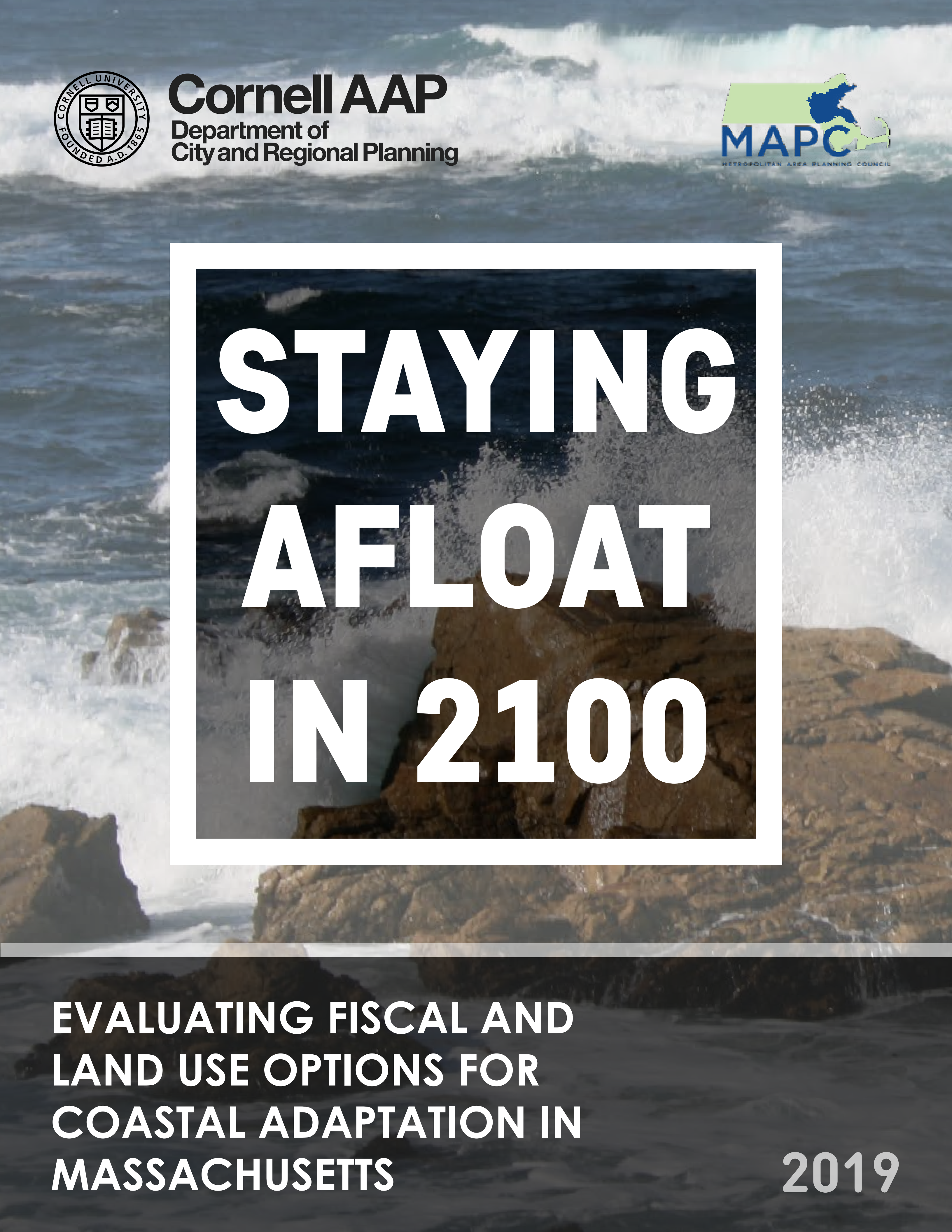

Cornell AAP
Department of
City and Regional Planning

MAPC
METROPOLITAN AREA PLANNING COUNCIL

STAYING AFLOAT IN 2100

EVALUATING FISCAL AND LAND USE OPTIONS FOR COASTAL ADAPTATION IN MASSACHUSETTS

2019

STAYING AFLOAT IN 2100

IN COLLABORATION WITH

TOWN OF HULL

TOWN OF HINGHAM

TOWN OF COHASSET

METROPOLITAN AREA PLANNING COUNCIL

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1 This was a linked course in which students provided technical assistance and tested land use scenarios.

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EXECUTIVE SUMMARY

Jason Carpenter/Flickr

Project Motivation

Recent disasters and growing concerns about climate change have led many coastal cities to conduct vulnerability assessments and develop climate adaptation plans. Yet despite rising sea levels and increasing flood risks from coastal storms, cities continue to build on the waterfront, albeit with flood resilient designs. These efforts can seem reasonable in the near term yet commit societies to long-term development in places that may not be feasible to protect over a period of many years.

Why do cities do this? With growing federal and state fiscal austerity, municipalities rely on their own source revenues to fund local services like schools, water and sewer utilities, roads, and emergency services. Property taxes constitute a third of municipal budgets nationwide and the bulk of local own source revenues. Fragmented U.S. metropolitan regions have on average over 100 municipalities each, meaning that many coastal municipalities have limited land area.[1] These fiscal and land use realities mean that municipalities cannot afford to forego development, much less retreat from advancing seas. In fact, they have every incentive to expand development on valuable waterfront properties to meet current day needs, which is what all cities—including so-called resilient cities—are doing.

These dynamics lay the foundation for new expressions of regional inequality and vulnerability at a municipal scale. What would it take to change this dynamic? How do we begin to measure the fiscal impacts of land use planning for climate adaptation when software tools and climate vulnerability assessments currently do not consider these issues together? What are the costs and benefits of alternative land use strategies, and for whom? What does this tell us about the scale of government at which adaptation planning should take place?

MAPC – Cornell Workshop

This report presents the results of an applied workshop that tackled these questions in the context of Hull, Hingham, and Cohasset, three coastal towns located south of the City of Boston, Massachusetts. It is the product of a collaboration between Boston's regional land use agency, the Metropolitan Area Planning Council (MAPC), and a workshop course with 11 students in the Department of City and Regional Planning (CRP) at Cornell University.

One of the densest coastal towns in New England, Hull is a peninsula that juts into the Boston Harbor. Six feet of sea level rise (SLR) is projected to chronically inundate [2]over half the town's two square miles. This threatens 30% of Hull's current revenues, or 48% of its own source revenues,[3] reducing its ability to maintain services and quality of life. Sea Level Rise (SLR) is projected to have less dramatic impact on Cohasset and Hingham, Hull's larger and wealthier neighbors.

We evaluated three land use and fiscal adaptation scenarios for Hull based on background research, vulnerability assessments, and conversations with local planners and administrators. The scenarios are (1) elevate houses and roads in Hull (2) retreat from flooded areas and build more densely inland and (3) move all Hull residents away and add the peninsula to the Boston Harbor Islands National and State Park. Our analyses developed new methodologies to connect fiscal and climate adaptive land use planning, and tried to identify the relative feasibility of these options. As a class, we considered the extent to which these strategies were consistent with delivering what residents of Hull said they most valued about their community. These attributes included a place to raise a family and grow old with high quality of services and schools; affordable housing; access to a beautiful natural environment; and a strong sense of community and place.[4]

The findings must be understood within a few constraints. This workshop was an exercise to develop and evaluate scenarios to understand how to answer the questions on the previous page from the perspective of local government. This means that our estimated costs are back-of-the-envelope calculations based on limited data and high estimates. Experts repeatedly cautioned that true estimates can only be derived through detailed assessments. Second, balancing the budget is certainly not the only goal in planning and community development. Our task was to try to develop a method to connect land use choices, fiscal impacts, and the impacts of climate change. Many other scenarios may be possible or desirable. Finally, there are incredible social and emotional costs associated with any of the scenarios we discuss. Many communities on the front line of climate change are grieving or in shock over its impacts. At the towns' request, we did not engage residents in this emotionally difficult thought experiment. We recognize the social, emotional, and equity implications of the scenarios, and understand that these impacts are difficult to assess in the scope of our project.

1 Savitch, H. V., & Adhikari, S. (2016). Fragmented Regionalism Why Metropolitan America Continues to Splinter. Urban Affairs Review, 53(2), 381–402.

2 Chronic inundation is flooding that occurs every two weeks, or at least 26 times per year.

3 Own source revenues comprise fees, charges, and taxes that local governments collect. They do not include transfers from state and federal governments.

4 Town of Hull. (n.d.). Wave of the Future: Hull Vision Statement. Retrieved from https://www.town.hull.ma.us/town-manager/pages/wave-future-hull-vision-statement; Town of Hull. (2015). Community Development Strategy. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/2016_cds.pdf

Research Findings

The findings show that there are difficult tradeoffs and no easy answers ahead. For example, Hull could spend over $640 million to elevate all the low-lying houses and roads; ring major public facilities and utilities with seawalls; renourish Nantasket Beach, which is a tourist attraction and important community resource; and build out the few remaining vacant parcels. This strategy may be the most economically and politically feasible for the town since homeowners foot most of the costs and it requires no broader policy reforms. However, this approach may gradually displace current residents due to rising housing costs and accessibility issues, given that Hull residents are generally older than residents in surrounding communities. Over time, residents will pay for disaster recovery and infrastructure maintenance and may have to continue elevating if seas continue to rise.

These challenges don't disappear if residents move to higher ground. People could continue to live in Hull if the remainder of Hull densified significantly. To maintain current tax rolls and service quality, Hull would need to replace its more land-intensive single-family homes with high rise condo housing, which costs more per square foot to build. This would be highly disruptive to residents and change the municipality to an unrecognizable form. Asking residents to retreat also likely requires federal or state buyouts. Buying out properties located in the lowest lying areas of Hull would cost an estimated $816 million but still leave the local government with fixed operating expenses for services like police, fire, and schools. On top of that, there would be an additional costs associated with maintaining resilience infrastructure in the future.

Residents could move (ideally as a community) to surrounding towns like Hingham and Cohasset and restore Hull back to what it once was—a sandbar which hosted a tidal ecosystem used for shellfishing and fishing by Wampanoag native peoples and colonial settlers. According to our models, this option has the potential to increase total regional tax receipts; offer more options for housing to retreating Hull residents beyond elevated homes or high-rise condos; and help neighboring towns like Hingham diversify its housing types and residents, which they say they want in their plans.[5] It must be said that these changes would be disruptive to Hingham and Cohasset, as well. However, collective resettlement can take a long time to organize. Buying out all the residents in Hull would cost over $2 billion. Ecological restoration would cost even more. A comparables analysis suggests that a natural park the size of Hull could produce additional regional revenues of $8 million a year, nowhere near the cost of relocation to justify federal expenditures on this scale.

5 Town of Hingham. (2017). Hingham Master Plan Goals. Retrieved from https://www.hingham-ma.gov/DocumentCenter/View/4943/Master_Plan_Goals_2017-revision

Policy Implications

These findings suggest that current fiscal, land use, and disaster policies incentivize coastal cities to keep building in vulnerable areas, to elevate and protect, and to gentrify waterfronts rather than make an orderly retreat to less vulnerable areas. The findings also underscore the fact that adaptation to climate change cannot rely only on local adaptation, but requires regional, state, and federal solutions. Collective resources could go towards building denser, more vibrant communities and new, restored public ecosystems. However, current policies of municipal incorporation, local land use controls, regional governance and wealth sharing, and federal infrastructure and disaster management policies do not enable decisionmaking that supports collective regional well-being. Based on this research, we recommend the following steps by MAPC and other regional planning agencies interested in advancing long-term climate adaptation:

- **Align the climate adaptation question with that of housing and schools:** Inequitable access to safe land under climate change has much in common with inequitable distribution of other resources like housing, schools, food, and health facilities**.** Rather than allowing market-driven adaptation to displace people to worse-off places, regional climate-informed land use planning should consider resettlement, retreat, or even redrawing municipal boundaries in ways that enhance regional equity and justice.
- **Incorporate fiscal vulnerability into climate vulnerability assessments**: Vulnerability assessments currently measure physical and social vulnerability, but not the impacts of climate change and adaptation to municipal expenditures and revenues. Our methods are a starting point. Municipal finance experts, adaptation planners, and regional agencies should develop guidelines for how cities account for fiscal impacts in future assessments.
- **Develop new scenario planning methods and tools to enable integrated analysis**: In conducting this research, we found no existing scenario planning software that permits an integrated analysis of climate change, land use planning, and fiscal impact, especially across multiple political jurisdictions and long time horizons. Our methodology is distilled in the full report so that MAPC and other regional agencies can apply it to metro areas, but the development of more and better decision-making tools is needed.
- **Bring creativity to land use, fiscal policy, and government administration**: Cities like Boston have been very open to considering blue-sky creative resilient urban designs as seen in recent design competitions like the Urban Land Institute's Urban Implications of Living with Water or Boston's Living with Water design competition.

We suggest that local, regional, and state agencies adopt a similar willingness to consider policy alternatives with respect to local land use planning; resource and wealth distribution; rules of municipal incorporation; and federal and state grantmaking standards to enable cities to collectively move towards desired regional visions.

- **Work with facilitators to engage residents in difficult conversations**: This workshop did not engage residents, but it is critical that regional and local planning agencies involve residents of both vulnerable communities and those that may receive climate migrants in these difficult conversations. This is especially true of historically marginalized and disenfranchised communities, which are the most likely to be displaced or exposed in the climate transition. The complexities, legal challenges, opposition, and social divisions are legion. But as our analysis suggests, change is on the way for residents of coastal places, whether they stay, adapt, or move. Residents likely have more agency to shape their adaptation options now if they devise strategies ahead of the next big storm so that they can move collectively towards desired futures. Analyses that reveal the true costs and benefits of different options can serve as a bridge to seemingly impracticable but desirable futures.

Many studies in the emerging field of climate adaptation have focused on assessing cities' infrastructure systems, the social impacts of climate change and adaptation responses, and the costs of action or inaction. However, few studies have examined how fiscal and land use policies drive municipalities to develop where they do and constrain their adaptation responses. Many guidelines and adaptation plans further advocate cities adopt land- and growth-based financing mechanisms, such as property taxes and municipal bonds, to implement adaptation projects. These strategies overlook how climate change affects future municipal revenue streams, how such financing mechanisms incentivize increased development in flood-prone areas, and how uneven capacity to use these growth-based tools can shape regional inequality.

In Massachusetts, recent research finds that six feet of Sea Level Rise (SLR) would jeopardize property tax rolls unevenly along the coast, devastating seven highly urbanized cities, moderately affecting 29 others, and affecting 63 others little or not at all (Figure 1 and 2). For impacted cities, present day budget needs pressure cities to develop. For instance, Boston, Hull, and other metro Boston municipalities including Cambridge, Chelsea, Somerville, Everett, and Revere have completed or are

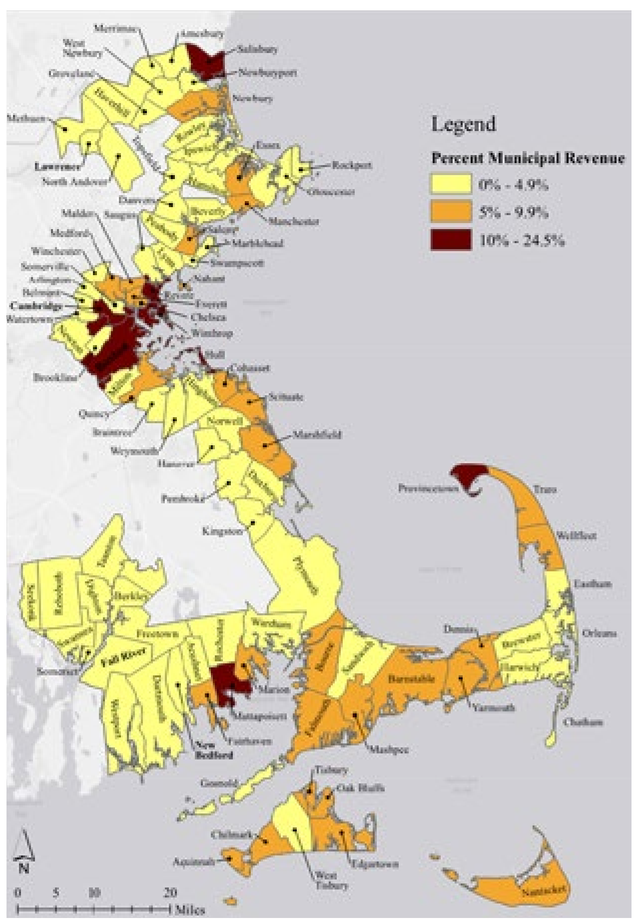


Figure 1: Percent of Total Municipal Revenue Jeopardized at 6 Feet of Sea Level Rise

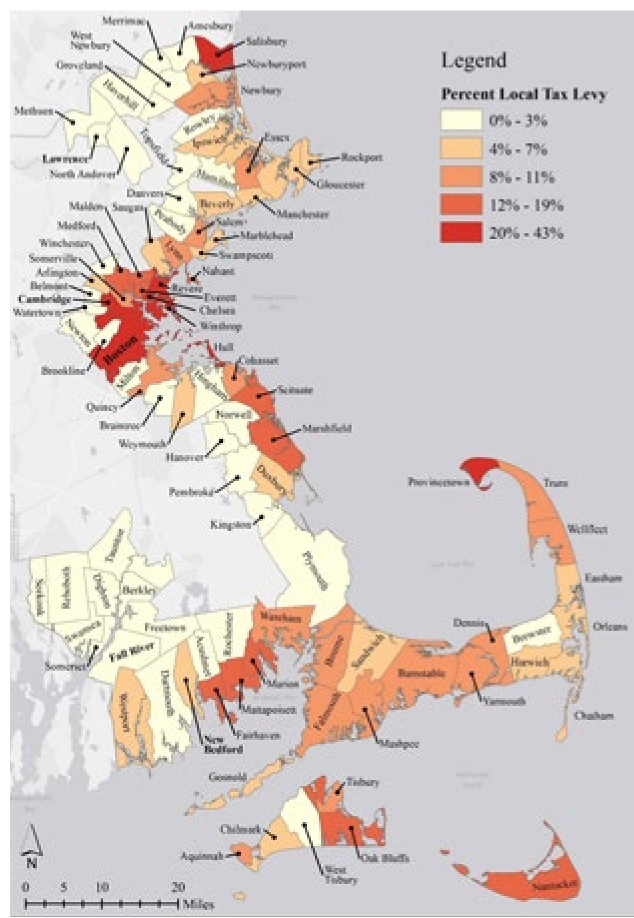


Figure 2: Percent of Own-Source Revenues Jeopardized at 6 Feet of Sea Level Rise

These estimates are based on the latest available sea level rise maps from NOAA and require ground-truthing to be more reliable (Shi & Varuzzo, under review).

developing vulnerability assessments and climate adaptation plans. Yet many new major redevelopments in these cities have been placed in or are proposed for areas that will be underwater with six feet of sea level rise (Figure 3). Other municipalities with less risk under sea level rise have little incentive to change their land use plans to account for rising risks elsewhere. In fact, the 2008 regional vision plan for metro Boston prioritizes dense urban compact growth, much of it around already urbanized coastal cities, and tasks inland and less urbanized municipalities to preserve open space and reduce sprawl.

This workshop course is an effort to consider the costs and benefits of alternative development scenarios for vulnerable coastal communities and what it would take to move towards more desirable futures. It was a collaboration between metro Boston's regional planning agency, the Metropolitan Area Planning Council (MAPC), and Cornell University's Department of City and Regional Planning (CRP) during the spring semester

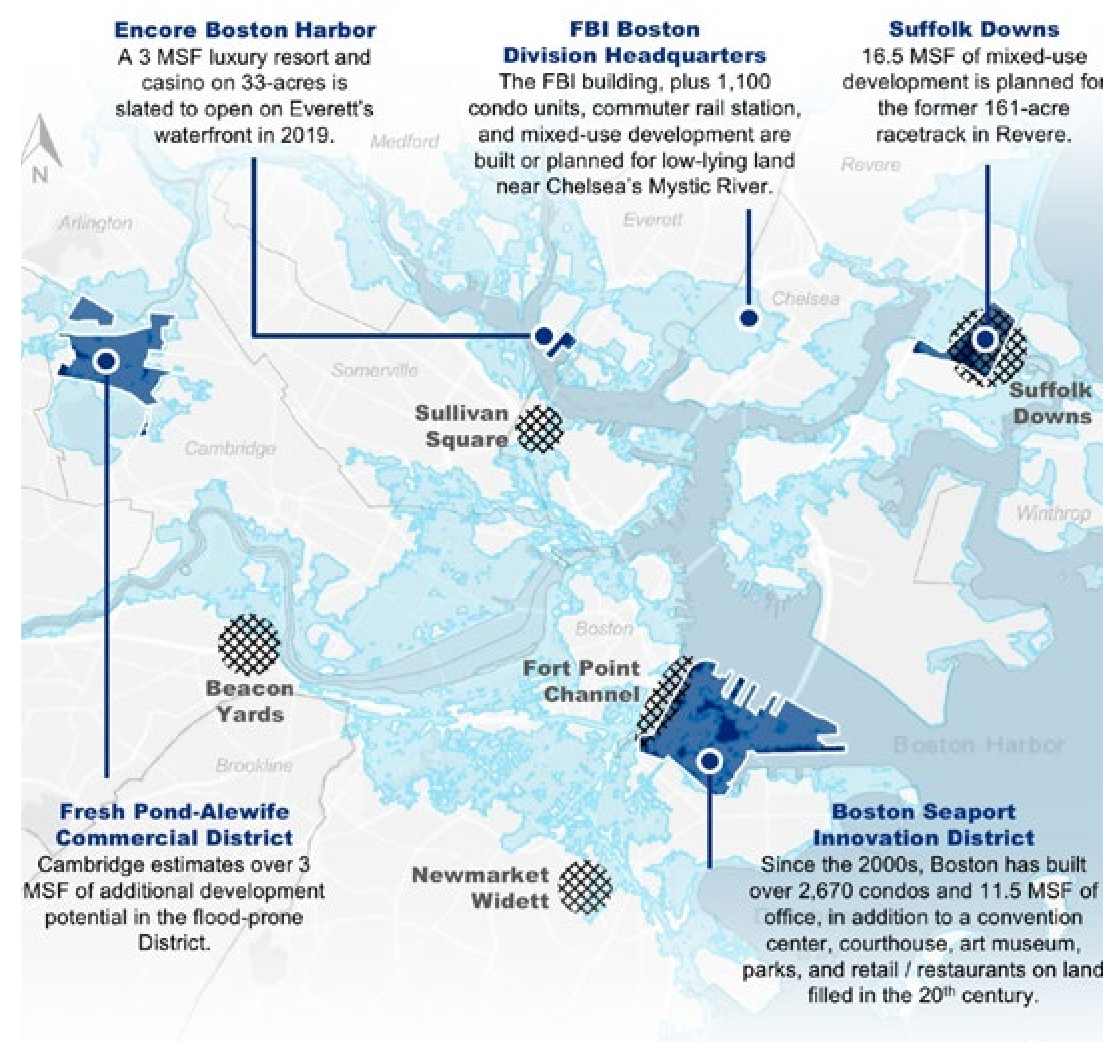


Figure 3: Major Redevelopment Proposals in Metro Boston in Relation to 6 Feet of Sea Level Rise (Shi & Varuzzo, under review).

of 2019. Cornell student Andrew Varuzzo (MRP '18) had written a thesis under Dr. Shi on the fiscal vulnerability of coastal Massachusetts. In fall 2018, Dr. Shi sought out MAPC to see if they were interested in evaluating responses to local fiscal constraints and climate vulnerability. MAPC was interested in identifying a methodology to jointly analyze fiscal impacts and land use planning for adaptation to climate change that could potentially feed into the forthcoming regional Metro Common planning process. Together, MAPC and Dr. Shi received a $5,000 grant from Engaged Cornell to support the workshop. A Cornell Institute for Social Sciences Small Grant to Drs. Shi and Minner also helped fund graduate research assistants. They then identified the towns of Hull, Hingham, and Cohasset as local clients (Figure 4) because the towns had varying climate vulnerabilities, were geographically next to each other, had all conducted climate vulnerability assessments, and were interested in understanding the fiscal impacts of different adaptation strategies. Table 1 compares the towns' baseline demographic contexts.

The workshop aimed to develop new methodologies to link fiscal impacts and local land use planning for climate adaptation, identify the tradeoffs between different options, and assess the implications for regional planning agencies like MAPC.

Figure 4: Location of study area relative to Boston

	Hull	Hingham	Cohasset
Land area (square miles)	2.8	26.3	10.06
Population	10,402	22,157	8,393
Population growth rate	0.57% (2010-2018)	11% (2000-2010)	16% (2000-2015)
Median age	53	45	45
% White alone	95%	95%	98%
Median household income	$80,584	109,970	$140,000
Mean household income	$101,606	$100,000	$208,201
Average cost of a single-family house	$365,800	$792,100	$852,300
% renters	32%		35%
Unemployment rate	4.70%	4.4% (2014)	3.80%

Table 1: Baseline Demographic Conditions in Hull, Hingham, and Cohasset (2017 ACS Estimates, Bureau of Labor Statistics)

Research Process

As part of a larger research project, this initiative involved two courses: the workshop course taught by Dr. Shi, whose work is presented in this report, and Dr. Minner's land use planning methods course. The students in latter course served as a consultant to the workshop.

Students in the workshop course first analyzed the socioeconomic conditions of all three towns, as well as their land use plans, fiscal health, and fiscal, social, and physical exposure to climate impacts. Table 2 shows the memos developed for each of the towns in the first month of the workshop. Students then formed teams to develop a synthetic vulnerability assessment for each town. Participants also developed rough scenarios for different land use responses to these vulnerabilities, taking into account fiscal realities. In March 2019, students presented to Hull Town Manager Philip Lemnios as well as planning staff from the three towns and discussed potential scenarios to assess. On the same trip, participants also toured the three towns with their respective planning directors to view existing shoreline conditions, coastal developments, and downtowns. We also met with resilience planning experts at the University of Massachusetts Boston and MAPC.

At the request of the local clients, we did not engage the broader public in this workshop due to the sensitivity of the questions, the towns' ongoing climate vulnerability assessments, and a related, concurrent public engagement process let by MAPC around social vulnerability in Hull. This workshop and report is primarily a thought exercise in an academic setting. It seeks to contribute to the conversation but does not commit the town or residents to any future. Because we did not engage with residents and given the multi-sectoral scope of the workshop, this work does not reflect a depth of knowledge of what makes Hull the place that it is to the community that calls it home. This is a clear limitation of the workshop and its research endeavors.

In the second half of the semester, we developed three adaptation scenarios based on the field visit and class discussions. Each team developed their own methods to calculate the fiscal impacts of different land use options using a mix of GIS, Excel, and Urban Footprint, a publicly accessible scenario planning tool. Methods are described in detail under their respective chapters later in this report. Partners at MAPC reviewed written drafts and digitally critiqued a draft presentation of the scenarios. Dr. Shi and three students returned to Hingham in May 2019 to present the final work. This report presents the research from the term, with editing and compilation support from three of the workshop students, Naomi Crimm, Audrey Wachs, and Josh Rotbert, as well as Dr. Shi.

In spring 2019, the students in Dr. Minner's Land Use Planning Methods class worked to support the climate adaptation workshop. Students in that course (1) evaluated Boston, Hingham, and Cohasset's comprehensive plans using the American Planning Association's Sustaining Places Plan Scoring Matrix (2) used an Exploratory Scenario Planning process to imagine these municipalities' future (3) conducted a build out

Memo 1 **Land Use Plans and Policies**	**Memo 2** **Vulnerability to Climate Change**	**Memo 3** **Fiscal Health and Gaps**
Overall characteristics of land uses in town and how they have changed over time	Buildings exposed to sea level rise compared to town overall	Overall budgetary health and conditions of the town
Exposure of different land uses to sea level rise	Social vulnerability to sea level rise compared to town overall	Fiscal impact of sea level rise on town revenues
Demographic trends and projections for town	Town's exposure to other climate hazards	Property tax structure and reliance for the town
Future proposals for land use (comprehensive plan, vision plans, project plans)	Impact of recent storm events on the town's physical assets and people	Cost of recent storm events and impact on fiscal health of town
Existing hazard mitigation policies	Major stakeholders or entities of relevance to adaptation, and actions on adaptation to date	Examples of inter-local agreements and cooperation and responses to fiscal stress

Table 2: Research Topics Developed for Each Town

Images from the March 2019 site visits and meeting with MAPC and town representatives (Dr. Shi and Cornell workshop participants)

Aerial view of Hull, Hingham, and Cohasset in relation to Boston
Source: deanandhamilton.com

analysis in Urban Footprint to ascertain much land Hull, Hingham, and Cohasset could develop given sea level rise and zoning code (4) analyzed the return on investment of potential infill properties in these three towns using Envision Tomorrow and (5) used Urban Footprint to enact and assess the feasibility of the workshop's three scenarios. The final analysis proved most beneficial to the Scenario 2 analysis of where and how to resettle Hull residents. The Urban Footprint analyses are discussed in the Scenario 2.

Finally, a PhD student whose work concerns the relationship between data, technology, risk perceptions, and adaptation served as the research advisor for the workshop. Ryan Thomas helped us access sea level rise data, document our research processes throughout, and helped us summarize and abstract the analytical methods so they can be replicated at the regional scale. This methodology is presented in the Appendix. Thomas, along with Drs. Shi and Minner, are working on a journal article that evaluates scenario planning tools for climate-driven fiscal vulnerability and response strategies.

Climate Projections

As with any climate vulnerability assessments, we had to make choices about which hazards to model, which climate projections to use, and which time horizons to consider. The workshop focused on climate hazards related to flooding (e.g. sea level rise, inland and coastal flooding, and storm surge) because they most directly affect property values. In reality, other hazards exacerbated by climate change like drought, heat, and wildfire also impact municipal finances. These hazards were outside the scope of our analyses.

We drew on data from a private consultant and a nonprofit advocacy group for our assessment of risks from flooding and sea level rise. The Cambridge, MA–based consulting firm Kleinfelder conducted vulnerability assessments for Hingham and Hull in 2015 and 2016, respectively, using Massachusetts Department of Transportation's dynamic model of storm surge flooding. This model showed the percentage probability and depth of flooding in 2013, 2030, and 2070 for both a 1% (the 1-in-100-year flood) and 0.2% (the 1-in-500-year flood). These assessments also estimated the costs to floodproof

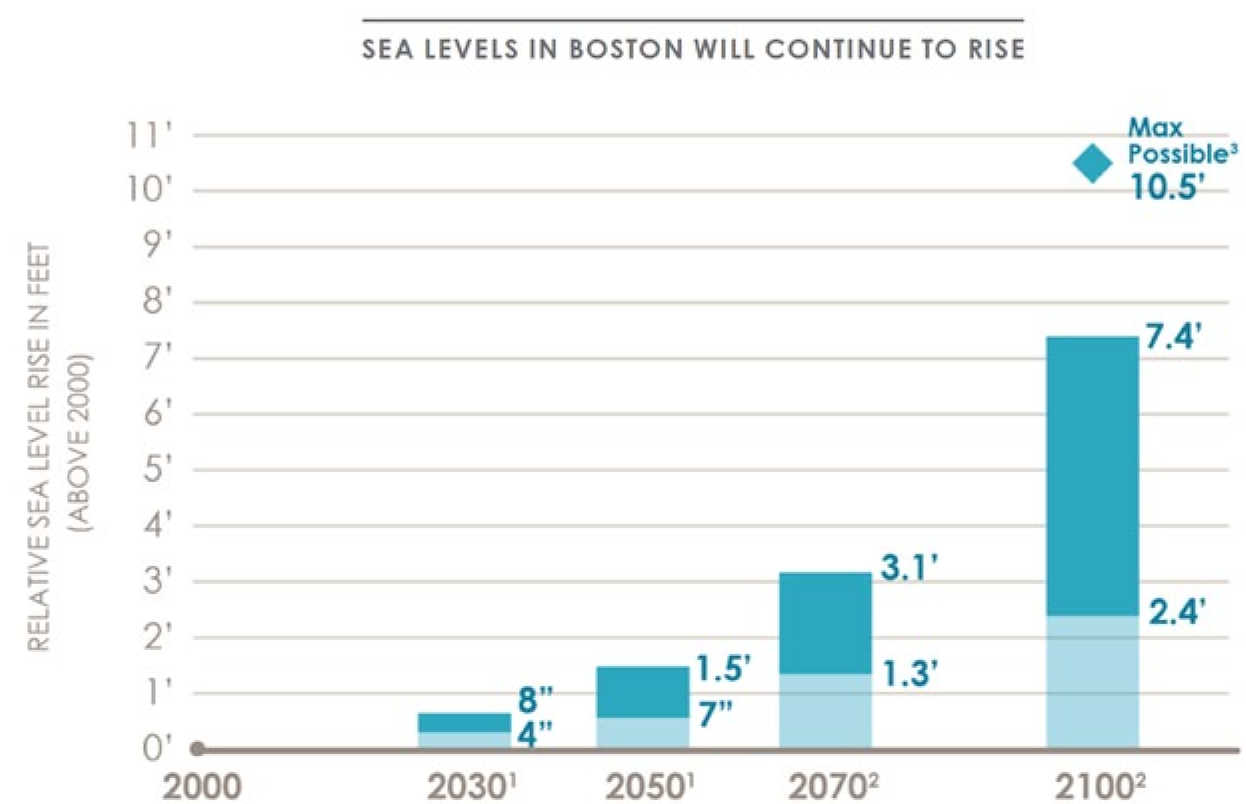


Figure 5: High and Low Estimates of Projected Sea Level Rise (Climate Ready Boston, 2016)

municipal critical infrastructure up to 2070. We also relied in the methodology and data from a 2018 report by research and advocacy group Union of Concerned Scientists (UCS). *Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate* used NOAA bathtub models of sea level rise based on elevation and volume of ocean water, supplemented by coastal tide gauges that calibrate local variation, and mapped areas that would be chronically inundated (flooded at least twice per month) in 2030, 2045, 2060, 2080, and 2100 at low, intermediate, and high projections of SLR.

We digitized both datasets for analysis in GIS, and early memos scrutinized vulnerability to both chronic inundation and storms. In the second half of the semester, we decided to focus on chronic inundation because it persistently affects properties. With storm flooding, it is possible to imagine elevating houses, evacuating during emergencies, and generally persisting as before but with better disaster preparedness. Chronic inundation permanently places areas under water, thereby affecting property values and necessitating systemic responses like elevating roads, utilities, and considering property relocation. Scenario 1's analysis draws on Kleinfelder's flood-based estimates of climate proofing costs to support the findings.

We chose to use UCS maps of chronic inundation for the time horizons of 2030, 2060, and 2100. Scenario planning for climate adaptation often extends 20, 40, or 50 years in line with long-term regional transportation planning time horizons. Given the exponential nature of sea level rise projections, this can result in plans that assume moderate levels of change and miss the dramatic increase in sea level rise expected later in the century. We therefore felt it was important to consider long-term implications and work backwards towards the present.

Finally, we debated whether to use low, medium, or high projections of carbon emissions. We ultimately chose to conduct the analysis with high emissions projections because that is what the world is currently on track to emit and because of limitations of student capacity. Given the semester timeframe, it was infeasible to have each team analyze the impacts of nine conditions (low, medium, and high emissions in 2030, 2060, and 2100). However, projections for SLR under high emissions in 2060 approximate SLR under low emissions in 2100; and projections for SLR under high emissions in 2030 approximate SLR under low emissions in 2060. In other words, the figures we present provide the lower-end estimates of change if they get pushed further out in time. Figure 5 visualizes this dynamic.

Data Sources

In addition to the climate data, we drew on diverse sources of quantitative, spatial, and qualitative data to conduct the vulnerability assessments presented in the next section. In general, municipal tax and finance data, socioeconomic data, land use, topographic, and environmental data came from MAPC or MassGIS, the spatial database maintained by the Commonwealth of Massachusetts. Cleargov.com provides an easy to use, visual presentation of municipal fiscal data nationwide. We used the social vulnerability map layers from Climate Central's Surging Seas online maps, in addition to mapping census-tract level census data in GIS. We also conducted extensive searches in and followed news media, social media, government websites, and other online sources.

Each of the scenario evaluation sections below detail their own data sources. We were fortunate that Kleinfelder's vulnerability assessments included estimated adaptation costs which provided us with unit estimates for the infrastructure it assessed. The RSMeans data provides detailed cost estimates for the construction industry specific to each locality nationwide but focuses on residential construction. Cornell's databases did not offer access to its facilities dataset, which may provide more unit costs of public infrastructure.


