Building a Flood Resilient Kittery:

Working Waterfront and Transportation Corridors

SUST 750 Sustainability Capstone

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I. Introduction

In addition to being a long-term focus of scientific research, climate change is a common term in today's vernacular. Anthropogenic climate change is often represented as an increase in average global temperatures, primarily caused by anthropogenic release of carbon dioxide and other greenhouse gases, and it is responsible for major changes occurring in earth's climate system, ecosystems, and social systems. There are several positive feedback loops that enhance initial perturbations in the climate system, including the ice-albedo feedback loop. As the climate warms, sea ice melts. Less surface area of sea-ice then allows more solar radiation to be absorbed by the darker (lower albedo) ocean, further raising the temperature of the water, and subsequently the globe itself. The feedback loop continues as warmer temperatures melt more sea-ice. Higher temperatures in the atmosphere and the ocean produce unpredictable and often extreme weather patterns, and sea-level rise occurs due to both melting of polar ice sheets and glaciers, and expansion of ocean water as it becomes warmer.

Around the globe, coastal communities are at risk of catastrophic damage from flooding, storm surge, and rising seas driven by anthropogenic climate change. In New England, flooding is already a frequent occurrence, which causes extreme concern for coastal communities. Storm surges from Nor'easter storms combined with high tides have wreaked havoc on coastal communities, damaging private property as well as natural and manufactured capital (Duprey 2020). Natural capital consists of all the living and nonliving components of natural ecosystems, such as coastal salt marshes and floodplains. This type of capital can protect inland ecosystems and human made infrastructure by absorbing storm surges and flooding. Manufactured capital is infrastructure built by people and relied on by society, such as roads, buildings, telecommunication systems, stormwater collection systems, and seawalls. This type of infrastructure is often built to withstand a certain level of stress, but aging and increasingly-damaging weather events put this type of infrastructure at risk of being destroyed or not serving its intended purpose.

Kittery, Maine is a coastal town on Maine's southern border with a land area of 17.8 square miles, a population of approximately 9,500 (US Census), and over 30 miles of coastline. Kittery is bordered by York, ME and Eliot, ME inland, and is bordered by the Atlantic Ocean, Piscataqua River, Spruce Creek, and Spinney Creek on the coast. The town is a popular tourist destination and is the location of the Portsmouth Naval Shipyard. It is vulnerable to sea level rise due to the length of the coastline and the high amount of coastal development.

The New England states that border the Gulf of Maine have begun implementing programs to address climate change-related hazards. The Massachusetts Municipal Vulnerability Preparedness (MVP) grant program awards cities and towns with funding to complete vulnerability assessments and develop resiliency plans to mitigate the effects of climate change. Over 200 municipalities across Massachusetts have participated in the program (MAPC 2018). After cities and towns complete the vulnerability assessment, they can apply for the MVP Action Grant, which helps fund implementation of their policies and resilience strategies at a municipal level. Like the MVP Program, Massachusetts also has the Coastal Resilience Grant Program. This program funds technical support for municipalities across the state for education on climate impacts, vulnerability assessments, redesign of critical infrastructure, and shoreline restoration. Under this programt, many towns have written adaptation plans and some have implemented their plans. Common hazards that have been identified throughout Massachusetts' coastal towns have been sea level rise, coastal flooding, severe storm/storm surge, extreme cold, heat/drought,

increased precipitation, and high winds. Recommendations for adapting to these hazards include wetland restoration, road system resiliency, improving reliability of critical infrastructure, increasing the height of seawalls, adapting critical transportation infrastructure to sea level rise, elevating low lying bridges, and maintaining barrier dunes and beaches.

Places like Nantucket and Gloucester have identified high risk infrastructure have developed plans to address their vulnerabilities. According to the Town of Nantucket Community Resilience Building Workshop Summary of Findings (2019), Nantucket identified sea level rise as the top hazard facing the town. They then identified wetland restoration, road system resiliency, and improving reliability of critical infrastructure, among others, as recommendations to improve resilience. Going forward, Nantucket will pursue the MVP Action Grant to address the recommendations. According to the Gloucester Community Resilience Workshop Summary of Findings (MAPC 2018), Gloucester identified sea level rise, extreme cold, heat/drought and high winds as the most significant climate change-related hazards facing the town. They also identified critical transportation infrastructure and facilities that are vulnerable. With the help of the MVP Program, they came up with recommendations such as increasing the height of their seawall, adapting their Wastewater Treatment Plant to sea level rise, elevating critical low-lying bridges, and dune restoration.

New Hampshire coastal towns have begun to identify the risk of sea-level rise and have implemented some ways in which their coasts can build more resilience. The New Hampshire Coastal Adaptation Workgroup, New Hampshire Coastal Risk and Hazards Commission, Rockingham Planning Commission, University of New Hampshire, and Seabrook-Hampton Estuary Alliance are all groups fully or partially directed towards making a more flood resilient New Hampshire Coast. Specifically, the City of Portsmouth is assessing the vulnerabilities of sea-level rise in this area and through the Coastal Resilience Initiative (Kirshen et al. 2013) and have been working towards developing strategies on ways that the community's infrastructure can be altered in order to mitigate the flood risk . Elevations were mapped to display where flooding is most likely to occur and how it will influence the infrastructure, saltmarsh, wetlands, etc. within that area. Similar to the City of Portsmouth, the towns of Seabrook, Hampton, and Hampton Falls are working towards protecting and preserving the estuary habitats in their recreational and commercial areas (SHEA, 2019). Along with studying "From Tides to Storms" and having meetings with the Coastal Hazards Adaptation Team, there have been discussions regarding outreach events, and the Seabrook-Hamptons Estuary Alliance has received grants from the NH Charitable Foundation to manage the local estuaries along with a Technical Assistance Grant which funds the discussion tables and a series of outreach projects (SHEA, 2019).

The *Maine Won't Wait* climate plan emphasizes the importance of greenhouse gas reduction in the long-term, but also recognizes that immediate adaptation action must be taken in the short-term. The plan is to incorporate official state sea-level rise projections into regulations by 2022, and to develop and implement updated land-use regulations, laws, and practices by 2024 (Maine Climate Council, 2019). This same plan looks to commit to managing 1.5 feet of sea level rise by 2050, and 3.9 feet of sea level rise by 2100. The plan also recommends preparing to manage for 3.0 feet of sea level rise by 2050 and 8.8 feet of sea level rise by 2100. With the flood risk increasing in coastal areas due to sea-level rise, it is also important to consider the future development and where and future influx of people moving into Maine will live (Schauffler, 2020). A key element for Maine to make the required changes is to appoint local leaders, adopt

plans, and use tools for climate resistance. These are the key steps presented in Strategy F of the Maine Won't Wait climate plan.

Cities and towns across the region, including Kittery, Maine, have begun to plan for how they will build resilience to the inevitable environmental, social, and economic repercussions of sea-level rise and coastal flooding. Kittery's coast is lined with natural and manufactured capital, from its small downtown with restaurants and shops to its schools to the Portsmouth Naval Shipyard to it forests and beaches and salt marshes. Much of this is at risk in the coming decades due to increased coastal flooding and sea-level rise. Kittery has made some initial efforts to address coastal flooding, such as the establishment of a Kittery Climate Adaptation Committee in April 2019 that will address the impacts of climate change by recommending policy changes, projects, and objectives. Kittery has also worked with FEMA to create a FEMA Flood Insurance Map overlay to their town GIS software to help residents see if their property is at risk. It is crucial to approach the issues in a way that considers the needs and possible contributions of the natural resources, current and future Kittery residents, policymakers, private landowners, owners of critical manufactured capital, coastal businesses, and tourists. While these are steps in the right direction, they are initial steps, and more will need to be done to help prepare Kittery for the future.

This paper seeks to: 1) assess waterfront natural and manufactured capital that is at risk for coastal flooding, 2) evaluate the resilience efforts in Kittery in relation to other efforts from other New England coastal communities, and 3) gather recommendations to mitigate the negative impacts of sea-level rise on Kittery, Maine.

II. Methods

A variety of methods were used in this project to gather new information, synthesize existing knowledge, and develop comprehensive and organized results. These methods included research using the internet and reading reports to obtain information regarding the approaches to sea level rise taken by other towns, states, and independent groups. GIS software and Excel spreadsheets with and the assessed value of Kittery properties was used to produce summary tables of properties at risk of flooding and visual representations of flood risk. Interviews with key stakeholders were used to explore vulnerabilities to flooding and climate resilience efforts in Kittery.

Desk Research and Background Information

Three New England States and the town of Kittery, Maine were examined to better understand coastal resiliency projects and programs currently in place. The topics explored included reports by state officials, FEMA maps, grants and funding, and historic data. Since each state's approach is different, background information was collected in more than one way. Lists of city and town grants aided in the search for information regarding many flood protection efforts in Massachusetts. Maine and New Hampshire did not have an accessible collection of grant data, so background data was accumulated by looking through municipal websites, state grants, and projects carried out by the state and municipalities. All the information was organized by state and transferred over to excel files for ease of use and analysis. These excel sheets included town names, type of grant, and specific planning and actions the town was taking. This will allow the

information to be presented in a way that could be easily understood by the reader. This information will be used for future recommendations for the town of Kittery.

