Climate Change Vulnerability / Risk Assessment and Adaptation Study Town of Sandwich

August 2019

PREPARED FOR:
Town of Sandwich
Natural Resources Department
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Sandwich, MA 02563

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1.0 INTRODUCTION

The Town of Sandwich is located along the southwest shoreline of Cape Cod Bay, with most of the Town east of the Cape Cod Canal. Jetties constructed in 1906 to stabilize the Canal entrance have caused an interruption in the natural longshore sediment transport moving from northwest to southeast, and this has resulted in long-term erosion and retreat of the downdrift shorelines. The shorelines and barrier beaches of Sandwich serve to protect salt marsh and estuarine systems at Sandwich Harbor and Scorton Harbor. The upper reaches of these systems directly abut many areas of downtown Sandwich where municipal infrastructure and private development are located. Several critical facilities and a major evacuation corridor are in the present-day 100-year floodplain that surrounds Sandwich and Scorton Harbors. An analysis of insurance claims between 1978 and 2013, as presented in the Massachusetts State Hazard Mitigation Plan, indicates that there were 135 flood insurance claims in the Town of Sandwich for a total value of $1.2 million. A number of these were repetitive loss claims. Due to the low-lying nature of the developed areas around Sandwich and Scorton Harbors, rising sea levels and increased storm frequencies and intensities associated with climate change will only increase the potential for flooding and storm damages in the Town.

1.1. PLANNING PROCESS AND GOALS

The Town of Sandwich received a planning grant from the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) to implement the Municipal Vulnerability Preparedness (MVP) Program's Community Resilience Building (CRB) framework in 2018. During the CRB Workshop, participants identified strengths and vulnerabilities, and prioritized actions to reduce vulnerability and enhance community resilience. The top hazards identified by the community to be addressed during the workshop were flooding, coastal erosion, sea level rise, and Nor'easters and snowstorms. Workshop participants specifically identified as a priority the need for a detailed vulnerability assessment to prioritize all Town assets to address coastal flooding and sea level rise.

The Town became an MVP Certified Community and applied for an MVP Action Grant to implement the coastal vulnerability assessment and adaptation plan. While CRB workshop participants identified the need to address infrastructural features as part of this project, the Town proposed to also address natural resources (e.g. beaches, dunes, marsh systems) given the significant concern that these features, which provide resiliency and others benefits to the Town as a whole, were also at risk.

The following primary goals were established for this project:

1) Identify areas of the Town that are vulnerable to the combined effects of sea level rise and storm surge from extreme storm events;
2) Assess the vulnerability of municipally owned public infrastructure and natural resources;

3) Identify adaptation strategies that will help to mitigate the near- and long-term effects of sea level rise and storm surge; and
4) Educate the public, Town officials, and legislators about those potential impacts.

1.2. ACKNOWLEDGEMENTS

The Town would like to thank EEA for funding this project through the MVP program, and specifically thank Margot Mansfield and Vallery Cardoso for their support to the project team.

The Town also wishes to acknowledge the contribution of the Massachusetts Department of Transportation under the direction of Steven Miller, Project Manager, and the Federal Highway Administration related to the modeling associated with the Boston Harbor Flood Risk Model (BH-FRM). The methodology from the BH-FRM was utilized as the basis for the development of the Massachusetts Coastal Flood Risk Model (MC-FRM), which was used for this Study.

The Town of Sandwich selected the team of Woods Hole Group and Kleinfelder to conduct this Study. Woods Hole Group, located in Bourne, MA, was responsible for client liaison, coastal flood modeling and natural resource impacts, and preparing the vulnerability assessment and adaptation plan. Kleinfelder, located in Boston, MA, assisted with the flood analysis, and was responsible for preparing the vulnerability assessment and adaptation plan for the Town. The team's primary members included:

- Joseph Famely, Senior Environmental Scientist, Woods Hole Group
- Kirk Bosma, PE, Coastal Engineer and Innovation Director, Woods Hole Group
- Brittany Hoffnagle, Environmental Scientist, Woods Hole Group
- Julie Conroy, AICP, Senior Climate Planner/Project Manager, Kleinfelder
- Kyle Johnson, Green Infrastructure Specialist, Kleinfelder
- Bella Purdy, Climate Resiliency Planner, Kleinfelder
- Nasser Brahim, Sr. Climate Planner, Kleinfelder
- Jonathan West, Graphic Designer, Kleinfelder

The Project Team worked closely with Town of Sandwich project Steering Committee:

- David DeConto, Natural Resources Director
- George Dunham, Town Manager
- Ralph Vitacco, Director of Planning and Economic Development
- Paul Tilton, Director of Public Works / Town Engineer
- Peter Wack, Chief of Police
- John Burke, Fire Chief
- Guy Boucher, Recreation Director
- Michael Dunning, Harbormaster
- Joanne Lamothe, Director of Public Library
- Mike Twoomey, Information Technology Director
- Maribeth Chassey, GIS Technician

1.3. CLIMATE CHANGE PRIMER

Assessment and planning methods were guided by the widespread consensus that there are natural causes of climate change, as well as anthropogenic changes, which have rapidly amplified over the past century. Natural climate changes result from any tip in the balance between energy entering and leaving the Earth's atmosphere, as shown in the illustration created by the United States Department of the Interior, National Park Service (Figure 1-1, source: Will Elder).

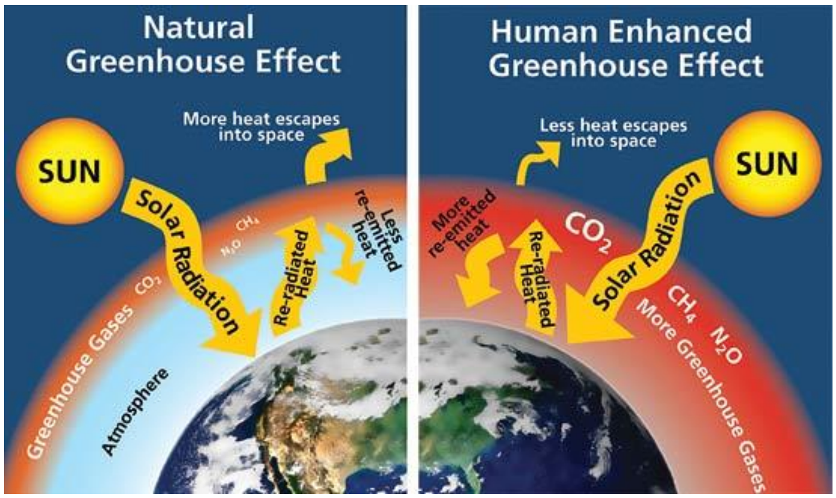


Figure 1-1. Natural versus Anthropogenic Climate Changes

Changes in the Earth's climate over time are often due to natural causes such as changes in solar energy, volcanic eruptions, and natural changes in Greenhouse Gas (GHG) concentrations. GHGs like carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) absorb energy, slowing or preventing the loss of heat to space. In this way, GHGs act like a blanket, making Earth warmer than it would otherwise be. This process is commonly known as the "greenhouse effect."

Although the earth's climate is known to experience these natural shifts over time, there has been a documented increase in GHGs due to human activity. Hence, the interest in the scientific community to potentially define a new geologic era: Anthropocene, as a human-dominated geological epoch, based upon recent global environmental changes (e.g. mass extinctions of plant and animal species, polluted the oceans and altered the atmosphere, among others). Anthropogenic climate change is a difficult subject to comprehend because its causes are largely invisible to the human eye. However, every day, all around us, carbon dioxide, methane, nitrous oxide, and other greenhouse gases pour from automobiles, buildings, airplanes, factories, and power plants. Everything requires energy to respire, move, grow and reproduce. Current human sources of energy generally come from non-renewable energy sources such as the following (in order of use): petroleum, natural gas, coal, and nuclear electric power. The first three categories are also known as "fossil fuels," because they were created as a result of biomass being compressed and "fossilized" under the Earth's surface over the course of millions of years. Fossil fuels have extremely high energy content and have historically served as the driving force behind industrialization, population growth, and economic development.

However, there are several problems associated with the conversion technologies used to turn the stored chemical energy in fossil fuels into active thermal energy (e.g., combustion), including the generation of GHGs. An exponential "spike" in GHG emissions occurred during the 1800-1900's (industrial revolution), as illustrated in Figure 1-2 (Luthi, D.M., et.al., 2008). This 800,000-year record of carbon dioxide concentration used to produce this graph came from ice core air samples, trapped in ancient ice bubbles. What is most important to note is the extreme jump from the preindustrial revolution era (approx. 1800) to 2008, revealing approximately a thirty-three percent (33%) increase in GHGs. This graphic provides a zoomed-in viewing of a portion of the "Anthropocene" timeframe; the post-industrial revolution era where the spike in GHGs have been documented.

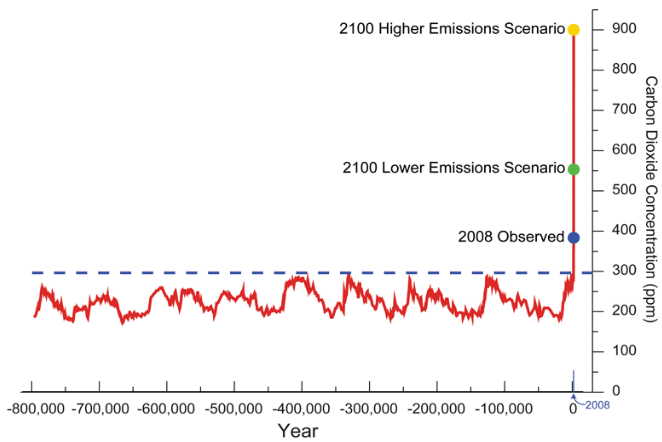


Figure 1-2. Carbon Dioxide Concentrations – 800,000 Year Record

As shown, there has been a steady increase in GHG emissions from approximately 320 parts per million (ppm) to over 400 ppm. Data such as this has resulted in pervasive consensus within the scientific community that human-induced greenhouse gas emissions have caused major alterations in the Earth's climate. This led to the Intergovernmental Panel on Climate Change (IPCC) producing their fifth assessment report (AR5) (IPCC, 2014.), which included a new approach to climate change forecasting built around the concept of Representative Concentration Pathways (RCPs). RCPs are concentrations of greenhouse gases (GHG) and pollutants resulting from human activities, including changes in land use. RCPs provide a quantitative description of concentrations of the climate change pollutants in the atmosphere over time, as well as their "radiative forcing" - a measure of the additional energy taken up by the Earth due to increases in climate change pollution. The four RCP scenarios are consistent with certain socio-economic assumptions as follows:

1) RCP 8.5 – Highest Emissions - A future with no policy changes to reduce emissions with increasing greenhouse gas emissions that lead to high greenhouse gas concentrations over time. This scenario includes the following conditions:

- Three times today's CO_2 emissions by 2100 and rapid increase in methane emissions,
- A world population of 12 billion by 2100,
- Increased use of croplands and grassland, and
- Lower rate of energy efficient technologies and heavy reliance on fossil fuels

2) RCP 6 – Intermediate High Emissions - Stabilization of radiative forcing shortly after year 2100, via the application of a range of energy efficiency technologies and strategies that reduce greenhouse gas emissions. This scenario includes the following conditions:
    - CO_2 emissions peak in 2060 at 75% above today's levels, then decline to 25%,
    - Reliance on fossil fuels yet with stable methane emissions, and
    - Increasing use of croplands yet declining use of grasslands.
3) RCP 4.5 – Intermediate Low Emissions - Stabilization of radiative forcing shortly after year 2100, consistent with a future with relatively ambitious emissions reductions. This scenario includes the following conditions:
    - CO_2 emissions increase only slightly before decline starting in 2040,
    - Stringent climate policies and strong reforestation programs,
    - Stable methane emissions,
    - Decreasing use of croplands and grasslands due to yield increases and dietary changes
4) RCP 2.6 – Lowest Emissions - Ambitious GHG emissions reductions resulting in a reduced radiative forcing. This scenario includes the following conditions:
    - CO_2 emissions stay at today's level until 2020, then decline in 2100, OR
    - CO_2 concentrations peak around 2050, followed by a modest decline to around 400 ppm by 2100,
    - Methane emissions reduced by 40%,
    - Declining use of oil,
    - A world population of 9 billion by year 2100, and
    - Use of croplands for bio-energy production.

It should be noted that this is a simplified summary of very complex analyses of climate change scenarios; yet it is offered to explain how scientists have arrived at regional climate impact projections. This information justifies a compelling need to plan for communities' future, and to remain adaptive and responsive to challenges as they arise. This can be done by engaging communities on the local level to better understand their vulnerabilities and the community assets that protect them, and to develop a plan for action. Further, stakeholder building is critical for much needed societal changes to occur. Therefore, the question must be posed to residents, government officials, businesses, etc.: What do you want your future to look like?

2.0 METHODOLOGIES

A series of analyses was conducted to determine the vulnerabilities of natural resources, high-risk developed areas, and municipal assets (infrastructure and Town-owned facilities). Different analyses were required to understand vulnerabilities of varying types of resources, from wide-reaching salt marsh areas to site-specific properties and structures. First, coastal inundation modeling was conducted to determine which areas of the Town would likely be exposed to coastal flooding in the near- and longer-term future. A slightly different ecological assessment and modeling effort was undertaken to determine vulnerabilities of natural resources. A risk assessment methodology was utilized to generate risk scores for each asset and assist the Town with prioritization of capital fund projects. Finally, a qualitative analysis of the Town's highly vulnerable ("high-risk") areas was conducted, based upon the results of the coastal inundation model. These targeted analyses are described within the following sections.

2.1 COASTAL INUNDATION MODELING

The Massachusetts Coastal Flood Risk Model (MC-FRM) developed by the Woods Hole Group is the most comprehensive and sophisticated model available for anticipating how climate change (specifically sea level rise and coastal storm events) will influence future coastal flood risks in Massachusetts coastal communities (MassDOT, 2019 in publication). MC-FRM was developed for the Massachusetts Department of Transportation (MassDOT) to assess potential flooding vulnerabilities to highways and other transportation infrastructure throughout the coastline of Massachusetts. The model is based on mathematical representations of the hydrodynamic processes that affect water levels along the coast, including tides, waves, winds, storm surge, sea level rise, wave set-up, wave run-up and overtopping, etc. These processes were modeled at a high enough resolution to identify site-specific locations in Sandwich that are vulnerable and may require adaptation responses.