VULNERABILITY ASSESSMENTS
PMillera4/Flickr

LOCAL CONTEXT AND VULNERABILITY ASSESSMENT

Hull

Relative location of Hull within the study area

Summary

The peninsular Town of Hull is one of the most vulnerable municipalities to climate change in Massachusetts, with sea level rise projected to permanently inundate 61% of the town by 2100. Hull has proactively implemented many of the best practices recommended for adaptation, which include setting stricter development regulations, protecting open space, integrating sea level rise considerations, incentivizing home elevation, obtaining grants to plant dune grass, and promoting climate education in public schools. Yet Hull is seeing the limits of what these strategies can accomplish. Moving forward, chronic inundation would first impact the town's densest neighborhoods which have the highest proportions of low-income, renter, and senior populations. If affected properties are taken off the tax rolls, whether due to abandonment or government buyout programs, the town could have a 30% budget shortfall to meet increasing infrastructure maintenance and capital investment needs and social support services. Since Hull is not the only municipality with this vexing problem, its challenges underscore the need for regional solutions.

Overview of Hull

Hull is located on the narrow, low-lying Nantasket Peninsula, twelve miles south of Boston. The towns of Cohasset and Hingham connect Hull to the mainland via two bridges and Black Rock Beach. The peninsula, really a sandbar, was historically a place for fishing and shellfish by the Wampanoag Native Americans. Incorporated by colonists in 1644, its economy centered on fishing and ship salvaging. As Boston grew over the centuries, Hull became a summer tourism destination because Nantasket Beach (meaning "the strait" or "low-tide place" in Wampanoag) is the longest beach in New England. Hotels, the Paragon Boardwalk, and summer homes were the foundation for the community's character and heritage. . In recent years, the metro Boston's tight housing market compelled homeowners to convert their dwellings into year round homes. These were mainly white working and middle class families. Especially after the 2008 recessionand foreclosure crises, retirees from Boston have bought properties in Hull and begun to elevate them, often adding usable square footage in the process.

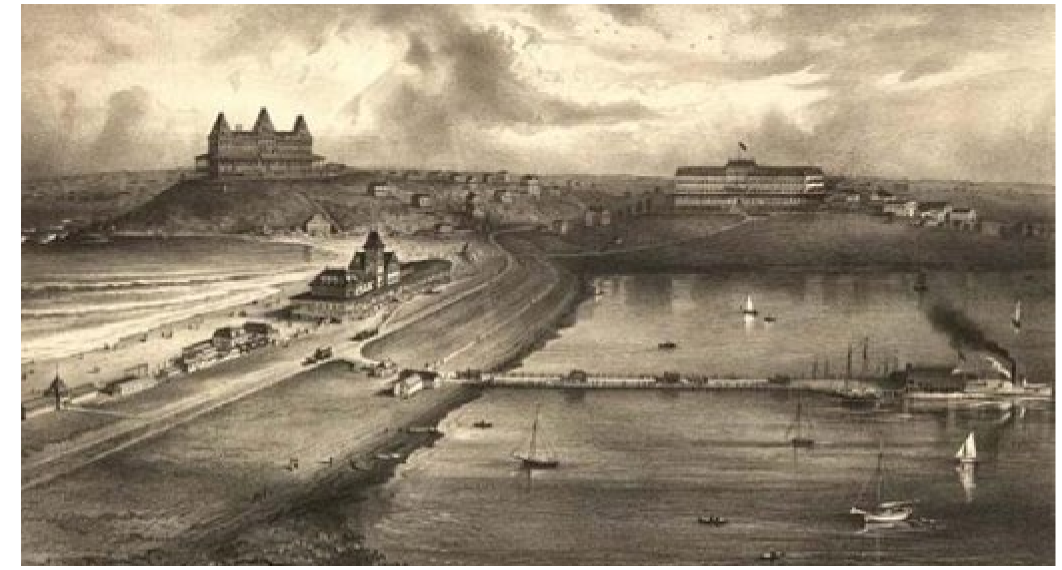
Today, this town of 2.8 square miles is fully built out, mostly with single family homes on postage stamp lots. The one-time summer retreat now has a population of 10,402, a median age of 52.8, and a growth rate of only 0.57% from 2010 to 2018. As of now, the median household income is $80,584, and the majority of residents (68%) own their own homes which have a median value of $377,000.[1] Hull's population is predicted to decline by 2030, and its current residents are greying. School-age children comprise only 10% of the population (compared to 20% in neighboring towns). Hull identifies as a "friendly, neighborhood-scaled, family-oriented, relatively affordable residential community".[2] The quality of the school system and the preservation and enhancement of open space and scenic views are two aspects of the community that residents value most.

The Town's Community Development Strategy recognizes the community's challenges, which also distinguish it from neighboring towns: According to this strategy, there's"limited year-round economic activity, extreme scarcity of developable land, and a large population of low- and moderate-income residents" Hull encourages mixed-use redevelopment of existing buildings and requires affordable housing in large-scale developments, in accordance with the state-wide Community Preservation Act. However, land vacancy (2.9% of residential parcels and 6.3% total) provides few opportunities for redevelopment or tax base expansion. The town is also investigating ways to improve local and regional transit. Developing a year-round economic base that increases jobs and tax revenues wasidentified as critical to meeting Hull's needs.[3] To this end, the town created the Nantasket Beach Overlay District (NBOD) to encourage multifamily and commerical redevelomentalong Nantasket Beach.

1 U.S. Census Bureau. (2017). 2013-2017 American Community Survey 5-Year Estimates [Data file]. Retrieved from https://data.census.gov/cedsci/table?q=&d=ACS%205-Year%20Estimates%20Data%20Profiles&table=DP03&tid=ACSDP5Y2017.DP03&g=0400000US25_1600000US2531680&lastDisplayedRow=33

2 Town of Hull. (n.d.) Wave of the Future: Hull Vision Statement. Retrieved from https://www.town.hull.ma.us/town-manager/pages/wave-future-hull-vision-statement

3 Town of Hull. (2015). Community Development Strategy. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/2016_cds.pdf



View of Nantasket Beach in 1879
(Karen Morley Real Estate)

Nantasket Beach and Paragon Park, Summer 1953
(Boston.com)

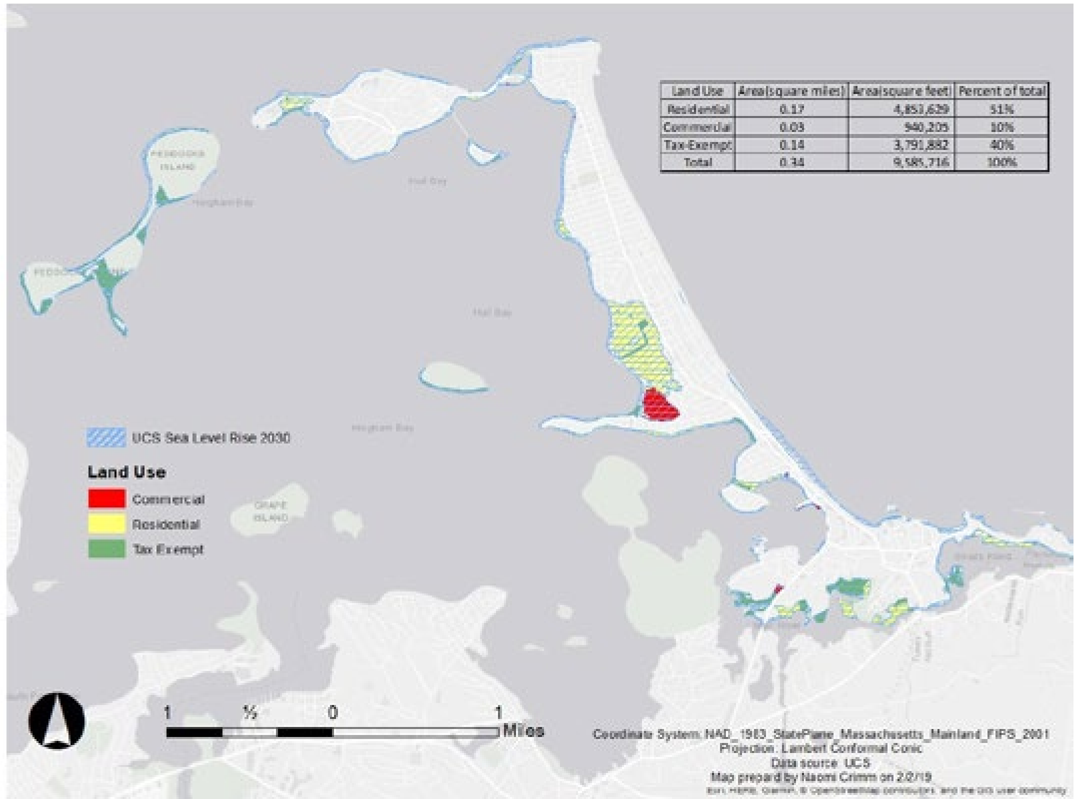


Figure 6: 2030 Chronic Inundation in Hull by Land Use Type

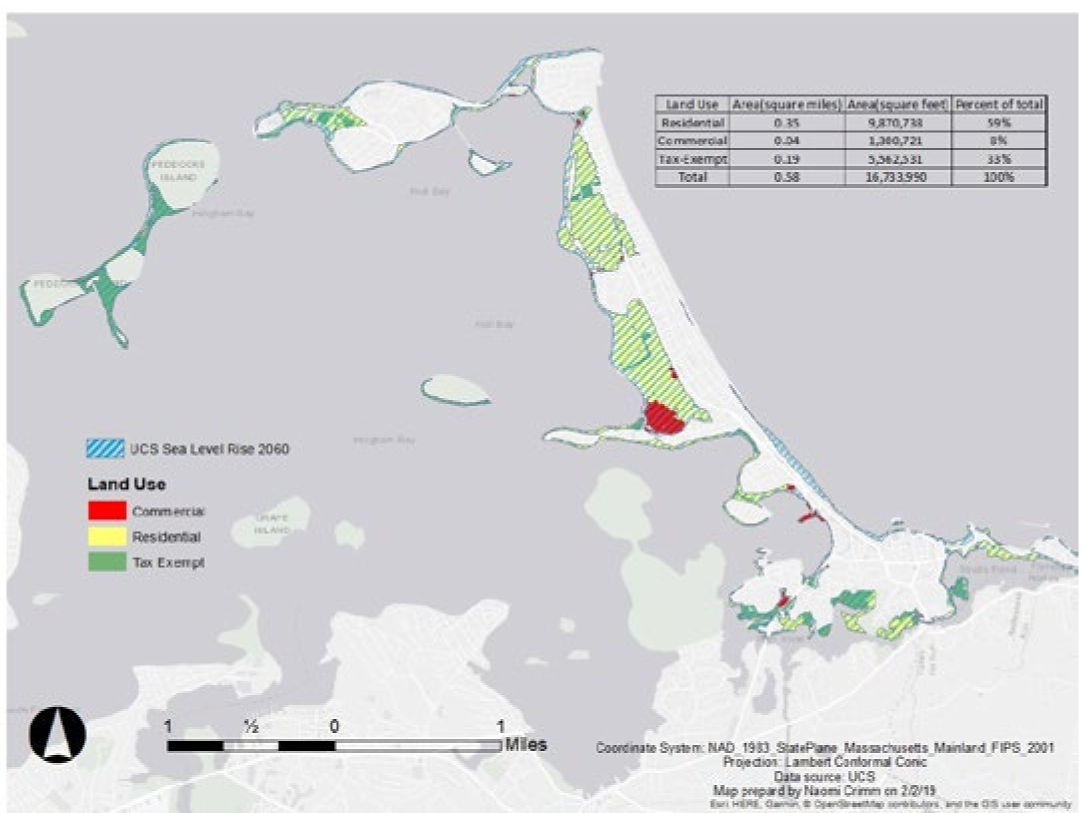


Figure 7: 2060 Chronic Inundation in Hull by Land Use Type

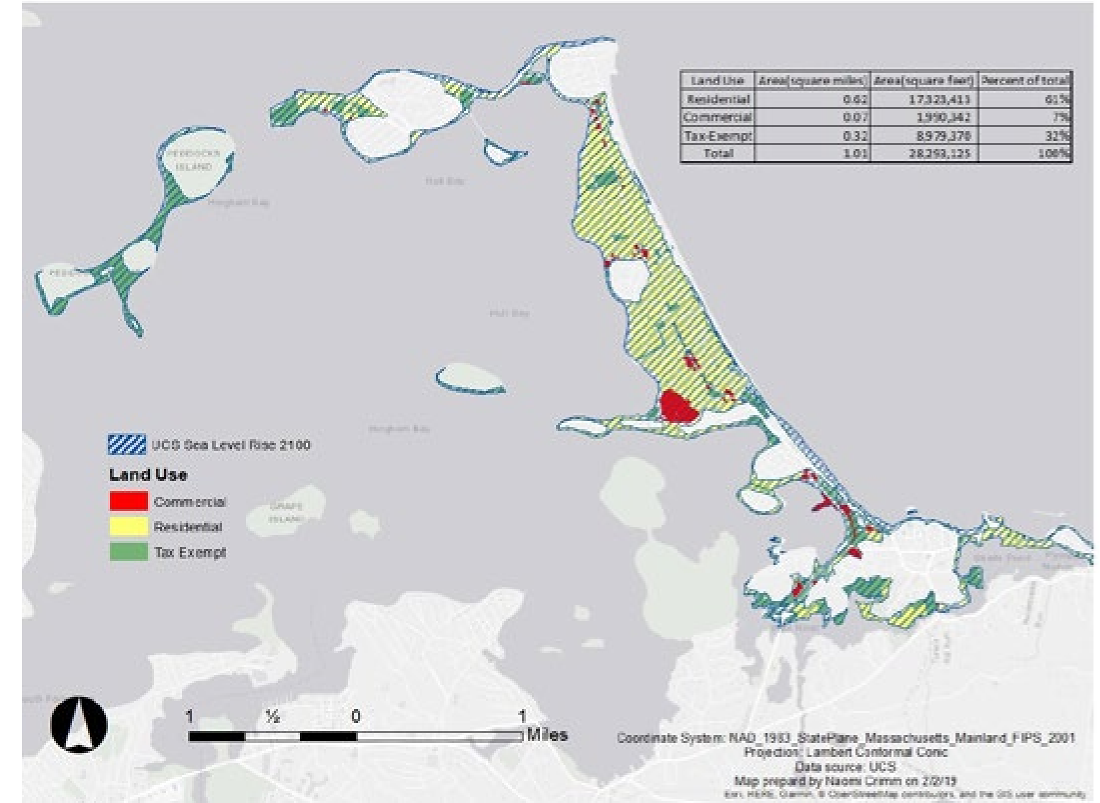


Figure 8: 2100 Chronic Inundation in Hull by Land Use Type

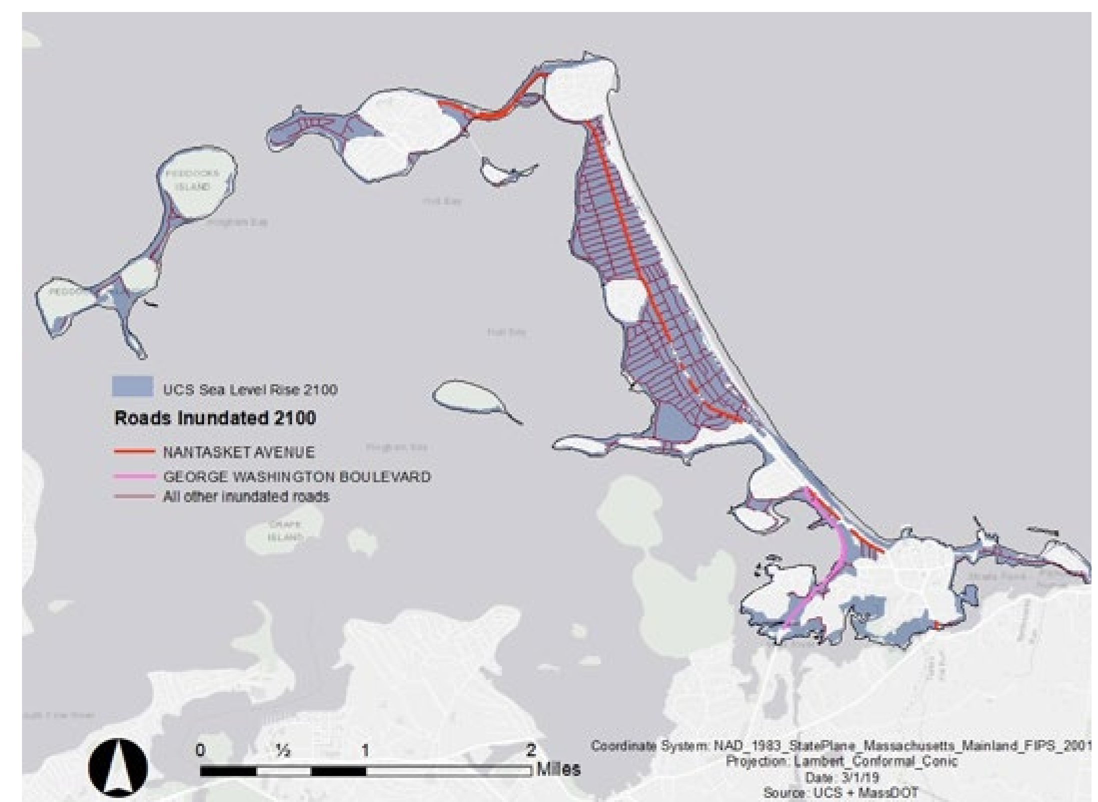


Figure 9: 2100 Road Network at Risk from Chronic Inundation in Hull

Physical Vulnerability to Flooding and Adaptation Responses

Located on a peninsula at the southern edge of Boston Harbor, Hull's building stock and infrastructure is exposed to sea level rise, floods and surges, hurricanes, tornadoes, thunderstorms, winter storms, extreme cold and hot weather, heavy snow, and droughts. [4]The most severe of these hazards is coastal flooding. Around 63% of the town (3,278 buildings) is in the FEMA floodplain, meaning that most of Hull has a 1% chance of flooding in any given year. Water is already a grave and growing threat to certain areas. The town has 229 repetitive flood properties that have received two or more payout checks of $1,000 or more from the National Flood Insurance Program (NFIP) in the last 10 years. Since 1978, owners have received $17.6 million in funds from NFIP, one of the highest payout rates in Massachusetts.[5] Hull's physical geography means that storm events in recent years, especially Nor'easters, have had an outsized impact compared to the neighboring towns. Hull's existing road network also increases its vulnerability. With only one main road and three bridges connecting it to the mainland, evacuation would be difficult in an emergency.

This situation will become more dire under projections of high level climate change and sea level rise projections according to UCS.[6] By 2030, 12% of Hull's land (0.34 square miles) may become chronically inundated. Of this land, 51% is residential property, 40% is tax-exempt, and 10% is zoned commercial (Figure 6). The areas impacted first are on the west side of Nantasket Avenue. Several critical facilities will be affected at this point, including the high school and the Municipal Light Plant. Over time, the percentage of residential land impacted increases, while percentages of tax-exempt and commercial land area impacted decreases. This finding has significant fiscal implications, discussed below. By 2060, the inundation area will encompass 21% of Hull's total land area, or 0.58 square miles (Figure 7). Facilities predicted to be impacted include the Waste Water Pollution Control Facility and Hull Memorial School. By 2100, one square mile of land and 35.5 miles of roads may become chronically inundated an area that is 61% residential (Figures 6, 8 and 9). The Senior Center would also be impacted by this time.

Hull has acknowledged the risk that flooding, sea level rise, and more frequent storm events pose for the community. The town's beach management plan, hazard mitigation plan, climate vulnerability assessment, and zoning laws and codes all include policies designed to adapt to and mitigate flooding through infrastructure improvements, conservation, hard armoring, and changes to building/code requirements. The town has strict zoning ordinances and participates in FEMA's community rating system (CRS), achieving discounts of up to $344,440 for the town overall.[7] It has a freeboard incentive program to encourage higher building elevations

4 Metropolitan Area Planning Council. (2018). Town of Hull Hazard Mitigation Plan Update 2018. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/2018_hazard_mitigation_plan.pdf

5 FEMA National Flood Insurance Program. (2018). Loss Statistics Country-Wide as of 09/30/2018 [Data File]. Retrieved from https://bsa.nfipstat.fema.gov/reports/1040.htm#25

6 Union of Concerned Scientists. (2018). Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate. Retrieved from https://www.ucsusa.org/sites/default/files/attach/2018/06/underwater-analysis-full-report.pdf

7 FEMA National Flood Insurance Program. (2014). CRS State Profile: Massachusetts. Retrieved from https://crsresources.org/files/200/state-profiles/ma-state_profile.pdf

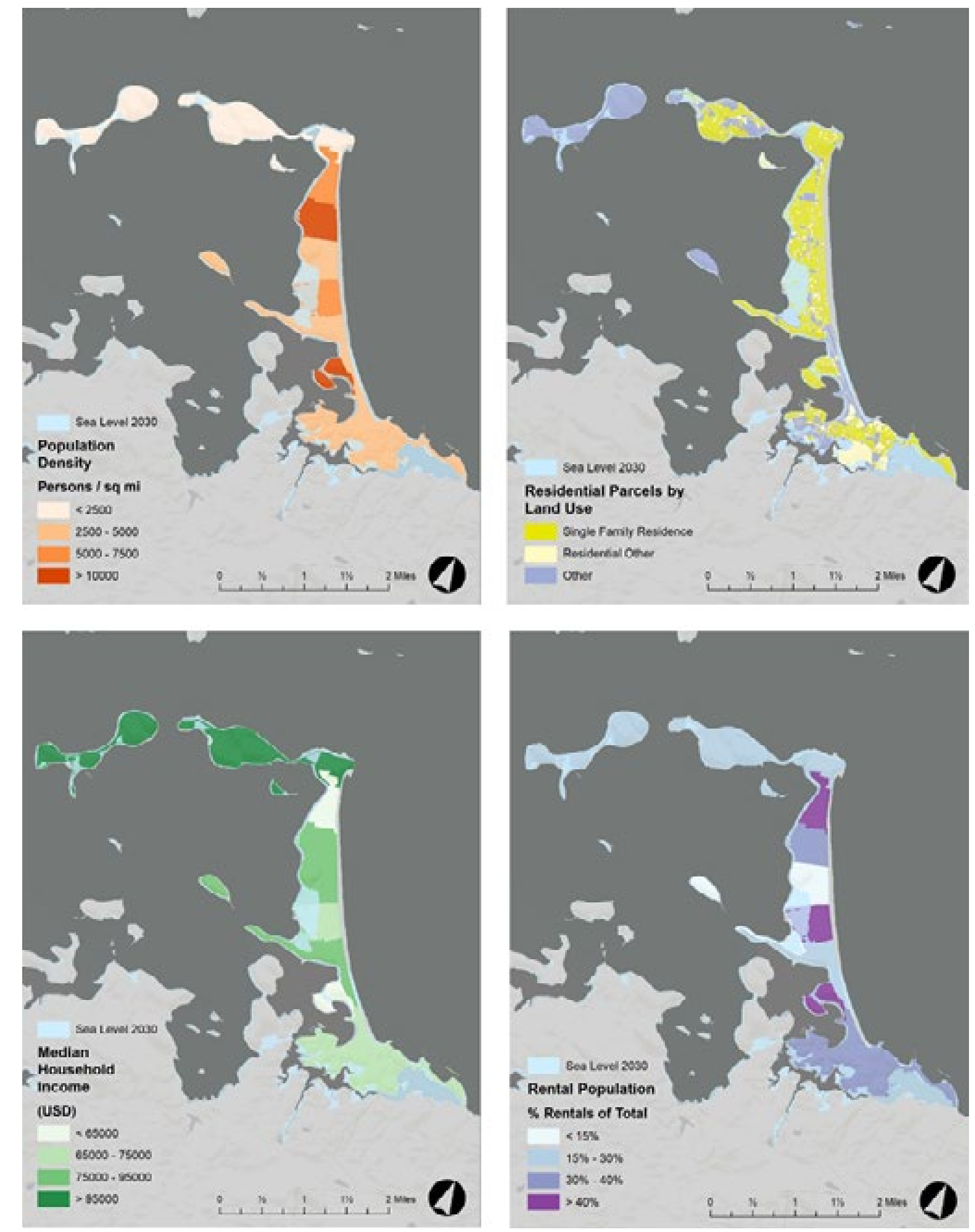


Figure 10: Social Vulnerability Metrics to SLR in Hull in 2030: Population Density, Residential Parcels, Median Household Income, and Rental Population

and has completed stormwater drainage system improvements, repaired seawalls, revetments, and flood control pump stations. The town regulates the subdivision of land and allows for cluster zoning to preserve open space, minimize stormwater runoff due to flooding, and limits development in floodplains.[8] The zoning bylaws outline a floodplain overlay district for all FEMA floodplain AO, AE, and VE areas, and includes specific construction measures to protect buildings against flooding.[9] This district required all permitted buildings to comply with raised elevation levels, water-resistant construction techniques, anchorage requirements, and foundation specifications, as well.

Hull took its first look at the impacts of climate change in 2009 with a study funded by the Massachusetts Office of Coastal Zone Management. Following the study, Hull revised building bylaws and began offering $500 rebates on building permit fees if homeowners raised new residences higher than regulations require. It also requires consideration of sea level rise in site plan reviews. But due to the revised FEMA floodplain maps, lack of land for expansion, and the almost stable rate of population growth, these policies do not affect most properties in town. For now, Hull can only rely on smaller, shore-based approaches to increase its near-term resilience. For instance, Hull has a community program to plant beach grass to reduce dune erosion (participants add 20,000 plants a year). Its middle and elementary schools participate in "Community Partnership for Resilience", an initiative to improve students' understanding of climate change.

Year	**2030**	**2060**	**2100**
Homes at Risk	491	1,264	2,550
Buildings at Risk	812	1898	3,587
Value at Risk	$150,394,200	$401,860,100	$920,616,700
Property Tax at Risk	$2,063,418	$5,513,612	$12,620,366
Population currently housed in at risk homes	874	2250	4,539
% 2016 Budget	13%	23%	30%
% 2016 Tax Levy	21%	37%	47%

Table 3: Fiscal Impact of SLR in Hull

8 Metropolitan Area Planning Council. (2018). Town of Hull Hazard Mitigation Plan Update 2018. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/2018_hazard_mitigation_plan.pdf

9 Town of Hull. (2014). Zoning By-law of the Town of Hull. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/zbl_2018_stm_0.pdf

Social Vulnerability

In Hull, sea level rise affects the densest parts of town. In this area, renters, residents with lower incomes, and seniors are disproportionately affected. We estimate the number of current residents (and households) that will be affected by chronic inundation is 874 people (318 households) between 2019 and 2030; 1,376 people (502 households) between 2030 and 2060; and 2,289 people (835 households) between 2060 and 2100. Seniors with fixed median household incomes between $65,000 and $75,000 comprise 20% of the population within areas predicted to be chronically inundated by 2030. Renters comprise 40% of the population in these areas (Figure 10). Age, income, and tenure status can constrain these households' ability to recover from a flood event or to finance adaptive measures. Physical limitations make it more difficult for an aging population to evacuate in an emergency, retreat from a hazardous area, or adapt in place with measures like home raising, which require the ability to comfortably walk up stairs.

Half of households in Hull carry federal flood insurance. Due to the revision of the FEMA floodplain maps, property owners in flood-prone areas saw increases of up to 25% in their flood insurance premiums in 2013. This hike in premiums has been difficult for people with fixed or modest incomes. Despite its forward-looking approach towards climate change, Hull appealed federal NFIP flood map revisions in 2016 because property owners of coastal homes objected to further premium increases. Future hikes in insurance premiums could lead to flood insurance foreclosures or induce current residents to move.

Fiscal Vulnerability

Hull's reliance on residential property tax revenue makes it especially vulnerable to climate-induced property devaluation. The town has an annual municipal budget of around $38-40 million, and residential property taxes constitute over 70% of Hull's municipal revenue. The 2008 financial crisis was particularly destabilizing, with many properties going into foreclosure. State aid constitutes 20% of the budget, but this funding has declined since 2015.[10] The majority of funds go towards schools (39%), pensions (20%), fire and police (17%), and debt service (6%) for school buildings and sewers. By contrast, public works receives 4% of the budget, and community development and planning only 0.04%.[11] Town Manager Philip Lemnios noted, '"[we] recognize [SLR]

10 Town of Hull. (2018). FY19 Budget Overview. Retrieved from http://www.town.hull.ma.us/Public_Documents/HullMA_Assessors/abatements/Property%20Tax%20Rates%20&%20Tax%20Levy

11 Cleargov.com. (2017). Town of Hull Expenditures. Retrieved from https://www.cleargov.com/massachusetts/plymouth/town/hull/2017/expenditures

as an existential threat'".[12] Consequently, Hull's FY19 budget allocated $60,000 for seawall repairs out of a total of $315,000 allocated for capital projects.[13] In 2019, the Massachusetts Office of Coastal Zone Management provided Hull with a $142,011 grant for Nature-Based Solutions for Community Resilience on North Nantasket Beach. Sea level rise will seriously impact Hull's budget and revenues. By 2100, 30% of its budget is impacted, or 47% of its tax revenue. This includes around 3,600 buildings (2,500 homes) worth $453 million that provide about $12.6 million in tax revenue (Table 3). Revenue losses would impair Hull's ability to pay for rising infrastructure expenditures due to increased flooding. The Town's 2016 Vulnerability Assessment estimates that retrofitting and floodproofing critical facilities alone will cost $1.8 million by 2030 and $25.8 million by 2070.[14] Elevating roads, sewer lines, and other infrastructure upgrades further increase expenditures, resulting in a larger debt burden and more fiscal stress as time goes on.

Land Use Change

As outlined in the previous section, the scope of future development in Hull is quite limited, as the community is almost completely built-out. On the other hand, town leaders have identified economic development as crucial for Hull to create jobs and expand tax revenues. To diversify its tax base, Hull created a redevelopment plan for Nantasket Beach and issued a call for proposals in 2019 to redevelop the town's last major open site, a five-acre lot in the middle of the peninsula that fronts the ocean on two sides. Most of the parcel lies in flood risk zone, with a substantial portion earmarked as Zone AO, which indicates a 1% annual change of 1–3 feet sheet flow flooding with SLR. Neither of the two submitted proposals moved forward, and the authority will reevaluate options.

12 Simpson, N. (2018, December 1). 'Existential Threat'. Patriot Ledger. Retrieved from www.infoweb-newsbank-com

13 Town of Hull. (2018). FY19 Budget Overview. Retrieved from http://www.town.hull.ma.us/Public_Documents/HullMA_Assessors/abatements/Property%20Tax%20Rates%20&%20Tax%20Levy

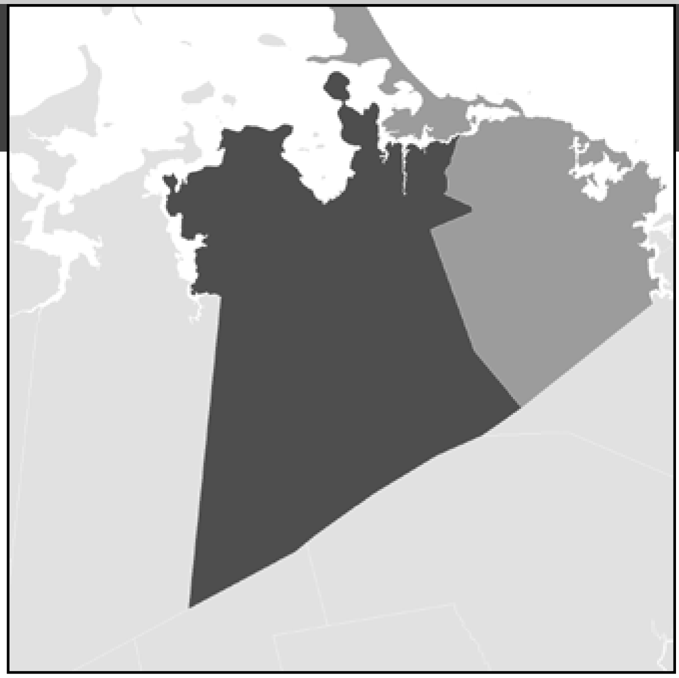
14 Martecchini, A., Brahim, N., & Bosma, K. (2016). Coastal Climate Change Vulnerability Assessment and Adaptation Study: Town of Hull, MA. Cambridge, MA: Kleinfelder. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/hullcl_1.pdf

Conclusion

Sea level rise could damage Hull irreparably. The most vulnerable financial assets at risk are the large number of single-family residential properties, which form a majority of the town's tax revenue base. Compounding this risk to Hull's fiscal health is the fact that Hull is home to a relatively large number of senior citizens, lower-income families, and renters who are less capable of withstanding the negative fiscal impacts of chronic flooding. The level and amount of flooding expected to occur in Hull over the next century necessitates timely and decisive action to not only protect municipal finances but ensure the health and safety of the most vulnerable members of the community.

LOCAL CONTEXT AND VULNERABILITY ASSESSMENT

Hingham



Relative location of Hingham within the study area

Summary

The Town of Hingham's geography, land use patterns, demographics, and fiscal health make it much less vulnerable to sea level rise than Hull or Cohasset. Its rocky shore and higher inland elevations help to buffer the community against future flooding, while renter and senior populations are concentrated away from the coast. Hingham's good fiscal health and vacant developable land inland also increase its adaptive capacity to sea level rise. Fiscal impacts of sea level rise, which will inundate high-value residential properties in its redeveloped harbor area, rise over time to 2% of the budget by 2100. Hingham has dedicated resources to studying the impacts of climate change and is accommodating flood considerations in new developments. However, the town's housing affordability issues and professed desire to diversify the tax base mean that Hingham will need to consider a long-term economic development strategy that more fully accounts for sea level rise. A regional approach could provide an opportunity for Hingham to achieve its goals while assisting its more vulnerable neighbors.

Overview of Hingham

The town of Hingham is located 15 miles south of Boston. Hingham was originally settled by Wompanoag Native Americans, and incorporated as a colony by English settlers in 1635. The town is home to a number of historical homes and buildings, including Derby Academy, founded in 1784 as the first co-educational school in the nation. Hingham's fishing industry peaked in the 19th century, when it had one of the largest mackerel fleets in the country, and its port served as an official port of entry into the country. During the 20th century, Hingham's ship-building operations employed 24,000 people, driving a boom in housing construction after WWII. The town has also prioritized preserving open space and historic resources, with 21 miles of shoreline and numerous parks, most notably World's End Park and Wompatuck State Park.

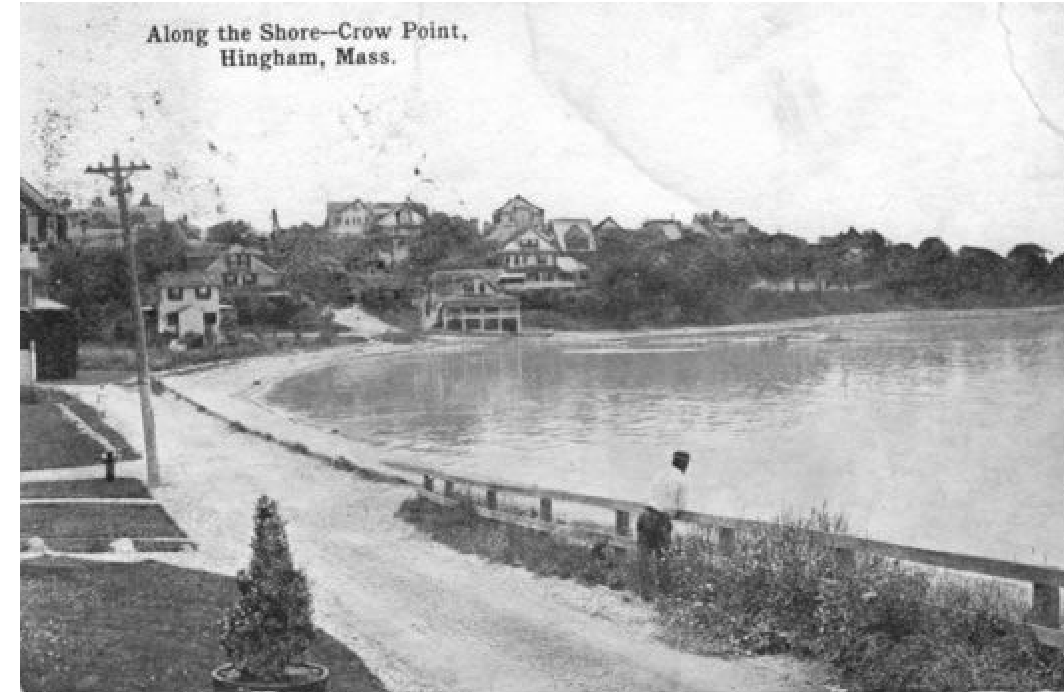
Hingham's connections to Boston via commuter rail, ferry, and Route 3A (a major road), as well as its strong school system and plentiful open space have made it one of the most affluent suburbs in the Boston metro region. Nevertheless, the town is challenged by a lack of affordable housing and an aging population. Hingham has a population of 22,000, and grew by 11% between 2000 and 2010. The current median age is 45, but the senior population is growing. Between 2000 and 2010, senior citizens increased by 55%, and the number of residents over 55 is expected to grow 47% by 2030. Its median household income is $125,144, and 50% of households' earn more than $100,000 per year, while only 20 percent of households earn less than $40,000 per year. The majority of residential units are single-family homes (75%), and owner-occupied (80%).[1] According to Zillow, the average value of homes in Hingham is $818,500 and prices are projected to increase 6.5% yearly.[2] Although the town is working to create additional affordable housing, many residents face housing cost burdens and spend more than 30 percent of their income on housing.