Mapping and Vulnerability Assessment

Geographic Information Systems software was used to visualize sea level rise/storm surge (SLR/SS) scenarios along the Kittery seacoast at high astronomical tide (HAT), HAT plus 3.9 feet of SLR, HAT plus 6.1 feet of SLR, and HAT plus 10.9 feet of SLR. Data for the maps was provided by the Maine Geological Survey and analyzed using ArcMap software. The maps produced were re-creations of SLR maps previously produced by the Alexandra Duprey on behalf of the Kittery Climate Action Committee (Duprey, 2020). These maps are considered "bathtub models" and assume a steady and even increase in hightide lines and does not account for damage caused waves. The maps were used to produce a comprehensive list of properties in Kittery that would be at risk of flooding at each of the SLR/SS scenarios. This was accomplished by using ArcMap's "Intersect" geoprocessing feature to create a table that combined the SLR/SS scenarios layer, computed by Christian Halsted of the Maine Geological Survey, with a layer of land parcels in Kittery. This list was then sorted using Microsoft Excel and property values were provided by the Kittery Planning Department. A visual assessment of flood risk on buildings was performed by observing flood ranges over aerial imagery on the map. This information allowed for a comprehensive assessment of flood risk to be produced that expanded on previous knowledge by offering both a visual representation of areas at risk as well as an approximate estimate of the value of properties at risk of flooding in each storm surge scenario. This information quantifies and supports the final recommendations.

Informative Discussions

To gather more information on past, current, and future programs, as well as known problems and possible solutions, select Kittery stakeholders and municipal staff were asked a series of questions. This included, but was not limited to, town planner and town officials, harbor master, Kittery Climate Adaptation Committee representatives, and state officials. Questions were curated to extract specific information relevant to the topic of study and were not intended to yield yes or no answers. All interviews took place via phone call or Zoom.

III. Results

Massachusetts Current Practices

Massachusetts towns have been making plans and implementing measures through the MVP Action Grant and the Coastal Resilience Grant Program to reduce damage from flooding due to sea level rise. The MVP Action Grant "offers financial resources to municipalities that are seeking to advance priority climate adaptation actions to address climate change impacts resulting from extreme weather, sea level rise, inland and coastal flooding, severe heat, and other climate impacts." We looked at towns along the coastline to better understand what may and may not work for the town of Kittery. Some of the common strategies across the state included plans for both natural capital, manufactured capital, and public education/awareness. In order to reduce wave energy, storm surge, and the damage from flooding, some towns have implemented a living shoreline along their beaches. A living shoreline uses trees, sand, dunes, rocks and other

natural materials to accomplish this. Another common theme in MA was putting an emphasis on educating the public regarding flood risk, which is important to towns' push for more resiliency. Other measures that have been taken include the reconfiguration of existing structures, the creation of floodable parks in a vulnerable area, permeable pavement, the construction of higher seawalls, and raising existing roads out of a potential flood zone.

Towns in Massachusetts have benefited from the system of applying for state-funded grants, as these programs provide funds for vulnerability assessments, provide recommendations for further action, and provide a grant specifically for taking action by implementing policies. Kittery, and the surrounding NH and Maine seacoast towns would benefit from a grant program similar to the MA MVP Program.

New Hampshire Current Practices

Similar to towns of Massachusetts, New Hampshire has assessed the risk of coastal flooding and storm-surge (Wake et al. 2019) created a variety of potential plans, received grant money, as well as even implementation of some projects. Looking closely at the coastal communities of New Hampshire; specifically Rye, Seabrook, Hampton, North Hampton, Hampton Falls, New Castle, Portsmouth, and Durham, all have evaluated the risk of flooding in these communities and begun to brainstorm possible projects and plans (Rockingham Planning Commission, 2015). Although there has been plenty of risk assessment and planning, there has been minimal specific implementation in these towns and action focused projects. For example, there have only been ordinances and projects completed in Rye, Hampton, Portsmouth, and Durham. One exemplary project is the Wagon Hill Farm Restoration in Durham, NH. Due to the consistent erosion of marsh ecosystems on the shore of Wagon Hill Farm, the University of New Hampshire and the Town of Durham are working together to prevent erosiaon via the careful design and constructions of a living shoreline (Strafford Regional Planning Commission, 2021). This project will help to stabilize the shoreline while also protecting the shore from flooding by adding natural infrastructure.

Maine Current Practices

Most Maine towns are in the early stages of preparing for the risks of coastal flooding and storm-surges related to climate change. Towns that are similar to Kittery in terms of location and threat level include Kennebunk, Wells, and York, ME. These three towns are part of the *Tides, Taxes, and New Tactics: Planning for Sea Level Rise and Coastal Adaption in Southern Maine* program which has been created by SMPDC. As of May 2020, all of these towns are in the research and planning stages. Portland has begun the process of designing structural changes to high-risk areas that would make them more resilient against rising tides and coastal flooding, however that is about the extent that Maine towns have gone in terms of coastal flooding resilience (Woodard & Curran). Saco attempted to get a grant that would allow them to protect Camp Ellis, however, they were not successful in attaining the grant and have gone back to rework their plan.

Kittery Current Practices

We assessed the programs and committees currently in place in Kittery that will help with climate adaptation. Currently, there are no climate adaptation infrastructure projects underway. Kittery, however, has worked with different stakeholders and institutions to assess what is vulnerable, as well as best practices in the event of severe flooding.

2020 Coastal Hazard Planning Best Practices Report

One report we identified was the 2020 Coastal Hazard Planning Best Practices Report. This project was completed in 2020 by Alexandra Duprey, a Sustainability Fellow at the University of New Hampshire. This report addressed the need for research on coastal hazard issues in Kittery. Due to its geographical location, Kittery has many natural and manufactured capital assets at risk of coastal flooding, as well as roads in flood paths that could leave people stranded. More specifically, this report was broken into five sections, each outlining a key aspect. One section addressed key vulnerabilities in Kittery related to sea level rise and storm surge. The next section performed basic vulnerability mapping at 4 flood scenarios:

- High Astronomical Tide (HAT) for the year 2020
- HAT + 3.9 feet of sea level rise/storm surge
- HAT + 6.1 feet of sea level rise/storm surge
- HAT + 10.9 feet of sea level rise/storm surge

These "bathtub" scenarios were overlaid on maps using GIS software. The report also identified current efforts (federal, state, regional and town level), created an overview of natural and manufactured capital strategies, and listed key recommendations with time frames for the town (Duprey 2020). We used the Duprey report as a basis for our GIS maps and risk assessment.

Summary and Recommendations Report for the Town of Kittery, ME | Maine Flood Resilience Checklist (SMPDC 2020)

This report was identified as a summary report of a workshop with Kittery stakeholders, discussing sea level rise, best practices, and the Maine Flood Resilience Checklist. The Maine Flood Resilience Checklist (FRC) is an assessment tool developed by the Maine Coastal Program. The FRC was designed to aid Maine coastal communities in identifying local flood risks, as well as evaluating their vulnerability to flooding related hazards and identifying specific actions each community can take in enhancing flood resilience. The workshop identified regulatory and land use strategies, policy strategies, as well as future studies and information needed, and information that should be shared.

Kittery Climate Adaptation Committee (https://www.kitteryme.gov/climate-adaptation-committee)

The Kittery Climate Adaptation Committee was created by the Kittery Town Council in 2019 in response to studies and reports on coastal flooding, and was charged to seek ways to create a more resilient Kittery as climate change progresses and sea-levels continue to rise. The committee is able to make recommendations for ordinances, policies, projects, and objectives related to sea level rise; to address actions to make Town properties more flood resilient; to establish three distinct subcommittees: Built and Natural Landscape Impacts, Energy Efficiency and Public Health and Safety; and to work with neighboring communities and the state of Maine to create a more resilient community.

Risk Assessment

The risk assessment produced flood maps of Kittery and rough data on the flood risk to Kittery properties under different sea-level rise/storm surge. Figure 1 shows the whole of Kittery, including the parcel divisions and all the flooding scenarios considered in this analysis.

Figure 1 shows the full extent of the coastal flooding that is projected in Kittery. The Excel analysis used the intersection of the flood scenarios and the parcels to determine which parcels were at risk. The Map Package used to create these images will be available in the appendix. All maps and analysis used this data as the baseline.