The model is based upon a numerical mesh that provides a digital representation of the geometry of the physical environment. The numerical mesh represents the bathymetry and topography (elevations) of the land, ocean, rivers, and bays at high resolution in order to predict the physical movement of water during coastal storm events (nor'easters, hurricanes, etc.). The model mesh creates discrete nodes at which the governing equations of water flow can be solved. While the model mesh encompasses the entire Atlantic Ocean, the resolution of the model grid gets finer – meaning the nodes get closer together – as the mesh gets closer to the shoreline. The mesh for a portion of Sandwich is shown in Figure 2-1, overlaid on an aerial image. The MC-FRM mesh has a resolution of 10 meters or less between nodal points, and sometimes as low as 2-3 meters to capture important changes in topography and physical processes related to storm dynamics. It includes areas of open water, estuaries, bays, rivers, and upland subject to present and future flooding.

Figure 2-1. MC-FRM Model Mesh for Sandwich

The MC-FRM is comprised of a tight coupling of the Advanced CIRCulation (ADCIRC) model, which calculates the water levels and velocities, and the UNSWAN model (unstructured Simulated Waves Nearshore), which calculates wave generation and transformation. These two models dynamically exchange information on physical processes every time step of the model simulation. This allows MC-FRM to provide an accurate representation of the resulting wave surface elevation, waves, winds, and flooding at each node, over each time step, in the model domain. The MC-FRM also includes the addition of wave run-up and overtopping at major coastal structures across the Commonwealth. This added module dynamically calculates the volume of seawater that advances landward over the coastal structure over time. The volume is calculated over each time step and allowed to flow over the landscape. MC-FRM was calibrated and validated to normal tidal conditions (at observation stations from the Caribbean Islands to Canada), as well as to historic storm events that impacted the coastline of Massachusetts (e.g., Hurricane Bob, Perfect Storm, Blizzard of 1978, etc.) Complete details on the development of the Massachusetts Coastal Flood Risk Model (MC-FRM) can be found in MassDOT (2019, in publication).

2.1.1 Sea Level Rise Scenarios

It should be noted that the science of climate change and translating climate risks into design criteria are new and evolving practices, involving uncertainty and variability in future greenhouse gas emissions pathways as well as in the downscaling of global climate projections for local application. The Commonwealth of Massachusetts has developed projections (temperature, precipitation, sea level rise) based on a range of medium to high greenhouse gas emissions scenarios (RCP4.5 and RCP8.5), which are inherently variable (Figure 2-2), and made them available on the Massachusetts Climate Change Clearinghouse (resilient MA) for use by communities in the MVP program.

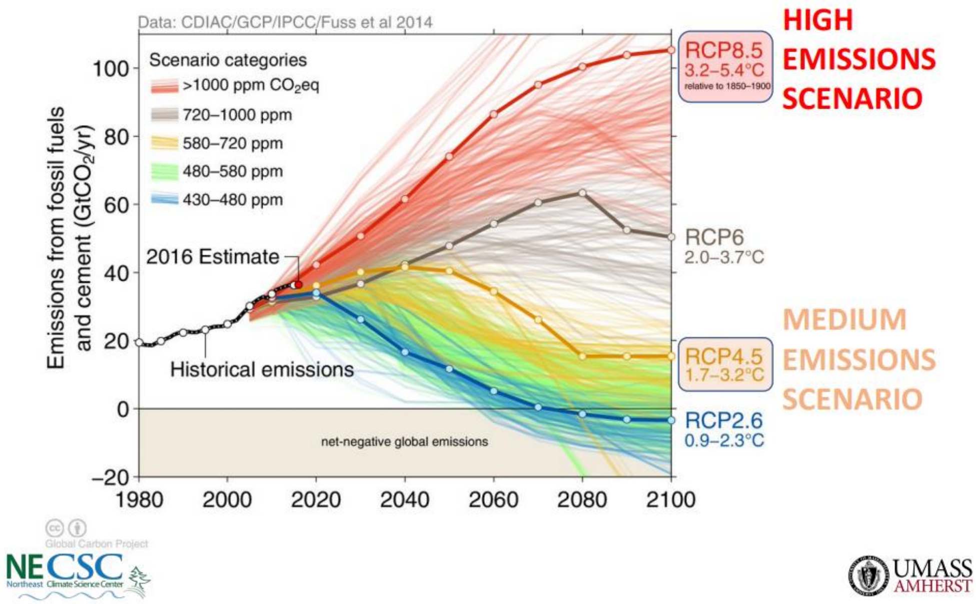


Figure 2-2. Global Emissions Scenarios Used in resilientMA Projections

The projections made in this report are aligned with the state standards, which have adopted a probabilistic approach to local sea level rise and storm surge projections. The Commonwealth has developed probabilistic local SLR projections downscaled from global models and adjusted for local landform subsidence. While there is variability in these projections (Figure 2-3), there is a high degree of confidence in the protectiveness of each projection given the associated emissions scenarios and embedded assumptions therein. The science of climate change is an evolving field that is constantly being updated and are inherently variable in nature. As such, projections made within this report provide guidelines for investment decisions based on the knowledge to date. The flood level predictions made in this report are based on some of the most recent developments in the science of climate change but are not guaranteed predictions of future events. It is recommended that these results be updated over time as science, data and modeling techniques advance. A full review of facility drawings, material testing, survey or analysis of a structure's ability to withstand the projected hydrostatic forces due to flooding were not completed for this Study. The findings include certain assumptions based on reasonable engineering judgment as to the ability of buildings and facilities to resist the projected hydrostatic forces due to flooding. These assumptions will require additional verification and customization during the design phase of individual projects.

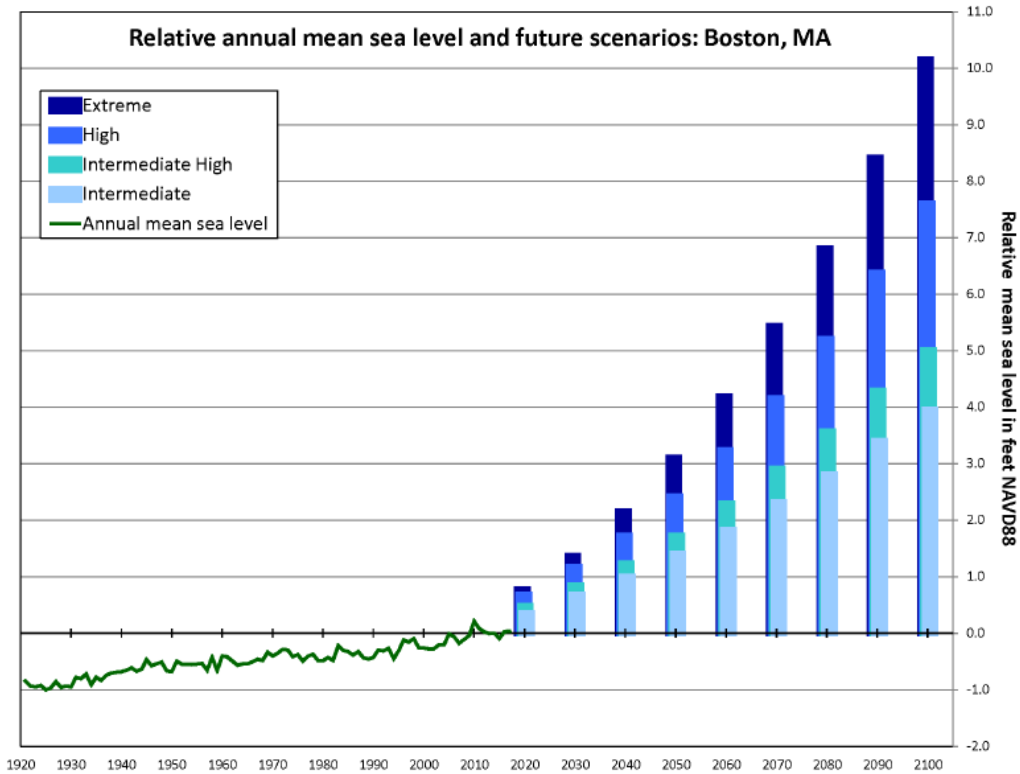


Figure 2-3. Mean Sea Level Probabilistic Projections for Boston

The National Oceanographic and Atmospheric Administration (NOAA) has been recording tidal observations since 1921 at Tide Gauge No. 8443970 in Boston, Massachusetts (Figure 2-4). Over this period of 96 years, relative sea level in this area has risen approximately 10.7 inches (2.82 mm per year, with a 95% confidence interval of +/ 0.16 mm/yr). This rate of sea level rise (SLR) is expected to increase in the future due to a volumetric expansion of the oceans coupled with glacial ice melt as a result of global warming caused by greenhouse gas emissions. Over that same time period, the global rate of sea level rise was about 1.7 mm annually (approximately 6.4 inches over the last 96 years). This significant difference between the RSLR experienced locally and the global SLR trend highlights the importance of accounting for local conditions.

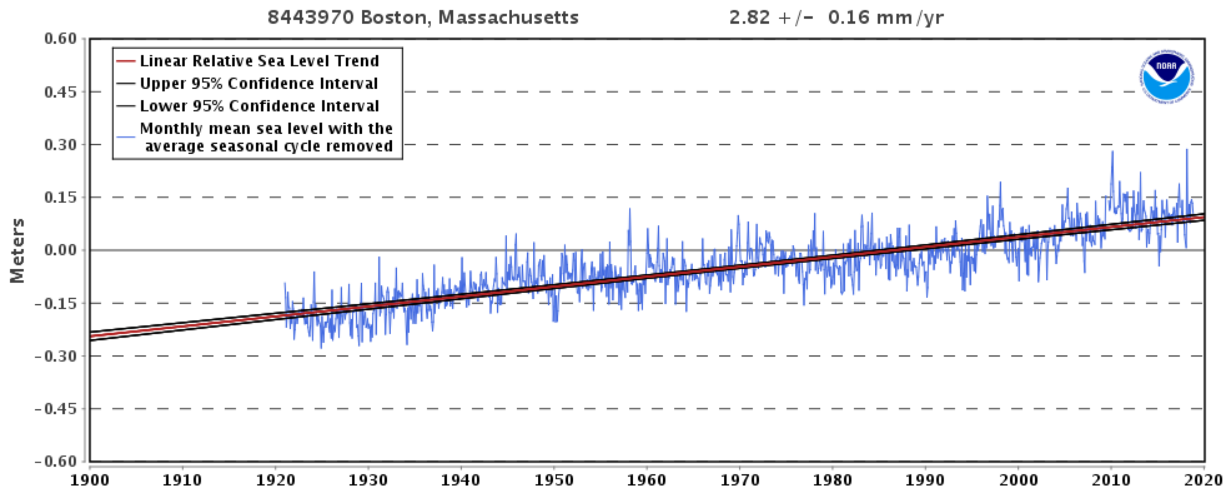


Figure 2-4. Relative Sea Level Rise Trend at the Boston Tide Gauge

For the purposes of this project, planning horizons were selected for two distinct time horizons: 2030 (medium term), and 2070 (longer term). These planning horizons were selected by the Sandwich Steering Committee, comprised of multi-departmental working group of municipal staff and committee members, to provide the most useful data for planning. The 2030 horizon was selected to provide today's decision-makers with not-too-distant scenarios for emergency planning and priority infrastructure protection. The longer term 2070 horizon was selected to provide the big picture context of how significant the coastal flooding challenge could become for the community and its natural resources. It also represents the conditions that should be considered when designing long-lived investments (e.g., new schools, bridges, stormwater systems) and planning future land uses. Using a common set of climate change planning horizons and modeling results also allowed the Town's study to align with other state and local studies being carried out throughout the region using MC-FRM results.

To estimate the amount of SLR that will occur by 2030 and 2070 locally in Sandwich, the project team used the relative sea-level rise (RSLR) projections used in the MC-FRM, which are the most up-to-date RSLR projects for the Massachusetts coastline (Douglas et al., 2016), drawing on long-term water level datasets from a series of tide gages around the state. In order to compare future mean sea level to "present day" conditions, a starting elevation for mean sea level must be calculated. A tidal-epoch, a 19-year time period, is traditionally used to calculate tidal datums. For this study, the 19-year tidal-epoch with a mid-point year of 2008 (i.e., 1999-2017) was used to calculate a starting elevation for mean sea level. Based on this methodology, the mean sea level in Boston in the year 2008 was at an elevation of -0.09 feet (NAVD88). This 2008 starting elevation of -0.09 feet (NAVD88) can then be used to compare to projected relative mean sea-level elevations under various scenarios (Table 2-1). Note that the values in Table 2-1 are elevations of the projected mean sea level at various times relative to a vertical datum of NAVD88, not the magnitude of change in elevation. For comparison, the baseline (i.e., year 2008) mean sea level elevation, is -0.09 feet (NAVD88). Based on the projected sea level elevations presented in Table 2-1, this means there is a projected change in mean sea level of 1.29 feet from present to 2030, and 4.29 feet from present to 2070, based on the "High" SLR scenario.

The data in Table 2-1 are recommended by Massachusetts CZM for assessing sea-level rise, and are being used by the Massachusetts Department of Transportation and other state agencies and communities for vulnerability assessments. As such, these sea-level rise projections were incorporated into the MC-FRM. The "High" SLR scenario was chosen for the MC-FRM because MassDOT and the state were interested in inundation risk probabilities that were unlikely to be exceeded (there is a 99.5% confidence level that the "High" scenario chosen will not be exceeded). In addition, selecting the "High" scenario also allows for the evaluation of inundation risk probabilities under other scenarios due to the bracketed nature of the results. For example, the "High" results in 2030 are equivalent to "Intermediate" results in 2050, and the "High" results in 2050 are the equivalent to the "Intermediate" results in 2070. In this way, the selected scenarios provide an upper bound of potential risk.