Hingham aims to safeguard its historic resources, particularly downtown, bolster its commercial tax base, protect critical infrastructure, and densify slightly while

Hingham Shipyard, 1949.
(Hingham Historical Society)

1 Cleargov.com. (2017). Town of Hingham Demographics. Retrieved from https://www.cleargov.com/massachusetts/plymouth/town/hingham/2017/demographics

2 Zillow. Hingham Home Prices and Values. Retrieved from https://www.zillow.com/hingham-ma/home-values/



Crow Point, Hingham.
(Hingham Historical Society)

Hingham Shipyard Marina
(docwa.com)

preserving its historic suburb look and feel. Most of Hingham's land area is devoted to single-family, owner-occupied detached homes on three-quarter to one-acre lots. Only 2.46% of the town is high-density residential. Combined with abundant open spaces, Hingham is low density overall. The town's main economic development goals are to encourage nucleated development downtown, around train stations, and build up the capacity of farther-flung commercial and industrial areas. The Downtown Hingham Overlay District aims to balance the city's historic attributes by encouraging mixed-use development, with commercial on the ground floor and office or residential above. The town proposes densifying housing near shops and transit to provide alternative housing options for middle-income people in older and younger age brackets. Economically, the town benefits from activity and development in its downtown, South Hingham, and Hingham Shipyard areas.[3] Nevertheless, residents worry that Hingham lacks a strong commercial tax base and has a high cost of living. Consequently, the town is trying to make it easier for businesses to open and prosper by making permitting and licensing processes easier and revising zoning regulations to encourage more small business development.[4]

Physical Vulnerability to Flooding and Adaptation Responses

Hingham experiences winter and coastal storms, extreme temperatures, and inland flooding. Notably, the town is protected from more extreme coastal storm surge and

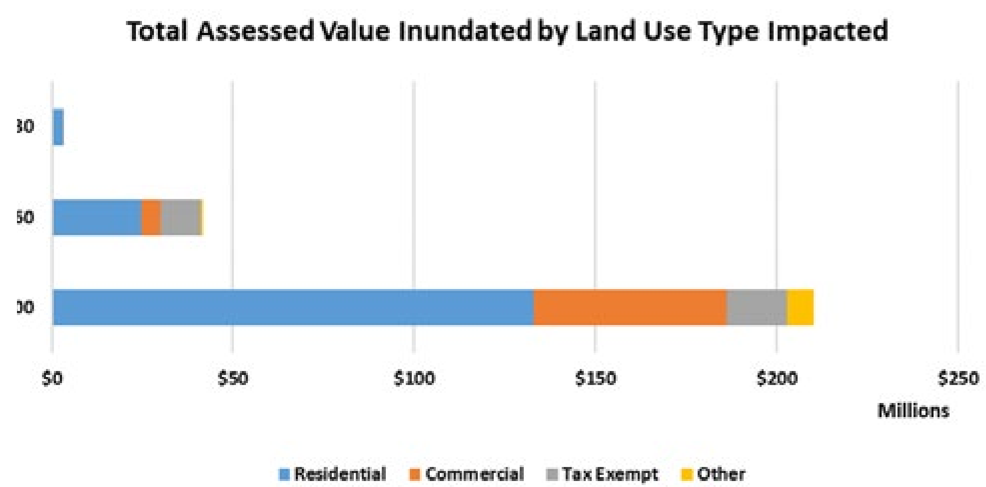


Figure 11: Total Inundated Assessed Value by Land Use Type in Hingham

3 Metropolitan Area Planning Council. (2014). Town of Hingham Hazard Mitigation Plan 2014 Update. Retrieved from https://www.hingham-ma.gov/DocumentCenter/View/2117/Draft-Hingham-Master-Plan-Update-PDF

4 Ibid.

Avalon Residences at Hingham Shipyard (hshassoc.com)

flooding by the peninsula of Hull and its own rocky shoreline. In recent years, major Nor'easter storm events have caused flooding and power outages, but the extent of the damage was not severe, and the town has been able to respond and recover quickly in emergencies. This is due, in part, to the fact that the town has its own municipal light plant. The town's stabilization fund, created in 2010, also allocates substantial funds for future storm events and disaster mitigation.

Local planners have proactively assessed climate vulnerability and taken steps to reduce flood risks. Local news articles make connections between the frequency and extent of the damage of intense storms and climate change, raising public awareness of climate impacts.[5] The town aims to acquire flood-prone vacant land and convert it into recreation and conservation areas. It also seeks to protect properties from flooding by enforcing zoning and building rules, protecting key infrastructure from harm, and educating residents on risks, especially with regard to new regulations that affect construction. The Shipyard developments and South Shore Industrial Park are in FEMA flood zones, though neither of these areas have experienced flooding recently. The 2016 updates to Hingham's Hazard Mitigation Plan ask that planners pay special attention to drainage in developments' flood zones to mitigatethe risk of future floods.[6]

Hingham's geography and growth characteristics make it less vulnerable to sea level rise. According to our analysis using the Union of Concerned Scientists (UCS) data, 1.26% of Hingham's total land area will be chronically inundated by 2030, a figure

5 Meyer, C.B. (2018, February 23). Hingham harbor wharf repairs to go before voters. Wicked Local Hingham. Retrieved from https://hingham.wickedlocal.com/news/20180223/hingham-harbor-wharf-repairs-to-go-before-voters

6 Metropolitan Area Planning Council. (2014). Town of Hingham Hazard Mitigation Plan 2014 Update. Retrieved from https://www.hingham-ma.gov/DocumentCenter/View/2117/Draft-Hingham-Master-Plan-Update-PDF

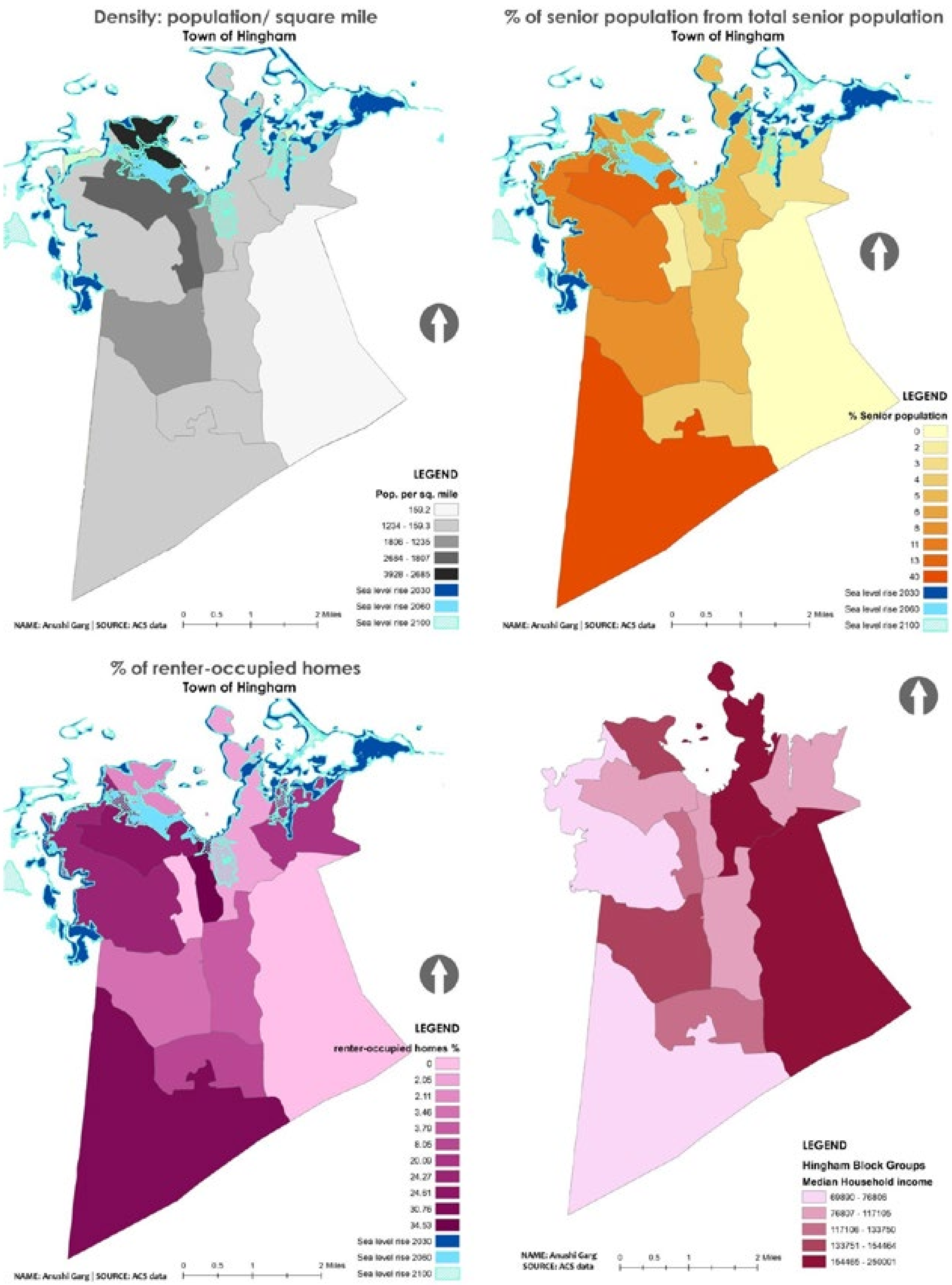


Figure 12: Social characteristics of Hingham (ACS 2018)

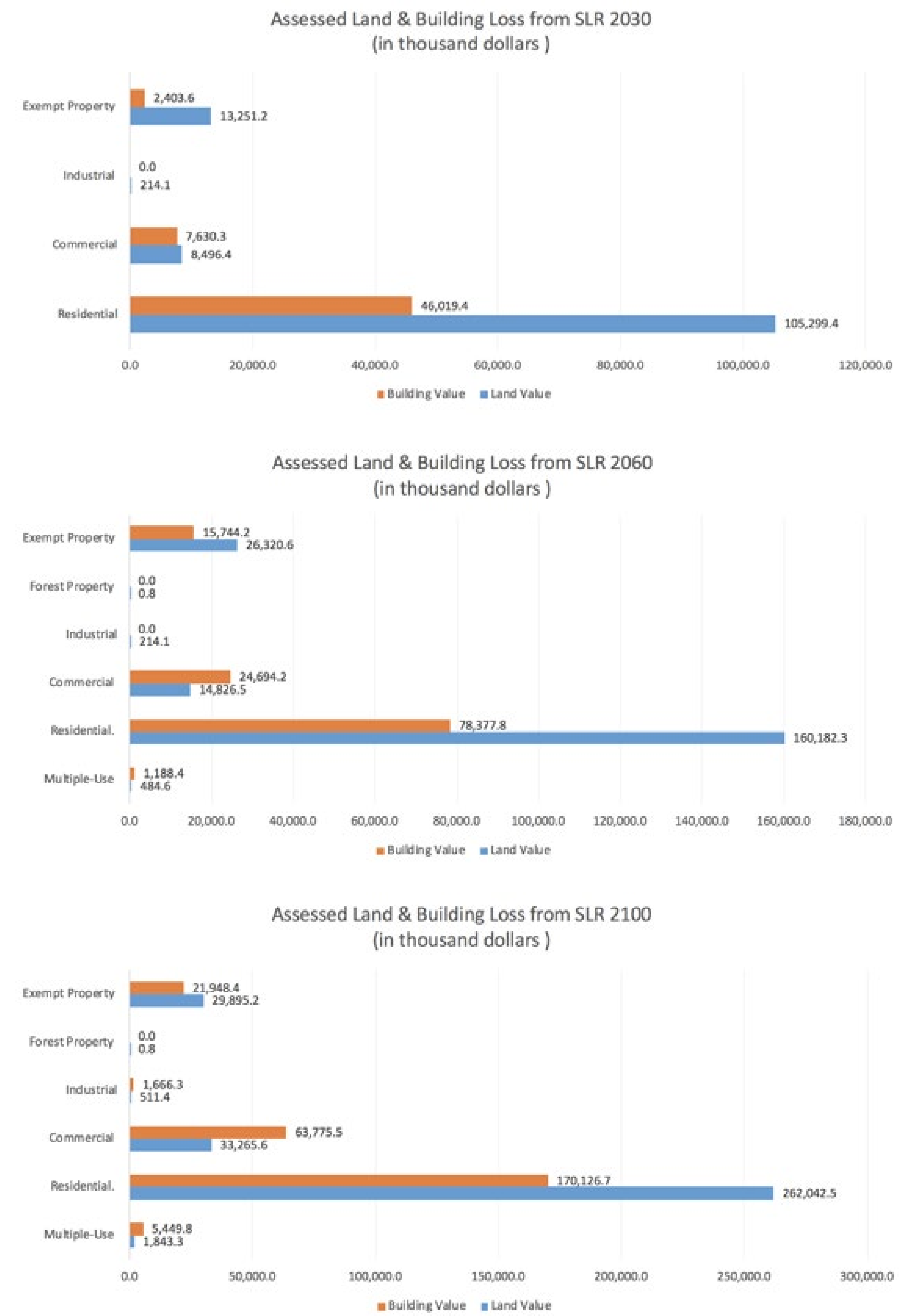


Figure 13: Assessed Value of Land and Building Loss from Sea Level Rise in Hingham in 2030, 2060, & 2100

which increases to 2.58% by 2060 and 5% by 2100. Infrastructure risks also increase exponentially over time. Less than half a mile of the town's 204 miles of road will be chronically flooded by 2030, a figure which increases to 3 miles by 2060 and 11 miles by 2100. The land inundated in 2030 is primarily open space (60%), followed by residential parcels (25%). Over time, residential properties account for more of the inundated land (Figure 13). This will impact Hingham's harbor and parts of its Main Street, where many businesses and higher-end housing are concentrated.

Social Vulnerability

Due to their high median incomes and high educational attainment rates, it is predicted that Hingham residents are better economically prepared for adaptation than their less wealthy and educated peers. Nevertheless, a projected rise in Higham's senior population and the density of development near the waterfront may increase the town's social vulnerability to climate impacts. Hingham's median age has risen to 45 from 43 over the past five years. By 2035, the town's senior population is projected to grow by 47%.[7] An aging population reduces the size of the workforce and increases vulnerability to storm events and flooding. The areas most impacted by sea level rise are located along the coast in north Hingham, which are predominantly single-family homes. These are also some of the densest populated areas of the town. In 2030, 15 buildings could be at risk, a figure which increases to 112 in 2060 and 393 in 2100.

On a positive note, the areas with the highest concentration of vulnerable populations will be less impacted by SLR. West and southwest Hingham hold about 35% of the population and contain 1,200 persons per square mile compared to 159 people per square mile on the east side (Figure 12). Compared to the rest of Hingham, east side residents have lower household incomes; the average household income is $70,000 annually. As Figure 12 shows, the western half of Hingham also holds a higher percentage of the total senior population and a greater proportion of renters.

Fiscal Vulnerability

Hingham's strong fiscal health increases its adaptive capacity to rising sea levels, yet its non-diversified tax base and amount of tax-exempt open space (18% of total land area) could constrain the town's ability to raise revenues to match rising adaptation expenditures going forward.

7 Metropolitan Area Planning Council. (2014). Town of Hingham Hazard Mitigation Plan 2014 Update. Retrieved from https://www.hingham-ma.gov/DocumentCenter/View/2117/Draft-Hingham-Master-Plan-Update-PDF

On the bright side, the town has enjoyed stable finances over the past decade. A wealthy tax base and high bond rating demonstrate Hingham's borrowing power and fiscal strength.[8] As sea levels rise, more than 70% of Hingham's residential properties will be submerged. This is a vexing problem since residential property taxes are the town's main revenue source. Figure 13 shows the breakdown of assessed land and building value lost from sea level rise in 2030, 2060, and 2100. According to our analysis, but while revenue losses are likely to be low (less than 1% of the 2016 town revenue by 2060, and 2% by 2100), expenditures for schools and infrastructure are likely to increase. According to the town's vulnerability assessment, adaptation costs are $555,000 at present, almost $29,600,000 to $40,600,000 by 2030, and $7,755,000 by 2070. The projected 2030 expenditures amount to 30-40% of the current budget.

Land Use Change

Hingham has a total of 3.6 square miles of vacant land, which comprises 16% of the town's total land area. However, much of this land is in the floodplain and unsuitable for development. From 2005 to May 2015, Hingham added over 2,500 housing units and 1.4 million square feet of commercial space. Through land use and zoning, Hingham can enhance the tax base in order to allow for the balanced mixed development of industrial and residential areas.

Conclusion

Hingham faces fewer impacts of SLR than the neighboring towns of Hull and Cohasset. With less low-lying land, more vacant land to build out, and a wealthy tax base that provides fiscal stability, Hingham is less vulnerable. Community members with less capacity to withstand climate change-induced hazards such as lower-income residents and senior citizens live further inland, away from flood-prone areas. The town's strong fiscal health can help to offset the costs of future adaptation. However, coastal residences are primarily and increasingly at risk, which will erode Hingham's capacity to generate revenue over time. In addition, critical areas of town are predicted to be impacted, such as the harbor front. Hingham will need to look at opportunities to enhance its tax base with an eye towards affordability to increase resiliency going forward.

8 Fitch Ratings. (2016, May 3). Fitch rates Hingham, MA's GO refunding bonds 'AAA'; outlook stable [Press release]. Retrieved from https://www.businesswire.com/news/home/20160503006899/en/Fitch-Rates-Hingham-MAs-Refunding-Bonds-AAA

LOCAL CONTEXT AND VULNERABILITY ASSESSMENT

Cohasset

Relative location of Cohasset within the study area

Summary

Despite its affluence, Cohasset's development and infrastructure patterns make it vulnerable to sea level rise. Figure 14 outlines some of these vulnerabilities, ranging from an aging population, to a relaxed building code, to repetitive disaster relief expenditures. The coastline is densely developed with large, stately homes. Cohasset's non-diversified tax base makes the vulnerability of the town's historic central business district and harbor of particular significance. There is limited road connectivity and public transit, as 23% of roads end in dead ends. Chronic inundation and storm flooding will make evacuations and service provision even more difficult in an emergency. Rising fiscal impacts from climate change will create a gap between revenues and expenditures for the town. With only 4% of undeveloped public land not at-risk, the scope of future development on government-owned land is limited. By working regionally, Cohasset has an opportunity to diversify its tax base to help achieve its economic development and resilience goals.

Overview of Cohasset

The town of Cohasset is located 25 miles south of Boston on the tip of the South Shore, where the Boston Harbor meets Massachusetts Bay. Cohasset was originally part of Hingham, until its valuable salt marshes were split up between landowners in 1647. By 1670, all of the land in Cohasset was divided among Hingham's proprietors. Fishing was a major industry in Cohasset, and from the 1840s-60s, the town had one of the leading fishing ports in the state. Cohasset then became a popular area for

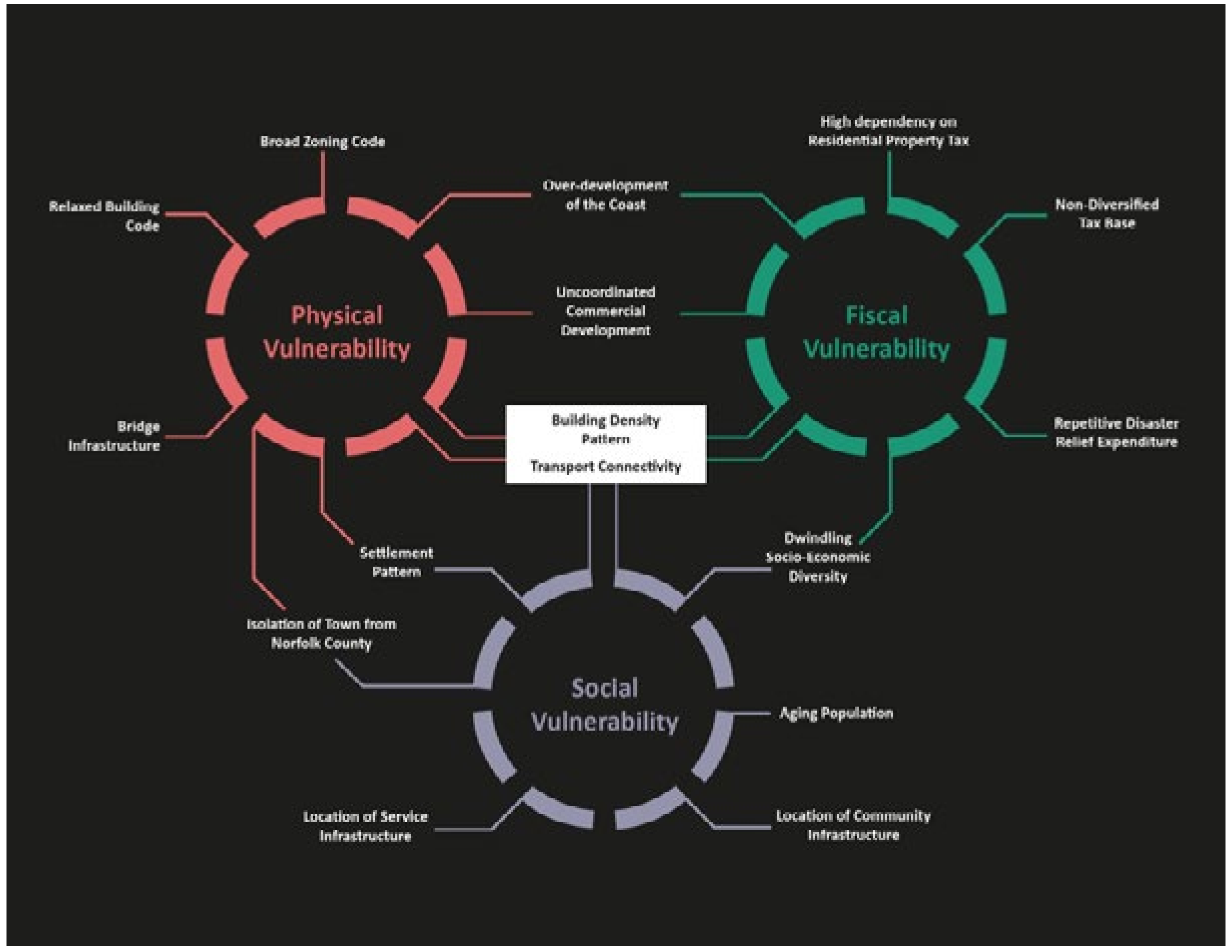


Figure 14: Cohasset's Physical, Fiscal, and Social Vulnerabilities

yachting, and has had a yacht club since 1894. When Boston and Gloucester's fishing industries overshadowed Cohasset's, the town's scenery made it an attractive place for summer residents, who built homes along the coast.[1]

Today, Cohasset, population 8,400, is one of the most exclusive suburban residential communities in Massachusetts. The town has a median household income of $140,000 per year. Residents are well-educated, as 39% have bachelor's degrees, and 34% have graduate degrees. Like Hingham, Cohasset residents' median age is 45.

The town features a dense, walkable village center with high-end shops and everyday services. It is home to a lively harbor and waterfront area east of downtown that is also the main economic hub for the community, and reflects Cohasset's heritage as a fishing village. This bedroom community's economy is primarily supported by retail, with a smaller proportion of its economic productivity generated in the healthcare, administrative, and professional scientific/technical services sectors. Commuting patterns also indicate that nearly 60% of its residents work outside of Cohasset.

1 Zillow. Hingham Home Prices and Values. Retrieved from https://www.zillow.com/hingham-ma/home-values/

South Main Street, Cohasset, 1917. (Cohasset Historical Society)

Sandy Cove, Cohasset. (Cohasset Historical Society)

Nearly 45% of Cohasset's current land area is devoted to residential development, and the town is home to some of the most expensive properties on the South Shore, as the coastal area south of Boston is known for its striking views. Most residents (around 70%) own their homes, and the average price of a single family home is $852,300. Average lot size is 92,500 square feet. Less than 10% of its geographic land area is assessed as having industrial, commercial, or agricultural uses—approximately 8% of which currently lies vacant. Reflecting local residents desires to maintain sensitive environmental and cultural resources, over 35% of the town's land area is protected, tax-exempt open space. The recent Open Space and Recreation Plan envisions the continued health and prosperity of a distinct community character as tied to the sensitive environmental resources that surround them.[2]

Relative to neighboring towns, Cohasset has had minimal development over the last 35 years. Expansion has been a low priority for residents as evidenced in the relatively flat population trends over time, and residents' desire to maintain the town's suburban character. The growth that has occurred since 1984 has also been restricted to a small portion of the town, along Route 3A. Planning and zoning documents indicate that these developments are almost exclusively commercial.[3]

2 Beals & Thomas, Inc. (2016). Cohasset Open Space & Recreation Plan. Retrieved from https://www.cohassetma.org/DocumentCenter/View/944/Adopted-Cohasset-Open-Space-and-Recreation-Plan-2010---2016

3 Amory Engineers PC. (2002). Town of Cohasset Massachusetts Zoning District Map. Retrieved from Cohasset Hazard Mitigation Plan, September 2012

Physical Vulnerability to Flooding and Adaptation Responses

Cohasset's residential areas are most affected by sea level rise. By 2100, 0.75 square miles of the 10-square mile town could be chronically inundated under a high carbon emission scenerio. This area includes almost 26% of Cohasset's land area that is currently zoned residential (Figure 15). The high projections[4] for 2030 and 2060 also indicate that a sizeable percentage of the town's residential areas could face serious flood risk over the next few decades (16% and 19% respectively) (Table 4). Although only 7 properties are at risk in 2030, this increases to 61 in 2060, and 199 by 2100. Most of Cohasset's commercial area, namely, the Village Business District, is also predicted to be flooded by 2100. Around 15% of commercially zoned areas are affected by FEMA flood designations, and an additional 7% are affected by sea level rise.

Year	2030	2060	2100
Land area inundated (sq. mi.)	0.24	0.42	0.75
Road inundated (mi.)	1.46	2.4	4.87
% inundation residential	15.76	19.12	25.98
% inundation commercial	2.43	2.87	8.11
% inundation industrial	0	0	0
% inundation open space	0	1.5	6.19

Table 4: Cohasset's Physical Vulnerability to Sea Level Rise under Projections of High Carbon Emissions (UCS, 2018)

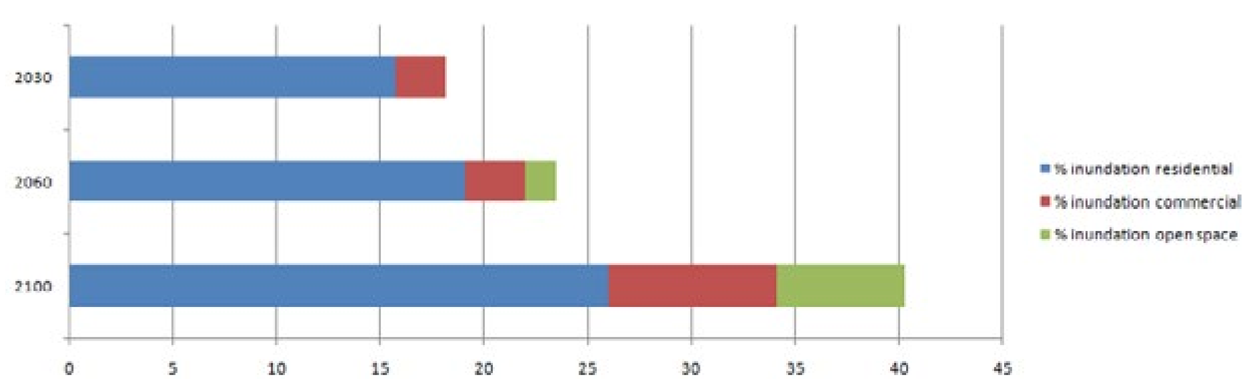


Figure 15: Current Land Uses in Cohasset Projected to be Chronically Inundated Over Time (UCS, 2018)

4 As stated in the introduction, the workshop used UCS's high sea level rise projections for the models.

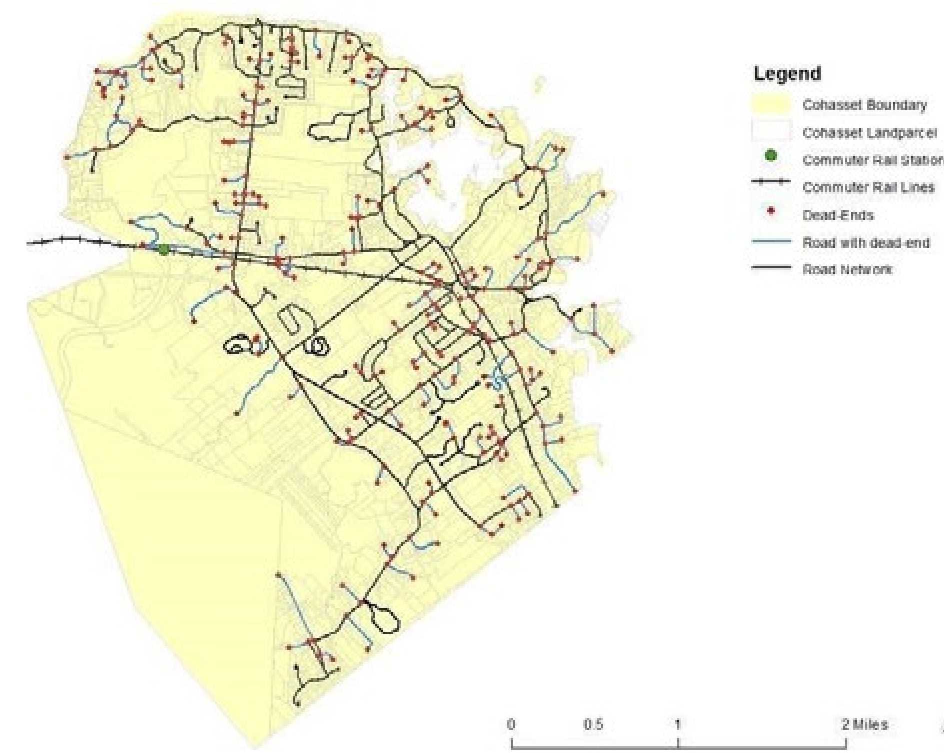


Figure 16: Dead End Roads in Cohasset

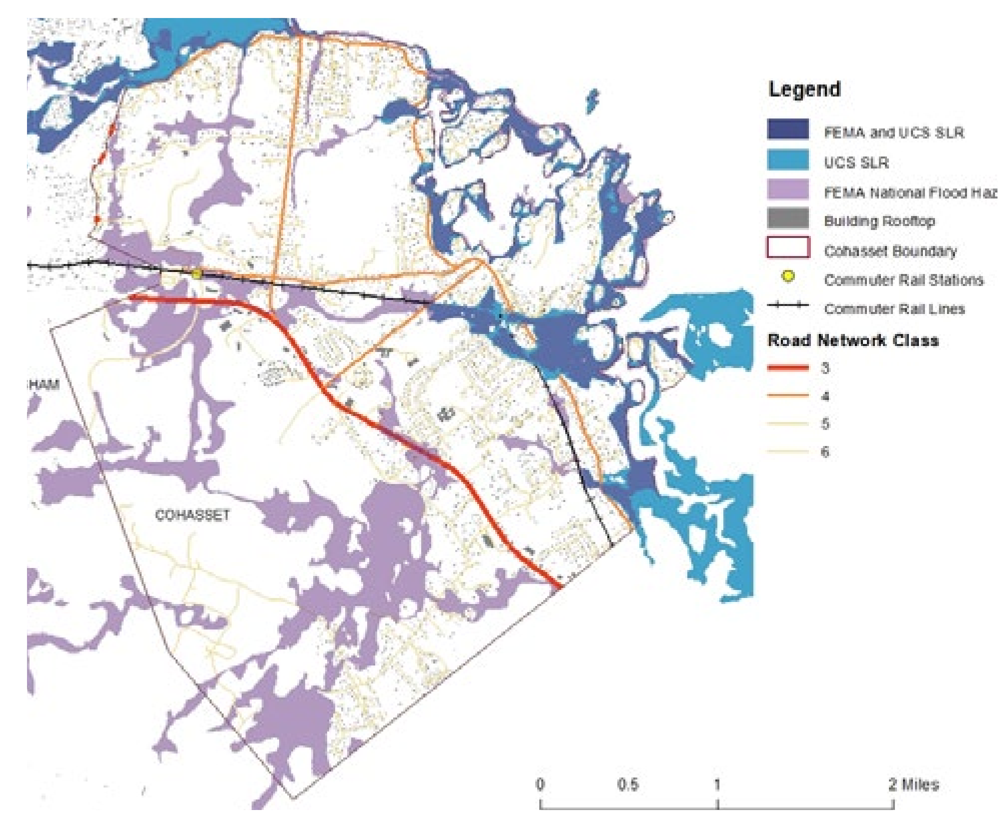


Figure 17: Road and Public Transportation Network at Risk of Flooding, Cohasset

Cohasset's road network increases its vulnerability in a storm event. The town has over 17 miles of dead-end roads (23% of total length of roads in Cohasset), presenting a concern for evacuations and rescue operations (Figure 16). By 2100, when combining FEMA floodplain maps and UCS predictions of sea level rise, 15.6% of all roads and 23.5% of the rail line could be inundated. This would seriously limit the town's connectivity to Boston (Figure 17).

Cohasset's current zoning and development patterns and the community's desire for a separation of land uses have delivered high density areas in the high risk zones along the coast, and left comparatively low risk land along the town's western boundary as protected open area. This arrangment reduces the town's potential capacity for adaptation and hazard mitigation.

Since 1991, the town has experienced 17 extreme weather events that resulted in federal or state disaster declarations, events with the potential to be exacerbated further by climate change.[5] Flooding, driven by hurricanes, Nor'easters, and other storms, presents the greatest hazard to the town, but the areas is also dogged by occasional drought and extreme temperatures.[6] Winter storms have had an outsized impact on the community.

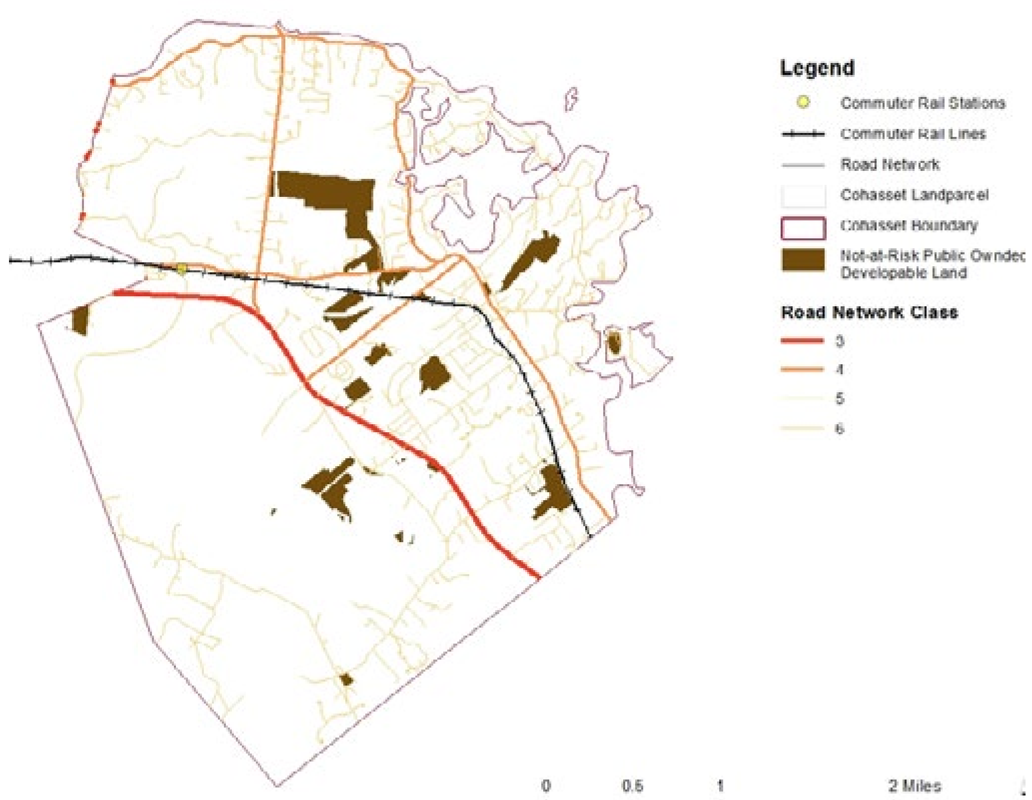


Figure 18: Public, Developable Land in Cohasset that is not at-risk to flood events

5 Metropolitan Area Planning Council. (2012). Town of Cohasset Hazard Mitigation Plan 2012 Update.

6 Ibid.

For example, during the winter storm of March 2015, Cohasset expended $440,000 on snow removal for the year, which was already $315,000 over the town's budgeted $125,000 for the year. Typically, during a 'bad winter' the town would previously expend $250,000, as reported by the Town Engineer.

