in the city. This will also provide the developers with information and data regarding climate change within the northeast and why they may find it important to think about adapting to flooding, storms and extreme heat.

- *Board members should adopt these guidance documents to be used for the whole city*: Our team's decisions about content in the documents were in part tailored to what would be best suited for the Everett Ave. Urban Renewal District in Chelsea. Because of our scope, we chose to interview commercial developers and most of our adaptation options were chosen to fit in a business and development environment and not a highly residential area. The FEMA maps, GIS maps that we created, and our findings on socioeconomic vulnerability show that there are other regions in the city that will also be subjected to similar impacts of climate change in the future. For example, there are other areas within the city that have been added to the flood zones recently. We have included maps of not only the Everett Ave. area but the whole city in our primary guidance document that show the levels of vulnerability related to income levels, minority populations, and language barriers. The maps can be used to assure that anything that is being built in the city does not unknowingly add to the vulnerability of the area. The city could do this by trying to ensure that they limit the number of socioeconomic vulnerabilities in an already physically vulnerable area. We recommend that

the guidance documents eventually be adopted for use throughout the entire city, to properly prepare multiple regions. We have also provided many adaptation and mitigation strategies that can be implemented in any type of developments and included maps that pertain to the entire city to aid in expanding the use of these documents.

- *Board members should continue to update the guidance documents as new information is introduced*: In order to ensure that these documents remain relevant and useful in years to come we recommend that the city continue to update and make changes to the document as new information is obtained. Climate change predictions are constantly changing as new data is acquired and it is important to add these changes to the documents. Also, board members may find that there are more adaptations that the city finds beneficial than what we have provided in the guidance documents. Through our interviews with the developers we had access to; our team was presented with various reasons as to why a developer would choose against implementing an adaptation or mitigation option. We were only able to interview three developers and because of this, we suggest that the Planning and Development Department in Chelsea update the document we provided with other concerns that developers may have. The concerns that developers have may be specific to the individual or to the type of development they are working on. As the boards meet with other developers in the future, more concerns may come from developers. Updating the list to include these new concerns as they arise is important to prepare the board members before recommending adaptations and mitigations to certain types of developers.

5.2.2 Recommendations for Planning for Climate Change on a Broader Scope

- *Board members or other city officials should consider updating and adapting other areas of the city's infrastructure and emergency planning*: We suggest that city adapt and update their

infrastructure protect them from the predicted impacts of climate change. We learned that there are many areas of infrastructure and planning sectors that are made vulnerable by the impacts of climate change. However, the limited time and scope of our project only allowed us to work with the Everett Ave area, which led our focus to be newly developed commercial and industrial buildings. Therefore we recommend that the city do an assessment of their planning sectors and infrastructure such as roads, sewer systems, public water facilities, and electric lines and determine if they need to be updated to account for climate change.

- *The city should asses the cost and benefits of requiring developers to adapt to climate change and then create zoning ordinances to enforce these requirements*: Though in our interviews with both board members and developers we found that board members and developers preferred recommendations to regulations, we still believe that over time some recommendations should be turned into regulations to force a change. We also learned from developers that recommendations are preferred because some of the adaptations are expensive and they may not add them because of cost, unless required. Therefore it is best that there is eventually some type of requirement that forces developers to mitigate and adapt to the impacts of climate change to some extent. However, the city should first determine whether the cost of these adaptations is worth the benefits for developers.
- *MIT Sea Grant College Program and the City of Chelsea or another project group should advocate that regulations for climate change adaptations be set at a state level*: From background research we learned that different municipalities are allowed to implement their own regulations but if a state regulation is stricter than that of the municipality, the stricter regulations must be followed. We therefore recommend that our sponsors at MIT Sea Grant College Program or another WPI project pursue having regulations implemented at a state

level. From an interview with one developer it was suggested that if regulations were going to be put in place that it should be at a state level because would allow all cities to stay competitive with each other in terms of development. It would also help to have more developers throughout the state implement adaptation and mitigation option which is important for the future of climate change.

5.3 Conclusions

Increased flooding due to sea level rise, increased frequency of severe storms and increased frequency of extreme heat events due to climate change may make Chelsea more vulnerable to climate change impacts. The increased risk of flooding put on the Everett Avenue Urban Renewal District will have severe impacts on the developments and buildings in that area for the future. Adding provisions to the plans of the developments such as adaptation and mitigation strategies will not eliminate these impacts but it may decrease the harm. Our team identified the physical and socioeconomic vulnerabilities of Chelsea to show potential concerns in the future. We then generated a structured set of guidance documents for the Planning Board, Zoning Board of Appeals, and Conservation Commission that included information on climate change, and adaption and mitigation options for the boards to consider, with a focus on Everett Ave. area. Furthermore, this project encourages the City of Chelsea to begin to adapt the whole city to climate change impacts and is the first step in a larger discussion or beginning to address climate change through regulation on a larger scale.

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Appendix A: Vulnerability Analysis Tables

Sensitivity Analysis Table

Sector	*Planning Area*	*Current/ Expected Stressors*	*Climate Conditions relevant*	*How are conditions expected to change*	*Impact of changes to the planning area*	*Changes in stresses to the planning area*
Infrastructure	Storm water management	Combined Sewer Overflows (CSOs). 70% of the city uses combined sewers.	Severe storms	Storms are predicted to be more severe (less rain days, but more severe precipitation)	Flooding in the area, water quality issues could arise because of untreated wastewater and debris	Uncertain but likely to get worse
Transportation	Roads	Winter road maintenance/ snow and ice removal	Warmer winter temperatures and winter storms	Warmer winters expected. Less winter storms but more severe. Could have more snow from storms. More severe storms	Less damages to the roads due to snow, ice and salt. The roads will require less maintenance and less salting. More water in the roads can create more flooding.	May get better overall but worse during a storm event.
		Delays and shutdown of roads	Flooding, sea level rise and precipitation	Frequency and intensity of extreme weather events expected to increase. Less days of rainfall but more rainfall concentrated into larger storm events. More rain all at once leads to larger flooding. Also produces more droughts	Shorter life expectancy of major roads and highways. More stress due to water leads to more damage. Coastal areas particularly. Lose evacuation routes. Could make roads shut down more and more delays in traffic due to worsened conditions	Likely worsens
		Damage to pavement	Extreme heat events and hotter days	Summers are predicted to be hotter and hotter than average days more severe heat waves.	More costly to repair. More maintenance required. Less times that construction can be done.	Likely worsens

Transportation	Public Transportation	Delays and shutdown of transportation	Flooding, sea level rise and precipitation	Frequency and intensity of extreme weather events expected to increase. Less days of rainfall but more rainfall concentrated into larger storm events. More rain all at once leads to larger flooding.	Flood can shut down railways and cause more delay or temporary times where these cannot be used at all.	Likely worsens
Human Health	Air quality/ pollution	Levels of ground level ozone, particle makeup of the air causing sickness and other bad health effects in people	warmer temperatures	Overall warmer temperatures. More frequent, more severe, longer heat waves in the summer.	Increases the frequency of days with unhealthy levels of air pollutants. More ground level ozone will be present in the air. More respiratory diseases, asthma and premature death.	Likely to worsen
Energy	Electricity	Power outages and damage to the power lines	Severe storms, extreme heat events, flooding	Sea levels are expected to rise. More severe storms, more severe flooding.	More severe storms would lead to more power outages and delays in repair. This would also cause the need for more repair which would make it cost more to maintain.	Likely to worsen
	Electricity (cont.)	Electricity demands to cool	Increases in temperatures, extreme heat events	Temperatures are rising. The number of extreme heat events will increase	Higher demand for electricity in order to cool areas with air conditioning. Projected demand would increase 5-20% if temps rise 1.8 degrees F. People would spend more money on cooling	Likely to worsen
	Electricity and Natural Gas	Demands for heating	Overall increases in temperature	Warmer winters are expected	Less demand for heating would require less energy use. This would decrease the most in the northern areas of the US. Demand for energy to heat would decrease 3-15%. People would spend less money on heating	Likely to worsen

Adaptive Capacity Table

Sector	*Planning Area*	*Projected impacts of climate changes minimal disruption or cost*	*Ability of the planning area to adapt with minimal disruption or cost*
Infrastructure	Storm water management	Flooding in the area, water quality issues could arise because of untreated wastewater and debris	Adapting by upgrading the system is very costly. Separating the waste and storm water would also be disruptive to buildings that are already builds and their businesses.
Transportation	Roads	More road maintenance required due to heat damages. Affects construction times.	Doing constant maintenance will increase the costs for the city and any reparations will cause disruptions to the economic development of the area
		Less salting required due to decrease in snow and ice. More water in the roads can result in flooding	
		Shorter life expectancy for the roads and highways. More maintenance required because of water damage. More shutdowns and traffic because of possible flooding. Flooding could affect evacuation routes.	
	Public Transportation	Increased number of extreme heat events. More flooding due to Sea level rise and severe storms	Removing flooding debris is costly. Maintenance is disruptive and costly. Adapting for the extreme heat events could be disruptive in some areas.
Human Health	Air quality/pollution	Increases the frequency of days with unhealthy levels of air pollutants. More ground level ozone will be present in the air. More respiratory diseases and asthma problems.	Unknown - Reducing the emissions is possible. Monitoring is a possibility.
Energy	Electricity	Sea levels are expected to rise, more severe flooding. There will be more extreme heat events. Warmer winters expected	Better protecting the electrical system can be costly for the city. There are some efforts by the city to improve the condition of the area. Maintenance and repair of electric lines are costly. Power outages are disruptive to the economy.

Vulnerabilities Table

Sector	*Planning Area*	*Is the area sensitive?*	*Ability of the planning area to adapt with minimal disruption or cost*	*Vulnerability*
Infrastructure	Storm water management	Yes - Flooding in the area, water quality issues could arise because of untreated wastewater and debris	Upgrading the system is very costly. Separating the waste and storm water would also be disruptive to buildings that are already builds and their businesses	We found the storm water management system to be potentially vulnerable to future flooding.
Transportation	Roads	Yes – The area is subjected to flooding. Severe storms and flooding represent a threat to public safety.	Protecting the area might be costly for the city. Doing constant maintenance will increase the costs for the city and any reparations will cause disruptions to the economic development of the area	We found the roads to be vulnerable to flooding due to severe storms and sea level rise.
	Public Transportation	Yes- public transportation railways are subjected to damage by extreme heat events and flooding.	Removing flooding debris is costly. Maintenance is disruptive and costly. Adapting for the extreme heat events could be disruptive in some areas.	We found the public transportation railways and routes to be vulnerable to flooding due to severe storms and sea level rise and vulnerable to damage by extreme heat.
Human Health	Air quality/pollution	We found that the area could be subjected to air pollution depending on the level of emissions	Unknown- reducing the emissions is possible but involves various factors.	We found the area to be slightly vulnerable to air pollution. While it is important to ensure that the pollution levels are not damaging, we found the area not to be a high concern.
Energy	Electricity	Yes- severe storms, flooding and extreme heat events affect the area's electrical system	Better protecting the electrical system can be costly for the city. There are some efforts by the city to improve the condition of the area. Maintenance and repair of electric lines are costly. Power outages are disruptive to the economy.	We found the area's electrical system to be vulnerable to flooding, extreme heat events and severe storms.