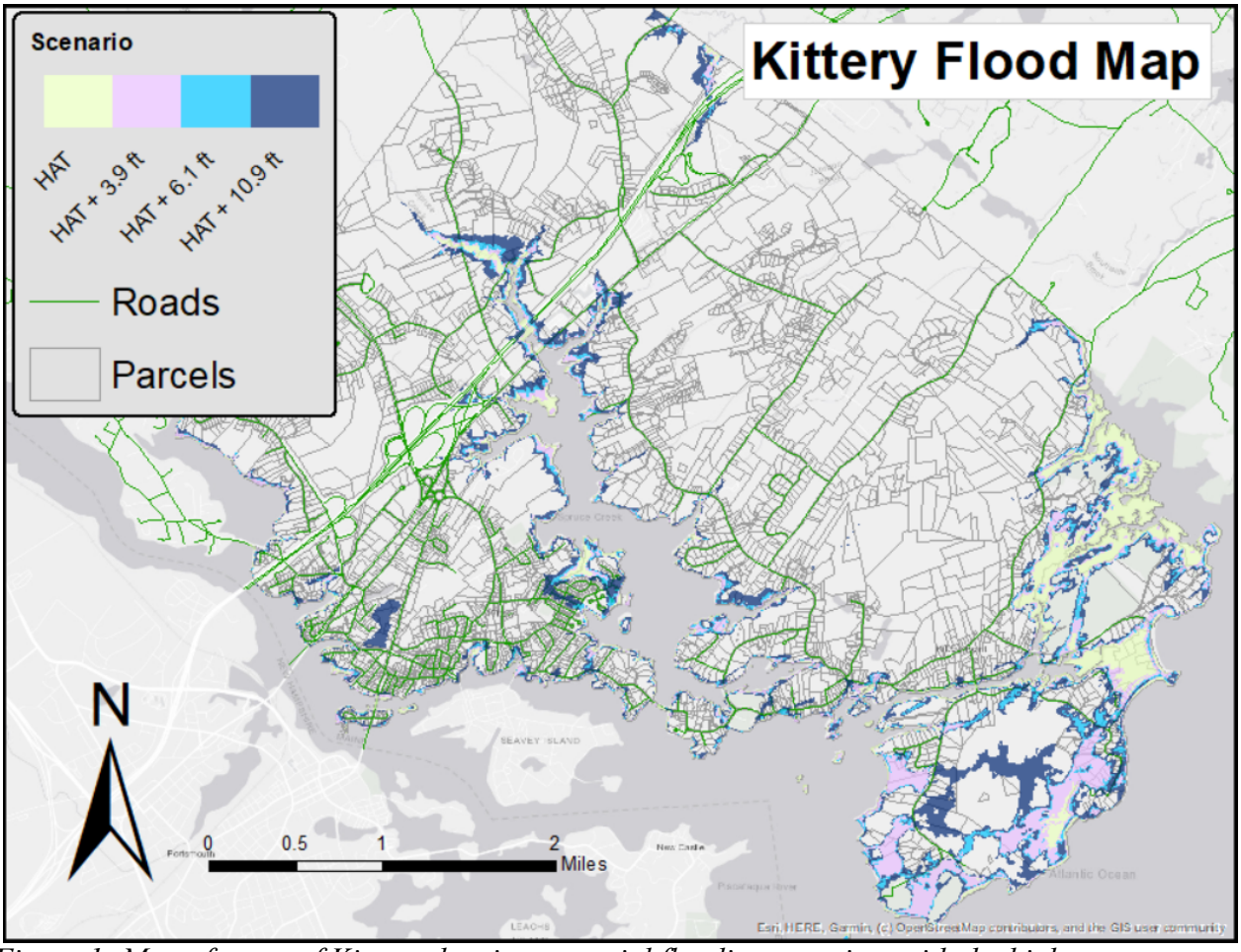

Figure 1: Map of town of Kittery showing potential flooding associate with the high astronomical tide (HAT) combined sea-level rise/storm surge scenarios of HAT +3.9 feet (current 100-yr storm), HAT + 6.1 feet (projected 2050 100-yr storm), and HAT +10.9 feet (projected 2100 100-yr storm)

Transportation Corridors

The risk assessment attempted to assess the potential impact of sea level rise on important roadways in Kittery. The results will be presented here in the form of maps and tables.

Figure 2 shows an enlarged portion of the flood map, particularly the intersection of Route 1 and Interstate 95 over Spruce Creek. This image shows the extent of the flooding and demonstrates that a flood would close off these key transportation corridors. Figure 3 shows the impact of a projected 100-year flood in 2100 on the roads of Kittery.

Though difficult to pinpoint, this flooding scenario would create some level of flooding at over 50 locations in Kittery, Maine (Figure 3) with the length of roadwasy at risk of flooing ranging from 1,400 feet under the current HAT to over 32,000 feet under the HAT + 10.9 feet of sea-level rise/storm surge scenario (Table 1). Approximately 10 of these locations occur along Route 103, which is listed as a level 2 priority road. It is challenging at this time to accurately assess the potenmtial damage a flooded road may suffer.

Table 1: Length of roadways at risk of flooding under high astronomical tide (HAT) and three sea-level rise/storm surge scenarios.

Risk at HAT	Risk at HAT + 3.9 ft	Risk at HAT + 6.1 ft	Risk at HAT + 10.9 ft
1,429 feet	6,550 feet	10,701 feet	32,113 feet

Flooded roads could prevent passage through Kittery until roads drain and are repaired, if necessary. Bridges on Route 103 over Spruce Creek and on Crockett Neck Road were also determined to be at risk. Damage to a bridge would incur a high cost to the asset owner for repair and may close the transportation corridor for several months while repairs occur.

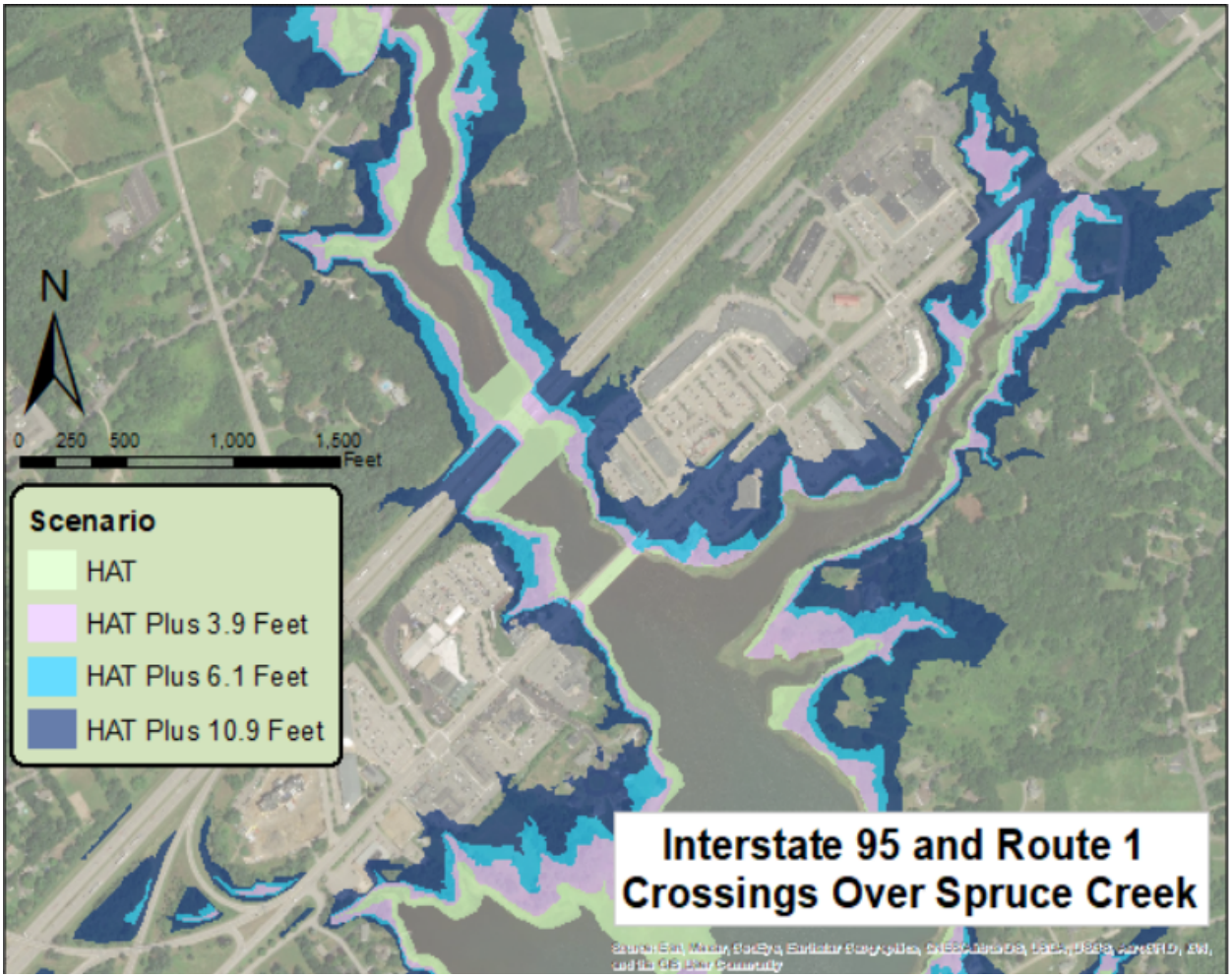

Figure 2: An example of the flood risk to working waterfronts and two major transportation corridors in Kittery for under high astronomical tide (HAT) and three sea-level rise/storm surge scenarios.