Cohasset has been successful in identifying the risks to the community due to climate change. It revised and accepted its FEMA maps in 2017, then applied for and received grants under the state's Municipal Vulnerability Preparedness (MVP) program to participate in a Community Resilience Building (CRB) Workshop for local stakeholders.[7] The CRB team identified natural resources;civic engagement, strong communications and elder services, as well community resources and infrastructure as Cohasset's main adaptation strengths. Going forward, top adaptation priorities include developing reliable power sources in conjunction with neighboring towns, increasing coastal flooding protection measures, accounting for SLR in town permitting and planning, and increasing emergency response times. Implementation strategies have yet to be developed, however.

Social Vulnerability

Cohasset's high household median income and low poverty rate mean that its residents have higher adaptive capacity to the impacts of SLR. Nevertheless, its large senior population, low coastal road connectivity, and high coastal exposure to flooding could pose risks for these groups. Around 10% of households in Cohasset (approximately 300 households) are seniors living alone. This requires the town to consider the dynamics of household types to plan for and provide emergency services effectively.

Fiscal Vulnerability

Cohasset's financial health is strong.[8] The Board of Selectmen attribute the town's to ongoing and consistent contributions to its reserve fund. The reserve allows the town to fund its own bond advances, pay cash for small capital projects, and sustain cash flow. Cohasset's cash reserve also protects its AAA bond rating, which will reduce interest costs for large capital projects in the long term.

However, sea level rise has direct implications for the local municipal tax base given that residential property comprises over 88% of total assessed land value in Cohasset. In the 2017 fiscal year, 83% of the Town's revenue came from property taxes. The tax levy from a total of 2,698 residential parcels is approximately $29.5 million,

7 Metropolitan Area Planning Council. (2012). Town of Cohasset Hazard Mitigation Plan 2012 Update.

8 Cohasset Visual Budget. (n.d.) Town Budget Visualised. Retrieved from http://www.cohassetvisualbudget.org/revenues/2019/l/6a1391c8

or 65% of the town's total annual revenue stream. Using FEMA and UCS data, by 2100 nearly 200 homes will be inundated by sea level rise, valued at $203 million dollars today. This represents 5% of the total 2016 budget and 8% of the 2016 tax levy.

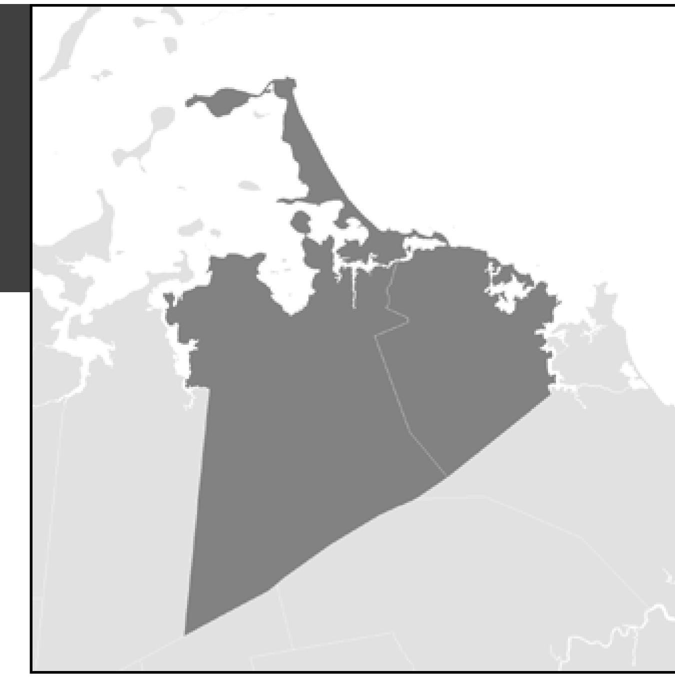
Land Use Change

The scope for future development in Cohasset is limited, as only 0.38 square miles of land is vacant, developable, and not at risk from SLR (Figure 18). Cohasset is 74% built out, which greatly limits the municipality's ability to use development to recoup losses to the tax base. In looking at the minimal development and relatively flat population trends over the past 35 years it becomes clear that growth has not been a priority for the Town. Cohasset's 2012 Hazard Mitigation Plan recognizes limited future growth possibilities, given the amount of land tied up in wetlands, floodplains, and State Park, yet sets a goal to encourage growth in areas not prone to natural hazards, and identifies four areas that have development potential. These are primarily marked for housing subdivisions.

Conclusion

Cohasset's development patterns put it at risk from sea level rise. Its densely developed coastline, with a high concentration of wealth single family homes, puts the tax base at risk. In addition, its areas of concentrated commercial development, the historic downtown and central business district, will be impacted by 2030 and 2060 respectively. Its road network lacks connectivity, and sections of public transit and critical infrastructure will be inundated. This is of particular significance for the town's senior population. The fiscal impact increases over time, leading to a predicted gap between revenues and expenditures. Regional collaboration could enable the community to achieve its economic development goals and diversify the tax base.

Synthesis of Regional Vulnerability and Scope for Adaptation



Summary

Hull, Hingham, and Cohasset have varying levels of vulnerability to climate change-induced sea level rise, based on each town's fiscal conditions, demographics, and physical geography, as outlined above. All three rely primarily on property taxes for revenue generation and face ever-increasing risks and fiscal gaps as sea levels rise to flood properties. However, Hull is the most vulnerable to SLR of the three towns, due to its low-lying geography and higher concentration of senior citizens and lower income residents. By comparison, Hingham and Cohasset's relative fiscal health and significant amount of open space diminish their vulnerabilities. Figure 19 maps chronic inundation in 2030, 2060, and 2100 in the three towns, illustrating Hull's vulnerability. Figures 20 and 21 show Hull's tax levy to be the most at risk, as well as its budget to be the most impacted, followed by Cohasset and Hingham. Relative to their wealthier neighbors, Hull residents have less adaptive capacity and will therefore be disproportionately negatively impacted by climate change-induced sea level rise.

Numerous critical infrastructure and utilities are at risk across the three towns. According to the 2018 Massachusetts Property Type Classification Codes,[1] there are 32 parcels for telephone, water, sewer, and other utilities in Hingham, Hull, and Cohasset. Figure 22 shows some of the utility properties that were affected by chronic inundation and storm flooding. While we don't know the extent of the share of critical infrastructure between the three towns at present, it is possible to envision a future where utilities are sited to minimize risk.

Regional collaboration presents opportunities for all three municipalities. In terms of existing local agreements, Hull tends to have most of its interlocal interaction with Hingham and Cohasset. Currently, the three towns share their water and sewage services. In

1 Commonwealth of Massachusetts Department of Revenue, Division of Local Services. (2016). Property Type Classification Codes. Retrieved from https://www.mass.gov/files/documents/2016/08/wr/classificationcodebook.pdf

addition, inland towns have many more opportunities for redevelopment. The three towns' redevelopment plans envision more housing diversity, age and wealth diversity, promoting affordable housing, and improving compact, Transit Oriented Development based growth. Cohasset in particular also needs to redevelop its downtown to move away from the coast. The Regional Rail line in Cohasset and Hingham is at risk, so rerouting it further inland could be necessary. Bundling projects and people could provide the density required to merit future investments in redevelopment measures. Finally, inland towns are also far wealthier than Hull, and merging municipalities, services, or otherwise sharing wealth could improve the access to schools and services for Hull residents.

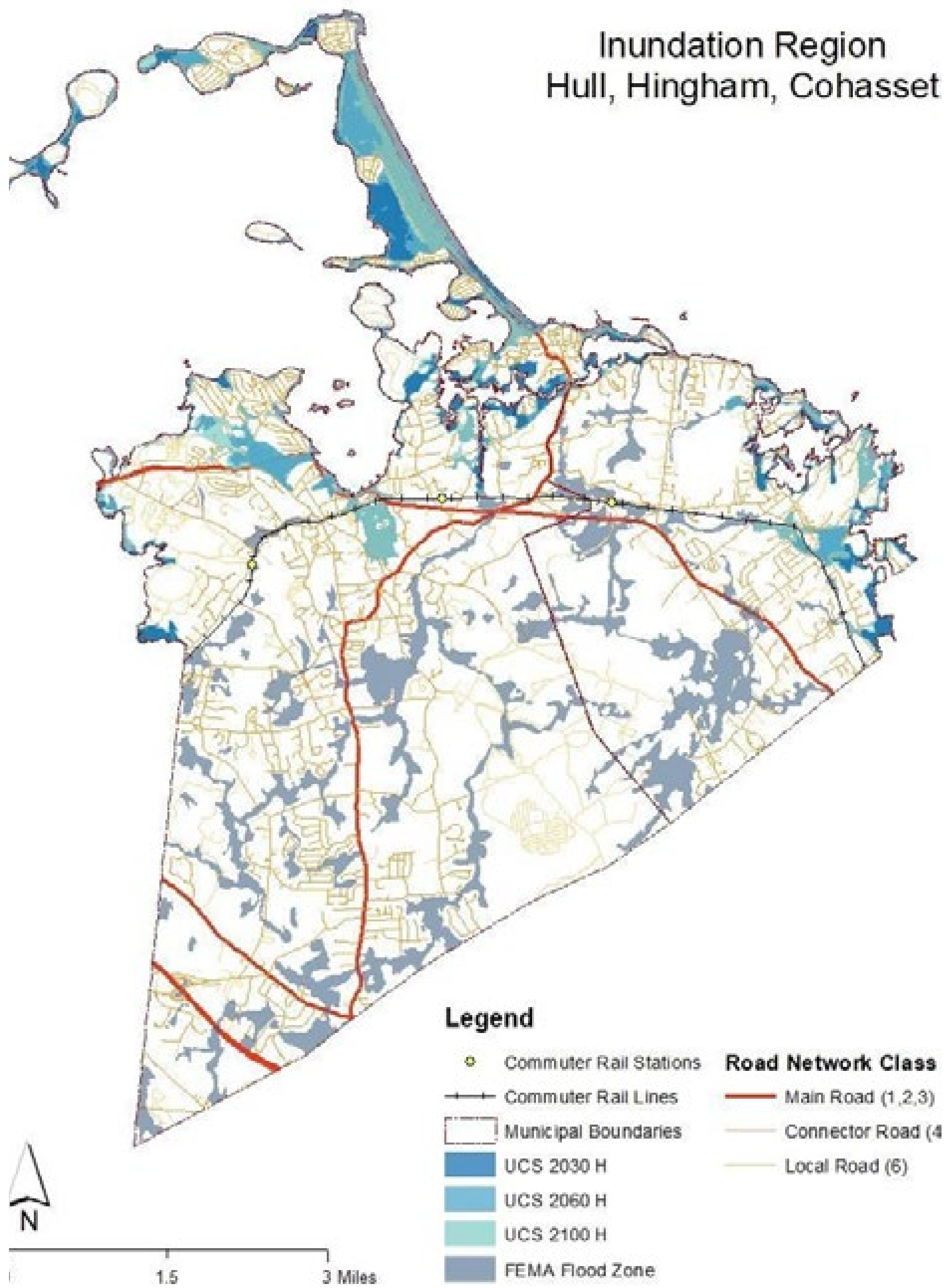


Figure 19: Inundation Areas in Hull, Hingham, and Cohasset

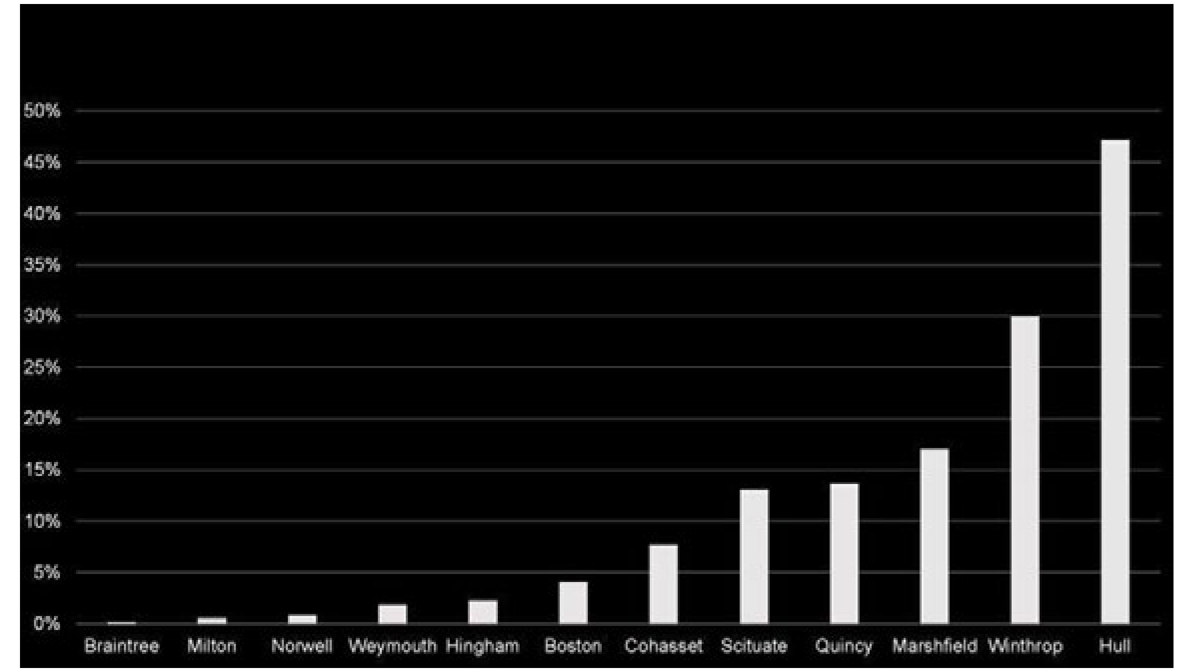


Figure 20: Percent of Tax Levies Impacted by SLR in 2100 across the South Shore

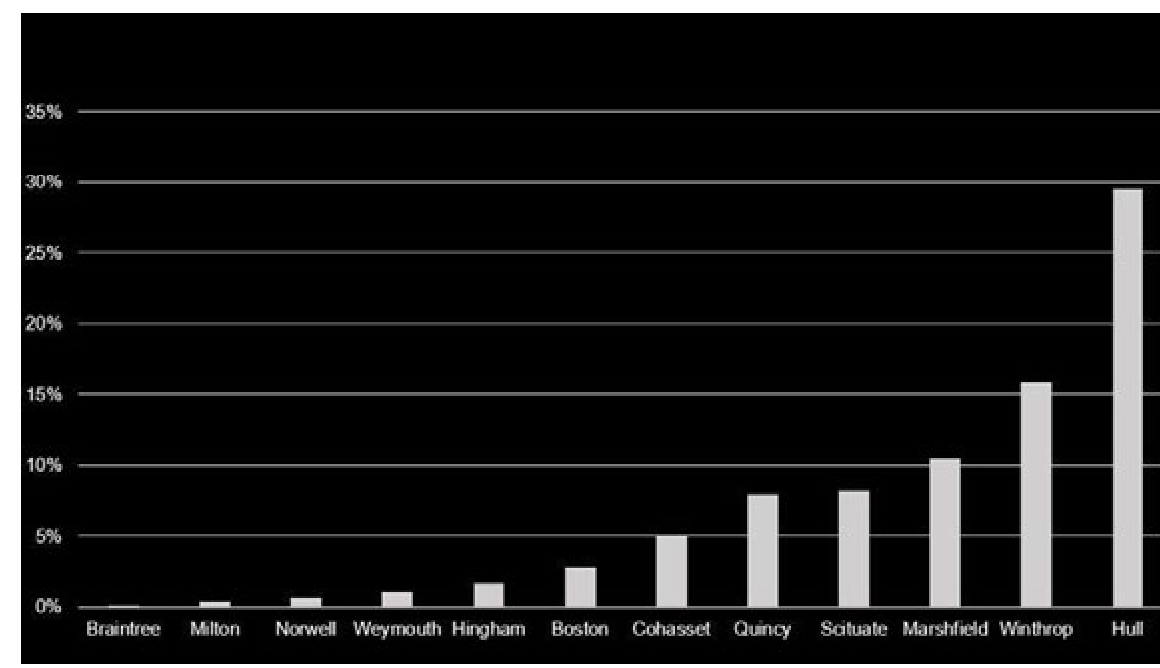
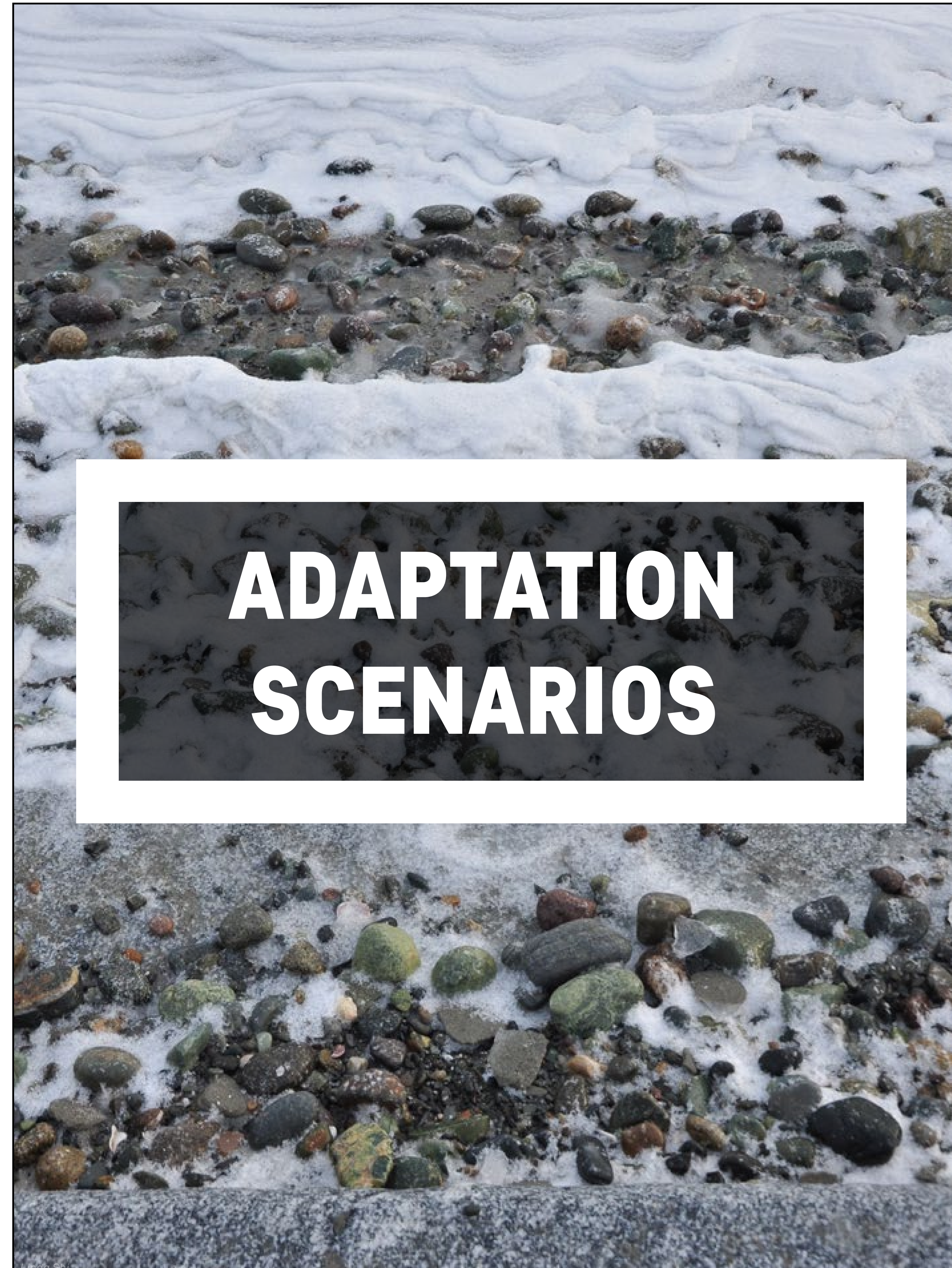


Figure 21: Percent of the Budget Impacted by SLR in 2100 across the South Shore

Figure 22: Utilities at Risk to Flooding in Hull, Hingham, and Cohasset



ADAPTATION SCENARIOS

We spent considerable time discussing which scenarios to evaluate, and at what scale, in what combination, in consultation with MAPC and local partners. First, for the sake of feasibility within the workshop's semester timeframe, we decided to focus our evaluation of scenarios on Hull. Partners in Cohasset and Hingham recognized that models developed for Hull would be readily applicable to their contexts. Early on, we determined that a "do nothing" scenario was not acceptable and didn't reflect reality. If Hull does nothing, it stands to lose nearly half its land and tax revenues, which would significantly impact its residents, environment, and ability to provide basic services. Moreover, Hull's leaders have been proactively amending zoning policies, seeking out coastal restoration grants, and pursuing flood mitigation. Far from doing nothing, town leaders are using every recommended tool available.

We also considered (but put aside) evaluating investments in coastal armoring. In 2018, the University of Massachusetts Boston released a study commissioned by the City of Boston evaluating the feasibility of a harbor barrier. The report analyzed three alignments of such a barrier, one of which would have placed a massive seawall down the main street running through Hull. The report found that a harbor barrier would take too long and cost too much money to build, and that by the time of its completion it would have to close too frequently to satisfy the Port of Boston, or have to open too often for the engineered structure to work properly.[1] During our field visit, we also found out that Massachusetts no longer permits the construction of new seawalls; it only permits raising old seawalls. Thus, seawall construction is not a feasible strategy for most newly vulnerable sites. Hingham has experimented with different models of coastal protection like sand dunes, elevated seawalls, piled stones (see below), but each posed their own challenges. We decided to leave aside scenarios involving armoring, both because others were evaluating these options and because of their infeasibility.

In the end, we identified three distinct scenarios (though they are not necessarily mutually exclusive). Each of the following sections summarizes the scenario's findings, its assumptions, methods, outcomes, and policy implications.

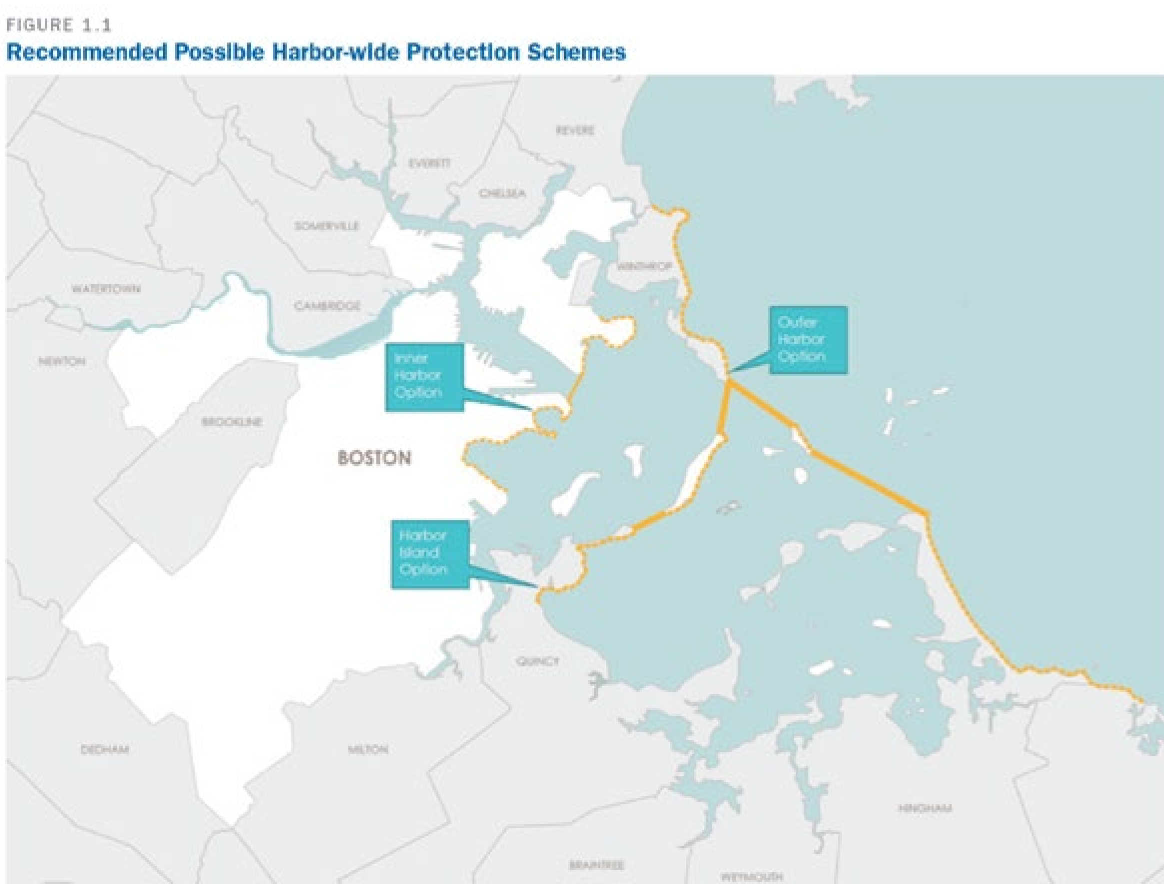


Figure 22: Possible Harbor-wide Protection Schemes for the Boston Metro Area (Climate Ready Boston, 2016)

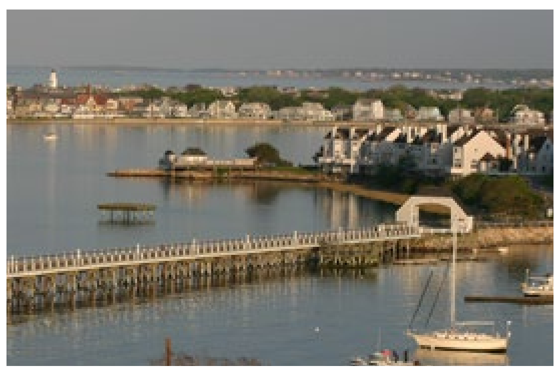
Seawalls in Hingham (top left) and Cohasset (top right) and sand dunes in Hingham (bottom) (Linda Shi)

1 A coalition of municipalities around Boston Harbor (but not including Boston) have since decided to pursue alternative assessments to see if this may be effective from their perspectives.

(Patsy Lynch/FEMA)

Scenario 1: Elevate and Micro-Protect

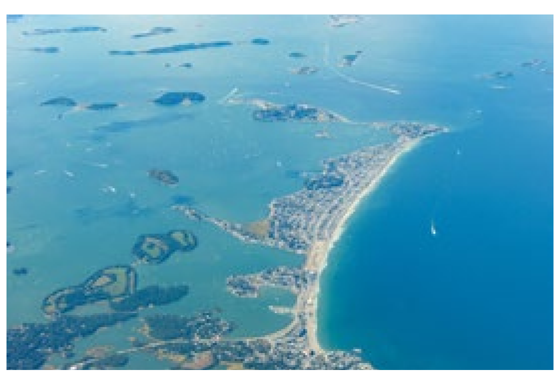
The first scenario evaluates efforts to reduce flood risks by elevating homes, elevating roads, ringing vulnerable utilities and public facilities with protective walls, and nourishing Hull's beaches. It offers an incremental approach with few drastic policy changes.



(David Brunke/Flickr)

Scenario 2: Accommodate and Densify

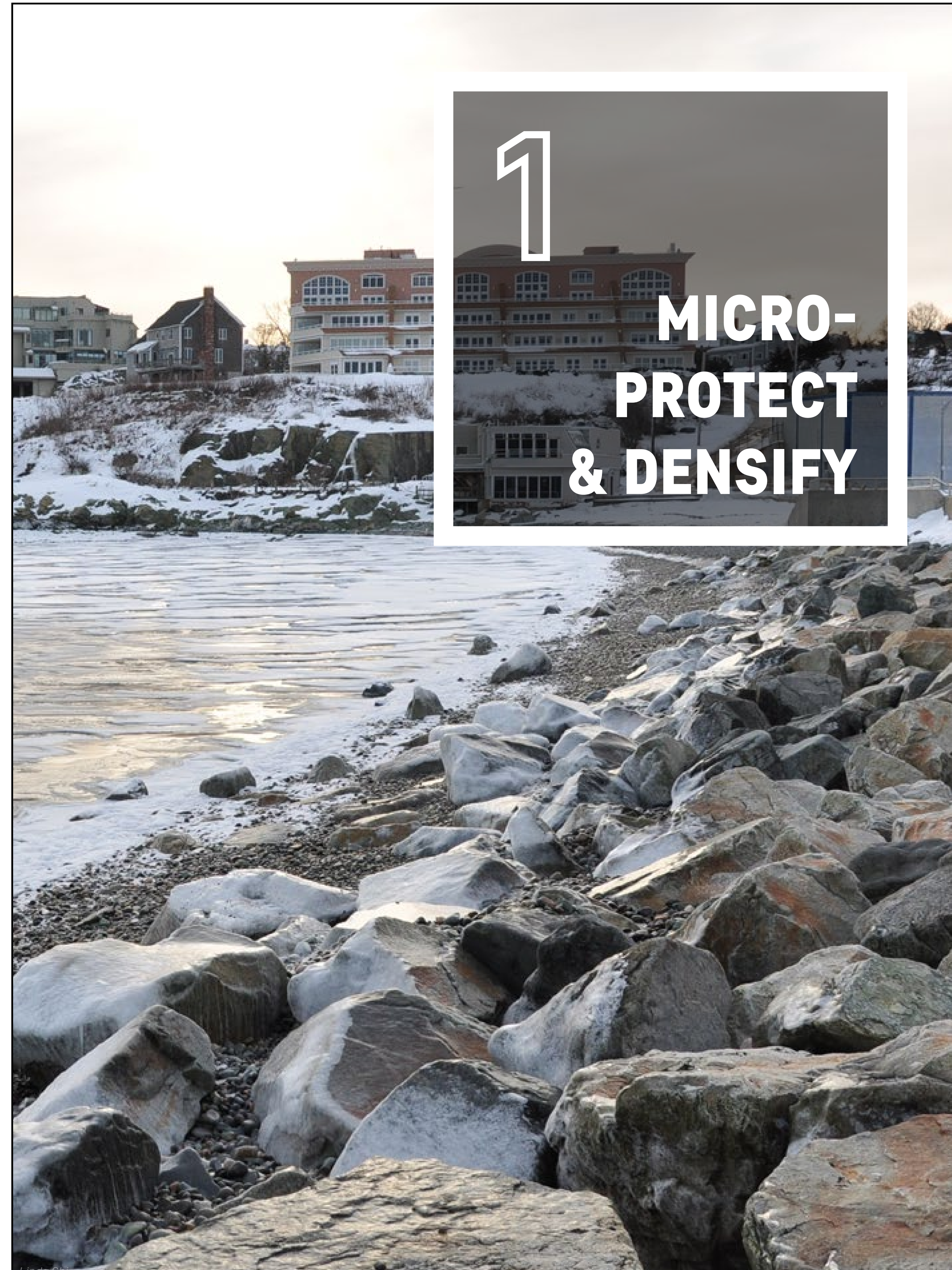
A second scenario evaluates retreating from flooded areas and accommodating residents either in more dense developments further inland in Hull or in surrounding towns. It reduces repetitive losses and flood risks but requires significant social and physical disruption.



(Eric Kilby/Flickr)

Scenario 3: Retreat to Restore

Finally, the third scenario estimates the costs and benefits of relocating Hull residents away from the flooded areas or even the entire town regardless of flood risk and adding the peninsula to the Boston Harbor Islands National and State Park. This proposal is perhaps the most ecologically ideal option, but clearly poses significant monetary and social costs.



Introduction

This scenario proposes that residents adapt by elevating and protecting critical infrastructure so that the community can remain in place. This approach is the most conservative and pragmatic of the three explored in the workshop. Changes must be made on an incremental basis in advance of projected impacts in order to safeguard residents. This strategy is the most politically feasible in practice because it relies on tested adaptation measures that can be implemented within existing land use regulations and financial mechanisms. Here, we considered the cost of elevating single-family homes out of the flood zone, the cost of raising roads 11 feet, and the cost of flood-proofing and adapting critical infrastructure.

We estimated that by 2060, owners of single-family homes will need to invest over $145 million in home elevation to lift their properties out of the chronic inundation zone. The municipality would have to spend about $92.6 million on the same timeline to raise roads and approximately $6.2 million to raise critical infrastructure. It is important to note that this is a low estimate, as we did not include other costs such as adapting drainage, septic systems, underground oil tanks, and electricity infrastructure and water. We also did not consider the increased maintenance costs of elevated structures.

These are massive sums for a town of 10,300 with a median household income of almost $81,000. It is unclear how Hull and residents would pay for these improvements if current resilience funding limitations persist. Existing funding sources include local property tax, private investment of homeowners in their properties, state grants, and FEMA grants. Property taxes are currently 70% of Hull's town budget and are capped by Proposition 2 ½.

The findings suggest that improvements to town-owned infrastructure exceeds the capacity of the municipality to pay for these changes by itself. Only higher-income residents may be able to elevate homes while keeping up with mortgage payments and property taxes. This approach has serious equity implications for Hull, especially given its large number of senior residents on fixed incomes. Under this scenario, it is likely that they would be displaced financially before being displaced physically by sea level rise.

Scenario Description & Assumptions

This scenario estimated what level of investment would be needed in Hull to protect critical infrastructure, roads, and single-family homes from inundation if the highest sea level rise by Union of Concerned Scientists (UCS) projections at 2030, 2060, and 2100 prove to be accurate. This approach takes a local, parcel-by-parcel, block-by-block look at improvements to the built environment. For ease of calculation, it assumes that current land values and adaptation costs will be stable at 2019 dollars and that state, federal, and local funding for adaptation measures will remain consistent. The strategy also relies on 2019 population data.

Our analysis should be considered as a thought exercise and a framework, and therefore our cost estimates represent rough estimates. There are several areas not accounted for in our research. Water, sewer, and utilities network disruption were not taken into account, as well as possible disruptions to parks and other public assets. We did not have a mechanism for costing relocation of commercial buildings or equipment, and therefore we do not consider relocating commercial or municipal properties. In addition, we rely on increased property taxes for residents, which potentially would exceed Massachusetts' residential property tax cap (i.e. Proposition 2 ½).

This scenario assumes that present-day institutional frameworks will not change substantially through the end of the century. These include the primacy of individual property rights, home rule and municipal independence, and the allocation of funds for major public works projects. We therefore estimate costs for adaptive measures that reflect institutional commitment to these values, and therefore assume rational buyers will factor these costs into the value of homes, roads, and critical infrastructure.

Private investment in homes reflects commitment to individual property rights that is a benchmark of American culture and the American dream. Single-family homes are among the easiest structures to elevate and they comprise the majority of Hull's housing, so our analysis identifies the number of single family homes, as opposed to multifamily and apartment buildings, which would need to be elevated by the years 2030, 2060, and 2100. We assume that private property owners will leverage their own capital for home elevation, and that the town will rely on its revenue, as well as grants from FEMA and the Commonwealth, to floodproof its infrastructure.

We assumed there would be no substantial change in the government arrangements in terms of local control and responsibility to levy and collect property tax and raise funds to pay for infrastructure repair. This means that local governments maintain autonomy over their budgets (i.e. no commonwealth-appointed emergency manager or other state takeover of budgets). Local governments will continue to compete for funding from the Commonwealth and FEMA. This analysis relies on MAPC's summarized version of the Massachusetts Land Parcel Database, UCS chronic inundation projections, MassDOT road data, and a 2016 vulnerability assessment produced by private consulting firm Kleinfelder for Hull.[1] According to the Mass DOT storm surge data, roads need to be raised 10'–12' above the base flood elevation (BFE) to be viable during an inundation event in 2100. Using the Kleinfelder report, we assess the critical infrastructure that is jeopardized by chronic inundation.

1 Martecchini, A., Brahim, N., & Bosma, K. (2016). Coastal Climate Change Vulnerability Assessment and Adaptation Study: Town of Hull, MA. Cambridge, MA: Kleinfelder. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/hullcl_1.pdf

Research Methods and Scenario Outcomes

Our research primarily uses spatial land use analysis to assess levels of inundation at three future intervals to determine the level of investment needed to preserve key elements of the built environment. The maps in Figures 23, 24 and 25 show the extent of predicted chronic inundation over time.