Information obtained from the EPA website about adapting to climate change (EPA, n.d.) and from the 2014 National Climate Assessment (Melillo et. al et al., 2014)

Appendix B: Interview Guide

Questions for the Board Members

All Boards

1. Would you mind if we record this conversation?
    i. If they mind – may we take notes?
2. Would you mind if we use your name in our project report (giving you credit)?
    i. If they mind – can we use the board's name instead?
3. Describe your board's main roles?
    i. What does your board do in relation to the Everett Ave. Renewal area?
    ii. What regulations do you already have in place that relate to:
        - Flooding
        - Storms/ Increasing severity
        - Extreme heat days
4. What are your board's biggest concerns about climate change:
    - Flooding
    - Storms/ Increasing severity
    - Extreme heat days

    i. What sources do you use when gathering information about climate change?
5. How many years into the future are you taking into consideration when you set regulations?
    a. How many feet of Sea Level Rise/ flooding are your buildings prepared for?
6. Have you seen any changes in the city of Chelsea due to climate change over the past few years?
    i. Have you experienced any flooding?
    ii. Have you seen any changes in extreme hot days?
    iii. Has the city experienced an increase in severity of storms?
    iv. Have you experienced any major storms?
        a. How did the town react to the storm?
7. How important is climate change in your decision making?
8. Have you seen developers in the Everett Ave. area addressing climate change issues in their plans preemptively?
    i. Focus on flooding and severe storms
9. What other members of the town do you work with?
    - For example: engineers, town officials, other organizations etc.

10. What would you like developers to know regarding flooding, increasing storm severity or extreme heat days before they propose your plans to you?
11. What form of deliverable would be the best format for you when receiving our proposed guidelines?

Planning Board

- Discussed in relation with the Zoning Board

Zoning Board

1. Are there any zoning regulations that limit adaptation to flooding/storms related damage?
    - For example: building height restrictions
2. Is there any regulation in place regarding building on sites that have been damaged/flooded in storms?
3. Is there any regulation in place that would require buildings to be retrofitted after being flooded or damaged by storms?

Conservation Commission

1. Have you done any specific work the Everett Ave. area?
    a. If yes - What part did you focus on the most?
    b. If yes - Could you describe any outcomes?
    c. If no – are you particularly concerned with that area?
        i. If yes – why?
2. How do you think flooding, more severe storms and more extreme heat days will affect the environment in Chelsea?
    a. What are you concerned the most with?
3. Do you work with the Planning and Zoning Board?
    a. If yes - In what ways?

Questions for the Developers

All of the developers

1. Would you mind if we record this conversation?
    a. If they mind – may we take notes?
2. Would you mind if we use your name in our project report (giving you credit)?
    a. If they mind – can we use the developer's name instead?
3. How important is climate change in your decision making?
4. What sources do you use when gathering information about climate change?
    a. What sources do you use when gathering information about climate change?
        - What format do you prefer?
5. Have you done anything to prepare your buildings for:
    a. Flooding
    b. Severe storms
    c. Extreme heat days
6. How many years into the future do you prepare your buildings for? Ex: 20 years, 50 years, etc.
    a. How many feet of Sea Level Rise/ flooding are your buildings prepared for?
7. How long do you plan your buildings to last before you redevelop them?
8. Do you find it is beneficial to prepare your buildings for future flooding?
    a. Why do you think so?
    b. Mention insurance – price relation
9. When you are planning your development, do you experience any specific limitations do you experience that are:
    a. Location specific (Chelsea)
    b. Related to:
        - Flooding
        - Increased storm severity
        - Extreme heat days
10. Would having regulations from the city's boards regarding flooding, storms and extreme heat days be beneficial for you in your planning?
    a. Why?
11. What risks deter you from selecting a development site?
    a. Has this happened in Chelsea?

ii. If so - Why?

12. What do you think the city of Chelsea can do to aid developers that want to help in urban redevelopment?

Apartment Complex Developer:

1. Does being in the FEMA flood hazard zone increase the price tenants have to pay to live in the apartments?
    a. Would raising the foundation to lower the insurance cost lessen the rent?
        i. Have you or any other developer you know done this?
        ii. Has this affected your business?
        iii. What about any other flood proofing options?
    b. Do you think the flood zones deter people from wanting to live in this complex?
        i. Have adaptation options made this more desirables?

Board of Health:

1. In what ways do you work with the planning and zoning board?
2. In what ways have you seen severe storms affect your area of work?
3. What health concerns do you see associated with flooding?
    a. How does this affect your word?
4. How does extreme heat days affect people's health?
    a. How does this relate to the Board of Health?

DPW:

1. Are any of your evacuation routs using roads that may be flooded in the event of a 100ry/500yr storm?
2. Have you notice any difference in the amount of snow/severity of bad weather over recent years?
3. Do you work with the Planning board, zoning board and conservations commissions?
    a. In what ways?
4. What restrictions do you have on place that determine where utilities can be placed?
    a. Which utilities?
        - Water, heat, electricity, etc?
    b. Do you consider flooding/ severe storms for this?

- Considerations like: having electric utilities in a basement that is prone to flooding

c. Give an example of petitions you grant

Metropolitan Planning Area Council:

1. Can you briefly describe the work you are doing with regard to Chelsea's hazard mitigation program?
2. What mitigations plans are in place for Chelsea that address flooding/ damage from storms/extreme heat?
3. Any mitigation planning specific to the Everett avenue area?
    a. Specific to addressing buildings developments

Chelsea Emergency Management:

1. Please briefly describe your main job within the city?
2. Do you work with the zoning board, planning board or conservation commission?
3. How do you think flooding or severe storms affect your current emergency plans?
    a. Are you currently taking into consideration the future projections for these three factors?
4. How have the FEMA flood maps affected your emergency management planning?
    a. Have you done anything to address these recent changes?
    b. Has it affected the Everett Ave. specifically?

Meeting with Harvard Design Graduate Student

1. Would you mind if we record this conversation? (have her sign form)

iii. If they mind – may we take notes?

12. Would you mind if we use your name in our project report (giving you credit)?
    i. If they mind – can we use the board's name instead?
13. Make sure to start by describing the project: state the goal, and a little update on what we have been doing so far.
14. What is your major, experience, etc.?
15. What did you work on the class you took that was related to Chelsea?
    i. Redevelopment?
    ii. Adaption?
    iii. Mitigation?

16. What major steps did you take when creating your report?
    i. What was the final outcome?
    ii. Can we use your report as a reference?
17. Are there any specific materials that you would recommend to us, that you found helpful?
18. What considerations would you take to prepare properties in Chelsea against flooding, severe storm impacts or extreme heat days?
19. Would you have any recommendations of any methods to mitigation / adaption be for a community who struggles financially? (only depending on if her project covered these topics)
20. What characteristics did you consider when identifying vulnerability?
    i. Did you use any scale to measure vulnerabilities? If so, what did you use?

Interview Consent Form

Consent form

Identifying Vulnerabilities and Providing Guidelines for the City of Chelsea, MA in order to Adapt to Climate Change

The goal of this project is to identify the vulnerabilities of the Everett Avenue area of Chelsea, Massachusetts due to climate change, and provide a guideline of practices best suited to address climate change in developing areas for the city's Zoning Board, Planning Board and Conservation Commission. We will also provide mitigation and adaptation options for Chelsea, that city officials can choose to adopt. The area we will be focusing on is the urban renewal section of Everett Avenue.

Participants Consent:

I am aware that my participation in this interview is voluntary. I am aware and understand the purpose of this research and project. If at any time, for any reason during the interview I wish to stop I may do so without having to give an explanation.

I understand that this research is part of an Interactive Qualifying Project at Worcester Polytechnic Institute and is sponsored by the Massachusetts Institute of Technology Sea Grant College Program. I am aware that the project will be publicly available. I understand that this interview will be recorded, unless I specify otherwise. I consent to my name or my organizations name being used in this report as a source, unless I specify otherwise.