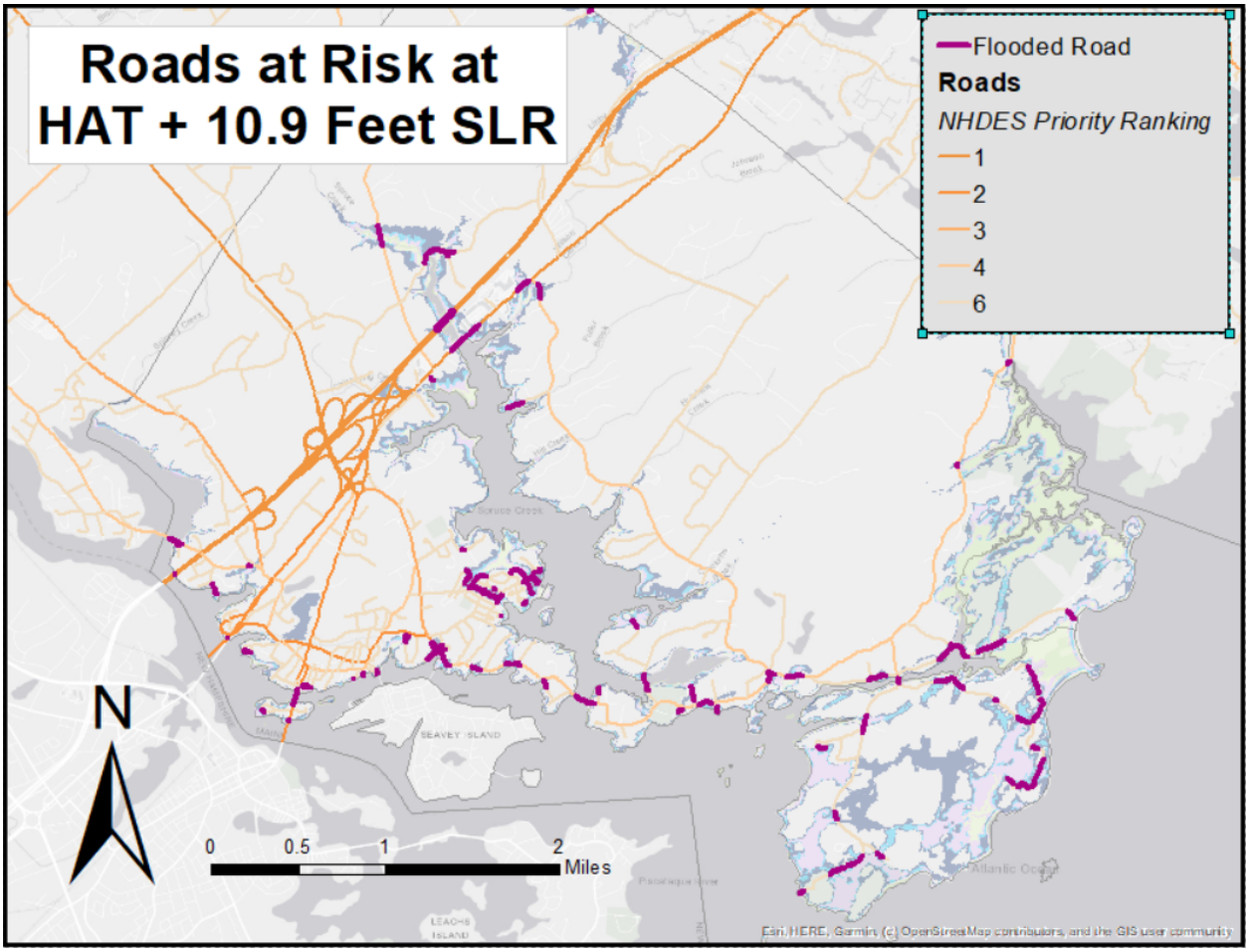

Figure 3: Map of road segments that could be flooded under a 10.9-foot sea-level rise/storm surge scenario. Road information from Maine DOT.

Parcel-by-Parcel Risk Assessment

The Town of Kittery has 4,438 parcels containing 4,845 assessed properties. As of the spring of 2021, the total assessed value of the parcels alone is $965,061,617 and the total value of all property improvements is $1,223,222,960, for a grand total of $2,188,063,677 worth of real estate in the Town of Kittery, Maine. The following table is the result of a risk assessment based on GIS data, flood mapping, and assessed property values provided by the Town of Kittery.

SLR Scenario	Number and Percentage of Parcels at Risk *% of total number of assessed properties in Kittery*	Number and Percentage of Buildings at Risk *% of total number of assessed properties in Kittery*	Value of Parcels at Risk *% of total town parcel values*	Value of Land Improvements at Risk *% of total town improvements value*	Total Economic Value at Risk *% of total town property value*
H.A.T. (2020)	673 *13.9%*	24 *0.5%*	$302 M *31.34%*	$4.8 M *0.4%*	$307 M *14.0%*
3.9 ft SLR (100 yr flood 2020)	848 *17.5%*	76 *1.6%*	$389 M *40.35%*	$34 M *2.8%*	$424 M *19.3%*
6.1 ft SLR (100 yr flood 2050)	943 *19.5%*	156 *3.2%*	$410 M *42.5%*	$75 M *6.14%*	$485 M *22.2%*
10.9 ft SLR (100 yr flood 2100)	1281 *26.4%*	426 *8.8%*	$493 M *51.07%*	$193 M *15.8%*	$687 M *31.4%*

Table 2: Assessed value of properties and buildings at risk of flooding during high astronomical tide (HAT) and three sea-level rise/storm surge scenarios.

These totals show the amount of property that will be at risk in any given scenario. The italicized percentages compare the at-risk value to the total value for the whole town of Kittery. For this assessment, protection provided by natural and manufactured capital was not considered, and the "at-risk value" as calculated includes the full cost of parcels and buildings regardless of whether the flooding came in contact with part or all of the building or parcel. For example, a parcel that is worth $10,000 will be assessed as $10,000 at risk regardless of whether a scenario shows 10% flooding or 100% flooding. Because of this, the true cost of damage will likely be a fraction of these totals. Another important factor is land use.

Type of Property	# of Properties with this Land Use in all of Kittery	At Risk at HAT + 10.9 ft SLR			
		Parcel Count	Building Count	Assessed Value at Risk	Tax Revenue at Risk
US GOVERNMENT-OWNED	22	21	2	$ 59,484	
MUNICIPAL-OWNED	64	5	7	$ 301,763	
MIXED USE	28	6	3	$ 66,238	$ 854
COMMERCIAL	203	48	23	$ 1,893,302	$ 24,423
INDUSTRIAL	27	7	0	$ 35,740	$ 461
FARMLAND	6	0	0	$ -	
NON-MUNICIPAL PUBLIC WELFARE	93	26	4	$ 69,325	
MIXED USE	14	2	2	$ 29,223	$ 376
RESIDENTIAL	4351	1128	385	$ 6,337,949	$ 81,759
COMMERCIAL HOUSING	16	3	0	$ 17,941	$ 231
STATE-OWNED	7	4	0	$ 29,369	
Grand Total	**4831**	**1250**	**426**	**$ 8,840,339**	**$ 218,002.83**

Table 3: Assessed value of different types of property and buildings at risk of flooding from the during high astronomical tide (HAT) + 10.9 feet of sea-level rise/storm surge scenario.

This table gives an approximation of different types of properties are at risk in the 10.9 ft SLR/SS scenario. As shown, privately owned residential properties make up approximately three quarters of the value at risk. Commercial properties accounted for most of the remainder. This table also displays an estimate of property taxes at risk each year if major flooding or repeated damage makes property inhabitable for the future.

Informative Discussions Summary

A total of eight individuals were asked 6 questions to help gain more background information on Kittery and their current work on coastal resilience. These individuals were all stakeholders in the community, including municipal employees of Kittery, residents, and those with a connection to the working waterfront.

Similar Themes Among Discussions: Transportation Corridor

Out of all the discussions, one thing was blatantly clear. All of the people we spoke to acknowledged that sea level rise is happening, and Kittery needs build resilience to coastal flooding. Areas of concern varied. Most agreed that Interstate 95, Route 1, and Route 103 over Spruce Creek are of concern. Each of these roads lie low over the tidal Spruce Creek. In an event of a 100-year storm, flooding and damage could make it impossible for emergency vehicles to pass, and for residents to evacuate. Route 103 is also a unique case, as it was

determined the span sits on rollers on top of concrete pillars, and a storm surge event could lift the span off its foundation. Many said that since these are state and federal owned and managed, it is critcal that the Town of Kittery collaborate with the State of Maine in terms of developing and implementing solutions.

Similar Themes Among Discussions: Working Waterfront

Concern was also expressed regarding working waterfronts. Most agreed that the Portsmouth Naval Shipyard is of major concern, however, it is not in the town's jurisdiction, as it is federally owned and operated. Workers, including many Kittery residents, rely on it for their jobs, and it could cause national security issues if compromised. Tourism and related jobs could be threatened as well. Many expressed concerns with Fort Foster, and potential impacts could result in revenue and seasonal jobs. Many acknowledge that local restaurants and lobster wharfs on the water are at significant risk, and many have already experienced flooding during recent winter storms.

Similar Themes Among Discussions: Manufactured Capital

Many agree that homes and infrastructure are at risk. Most acknowledge concerns with the transportation corridors mentioned earlier, and say it will cause commute delays, and potentially very serious issues in emergency situations. One individual pointed out that these main roads may need to be eventually abandoned, and smaller neighborhood roads will become the main roads. Many also mentioned that high-value homes along the coast of Gerrish Island, as well as Spruce and Chauncey Creek and the Back Channel, will see increasing amounts of damage in future year. When asked about what Kittery would do in order to compensate for the loss of tax revenue if these properties were abandoned , most acknowledge that there is no plan, or said they do not know what could be done. There is also a consensus that new homes should not be built in current and potential future flood zones, and that is something the town should consider creating an ordinance for.

Similar Themes Among Discussions: Natural Capital

Many agreed that natural capital and ecosystems are at risk. Much of Kittery's "hard coast" is natural lands, granite ledge, and salt marshes. In an event of a 100-year storm, this would absorb much of the energy from large storm surges. But many expressed concern about the effect this would have on the wildlife. While not much is possible to protect this wildlife, some suggested that these ecosystems could be important for controlling flooding in Kittery. Some suggested that ordinances be created to restrict building in low-lying areas, which would allow storm surge to collect and protect infrastructure. Negative impacts on coastal habitats will also have negative impacts on the tourism industry, as people may not have the opportunity to use the beach or eat at coastal restaurants.

Similar Themes Among Discussions: Next Steps

There appears to be a consensus regarding next steps need to be taken now to build resilience to coastal flooding, now and in the future. Some suggest that Kittery hold community discussions,

not only to inform the public on coastal flooding risk, but also to gain information, ideas, and opinions. Kittery has already held several of these types of workshops, and more should be planned. Most people agreed that no more homes should be built on the coast, and that all land not built on should be conserved. Ordinances could be created that allows Kittery to prohibit building at certain low elevations or in certain floodplains. And conserving these areas will not only protect manufactured capital in the future but create natural capital that can reduce damage to manufactured capital. Some suggested that the town invest in infrastructure that is at risk, and others prefer a focus on building new infrastructure away from flood zones. Finally, a few suggested that Kittery should look into expanding and strengthening its stormwater management system and build it up in a way that allows for areas to flood during high tide, and drain effectively as the tide draws out.