Table 2-1. Relative Mean Sea Level (feet NAVD88) for Boston, MA

Scenario	Cross-walked probabilistic projections	2030	2050	2070	2100
High	Extremely unlikely to exceed (99.5%) under RCP8.5	1.2	2.4	4.2	7.6
	• Unlikely to exceed (83%) under RCP8.5 when accounting for possible ice sheet instabilities • Extremely unlikely to exceed (95%) under RCP4.5 when accounting for possible ice sheet instabilities				

2.1.3 Storm Events and Wave Run-up

Figure 2-5. Storms Used in MC-FRM for Present and 2030 Simulations

The storm climatology parameters in MC-FRM include wind directions and speeds, radius of maximum winds, pressure fields, and forward track. MC-FRM requires storm input data to run storm surge simulations and generate flooding results. Without input data, MC-FRM cannot determine which areas of Sandwich will likely be exposed to coastal flooding in the medium- and longer-term future, as much of the community's flood risk profile is dependent on storms.

As part of the development of MC-FRM, a large statistically robust sample of storms, including tropical (hurricanes) and extra-tropical (nor'easters) storms, was developed specifically for the coast of Massachusetts existing and future climatologies. This storm data set includes historic storm events, as well as future storm conditions, and was used to assess coastal flooding risks in the Present, 2030, and 2070.

Figure 2-5 shows a representation of the tropical storm tracks representing some of the tropical storms used in MC-FRM.

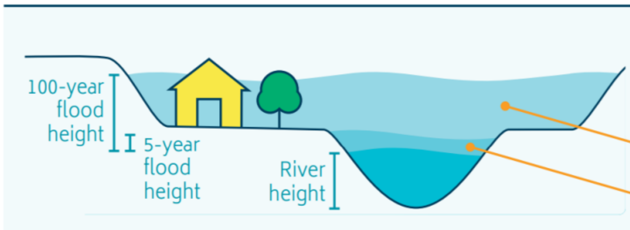
To assess coastal flooding risks in 2070, a different sample of storms reflecting a late 21st century climatology was used. This storm sample includes some very powerful hurricanes, for example, reflecting projections that tropical storms will be more intense on average in the second half of the century assuming that air and ocean temperatures are significantly higher than in the past. This set of storm input data was created by MIT professor Dr. Kerry Emmanuel based on climate projections.

Fully optimized Monte Carlo simulations were run in MC-FRM using the respective storm sets and SLR projections for present, 2030, and 2070. These simulations importantly included the tide cycle as a dynamic element of the model. In Sandwich, the wide tide range means that the same storm surge can result in very different flooding outcomes depending on whether it coincides with high, mid, or low tide. Results of the Monte Carlo simulations were used to generate cumulative probability distribution functions of the storm surge water levels at a high degree of spatial precision. In particular, they provide an accurate and precise assessment of the probability of water levels from combined SLR and storm surge exceeding the elevation of the ground at each node in the model.

2.1.4 Results: Inundation Maps

The results of MC-FRM simulations for Present, 2030, and 2070 were used to generate two types of coastal flooding maps for the Town: percent probability of flooding maps (a screening tool to identify location, structures, and assets that are likely to flood) and depth of flooding maps (a tool to estimate the scale of flooding and impacts for a given percent probability of flooding). Each of these maps are described in more detail below.

1) Percent Probability of Flooding Maps: Finer-grain probability from MC-FRM was obtained from nodes in the model that represent the locations of elements that stakeholders identify as critical. Town stakeholders were consulted to determine if the level of risk represented in the detailed probability data is acceptable, or if some adaptive response action may be required. This probability-based approach of the proposed modeling is beneficial when assessing the vulnerability of, and risk to, infrastructure and when developing adaptation strategies to mitigate future flooding damage. It produces information that can be used to inform engineering design criteria since it provides the probability of an event occurring in this changing regime, such as the “new” 1 in 100 year flood event (1% probability), as illustrated in Figures 2-6 and 2-7 from the Coast Adapt info-graphic series (NCCCARF, 2019). In particular, an accurate and precise assessment of the exceedance probability of combined SLR and storm surge is provided to identify areas of existing and near-term vulnerability requiring immediate action in Sandwich, as well as areas that will benefit from long-range planning for future preparedness and risk reduction.



Recurrence interval	Probability of occurence per year	% chance in any year	Annual exceedance probability (AEP)
100 years	1 in 100	1%	0.01
5 years	1 in 5	20%	0.20

Figure 2-6. A '1-in-100-year flood'

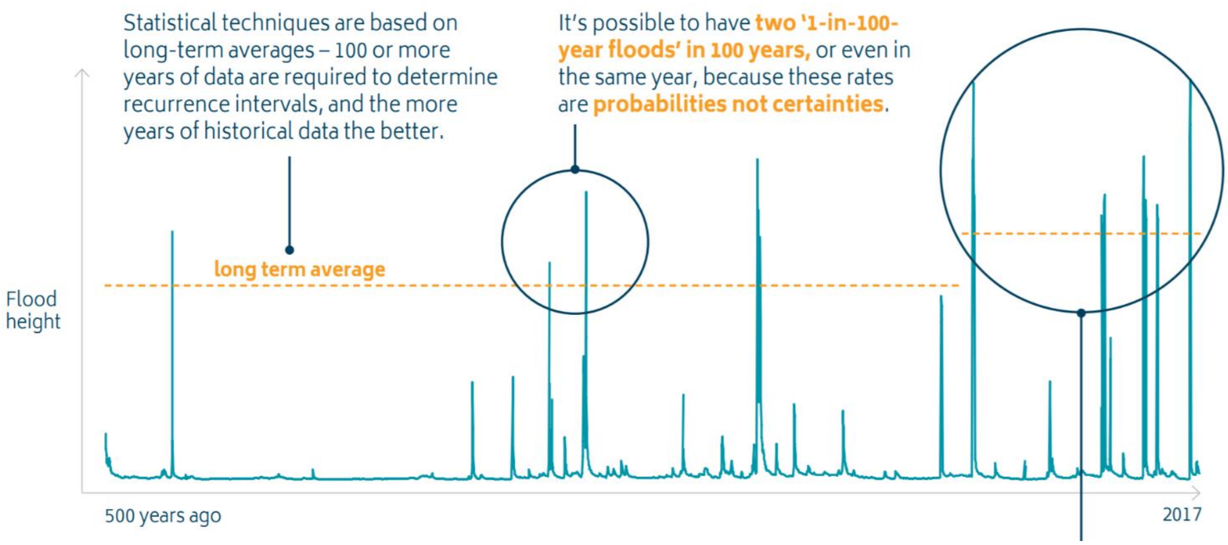


Figure 2-7. Flood Probability Statistics

The 1% probability level was selected because this is the benchmark for the Federal Emergency Management Agency's (FEMA's) Flood Insurance Rate Maps (FIRMs). Although FEMA FIRMs are not forward-looking and do not incorporate sea-level rise into the mapping, FEMA does periodically update their modeling to account for increased sea level rise that has occurred (as well as other changes, such as changes in topography or armoring of particular areas). As such, the 2030 and 2070 1% probability of inundation extents may provide a projection for the expected future FEMA flood zones. Additionally, the 1% probability level corresponds to a 39.5% cumulative probability over a 50-year period, and a 63.4% cumulative probability over a 100-year period. Thus, the 1% event flood level is highly relevant to the design and assessment of infrastructure that may have a design life of 50 to 100 years. The 0.1% probability level was selected because it represents a worst-case scenario. The 0.1% probability level corresponds to a 4.9% cumulative probability over a 50-year period, and a 9.5% cumulative probability over a 100-year period. Although an unlikely event over the design life of infrastructure, the 0.1% probability level provides perspective on extreme flood levels that may inform present and future planning.

2) Depth of Flooding Maps: Existing ground elevations derived from the 2016 USGS CoNED Topobathymetric Model are layered against projected flood water elevation, for a given

percent probability of flooding at the storm year of interest. The datum for depth calculations is NAVD88. For this study, two sets of Depth of Flooding Maps were produced:

- Depths at 1% Probability of Exceedance, which has approximately a 100-year recurrence interval; and
- Depths at 0.1% Probability of Exceedance, which has approximately a 1000-year recurrence interval.

The following coastal flood maps are included in Appendix A:

- A-1: Present – Percent Probability of Flooding Map
- A-2: 2030 – Percent Probability of Flooding Map
- A-3: 2070 – Percent Probability of Flooding Map
- A-4: Present - Depth of Flooding at 1% Annual Probability (≈100-year recurrence)
- A-5: 2030 - Depth of Flooding at 1% Annual Probability (≈100-year recurrence)
- A-6: 2070 - Depth of Flooding at 1% Annual Probability (≈100-year recurrence)
- A-7: Present - Depth of Flooding at 0.1% Annual Probability (≈1000-year recurrence)
- A-8: 2030 - Depth of Flooding at 0.1% Annual Probability (≈1000-year recurrence)
- A-9: 2070 - Depth of Flooding at 0.1% Annual Probability (≈1000-year recurrence)

2.1.5 Model Disclaimer

The flood maps and probabilistic data presented in this report are derived from output of MC-FRM for sea level rise and coastal storm simulations. These maps and data are provided without any guarantees or warranty. This information is not intended for use as a flood insurance determination, nor should it be directly related to FEMA FIRM maps or data since these data and FEMA data are for different purposes. This information cannot be used for the purpose of boundary resolution or location.

This public information should be accepted and used by the recipient with the understanding that the maps and data received were developed and collected for future flooding analyses purposes only. No liability is assumed as to the accuracy, sufficiency or suitability of the information contained herein for any other particular use. While every effort has been made to assure the accuracy and correctness of the data presented, it is acknowledged that inherent mapping inaccuracies are present due to interpolation between MC-FRM calculation nodes. Any reliance upon the maps or data presented herein used to make decisions or conclusions is at the sole discretion and risk of the user. This information is provided with the understanding that these data are not guaranteed to be accurate, correct or complete and assumes no responsibility for errors or omissions. Data and documents may not be the most currently available data, and the data is subject to constant change given the changing climate.

Assets located near boundaries of a probability zone may or may not be within the probability zone due to mapping inaccuracies and interpolation between model nodes. MC-FRM nodal spacing varies throughout the Town of Sandwich. The GIS rasters will interpolate the values between model nodes and create probabilities that may be inaccurate between model nodes. Therefore, care should be taken when using the raster data to evaluate site-specific properties or locations.

The probability maps should not be applied at such a granular level as to assess the fate of individual buildings or properties. Rather, they should be used as a tool to identify areas that may be vulnerable to flooding. Once those areas are identified, detailed information for individual buildings or other infrastructure can then be extracted from the closest model nodes. This approach has been used on many previous vulnerability assessments, including for MassDOT, and is the approach being used for this project. Nodal data are more accurate on a property scale than interpolated values shown on the maps.

2.2 COASTAL WETLAND MODELING

The methods utilized to evaluate the impacts on coastal wetlands differ from the coastal inundation model for developed areas. Wetland resources are unlikely to convert/change due to an episodic storm event; rather, increasing water levels caused by sea level rise will be the dominant influence on the future location and condition of wetland resources. The results of this ecological assessment and modeling effort are used to answer a number of important questions specific to coastal marsh systems and sea level rise (independent of storm surge). For example, results are used to assess if specific marsh systems have adequate space to migrate landward in response to the changing climate or if their migration may be hampered by topographic features or infrastructure and developed areas. The results are also used to determine the timeframe that a marsh's accretion rate can no longer be expected to keep up with the rate of sea-level rise, or over what timeframe specific resource areas within a marsh are expected to transition (e.g., high marsh to low marsh, or low marsh to tidal flats, etc.) due to climate change. By identifying a likely timeframe for these changes, coastal managers can plan their monitoring and conservation effects to be most effective.

The assessment of natural resource impacts from sea level rise in Sandwich relies on statewide modeling conducted by Woods Hole Group on behalf of the Massachusetts Office of Coastal Zone Management (Woods Hole Group, 2016), which uses the Sea Level Rise Affecting Marshes Model (SLAMM). In addition to the effects of inundation, second-order effects occurring due to changes in the spatial relationship of various coastal processes are taken into account with this type of modeling. For example, if the fetch for wind-driven waves is greater than 9 km, the model assumes moderate erosion. However, if the area is exposed to the open ocean, severe erosion of wetlands is assumed. Full discussion of marsh migration modeling methodology is provided in the statewide report "Modeling the Effects of Sea-Level Rise on Coastal Wetlands" (Woods Hole Group, 2016).

High resolution elevation data may be the most important SLAMM model data requirement, since the elevation data demarcate not only where saltwater penetration is expected, but also the frequency of flooding for wetlands and marshes when combined with tidal range data. Input elevation data also helps define the lower elevation range for beaches, wetlands and tidal flats, which dictates when they should be converted to a different land-cover type or open water due to an increased frequency of flooding. For the Sandwich area, the 2011 USGS LiDAR flight was used. In order to reduce processing time within the SLAMM model, areas of higher elevation within each regional panel that are unlikely to be affected by coastal processes, such as sea level rise, were excluded prior to processing. All areas above an elevation of 60 ft. (NAVD88) were clipped from the input files.

Accretion, or the deposition and build-up of sediment, is an important process because it may help counter permanent inundation of marshes and beaches from long-term sea level rise, so the model was run in two ways:

1) In areas where there are no observed accretion data, the model is run with an accretion rate equivalent to the historic SLR rate, which is a very reasonable assumption given measured accretion rates in the mid-Atlantic and northeast.
2) In areas where there are observed accretion data, the model is run with the observed data AND with an accretion rate equivalent to the historic SLR rate.

SLAMM was intentionally run first without the limitation that impervious surfaces (roads, parking lots, etc.) would not be subject to change to see how and where the marshes and other natural resources would migrate, if there was no restriction to their migration. As such, the ecological modeling assumes that existing infrastructure may not remain in place. The mapping results therefore do not reflect certain realities. For example, by 2070, the SLAMM model projects that the Boardwalk Parking Lot (Figure 2-8) will begin to shift to a transitional scrub-shrub wetland – an obviously unlikely scenario if the existing surface remains paved. However, an additional post-processing step was applied to overlay the impervious layer to indicate developed areas that are not expected to naturally transition to wetlands.