Participant's Signature/Date

_____

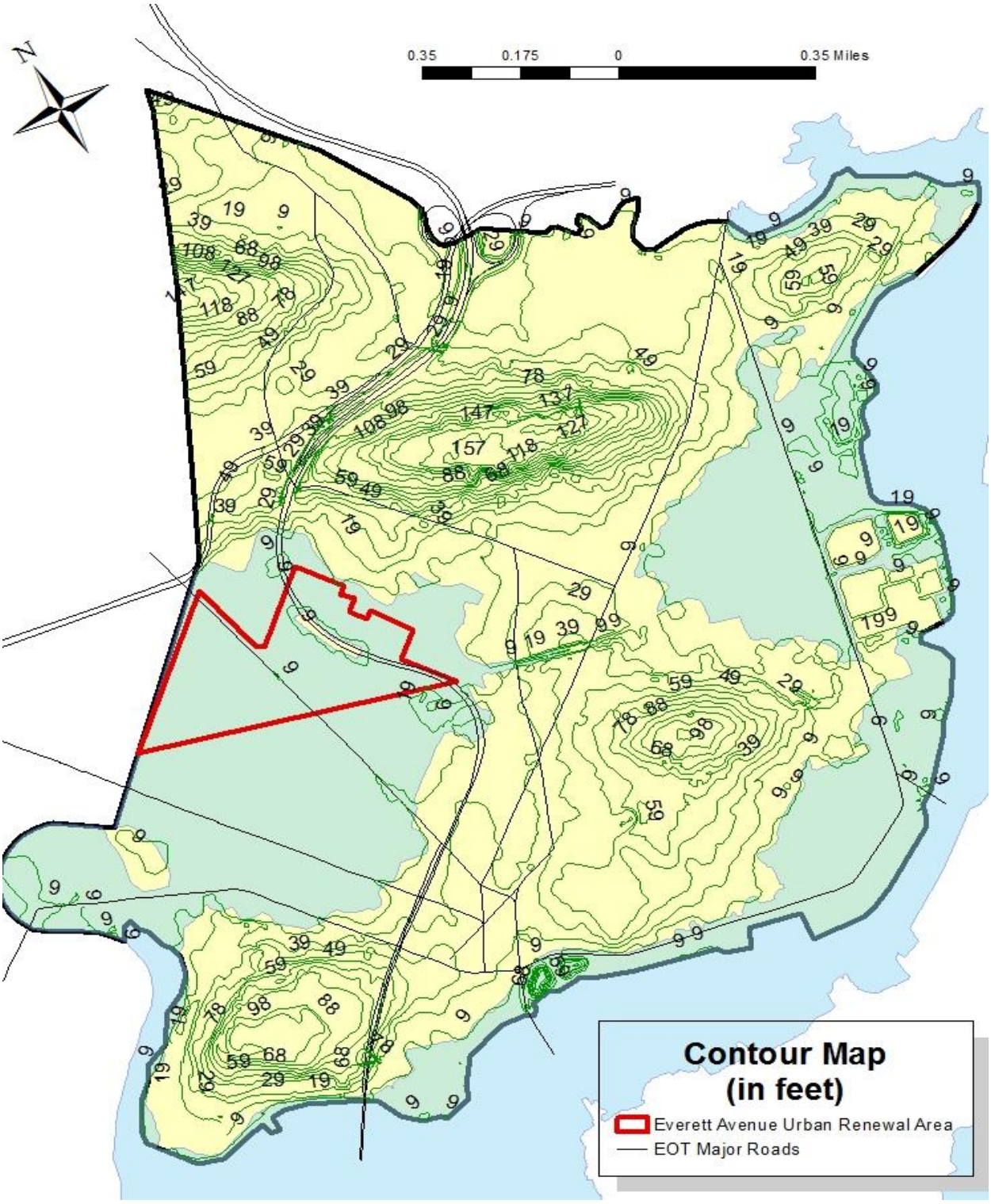
Interviewer's Signature/Date

_____

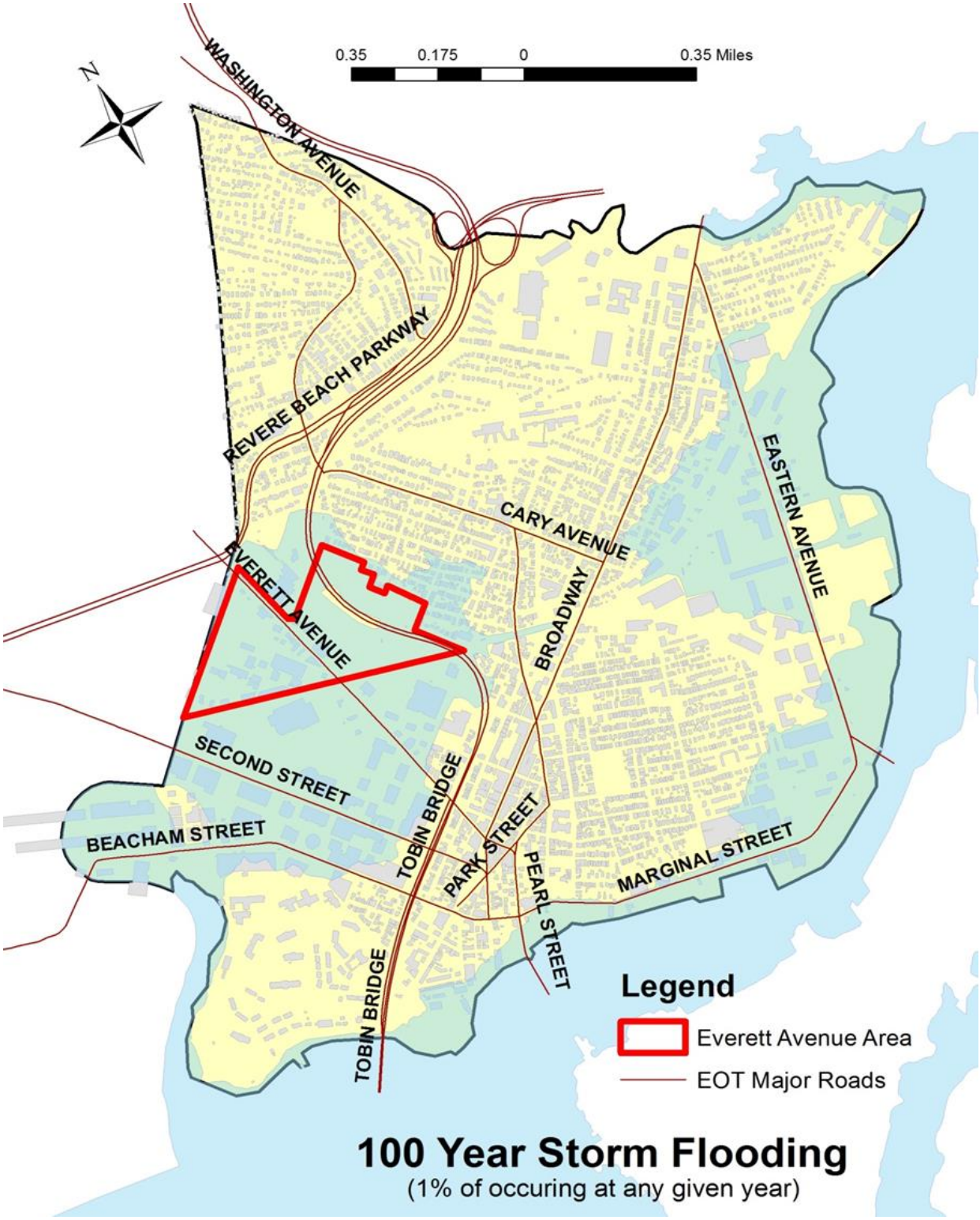
Appendix C: Maps

All data layers were obtained from Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, MassIT and the City of Chelsea, Massachusetts.

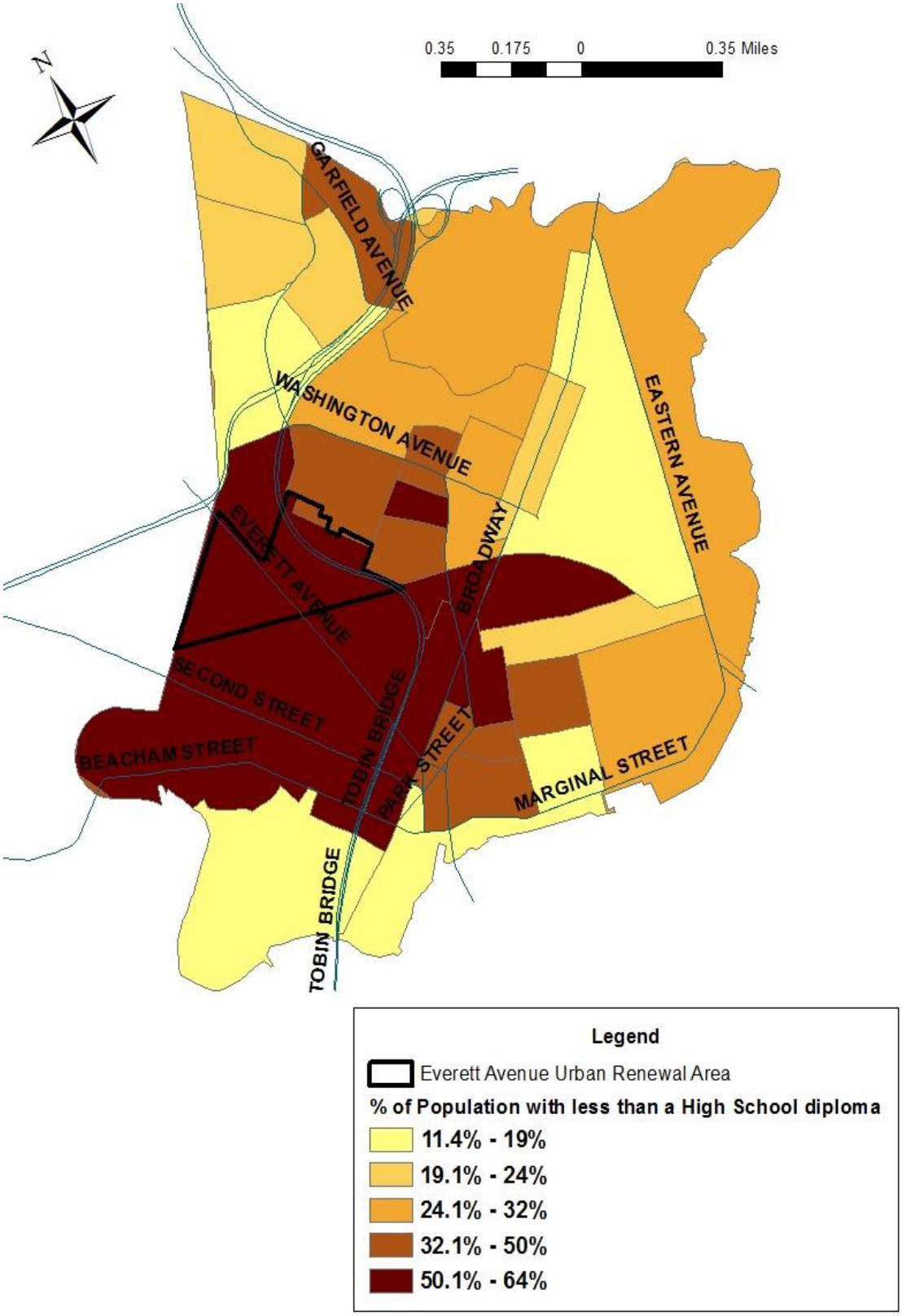
Contour Map:



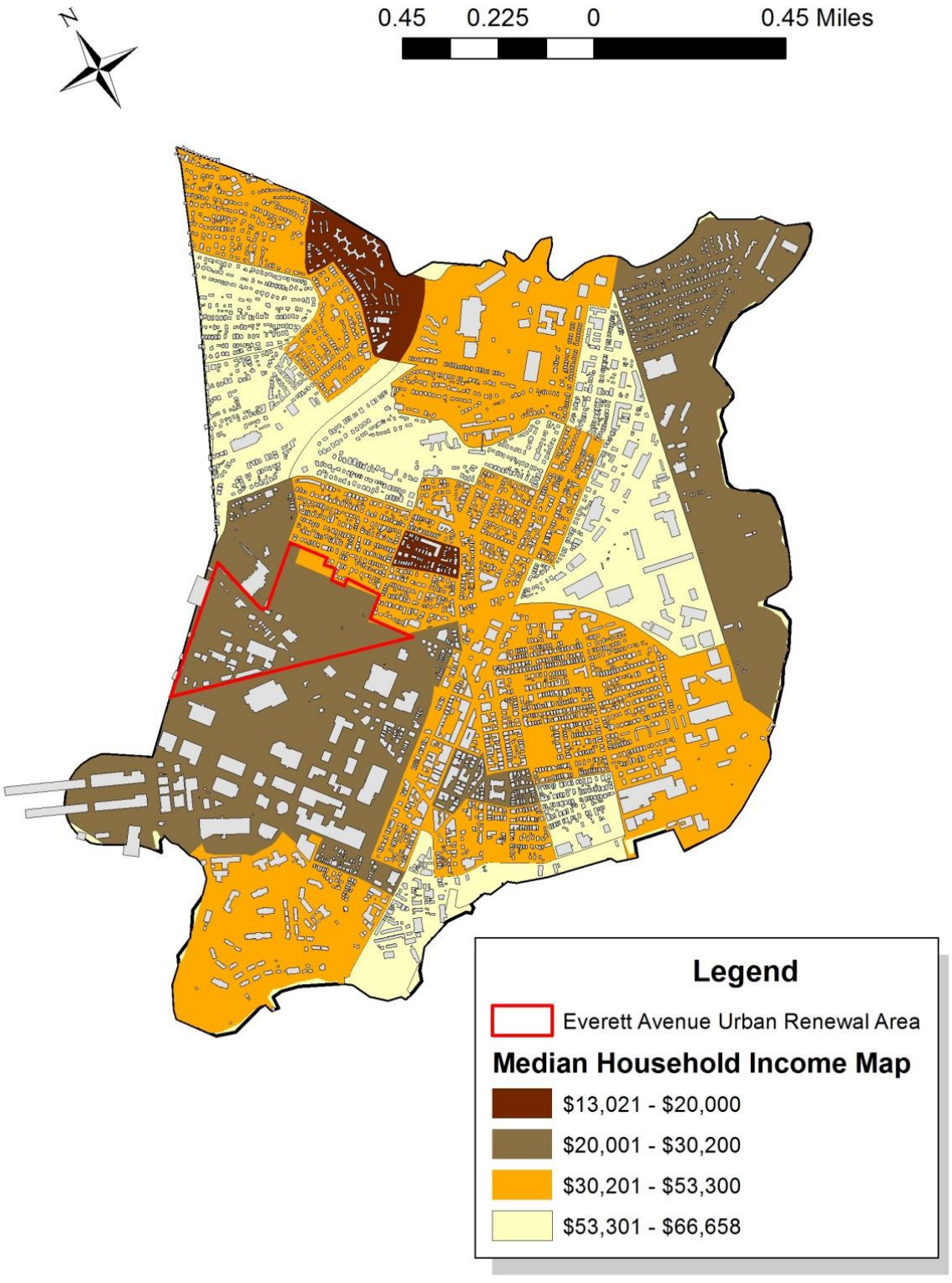
100 Year Flood Map with Major Roads



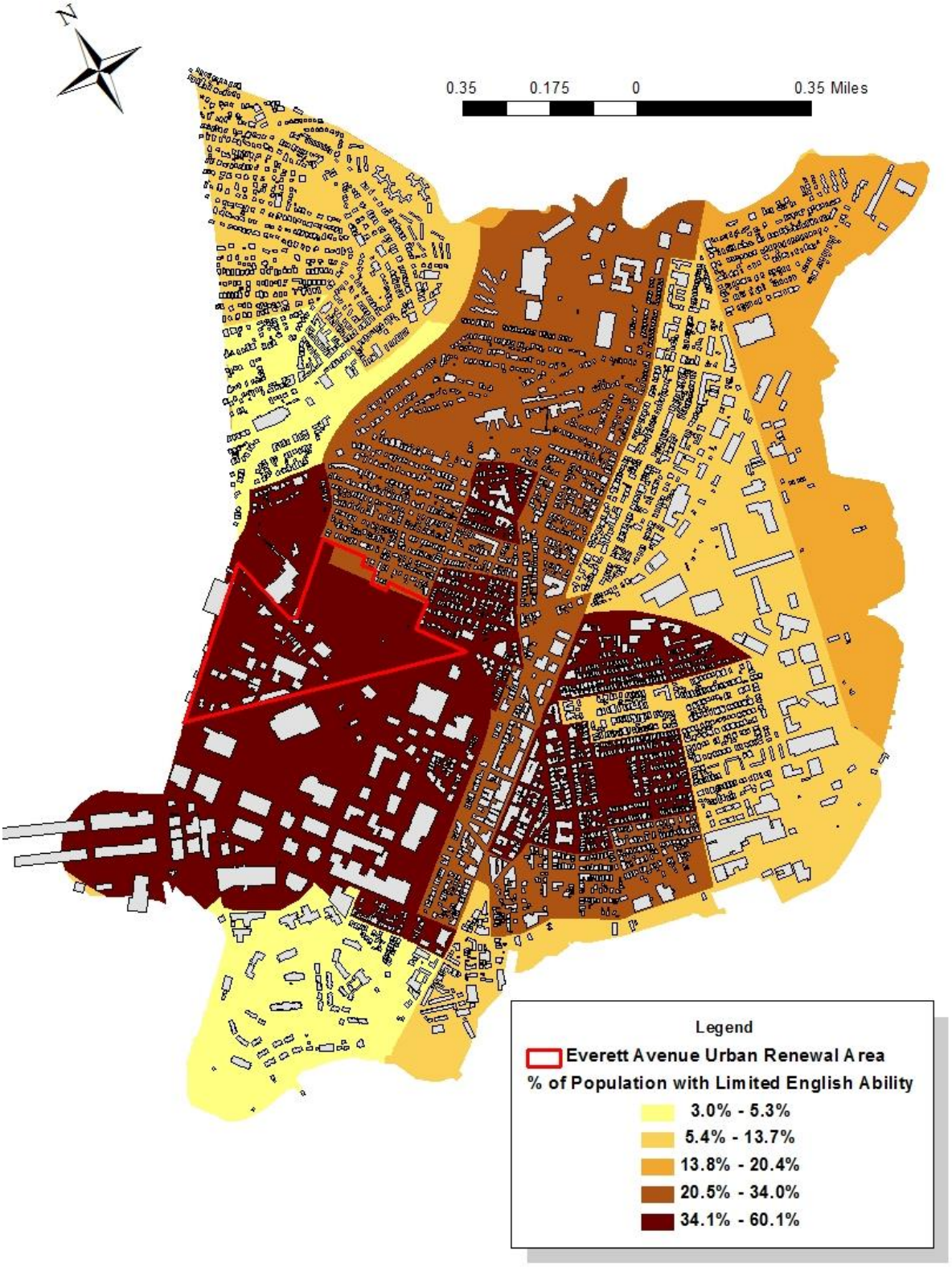
Education Map



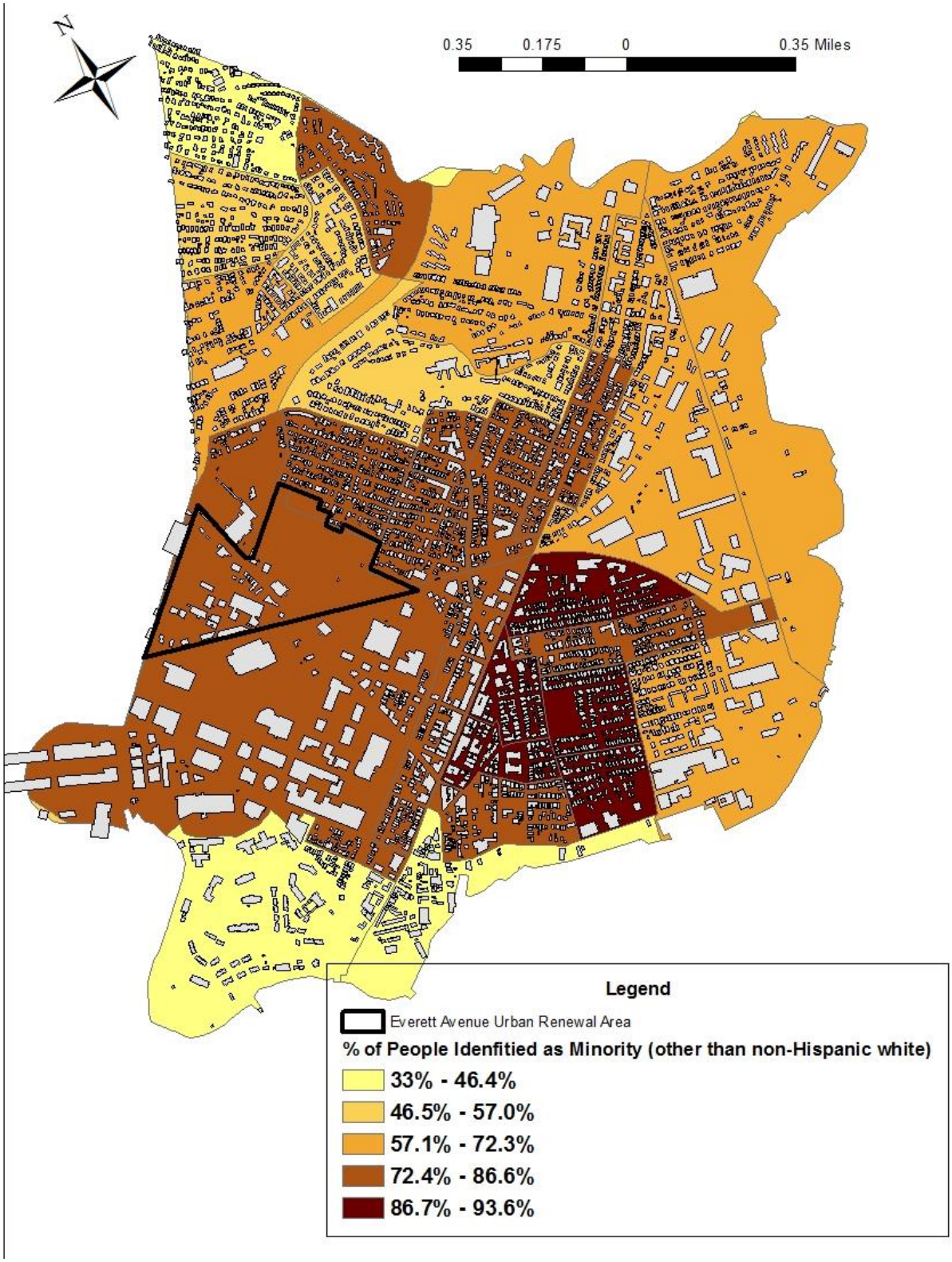
Income Level Map



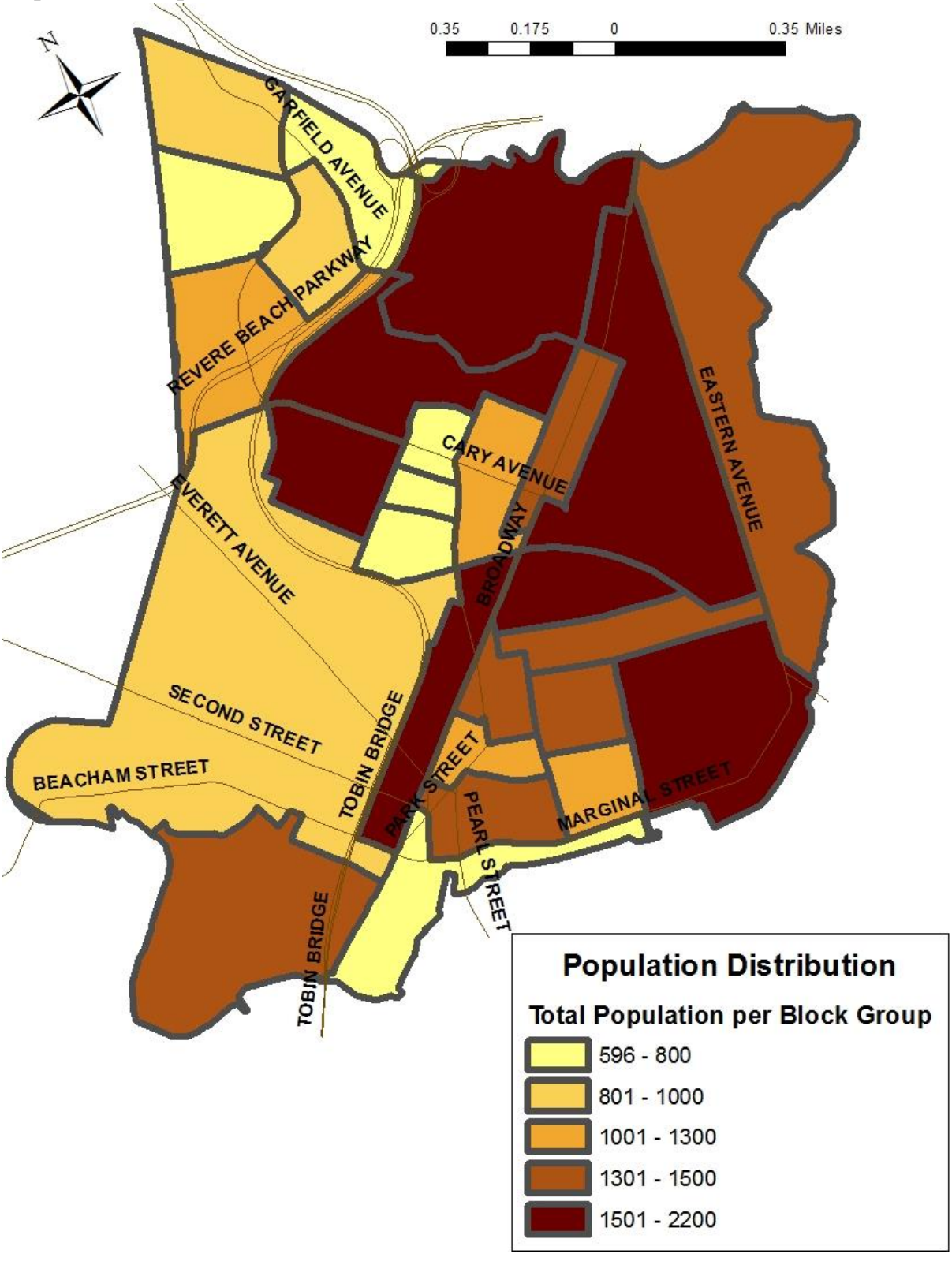
Limited English Ability Map



Minority Map



Population Map



Appendix D: Interview Tables

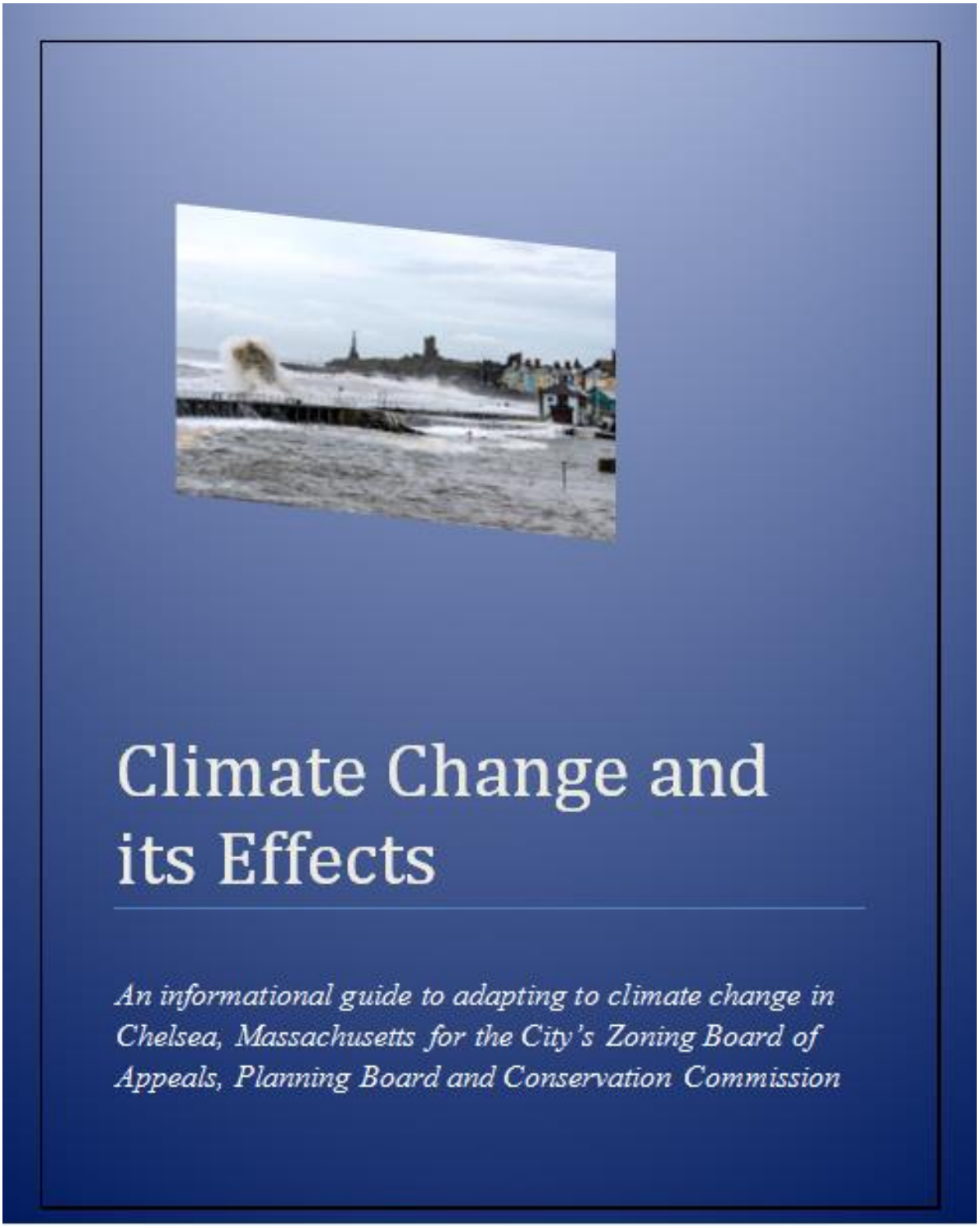
Interviewee	Developer 1	Developer 2	Developer 3	Planning and Development (planning board, zoning board and conservation commission)	Board of Health	Planning Board	Department of Public Works
Role in Job	A real estate development company and our activities, mostly include retail and office.	A small real estate company. Tend to hold onto their properties longer than most developers.	Hotel developer	Conservation Commission, Planning Board and Zoning Board	In charge of sanitation and health in the city, that have to do with housing codes, restaurant codes, food safety concerns, hazardous waste, solid waste, air quality, noise, odors.	The board addresses applications for the city for permit and usually new construction and renovations and additions and changes in building conditions within the city and for specific projects. And they are in charge basically with proposals with respect to their change in the neighborhood.	Maintenance of public infrastructure including roadways, sidewalks, sanitary and storm sewer collection system, water distribution system, street trees and planted areas, municipally owned street lights and traffic signal controls. Proposing, planning and oversight of construction of improvements of the public infrastructure in the nine areas stated above is also a main role of the DPW.
Belief of Climate Change	no sure, doesn't think that there is enough proof	climate change has not been looked at until recently	Have not taken climate change into account in a development yet	It is definitely in their minds now	Have a good understanding of climate change and the issues regarding climate change effects.	virtually no attention has been paid to these issues	not utilized as a relevant factor
Adaptations That Have Been Implemented When Building	raised the building to save on removing soil and insurance	Moved transformer above the 100 yr. flood stage. They have installed rain gardens into one of their properties. Adjusted their site to push run off to Spruce St.	They only put in adaptions that are required by the city. They have a put white roofs on all their buildings.	Some developers have been making changes but most are not concerned about it. The warmer winters and heat days have caused concerns for rodents.	N/A	no attention has been given to climate change	Evacuation routes for flooding. When we are in storm mode, most other work ceases and it's an all-hands-on-deck in reacting to whatever needs are warranted whether it is snow and ice control, tree work, or repair to buildings damaged by

							high winds, blocking off flooded streets from motor vehicular traffic.
Concerns Regarding Flooding, Storms, and Heat Events.	none	Have been prepared for flooding and storms but have not seen a need to take heat into account yet.	Not very concerned as of now.	Had no concerns until the new flood maps came along, the boards need education	Haven't seen cause for concern that the board of health would deal with	none	• Flooding-capacity of the system to handle flow and impassibility of roads for emergency response • Storms-capacity of systems to handle flows • Extreme heat day-accelerated deteriorati on of pavements
Concerns Regarding Costs Related to Climate Change	insurance, added costs of adaptations she believes unnecessary, developers build to minimum standard	Find it beneficial to plan for the future in terms of resale. It's an additional cost but it makes sense	The cost of adapting is too high. It is better to just pay the insurance.	The adaptations we provide need to be something that isn't too expensive to be done. Don't want to push additional costs for the developers	N/A	N/A	received many grants