IV. Discussion

Key Vulnerabilities

The Route 1 and Interstate 95 bridges that run over Spruce Creek are highly vulnerable areas that are not only valuable to Kittery, but to the entire state. They are two of the primary transportation routes that allow the movement of tens of thousands of cars per day (even more on weekends) through Kittery and if they were damaged, detours would affect every vehicle person trying to travel north into Maine or southward into New Hampshire. A closure of 95 or Rt 1 would have significant economic and safety impacts on the entire state.

The Portsmouth Naval Shipyard is also rather vulnerable to coastal flooding. The shipyard sees minor coastal flooding at the current HAT scenario, as do its two main points of entry. Gate 2, located on Route 103, is how hundreds to thousands of workers get to and from work. Flooding will cause commuting delays, and could cut the island off from the mainland, making it impossible for people to leave and for emergency personnel to enter and exit. While this has been identified as a risk, it has been acknowledged that this is a federal matter, and that Kittery does not have much say as to what happens there. However, the flooding and closure of Route 103 by Gate 2 of the shipyard would also have wide ranging impacts on traffic flow in Kittery.

Figure 3 and the GIS data associated with it provides a starting point for a deeper risk assessment. The locations where flooding is most likely to occur will be the best location to install stormwater Best Management Practices (BMPs) or employ other resilience techniques.

Working waterfronts, including fishing piers, restaurants, and shops along the back channel are also at risk of flooding. This would affect boat access to the water and have a negative impact on the working waterfront jobs in Kittery. Along with working waterfront this would negatively affect recreational access to the ocean and businesses that source their seafood locally. Local wildlife may also suffer from runoff that may be washed into the ocean from the land's surface.

The parcel-based risk assessment performed using GIS and Excel shows an estimate of the potential maximum financial impact of flooding associated with each SLR scenario, based purely on elevation data, and focused only on property values. Other factors will also affect the results, such as lost business revenues, fewer Kittery residents in the long run, repeated home repairs and

mitigation, and damages to non-real estate property such as vehicles. Actual damages could be reduced by flood mitigation provided by natural and manufactured capital such as seawalls and waterproofed structures. Based on this study, a home that is at risk during a certain flood scenario is unlikely to be damaged to the full cost of the structure or property. A more likely scenario is partial property damage and possible water damage to basements, or ground-level structural damage. This damage can likely be repaired for a fraction of the cost of the property but may be damaged frequently. Properties that are at risk so frequently may require repairs multiple times a year, installation of flood resilience upgrades, or they may become completely unlivable, which poses a risk to individual homeowners and the town's tax revenue over time. In addition, our analysis only considered a "bathtub" model, and does not account for structural damage related to storm surge and waves.

V. Recommendations

Currently, much of Kittery's response to climate adaptation is in the planning stages. Steps have been made in the right direction when it comes to the Kittery Climate Adaptation Committee, etc. However, we found that many other communities have already made it to the implementation phase for climate resiliency. Based on that, we have come up with recommendations for the following areas:

Local Programs

York, Wells, and Kennebunk are all part of the Tides, Taxes, and New Tactics program working with MIT SIC (Massachusetts Institute of Technology Science Impact Collaborative) with the goal of preparing coastal towns in Maine for rising sea levels and coastal flooding. We recommend that Kittery look into this program to see whether they can get any assistance from a group with experience in this field.

Working Waterfront

We recommend an in-depth assessment of all jobs and businesses that are at risk of flooding from the three SLR/SS scenarios. Not all jobs are at risk of flooding in Kittery, but many vital occupations are close sea level. Occupations such as lobstermen and fishermen, shipyard workers, and restaurant workers are at risk. Many businesses, such as Warren's Lobster House and SeaView Lobster Company already see flooding during significant weather events. The Town of Kittery and Kittery businesses and residents should begin to explore what to protect, what to adapt to, and what to retreat from. Another occupation at risk are emergency first responders. We recommend Kittery look at its transportation corridors and ensure there is safe passage to all parts of Kittery in the event of a major storm.

In Massachusetts, many coastal towns have plans in the works to better adapt to rising sea levels. For short term relief, Quincy has plans to construct a higher seawall. More concrete plans in the works include deployable flood walls in East Boston, permeable pavement in Winthrop, construction of living shorelines in Newbury, and preliminary analysis of storm tide pathways throughout Scituate. Similar to Quincy Massachusetts, Rye and Hampton, New Hampshire have also built both rock wall and sand barriers in hopes to protect the shoreline from sea-level rise (Rockingham Planning Commission, 2015).

Transportation Corridors

We recommend an immediate and comprehensive assessment of the Interstate 95, Route 1, and Route 103 bridges over Spruce Creek. As stated before, we identified these bridges as sites of concern. We acknowledge that these bridges are out of the jurisdiction of the town, but we recommend that Kittery begin coordinating with the State of Maine and the Federal government to ensure safe passage over Spruce Creek in the future. An immediate assessment and strong dialogue will ensure that these bridges will get the attention needed to prevent any issues or disaster. It is in the town's best interest to future-proof these roads, as blockage or bridge failure could create dangerous situations in case of emergency evacuation and create impassible situations for residents and emergency services. This goes for low-lying roads, culverts, and bridges as well.

We also recommend Kittery enhance their existing stormwater management systems to accommodate storm surge and flooding. Flooding on low lying roads will become prevalent during high tides, so it would be imperative that drainage be as fast as possible to eliminate ponding. Solutions could include additional, high volume culverts, or permeable pavement surfaces that towns such as Hull, Newbury, and Lynn have incorporated.

Manufactured Capital

We recommend an in-depth assessment of all properties we identified as at risk for coastal flooding, focusing on structures and manufactured capital. 31.4% of property value will be at risk of flooding by 2100. Using the "bathtub" model used in our report, as well as in *A Town in High Water: Coastal Hazard Planning Practices for Kittery* by A. Duprey, it is hard to estimate the true total economic value of manufactured capital that will be at risk. We encourage further research into the mechanics behind these flooding scenarios to understand, more in depth, what will be at risk. Using our models, we value the total economic value of buildings at risk for flooding to be $195 million by 2100. Many of these properties may be abandoned. This will result in a large deficit of property tax revenue of upwards of $200,000 per year at the current tax rate of $12.90 per thousand dollars, without considering the lost income taxes and local business patronage if homeowners leave Kittery. Many of the coastal properties are worth significantly more than properties inland, which adds to the deficit. We recommend that Kittery educates landowners so they may undertake their own professional risk assessments, since individually assessing properties is outside the scope of this project. Kittery may offer resources to its citizens to help them in these efforts.

Since coastal properties will likely become unsafe to access, we recommend Kittery explore the route of land buybacks, or offer incentives to encourage inland land use and development, or build in existing areas that aren't at risk of flooding to eliminate sprawl. Encouraging development inland will reduce the risks of living in flood zones, protecting citizens and emergency services, and encouraging people to stay in Kittery.

A look at Portland's *Bayside Adapts* program allows for third party contractors to design shorelines that are highly adapted to rising tides and storm surges. Similar strategies can be used to obtain different insights and broaden the range of ideas for building resilience.

Natural and Conserved Areas (Natural Capital)

We found that, although rising seas will adversely alter coastal ecosystems, those coastal ecosystems also provide ecosystem services that protect inland residences and structures. We recommend a move to create ordinances to limit construction and development in low-lying areas. By keeping low-lying parcels undeveloped, they can act as storm water and energy storage, diverting it away from residences. Kittery already has this, in the form of Seapoint Beach and Fort Foster. They are beneficial in that they help defend against storm surge and protect areas further inland.

Durham, New Hampshire is where the Wagon Hill Farm living shoreline conservation project has been successfully implemented (Strafford Regional Planning Commission 2021). Not only does this project restore these living shorelines, but it assists in stormwater drainage along with minimizing the erosion in the area.

Areas of value for the visitor economy

Kittery Foreside, Fort Foster, and Seapoint Beach are all areas that attract visitors to Kittery. Along with tourism, there are many seasonal and full year jobs at risk in these areas from potential damage to infrastructure. Kittery could encourage business to redevelop outside of risk areas and build more resilient infrastructure. Kittery should also begin planning the future of its major tourism locations. There is no doubt that areas such as Fort Foster have great intrinsic value to the town, residents, and its visitors, but it will and has flooded and been damaged by strong coastal storms (e.g., March 2018). We recommend that Kittery investigate the potential loss of tourism revenue as sea-level rise and flood risk increase, with expected impacts on the tourism economy.

Education/Community Outreach

Community involvement will be key in raising awareness and implementing practices that will prepare Kittery for a more flood resilient future. Community outreach and public information sessions will be key in informing the public on safety risks involving coastal flooding, as well as gain information, ideas, and opinions from citizens to improve response by the Town and by residents. Examples of this can be seen in surrounding local coastal communities. In New Hampshire, they have assessed the vulnerabilities and provided awareness to the towns (Coastal Adaptation Hazards Commission, 2016; New Hampshire Coastal Risk and Hazards Commission, 2016). Kittery itself hosts the Kittery Block Party in Wallingford Square every summer. This would be an excellent place to share information pertinent to coastal adaptation. It is important that citizens of all ages and demographics be involved in this process. School programs could be implemented as well, or coastal adaptation programming could be incorporated in existing curriculum to help bring awareness in school-aged children.

VI. Conclusion

Kittery's coast is already at risk of significant flooding from large coastal storms. Hurricane Sandy (2012) and Winter Strom Riley (2018) are more recent example that show New England is vulnerable to flooding from large coastal storms, and the science suggests that stronger hurricanes will likely become more prevalent as climate change continues to affect the planet and its weather

patterns. A basic assessment of quantitative and qualitative risk proves that Kittery's local economy, real estate market, and recreational spaces could suffer significantly in the case of a major coastal storm, and the risk will only increase in the future as sea-levels continue to rise. However substantial coastal resilience efforts can and should be considered, discussed, and implemented by the public sector, private sector, and residents to make Kittery a viable and vibrant place to live and work for many generations to come.