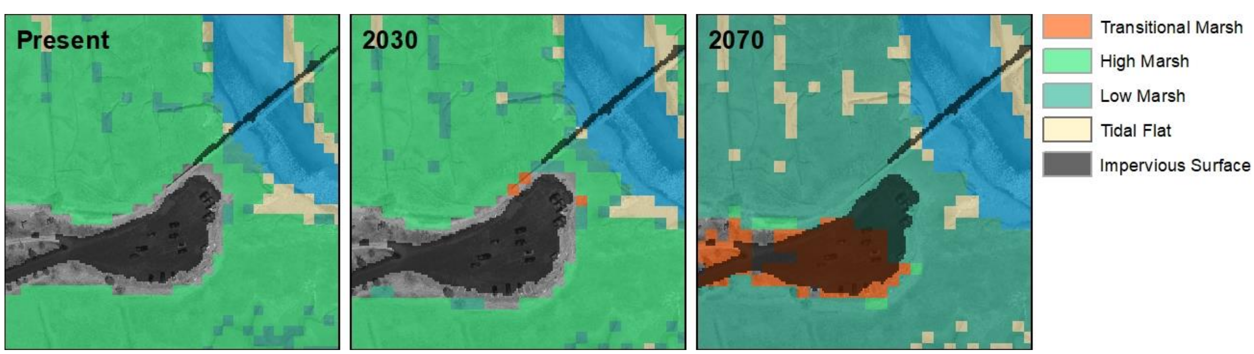


Figure 2-8. Example of Developed (Impervious) Area as a Barrier to Wetland Migration

Figures B1 through B3 in Appendix B show the wetland classification areas for 2011, 2030, and 2070 respectively based on the marsh migration modeling. Figure B1 presents the current conditions, as defined by the National Wetlands Inventory (except for non-tidal upland swamp). Figure B2 shows the change in wetland classification locations projected to 2030, impacted by SLR. Similarly, Figure B3 shows the change in wetland classification locations projected to 2070 impacted by SLR. Both the results shown in Figures B2 and B3 for 2030 and 2070, respectively, are based on the SLAMM modeling using the "High" SLR projection scenario. Existing infrastructure was overlaid on the SLAMM modeling results for further analysis, since the model does not consider limits to migration imposed by existing infrastructure. Patterns of topography and development in Sandwich are such that, aside from some fringe migration along roadway edges, only a few developed (impervious) areas inhibit the migration of salt marsh resource areas. These areas of development limiting marsh migration are highlighted within the management area units described in Section 3.1.

2.3 RISK ASSESSMENT

A risk assessment was completed to determine the specific, site-level vulnerabilities of municipal assets: Town-owned properties, facilities, and infrastructure. Risk is defined as the probability of an asset flooding, multiplied by the consequence of that asset failing. Put into mathematical terms, risk (R) equals:

$$(R) = \textit{Probability of Flooding } (P) \times \textit{Consequence of Failure } (C)$$

or

$$R = P \times C$$

Each node in MC-FRM has unique probability of exceedance data associated with it, which provides the likelihood (0-100% probability) of exceeding water surface elevations at that node. Using risk to assess the vulnerability of infrastructure allows one to take into account both how likely a damaging flood event is, and what the consequence of that damaging flood is to the community. These risk scores can be ranked to assist municipalities with the prioritization of adaptation investments over time.

The risk assessment process, which was applied to the Town of Sandwich assets, is described below.

2.3.1 Determine Critical Assets Subject to Flooding

Municipally owned infrastructure was mapped as an overlay in the GIS project map. The extent of the MC-FRM grid was then used to screen out assets that are not anticipated to experience flood exposure through 2100. The MC-FRM grid has a landward extent to elevation 8 meters (NAVD88); all assets located above that elevation were excluded from further analysis.

The Town owned/controlled asset classes included in the vulnerability assessment were dams, facilities, footbridges and the Boardwalk, hydrants, marina infrastructure, marina docks, open space, parking areas, roadways, and septic systems. (Note that boat ramps and stormwater outfalls were evaluated using different approaches, described after the standard risk assessment approach).

2.3.2 Determine Critical Elevations

Critical elevations are defined as the elevation at which flood water will cause the asset to cease to function as intended or sustain significant damage. The critical elevation for a building may be the first floor, or a basement windowsill elevation (above which water can enter the basement and damage critical mechanical equipment located there). In another case, the critical elevation could be the bottom of a critical electrical transformer or electrical panel, above which flood water would damage the equipment and shut down the facility. For other assets, such as roads, parking lots, open space, etc., the critical elevation is the ground elevation.

The methods for determining the critical elevation for each type of standard asset are described below.

- **Dams**: The critical elevation for Lower Shawme Dam was considered to be the crest of the dam, as derived from the 2016 USGS CoNED Topobathymetric Model (the 2016 Massachusetts Digital Elevation Model or DEM).
- **Facilities**: These assets are generally buildings and small shed-type structures, but also include installed generators and outdoor fuel tanks. For half (12 of 24) of the facilities, the critical elevation was considered to be the lowest ground elevation extracted from the 2016 Massachusetts DEM within the footprint of the structure. Where the critical elevation was clearly above ground level for a particular asset, the critical elevation was determined from (a) the FEMA National Flood Insurance Program Elevation Certificate (either top of bottom floor or elevation of lowest mechanical equipment), (b) measured from ground in the field and added to 2016 Massachusetts DEM elevation information, or (c) surveyed directly in the field.
- **Footbridges and Boardwalk**: The critical elevation for the Town Boardwalk was surveyed in the field as the top of the decking at the lowest point of the structure. The critical elevations for the footbridges, which are at-grade wooden platforms in the vicinity of Town Hall and Dexter Grist Mill, were considered to be the lowest ground elevation extracted from the 2016 Massachusetts DEM within the footprint of each structure, or the elevation of the adjacent sidewalk.
- **Hydrants**: According to the Fire Department, fire hydrants lose functionality when inundated with more than 8 inches of water and require the installation of an adapter to function in these conditions. For the purpose of this screening assessment of 213 hydrants, the critical elevation was conservatively set as the ground elevation extracted from the 2016 Massachusetts DEM at the location of each hydrant.
- **Marina Infrastructure**: This asset group consists of fuel tanks, fuel system infrastructure, pumpout infrastructure, and a compressor unit at the Harbormaster Office. The critical elevation for ground-associated tanks and monitoring wells was considered to be the ground elevation extracted from the 2016 Massachusetts DEM at the location of the

asset. The critical elevations for the elevated compressor unit and the fuel infrastructure on fixed piers were surveyed. The critical elevation for the fuel and pumpout infrastructure on the floating G Dock was the critical elevation for the G Dock (see derivation below).

- **Marina Docks**: The critical elevation for fixed piers at Sandwich Marina was survey as the top of decking for each pier. The critical elevation for floating docks was surveyed as the top of the shortest piling supporting the main dock and fingers.
- **Open Space**: The critical elevation for open space was considered to be the lowest ground elevation extracted from the 2016 Massachusetts DEM within the footprint of the parcel.
- **Parking Areas**: The critical elevation for paved parking lots was considered to be the lowest ground elevation extracted from the 2016 Massachusetts DEM within the footprint of the lot.
- **Roadways**: The critical elevation for roads was considered to be the lowest ground elevation extracted from the 2016 Massachusetts DEM within the footprint of the road segment (assuming a standard 20-foot roadbed width).
- **Septic Systems**: The critical elevation for septic systems and tight tanks was considered to be the lowest ground elevation extracted from the 2016 Massachusetts DEM at the location of the system.

The methods for determining the critical elevation for each type of non-standard asset are described below:

- **Boat Ramps**: Boat ramps are located in intertidal areas, and are therefore inundated daily under present day non-storm conditions. Therefore, the long-term viability of these assets with respect to sea-level rise was considered, rather than implementing the risk-based storm surge approach. The critical elevation for boat ramps was considered to be the elevation at the top of the boat ramp. These assets will be considered "ineffective" when the future MHW elevation is projected to be at or above the critical elevation. At that point the structure would be completely underwater during at least some portion of the day and would no longer be functioning as intended. This also assumes that the ramps will be maintained and resistant to storm damage, such that they are functional until sea level rise makes them ineffective. The critical elevation for the Sandwich Marina Boat Ramp is 13.5 feet (NAVD88).
- **Stormwater Outfalls**: Without a piped infrastructure model, it is impossible to quantity the impact of storm surge on stormwater outfall drainage. The potential for drainage backups can be estimated by comparing storm surge water surface elevations to the elevation of the stormwater collection point for each outfall. Therefore, the critical elevation for stormwater outfalls was the elevation (extracted from the 2016 Massachusetts DEM) of the nearest connected catch basin or inlet structure.

2.3.3 Obtain Probability of Exceedance Data

Probability of exceedance data – the probability that storm surge will exceed the critical elevation of the asset – from the MC-FRM were summarized for each municipal asset for present day, 2030, and 2070 planning horizons.

For assets with critical elevations defined as the ground surface, probabilities were extracted from the model results (using best professional modeling judgment when non-point assets intersected areas of model interpolation). Probability was extracted directly from MC-FRM results at the location of the point assets (hydrants, select marina infrastructure, and septic systems). Probability was extracted as the maximum value from MC-FRM within the footprint of the polygon assets (dams, roadways). Probability was extracted as the spatially weighted average from MC-FRM within the footprint of the large area polygon assets (open space, parking areas).

For assets with documented critical elevations, the critical elevations were compared to water surface elevation (WSE) distribution curves obtained for representative model nodes in the MC-FRM grid. Figure 2-9 provides an example of a WSE distribution curve – in this case from the model node representative of conditions at Fire Station 1. These representative WSE curves were used to assess the probability of exceedance of critical elevations for facilities, footbridges and the Boardwalk, marina docks, and select marina infrastructure.

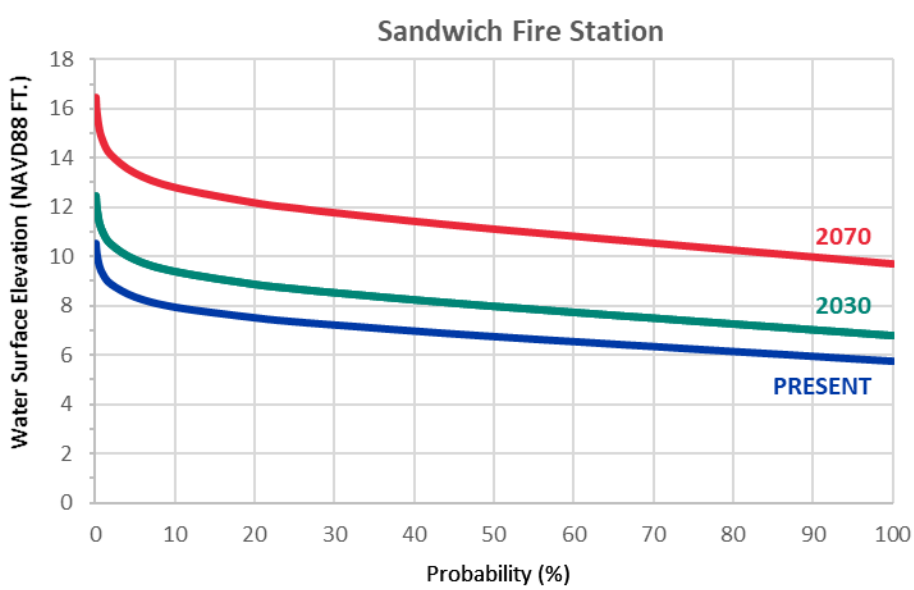


Figure 2-9. Example Water Surface Elevation Distribution Curve

Probabilities of exceeding each asset's critical elevation are documented (present-day, 2030, and 2070) in the asset tables in Appendix C according to the methods described above.

2.3.4 Determine Consequence of Failure Score

The consequence of failure for each asset subject to potential flooding was rated on a scale of 0 through 4 (from low to high consequence) for six different potential impacts in accordance with the guide shown in Table 2-2. It should be noted that that the consequence of failure scores remain constant for an asset over its lifetime, and that only the probabilities of flooding change over time. The only instance where the Consequence of Failure score would change is if some known changes can be anticipated in the future, such as construction of a redundant facility, which would make failure of the asset in question less consequential. For the purposes of this study, we have not anticipated any future changes that would change the Consequence of Failure scores.

Table 2-2. Consequence Scoring Categories and Scales

Rating	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impact on Safety & Emergency. Services	Impact on Economic Activities	Impact on Health & Environment
4	Whole town/city	> 30 days	> $5m	Very high	Very high	Very high
3	Multiple neighborhoods	14 - 30 days	$1m - $5m	High	High	High
2	Neighborhood	7 - 14 days	$100k - $1m	Moderate	Moderate	Moderate
1	Locality	1 - 7 days	$10k - $100k	Low	Low	Low
0	Property	< 1 day	< $10k	None	None	None

Each impact is rated separately, and then, a composite Consequence of Failure score is calculated by summing the individual scores, dividing by 24 (the highest total possible), and normalizing to 100 using the following equation:

$$\text{Composite Consequence of Failure Score } = \frac{\sum \text{all six ratings}}{24} \text{x } 100$$

Consequence scores for each asset were developed in coordination with the project Steering Committee. To ensure a consistent understanding of the different scoring categories within each type of potential impact, the Steering Committee first agreed to a basic set of assumptions for each type of asset, and then reviewed and adjusted draft scores based on local and institutional knowledge.

Composite consequence scores can be as low as 0 and as high as 100. The higher the rating, the more consequential is the failure of the asset. Table 2-3 provides an example of the consequence scoring process for a hypothetical municipal asset – in this case a fire station (note that the scoring in this table is meant to demonstrate the process only and does not reflect the consequence associated with inundation at either of the two Town of Sandwich fire stations evaluated in this vulnerability assessment).