Amount of Time Buildings are Planned for	expected to last at least 50-60 years	expect to own buildings for 5-10 years	10-15 years two or three renovation cycles	planning and zoning boards plan for 10yr flood and conservation commission plan for 100yr flood	N/A	N/A	N/A
Would Recommendations from the Boards be Helpful for Developers?	Requirements should be a state wide thing, otherwise no one will want to build in Chelsea	N/A	Recommendations would be better and easier than requirements.	Recommendations are better than requirements	N/A	you would have to get everyone interested in the topic for it to be effective	N/A

How Can the City Help Developers	have the city provide incentive for these adaptations or discounts	The city was very helpful with bringing in new infrastructure when they were building on a site of an old building and all of the pipes needed to be changed	Cut down on parking requirement to be able to add more green space	The city has been working very hard to work in combination developers to help them	N/A	N/A	N/A
Would an Informational Tool on Climate Change be Helpful?	She would not even look at it	His civil gives him all his information and he works with the city	A map or a written study	Needs to be something that is quick and easy to look at for board members to look at quickly	Visuals are very effective. They use a lot of internet sources	board members usually don't pay attention to information like what you are proposing	N/A
Recommendations for our team	look into LEED certification, or a plan for sites to trade soil	good luck	a suggestion of putting a transformer on a raised platform is pretty easy for developers	a pamphlet or something similar would work best	All of the city boards need to come together when making decisions on certain issues. The board of health is often left out	A presentation of some sort would work best. You are going to need to get people hooked into whatever you present in order for them to care	N/A

Appendix E: The Deliverables

Climate Change and its Effects: An Informational Guide for Adapting to Climate Change in Chelsea, MA. for the City's Zoning Board, Planning Board, and Conservation Commission



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This document was designed and produced by Jillian Hennessy, Lauren Richard, Santiago Rojas, and Keith Guay as part of an Interactive Qualifying Project at Worcester Polytechnic Institute with the help of the Massachusetts Institute of Technology Sea Grant College Program and the City of Chelsea, Massachusetts.

THE BASICS

Climate change causes warming temperatures, rising sea levels, increasing number of extreme heat events, increasing number of severe storms, and increasing number of heavy precipitation events. Locally, along with climate change, land subsidence is going to increase the impacts of sea level rise.

WHY SHOULD WE CARE?

- Increased number of severe storms and flooding will damage infrastructure and property
- Severe storms, especially flooding, are directly related to injury and loss of life in a community (See population density of Chelsea)
- Even with no change in frequency or intensity of storms, a sea level rise of 2 ft. would more than triple the frequency of dangerous coastal flooding throughout most of the Northeast
- Increased precipitation from storms may overwhelm combined sewer systems, releasing untreated water into local bodies of water
- Increased precipitation may generate more runoff, causing more water to be sent to the Deer Island treatment facility for treatment and costing the city of Chelsea more money
- Increased heat days (over 90 °F) and poor air quality can pose health risks to the young, elderly and those with preexisting health conditions
- New areas, such as the Everett Ave. area, have been included by FEMA in the 100yr flood zone. With climate change, the likelihood of this event may increase and the flood depths may be higher (See 100yr flood maps)

There is much you can do to protect the City of Chelsea from the impacts of climate change. These guidelines provide adaptation and mitigation strategies in order to reduce risks associated with climate change impacts.