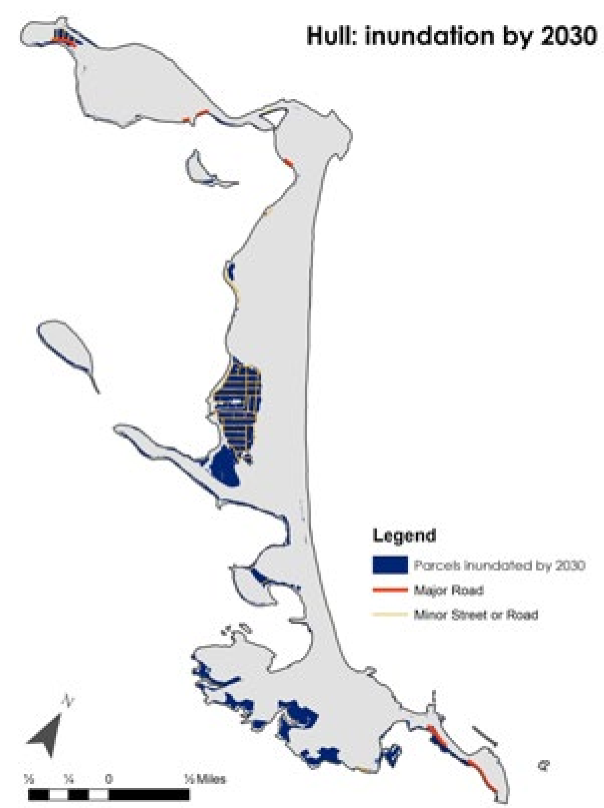


Figure 23: Inundated infrastructure in Hull by 2030

Critical Infrastructure

A crucial part of our scenario was to calculate the cost of potential infrastructure losses due to chronic inundation in the years 2030, 2060 and 2100. For this, we project UCS chronic inundation data on the infrastructure facilities of Hull to determine which would be subject to chronic inundation at each interval. Excluding roads, the following utilities, public facilities, and green infrastructure were included in our calculations:[2]

Adaptation Measure	Location	Unit Cost
Flood wall	Hull High School	$650,000
Elevation	Windmill 1	$150,000
Flood proofing, elevation	Wastewater pump station 9	$300,000
Flood perimeter wall	Sewer plant on Nantasket/ Spring Street	$3,000,000
Flood panels	Memorial Middle School: Alt 1	$184,000
Flood wall	Memorial Middle School: Alt 2	$442,000
Flood wall	A Street Fire Station	$300,000
Berm	Wastewater pump station 6	$55,000
Flood wall	Wastewater pump station 6	$102,000
Wet flood proof	Municipal Light Department	$50,000
Dry flood proof	Municipal Light Department	$100,000
Flood walls and other flood proofing	DPW barn and salt shed	$500,000
Beach nourishment study	North Nantasket Beach	$175,000
Beach nourishment	North Nantasket Beach	$25,000,000
Total		**$31,008,000**

Table 5: Adaptation measures and costs for Hull critical infrastructure. (Martecchini et al. 2016)

The suggested steps included dry and wet floodproofing walls and barriers, and construction of flood walls and gates to prevent the entry of water. In reality, upgrading might require more major and permanent steps, such as replacement of equipment. In several cases, the repeated flooding or force of water may cause breakage in these floodwalls.

The report by Martecchini et al. for Kleinfelder, from which we derived these figures also includes segments on beach renourishment and green infrastructure, which we included in our cost analysis.

Single-Family Homes

Since we only calculate inundation of single-family homes, we assumed that there is one parcel per home. Calculations also include parcels that are partially inundated (i.e. a parcel is counted if even a small portion of the parcel is in the inundation zone).

Chronic Inundation	Inundated Parcels	Inundated Single-Family Homes	Single family homes as % of inundated parcels
UCS today	894	684	76.51%
UCS 2030	1,048	816	77.86%
UCS 2060	2,027	1,610	79.43%
UCS 2100	3,289	2,562	77.90%

Table 6: Total number of inundated parcels and number of single-family homes subject to chronic inundation.

Chronic Inundation	Major Road (miles)	Minor Road (miles)
UCS today	0	4.7
UCS 2030	0	6.5
UCS 2060	0	16.86
UCS 2100	0.52	34.69
Total	**0.52**	**34.69**

Table 7: Total inundated linear miles of inundated state and local roads.

2 Our selection of critical utilities in this section relied on the study by Martecchini et al. for Kleinfelder (2016). See Town of Hull. (2016, June 30). Martecchini, A., Brahim, N., & Bosma, K. (2016). Coastal Climate Change Vulnerability Assessment and Adaptation Study: Town of Hull, MA. Cambridge, MA: Kleinfelder. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/hullcl_1.pdf

Our analysis does not include commercial buildings or multifamily housing.

By 2100, more than 2,500 single family homes could be chronically inundated and thus eligible for elevation. That figure comprises almost 78% of total parcels that could be chronically inundated during this time. This percentage of single family homes as a share of total inundated properties is relatively stable over time.

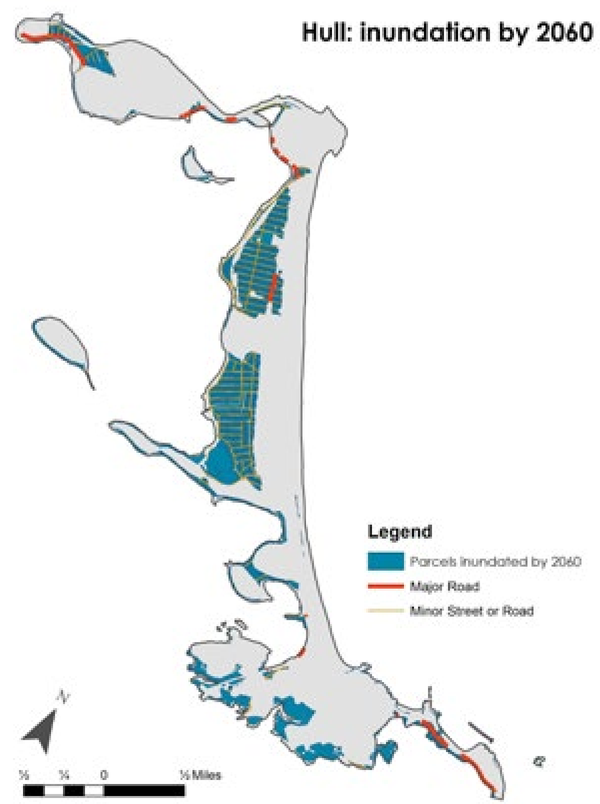


Figure 24: Inundated infrastructure in Hull by 2060

Roads

To price out road elevation by 2030, 2060 and 2100 we examine where the town's existing road network intersect with UCS chronic inundation projections. The resulting output was the miles of roads inundated at each time period. For local roads,[3] we separate major and minor roads according to MassDOT classifications. This is necessary because the cost of elevation of major and minor roads varies due to the grade of construction as well as road width. The process was repeated for all three time intervals:

By 2100, about 35 miles of minor roads and a half-mile of major roads (e.g. Nantasket Avenue) could be chronically inundated. To estimate road elevation costs, we use figures from the report by Martecchini et al. for Kleinfelder, to obtain the per unit cost of upgrading major and minor roads. Per its calculations, elevating a minor road would cost $5,016,000 per linear mile ($950 per foot), while elevating a major road like Nantasket Avenue would cost $10,032,000 per linear mile ($1,900 per foot). We then mulitply the unit costs by the length of road inundated to get the total cost of road elevation in 2030, 2060 and 2100. Based on the Kleinfelder report, we assume that roads would have to be elevated to a median height of 11 feet. This approach does not account for network disruption, which if included would have a far greater impact on travel within and through Hull.

Besides infrastructure, home, and road elevation, there are some other critical infrastructure services that would have to be upgraded for Hull to function continuously. Although these costs could be expensive, we restrict our scenario to the information we had available, and provide minimum figures.

3 In our calculations, 0.52 miles of Massachusetts Route 228 fell within the 2100 chronic inundation projection for Hull. In Hull, Route 228 segues into Nantasket Avenue (Hull's main street), so we classified this portion of the road as a major local road for our cost analysis.

				Phase of investment				Year			
Adaptation measure	Location	Unit cost	Units/miles	2019	2030	2060	2100	2019	2030	2060	2100
Total home elevation		$ 145,022	2708	57.64%	5.43%	36.93%	0.00%	$ 226,363,523	$ 21,324,669	$ 145,031,313	$ -
Raise road 11'	Nantasket Avenue	$ 10,023,919	6.30	0.00%	0.17%	99.83%	0.00%	$ -	$ 107,356	$ 63,043,332	$ -
Raise road 11'	Local roads	$ 5,290,402	34.69	32.29%	48.47%	19.24%	0.00%	$ 59,259,910	$ 88,954,098	$ 35,310,024	$ -
Total road elevation		$ 15,314,320	40.99					$ 59,259,910	$ 89,061,454	$ 98,353,356	$ -
Flood wall	Hull High School	$ 685,558	1	0%	100%	0%	0%	$ -	$ 685,558	$ -	$ -
Elevation	Windmill 1	$ 158,206	1	0%	0%	0%	100%	$ -	$ -	$ -	$ 158,206
Flood proofing, elevation	Wastewater pump station 9	$ 316,412	1	0%	0%	0%	100%	$ -	$ -	$ -	$ 316,412
Flood perimeter wall	Sewer plant on Nantasket/ Spring Str	$ 3,164,116	1	0%	100%	0%	0%	$ -	$ 3,164,116	$ -	$ -
Flood panels	Memorial Middle School: Alt 1	$ 194,066	1	0%	100%	0%	0%	$ -	$ 194,066	$ -	$ -
Flood wall	Memorial Middle School: Alt 2	$ 466,180	1	0%	0%	100%	0%	$ -	$ -	$ 466,180	$ -
Flood wall	A Street Fire Station	$ 316,412	1	0%	100%	0%	0%	$ -	$ 316,412	$ -	$ -
Berm	Wastewater pump station 6	$ 58,009	1	0%	100%	0%	0%	$ -	$ 58,009	$ -	$ -
Flood wall	Wastewater pump station 6	$ 107,580	1	0%	0%	100%	0%	$ -	$ -	$ 107,580	$ -
Wet flood proof	Municipal Light Department	$ 52,735	1	0%	0%	0%	100%	$ -	$ -	$ -	$ 52,735
Dry flood proof	Municipal Light Department	$ 105,471	1	0%	0%	0%	100%	$ -	$ -	$ -	$ 105,471
Flood walls and other flood proofi	DPW barn and salt shed	$ 527,353	1	0%	0%	0%	100%	$ -	$ -	$ -	$ 527,353
Total critical infrastructure		$ 6,152,096									
Beach nourishment study	North Nantasket Beach	$ 184,573	1	0%	100%	0%	0%	$ -	$ 184,573	$ -	$ -
Beach nourishment	North Nantasket Beach	$ 26,367,632	1	0%	100%	0%	0%	$ -	$ 26,367,632	$ -	$ -
Total beach nourishment		$ 26,552,205									

Table 8: Cost of investment today (2019), 2030, 2060, and 2100.

Costing Adaptation Measures

We estimate the total cost of various adaptation measures required to maintain Hull's existing single-family homes and infrastructure through 2100. This includes elevating single-family homes and roads, floodproofing critical infrastructure, and filling beaches. All values are adjusted for inflation. Table 8 shows our model and highlights the adaptation measures, units, and unit costs.

According to the U.S. Environmental Protection Agency (EPA)–administered Resilience and Adaptation in New England (RAINE) database, in 2016 the cost to raise a home in neighboring Scituate, MA ranged from $100,000 and $175,000.[4] We use $145,022. The inflation-adjusted average of these low and high values were used to estimate the per unit cost of raising a home in Hull. The costs associated with raising roads, floodproofing critical infrastructure, and filling beaches are derived from the 2016 Kleinfelder report.[5] Our analysis and that of the Kleinfelder report indicates that adaptation measures must take place ahead of the projected year when areas become impacted.

4 Resilience and Adaptation in New England (RAINE). (2016). Scituate, MA. Retrieved from U.S. Environmental Protection Agency Website: https://geopub.epa.gov/RAINE/pdf/scituate_coastalresourceofficer2.pdf

5 Martecchini, A., Brahim, N., & Bosma, K. (2016). Coastal Climate Change Vulnerability Assessment and Adaptation Study: Town of Hull, MA. Cambridge, MA: Kleinfelder. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/hullcl_1.pdf

Determining Phases of Investment

Next, we determined how investments will be phased from now through 2100. For ease of calculation and given data availability, our analysis of investment phasing is lumpy.

For instance, investments that must be made to avoid chronic inundation in 2030 are in the 2019 column. Investments that must be made to avoid chronic inundation in 2060 are in the 2030 column and investments that must be made prior to 2100 are in the 2060 column.

According to UCS chronic inundation projections, 58% of the 2,708 homes at risk in Hull must be raised by 2030 to avoid chronic inundation. They are therefore in the 2019 column because they are investments that must be made prior to the year 2030. Correspondingly, an additional 5% of the 2,708 homes that are projected to be chronically inundated by 2100 will be chronically inundated by 2060. The phase of investment in the year 2030 is therefore 5%, as this investment must be made prior to 2060.

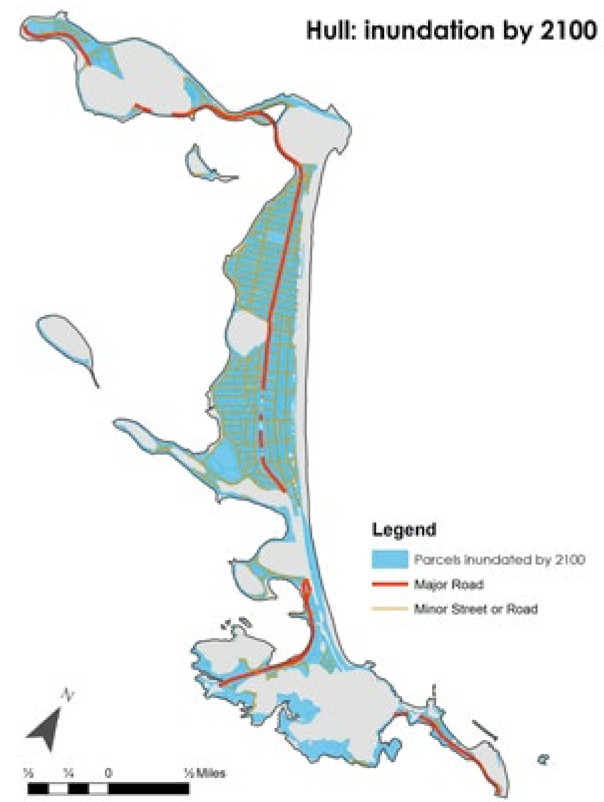


Figure 25: Inundated infrastructure in Hull by 2100

Calculating Cost of Investment Over Time in 2019 Dollars

Next, we calculated the cost of each investment by first multiplying the unit cost by the corresponding units or miles and then multiplying that figure by each phase of investment. By the same logic, the total investment in home elevation required to avoid chronic inundation by 2060 is $21,324,669 in 2030. To avoid chronic inundation in 2100 requires making a $145,031,313 investment in 2060.

Present Value of the Investments Over Time

We calculate the present value of each investment using a range of discount rates between 2% and 10%. This allows us to see how the present value of each investment might change over time according to low and high interest rates.

For example, the present value of the projected $21,324,669 investment in home elevation in the year 2030 according to a 2% interest rate is calculated by multiplying the investment by the present value factor. This factor is calculated by dividing one by (one plus the discount rate) to the 11th power (as 2030 is 11 years in the future.) According to this formula, the present value factor for the year 2060 at a 2% discount rate is $1/(1+2\%)^{41}$as 2060 is 41 years in the future. The present value factor for the year 2100 at a 2% discount rate is $1/(1+2\%)^{81}$ as 2100 is 81 years in the future.

Massive Investment Needed

At a 2% discount rate, the total investment required is $483,419,522 (Table 9). Of the total investment, 64% (or $307,909,550) is investment in home elevation, a cost borne by individual homeowners. Because 58% of the homes at risk of chronic inundation are projected to experience these impacts by 2030, a majority of homeowners with properties at risk will need to raise their homes in the next 11 years. The town will be responsible for paying for investments in local roads: 32% of this investment must be made prior to 2030 and 48% of this investment must be made prior to 2060. The town is also responsible for investments in beach nourishment and critical infrastructure. To offset the impacts of chronic inundation, the majority of these investments must be made before 2060 (Figure 26).

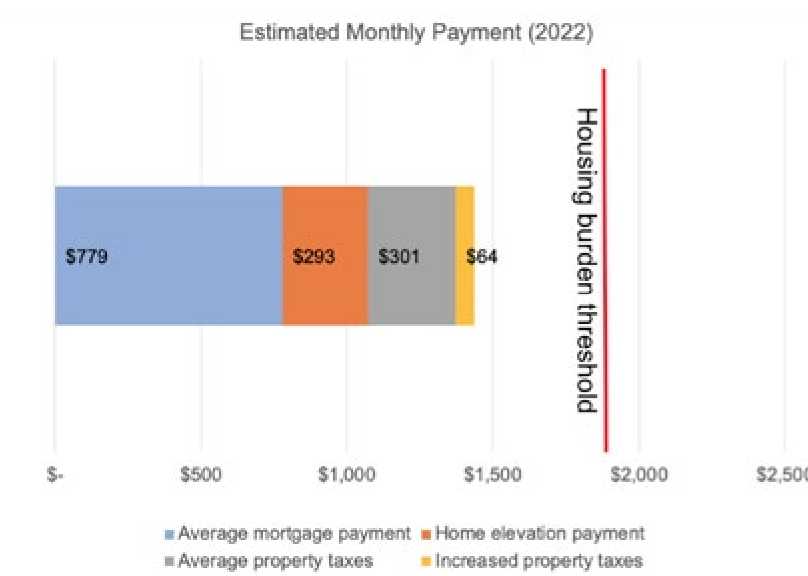


Figure 26: Estimated monthly payments for an elevated home at the Hull median home value. Here, the housing cost burden threshold is 30% of the Hull median gross income.

Adaptation measure	Year 2019	2030	2060	2100
Home elevation				
Total outlay: home elevation	$ (226,363,523)	$ (21,324,669)	$ (145,031,313)	$ -
PV factor	1.00	0.80	0.44	0.20
PVCF	$ (226,363,523)	$ (17,150,643)	$ (64,395,384)	$ -
PV	$ (307,909,550)			
Road elevation				
Total outlay: road elevation	$ (49,386,105)	$ (74,132,689)	$ (92,577,405)	$ -
PV factor	1.00	0.80	0.44	0.20
PVCF	$ (49,386,105)	$ (59,622,182)	$ (41,105,313)	$ -
PV	$ (150,113,600)			
Critical infrastructure				
Total outlay: critical infrastructure	$ -	$ (4,418,160)	$ (573,760)	$ (1,160,176)
Cash flow	$ -	$ -	$ -	$ -
PV factor	1.00	0.80	0.44	0.20
PVCF	$ -	$ (3,553,363)	$ (254,755)	$ (233,297)
PV	$ (4,041,416)			
Beach nourishment				
Total outlay: beach nourishment	$ -	$ (26,552,205)	$ -	$ -
Cash flow	$ -	$ -	$ -	$ -
PV factor	1.00	0.80	0.44	0.20
PVCF	$ -	$ (21,354,957)	$ -	$ -
PV	$ (21,354,957)			
TOTAL				
Total outlay	$ (275,749,628)	$ (126,427,723)	$ (238,182,478)	$ (1,160,176)
Cash flow	$ -	$ -	$ -	$ -
PV factor	1.00	0.80	0.44	0.20
PVCF	$ (275,749,628)	$ (101,681,145)	$ (105,755,452)	$ (233,297)
PV	$ (483,419,522)			

Table 9: Total Investment Over Time – 2% Discount Rate

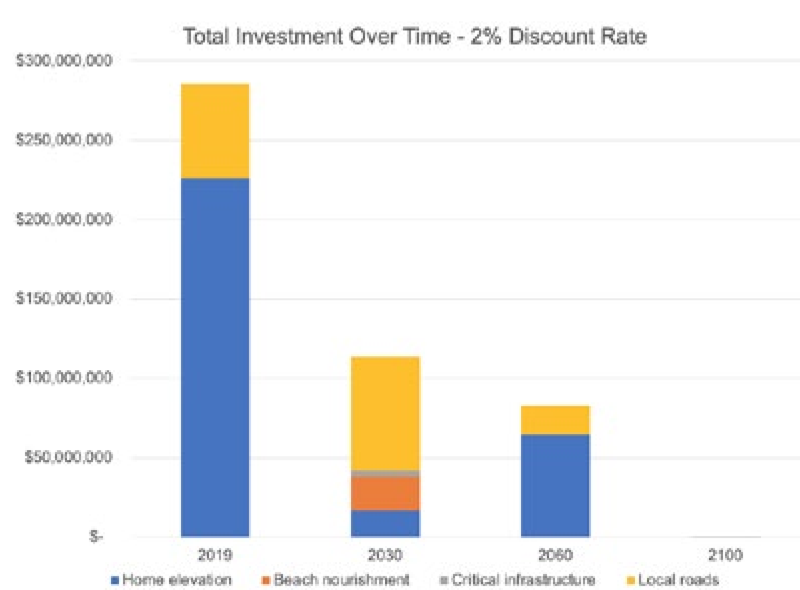


Figure 27: Total Investment Over Time – 2% Discount Rate

Adaptation measure	Year 2019	2030	2060	2100
Home elevation				
Total outlay: home elevation	$ (226,363,523)	$ (21,324,669)	$ (145,031,313)	$ -
PV factor	1.00	0.35	0.02	0.00
PVCF	$ (226,363,523)	$ (7,474,166)	$ (2,913,142)	$ -
PV	$ (236,750,831)			
Road elevation				
Total outlay: road elevation	$ (49,386,105)	$ (74,132,689)	$ (92,577,405)	$ -
PV factor	1.00	0.35	0.02	0.00
PVCF	$ (49,386,105)	$ (25,983,055)	$ (1,859,537)	$ -
PV	$ (77,228,698)			
Critical infrastructure				
Total outlay: critical infrastructure	$ -	$ (4,418,160)	$ (573,760)	$ (1,160,176)
Cash flow	$ -	$ -	$ -	$ -
PV factor	1.00	0.35	0.02	0.00
PVCF	$ -	$ (1,548,538)	$ (11,525)	$ (515)
PV	$ (1,560,578)			
Beach nourishment				
Total outlay: beach nourishment	$ -	$ (26,552,205)	$ -	$ -
Cash flow	$ -	$ -	$ -	$ -
PV factor	1.00	0.35	0.02	0.00
PVCF	$ -	$ (9,306,386)	$ -	$ -
PV	$ (9,306,386)			
TOTAL				
Total outlay	$ (275,749,628)	$ (126,427,723)	$ (238,182,478)	$ (1,160,176)
Cash flow	$ -	$ -	$ -	$ -
PV factor	1.00	0.35	0.02	0.00
PVCF	$ (275,749,628)	$ (44,312,146)	$ (4,784,204)	$ (515)
PV	$ (324,846,493)			

Table 10: Total Investment Over Time – 10% Discount Rate

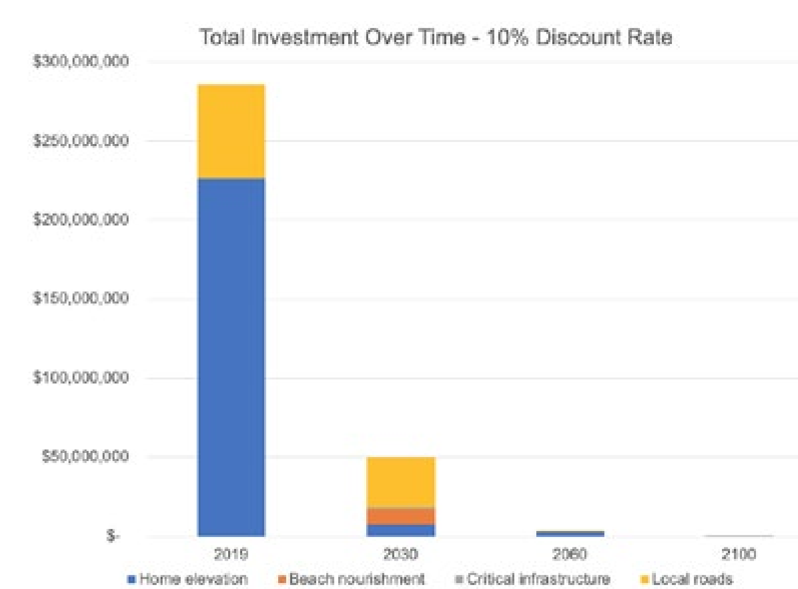


Figure 28: Total Investment Over Time – 10% Discount Rate

At a 10% discount rate, the total investment required is $324,846,493. Of this, $236,750,831 (or 73%) is investment in home elevation. (Table 10). The phasing of investment remains the same at a 10% discount rate, as does the dollar value of investment required in the present day. However, the present value of future investments is 32.8% lower at 10% than it is at 2%, indicating that the present value of the total investment required is highly variable based on future interest rates.

Costs to Single-Family Homeowners

Conscious that Hull will need to increase property taxes to pay for adaptation investments, we estimate the cost of the increased property taxes by dividing the total adaptation costs by 4,892, the number of households in the town.[6] We add the estimated average monthly cost of home elevation for affected parcels, and estimate average monthly mortgage payment[7] and property tax payment[8] to this value.

We compare this estimated average monthly housing payment to the average monthly gross income in Hull.[9] Assuming that housing costs greater than 30% of gross income are burdensome,[10] this allows us to determine whether the price of adaptation will be a burden to the average household in the town. If the cost of home raising is amortized like a 30-year fixed mortgage, the average household in Hull is likely to be able to afford monthly payments in the long-term.

However, if homeowners must pay for more than 7% of the total cost of home raising upfront, their total housing costs may exceed 30% and push the average household in Hull beyond the threshold of affordability.

Policy Implications

Existing Policies that Facilitate this Scenario

The three towns belong to a state that takes climate change seriously. In 2016, Governor Barker signed an executive order that recognized climate change as a "serious threat" to the safety of Massachusetts residents and the integrity of the Commonwealth's communities. The order called for a reduction in greenhouse gas emissions and mandated the creation of a both a statewide Climate Adaptation Plan as well as resources for each community in the Commonwealth to establish and carry out vulnerability assessments.[11]

The Climate Adaptation Plan recognizes that the effects of climate change are not confined to one municipality. Moreover, the adaptation interventions of one community might negatively impact its neighbor. Going forward, intermunicipal cooperation across the region and the state is key for protection, because climate change adaptation is, as Hull Town Manager Philip Lemos noted "beyond what local government can take on by itself."[12] The Commonwealth, with resources like Resilient Massachusetts and technical assistance through the Office of Coastal Zone Management,[13] is building a policy framework under which these resource- and idea-sharing opportunities can manifest.

Aspects of the National Flood Insurance Program funding structure can help to facilitate demolition and relocation measures. The NFIP provides flood insurance to property and business owners and encourages communities to enforce floodplain management regulations to mitigate the effects of flooding on new structures. NFIP policyholders can add Increased Cost of Compliance (ICC) coverage to provide additional funds to help cover mitigation measures to reduce flood risks. The structure of these ICC payments creates a sort of loophole in funding limitations, allowing for community partnerships in adaptation and mitigation of flood risks.

Existing Policies that Hinder this Scenario

Currently the three municipalities do not collaborate on a regional scale, but do share water and sewage services. It follows that Hingham and Cohasset, the towns with the lowest risk, will have little incentive to help or protect Hull, the town with the highest risk. Proposition 2½ would need to change to enable greater increases to property taxes to fund the fortifications discussed above.

Policy Changes Needed Under this Scenerio

While there exists a vast infrastructure of post-disaster recovery financing at the federal and state levels, there is comparatively little current, systematic approaches

6 United States Census Bureau. (2017). Hull CDP, Massachusetts. [Data file]. Retrieved from: https://www.census.gov/quickfacts/fact/table/hullcdpmassachusetts/INC110217

7 Zillow. Hull Home Prices and Values. Retrieved from https://www.zillow.com/hull-ma/home-values/

8 Ibid.

9 United States Census Bureau, Ibid.

10 U.S. Department of Housing and Urban Development. (n.d.) Rental Burdens: Rethinking Affordability Measures. HUDuser.gov. Retrieved from https://www.huduser.gov/portal/pdredge/pdr_edge_featd_article_092214.html

11 Exec. Order No. 569. (2016). Establishing an Integrated Climate Change Strategy for the Commonwealth.

12 Lemos, P. (2019, May 16). Personal communication.

13 Massachusetts Executive Office of Energy and Environmental Affairs. (n.d.). Massachusetts Office of Coastal Zone Management (CZM). Retrieved from http://resilientma.org/resources/resource::2082/massachusetts-office-of-coastal-zone-management-czm

to pre-disaster financing and prevention.[14] A report produced by UMass Boston's Sustainable Solutions Lab outlines strategies to share costs among state, federal, and local government as well as private sources for district-level improvements. A 2017 bill being studied by the Massachusetts state legislature's Telecommunications, Utilities and Energy committee advocates for a carbon tax that would fund resiliency, transit, and clean energy.[15] Although the report focused on recommendations for the City of Boston, town and village governments could adapt the recommendations to suit their needs, or work with the state to generate financing mechanisms especially for smaller municipalities.

Current tax structures would need to change in this scenario. We calculated increased property tax for residents to enable increased municipal adaptation measures, which would likely exceed the current tax cap. Residents would need to override the cap.

This scenario will have inequitable results for different populations, and therefore policies would be needed to mitigate some of these impacts. In particular, alternative financing mechanisms and loans to facilitate lower income residents elevating their homes will be needed. For those who cannot afford to elevate their homes, it will be important to provide affordable housing in non-vulnerable areas of the region. State and federal funding could help to reduce the fiscal burden on residents and the municipality.

Hull could also look to communities with significant assets that are facing similar problems. Due to coastal subsidence and climate change, sea levels in Norfolk, VA have risen one-and-a-half feet since the early 1990s, about twice the global average. The city has invested in traditional water-control techniques like floodwalls, pumps, and road raising, but is also using sea level rise as a chance to revitalize the city through rezoning.[16] The city divided its area into four zones that correspond to different adaptation approaches. Red zones are areas (like the U.S. Naval base) that are dense and require rigorous protection, while yellow zones are areas where adapt and retreat strategies could be deployed to safeguard people and assets.[17]

Norfolk is innovating within its zoning codes, an existing framework, an approach which ties into the conservative, pragmatic approach outlined in this case scenario.

14 Levy, D. L. (2018). Financing Climate Resilience: Mobilizing Resources and Incentives to Protect Boston from Climate Risks. Retrieved from UMass Boston Sustainable Solutions lab website https://www.umb.edu/editor_uploads/images/centers_institutes/sustainable_solutions_lab/Financing_Climate_Resilience_April_2018.pdf

15 An Act to promote green infrastructure, reduce greenhouse gas emissions, and create jobs, H.1726, 190th, General Court of the Commonwealth of Massachusetts. (2017).

16 Ibid., pp: 225.

17 Kusnetz, N. (2019, March 07). Norfolk Wants to Remake Itself as Sea Level Rises, but Who Will Be Left Behind? Inside Climate News. Retrieved from https://insideclimatenews.org/news/15052018/norfolk-virginia-navy-sea-level-rise-flooding-urban-planning-poverty-coastal-resilience

While Norfolk faces a distinct set of challenges and opportunities, these strategies could be modified and adapted to fit into a New England town governance structure. In the short-to-medium term, it would be possible to build on the proactive approach Hull has already adopted towards adaptation.

Conclusion

This scenario explores the implications of a market-based adaptation approach to SLR. While the scenario is politically feasible under today's institutional frameworks, it is expensive, prohibitively so for many residents of Hull, and will therefore lead to displacement.

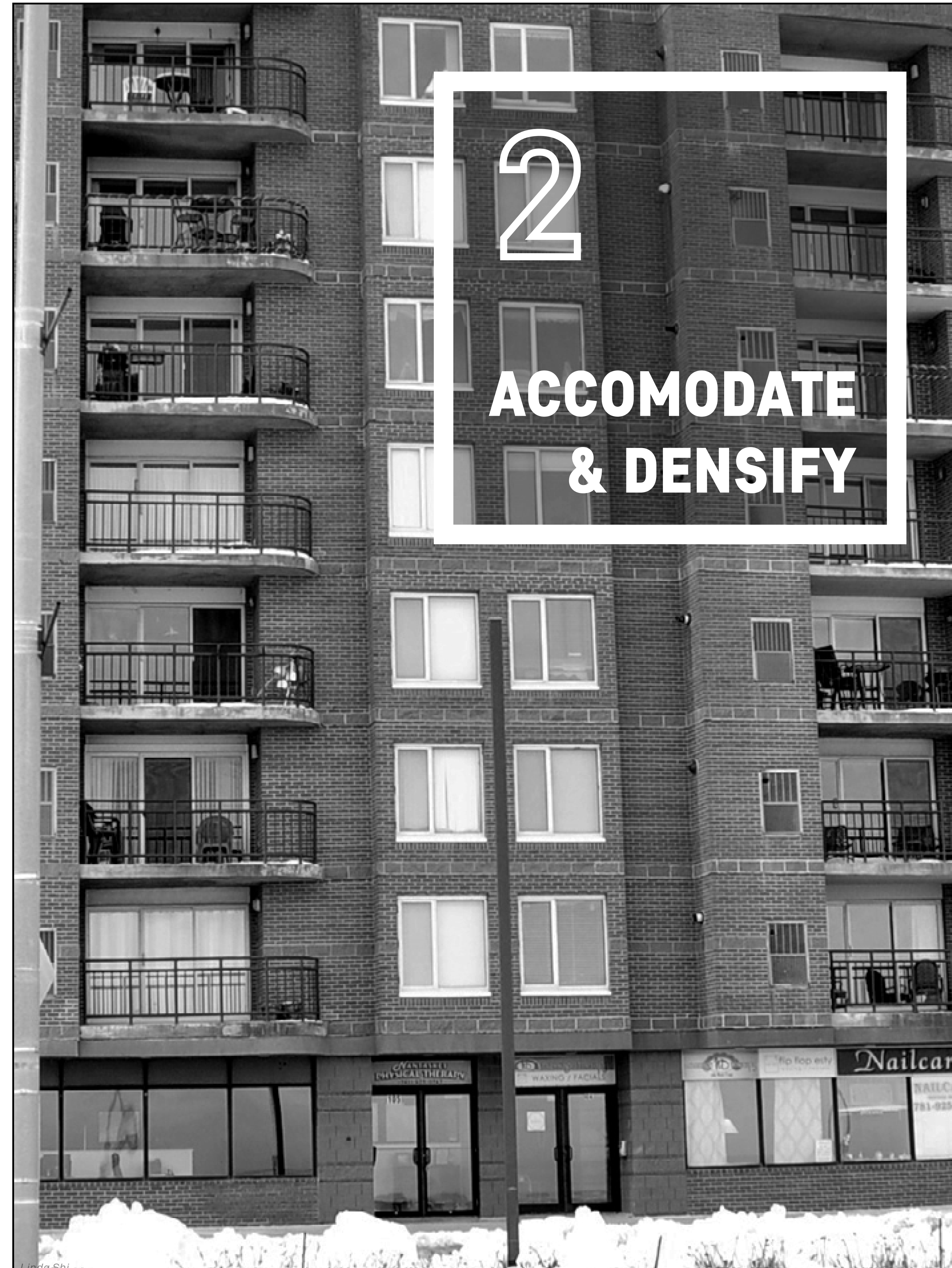
This scenario demonstrates how market forces have inequitable impacts. It is important to reiterate here that our figures represent a low estimate, as they leave out the added costs of adapting electricity, sewer, and water services, among others. The greatest fiscal burden in this scenario is on the residents of Hull. If single-family homeowners do not pay to elevate their homes, the Town will lose almost half of its tax base. The cost burden of home and infrastructure work may raise home prices and taxes to a point where people are driven out. It is not realistic or feasible to expect half of the Town to elevate their homes. In addition, with a large renter population, questions remain about whether landlords will be willing or able to assume the costs of home elevation. Hull has an aging population, and therefore elevating homes up to eleven feet could also present significant accessibility issues. For a senior citizen with mobility limitations and a fixed income, home elevation is prohibitively expensive. Most likely, it will be wealthier residents and/or those who have the deepest commitment to Hull who are able or will chose to elevate.