Table 2-3. Consequence of Failure Scoring Example

Scoring Category	Rating	Rationale
Area of Service Loss	4	A Fire Station which serves as the emergency services command center for the Town. The area impacted by service loss due to flooding of the station is therefore the entire Town.
Duration of Service Loss	1	While the Fire Station structure, equipment, and contents could take longer to restore from flood damages, it is assumed that the emergency services provided from the Fire Station would be quickly relocated to and provided from another Town-owned facility and that all movable equipment would be moved to dry ground before a storm.
Cost of Damage	2	It is assumed that the apparatus would be relocated prior to flooding. The costs of damages to the building structure, other equipment, and contents at the Fire Station could be upwards of $100,000, but unlikely to exceed $1,000,000. *Note that these are order-of-magnitude estimates made without a detailed appraisal and shall not be used for insurance purposes.
Impacts to Public Safety Services	4	Flooding of this essential facility would have a very high impact on the Town's capabilities for the duration of service loss, and to a lower extent thereafter, to provide public safety services (e.g., firefighting, emergency medical services, hazardous materials response).
Impacts to Economic Activities	2	The Fire Department plays a role in supporting business preparedness, response, and recovery. Flooding of the Fire Station could have a moderate impact on businesses by reducing the Fire Department's capabilities to respond to incidents, inspect or approve post-flood safety measures, and address public safety concerns that might inhibit economic activity.
Impacts to Public Health & Environment	2	The Fire Department is responsible for providing first-response to hazardous materials incidents. Flooding often results in hazardous material releases to public areas and the environment, and fast response is critical to containing the negative impacts of such incidents. Reduced response capability due to flooding of the Fire Station, in addition to potential releases of hazardous materials stored in the station's garage, would have moderate consequences for public health and the environment.
Consequence Score	15	Fire Station carries high consequences for the example community if it is damaged or loses functionality due to flooding
Composite Consequence Score	63	

The Consequence Scoring methodology and results are important tools for stakeholders to discuss, build consensus on, and ultimately use for decision-making. They help answer the questions of which facilities and services are most important for the Town to maintain in the context of flooding, and why. This process breaks down the higher-level concept of Consequence into more easily defined scoring categories and scales, and in doing so, can lead to some surprising results comparing seemingly disparate systems. An iterative process of adjusting ratings for individual assets relative to others helps calibrate the scores and rankings to better reflect stakeholder values and ultimately provides better inputs to the risk assessment. Stakeholder values influence the priority assigned to public investments of time and money, and the same is true for adaptation investment.

The composite consequence of failure scores for an example subset of Town of Sandwich assets are presented in Table 2-4. For the assets presented, total consequence scores ranged from 16.7 to 100 out of a possible 100. This consequence of failure score will then be combined with the probability of flooding to determine an overall risk score for each asset.

Table 2-4. Consequence of Failure Scoring (Subset of Assets)

Asset Name	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impact on Public Safety & Emergency Services	Impact on Important Economic Activities	Impact on Public Health & Environment	Consequence Score	Composite Consequence Score
Fire Station	4	4	4	4	4	4	24	100.0
Marina Fuel Tank	4	4	2	4	4	4	22	91.7
Sandwich Water District Building	4	4	4	0	1	1	14	58.3
Sandwich Public Library	4	4	4	0	2	0	14	58.3
Town Hall Annex	4	4	4	0	2	0	14	58.3
Town Hall	4	4	4	0	2	0	14	58.3
Dexter Grist Mill	1	4	4	0	3	0	12	50.0
Seasonal Bathrooms	2	3	1	0	3	1	10	41.7
Harbormaster Office	1	4	2	1	0	0	8	33.3
Marina Landscapers Shed	1	3	0	0	0	0	4	16.7

2.3.5 Calculate Risk Scores and Rankings

A risk score was then calculated for each infrastructure asset subject to flooding in a given time horizon using the following equation:

$$\mathbf{R_{tn} = P_{tn} \times C_{tn}}$$

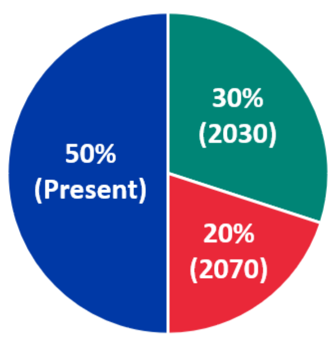
Where:
R_{tn} = Risk Score at a given time horizon
P_{tn} = Probability of Exceedance at a given time horizon
C_{tn} = Consequence of Failure rating at a given time horizon
tn = Time horizon n (present, 2030, or 2070)

Assets were then ranked according to their risk scores for each time horizon. Finally, composite risk scores and rankings were developed taking into account the risk scores from all time horizons using the following equation:

$$\mathbf{R_{Comp} = (R_{Present} \times W_{Present}) + (R_{2030} \times W_{2030}) + (R_{2070} \times W_{2070})}$$

Where:
R_{Comp} = Composite risk score for all time horizons
$R_{Present}$ = Risk score for present day time horizon
R_{2030} = Risk score for 2030 time horizon
R_{2070} = Risk score for 2070 time horizon
$W_{Present}$, W_{2030} W_{2070} = Weighting factors for each respective time horizon

A weighting factor is used to give more emphasis to assets vulnerable to flooding in the nearer time horizons. For example, a facility which is susceptible to flooding today and more flooding in the future should probably get more priority than a facility that is only vulnerable to flooding starting in 2070. The weighting factors can be adjusted, but for the purposes of this study, the following weighting was utilized:



2.4. STORMWATER SYSTEM

Stormwater system vulnerability to coastal inundation and drainage backup was evaluated by comparing drainage inlet (catch basin) elevations to storm surge WSE distribution curves. Without a piped infrastructure model, it is difficult to determine the WSE at which stormwater begins to back up in upgradient drainage areas due to increased hydraulic pressure on the drainage outfall exerted by coastal storm surge. This stormwater system vulnerability assessment approximates potential impact with a simple comparison of hydraulic heads. If the WSE from a MC-FRM storm surge distribution curve was above the elevation of the nearest connected stormwater inlet, the stormwater outlet was judged to have “certain” vulnerability to backup at the associated probability level, because coastal storm surge would be preventing upland stormwater from entering the catch basin. If the WSE from a MC-FRM storm surge distribution curve was below (within 5 feet) the elevation of the nearest connected stormwater inlet, the stormwater outlet was judged to have “potential” vulnerability to backup at the associated probability level, because coastal storm surge would be exerting some unknown pressure from the outfall up the drainage pipe and possibly inhibiting some degree of drainage from the catch basin. If the WSE from a MC-FRM storm surge distribution curve was more than 5 feet below the elevation of the nearest connected stormwater inlet, the stormwater outlet was assumed not vulnerable to backup at the associated probability level, because coastal storm surge would be exerting little (if any) pressure from the outfall up the drainage pipe and drainage from the catch basin would not likely be inhibited. Representative WSE distribution curves were extracted from MC-FRM model nodes for outfall in (1) the Mill Creek and Old Harbor vicinity and (2) the Scorton Creek vicinity for use in the stormwater outfall vulnerability assessment.

3.0 VULNERABILITY ASSESSMENT

The vulnerability assessment was prepared using the methodologies previously described and was guided by discussions with the Steering Committee. It should be noted that in assessing future coastal conditions, the planning team noted that several areas of Town have already been impacted by climate changes in the form of erratic and extreme weather events, as well as the increase in sea level rise and more intense coastal storms along its shoreline. One climate impact was noted by the planning team in various conversations with the Steering Committee – precipitation-based flooding – because it often is compounded by coastal flooding and the combined effects can overwhelm aging infrastructure. The Town may want to consider assessing vulnerabilities to stormwater inundation in a future assessment, especially as it may co-occur with coastal storm surge flooding; however coastal inundation from sea level rise and storm surge was the focus of this vulnerability assessment.

Three primary classifications of land uses were assessed for their vulnerabilities to climate changes, as listed below.

1) Natural Resources (via SLAMM Model),
2) High-Risk Development (qualitatively), and
3) Municipal Assets (via MC-FRM).

3.1. NATURAL RESOURCES

Natural Resources provide numerous valuable ecosystem services, from fisheries habitat, to carbon sequestration and storm damage protection. They are also an important component of the identity of the Town of Sandwich and a significant driver for the local tourism industry. However, they are also vulnerable to climate change impacts like sea level rise. Impacts to natural resources including beaches and salt marsh, were assessed on a semi-quantitative basis.

Town-wide areas of each type of wetland classification are summarized in Table 3-1.

Table 3-1. Summary of SLAMM results for wetland areas town-wide

Wetland Category	Area (acres)		
	Present	2030	2070
Upland	3891.7	3871.9	3662.1
Irregularly Flooded Marsh	1054.0	1024.9	136.3
Open Ocean	685.3	690.3	750.0
Nontidal Swamp	310.5	291.2	224.3
Ocean Beach	243.0	248.5	276.1
Estuarine Open Water	235.5	237.8	272.4
Regularly Flooded Marsh	137.9	193.4	1151.4
Tidal Swamp	129.6	109.6	54.0
Inland Fresh Marsh	111.3	106.7	60.3
Inland Open Water	98.6	98.6	94.1
Estuarine Beach/Tidal Flat	78.5	92.3	214.9
Tidal Fresh Marsh	12.3	5.9	2.5
Transitional Marsh/Scrub-Shrub	0.0	17.2	89.7

One of the major habitat changes that is projected to occur between present and 2070 is a nearly complete conversion of Sandwich's salt marsh ecosystems from a dominant irregularly flooded marsh (high marsh) to a dominant regularly flooded marsh (low marsh). Figure 3-1 shows the combined areas of both irregularly flooded salt marsh and regularly flooded salt marsh in Present, 2030 and 2070. At Present day, the combined total area for high and low salt marsh areas is 1,192 acres. By 2030, the overall salt marsh are has increased by 26 acres, maintaining a similar high marsh to low marsh ratio. By 2070, the overall marsh area increases by another 70 acres, however over this time period the habitat experiences a significant shift in the percentage of high and low marsh; this is due to high marsh converting to low marsh as sea-level rises.

Another major trend to note is the change in total area of combined open water habitats and combined wetland habitats (Figure 3-2), as well as the associated change that infers on the total upland area. Between Present and 2070 the combined open water areas in the Town of Sandwich are expected to increase by 98 acres (from 1,019 to 1,117 acres). This increase in open water is supplemented by an increase in 132 acres of wetland (from 2,077 to 2,210 acres). The increases in open water and wetland area is balanced by a loss of 230 acres of upland by 2070 (3,892 to 3,662 acres).

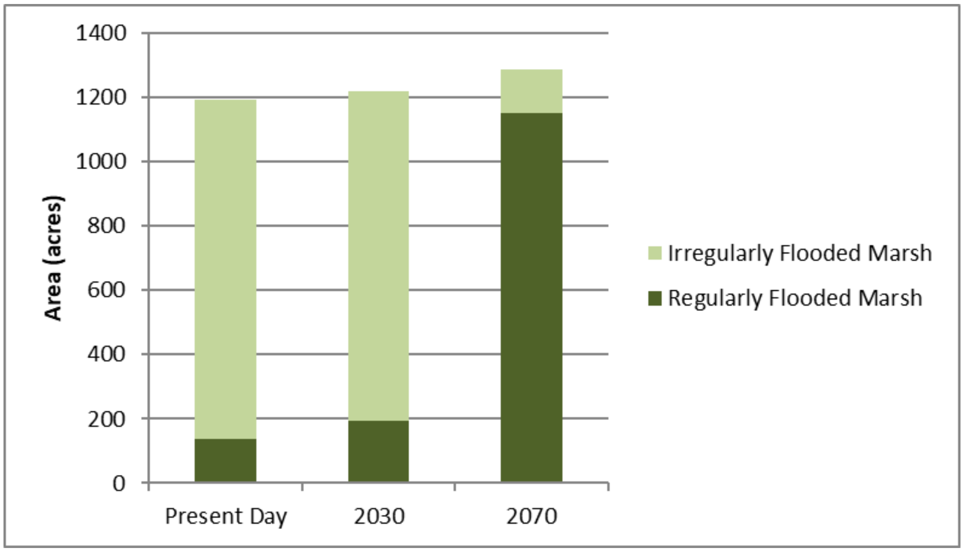


Figure 3-1. Summary of Town-wide salt marsh area change over time

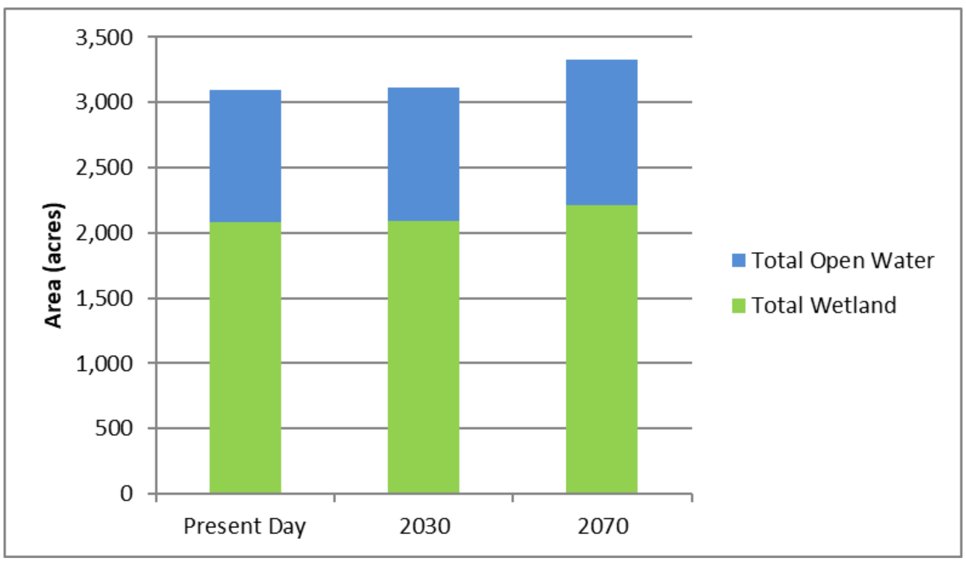


Figure 3-2. Summary of Town-wide open water and wetland area change over time

These trends indicate an overall resilience in Sandwich's salt marsh systems and potential to keep pace with sea level rise longer than other marshes in Massachusetts (where trends are generally conversion to low marsh by 2030 and tidal flat or open water by 2070), as well as an ability to migrate inland with the rising tide. Still, it will be important for the Town to support salt marsh migration by removing barriers and limiting development in potential sending areas. Additionally, any actions to further increase salt marsh resilience and stem the conversion from high marsh to low marsh (and, eventually, to tidal flat or open water) will preserve important marsh ecosystem services, such as coastal flood protection, into the future. On the other hand, it is notable that a Town-wide loss of 230 acres of upland may have environmental, social, and/or economic impacts depending on the nature and disposition of the upland converted to wetland area.