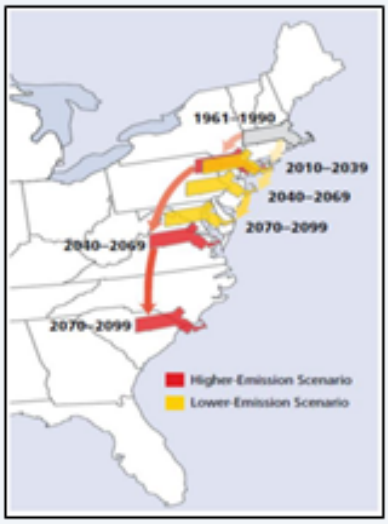
THE FACTS

CURRENT CLIMATE OBSERVATIONS IN MASSACHUSETTS

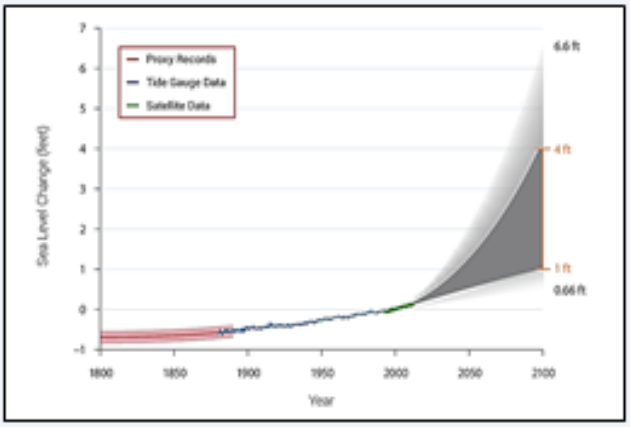
- Since 1958, precipitation, such as rain and snow, increased 70%; with heavier downfall in fewer events
- Between 1895 and 2011, New England has experienced an average temperature increase of almost 2°F
- Since 1900, the sea level in New England has risen 1 ft.
- Since 1991, Chelsea has experienced 17 natural hazards, primarily flooding, that involved state or federal disaster declarations

PREDICTIONS ABOUT THE FUTURE CLIMATE

- By 2080 average temperatures are expected to increase between 3 and 10 °F depending on emissions scenarios
- Global sea levels are expected to rise between one and four feet by 2100, and the Northeast is expected to exceed the global average due to land subsidence



Massachusetts could potentially have temperatures similar to the Carolinas by 2099 if steps are not taken to reduce emissions (Reprinted from UCS and NECIA)



Sea levels are currently predicted to rise between one and four feet by the year 2100 (Melillo, 2014)

SOME SOCIAL GROUPS EXPERIENCE MORE DIFFICULTIES THAN OTHERS

It is important to consider the diversity of people living within the community of Chelsea to understand where additional aid may be needed when addressing climate change impacts. The following tables explain how some groups of people are more vulnerable to the impacts of climate change than others.

Socioeconomic Characteristic	How it can affect vulnerability of an area	Map/ Info
Level of Income	Wealth usually allows communities to adapt more easily. Low income areas usually have more difficulty recovering from impacts, which increases their level of vulnerability to future climate change impacts.	Map
Language Barrier	Language barriers may affect the residents' understanding of warning information or evacuation protocols.	Map
Ethnicity	Cultural barriers may affect access to recovery funding.	Map
Education	Education is generally connected to socioeconomic status and earnings. Lower education levels may affect the residents' understanding of warning information, access to recovery resources, or climate change issues in general.	Map
Age	Children may have a more difficult time following evacuation protocols or making informed decisions during a disastrous event; therefore, they may be more susceptible to harm.	More Info
	Elderly people may have a more difficult time evacuating, and they may be more susceptible to harm during an event. Elderly people may be more affected by heat and therefore more vulnerable to heat related illness than younger people. An increasing number of elderly people in the world will be exposed to even more extreme heat conditions, potentially causing more heat related illness and possibly death.	
Gender	Women may have lower wages than men and may take on more family care responsibilities which may make them more vulnerable.	More Info
Disabilities	People with disabilities may have a more difficult time evacuating in the event of a storm. Disabled persons may depend on other people for mobility assistance.	More Info

Note: Certain developments (schools, hospitals, etc.) may lead to increased vulnerability of an area by increasing the population of vulnerable social groups. It is important to consider whether a development will increase the socioeconomic vulnerability when looking into adaptation.

WHAT CAN BE DONE TO LIMIT THE IMPACTS OF CLIMATE CHANGE?

This section provides possible adaptation and mitigation options that developers can implement to address the potential impacts of flooding, damage from storms, and extreme heat.

IS THIS AREA IN THE FLOOD HAZARD ZONE?		
Adaptation Strategy	**Benefits**	**More Info**
Elevate the building above flood levels	• Lowers insurance cost • Avoids damages caused by flooding • Decreases the hazard for the residents/users of the building	Building Green
Elevate electrical and mechanical equipment	• Avoids power outages • Prevents damage to expensive equipment which reduces cost of repair/replacement • Reduces hazards to the population	Building Green
Add flood proofing components to building	• Reduces damages caused by flooding • Decreases the repair costs after a flooding event	Building Green
Use wall materials that are resistant to flooding	• Avoids costs of repairing the structure after a flooding event	Building Green
Reduce impervious surfaces outside of your building	• Aids in reducing stormwater runoff • Reduces the urban heat island effect • Provides aesthetic value	Low Impact Development
Install a rain garden	• Reduces flood water • Reduces maintenance (fertilizers, mowing, etc.) required compared to having lawns • Provides aesthetic appeal • Reduces urban heat island effect with vegetation and possible replacement of pavement	Low Impact Development
Install below grade storage for stormwater runoff	• Reduces flood water • Lessens the amount of water entering combined sewers (limits overflow)	Low Impact Development
Have backup generators	• Prepares buildings for power outages • Allows buildings to maintain functionality in extreme events • Lessens the need for evacuation in situations • Aids in public safety	Building Green

WHAT CAN BE DONE TO LIMIT THE IMPACTS OF CLIMATE CHANGE?

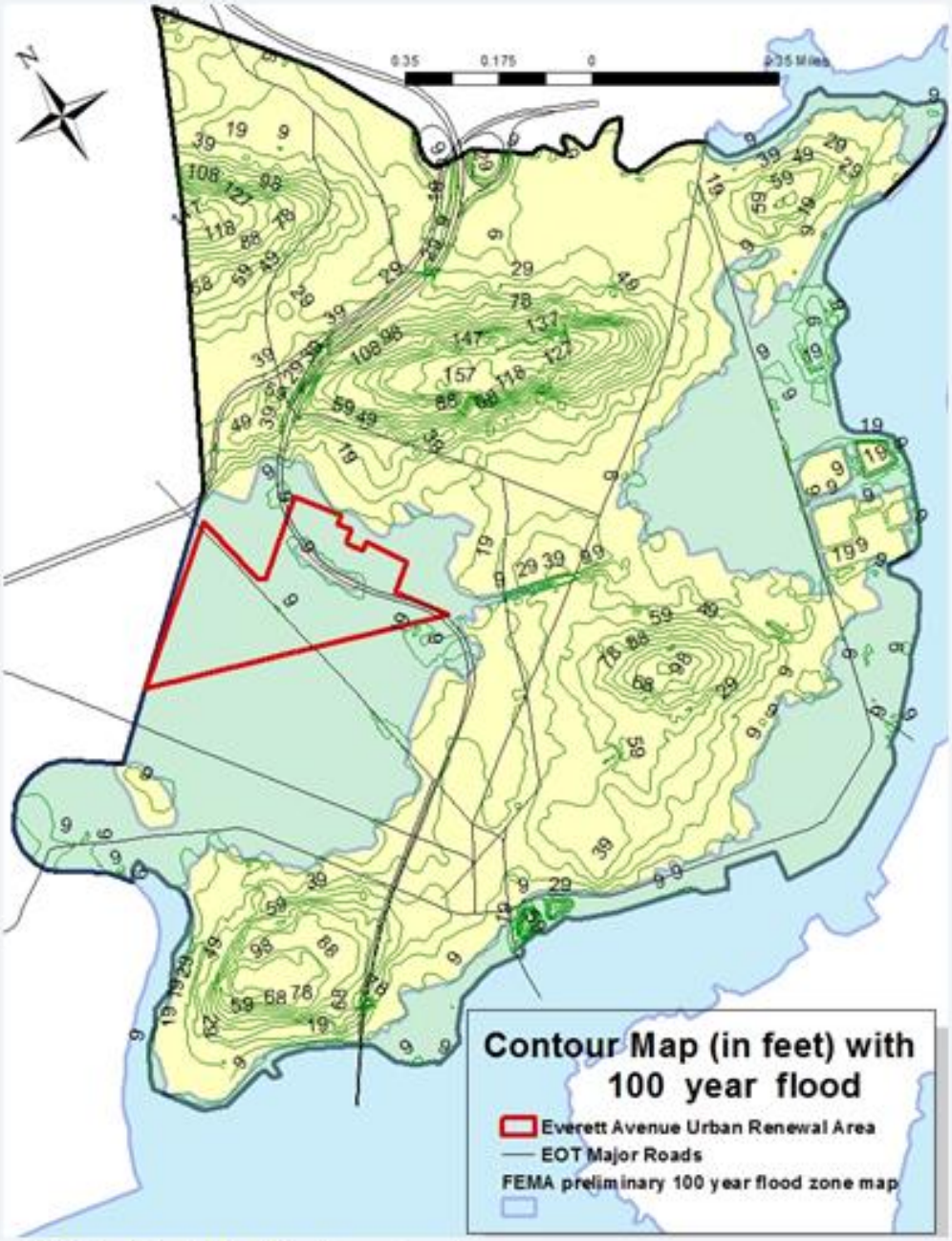
This section provides possible adaptation and mitigation options that developers can implement to address the potential impacts of flooding, damage from storms, and extreme heat.