These approaches may keep structures and infrastructure out of harm's way, but there are tradeoffs. Raising homes out of the floodplain is effective, but the total effect of raised homes and roads changes the ground relationship between buildings and the street. Cumulatively, many raised homes and streets alter the aesthetic character of a community. An emerging literature on the mental and emotional response to climate change–related impacts suggests major changes to the landscape can induce "ecological grief," a sense of loss catalyzed by irrevocable changes to one's community.[18] In the end, this scenario requires a huge investment on the part of both the municipality and residents, in order to merely maintain the status quo. By the end of the century, Hull may have to further elevate its structures if seas continue to rise.

18 Cunsolo, A., & Ellis, N. R. (2018). Ecological grief as a mental health response to climate change-related loss. Nature Climate Change, 8(4), 276. doi:http://dx.doi.org/10.1038/s41558-018-0092-2

2

ACCOMODATE & DENSIFY



Linda Shi

Introduction

This scenario explores the feasibility of moving those Hull residents living within six feet of SLR to other parts of Hull or neighboring municipalities. We assessed three approaches to resettling residents. The first approach, herein referred to as Consolidate Lots & Downsize Homes, accommodates displaced Hull households in smaller single-family homes on higher ground within Hull. A second approach, herein referred to as Upzoning to Multifamily Housing, consolidates displaced Hull residents in compact, dense, multi-family homes on higher ground within Hull. A third approach, herein referred to as Regional Accommodation, proposes a few high-end multifamily developments in Hull to maintain its current municipal revenue level. However, most displaced residents live in comparatively affordable housing in the neighboring towns of Hingham and Cohasset.

Each approach has a different fiscal outcome for the three municipalities. Lot Consolidation results in decreasing revenues for Hull. Smaller lot sizes generate a net loss of tax revenue of approximately $5.5 million annually for Hull. These numbers are underestimates, as we do not account for infrastructure upgrades in our calculations. Upzoning to Multifamily Housing enables Hull to increase its revenue. The Regional Accommodation approach enables the municipality to break even financially and enables the region to increase revenues.

The picture becomes more complicated when both the preservation of town character and affordability are considered. The outcomes disproportionately affect low-income and elderly residents. Consolidating lots best preserves Hull's community character, yet it requires substantial municipal investment to reconsolidate the land and upgrade infrastructure. This investment would result in higher user fees and tax increases to residents. Upzoning could attract development, thereby reducing the direct costs for the municipality. However, upzoning leads to a complete loss of the community character of Hull, while increasing housing unaffordability for existing residents. Both strategies would likely price lower income residents out of Hull. Regional Accommodation gives residents the opportunity to live in newly developed parts of the region at a price point they can afford. This approach takes into account the needs of the residents by addressing affordability and relocation as a community, as well as the needs of the municipality to maintain the same level of services.

The benefits of the Regional Accommodation approach explored in this study extend to the Boston metropolitan area, as the new housing development can help to address the region's affordability issues. For the towns of Hingham and Cohasset, an influx of new residents from Hull can lead to an increase in the overall capacity of the towns to sustain commercial development. This will have a positive impact on the overall economy of the region. Hull, Hingham, and Cohasset could become an already developed haven ready to absorb some of the economic and sea level rise displacement from metro Boston.

Many current federal, state, and local fiscal and land use policies would need to change to facilitate this scenario. The municipalities might think about investigating the feasibility of land banks, intermunicipal transfers of development rights, and land readjustment as strategies to manage vulnerable property. Going forward, town decisionmakers will have to consider tradeoffs between remaining solvent, preserving community character, and maintaining affordability for low income residents and senior citizens.

Scenario Description and Assumptions

This scenario presents three major approaches to addressing SLR displacement and future development goals for the region. Each approach explores a unique strategy for accommodating displaced residents through different development possibilities and policy provisions.

In our data analysis and scenario elaboration we made several assumptions regarding property tax. For a property to be considered inundated the centroid of the parcel must fall within the chronic flood zones as listed in the maps created by UCS.[1] The high projection was used for 2030, 2060 and 2100. The scenario assumes that the tax rate will remain relatively similar to current rates due to Proposition 2 ½, which limits the ability of local government to increase property taxes.[2] Finally, based on the current average price per square foot, we assume that larger units will result increase unit prices in a linear fashion and result in higher property tax revenues per unit.

For all of the following approaches, we assume that property owners experiencing inundation will be bought out by both federal and local governments. This would follow a similar pattern as buyouts that are already being done by FEMA, where 75% of the buyout is covered by the federal government (i.e. FEMA) while the leftover 25% is covered by the state or the municipality.[3] The other assumption is that the buyouts can occur on properties that are experiencing chronic inundation as defined by the UCS, and not from disaster storm events as is currently the case. When taking multi-family developments into consideration, the listed costs are created assuming that there are no additional fees associated with the transition in building typology or home ownership structure.

1 Union of Concerned Scientists. (2018). Underwater Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate. Retrieved from https://www.ucsusa.org/sites/default/files/attach/2018/06/underwater-analysis-full-report.pdf.

2 Commonwealth of Massachusetts. (n.d.). Proposition 2½ and Tax Rate Process. Retrieved from https://www.mass.gov/service-details/proposition-2-12-and-tax-rate-process

3 FEMA. (2014). For Communities Plagued by Repeated Flooding, Property Acquisition May Be the Answer. Retrieved from https://www.fema.gov/news-release/2014/05/28/communities-plagued-repeated-flooding-property-acquisition-may-be-answer

When looking at densifying Hull, the variables of the model implemented in this report focus exclusively on residential land use. We do not take commercial properties into account here. Our cost analysis only assesses housing costs; we do not account for the cost of upgrading sewer, water, electricity, and other infrastructure. Our cost estimations, therefore, are to be viewed as underestimates. In addition, for our calculations we assume that populations remain the same during each time period of SLR projections, and do not take into account future population projections. Therefore, our results are based on current demographics. Finally, the feasibility of each of these approaches is contingent on Hull forging partnerships with developers, or the town's ability to generate developer interest. More specific outcomes for each approach are outlined below.

Research Methods and Scenario Outcomes

1. Consolidate Lots and Downsize Homes

The first approach entails accommodating displaced households on smaller single-family homes within their respective towns. Scenario planning conducted by students[4] in Dr. Jennifer Minner's spring 2019 land use planning methods course at Cornell determined that Hull is able to sufficiently accommodate all of its displaced residents internally on non-vulnerable land using smaller lot and unit sizes. This downsizing would require a major decrease in the square footage of homes in Hull, from about 1,600 square feet to 1,000 square feet. Non-inundated property would also need to be reconsolidated and included in redevelopment projects in order to accommodate the new homes. Construction of the new homes would require upgrading and re-siting critical infrastructure for the increased density (as in Scenario 1). This approach best preserves the town's community character because the prominent housing typology remains relatively similar.

2. Upzoning to Multifamily Housing

The second approach reconsolidates displaced Hull residents into compact multifamily homes outside of inundated areas within the town. These units would increase in size to 2,000 square feet to maintain tax revenues without requiring the construction of an excess number of units.[5] For the construction of compact multifamily homes in Hull to come to fruition, upzoning from single family homes to multifamily compact

4 Jenkins, D., Gensler, C., Zhu, Z., and T. Wu. (2019). Climate-change induced relocation scenario for Hull, Hingham, and Cohasset, MA

5 Recall the assumption that, based on the mean price per square foot, building larger units will fetch higher prices and require higher property tax revenues per unit.

View of Hull from Fort Revere (Jude/Flickr)

developments will be necessary. This tool will be used as a way to attract development projects into the region in order to reduce direct costs for the municipality. The net increase in tax revenue from these proposed development schemes could be paired with shared service agreements in the region to help Hull avoid projected financial gaps.

3. Regional Accommodation

This approach represents a middle ground between the first two. Hull would build fewer, less dense, yet higher-end, multifamily developments on non-vulnerable land. The housing would increase in size, quality, and therefore price, so that the municipality can maintain the same level of service provision. Affordable single family and

Table 11: Key fiscal and land-use characteristics for Hull's residential properties

Hull 2019 Tax Rate $13.05 per $1000	Median Tax Revenue per Parcel	Median Unit Count per Bldg.	Median Tax Revenue per Unit	Median Tax Revenue per Sq Ft
Mixed Use	5,459.47	4	1,559.85	1.49
Single Family Residence	4,121.19	1	4,121.19	2.50
Condominium	28,331.55	9	3,147.95	3.27
Two/Three Family Residential	4,050.72	2	2,025.36	1.95
Residential Other	4,149.90	2	2,074.95	2.51
Apartments 4 or more units	6,475.41	6	1,079.24	1.76

multifamily homes would be constructed in Hingham and Cohasset to accommodate residents interested in maintaining their current lifestyle and living in a less dense environment similar to Hull's current typology. This would directly aid residents faced with affordability concerns, as they are given the opportunity to live in newly developed parts of the region at a price point they can afford.

Overall Approach

Our overall approach was to break down property tax revenue into per unit and per square foot costs, then use the initial revenue gap discussed above as a benchmark to determine the number and size of additional units needed to fill the gap. The dynamic goal-seeking nature of this approach required exploratory analysis (i.e. trial and error), so we created a tax revenue projection tool in Microsoft Excel which allows users to plug in the number and size of units by type and return an estimate fiscal impact using existing residential use typology and tax revenue information (Table 13).

We modeled tax revenue projections and project tax revenues for each residential land-use type to give an indication of the potential tax revenue gain and loss associated with each category and at different sizes. Any loss or gain of specific building typologies due to a change in environmental conditions or policy goals can exert very different fiscal, physical, and social realities for each community. Using household displacement projections, as well as the potential tax revenue gains from additional development, we project the annual fiscal impacts for each community for three time periods: 2030, 2060, and 2100 (Figures 29 & 30). There are infinite possibilities; we show three. We calculate the median square foot per unit, median tax revenue per unit, median tax revenue per square foot for each building typology in all three towns in the study area (Table 14). This gives us information about the building types that would generate the most tax revenue per parcel, per unit, and per square foot. With that information, we then experiment with the number of units and the unit size needed for each building type to generate the amount of revenue lost to sea level rise for each municipality, which generated our three approaches.

For Consolidate Lots and Downsize Homes, we multiply the property tax revenue per square foot by the square foot per unit to get the total tax revenue per unit for all homes predicted to be inundated by 2030, 2060, and 2100. The approach assumes new units in Hull will be sized at 1,000 square feet and accounts for the number of homes displaced by the accommodation of vulnerable residents. This was subtracted from what would be earned in tax revenue if homes remained at current square footage of 1,651 square feet per unit to get the revenue difference.

Given that downsizing homes would result in a net loss of tax revenue, we also calculate revenues if the building typology was changed to condominiums to further increase density in order to develop the Upzoning to Multifamily Housing approach. We calculate the number of condominium units needed based on the number of displaced households due to sea level rise, as well as those living on non-vulnerable land that

Regional Accommodation

	Units 2030	Units 2060	Units 2100	Total Revenue 2030	Total Revenue 2060	Total Revenue 2100
	-	-	-	-	-	-
	(515)	(1,100)	(2,200)	(2,122,413)	(4,533,309)	(9,066,618)
	240	480	960	1,571,974	3,143,947	6,287,895
	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
Total	**240**	**480**	**960**	**(550,439)**	**(1,389,362)**	**(2,778,723)**

	Units 2030	Units 2060	Units 2100	Total Revenue 2030	Total Revenue 2060	Total Revenue 2100
	100	200	400	1,190,389	2,380,778	4,761,556
	(20)	(40)	(150)	(131,209)	(262,418)	(984,068)
	25	100	200	126,847	507,387	1,014,774
	50	100	200	128,316	256,631	513,263
	-	-	-	-	-	-
	50	100	200	86,558	173,117	346,234
Total	**225**	**500**	**1,000**	**1,400,901**	**3,055,495**	**5,651,758**

	Units 2030	Units 2060	Units 2100	Total Revenue 2030	Total Revenue 2060	Total Revenue 2100
	100	200	300	417,734	835,469	1,253,203
	(30)	(60)	(150)	(263,934)	(527,868)	(1,319,670)
	125	300	700	712,290	1,709,495	3,988,822
	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
Total	**225**	**500**	**1,000**	**866,090**	**2,017,096**	**3,922,355**

Totals					
Units 2030	Units 2060	Units 2100	Total Revenue 2030	Total Revenue 2060	Total Revenue 2100
690	1,480	2,960	1,716,551	3,683,229	6,795,389

Table 12: Example model calculations for each approach. Fields in this model are customizable to reflect tax revenue outcomes from changes to land use, development scale, and development area values

Hull

2019 Tax Rate $13.05 per $1000	Unit Count	Total Tax Revenue per Unit	Square Foot per Building	Square Foot per Unit	Property Tax Revenue per Sq Ft
Mixed Use	4	1,560	3,662	1,046	1.49
Single Family Residence	1	4,121	1,651	1,651	2.50
Condominium	9	3,147	8,651	961	3.27
Two/Three Family Residential	2	2,025	2,078	1,039	1.95
Residential Other	2	2,075	1,656	828	2.51
Apartments 4 or more units	6	1,079	3,675	613	1.76

Hingham

2019 Tax Rate $11.81 per $1000	Unit Count	Total Tax Revenue per Unit	Square Foot per Building	Square Foot per Unit	Property Tax Revenue per Sq Ft
Mixed Use	1	11,904	3,462	3,462	3.44
Single Family Residence	1	6,560	2,044	2,044	3.21
Condominium	4	5,074	7,642	1,911	2.66
Two/Three Family Residential	2	2,566	2,070	1,035	2.48
Residential Other	2	3,743	1,362	681	5.50
Apartments 4 or more units	10	1,731	15,138	1,514	1.14

Cohasset

2019 Tax Rate $12.90 per $1000	Unit Count	Total Tax Revenue per Unit	Square Foot per Building	Square Foot per Unit	Property Tax Revenue per Sq Ft
Mixed Use	2	4,177	5,927	2,964	1.41
Single Family Residence	1	8,798	4,322	4,322	2.04
Condominium	5	5,698	8,309	1,662	3.43
Two/Three Family Residential	2	4,177	4,970	2,485	1.68
Residential Other	2	5,150	4,460	2,230	2.31
Apartments 4 or more units	6	1,597	7,664	1,277	1.25

Table 13: Comparison of regional differences in size and tax revenue

would be displaced by the new construction. We subtract the revenue generated from the condominiums from the revenue lost due to inundated single family homes, leading us to determine that for Hull we would need to increase both the number and size of the units to make up the lost tax revenue.

We repeat this process for the Regional Accommodation approach. After subtracting out revenue lost due to inundated single family homes, we increase the number of units of mixed-use developments and multifamily residences in Hingham and Cohasset. This accommodates Hull residents and enables revenues to increase for the region.

This model also helped us to assess affordability concerns in this scenario, considering the fact that some communities have residential property valued higher per square foot than others (Table 13). In addition to providing insight into how much tax revenue different building typologies generate, this model has the potential to show the effects that a direct change to factors such as median square foot per unit or

Potential Hull Tax Revenue Gains: Lot Consolidation Approach				
	Now	2030	2070	2100
No Change to Average Unit Size	-	2,307,866	5,769,666	14,012,046
With Average Unit Size Decrease	-	1,397,860	3,494,649	8,487,005
Difference	-	(910,007)	(2,275,017)	(5,525,041)

Table 14: Potential tax revenue gains using Lot Consolidation

number of units per building have on fiscal outcomes in order to better outline the ramifications of potential solutions. The ability to identify fiscal outcomes through a change in land use type, unit size, and number, provides a way to measure potential development and policy possibilities. This was especially relevant when addressing affordability concerns in this scenario, considering the fact that some communities have residential property valued higher per square foot than others (Table 13). This also opens up the potential for community leaders to balance goals and desires regarding the look and feel of residential development against the potential fiscal impacts related to each type of development.

Scenario Outcomes

We find that for Hull, the Upzoning to Multifamily Housing approach enables the municipality to increase its revenues, Regional Accommodation enables the municipality to break even financially, while Consolidate Lots and Downsize Homes results in a decrease in revenues. For the region, Consolidate Lots and Downsize Homes decreases regional revenues even more than for Hull alone, while Upzoning to Multifamily Housing and Regional Accommodation increase revenues by approximately the same amount. However, this does not take into account non-quantifiable positive social outcomes, which serve to elevate the regional approach over upzoning (Figures 29 & 30).

The approaches detailed above have different political, physical, fiscal, and social impacts for each community. In evaluating the outcomes of each, it is important to consider each town's community vision, and the extent to which our approach does or does not assist in advancing each municipality towards its desired future. Hull's community identity, as described in its vision statement, is a "friendly, neighborhood-scaled, family-oriented, relatively affordable residential community." This includes providing high-quality education, open space for public enjoyment, expanded public transportation, and protection and enhancement of waterfront amenities for tourism and recreational purposes.[6]

6 Town of Hull. (n.d.) Wave of the Future: Hull Vision Statement. Retrieved May 16, 2019: https://www.town.hull.ma.us/town-manager/pages/wave-future-hull-vision-statement

Hull - Annual Tax Revenue Trend			
Consolidate Lots & Downsize Homes			
Now	2030	2070	2100
-	(910,007)	(2,275,017)	(5,525,041)

Regional - Annual Tax Revenue Trend			
Consolidate Lots & Downsize Homes			
Now	2030	2070	2100
-	1,089,690	2,012,860	2,853,667

Table 15: The effect that the Lot Consolidation approach would have on annual municipal tax revenues in Hull and in the region. Note that this approach creates a net loss in tax revenue, in part because of a decrease in the average size of single-family units.

Outcomes of Consolidate Lots & Downsize Homes

Hull currently spends approximately 23.5 million dollars on education, roads, refuse and recycling, public safety, culture and recreational services.[7] The strategy to build smaller lot sizes with single family homes of 1,000 square feet generates a net loss of tax revenue of $5.5 million dollars annually (20% of current tax revenue because smaller units mean less tax revenue per unit). However, there is not enough space remaining on the non-inundated areas of Hull to enable home sizes to remain the same as the current average. While this approach maintains Hull's neighborhood scale with single-family home building typology, sustaining service provision such as a high-quality school system with lower tax revenues will become increasingly difficult.

Table 14 demonstrates the effect that a change to the average size of a single-family unit could have to annual municipal tax revenues. This approach entails less displacement and fewer changes to community character through a maintenance of current building typology. This may lead to more favorable outcomes for residents, as other relocation studies have found that those displaced from their communities from natural disasters experience high levels of general psychological distress and posttraumatic stress.[8] After Hurricane Katrina in New Orleans, for example, Wadsworth et al. (2009) found that displaced flood victims experienced high levels of psychological distress for more than one year following the disaster.[9] By enabling residents to stay within the community, this approach maintains informal social networks of support, and may result in lower levels of stress. Support networks are important for creating better individual outcomes in terms of financial security, employment, health, and social integration during relocation events.[10] Though people would move to smaller homes in areas not under threat of inundation, the distress experienced would be minimized over time as residents maintain existing community ties.

This approach is perhaps more politically feasible, or at least more likely to generate community support. Of course, this will depend on residents' willingness to move and their attachment to place, as studies have found that those participating in voluntary relocation programs report greater benefits than those displaced involuntarily.[11] Yet, additional public investment will be needed to complement private redevelopment, making it progressively more unaffordable for current residents to live in Hull. Without a robust tax base, funds used for infrastructure upgrades and service provision will likely be passed onto residents via user fees and other tax increases.

This approach provides an individualized response to SLR for Hull, and does not take into account a larger regional strategy. In comparison to its neighbors, Hull will need the greatest amount of reconstruction, even though it is the town with the least amount of revenue and undeveloped land.[12] Hingham and Cohasset have enough open space to reconsolidate their displaced residents. This approach therefore results in a net tax deficit of $6.2 million regionally by 2100. This approach results in a more inefficient use of vacant and less vulnerable land. This drives up costs for the municipality, as a greater number of buyouts and demolitions would be required, both for residents being displaced by sea level rise and for those who currently live in homes in the areas identified for redevelopment. Hingham and Cohasset on the other hand, have much more vacant available land zoned for residential (Table 15). This approach does not take advantage of this regional asset. It primarily responds to the needs of each individual town in isolation, and therefore Hull, as the most vulnerable municipality of the three, remains comparatively worse off financially, physically, and socially.

7 Cleargov. (n.d.) Hull Expenditures. Retrieved from https://www.cleargov.com/massachusetts/plymouth/town/hull/2017/expenditures

8 Blaze, J. T., & Shwalb, D. W. (2009). Resource loss and relocation: A follow-up study of adolescents two years after Hurricane Katrina. Psychological Trauma: Theory, Research, Practice, and Policy, 1(4), 312-322. http://dx.doi.org/10.1037/a0017834

9 Wadworth, M.E., Santiago, C.D., and L Einhorn. (2009). Coping with Displacement from Hurricane Katrina: Predictors of one-year post traumatic stress and depression symptom trajectories. Anxiety, Stress, Coping, 22(4), 413-32. doi: 10.1080/10615800902855578

10 Goetz, E. G. (2010). Better neighborhoods, better outcomes? Explaining relocation outcomes in HOPE VI. Cityscape, 5-31.

11 Ibid; Goetz, E. G. (2003). Housing Dispersal Programs. Journal of Planning Literature, 18(1), 3–16. https://doi.org/10.1177/0885412203251339

12 Cleargov. (n.d.). Town of Hull Revenue. Retrieved May 16, 2019, from https://www.cleargov.com/massachusetts/plymouth/town/hull/2017/revenue

Hull - Annual Tax Revenue Trend			
Upzoning to Multi-Family Housing			
Now	2030	2070	2100
-	1,807,521	3,654,054	7,308,107

Regional - Annual Tax Revenue Trend			
Upzoning to Multi-Family Housing			
Now	2030	2070	2100
-	1,684,805	3,408,621	6,620,197

Table 16: The effect that the Upzoning to Multifamily Housing approach would have on annual municipal tax revenues, both in Hull and in the region. Note that this approach generates significant additional tax revenues. This is due to a change in residential

Outcomes of Upzoning to Multi-Family Housing

Upzoning existing single family homes to multifamily residences enables Hull to maintain the same level of service quality that residents value. New and larger condos allow the town to increase tax revenues, thereby increasing revenues for the region. By 2100, Hull could have a net annual tax revenue gain of $7.3 million yearly, and the region will gain up to $6.6 million in tax revenue (Table 16). Multifamily homes provide the option of creating more housing than what is required to accommodate displaced residents; doing so would further diminish the fiscal impact of inundation by producing more revenue per square foot than single family homes. Although the upfront cost will still be high because of the need for buyouts, private investment could lead to a decrease in infrastructure costs, thereby minimizing the investments the municipality would need to make.

This approach results in affordability issues for residents, causing a distinct population shift in Hull, as creating larger units also increases the costs for residents. The revenue from the buyout will be equivalent if not less than the price needed to move into one of the reconsolidated homes. While a number of units could be designated as below market rate, this approach necessitates an influx of new residents, and would be attractive to people outside of the South Shore from Boston or Cambridge who are able to afford the higher prices. Therefore, this approach's affordability outcomes for current inhabitants means a further deviation from the town's vision: there is less maintenance of the neighborhood-scale community, and the municipality becomes less affordable.

Hull - Annual Tax Revenue Trend			
Regional Accommodations			
Now	2030	2070	2100
-	235,548	182,612	365,224

Regional - Annual Tax Revenue Trend			
Regional Accommodations			
Now	2030	2070	2100
-	1,716,551	3,683,229	6,795,389

Table 17: The effect that the Regional Accomodation approach would have on annual municipal tax revenues, both in Hull and in the region. Note that this approach generates significant additional tax revenues. Though this approach allows Hull to maintain current service levels, revenue gains for the region are substantial.

Outcomes of Regional Accommodation

This approach would result in lower cost of service provision for the town of Hull, as fewer residents would be relocated within the town.

This approach envisions regional efforts to provide shared services, integrating land use planning, and/or merging school districts. Hingham has enough undeveloped land to consolidate the displaced residents without the need for redistributing parcels. Therefore, the region benefits economically (Tables 13 & 17). Hull will be able to maintain current service levels, while the region will have a net gain of $6.8 million (Tablr 16). Hingham and Cohasset would benefit from increased tax revenues due to the influx of new residents, while Hull benefits through the relief of infrastructure and school district costs. Sharing services can greatly decrease the fiscal impact of the new developments. In particular, sharing services like education, which makes up 38.8% of Hull's expenditures, would help the town's bottom line long-term.[13]

This approach would have implications for town identity. It addresses Hull's vulnerability as well as Cohasset and Hingham's visions for more affordable housing, economic and tax diversification, and a more diverse population. Hingham's 2017 master plan goals include measures to "[provide] and maintain economically diverse housing [and] encourage and maintain a mix of housing types in various locations throughout the

13 Cleargov. (n.d.) Hull Expenditures. Retrieved from https://www.cleargov.com/massachusetts/plymouth/town/hull/2017/expenditures

town by supporting development that provides for households at all income levels."[14] Cohasset's 2016 master plan vision prioritizes cultural, racial, and economic diversity and narrow tax base.[15] Regional Accommodation would provide affordable housing for both communities, thereby increasing diversity.

Policy Implications

Existing Policies that Facilitate this Scenario

Massachusetts does prioritize and provide resources for climate adaptation for local municipalities. This includes making resources available for each community in the Commonwealth to establish and carry out vulnerability assessments,[16] as well as programs like Resilient Massachusetts and technical assistance through the Office of Coastal Zone Management.[17]

14 Town of Hingham. (2017, March 20). Hingham Master Plan Goals. Retrieved from https://www.hingham-ma.gov/DocumentCenter/View/4943/Master_Plan_Goals_2017-revision

15 Metropolitan Area Planning Council. (2016). Visioning Our Master Plan. Retrieved from https://www.cohassetma.org/DocumentCenter/View/235/Cohasset-Master-Plan---Visioning-Our-Master-Plan---Phase-1-PDF

16 Exec. Order No. 569. Establishing an Integrated Climate Change Strategy for the Commonwealth (2016).

17 Massachusetts Executive Office of Energy and Environmental Affairs. (n.d.). Massachusetts Office of Coastal Zone Management (CZM). Retrieved from http://resilientma.org/resources/resource::2082/massachusetts-office-of-coastal-zone-management-czm

View of the Hingham Ferry (The West End/Flickr)

Existing Policies that Hinder this Scenario

Community Rating System

Hull might think about revising its participation in the Community Rating System program in the short term. Hull's current Class 8 rating means that homeowners get a 10% discount on their flood insurance premiums.[18] This incentivizes the adoption of certain mitigation measures that are not necessarily useful in the context of the accommodation and densification approaches explored here. For example, the municipality gets points for granting elevation certificates, as well as enabling flood proofing and retrofitting measures which serves to motivate residents to stay in their homes.[19] If Hull were interested in implementing either approach, a first step might be to disincentivize landowners from elevating, floodproofing, and retrofitting their homes. This raises the question of whether near term adaptation conflicts or inhibits long-term adaptation and how mixed strategies affect total costs over time.

FEMA Buyout Policy

FEMA buyouts currently only happen after a disaster.[20] The current buyout policy does not include properties that suffer from chronic inundation. A 2019 study of eight U.S. buyout programs found that historically buyouts lack transparency, which increases public distrust of the process and reduces participation.[21] The buyout process often becomes politicized, resulting in legislators advocating for buyouts for particular neighborhoods and not others. Therefore, in order for buyouts to become politically and socially feasible, the process should be made more transparent, and residents should be more involved in pre-disaster planning in order to increase trust. This enables homeowners to more fully understand decision-making criteria and thus encourages participation.[22]

18 Metropolitan Area Planning Council. (2018). Town of Hull Hazard Mitigation Plan Update 2018. Retrieved from https://www.town.hull.ma.us/sites/hullma/files/uploads/2018_hazard_mitigation_plan.pdf

19 FEMA National Flood Insurance Program. (2014). CRS State Profile: Massachusetts. Retrieved from https://crsresources.org/files/200/state-profiles/ma-state_profile.pdf

20 FEMA. (2014, May 28). For Communities Plagued by Repeated Flooding, Property Acquisition May Be the Answer. [Press Release]. Retrieved from https://www.fema.gov/news-release/2014/05/28/communities-plagued-repeated-flooding-property-acquisition-may-be-answer

21 Siders, A.R. (2019). Social justice implications of US managed retreat buyout programs. Climatic Change 152(2): 239-257. https://doi.org/10.1007/s10584-018-2272-5

22 Tucker, D.T. (2018). Stanford research finds transparency may improve U.S. home buyout programs. Stanford News. Retrieved on May 15, 2019: https://news.stanford.edu/2018/09/10/managed-retreat-buyouts-offer-lessons-success

Annual Revenue Trend Hull

	Now	2030	2070	2100
Consolidate Lots & Downsize Homes	-	(910,007)	(2,275,017)	(5,525,041)
Upzoning to Multi-Family Housing	-	1,807,521	3,654,054	7,308,107
Regional Accommodations	-	235,548	182,612	365,224

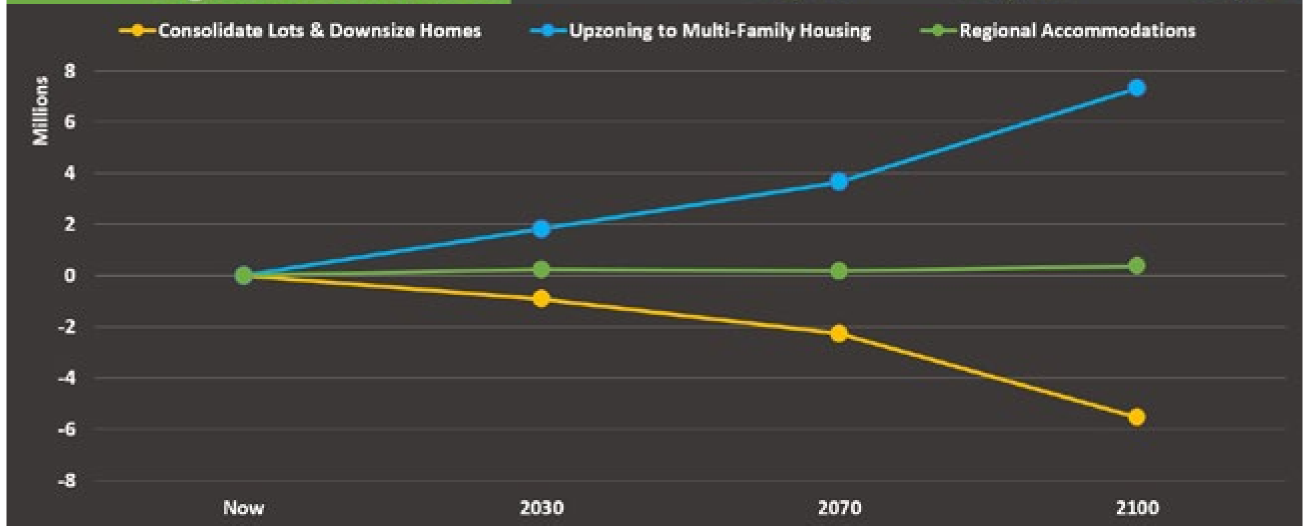


Figure 29: Annual tax revenue trend in Hull under the three approaches

Regional Annual Tax Revenue Trend

	Now	2030	2070	2100
Consolidate Lots & Downsize Homes	-	1,089,690	2,012,860	2,853,667
Upzoning to Multi-Family Housing	-	1,684,805	3,408,621	6,620,197
Regional Accommodations	-	1,716,551	3,683,229	6,795,389

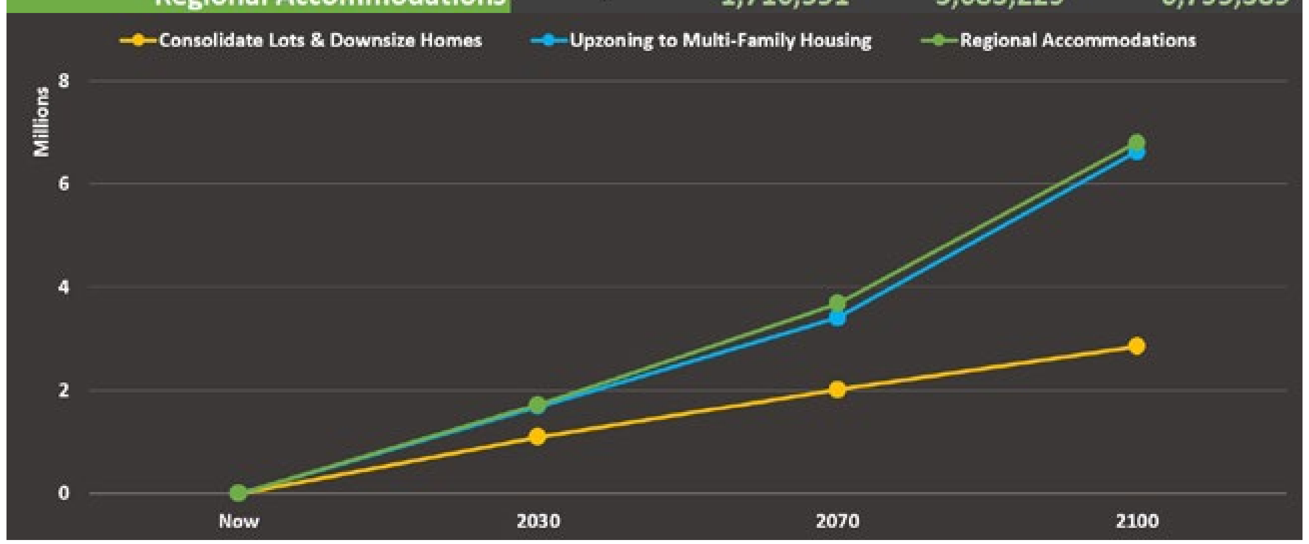


Figure 30: Annual regional tax revenue trend under the three approaches

Policy Changes Needed Under this Scenario

Existing policies in many ways do not support these approaches. Therefore, policy changes at different time periods would be required for all approaches explored. We envision two frameworks for altering how land is administered in Hull to achieve the approaches outlined above. The first is a market-driven method requiring significant investment of private capital, combined with a land bank, while the second is a more collaborative land readjustment system.

Market-Driven Policy Framework

In the first framework, inundated land is bought by a municipal land bank or a land trust which then manages the properties. While primarily used to administer vacant abandoned land to reduce blight, land banks have also been used for properties affected by recurring flooding.[23] In Hull, a land bank would manage the demolition of properties in flood impacted areas of the town. In the case of a storm event, FEMA-funded buyout properties would then be transferred to the land bank. But in the case of vulnerable properties that would not be applicable for a FEMA buyout, the land bank would need to find a way to offset the costs of acquisition, maintenance, and demolition. Many rely on foundation funds when starting out to cover operating expenses.[24] For residents

23 Martin, A. (n.d.). Broome County Land Bank Corporation. Retrieved from http://broomelandbank.org/about

24 Kildee, D., & Hove, A. (2008). Land Banking 101: What Is a Land Bank? Center for Community Progress. Retrieved from https://www.communityprogress.net/land-banking-faq-pages-449.php#What%20is%20a%20land%20bank?

View of the Cohasset Harbor (The West End/Flickr) interested in moving to Hingham and Cohasset in the regional approach, homeowners could sell their property to the land bank for maintenance, thereby preventing an influx of new inhabitants in vulnerable areas. This provides a potential solution for Hull to assist both homeowners left on land that is not inundated and those in flood-prone areas. Partnerships with land trusts can be helpful financially for the municipality. For example, Pacifica, CA partnered with two land trusts to purchase and remove homes, rebuild dunes, and restore the beach. This resulted in a reduction in flood hazards and reduced costs as restoring the area to wetlands meant that less physical infrastructure was required.[25] Therefore, the development of other land management organizations can help relieve the town of Hull of some of the financial burden of purchasing and managing vulnerable properties, as well as implementing restoration measures.

Land Readjustment Policy Framework

In the second framework, subdivided, individually-owned land is pooled for subsequent planned urban development and updated uses. Landowners each then receive a portion of the proceeds from the new development, now assessed at a higher value due to the improvements made, and become stakeholders in the redevelopment.[26] It is, essentially, a property rights exchange, which can be initiated either by the landowners themselves, or by the municipality.[27] This technique is most common in South Asia. For example, in Pune, India, farmers of an agricultural community facing urbanization, formed a private limited company and pooled their land together to build a mixed-use township on 400 acres. This enabled enhanced local control of future development and ensured that profits stayed within the community.[28] This model could serve to assist Hull residents with some of the resettlement issues that the municipality may face with sea level rise.

Challenges associated with this approach include obtaining consent from all landowners to move forward with land readjustment and disagreements between the government and landowners on the valuation of their land. According to the World Bank, strong local institutions supported by strong laws and government institutions are necessary for land readjustment to work.[29] Land value increases would need to be high enough to cover the cost of construction. In Japan, land readjustment is largely government-initiated, and though the government can legally proceed without a majority (80%) of landowners' consent. Public opposition can be enough to halt projects.[30] Hull would need to consider these challenges and opportunities in order to use this because public opposition can halt such projects.