It is evident that there is a lot that Kittery could do to prepare for the future. Community involvement is likely the most important step, followed closely by a need to assess key transportation corridors. Planning for coastal adaptation will only be successful if a majority of residents agree that there is a problem, that they are at risk, and that they can help in preparing Kittery for the future. Kittery should begin working with the State and Federal governments to assess the transportation corridors that are not under municipal jurisdiction and develop a plan to future proof them. This report is represents an early step in a long journey of adaptations and improvements to make Kittery a great and resilient place to live for centuries to come.

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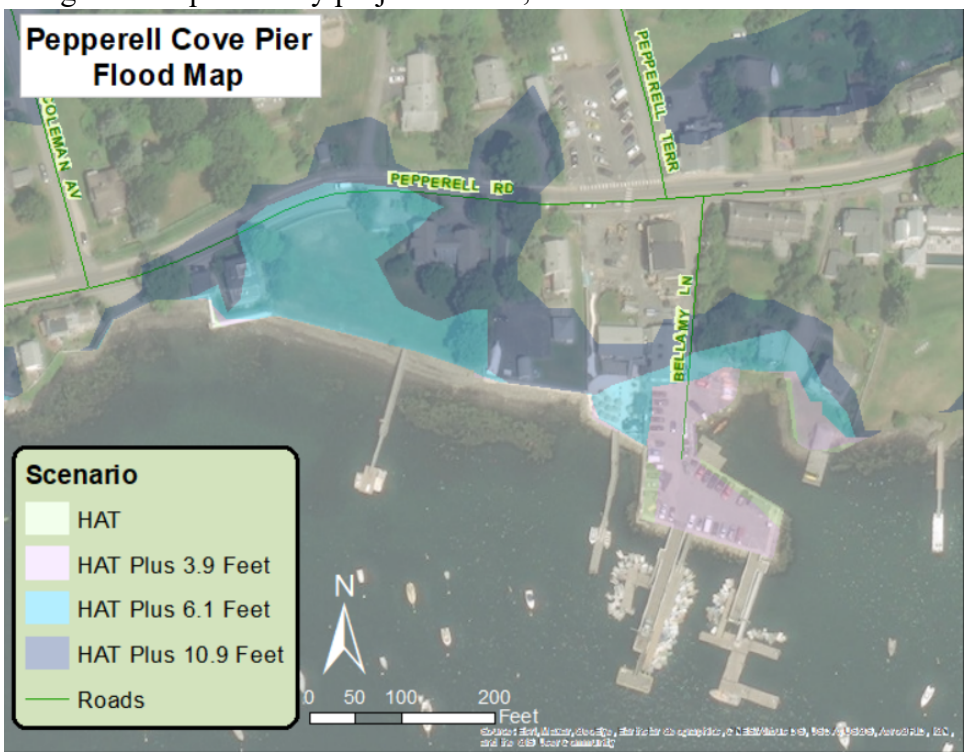
Appendix A: Assessed Property Value at Risk Analyses

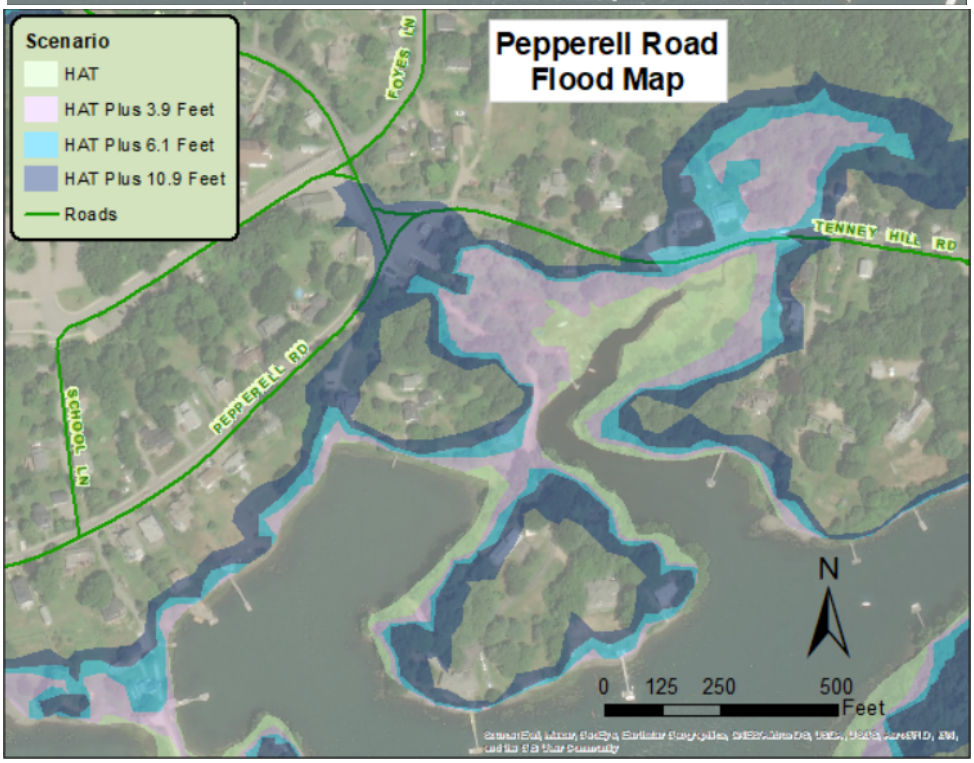
All analyses of properties that could be affected by sea-level rise and storm surge in Kittery are available in an Excel Workbook available from project mentor Dr. Cameron Wake (E-mail: cameron.wake@unh.edu)

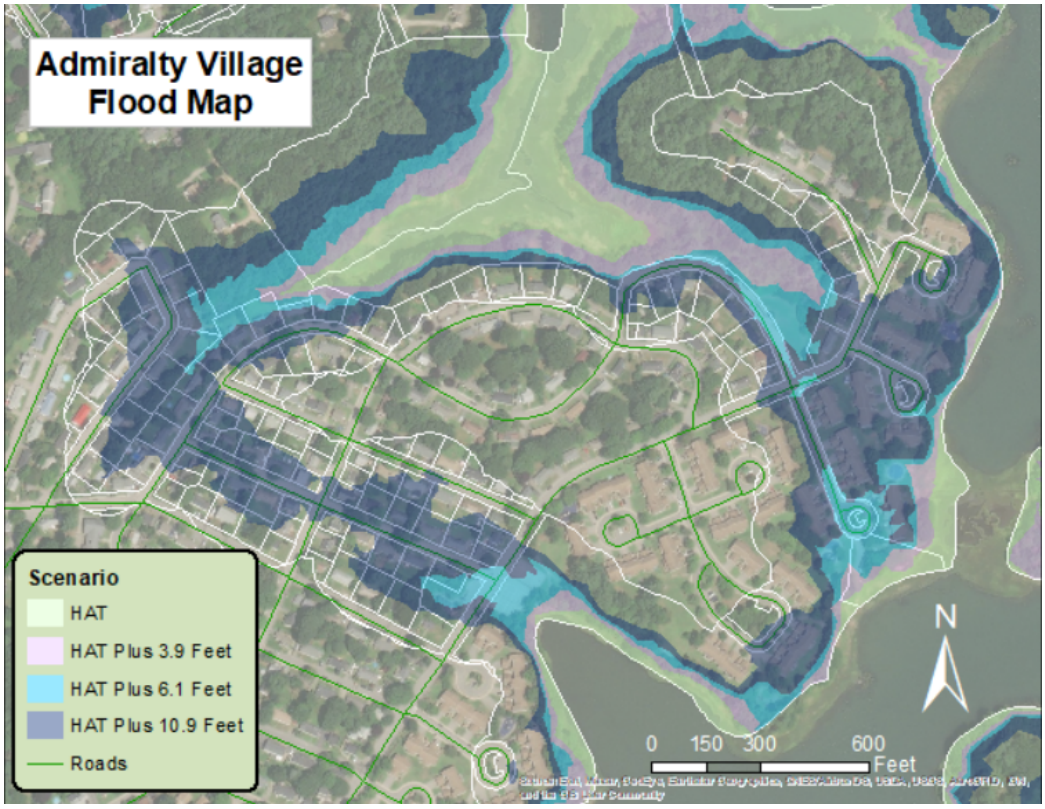
This file contains the Land Use Assessment, the Property Value Assessment, and the Roads at Risk Assessment, along with two other sheets containing source data.

Appendix B: Mapping and GIS Data

The Map Package can be provide by project mentor, Dr. Cameron Wake.