HOW CAN YOU REDUCE THE URBAN HEAT ISLAND EFFECT?		
Adaptation Strategy	**Benefits**	**More Info**
Use reflective roofing or "cool roofs"	• Reduces heat of a building decreasing need for air conditioning • Reduces greenhouse gas emissions due to lower energy use • Helps prevent heat related illness and death	EPA Cool Roofs Cool Science
Install a green roof	• Lasts for a long period of time, if installed and maintained correctly • Reduces greenhouse gas emissions, energy use • Addresses stormwater management as well • Adds aesthetic value	EPA Green Roofs
Use "cool pavements" instead of regular pavement surfaces	• Reduces emissions and energy use by reducing urban heat island effect • Cools the air and improves people's health • Aids in stormwater management as well if pervious surfaces • Reduces cost spent on cooling energy	Cool Science
Plant trees and vegetation	• Reduces energy use by shading buildings • Improves air quality and lowers greenhouse gas emissions • Adds aesthetic value	EPA Trees/ Vegetation
Use efficient electrical and mechanical equipment	• Creates less waste heat which can reduce the urban heat island effect • Reduces emissions • Reduces energy needed to cool buildings • Reduces energy costs	N/A

MAPS

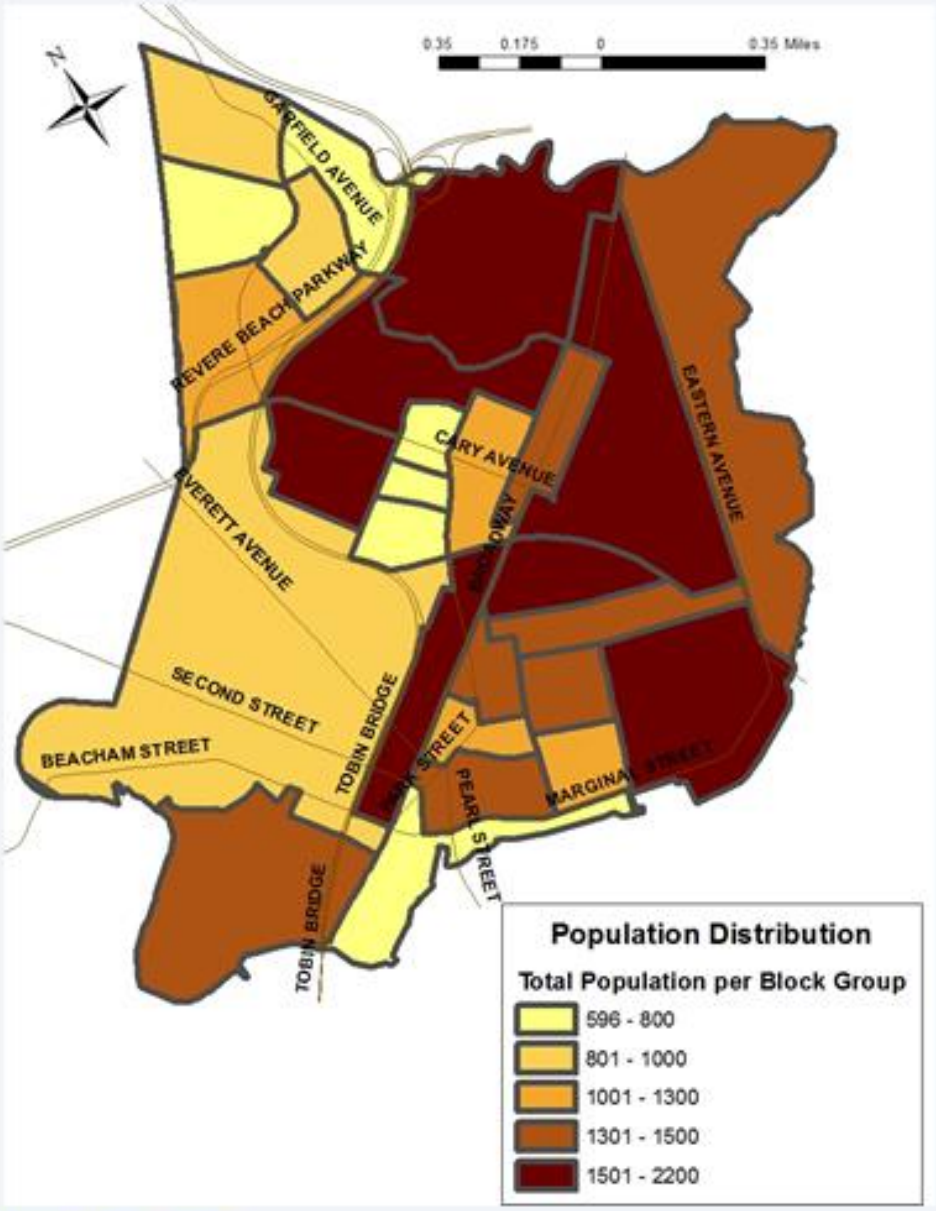
100 Year Flood Map 1 (with major roads)

MAPS



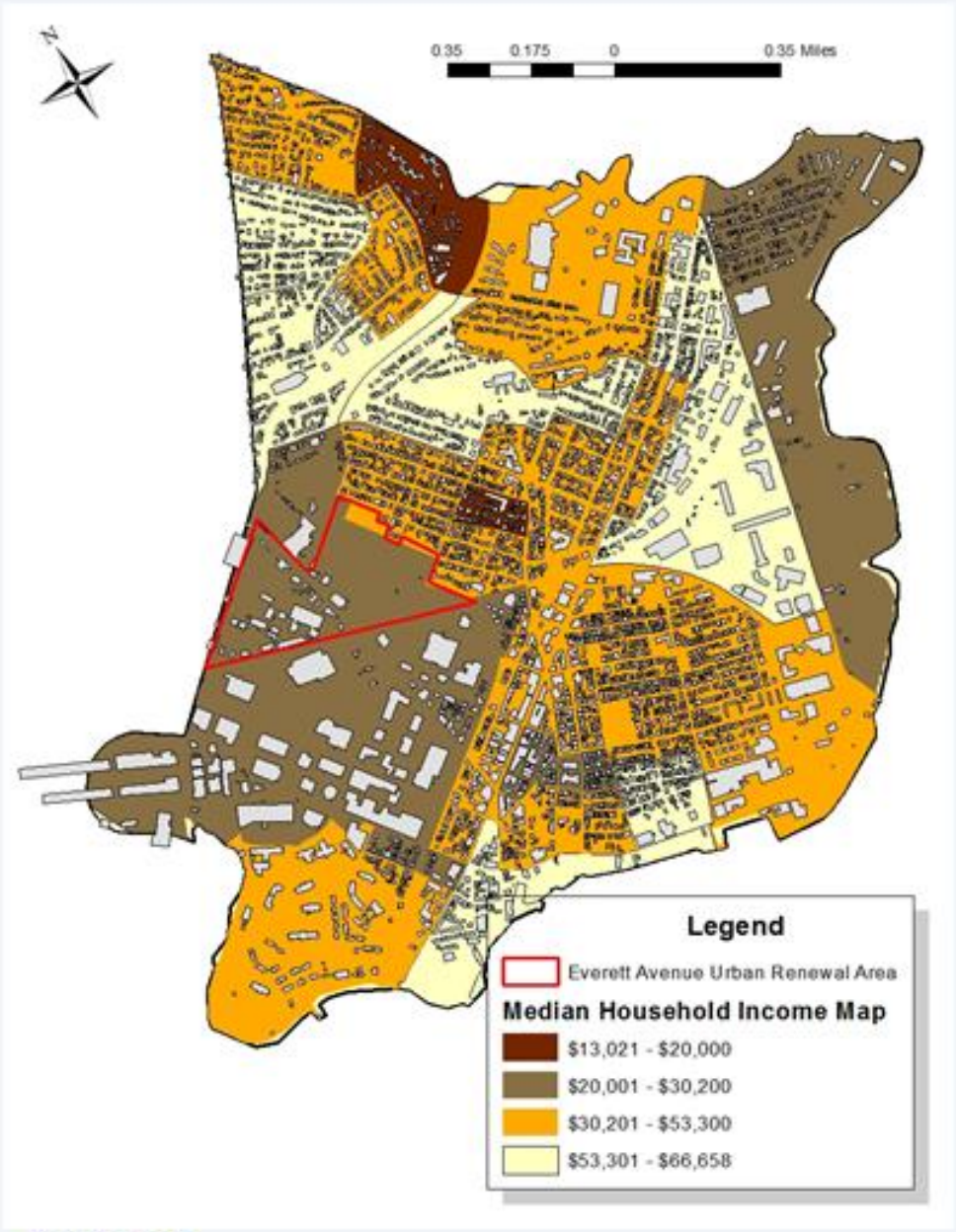
100 Year Flood Map 2 (with contours)