Land readjustment could be an implementation strategy for any approach, but would be more realistic for Upzoning to Multifamily Housing and Regional Accommodation, as land would be pooled to develop multifamily residences. This would entail a government initiative in which landowners in the non-vulnerable area of the peninsula closest to Hingham agree to pool their land in order to construct multifamily, high-density developments. Each landowner would become a stakeholder in the new development and therefore benefit from its construction and the rental of its units, in addition to becoming an owner of a unit. This strategy would reduce Hull's costs, as the municipality would not need to buy the land from the owners. It would enable community members to have greater control over the design and outcome of their new residences, instead of conceding to a developer's desires. It would require significant organizational capacity-building, as there would need to be an institution or agency with extensive political and community support that manages the process and the decision-making. It would also require residents to be interested in an alternative land ownership model, and to buy into the vision for the redevelopment of Hull. The negotiation process to get all landowners involved and enforce mutual agreements can be costly if there is little trust and capacity to communicate.[31] In order to minimize the free-rider problem for landowners that refuse to concede to the readjustment or sell their property, a land readjustment law or referendum requirement could be implemented.[32] Nevertheless, the municipality would have to demonstrate that the regulation serves a compelling public interest to withstand a takings claim. There must be strong incentives and/or extensive restrictions on development without land readjustment for it to be successful. [33]Additionally, the consolidated land could be administered by a land bank.

25 Kershner, J. (2010). Restoration and managed retreat of Pacifica State Beach. Climate Action Knowledge Exchange. Retrieved from https://www.cakex.org/case-studies/restoration-and-managed-retreat-pacifica-state-beach

26 Amirtahmasebi, R., Orloff, M., Wahba, S., & Altman, A. (2016). Regenerating Urban Land: A Practitioner's Guide to Leveraging Private Investment. Retrieved from https://openknowledge.worldbank.org/handle/10986/24377

27 Hong, Y. H., & Needham, B. (Eds.). (2007). Analyzing land readjustment: Economics, law, and collective action. Cambridge, MA: Lincoln Institute of Land Policy.

28 Sami, N. (2013). From Farming to development: Urban coalitions in Pune, India. International Journal of Urban and Regional Research, 37.1, 151-64. DOI:10.1111/j.1468-2427.2012.01142.x

29 Ibid.

30 Sorensen, A. (2007). Consensus, persuasion and opposition: organizing land readjustment in Japan. In Hong, Y. H., & Needham, B. (Eds.) Analyzing land readjustment: Economics, law, and collective action. (pp. 89-114) Lincoln Inst of Land Policy.

31 Hong, Y. (2007). Assembling land for urban development: Issues and opportunities. In Hong, Y. H., & Needham, B. (Eds.) Analyzing land readjustment: Economics, law, and collective action. (pp. 3-34) Lincoln Inst of Land Policy.

32 Ibid.

33 Sorensen, A. (2007). Consensus, persuasion and opposition: organizing land readjustment in Japan. In Hong, Y. H., & Needham, B. (Eds.) Analyzing land readjustment: Economics, law, and collective action (pp. 89-114). Cambridge, MA: Lincoln Institute of Land Policy.

Regional Strategies

We also explore whether and how intermunicipal transfer of development rights (TDR) might work for the region. Several aspects of TDRs make this strategy difficult to implement in the South Shore's current situation. TDRs are contingent upon the value of the land. If property is continually flooded, then it has no value, rendering the implementation of this tool infeasible.[34] TDRs work better when there is increasing value of land, which is probably not the case in Hull if sea level rise continues. A way to approach this challenge could be the establishment of a development rights bank which would hold development rights until the market demand exists for their use in a receiving district, at which point they are sold.[35] For the Upzoning to Multifamily Housing and the Regional Approach, intermunicipal TDRs could be used to transfer development rights from land in Hingham or Cohasset to build the multifamily developments in Hull. This could be a way for Hull to avoid changing its zoning regulations, and for Hingham and Cohasset to advance their open space preservation goals.

Sharing services and merging school districts would be a policy change that would enable Hull to reduce infrastructure costs under Regional Accommodation, thereby avoiding projected financial gaps. This is a strategy that would build upon the current proposal for a regional sewer system between Hull, Cohasset, and Scituate. It would help resolve North Scituate's lack of municipal sewage, while taking advantage of Hull's extra sewage capacity.[36] A full feasibility study would enable each municipality to more comprehensively evaluate the potential benefits and drawbacks of this policy.

Economic development policies that encourage a regional economic draw and private investment to the area would be needed in order to generate the capacity to fill the multifamily units to maintain current tax revenues under Upzoning to Multifamily Housing. This will also help to address Massachusetts' power dynamics in the allocation of resources by elevating the area's importance to the state's economy. Therefore, creating an economic hub may enable the region to attract more state funds to be used on adaptation measures. Furthermore, in order to implement a regional adaptation agenda, a regional regulatory body that acts as the liaison between the municipalities, and the state and federal governments, would be essential in coordinating the multi-stakeholder agendas.

34 Center for Land Use Education. (2005). Planning implementation tools: Transfer of Development Rights. Retrieved from https://www.uwsp.edu/cnr-ap/clue/Documents/PlanImplementation/Transfer_of_Development_Rights.pdf

35 NY State Department of State. (2010). Transfer of development rights. Retrieved from https://www.dos.ny.gov/lg/publications/Transfer_of_Development_Rights.pdf

36 Adams, A. (2019, February 21). Cohasset, Scituate, and Hull set to meet about regional sewer system. Wicked Local Scituate. Retrieved from https://scituate.wickedlocal.com/news/20190221/cohasset-scituate-and-hull-set-to-meet-about-regional-sewer-system

State Revision of Fiscal Policy

State revision of Proposition 2 1/2 would greatly alleviate the municipality's difficulties in generating revenue. For the Lot Consolidation Approach, this would enable the municipality to increase the tax levy to sustain or increase its level of service quality, while still maintaining community character. This approach puts a greater financial burden on residents. This points to the larger question of the feasibility of property tax reliance in coastal Massachusetts.

Conclusion

The three approaches to this scenario suggest that tradeoffs would be required between maintaining Hull's community character, maintaining fiscal viability, and maintaining affordability. Consolidate Lots & Downsize Homes retains the town's neighborhood feel, but limits the ability to sustain the same level of service provision, as Hull will experience a net loss of $5.5 million in tax revenue yearly. Upzoning to Multifamily Housing maintains the same level of service provision for residents as tax revenue increases, but would require a significant change to town character, residents' lifestyles, and affordability. Although multifamily high density development conflicts in many ways with the community's vision, from a purely financial point of view, this is the most feasible option for the municipality.

The amount of development needed in Hull to offset the tax deficit, coupled with public infrastructure upgrades as well as home buyouts and demolitions will be extensive. Some of these costs will be passed on to residents, which will completely change the demographic makeup of the community, as residents unable to afford higher housing and living costs will be displaced. Town decisionmakers will need to seriously consider how to ensure equitable outcomes for residents.

Our Regional Accommodation analysis shows the benefits of thinking beyond current municipal borders to relieve financial burdens by sharing services, providing affordable housing, diversifying the tax base, and increasing socioeconomic diversity. However, the way that Hull residents are able to continue to live in a lower-density, neighborhood-scale community with a high level of services is to move to affordable housing provided in Hingham and Cohasset. The new housing development can help to address the region's affordability issues, extending the benefits of this approach to the metro Boston area as well. This development will also help to address Massachusetts' power dynamics in the allocation of resources by elevating the area's importance to the state's economy. Therefore, creating an economic hub may enable the region to attract more state funds to be used on adaptation measures going forward.

For any approach explored here, state and local policies changes would be needed, as current fiscal and land use policies in many ways do not facilitate these proposals.

The municipalities might think about investigating the feasibility of land banks, inter-municipal TDRs, and land readjustment as strategies to manage vulnerable property. The more that the three towns can do now to prepare for future sea level rise, the more control they can have of the adaptation process, thereby limiting future costs.

Kelly Fike/U.S. Fish and Wildlife Service

Introduction

The last scenario investigates mitigating the risks of chronic inundation in Hull by proactively adopting managed retreat from the coast and transforming currently developed land back to open space. This strategy would rely on FEMA's home buyout programs. We examined two scenario sub-options: one a partial retreat scenario in which only residents at risk of inundation in Hull by 2070 are resettled; the other, a full buyout process of all properties in Hull by 2100. In both cases, formerly occupied land becomes parkland to be added to the Boston Harbor Islands National and State Park.

We find that a partial buyout of only the at-risk properties by 2070 will cost approximately $816 million, $612 million of that to be paid by FEMA, and $204 million to be shouldered by the state and the municpality, per current FEMA policy. Taking into account average historic annual budget increases, we projected the town budget to fall to $53.2 million as a result of losing half its residents. Turning these areas into parkland can generate $4 million per year for the region. The question remains whether this budget can support the remaining residents' service needs. In a full buyout scenario by 2100, the total cost rises to $2.17 billion dollars, for which $1.55 billion will be paid by FEMA and $517 million by the state and/or region. Adding this land to the Boston Harbor Islands Park will generate $8 million yearly in regional economic activity. These figures should be viewed as general order-of-magnitude cost references, as we are only able to account for buyout costs and not restoration costs.

We review case studies of municipalities that have faced similar challenges like New York City, Isle de Jean Charles, LA, and Kinston, NC. We find that large scale relocation is possible but costly and can help to reduce infrastructure upgrade costs. The cases illustrate the importance of proactive state involvement in terms of policy and funding. They also demonstrate that resettlement efforts that keep communities together in the area are the most effective in reducing future vulnerability, increasing resilience to future events, and maintaining regional tax bases.

These findings demonstrate the benefits and challenges of managed retreat for both Hull and the greater region. This scenario offers an opportunity to protect citizen's safety and keep communities together, while providing a regional economic draw. It is also an extremely costly scenario and relies heavily on FEMA buyout money. Significant policy changes would be needed to generate both the necessary funds and land to enable this scale of relocation. Policies to merge infrastructure, public utilities and even town administration may help facilitate relocation. When phased with the other two scenarios explored in this report, this approach outlines a long-term strategy for Hull, Hingham, and Cohasset to adapt to sea level rise.

Scenario Description and Assumptions

This scenario proposes a managed retreat of Hull through property buyouts and converting current property into parkland. This ecologically-conscious scenario enables the municipalities to protect citizens' safety, decrease vulnerability, and increase economic development opportunities. Considering the history of Hull, from sparsely populated fishing village turned built-out seaside community, this proposal allows Hull to return to its roots in nature while preserving the land for generations to come.

The approach buildings on the existing presence of parkland in Hull, namely Peddocks Island, Bumpkin Island, and the Weir River Estuary Park. The Boston Harbor Islands National and State Park is already an asset to the residents and tourists; over half a million people visited the park in 2016.[1] The addition of the chronically inundated land in Hull to the Boston Harbor Islands State Park allows for the tourism industry in the Boston Metro region to grow and for displaced residents to continue to enjoy their homelands in a safe and mutually beneficial way. The ecological protection opportunities presented in this scenario allow for the peninsular landmass of present-day Hull to continue to protect its neighboring communities in Massachusetts Bay by bearing the brunt of storms.

We explore two options for this scenario: a partial retreat and a full retreat. With the partial retreat scenario, a managed retreat takes place only in inundated areas in Hull by 2070. With a full retreat scenario, residents and property owners retreat from all land and properties by 2100 regardless of inundation risk. The population in Hull is aging, with many on fixed incomes, causing the burden of personal adaptations to homes to become too expensive. Hull also has a high renter population, many of whom would have uncertain futures after chronic inundation of their rented properties. We use a combination of the highest projections by the Union of Concerned Scientists and FEMA floodplain data to assess future flooding. Our cost estimates only take into account buyouts, and do not look at costs to demolish homes, roads, and infrastructure, and restore Hull to parkland. In the partial buyout scenario we do not take into account upgrading infrastructure and building bridges as Hull becomes disconnected islands surrounded by open space. Therefore, the costs listed should be viewed as underestimates of the full cost to implement this scenario.

This scenario relies on the change to FEMA buyout programs that would enable proactive buyouts chronically inundated and future inundated properties due to the

1 Boston Harbor Islands. (2019). About the Park. Retrieved from https://www.bostonharborislands.org/about-the-park/

high costs to maintain infrastructure and roads throughout periods of repetitive chronic inundation from sea level rise and storm surges. According to FEMA buyout policies, once a flood-prone structure is purchased from willing sellers, the structures are demolished, with the property to be maintained for open-space purposes in perpetuity.[2] To get a general estimate of buyout costs, both scenario options assume that the market value of all properties would be the same as the assessed value. We use current population figures for Hull and project that Hull's population will decrease by up to half of the current total population by 2100.

Research Methods and Scenario Outcomes

This scenario estimates the cost to buyout properties in Hull that are vulnerable to inundation, the economic impacts of enlarging the Harbor Island Park, and the policy barriers and opportunities. We draw on revenues and cost estimates from the Micro-Protect and Elevate and the Accommodate and Densify scenarios. Future town budgets are calculated by subtracting tax revenues lost to inundation. Buyout costs are estimated by summing the present value of homes predicted to be inundated for the partial and full retreat. This research helped to identify the fiscal health and scope for future development of each municipality in order to assess reasonableness of adaptation costs.

- Case Study Analysis: We research related case studies that shared similar physical conditions, demographics, and political constraints to acquire the precedent costs, develop strategies, and understand the policy implications for other municipalities. This also gives us alternative post-disaster solutions.
- Economic Impact Analysis: We calculate the impact of a larger park based on Boston Harbor Islands financials as well as State and national precedents of parks roughly the same size as Hull. This enables the assessment of the direct and indirect impacts of additional parkland on the area and throughout the region. This analysis can capture spillover effects that might occur such as an increase in home value within the area due to the new amenities. While we can not directly calculate the economic impact of a local and state park in Hull due to data limitations, we are able to get a ballpark figure by taking an average of the economic activity of similar parks from existing studies. This is presented in Table 21.
- Policy Analysis: We analyzed fiscal policies, property taxes, zoning ordinances, and flood insurance policies to understand the relationships between them and reveal problems, gaps, or opportunities.

2 FEMA. (2015, February 27). Hazard Mitigation Assistance Guidance. Retrieved from https://www.fema.gov/media-library-data/1424983165449-38f5dfc69c0bd4ea8a161e8bb7b79553/HMA_Guidance_022715_508.pdf

Scenario Outcomes

Partial Retreat Scenario

The estimated total buyout cost for residents by 2070 would be $816 million, $612 of that coming from FEMA and $204 million from regional and state funds. With a decreased tax base, the estimated town budget would fall to $53.2 million a year, and the population would decrease to approximately 5,800 people. Creation of a park within the chronically inundated land could generate approximately $4 million a year in economic impact regionally. Table 18 shows an approximate partial retreat scenario through 2100; Table 19 shows the costs to Hull, Hingham, and Cohasset for buying out flooded properties.

Full Retreat Scenario

Creation of a park within all land encompassing Hull would result in an estimated total buyout cost of $2 billion, and could generate approximately $8 million a year in economic impact regionally. With a nonexistent tax base and dissolving and/or merging of the Town of Hull municipal structure, the estimated town budget would fall to roughly $0 a year, and the population would also fall to 0 people. Table 20 shows an

Action Plan/ Timeline	**2019**	**2030**	**2070**	**2100**
Retreat of inundated Population	Survey and Participatory Process	900	3,700	0
Remaining population	Survey and Participatory Process	9,530	5,800	5,800
Elevation costs of roads	Maintain all Existing Roads	Elevate Main Roads and Maintain Local Roads	Elevate and Maintain All Roads	Maintain Roads
Public infrastructure	Start Regional Cooperation Network	Move/Share Public and Maintain Existing Infrastructure	Maintenance of Public Infrastructure Only in Un-Inundated Areas	Maintenance of Public Infrastructure Only in Un-Inundated Areas
Town revenue	+	-	-	Stagnant
Park construction	Begin the Planning Process and Collaboration	Begin Construction	Gain Revenue	Estimated $4 Million

Table 18: Timeline for Partial Retreat Scenario

	Cost	Hull	Cohasset	Hingham
2030	Inundated Property Value	$216,600,000	$84,300,000	$17,300,000
	FEMA Buyout	$162,450,000	$63,225,000	$12,975,000
	Regional & State	$54,150,000	$21,075,000	$4,325,000
2070	Inundated Property Value	$282,400,000	$91,200,000	$60,000,000
	FEMA Buyout	$211,800,000	$68,400,000	$45,000,000
	Regional & State	$70,600,000	$22,800,000	$15,000,000
2100	Inundated Property Value	$816,000,000	$286,700,000	$180,500,000
	FEMA Buyout	$612,000,000	$215,025,000	$135,375,000
	Regional State	$204,000,000	$71,675,000	$45,125,000

Table 19: Buyout costs for Hull, Cohasset, and Hingham

Action Plan/Timeline	2019	2030	2070	2100
Retreat of Inundated Population	Survey and Participatory Process	900	3,700	0
Remaining Population	Survey and Participatory Process	9,530	5,800	0
Elevation Costs of Roads	Maintain all Existing Roads	Maintain all Existing Roads	Maintain all Existing Roads	Remove Road Infrastructure
Public Infrastructure	Start Regional Cooperation Network	Move/Share Public and Maintain Existing	Removal/No Further Maintenance of Public Infrastructure	Removal/ No Further Maintenance of Public Infrastructure
Town Revenue	+	-	--	$0
Park Construction	Begin the Planning Process and Collaboration	Begin Restoration	Gain Revenue	Estimated $8 Million

Table 20: Timeline for Full Retreat Scenario

approximate full retreat plan through 2100. The Hull buyout costs for the municipality and the region greatly exceed the amount of economic activity generated from a park. Nevertheless, the location of the Boston Harbor Islands close to an urban center means that it already attracts half a million visitors annually. The addition of parkland will increase the capacity of the area to accommodate more visitors, further increasing economic activity.

Park Typology	State	Site	Park System	Area [acres]	Total Impacts		
					Economic Activity	Labor Income	Employment
Hull	MA	Statewide	State of Massachusetts	450,000	$1,096,322,748	$447,553,157	8,149
Case Studies							
Big Parks	KS	Shawnee Mission Park	Johnson County Park & Recreation District	1,600	$1,979,552	$622,541	20
Big Parks	MO	Forest Park	City of St. Louis Parks, Recreation, and Forestry	1,300	$4,255,194	$1,460,977	39
Big Park	MD	South Germantown Park	Maryland National Capital Park & Planning Commission	736	$13,974,870	$5,012,018	131
Regional Park	OH	Winton Woods	Great Parks of Hamilton County	2,500	$21,840,284	$7,620,396	202
Regional Park	CO	Highland Heritage Regional Park	Douglas County Parks, Trails and Building Ground	92	$1,258,580	$449,352	11
Average				**1,534**	**$8,661,696**	**$3,033,057**	**81**

Table 21: Economic Impact Analysis of Local and Regional Parks (National Recreation and Park Association, 2015)

Lessons from Past Buyout Efforts

In order to more comprehensively understand the process and ramifications of mass relocation due to sea level rise, we identify specific precedents that can help formulate this scenario as a viable option. We select the cases below for their potential applicability to the situation in Hull: a need for large-scale buyouts and an effort towards managed, coordinated resettlement. We assess three main categories from New York City, Kinston, NC, and Isle de Jean Charles, LA: cost considerations and constraints, physical and policy frameworks for implementation, and quantification of vulnerability at the end of the planning or physical relocation process.

Cost Considerations and Constraints

The three case studies illustrate how costly buyouts can be for communities, but also provide precedents for how Hull might proceed down this path.

Hurricanes Fran (1996) and Floyd (1999) were extremely costly for the town of Kinston, North Carolina. Much of the town lies within the FEMA 100-year floodplain and Kinston has a poverty rate of over 32%. Hurricane Fran caused $5 billion in damages, along with 24 deaths, becoming the costliest and deadliest hurricane at that time. [3]Damages for homes and businesses were estimated at approximately $2.3 billion, with costs related to public property (e.g. debris removal, roads and bridges, public buildings, utility repair) estimated at about $1.1 billion. Hurricane Floyd caused 52 fatalities throughout North Carolina, most from freshwater flooding, as well as $7.8

3 Smith, J. (2014, September 14). How Hurricane Floyd severely affected Southeastern part of Kinston. kingston.com. Retrieved from https://www.kinston.com/20140913/how-hurricane-floyd-severely-affected-southeastern-part-of-kinston/309139991

billion in damages.[4] A year after Floyd, over $1.9 billion in federal and state disaster assistance was given to North Carolina residents. The Hazard Mitigation Grant Program initially issued over $149 million for the acquisition of over 2,000 homes, and later another $104 million to buy out 1,800 homes, resulting in the largest buyout program in history.[5]

Hurricane Sandy ultimately resulted in a total of $65 billion in damages and 117 deaths within the United States.[6] In New York, Sandy damaged or destroyed an estimated 300,000 homes with 10,000 of those homes losing over half their value. Additionally, 14 counties were designated as federal disaster areas.[7] In the aftermath of Sandy, New York Governor Andrew Cuomo put together a comprehensive SLR and flood mitigation plan which included the goal to transform the inundated coastal flood zones into conservation land. Ultimately, implementation of the policy brought $1.71 billion

4 Ibid.

5 Federal Emergency Management Agency. (2000, September 7). Approaching One Year, North Carolina Floyd Assistance More Than $1.9 Billion [Press Release]. Retrieved from https://www.fema.gov/news-release/2000/09/07/approaching-one-year-north-carolina-floyd-assistance-more-19-billion

6 Associated Press. (2012, November 29). What We Know about Superstorm Sandy a Month Later. Retrieved from https://weather.com/news/news/superstorm-sandy-one-month-20121129

7 FEMA. (2013, November). Mitigation Assessment Team Report: Hurricane Sandy in New Jersey and New York. Retrieved from https://www.fema.gov/media-library-data/1386850803857-025eb299df32c6782fdcbb6f69b35b13/Combined_Sandy_MAT_Report_508post.pdf

View of Boston skyline from Peddocks Island, Boston Harbor Islands Park (AnubisAbyss/Flickr)

in supplemental Community Development Block Grant (CDBG) funds.[8] This means that cost constraints were to some extent mitigated, but the likelihood of ongoing federal funding is not clear.

The recovery from hurricanes Sandy, Fran, and Floyd highlights the costs of large buyouts for federal, state, and local governmens. These cases provide precedent for buyouts of this scale. In order to apply this to our scenario, we must still acknowledge the constraints of these buyout processes and policy frameworks. All of the case studies mentioned in this section look at mitigating risks after a catastrophic event, rather than before. One thing is clear is terms of raising capital for sea level rise projects: state and federal funding and policy is king, so programs at these levels is most likely to be successful.

Implementation Limitations

The cases of Isle de Jean Charles and New York City suggest that federal FEMA/HUD policy, cost, and residents' reluctance to move are some of the potential limitations to implementing a buyout and resettlement program for Hull.

Implementing buyouts and resettlements in Isle de Jean Charles in southern Louisiana was constrained by cost. Only 320 acres of the original 22,000-acre community remain. Affected by coastal erosion and salt-water intrusion caused by canals running through the marshland, as well as levees separating the island from the river, and rising sea levels, the Isle de Jean Charles has been considering total tribal resettlement for over 15 years.[9] With only 91 residents remaining, the State of Louisiana repaired the only road connecting the Isle to the mainland for the last time in 2011 for $6.24 million. In 2016, the U.S. Department of Housing and Urban Development (HUD) awarded Louisiana $48 million in CDBG funding to be used towards the resettlement of Isle de Jean Charles. However, it is estimated that over $100 million is needed to complete the project.[10]

In the aftermath of Hurricane Sandy, implementation was constrained by FEMA policy as well as residents' doubts about and approval of the buyout scenario. In order to receive a CDBG grant for Sandy, New York State buyout laws had to completely align with HUD policies. Specifically, homes had to be located in the 500-year floodplain and have sustained damages greater than 50% of their pre-storm fair market value to be offered a buyout. Buyouts pre-Sandy equalled market value for the property. Even after

8 Binder, Sherri B. (2014). Resilience and Postdisaster Relocation: A Study of New York's Home Buyout Plan in the Wake of Hurricane Sandy (Doctoral dissertation). Retrieved from https://scholarspace.manoa.hawaii.edu/handle/10125/100297

9 Isle de Jean Charles, Louisiana (IDJC). (2019). Retrieved from http://www.isledejeancharles.com/

10 Lowlander Center. (2017). Resettlement and Survival. Retrieved from http://www.coastalresettlement.org/

complying with these regulations, homeowners could not be guaranteed a buyout. This ultimately meant that many homeowners were quite skeptical of buyouts, therefore producing divided results in the efficacy of the program.[11] Some neighborhoods, including Oakwood Beach and Ocean Breeze, Staten Island, worked with the state-run buyout and acquisition program, which bought out large groups of homes in order to turn the repossessed land back to nature. However, many others were not so successful. In one instance, the City of New York added another type of cash incentive for unloading homes, ultimately offering up to $150,000 in additional money for the buyout. The payout relied on the income of the homeowner and on where they moved, according to the City of New York. Despite the extra incentive, only six homeowners took this option.[12] Most applicants opted instead to have their homes repaired or elevated—despite delays and other issues involved with the larger New York State Build It Back program. Unlike the larger neighborhood buyout program, the City now has to assess what to do with the individual lots and damaged homes dotted across coastal communities.

Our scenario draws on the precedents created in both Isle de Jean Charles and New York City for information about the difficulties and costs of a full, structured resettlement process. The population in Hull is roughly 100 times the size of Isle de Jean Charles, so while costs cannot be estimated exactly for a resettlement plan for Hull, it is clear that full resettlement will be extremely costly. Nevertheless, it potentially provides a less emotionally disruptive option, should residents prefer to move together. Full coordination between the city, state, and federal governments would be necessary to plan for resettlement of Hull as a whole.

Impact on Social Vulnerability

The cases of New York, Isle de Jean Charles, and Kinston also demonstrate how social vulnerability can increase or decrease after an event, depending on policies implemented.

After Hurricane Sandy, household vulnerability increased in many instances. Those relocated or displaced wanted a sense of community and wanted to stay close to home. Ultimately, 60% of buyout participants moved within five miles of their original home. Overall vulnerability and social vulnerability were the largest increases, with 321 of the 323 buyout participants considered by a Duke University study reported a higher level of vulnerability. For social vulnerability, an increase was felt by a total of 99% of participants.[13] However, this does not take into account the vulnerabilities

11 Siders, A.R. (2019). Social justice implications of US managed retreat buyout programs. Climatic Change 152(2): 239-257. https://doi.org/10.1007/s10584-018-2272-5

12 Honan, K. (2017, October 27). City Had Millions to Buy Out Sandy-Damaged Homes, But Most Didn't Want It. Retrieved from https://www.dnainfo.com/new-york/20171027/great-kills/hurricane-sandy-buyout-acquisition-build-it-back-federal-program/

13 McGhee, D. (2017, April). Quantifying the Success of Buyout Programs: A Staten Island Case Study (Masters

mitigated by finding a permanently safe home, rather than going through the process of reconstruction, only to be equally vulnerable as before the disaster event.[14]

The Isle de Jean Charles case illustrates the social complications of relocating communities. In a survey of residents in Isle de Jean Charles, many agreed that the new settlement should be safe from flooding, but there is still disagreement about staying near fishing opportunities versus settling on safe lands. Regarding desire to relocate, only 42 residents answered a positive yes to want to resettle, with 21 residents being sure they did not want to resettle. Unsure residents were concerned about the resettlement process, and being close to work, school, and grocery stores, while maintaining the safety they feel on the island.[15] Despite being unsure, over 50% of residents wanted to resettle as a community. However, Albert Naquin, Chief of the Isle

Thesis). Retrieved from https://dukespace.lib.duke.edu/dspace/handle/10161/14168

14 Koslov, L. (2016). The Case for Retreat. Public Culture. Retrieved from https://read.dukeupress.edu/public-culture/article-pdf/28/2 (79)/359/455501/0280359.pdf

15 Concordia. (2018). Isle de Jean Charles Resettlement. Retrieved from http://concordia.com/projects/isle-de-jean-charles-resettlement/

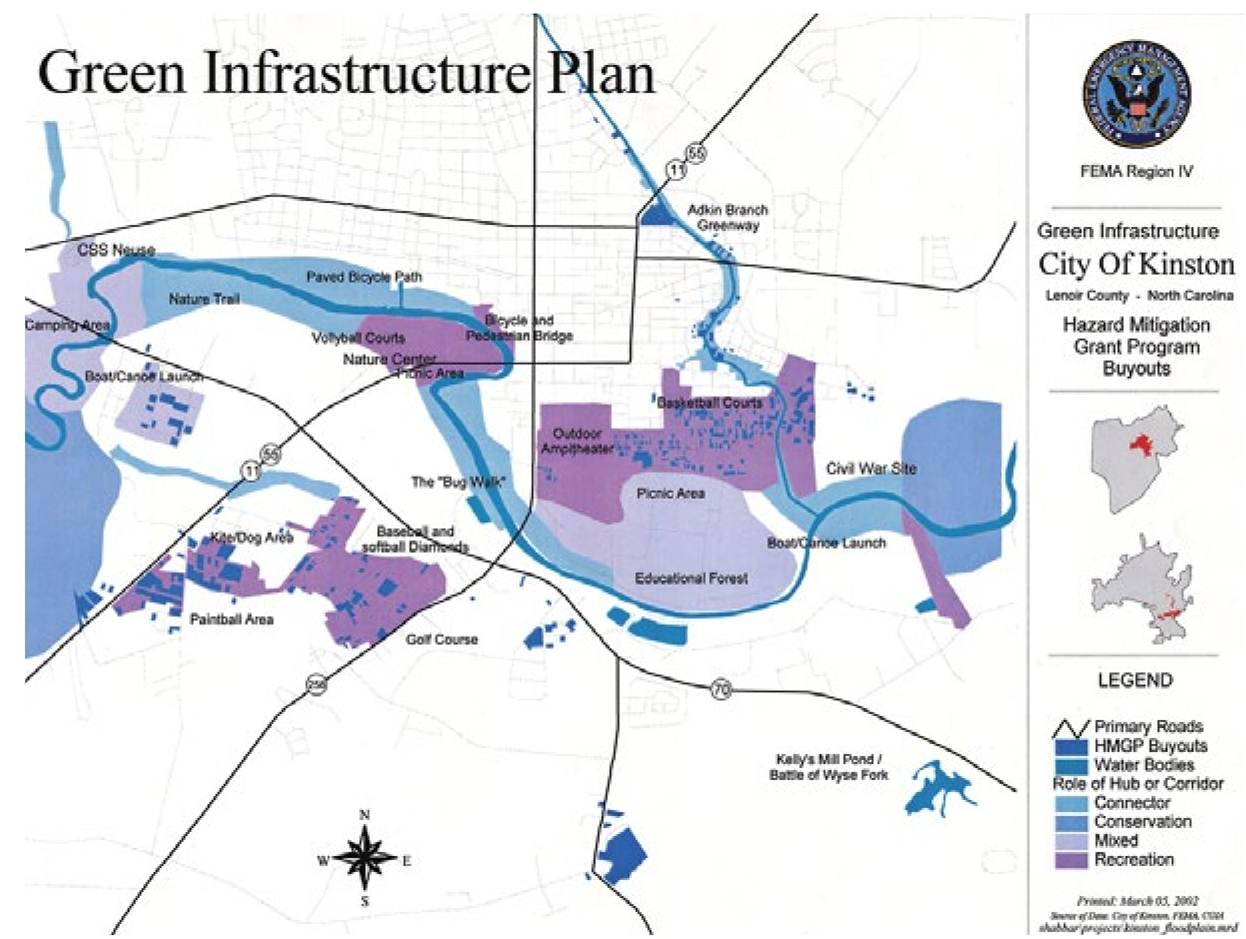


Figure 31: Kinston, North Carolina's Green Infrastructure Plan (City of Kinston)

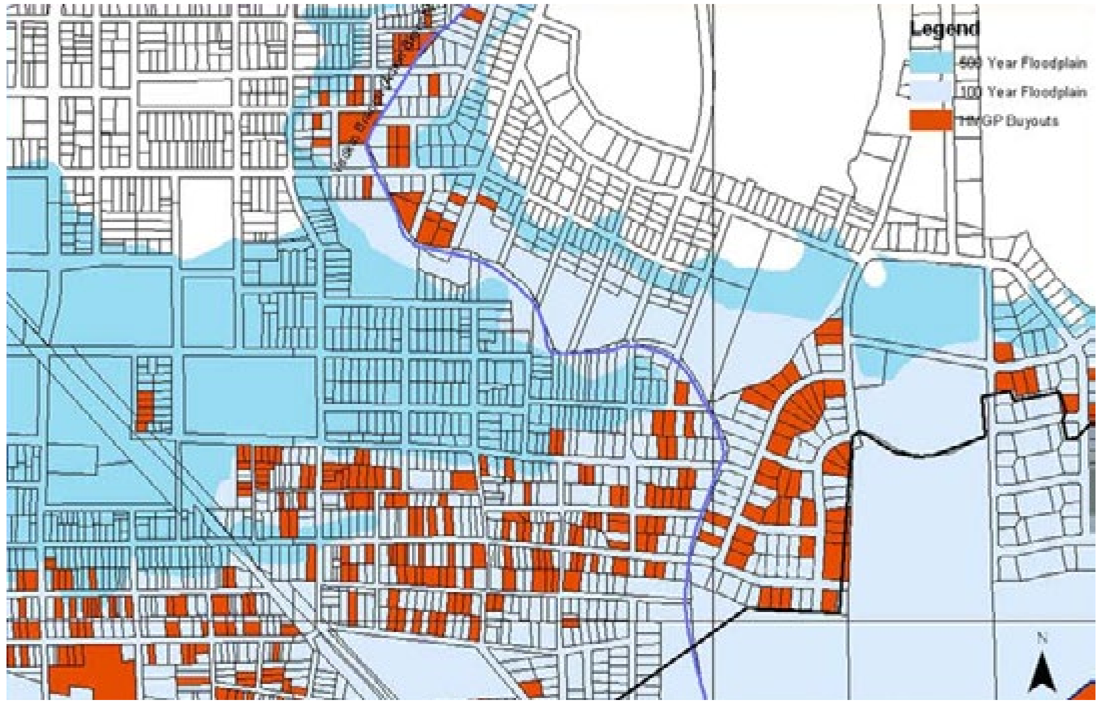


Figure 32: Hazard Mitigation Grant Program Acquisitions in Kinston, North Carolina (City of Kinston)

de Jean Charles tribe, is encouraging residents not to move, stating that "the plan was to reunite the tribe and now it's going to be destroyed," accusing the state of "hijacking" the plan by allowing vacant lots in the resettlement to be auctioned to the public. Many residents feel that holding ties to their native land, and keeping tradition by living as a tribe is more important than building a new, safe community.[16]

Differing from New York and Isle de Jean Charles, Kinston took measures to incentivize residents to stay within the city district in order to help maintain the social fabric and proximity to schools, friends, and neighbors. FEMA buyout programs require that land be maintained as open space, but Kinston desired for that land to benefit the community. The City of Kinston partnered with the County, as well as the University of North Carolina's City and Regional Planning Department to develop the Kinston-Lenoir County Green Infrastructure Plan (Figure 31) for the Neuse River floodplain.[17] This plan focused on heritage tourism around a Civil War site and historic buildings, and passive recreation through an educational forest and nature trail, and active recreation including bicycle paths and use of the Neuse River.[18]

16 Jarvie, J. (2019, April 25). On a sinking Louisiana island, a historic tribal land, many aren't ready to leave. Los Angeles Times. Retrieved from https://www.latimes.com/nation/la-na-jean-charles-sinking-louisiana-island-20190423-htmlstory.html

17 NOAA Office for Coastal Management. (2018). Out of Harm's Way: Relocation Strategies to Reduce Flood Risk. [Report]. Retrieved from https://coast.noaa.gov/digitalcoast/training/kinston-flood-risk.html

18 FEMA. (2013, November). Case Study: Innovative Floodplain Management. Retrieved from https://www.fema.gov/media-library-data/20130726-1515-20490-7614/kinston_cs.pdf

View of Spectacle Island, Boston Harbor Islands Park (AnubisAbyss/Flickr)

Kinston developed a coordinated relocation plan to protect the social and economic bases of the community, utilizing GIS as an educational tool to generate community support for the acquisition plan. The municipality created a demographic profile of residents living in the 100-year and 500-year floodplains to help identify the number and price range of homes needed to accommodate residents wishing to relocate outside of the floodplain. A map of the HMGP acquisitions in Kinston is shown in Figure 31. The town's floodplain administrator set the goal to remove all residential structures from the floodplain, with a coordinated relocation plan to allow residents to move into the same neighborhoods together to retain social cohesion. A partnership between the North Carolina Office of the Governor, the Department of Correction and the Division of Emergency Management was created to build replacement homes for displaced residents, using $1.5 million from the governor's relief fund (FEMA, 2013). Over 100 new homes were built from this partnership, and the abandoned high school in Kinston was converted into housing units for the elderly.[19]

These examples suggest that vulnerabilities can both be worsened or lessened depending on how resettlement and adaptation to SLR is managed. Kinston made the most of its situation post-buyouts and made the now–open space areas available for use by the community. The municipality's structured plan to rebuild homes and

19 Ibid.

resettle together should be considered as a model for Hull, as this will also help reduce vulnerabilities and keep social cohesion and ties to their neighborhoods. While enough land to relocate within the city district does not exist in Hull, a regional partnership with the county and neighboring towns can be substituted here to keep ties to Hull strong, as well as maintain the tax base in the region.