The barrier beach and dune system fronting much of the Sandwich coast (Town Neck Beach, Springhill Beach, East Sandwich Beach) plays an important role in the protection of inland development and infrastructure from coastal storm surge, but also is vital to the preservation of the large salt marsh systems behind them. The wave dissipation and tidal attenuation created by these large beach and dune barriers provide enabling conditions (low energy area with sufficient tidal range) for salt marsh vegetation (both low marsh and high marsh) to grow. By 2070, SLAMM projects a significant narrowing of the barrier beaches throughout Sandwich due to sea level rise and assumed erosion. Compounded by potentially stronger and more erosive future storms and wave action, as well as the lack of a sediment supply, the sustainability of these important protective features will likely be in greater jeopardy. In the absence of these protective features, the low-lying areas (currently salt marsh) would transition to open water over time. Not only would this transition subject inland developed areas to greater wave action and storm surge, but it would also represent a significant loss of resource area for the Town.

A related Town-wide vulnerability is the projection for increasing expansion of tidal flats within the marsh systems of Sandwich. Salt marshes provide a natural sponge to buffer inland areas from storm surge, and act as a natural break, absorbing wave energy. Conversion of low marsh areas to tidal flats and open water would result not only in a reduced capacity for Sandwich's salt marsh systems to protect inland areas, but also in a loss of salt marsh habitat for the Town.

Although it is useful to look at Town-wide projected changes, in order to more effectively quantify and plan for future wetland area changes, three (3) natural resource management units – corresponding to the three major salt marsh systems in Sandwich and their fronting beaches – were examined in more detail. The three (3) natural resource management units included:

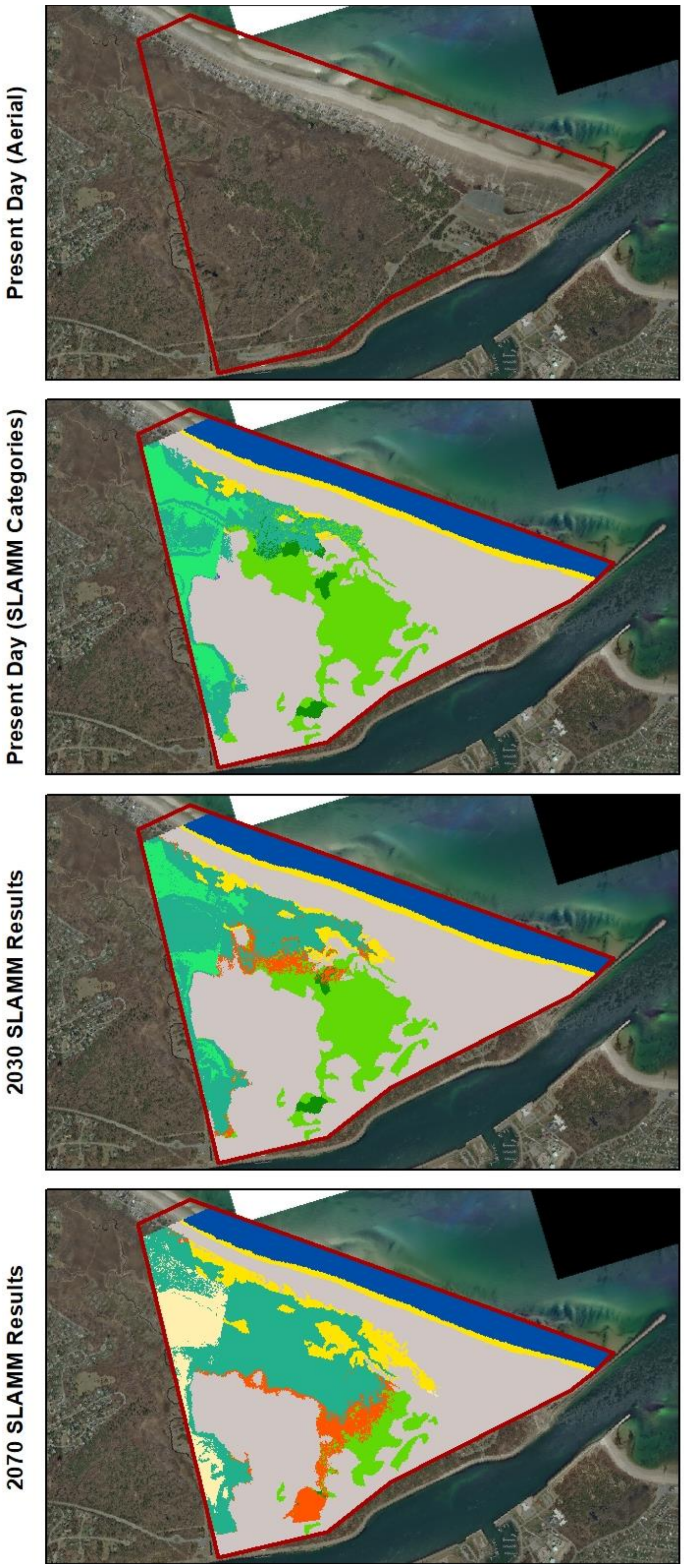
1) Scusset Beach and Marsh,
2) Old Harbor and Mill Creek, Town Neck and Spring Hill Beaches; and
3) Scorton Creek and East Sandwich Beach.

3.1.1 Management Area 1: Scusset Beach and Marsh

Patterns of wetland change projected for the Scusset Marsh system (Figure 3-3) are similar to projections for many coastal areas of the Commonwealth. In the near-term (2030), there is a projected expansion of salt marsh, particularly low marsh, into the high marsh and freshwater wetland (nontidal swamp) resources areas. This expansion of the tidal wetland resource area also results in some losses of upland due to conversion to back-dune environments (sandy areas that are intermittently flooded by extreme high tides and storms, categorized as ocean beach in SLAMM) and transitional marsh/scrub-shrub habitat. By 2070, there is a projected total loss of high marsh due to further expansion of the low marsh and conversion of lower elevations to tidal flats. Wetland projections for 2070 also exhibit additional loss of upland area and freshwater marsh to back-dune conditions and transitional marsh habitat.

Existing patterns of sediment transport and shoreline change are expected to continue at Scusset Beach, where eroding bluffs in the Sagamore area contribute sand which is transported southeast and accumulates at the northern jetty for the Cape Cod Canal. These conditions will continue to contribute to the accretion of Scusset Beach for the foreseeable future. It appears that sea level rise may outpace the level of beach accretion assumed by SLAMM by 2070, but more a more detailed coastal processes analysis could better refine projections for the beach and dune, which are subject to wind and wave action in addition to tidal regime.

There is ample room for salt marsh expansion in this low-lying open area, which is part of a USACE restoration project with tidal connection to the Cape Cod Canal, with very few barriers to migration. By 2070, movement of the tidal range pushes a back dune (occasionally flooded on very high tides) condition into the back side of Phillips Road and the houses on the south side of the road. Of greater concern to natural resources, however, is the large-scale (39 acre) loss of low marsh to tidal flat between 2030 and 2070. Though the Scusset system is able to migrate laterally, it is generally low (possibly due to pre-restoration subsidence and lack of sediment supply) and therefore susceptible to marsh loss when the tidal range shifts too high to accommodate even the low marsh community.



	Area (acres)		
	2011	2030	2070
Upland	300.0	289.0	251.1
Nontidal Swamp	83.4	66.1	23.8
Inland Fresh Marsh	8.2	3.6	0.2
Transitional Marsh/Scrub-Shrub	0.0	13.4	26.2
Regularly Flooded Marsh	58.0	87.3	123.6
Estuarine Beach/Tidal Flat	0.1	0.2	39.3
Ocean Beach	22.9	29.2	45.5
Open Ocean	70.9	70.9	73.2
Irregularly Flooded Marsh	39.3	23.3	0.0
Tidal Swamp	0.1	0.0	0.0

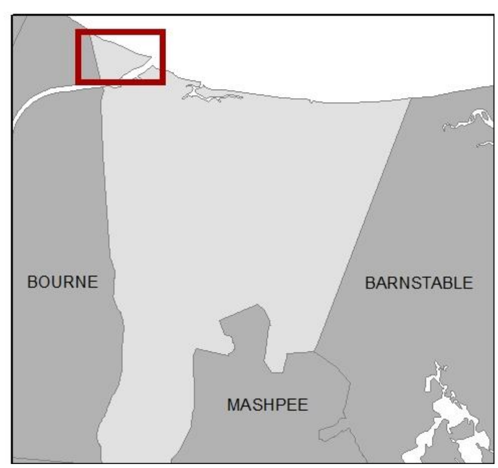


Figure 3-3. SLAMM Profile for Scusset Beach and Marsh

3.1.2 Management Area 2: Old Harbor and Mill Creek, and Town Neck and Spring Hill Beaches

Patterns of wetland change projected for the Old Harbor and Mill Creek system suggest a moderate level of resilience in the salt marsh system. In the near-term (2030), there is very little change within the system as most vegetation types are able to shift with the tidal range. By 2030, the Old Harbor and Mill Creek system loses approximately 20 acres of high marsh, with most of that area being converted to low marsh. By 2070, almost all of the high marsh in the system converts to low marsh, transitional marsh expands into formerly upland areas, and areas of open water and tidal flat increase coverage within the marsh. In response to these patterns, upland area decreases.

A greater concern is the ongoing erosion along Town Neck and Spring Hill Beach. The beaches at Town Neck and Spring Hill experience narrowing and erosion over time due to sea level rise and increasing storm events. Existing patterns of sediment transport and shoreline change are expected to continue at Town Neck Beach, where natural longshore transport and storm-induced erosive events carry sediment east toward the inlet at the expense of the beach, which is cut off from its natural sediment supply by the Cape Cod Canal. Without the ongoing efforts to nourish Town Neck Beach and fortify the dune, sea level rise will compound the future losses in this resource area. Erosion and loss of beach to sea level rise are expected to continue at Spring Hill Beach as well, but more a more detailed coastal processes analysis could better refine projections for these beaches and dunes, which are subject to wind and wave action in addition to tidal regime. A detailed coastal processes study and sediment budget for this area is being prepared as part of the USACE Section 111 Study. It is likely that the barrier beach, specifically Town Neck Beach, may eventually be lost over the next 50-100 years without any mitigative measures. This would create a different system (loss of marsh) than projected by the SLAMM results, which don't include the direct impacts of episodic events (storms).

Within the 2070 timeframe, there appears to be enough room for salt marsh expansion without many significant barriers to migration. Aside from some minor fringe impingements, there are only a few areas within the Old Harbor and Mill Creek system where impervious surfaces act as a barrier to marsh migration – the Boardwalk parking lot (Figure 3-4), Willow Street and adjacent development (Figure 3-5), and portions of Route 6A between Liberty Street and Main Street (Figure 3-6).