MAPS



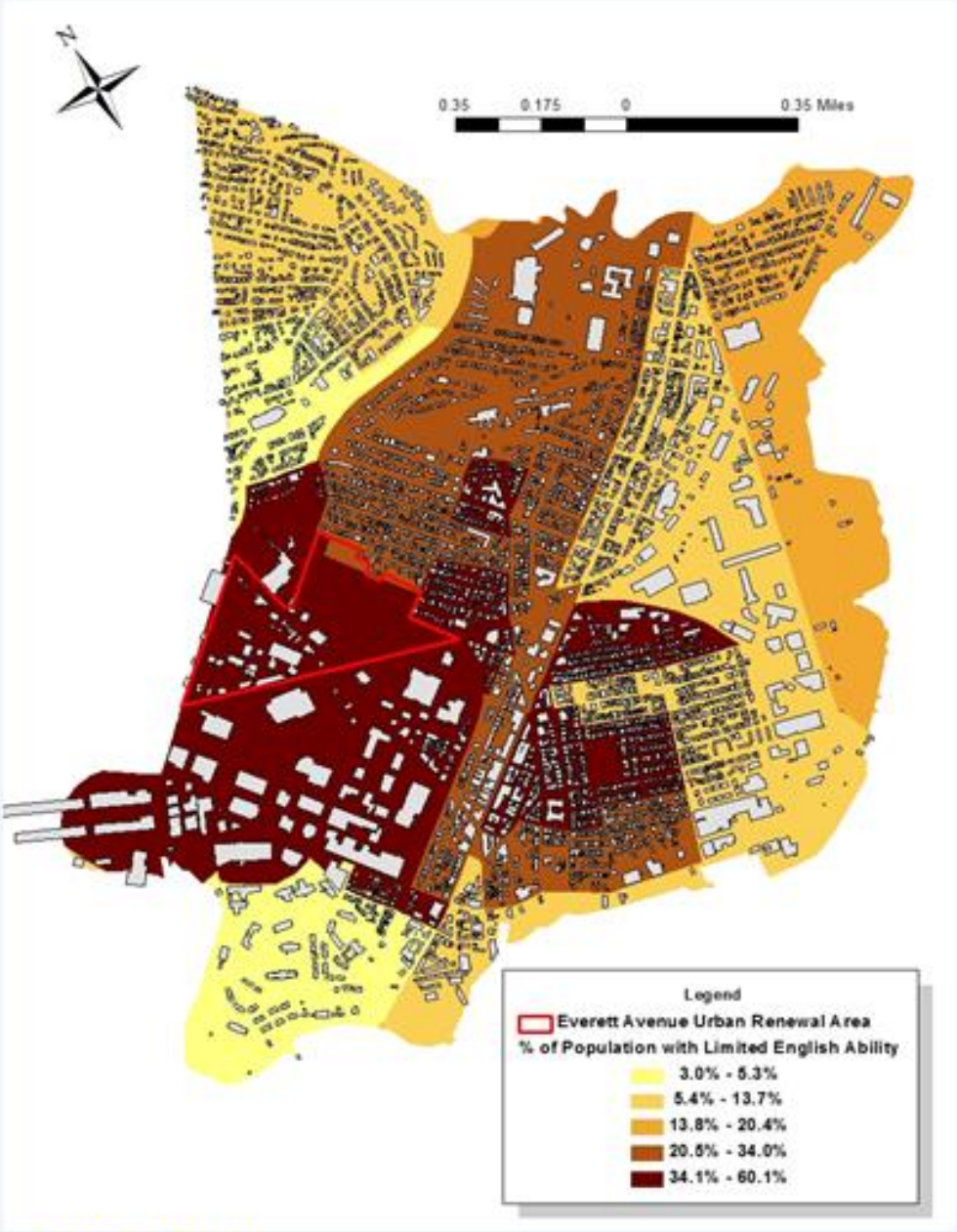
Population Density

MAPS



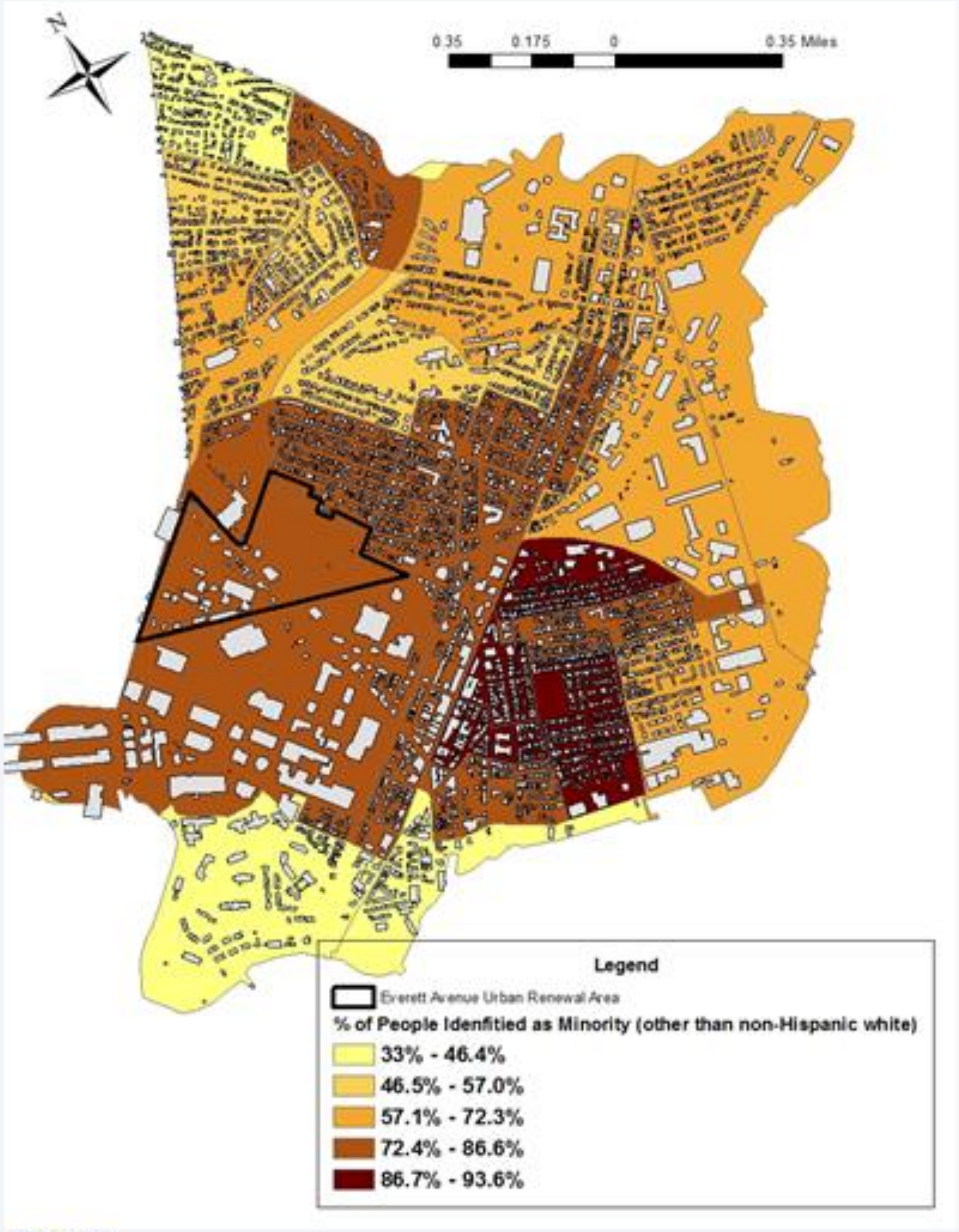
Income Levels

MAPS



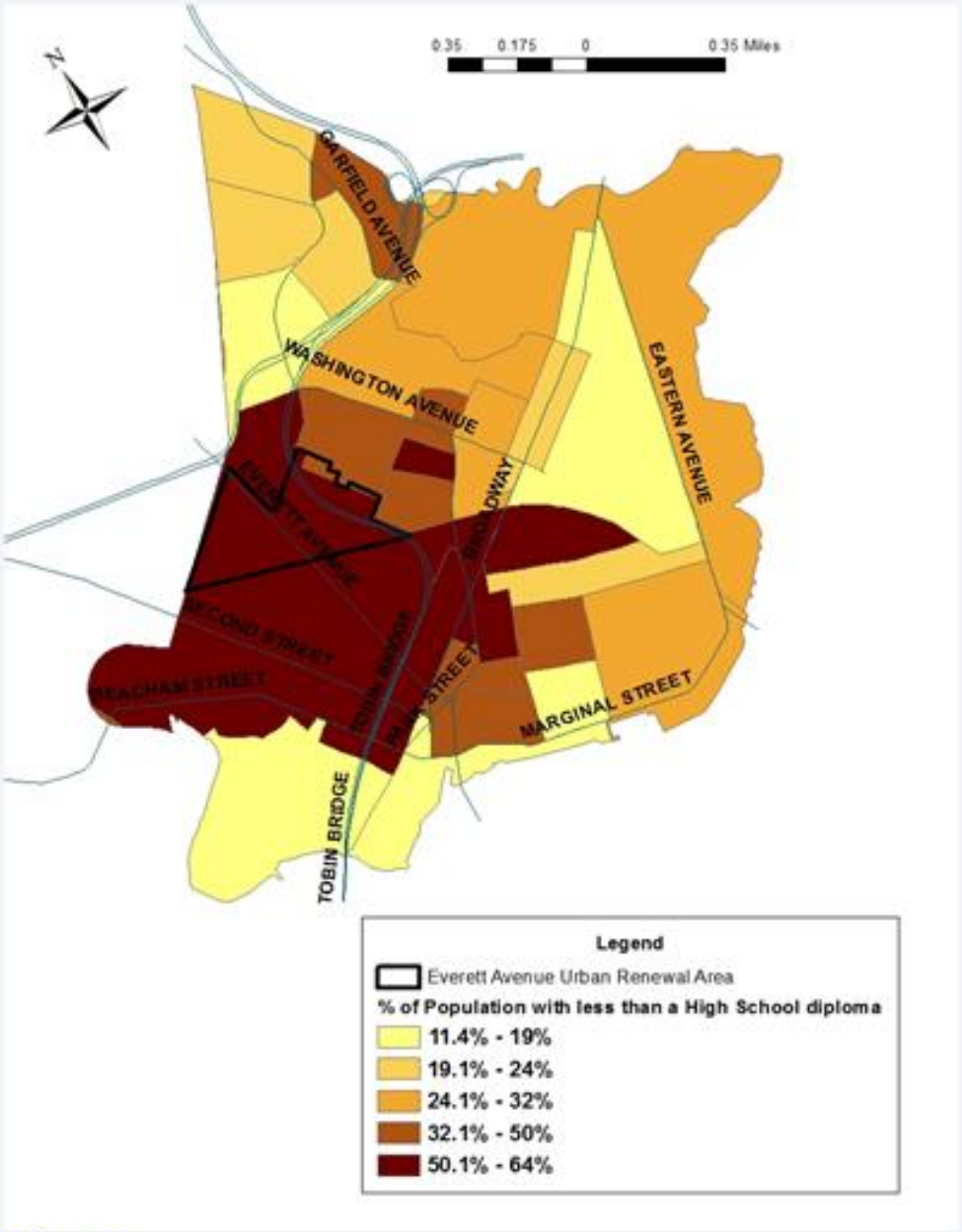
Language Barriers

MAPS



Ethnicity

MAPS



Education

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Potential Concerns of Developers Supplemental Document

POTENTIAL CONCERNS

When recommending adaptation or mitigation options, developers may be reluctant to implement them. The list below addresses potential reasons why they would make the decision not to implement a strategy.

Adaptation Strategy	Concerns from Developers
Elevate the building above flood levels	• Pipe materials can no longer be PVC if the building is over 60ft tall (This can be a costly change) • Insurance premium is less expensive than adding handicapped accessibility • Insurance premium is less expensive than elevating the building • Developers have skepticism of the new FEMA flood maps and the need to adapt
Install a rain garden	• Some companies do not want to give up the parking spaces • Rain gardens can be complicated to keep alive • Development may lack space for a rain garden, trade-offs between parking space and stormwater management
Raise electrical and mechanical equipment	• Building/Structure is visually unappealing because of this • Change can have added cost
Reduce impervious surfaces (Use "cool roofs" or "cool pavements")	• Initial cost of materials can be high • Roofs can have some added maintenance • Some materials are not good for high-traffic areas
Install or increase below grade storage for stormwater runoff	• Larger than required storage is not necessary to have
Use efficient electrical and mechanical equipment	• Initial cost of these materials may be too high
Install a green roof	• Green roofs may be hard to maintain • Initial cost of creating a green roof can be high
Other Miscellaneous Solutions to Potential Climate Change / Green Problems	
Become LEED certified	• LEED Certification can be expensive

NOTE: It is recommended that this table be updated to include future concerns that developers may have as they are discovered in meetings with them. New concerns may be brought up by specific developers

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RESPONSES TO CONCERNS

Some concerns that developers have may be addressed through the use of incentives or trade-offs. Here possible ideas are listed that can reduce developers' concerns and promote the decision to adapt.

If developers believe the cost is too high to implement adaptations:

- Initial cost to adapt can end up saving money in other areas, for example by reducing energy costs with cooler buildings, or reducing the cost of repairing or replacing aspects of the building damaged in storms
- Some options have aesthetic value which makes developments more appealing
- Adaptation options that have been implemented can increase the resale value of the development
- Some adaptations may be promoted through various grant programs (Developers/ the city could potentially get some funding to help implement options)
- Encourage the developer to think about the added cost of the building being temporarily unusable due to storm damage and cost of repair

If developers do not want to put in a *rain garden* or *add vegetation* due to cost/lack of space: Consider reducing the number of parking spaces required for a development.

- Some developers believe the number of parking spaces required is more than their development would need
- Replacing some parking spaces with a rain garden would aid in stormwater management while working to reduce the excess heat the development produces (It would also allow developers to spend less money on the materials needed for parking spaces)

Note: Being LEED certified is something to check for in developments; however, some developers believe that it is too expensive to get LEED certification. Consider recommending that developers follow the standards to be LEED certified even without the certification.

- If a developer follows LEED standards, even without certification, they can be considered "LEED certifiable" which can be explained as an attractive qualification to those they are proposing building plans

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