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HAT Plus 6.1 Feet
HAT Plus 10.9 Feet
Roads
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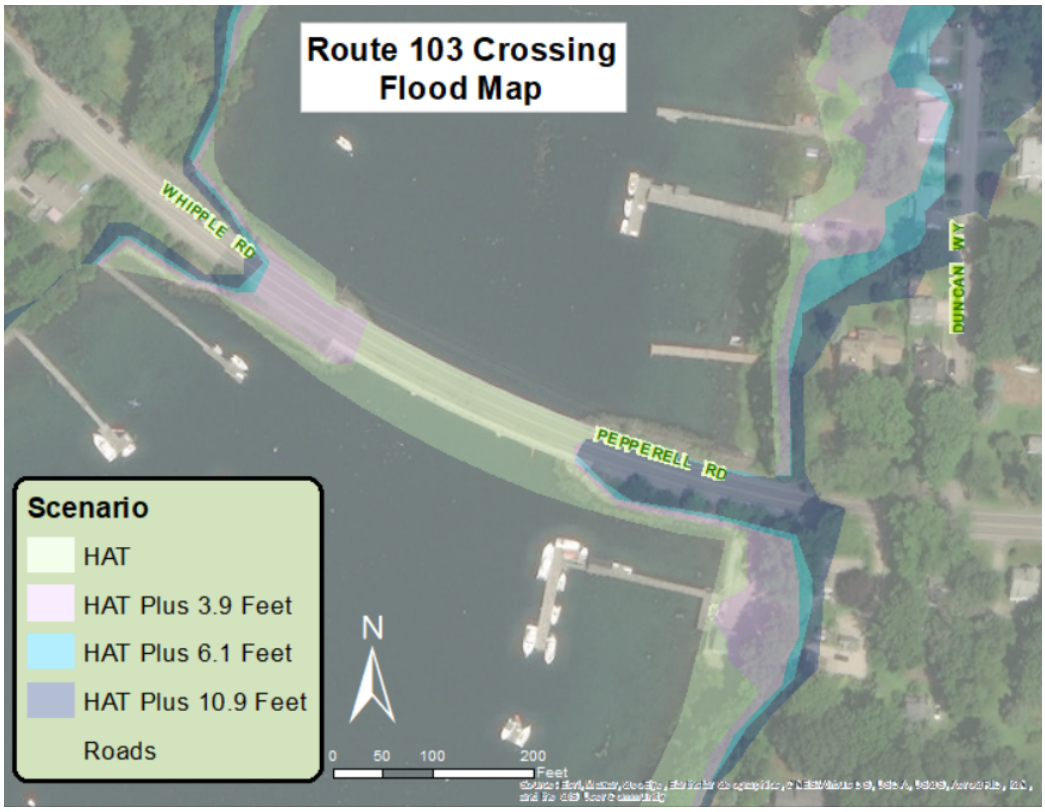
Feet


Route 103 Crossing
Flood Map
WHIPPLE RD
PEPPERELL RD
DUNCAN WY
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HAT
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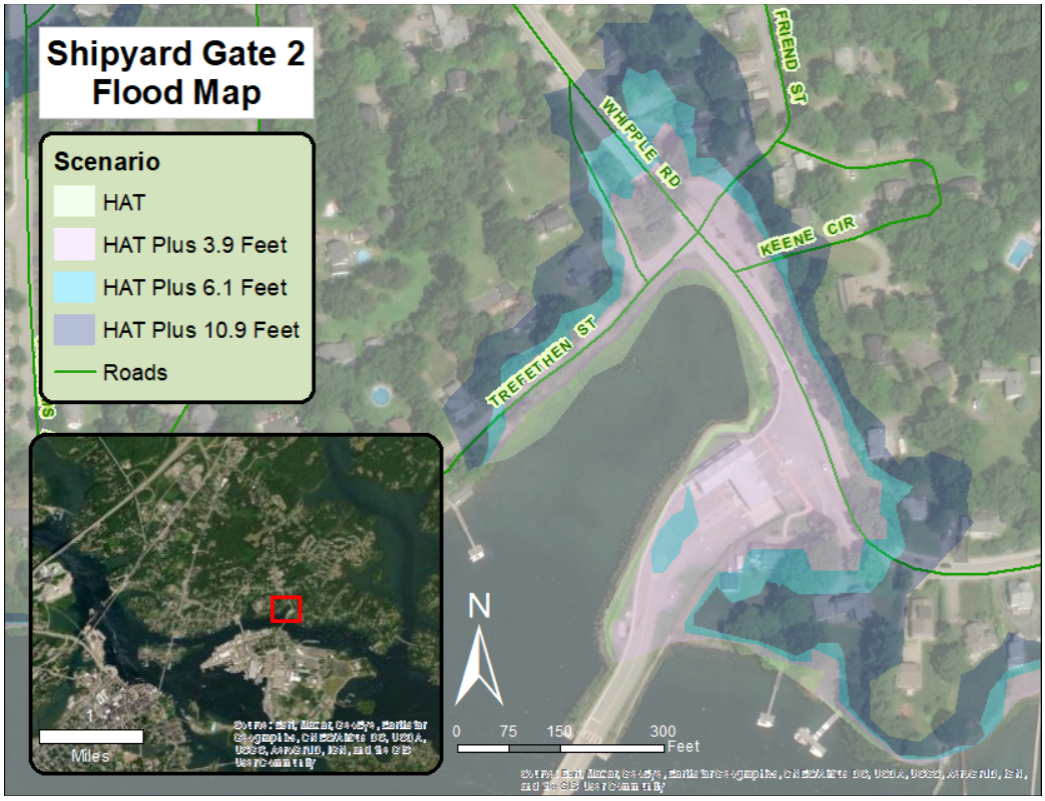
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Flood Map
Scenario
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HAT Plus 6.1 Feet
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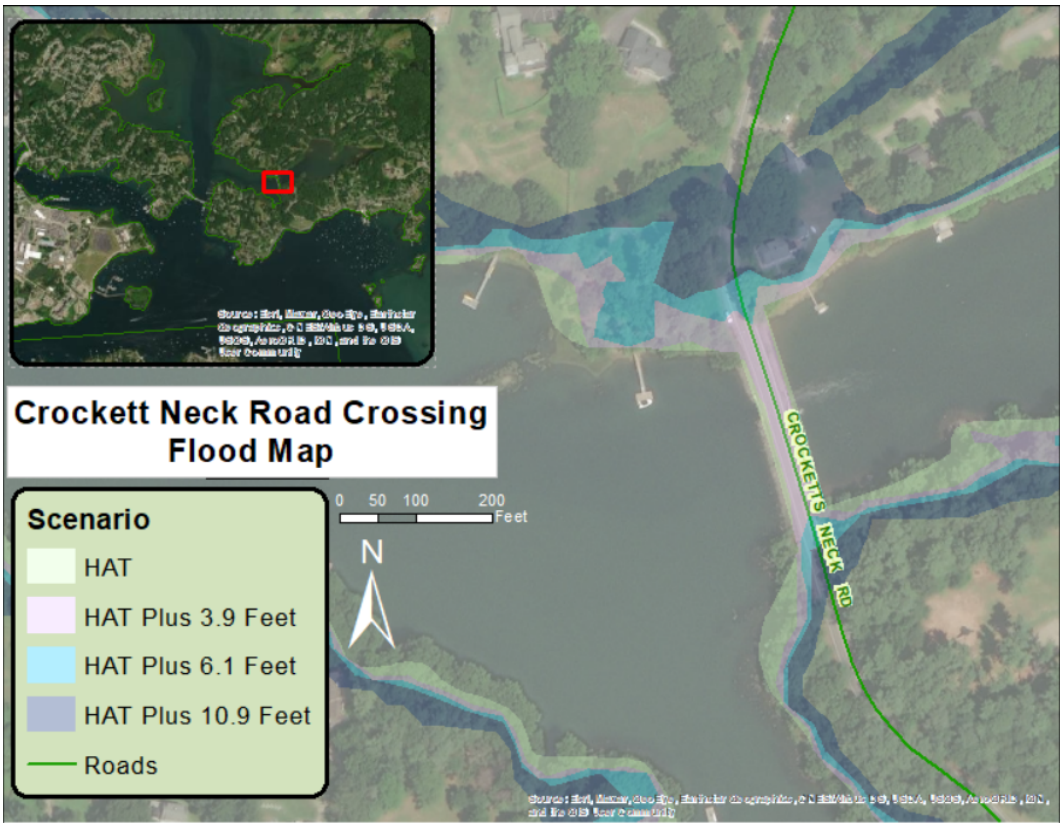
Crockett Neck Road Crossing
Flood Map
Scenario
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Roads
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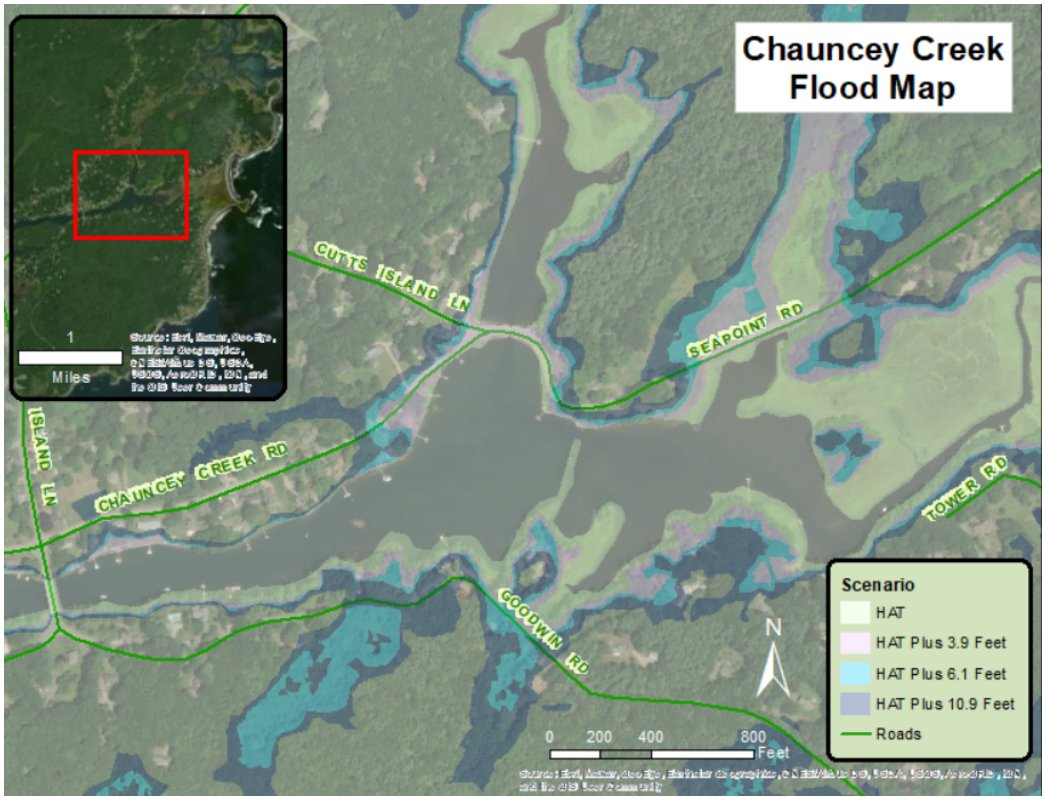
CROCKETTS NECK RD