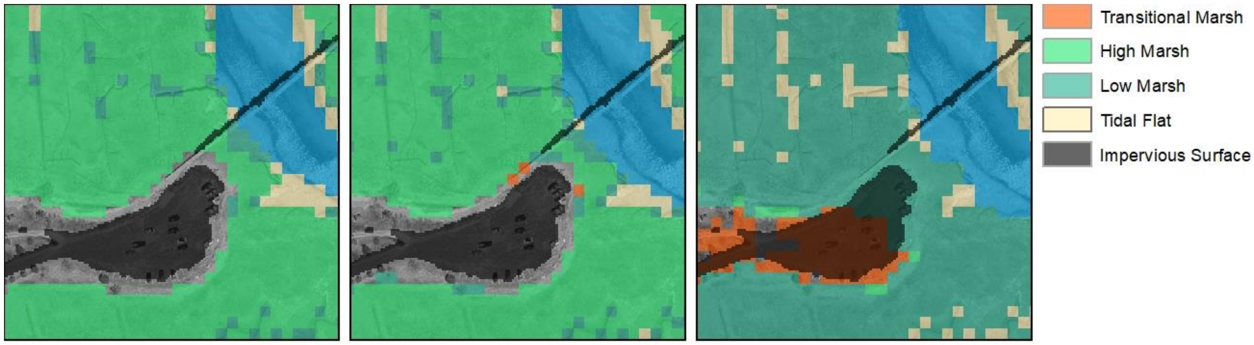


Figure 3-4. Boardwalk Parking Lot Barrier to Marsh Migration

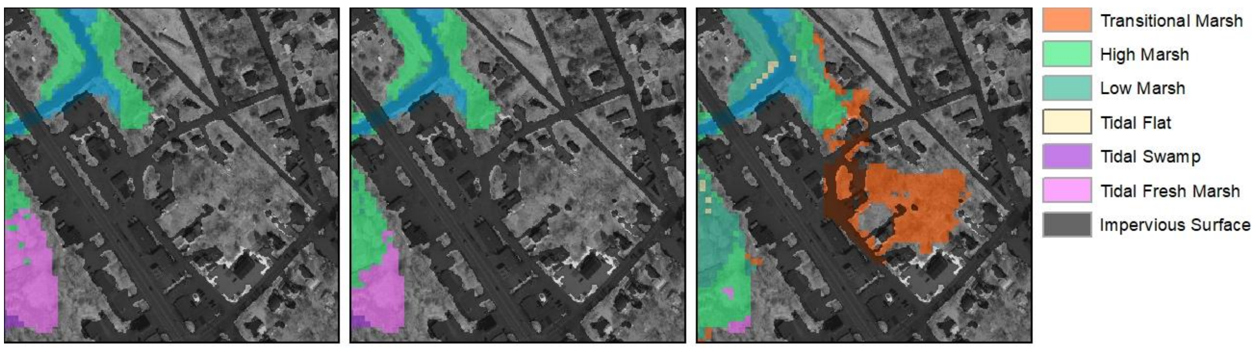


Figure 3-5. Willow Street Barrier to Marsh Migration

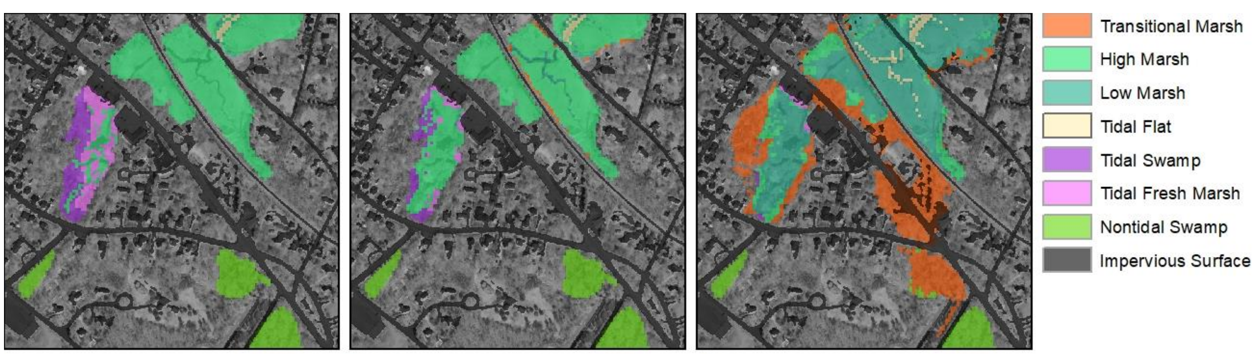
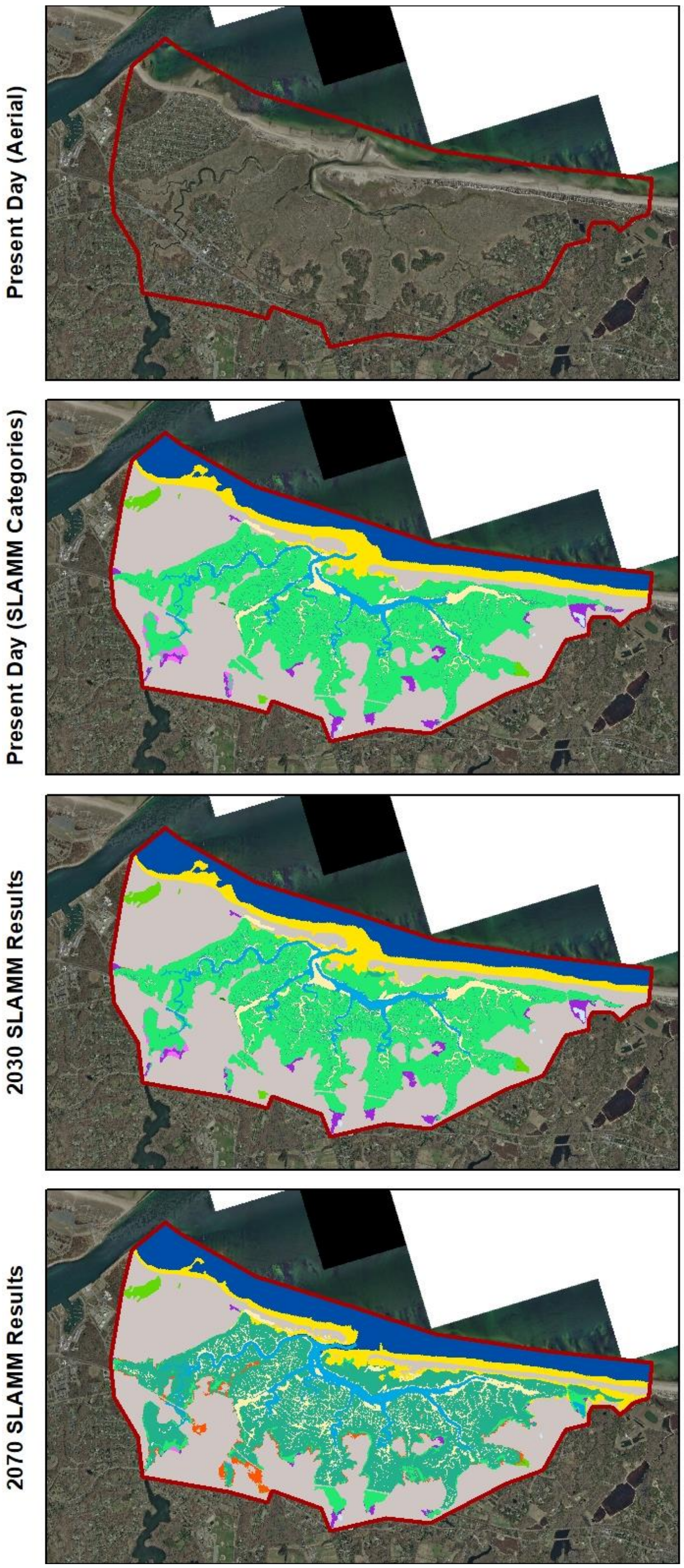


Figure 3-6. Route 6A (between Liberty and Main) Barrier to Marsh Migration



	Area (acres)		
	2011	2030	2070
Upland	675.9	670.7	598.8
Nontidal Swamp	11.7	11.7	9.3
Inland Fresh Marsh	0.2	0.2	0.0
Tidal Fresh Marsh	7.4	3.6	0.9
Transitional Marsh/Scrub-Shrub	0.0	1.1	22.8
Regularly Flooded Marsh	42.6	58.4	483.7
Estuarine Beach/Tidal Flat	53.0	62.6	107.0
Ocean Beach	110.4	107.8	102.8
Inland Open Water	2.2	2.2	0.5
Estuarine Open Water	52.3	54.3	73.8
Open Ocean	198.6	203.9	236.9
Irregularly Flooded Marsh	515.0	495.9	50.3
Tidal Swamp	23.1	20.3	6.1

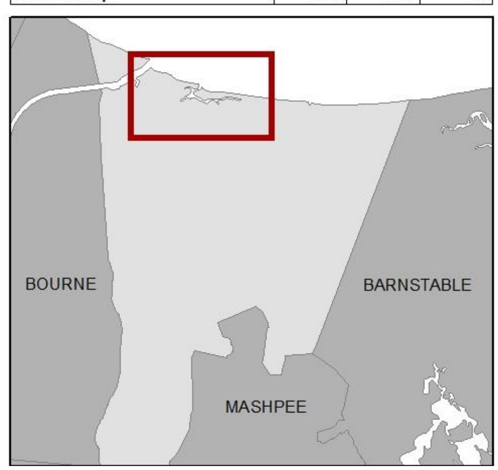


Figure 3-7. SLAMM Profile for Old Harbor and Mill Creek, and Town Neck and Spring Hill Beaches

3.1.3 Management Area 3: Scorton Creek and East Sandwich Beach

Patterns of wetland change projected for the Scorton Creek system suggest a moderate level of resilience in the salt marsh system. In the near-term (2030), there is very little change within the system as most vegetation types are able to shift with the tidal range. By 2030, the Scorton Creek system is projected to gain approximately almost 10 acres of low marsh and 5 acres of high marsh. By 2070, almost all of the high marsh in the system converts to low marsh, transitional marsh expands into formerly upland areas, and areas of open water and tidal flat increase coverage within the marsh. In response to these patterns, upland area decreases.

East Sandwich Beach, however, appears to experience narrowing and erosion over time due to sea level rise. Existing patterns of sediment transport and shoreline change are expected to continue at East Sandwich Beach, where natural longshore transport and storm-induced erosive events carry sediment east at the expense of the beach, which is also affected by the reduced sediment supply due to the Cape Cod Canal jetties. A more detailed coastal processes analysis could better refine projections for this beach and dune system, which is subject to wind and wave action in addition to tidal regime.

Within the 2070 timeframe, there appears to be enough room for salt marsh expansion with a few minor fringe impingements, however there is one significant barrier to migration in the Scorton Creek system. Currently, there is a tide gate on the culvert under Ploughed Neck Road. This tide gate restricts tidal flow into the western upper reaches of Long Creek, and has created an impounded freshwater wetland system where a significant cranberry operation exists. The tidal restriction also likely protects upstream development from moderate storm surge that does not overtop Ploughed Neck Road. Elevation and hydrology in the area west of Ploughed Neck Road suggest that the resource area may have been a salt marsh at one time, and would likely transition to salt marsh again if the tidal restriction were removed (Figure 3-8). This may present an opportunity for restoration of the resource area, but any decision to move forward on removing such a barrier to salt marsh migration must be balanced against agricultural and flood protection interests.

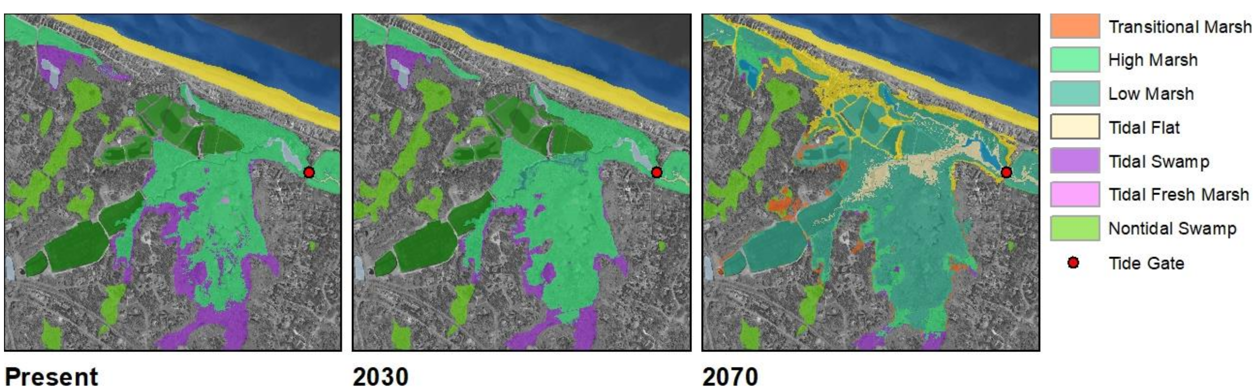
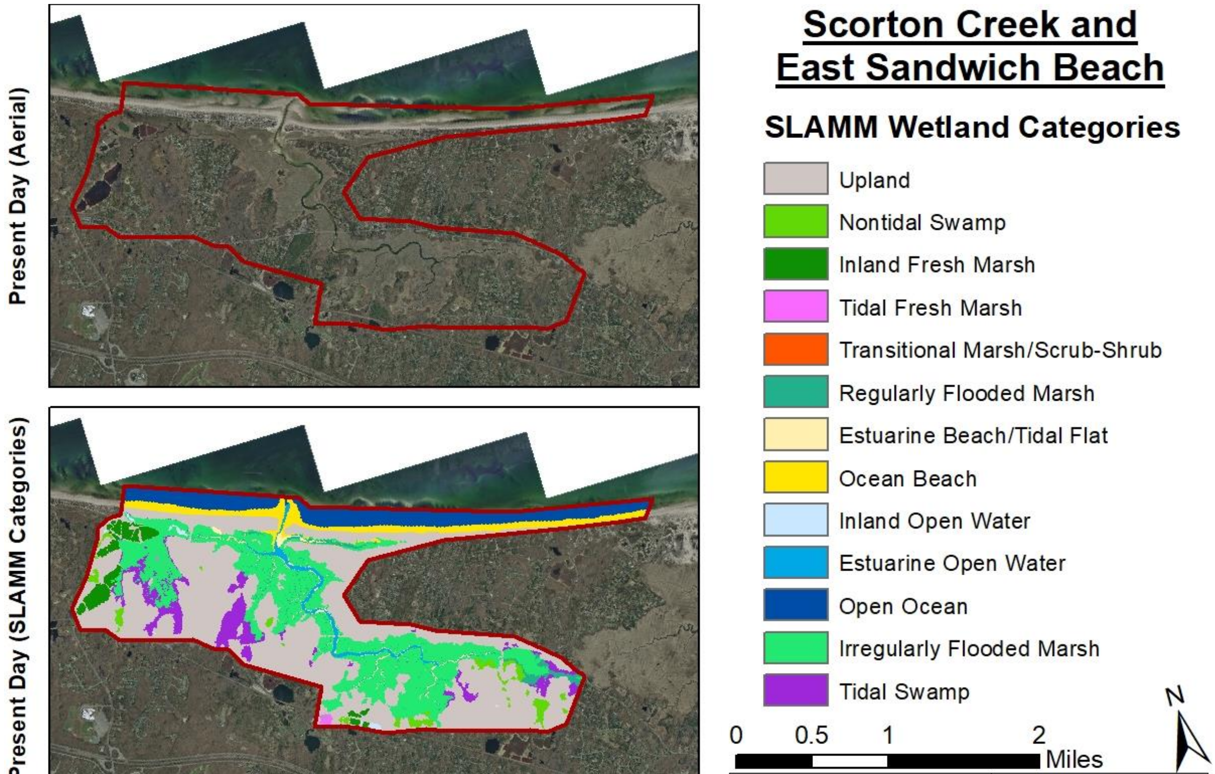


Figure 3-8. Ploughed Neck Road Barrier to Marsh Migration



	Area (acres)		
	2011	2030	2070
Upland	959.0	955.7	870.9
Nontidal Swamp	38.8	38.6	21.1
Inland Fresh Marsh	47.1	47.1	4.3
Tidal Fresh Marsh	3.6	0.9	0.2
Transitional Marsh/Scrub-Shrub	0.0	1.2	34.2
Regularly Flooded Marsh	36.3	44.9	517.0
Estuarine Beach/Tidal Flat	19.6	24.7	62.2
Ocean Beach	109.0	110.9	122.8
Inland Open Water	5.1	5.1	2.4
Estuarine Open Water	26.9	26.9	40.8
Open Ocean	213.6	213.6	237.9
Irregularly Flooded Marsh	483.9	488.8	85.4
Tidal Swamp	101.9	86.6	45.7

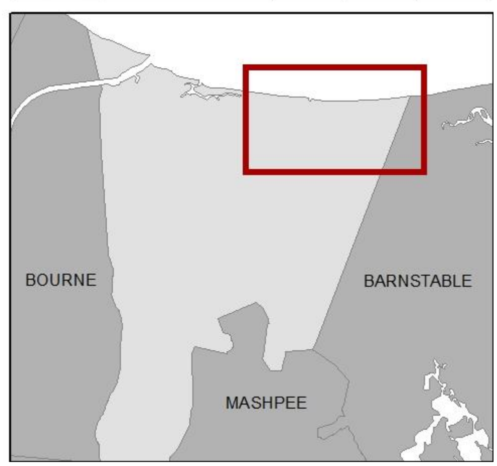


Figure 3-9. SLAMM Profile for Scorton Marsh and Scorton Creek / East Sandwich Beach

3.2. HIGH-RISK DEVELOPMENT

This section of the report describes the most vulnerable neighborhood areas of coastal Sandwich at a high risk of coastal flooding. For each high-risk area the potential pathways, sources, and depths of coastal flooding are described with a focus on the longer term (2070). With this information, the Town can begin the process of considering adaptation measures that would be best employed within these neighborhoods.