Restoration for Better Opportunities

The case studies and the associated climate challenges they each face demonstrate the effectiveness of resettling the population and demolishing the structures at risk of inundation for the safety and preservation of each community. Overall, resettlement can avoid high infrastructure costs. In almost all cases, safety improves after relocation, and social vulnerability can be reduced through collective resettlement. The cases demonstrate that large-scale relocation is costly, yet possible. Proactive state involvement in terms of funding and policy is paramount.

Policy Implications And Recommendations

Existing Policies that Facilitate this Scenario

Some existing federal buyout policies and statewide funding streams would help to facilitate this scenario. For example, FEMA requires that inundated and bought out land become open space. This enables Hull's transition to a state and national park, creating an easy avenue for the Boston Harbor Islands to acquire the land to add to their stock.

According to the 2017 Massachusetts Statewide Comprehensive Outdoor Recreation Plan, the Commonwealth of Massachusetts is aware of the value and is highly supportive of outdoor recreation projects through several funding opportunities. The Land and Water Conservation Fund (LWCF) is one such opportunity. It provides a steady investment in outdoor recreation for preserving, protecting, and assuring the availability of close-to-home outdoor recreation areas and conservation land. The program invested $16.7 billion over the past 52 years.[20] The fund can be used for the acquisition of land, the development of new parks and the renovation of existing parks. In addition, there are several state-funded municipal grant programs, including:

- Parkland Acquisitions and Renovations for Communities (PARC) Grant Program
- Local Acquisitions for Natural Diversity (LAND) Grant Program

20 Executive Office of Energy and Environmental Affairs (EEA). (2017, December). Massachusetts Statewide Comprehensive Outdoor. Retrieved April 05, 2019, from https://www.mass.gov/files/massachusetts-scorp-2017-for-submission.pdf

- Gateway City Parks Grant Program
- Landscape Partnership Grant Program
- Conservation Partnership Grant Program
- Drinking Water Supply Protection (DWSP) Grant Program
- Retreat to Restore can work through state funds for outdoor recreation grants and other sources of funding.

Policy Changes Needed Under this Scenario

Ultimately, this scenario would require regulation changes, specifically with FEMA, in order to occur. Under the current system it does not make financial sense because park revenues go to state and federal entities, and costs for full buyouts are assessed on a per case basis. In addition, damages to second or vacation homes are not eligible, which would pose a problem for some residents in Hull. FEMA also encourages acquisition and removal over relocation to a new site. Participation in the buyout program is voluntary, and eminent domain cannot be used if property owners choose not to participate.

The laws prohibiting the use of eminent domain in flood buyouts need to be changed to achieve comprehensive relocation. More complete and long-term funding opportunities are needed, and the availability of these monies will need to become more easily accessible.

Eminent Domain

More proactive interpretations of eminent domain would facilitate this scenario becoming reality. Currently, eminent domain may be used for a public works project, but there is limited information and examples of a court upholding a government's right to eminent domain for the safety and wellbeing of the property owners. Since private property rights are heavily protected in the U.S., it is not likely that eminent domain will be able to be used in this case to remove properties and residents from chronically inundated lands. We recognize that this would be very costly and difficult to accomplish considering the legal ramifications, residents' personal ties to Hull, and coastal land ownership structures. States have the power to promote the welfare of its citizens. However, this is an unprecedented case, and getting 100% participation in a buyout program for the whole of Hull to become parklands is likely to be an uphill battle.

Rolling Easements

Rolling easements can be a regulatory tool used by the town to ensure safety of the residents from chronic inundation by means of inland relocation. Rolling easements are also a way to ensure the land for public usage such as beaches, especially in the scenario of changing coastlines, thus prohibiting hard shoreline armoring and structure that would potentially block public acess of the shoreline. Municipalities can use rolling easement policies as an early warning tool to notify waterfront property owners of the limited nature of their property rights, resulting in futures cost savings towards emergency response and disaster relief efforts.In the case of Hull, rolling easements can prove to be a better policy tool in facilitating a state park scenario, in comparison to eminent domain, since it allows for the public to have a right on usage of the waterfront.[21]

Buyout Program

This scenario proposal relies on an increase in the availability of funds for buyouts. FEMA's Hazard Mitigation Grant Program currently states that FEMA is to cover 75% of a buyout, with the state, municipality, or property owner to cover the remaining 25% of the costs. The costs to both FEMA and the state will be extremely high to buy out an entire town of 10,000 people, and therefore increased funding would be needed for this scenario to be completed. The reliance of buyouts is highly uncertain given the number of structures that need to be relocated under climate change. The fact that resettling half of a small town costs $816 million hints at an unviable future of this approach.

Sales to Land Trusts (Conservation Easements)

Reluctant property owners in Hull may oppose to forfeiting their land towards a buyout, but may see value in preservation of the community. In such a case, conservation easements could be employed as a viable option to where the land can be sold to a land trust but still kept under private ownership, ensuring limited uses of the land and facilitating its return to its ecologically beneficial state. Restrictions on the conserved land are enforced by the land trust, and continue to hold even in a case where the land is sold.[22] Although, such easements do not automatically allow public uses of the land, but continue to allow economic benefits to the community. Conservation easements also allow land to be protected at a much lower cost to municipalities and land trusts as compared to traditional buyouts, thus, can be an effective tool towards managing reluctant property owners in Hull.[23]

21 Novak, E. (2016, May 31). Resurrecting the Public Trust Doctrine: How Rolling Easements Can Adapt to Sea Level Rise and Preserve the United States Coastline. Boston College Law Review, 60, 575. Retrieved from https://lawdigitalcommons.bc.edu/ealr/vol43/iss2/13/

22 Land Trust Alliance. (2014, December 23). Conservation Options. Retrieved from https://www.landtrustalliance.org/what-you-can-do/conserve-your-land/conservation-options

23 The Nature Conservancy. (2019). Private Lands Conservation. Retrieved from https://www.nature.org/en-us/about-us/who-we-are/how-we-work/private-lands-conservation/

Land Swaps

National and State Park requirements allow the state and federal governments to form partnerships to trade chronically inundated land for not-at-risk land. The Commonwealth of Massachusetts could potentially enter into such a partnership and exchange the chronically inundated land in Hull for a safe inland parcel, thus ensuring the relocation of the displaced residents as a community, thereby reducing social vulnerability and increasing communal cohesion and wellbeing. Exchanging not vulnerable South Shore land for vulnerable land in Hull to add to the Harbor Islands National Recreation Area is a potential policy option for relocation that the municipality can explore to implement this scenario.

Infrastructure Policies

In order for this scenario to be feasible, a merger of public infrastructure will be necessary between Hull and neighboring Hingham and Cohasset. Early in the buyout process, public schools would need to be accepting of displaced students and families, in an attempt to=decrease students' social vulnerabilities by allowing the opportunity to go to school with their former classmates by being in the same region. Merging and situating public infrastructure such as water and sewer in safe, un-inundated areas reduces health risks for all populations along with increasing reliability on the infrastructure. Ensuring that roads are able to be maintained throughout periods of inundation and flooding is essential to maintaining other public infrastructures in line with public good, such as police and fire safety. Merging Hull's police and fire departments with a neighboring town can be a first step to integrating the towns before the buyout process takes place. Once homes begin to be bought out, ensuring that there is enough housing stock is critical to maintaining the tax base and reducing vulnerability. We can look to Kinston, North Carolina and their housing program to build homes and elderly housing facilities from existing buildings and similar funding opportunities. The necessary changes in infrastructure policies for this scenario rely heavily on cooperation between municipalities and the region, as well as the state. If a neighboring town were to absorb and merge with Hull, it is important to consider the amenities gained by the future addition of the parklands and beachfront, as well as tax revenues.

Conclusion

This scenario leaves a legacy for the town of Hull, but it comes at a high price. This scenario creates benefits in social wellbeing, ensuring the safety of coastal residents as sea levels rise. In financial terms, there is economic potential in adding to the existing Boston Harbor Islands Park, and there is a longstanding, proven ability to sustain it for years to come. Regional cooperation would create positive social benefits and cohesion, allowing schools, municipalities, communities, and residents to become more integrated across the South Shore. The increase in parklands and beaches will keep tourism high in the area, as well as attract new revenues in neighboring areas, aligning with goals set forth in Hingham and Cohasset to diversify tax bases and increase commercial properties.

However, the buyout costs are extreme for this scenario. This would put a financial burden on the municipality and the region. Whether the reduced budget from a partial retreat scenario will be enough to support the remaining residents as well as the necessary infrastructure upgrades for Hull is questionable. Providing affordable housing options for those resettled will be crucial to mitigate climate gentrification. This scenario requires regional, state, and federal collaboration, and policies encouraging that collaboration, in order to reach a sustainable and equitable outcome. Its expense makes this scneario unlikely to happen, yet there are precedents. The cases of New York City, Kinston, and Isle de Jean Charles provide precedents for large scale resettlement. They demonstrate the importance of state involvement early on. The case studies illustrate that resettlement can avoid high infrastructure costs, improve safety, and reduce social vulnerability if done collectively. If the region did want to take this approach, creativity would be needed. Certain policies like land swaps or utilizing land trusts could assist in lowering costs.

The retreat to restore scenario provides a long-term option for the Town of Hull and the greater region to decrease vulnerability and increase economic activity, providing a legacy of restored public waterfront. Although generating public support to relocate will be challenging, and massive funding, policies changes, and coordination from local, state, and federal governments is necessary, this scenario could be a long-term strategy for Hull and its neighbors to adapt to sea level rise.

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TECHNICAL APPENDIX

METHODOLOGY FOR REGIONAL ANALYSIS

Data and methods for assessing fiscal impact of sea level rise

Overview

This technical appendix describes a number of special operations and data sets necessary to use sea level data to assess fiscal impact of scenarios. Given the novelty of adaptation planning practice, data sources, and methods needed to integrate fiscal maps and scientific models may be unfamiliar to GIS professionals in both scientific and social science fields. The methodology described here was developed using scenario planning support software, GIS, and Excel. We found that the scenario planning support software supported fiscal impact analysis, but not better than calculations using a generic GIS software. As such, this technical appendix describes a general methodology that could be implemented in a number of GIS applications.

The sections below (1) introduce the scientific and government data sets, (2) explain the methodology for creating scenarios, (3) describe the key aspects of scenarios needed to estimate fiscal impacts, and (4) details the GIS operations used to combine the data sets and scenarios to estimate fiscal impacts.

Description of the Data

In general, two types of data are needed to estimate the fiscal impacts of sea level rise: the location of inundated areas over time and the property tax maps. Local government planners throughout the US likely have access to both of these sources, since the National Oceanic and Atmospheric Agency (NOAA) openly publishes sea level rise data and property taxes are administered through local government. Before using available NOAA data, users need to perform manipulations on the data, described in a technical document available through the website Sea Level Rise Viewer. The NOAA data set may be error prone at high resolutions, particularly in areas with complex coastal geography and locally-managed infrastructure works, such as culverts and small sea walls, that impact water flows. However, in some locations multiple options exist for sea level rise data. The Union of Concerned Scientists has published an alternative data set based on the NOAA data set, but in a format intended to be more understandable to decision makers. The NOAA data set contains a layer for each 1 foot of sea level rise, whereas the UCS data contains estimates of the location of chronically inundated areas at multiple points in time under high, medium, and low scenarios. As for the taxation data, these are required to be at the parcel level containing land use and taxable value, and usually need to be joined to a tax rate lookup table (i.e., the tax rates will not be contained in the same file).

The sections below detail the available data formats and requirements for fiscal impact analysis in the Boston region in Massachusetts.

Scientific Data Sets for Estimating Inundated Area

National data for sea level rise projections are readily available from the NOAA website Sea Level Rise Viewer for viewing and mapping. While we describe two data sets developed that extend the NOAA data, a similar process to the one described below could be replicated at any coastal location in the US using the NOAA data set.

We acquired two sets of sea level rise data, one from Massachusetts Department of Transportation (MassDOT) showing storm surge flood levels and one from the Union of Concerned Scientists (UCS); in both data sets, each time period is represented by a separate file. There are two types of files in this data set (1) representing the risk, or projected frequency of flooding, and (2) representing the depth of a 100-year flood event. Each of these file types has a separate file for present day (2018), 2030, and 2070. In MassDOT's risk data, cell values represent the flood frequency per 1,000 years. Positive values range between a maximum of 1,000, denoting permanently flooded, and a minimum of 1, denoting areas projected to flood once in 1,000 years. For example, a pixel in the risk file with the value 200 represents a 20% (200/1,000) chance of flooding in that area, which corresponds to a 1:50 likelihood annually, or the 50-year floodplain.[1] The depth files represent the water level during 500-year and 100-year flood events, respectively, in both 2030 and 2070. For example, in 2070, most of the present-day 100-year floodplain in our study area is projected to be under between 10 and 20 feet of water. We use the risk files to estimate the location of chronic inundation and depth files to color descriptions of the scenarios.

The risk files needed to be transformed to be compatible with the Massachusetts parcel database (described below). To do this, we performed two data operations: first, we "binned" the risk estimate raster into discrete values, then we "vectorized" the binned raster. Vector data is composed of nodes and lines while raster data is composed of a gridded continuous surface. The continuous raster values has to be simplified into binned value ranges in order to be vectorized. The "vectorize" function can be performed with most common GIS software (GDAL/OGR contributors 2019). Due to the data files' size and format,[2] the GIS processing may need to be done using

1 Note that some risk researchers are moving away from this traditional form of describing floods, which assumes a static level of risk over time. Some argue it is commonly misunderstood by floodplain residents. As sea level rise continually shifts the location and frequency of flooding within floodplains, the "#-year floodplain" format may become obsolete.

2 The data files for all coastal areas of the US are divided by states, with most state-level data further divided into groups of counties. These data would need to be combined (using a mosaic technique) for state-level

command line tools or other methods that do not read the file into active memory (RAM). We binned the values into the following annual maximum probabilities: 0.1%, 0.2%, 0.5%, 1%, 2%, 5%, 10%, 20%, 25%, 30%, 50%, 100%. Raster cells with an annual percent probability of 50-100% were considered chronically inundated.

The Union of Concerned Scientist data was acquired as a vector file already compatible with land use and regulations data. However, a few features of the UCS

analysis or divided (by cropping) to shrink the size of data for smaller area studies. Data file sizes range between a few hundred megabytes (very small) and 22.0 gigabytes in Southern Louisiana (very large). Several of the data files for large coastal states are over 8 gigabytes, which is currently a common random access memory (RAM) size limit for computers.

Box 1: Detailed Metadata

The UCS data based on National Oceanic and Atmospheric Agency (NOAA) modified bathtub model, which use the projected volume of water in the ocean, detailed digital elevation models (DEM), and tidal gauges to estimate sea levels over large areas like the globe or entire US. The NOAA estimates rely on 381 tidal gauges across the continental United States. Approximately 25 are located near the Massachuestts costs, in New Hampshire, Massachusetts, and Rhode Island. The NOAA method uses spatial interpolation to generate a model of the impact of other variables (i.e. volume of water and elevation) on local mean high water levels. However, many of these are concentrated in the Narragansett Bay of Rhode Island and outside of the Boston region. Three tidal gauges straddle the Boston region in Boston Harbor, Chatham, Lydia Cove, and Fort Point, New Hampshire near Portsmouth. The relatively sparse data points in the Boston region may contribute to higher errors in the NOAA model in that region.

In the UCS estimates, the NOAA modified bathtub model is adapted to new research on the best method to present sea level rise data to decision-makers; instead of downscaled with tidal gauges that enable more accurate local predictions from the bathtub model (for a review of interactions between sea level rise causes, see Idier et al. 2019). The UCS data contain low, medium, and high scenarios of climate change. Though a range of possibile emissions scenarios exist, in order to provide recommendations that would prove useful in every possible future, we only evaluated land use scenarios based on the high emission scenario. The UCS data are presented in a raster GIS format with a value for each pixel representing the average depth of water for each time period of 2030, 2070, and 2100.

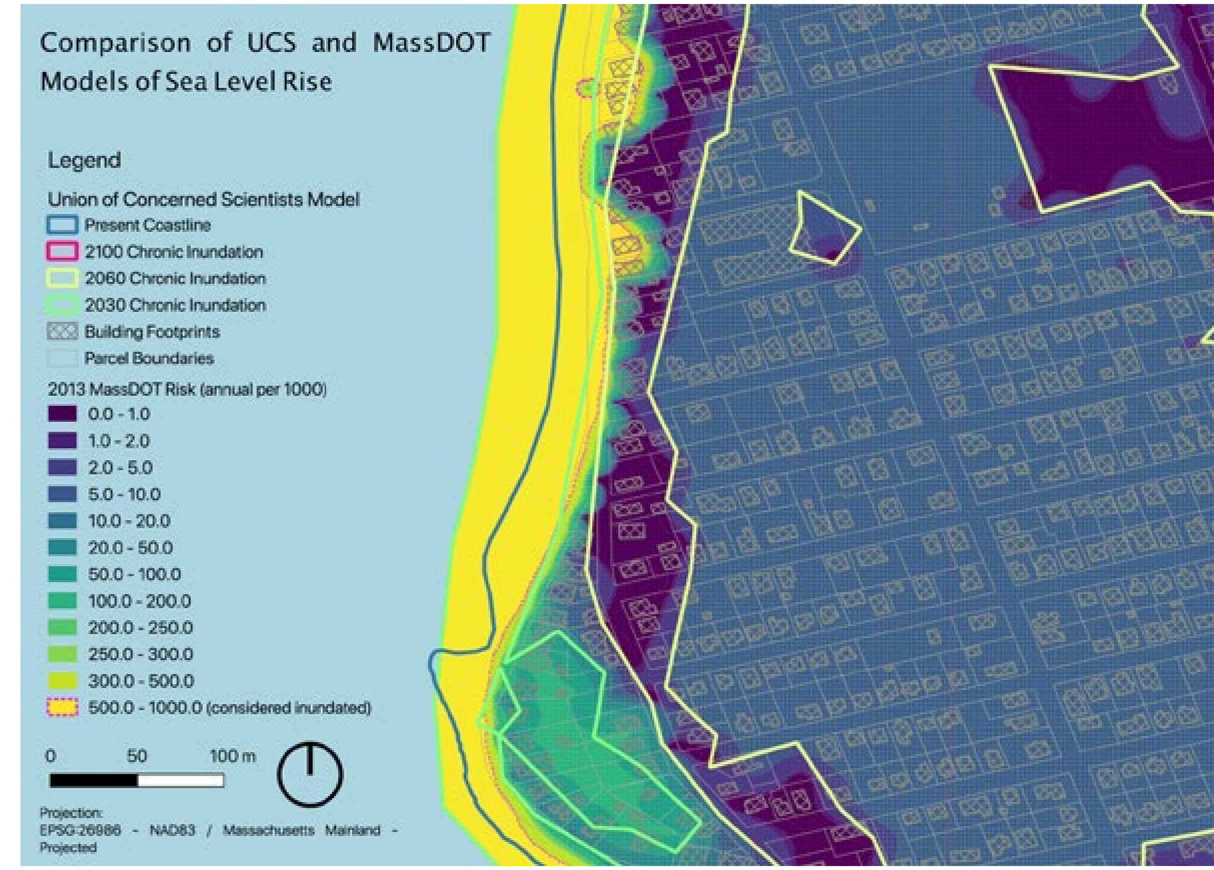

Figure 33: Visual comparison of UCS and MassDOT Sea Level Rise Models

should be noted. First, the UCS data was produced with decision-makers in mind using a well-researched threshold for "chronic inundation" of 26 times per year (Union of Concerned Scientists 2018; Dahl et al. 2017). The chronic inundation data were calculated using the NOAA (2017) projections of sea levels, elevation, and 20 years of tidal data. The method used in calculating chronic inundation is an improvement on the NOAA inundation data only insofar as the UCS data uses longer time series data that captures two lunar cycles and eight El Niño cycles.

Differences Between Sea Level Data Sets

Figure 33 shows the results of this manipulation overlaid with the UCS estimates for chronic inundation. The bright yellow base layer representing 50%-100% chance of inundation per year represents chronic inundation for the MassDOT model. While we did not perform a sensitivity test or other formal comparison of the two models, this close-up map (note the scale in meters) demonstrates general agreement with moderate differences between the two models. The top right of this map, for example shows the low chance MassDOT model generally agreeing with the 2060 chronic inundation line.

Land Use and Tax Rate Data

Data regarding land use come from a statewide parcel level database maintained by the regional planning organization in Boston, Metropolitan Area Planning Council (MAPC). The parcel database contains information on the following metrics, for all areas of the state:

- property value, which is comprised of:
  - land value, and
  - building value,
- land uses (needed for tax exemption status), and
- zoning district (needed for scenario development)

This information is needed, to combine with tax rates collected from local municipal websites. Note that local governments levy taxes and issue tax waivers per parcel, so land use information enables excluding certain exempt properties and applying tax rates selectively. Additional information about the allowable land uses and densities within different zoning districts enables scenario development. For example, one of the baseline scenarios could take the form of a build out analysis under current zoning with various assumptions regarding which properties would be developed only vacant properties, under developed properties, or allowing lot consolidation and development. It is important to identify public land uses that house critical infrastructure and would need to be relocated when sea levels reach them. Mark these parcels with a special land use code so they can be identified later. The Scenario Evaluation section below describes how this works in practice.

Cost Estimates

The final data set needed to assess fiscal impacts relates to the cost of maintaining and constructing infrastructure. Depending on the selected adaptation strategy, municipal governments may be responsible for maintaining or elevating roads, constructing seawalls, or relocating utilities and public facilities like schools. Cost data are particularly difficult to acquire because they are highly variable geographically. For example, even within the same locale, governments typically require administrators to obtain three cost estimates before contracting with a construction company. Still, costs are an important part of the fiscal impact equation and must be estimated. RSMeans, a proprietary construction cost database, provides local construction cost information that enables the calculation of rough estimates for road elevation, sewer modification, elevating on an open foundation (i.e. stilts, the only approved method of retrofitting coastal vulnerable properties; FEMA 2014), and relocating vulnerable home utilities to floors above the base flood elevation. These estimates are contingent on the local availability of specialized labor, variation in the cost of materials, and the local demand for such services. Comparable project reports and case studies also offer an information source, albeit labor-intensive to collect, on the costs of coastal retrofitting. We used RSMeans, the Kleinfelder report, and other case study reports to estimate retrofitting costs.

Developing Scenarios

The scenario development was done in consultation with local planners and MAPC. Scenarios can be defined by what varies in each scenario. We assume sea level rise is constant, and rather construct "adaptation scenarios" to evaluate what impacts adaptation policies themselves would have on neighboring municipalities. While fiscal impacts should not be the only consideration for setting public policy, we assumed that fiscal impacts would be a motivating factor, and serves as our analytical entry point to assess the drivers of municipal behavior. For this technical appendix, we describe the principles by which we developed scenarios and the criteria we used to modify them iteratively through consultation with the local planners.

We used two overarching principles to generate scenarios for filling the fiscal gap caused by sea level rise. The fiscal gap is based on the revenue lost from inundated land. Analysts propose developments on dry land that could make up for this difference or "gap". The two strategies are:

1. **Municipal approach.** The organizing principle for this strategy is filling the fiscal gap for each municipality. In this strategy, analysts use the value of the fiscal gap for each municipality to propose developments that could raise revenues to fill that gap through real estate development on dry land within the same municipality.
2. **Regional approach.** The organizing principle for this strategy is filling the fiscal gap for the region overall (three municipalities combined). In this strategy, analysts use the same strategy as above, but the fiscal gap is calculated for all three municipalities combined and proposed real estate developments can occur anywhere within the three municipalities in the study area.

These principles on their own were not sufficient to generate realistic scenarios because they can result in uncharacteristic development styles, for example high rise structures on future islands disconnected from the mainland. A number of additional considerations for scenario assessment beyond fiscal impacts emerged through the process of trial and error, which could be codified for future applications.

The criteria for evaluating scenarios listed below emerged in conformance with good planning practice in response to concerns about the proposals generated using the single lens of filling the fiscal gap. We propose climate adaptation strategies should minimize fiscal impacts and:

- **Avoid climate gentrification.** Assume displaced residents will relocate in neighborhoods with housing at a similar price-point to their current housing.
- **Provide potentially displaced residents with a range of housing choice.** Where residents were displaced from their current neighborhood because of inundation, scenarios should provide residents with options regarding living in similar housing types elsewhere in the region or maintaining their location in different housing typologies.
- **Intensify development in areas that maintain road connectivity.** Some areas along peninsulas will become islands under rising seas, and these are not suitable for dense settlements because of evacuation concerns.
- **Preserve green infrastructure and preserve or replace existing conservation land.** Porous land, such as forests, wetlands, and open meadows can absorb flood water and provide a vital "service" during extreme flood events. New developments should not displace this so-called "green infrastructure". It is possible in built-out municipalities that inland parks may be the only place available for new developments to accommodate retreating communities, but they should be preserved or replaced if possible.
- **Ensure climate change impacts do not result in a double-jeopardy by increasing tax rates on the most vulnerable municipalities.** We explored the possibility of changing local tax rates to cover the fiscal gap. In our case, the municipality with the most vulnerable properties also has the lowest median income. Raising taxes here to pay for adaptation services would result in double-jeopardy of displacement and financial stress for households. We ultimately decided that raising local taxes to pay for adaptation infrastructure was not appropriate in our context.
- **In addition to these, through the scenario development process it is useful to identify policies that would need to be changed to enable in each scenario.** Policies ranged in terms of scale and concomitant level of control that the local municipalities have to change them or advocate changing them. These policies included local zoning codes (easy to change), Massachusetts State aid for adaptation, and national FEMA flood buyout regulations (difficult to change and unpredictable). These issues relate to social institutions and norms, particularly around the acceptability of socializing costs of adaptation (see tax rates above), and indicate the likelihood of each scenario.

Evaluating Fiscal Impacts of Scenarios

Iterative scenario development and evaluation inform the selection of final scenarios, which are then evaluated for their impacts to local and regional fiscal revenues. Note that "regional" here refers to the three municipalities included in the project. The methodology described below points to future development of a more complex regional assessment of scenarios, for example for the entire Boston region of 101 municipalities.

Scenario evaluation

Based on the data sets described above, net fiscal impacts represent the difference between future revenue (including new revenue from proposed development, costs of construction and maintenance, and lost revenue from inundated property) and current revenue. Projected future revenue can be calculated using the municipal median[3] per unit or per square foot price to calculate property value and then multiplying by the residential property tax rate.

Some proposed adaptations will create spillovers that affect neighboring municipalities either directly (e.g. seawalls that extend flood protection beyond local jurisdictional boundaries) or indirectly (e.g. by zoning to allow vulnerable neighboring municipality residents a place for relocation). However, the impacts of each scenario were evaluated separately for each municipality, rather than considered together. Housing demand predictions are not considered in this methodology, though they would be factored into the regional analysis (described below). The (as yet untested) method for scaling up described below could be the focus of future research. Revenue changes are calculated for proposed developments and properties that would be chronically inundated in 2030, 2070, and 2100.

GIS Operations for Simple Fiscal Impact Assessment

The first method described here is "simple" in that it takes a discrete view of time (using time intervals or periods) and does not consider regional impacts. The description of GIS operations assumes analysts work with the UCS data described above representing the date of chronic inundation. The method also applies to NOAA data, which represents sea level rise rather than chronic inundation. Adapting this method to the NOAA data entails translating the results in terms of climate scenarios corresponding to the chosen sea level rise depth. For example, current high estimates project approximately 6 feet of sea level rise in 2100. To test this scenario,

3 The mean may be used to project in some circumstances, but in this case the distribution was heavily skewed and projecting using the median may reduce pressure to gentrify to meet a high per square foot price.

analysts would substitute the NOAA 6 feet layer for the UCS 2100 layer.

The steps below walk through a generic process replicating our fiscal impact analysis. This process is conceptually simple and there are several points at which additional complexity may make the estimate more accurate. We indicate one such point in Box 2. Where we refer to specific column names, these are in the Massachusetts parcel database used in our case.

Initial Data preparation

1. **Create a lookup table of property tax rate and land use.**
    - Create from the parcel layer a unique list of land use (luc_1) and municipality (muni)
    - Look up tax rates for each municipality and enter them in a third column for the corresponding land use and municipality.
    - The final lookup table should have three columns with land use code, municipality, and tax rate.
2. **Classify land based on the chronic inundation date.**
    - Import additional data: use a shapefile of inundation for each time period (sea level rise depth if using NOAA data).
    - Create a new layer with an attribute containing the year in which you expect the land to be chronically inundated.

Steps 3-7 will be repeated for each scenario, so it may be worthwhile to functionalize each of these steps in the method. This could be done in ArcGIS through the ModelBuilder, or in R or Python by creating a function.

3. **Calculate property tax revenue for each parcel**
    - Separate building and land revenue
        - » Join the building value and land use code from the parcel layer to the building footprint layer.
            - › Import the parcel database and building footprints.
        - » Use a spatial join to add building value (bldg_value) and land use code (luc_1) columns to the building footprint layer.
    - For each of the resulting layers, building footprints and parcels, multiply the tax rate by the building value and land value, respectively.
        - » Name the resulting column with a common name (e.g., "revenue") in each of the layers.

Box 2: Considerations for Calculating a Baseline

Demographic trends

Many scenario planning projects take as their focus to develop projections of population and land use change based on demographic shifts and land development suitability based on a number of factors. In this exercise we took a simplistic approach to this because we focused on policy scenarios in which the land use remained constant. Adding in a bit of demographic change would be done at this point, and would make the scenarios more realistic. However, such a projection would need to include the expected effect of demographic trends on property values, not just population.

Property depreciation rate

This method assumes that the land value and building value go to zero only when the centroids are intersected by chronic inundation. A more sophisticated method could employ a discount rate based on the percentage of area inundated for land value. Recent research from Florida demonstrated an annual decline in property values for flooded parcels using a hedonic pricing model (McAlpine and Porter 2018).

Calculate Fiscal Impacts

The fiscal impact calculation will be repeated for each of the scenarios. The business as usual scenario, or the naïve scenario assuming no action can be calculated on the 'existing land use' layer from the base year. Without proposing land use changes, as in the baseline scenario, the fiscal impacts are essentially representing fiscal vulnerability of the current land use pattern. Step 4 describes the process for calculating the fiscal impacts and vulnerability.

4. **Calculate the baseline revenue gap for each municipality**
    - Intersect the inundation layer with the centroids of both the parcel layer and the building layer. Note that, at this point, the parcel layer revenue column should contain only the revenue from land and not the building layer.
    - Sum the revenue column for each layer simultaneously grouped by the following two variables:

    » Municipality and
    » Date of inundation (e.g. ≤2030, ≤2060, ≤2100)

- **Fiscal impact:** Combine (sum) building and land revenue inundated for each municipality and cumulatively sum the lost revenues for each subsequent date of inundation (e.g. 2060 lost revenue = lost revenue in 2030 + additional lost revenue in 2060)
- Additional outputs for each municipality and each period:
    » Median number of units per building inundated
    » Building area inundated
    » Parcel area inundated
    » Average square footage of units inundated

The additional outputs are used to develop scenarios of land use change that could mitigate the fiscal gap generated by sea level rise. Here is where the criteria discussed in the section Developing Scenarios could be added to the process to examine the potential for land use decision makers to intervene and mitigate potential social costs of adaptation measures.

Assessing Fiscal Impacts of Adaptation Scenarios

Steps 5-6 relates to the section above, Developing Scenarios. We used the 'by hand' method in setp 5. Programmatic selection of alternatives would be possible by encoding the criteria mentioned in the Developing Scenarios section into a development suitability analysis.

5. Develop scenarios and corresponding land use and value changes

- Modify the input base layer of parcels and buildings
    » Choose a decision criteria to locate the proposed developments. These can be done programmatically or by hand:
        › Programmatically: suggest parcels in the target land area and add or modify features with the desired attributes (building value, land use). These of course need to be reviewed by planning analysts or decision makers to select areas for development that can be assessed.
        › 'By hand': Use a GIS or sketch planning tool[4] to create feature polygons with the necessary attributes (building value, land use).

4 Sketch tools we tested include Envision Tomorrow, Urban Footprint, Geodesign Hub, and other scenario planning tools mentioned in the body of the full report.

- Repeat step 3 above.

Step 6 was done through qualitative research, and based on this experience we suggest it is not possible to link this to a programmatic assessment.

6. Assess infrastructure costs.

- Determine each municipality's infrastructure costs based on the chosen allocation of new development.
    » For road elevation and sea walls, calculate the length that needs to be elevated or constructed and multiply it by the unit cost described above.
    » Identify key public facilities, like schools and energy generation sites, that would be necessary to move in each time period. Sensitive public land uses may be marked with a special land use code and identified by intersecting these with the inundation layer.
- Sum the costs of infrastructure construction and maintenance.

7. Repeat step 4 above, taking the following additional steps after calculating the revenue gap for the scenario. Do this step for each municipality and time period, as in step 4.

- Calculate the difference between the revenue change (step 4) and infrastructure costs (step 6). The infrastructure costs (considered as positive values, not negative) should be subtracted from the change in revenue.

Extending the Assessment Methodology: Temporal and Regional Considerations

The workshop analysis of scenarios took a rather narrow view of the temporal aspect of scenarios and regional considerations. The temporal analysis is limited to the present and three future time periods. The regional analysis was limited to three municipalities of Hull, Hingham, and Cohasset, rather than viewing interactions between municipalities within the region. Disaggregation of the temporal resolution could be done through using different sea level rise data sets or through interpolation. The highest resolution of sea level rise data sets is decadal. Another possible extension of the methodology in terms of temporality would be to link changes in the first time period to changes in the subsequent period to demonstrate path dependencies. Regional dynamics were considered in terms of the impacts being calculated by municipality and for the three municipalities together. To scale up this regional dimension could be easily done using the existing methodology of disaggregating outputs of the assessments by municipality and by the region overall. Additionally, a more sophisticated model could further downscale storm surge and sea level rise models to account for local infrastructure decisions.

Accounting for Temporal Dynamics

The method described above ignores the life cycle of buildings and urban developments, which may be used in long-term planning such as phased retreat scenarios. For example, older buildings may be identified for early relocation buy-out programs, while newer buildings may be protected. In other locations, building dense residential developments in the short term may offset the costs of retreat in the medium or long term. Incorporating temporal dynamics would require creating additional parameters for proposed developments that can be compared to flooding timelines.

8. Assign date values to existing buildings and proposed developments

- If available, access "year built" information for existing buildings.
- For proposed developments, add the following temporal information.
  - » Year built (this could be in the future for proposed developments).
  - » Life span

9. Identify annual inundation zones using one of the following two methods

- Use a detailed flood level data set, like the MassDOT data, and translate the flood levels into the year of inundation.
- Use an interpolation method, like spline ("Spline—Help | ArcGIS for Desktop" n.d.; Bergen and Lindstrom 2019), to fill in years between 30-year periods from the UCS data.

10. Calculate the net revenue for each year.

- As described in step 7.

Integrating these date considerations into the scenario evaluations would add nuance to the model and allow analysts to place constraints on the scenarios, such as identifying the change in annual costs over time.

Scaling up model to the region

The scenario assessments in the workshop did not consider regional impacts of fiscal policies related to sea level rise. The scenario development process described in the section, Developing Scenarios, pointed to a number of issues that are not well-integrated into scenario planning software and therefore limit the scaling up of scenarios development across more than a handful of autonomous municipalities.

Instead, scenarios considered the local effects and included some initiatives that require cooperation across boundaries of municipal jurisdictional boundaries. The methodology described above can be easily extended to disaggregate impacts by any number of municipalities and compared to the region overall.

Future directions for tool development

The scenario development methods described in this Technical Appendix are limited to three municipalities. The scenario assessment methods point to promising directions to scale up and "functionalize" some aspects of the calculations that could apply to a larger number of neighboring municipalities. The criteria mentioned in the section Developing Scenarios also point to policies that municipalities could consider to mitigate negative social outcomes of climate change adaptation - climate gentrification, community isolation, loss of green infrastructure, and double-jeopardy of low-income climate vulnerable communities being further taxed to pay for adaptive infrastructure needs.

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