Chauncey Creek Flood Map
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SEAPOINT RD
ISLAND LN
CHAUNCEY CREEK RD
TOWER RD
GOODWIN RD
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Miles
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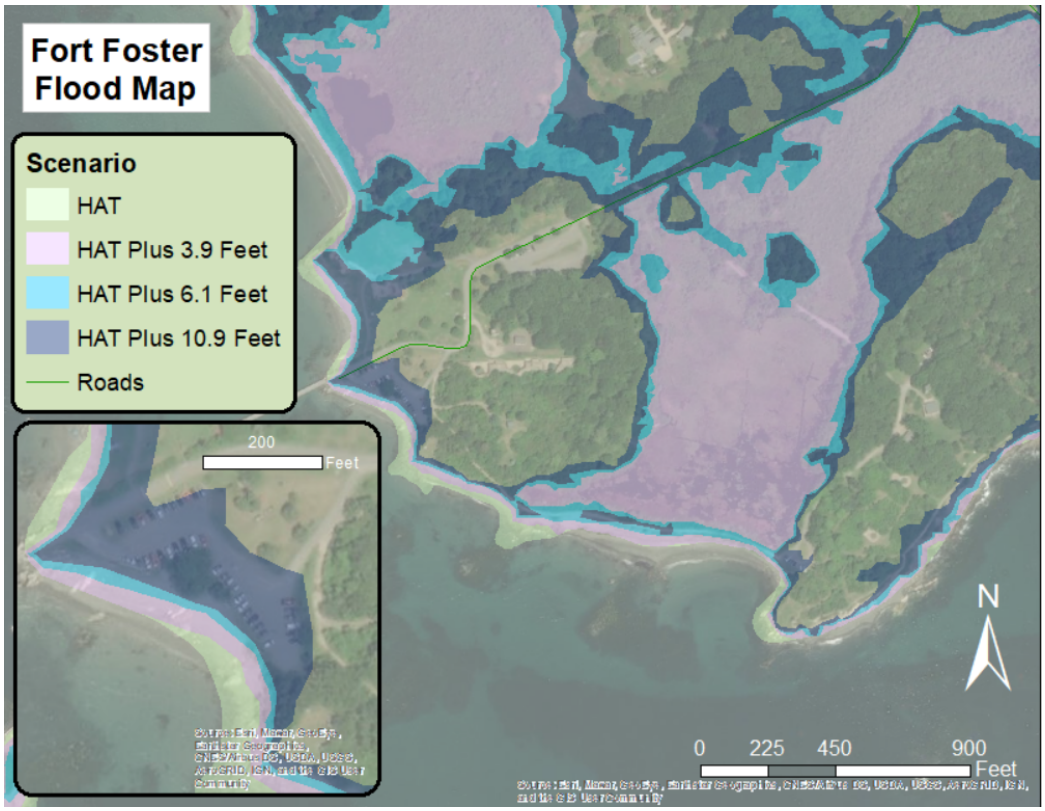
Feet
Scenario
HAT
HAT Plus 3.9 Feet
HAT Plus 6.1 Feet
HAT Plus 10.9 Feet
Roads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HAT Plus 6.1 Feet
HAT Plus 10.9 Feet
Roads
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Feet
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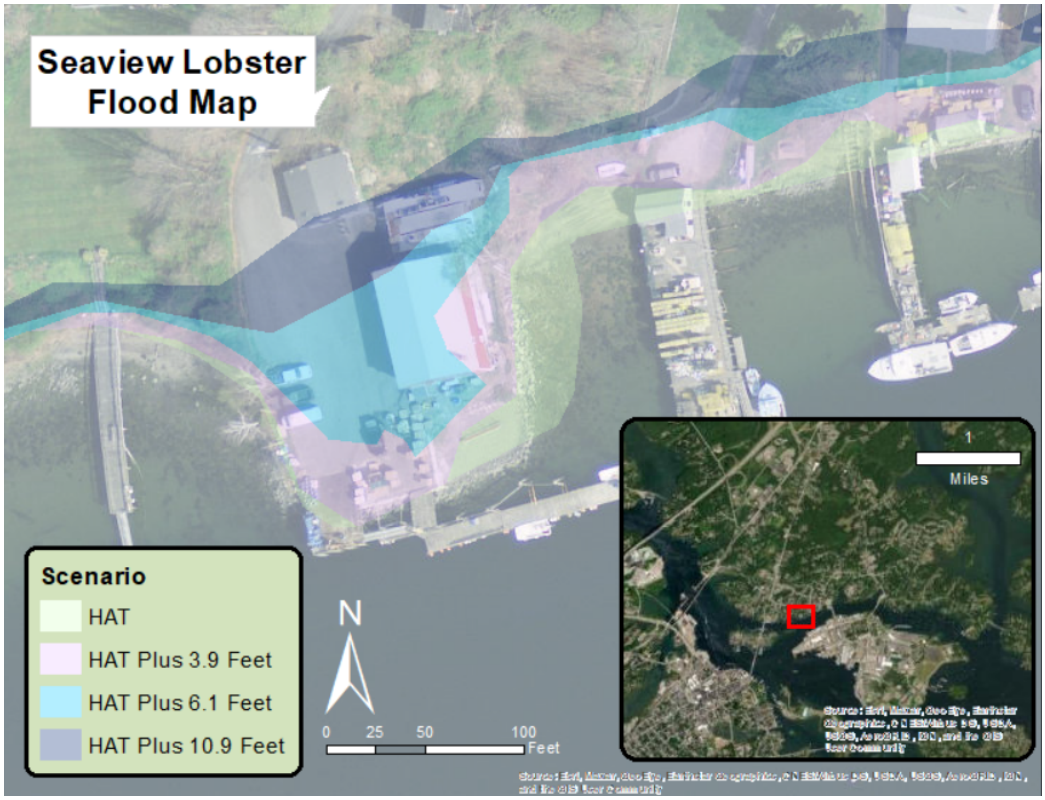
Feet


Seaview Lobster
Flood Map
Scenario
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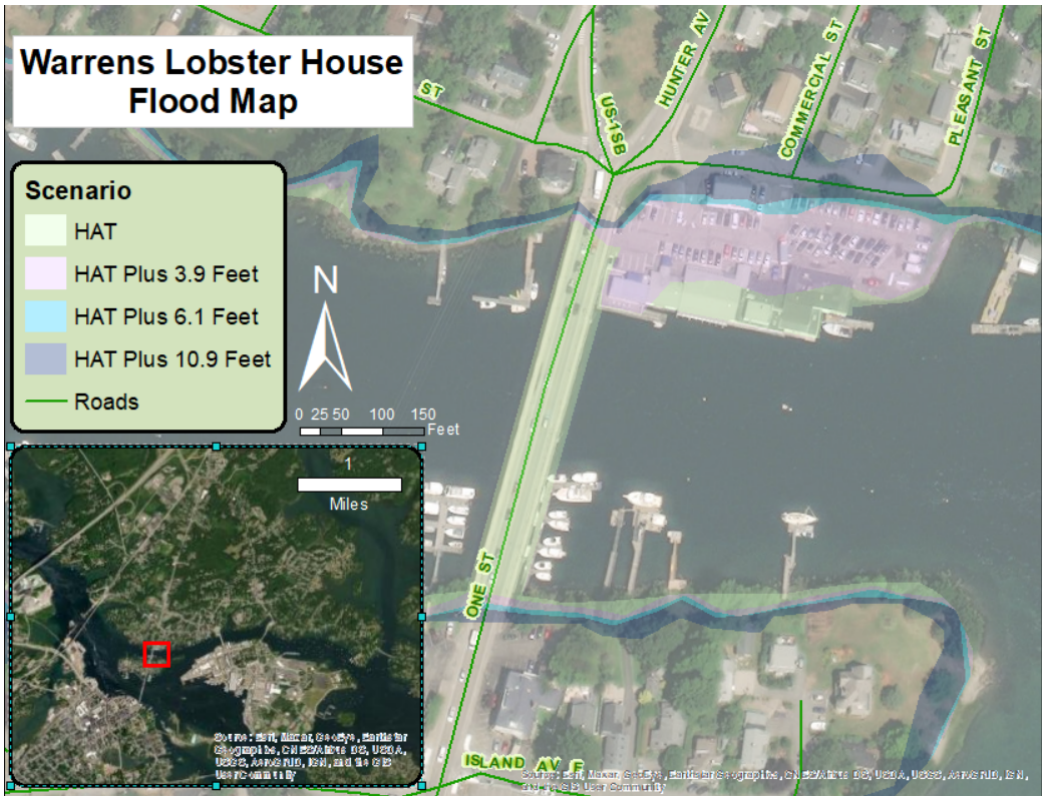
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Flood Map
Scenario
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Feet
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Miles
US-1SB
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COMMERCIAL ST
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