The following three (3) high risk areas of Sandwich are marked in Figure 3-10:

1) Sagamore / Scusset Beach,
2) Town Neck/Downtown (Town Neck Beach), and
3) East Sandwich (Springhill Conservation Lands, East Sandwich Beach, and Scorton Neck).

Figure 3-10. High Risk Areas of Sandwich

3.2.1. Sagamore / Scusset Beach Area

The neighborhood of Sagamore Beach is a residential area in the Town of Sandwich. Scusset Beach, located closest to the Cape Cod Canal, is a public beach and campsite owned and operated by the Massachusetts Department of Conservation and Recreation (Figure 3-11). The access roadway to Sagamore Beach is Phillips Road, running in a northwest-southeast fashion, coming to a dead end at the edge of the Scusset Reservation.

There are approximately 145 homes that line both the beach and marsh side of the barrier beach. The results of the SLAMM model indicate the transition of the marsh system and the migration of the marsh in the northeast segment, as shown on the map. The combination of the marsh transition, and sea level rise and storm surge on the beach side, results in coastal flooding to development on both sides of Phillips Road. Additionally, the one way in and out of the roadway does not allow for efficient evacuation in emergency situations.

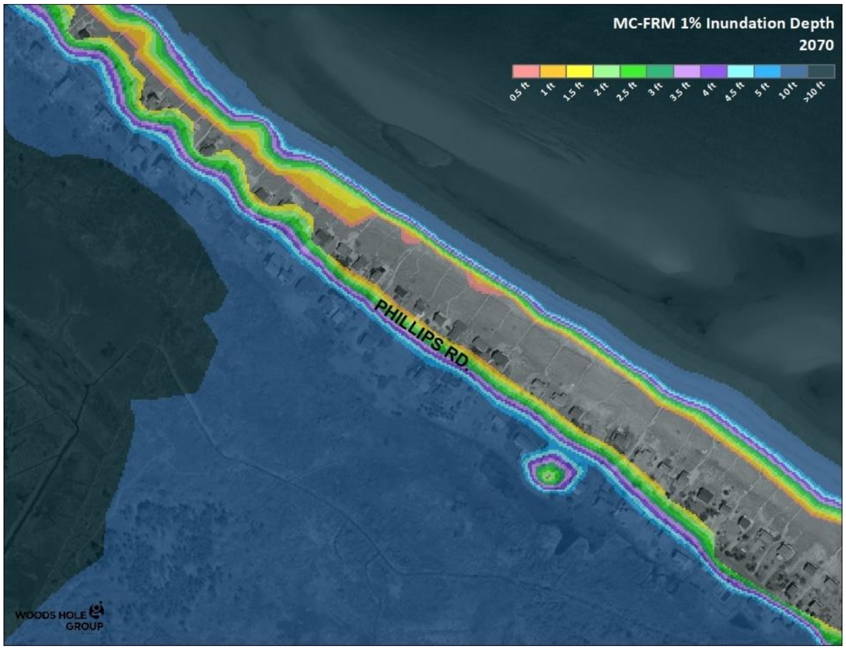


Figure 3-11. Sagamore / Scusset Beach 2070 1% Flood Inundation Depth

3.2.2. Town Neck / Downtown Sandwich

Town Neck beach has been severely eroding over time, primarily due to the changes in coastal processes due to the Cape Cod Canal jetty. This issue has been studied over the past decade by the Woods Hole Group, as documented in the Beach Management Plan for the Town of Sandwich Beaches and the USACE Section 111 Study (in progress). This starvation of sand at Town Neck Beach has left beach development extremely vulnerable. Figure 3-12 shows the change in the shoreline from 1860 to 2009 and the dramatic decrease in beach area. Figure 3-13 illustrates the severe erosion at the beach and adjacent high-risk development.

Adjacent to Town Neck and the Marina is the historic downtown of Sandwich. Although this area is not located along the immediate coastline, it abuts the Old Harbor marsh system, which extends inland to River Road and properties along Main and Jarves streets. In present day conditions this area is frequently flooded due to extreme precipitation and coastal flooding via the Old Harbor marsh on the southern side of Route 6A through Mill Creek at River Street (Figure 3-14).

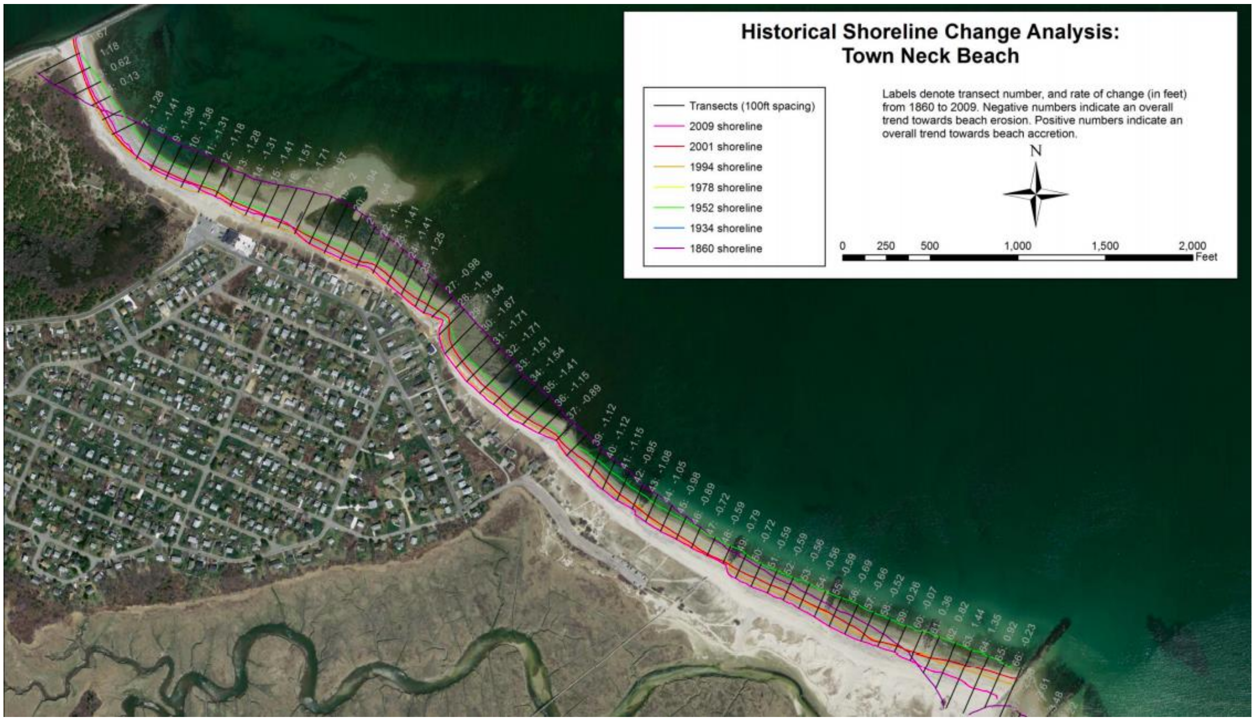


Figure 3-12. High Risk Development Area: Town Neck

Figure 3-13. Town Neck Beach Erosion

Figure 3-14. River Street, Downtown during March 2018 Coastal Storm

This downtown area is essential to the Town's economic vitality as it is home-base for tourism and numerous commercial businesses along Route 6A and Jarves Street. Figure 3-15 shows the potential depth of flooding at the 1% probability level in historic downtown from Tupper Road to Jarves Street. Notably, the Glass Museum, Town Hall, and Town Hall Annex are all located within this area. Greater depths of flooding are generally associated with the wetland area, but do intersect some developed areas of River Street, Route 6A, and Willow Street. Additional, but less intense, flooding is possible along Jarves Street and Tupper Road. A more site-specific investigation of critical elevations in the business district would better inform adaptation planning for this business district.

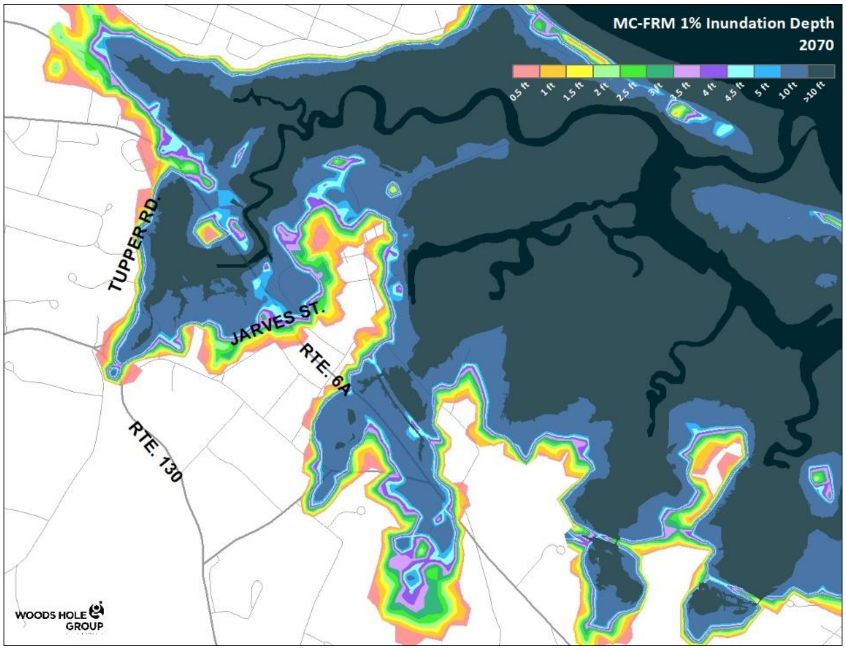


Figure 3-15. Downtown Sandwich 2070 1% Flood Inundation Depth

The Spring Hill area of Sandwich is located on the eastern side of the Old Harbor outlet to Cape Cod Bay. The western portion of the beach is Town-owned; known as the Spring Hill Conservation Lands. The eastern portion of the beach is generally private with numerous homes located in the coastal dune along Salt Marsh Road. The only access to this development is via Foster Road. Roos Road is located at the end of Salt Marsh Road but is unmarked and unpaved providing very limited vehicle access. Additionally, only off-road capable vehicles can pass from Roos Road to North Shore Boulevard Extension to connect to East Sandwich Beach. This barrier beach area, and associated access roads, are highly vulnerable to coastal flooding.

3.2.3. East Sandwich

East Sandwich is a vast area of the Town's coastline comprised of the barrier beach areas of East Sandwich Beaches and the Scorton Creek marsh system. Development within these areas are located on the barrier beaches, which are accessible by one-in one-out roadways that cross the salt marshes, thereby making these areas isolated in during projected flood conditions.

East Sandwich Beach is located near the center of Sandwich's northern coast, and consists of two discrete beach segments which can both be accessed from North Shore Boulevard. The first segment is located at the western end of North Shore Boulevard; with the vast majority of residential properties located within the coastal dune (only five properties are on the salt marsh side of the road). The eastern segment of the beach is densely developed with residential properties on both the coastal and salt marsh side of the road. The only access to the Beach is via Ploughed Neck Road.

The eastern side of Scorton Harbor, at the outlet to Cape Cod Bay, is a continuation of East Sandwich Beach that is primarily private. There are few public access points and none include

Town-sponsored parking. There is limited access at the end of Torey Road where there is a small parking area. Another access point, largely unknown, is at the corner of Carlton Drive East and West where a small parking area is located and a pathway to the beach thorough the coastal bluff vegetation. The developed areas surrounding the beach are generally comprised of larger homes set-back from the beach. There are only ten homes located at the edge of the beach off of Hammond Road, which are within the 2030 and 2070 projected coastal inundation area, as shown in Figure 3-16.

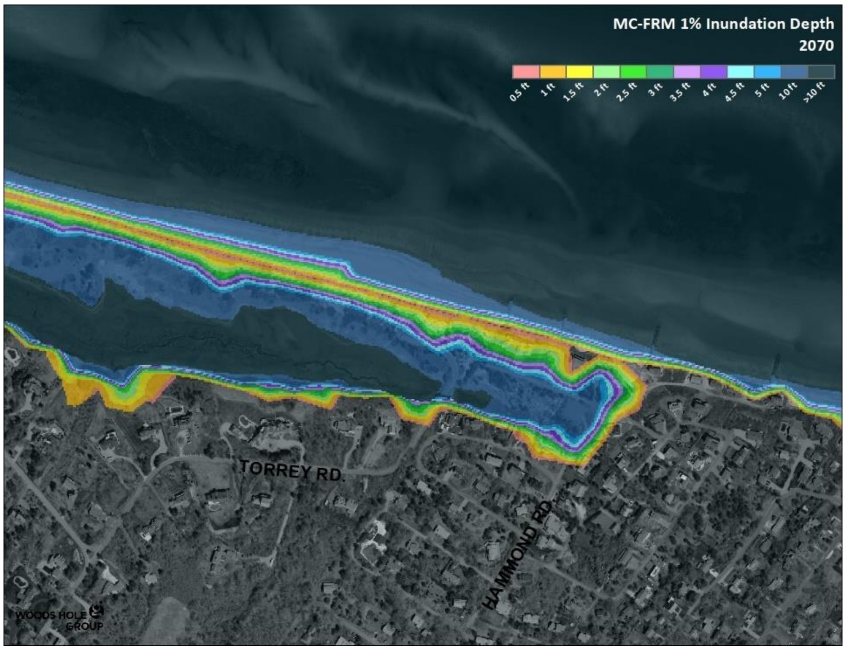


Figure 3-16. East Sandwich Beach 2070 1% Flood Inundation Depth

3.3. MUNICIPAL ASSETS

A risk-based vulnerability assessment was performed for each municipally owned asset (facilities, infrastructure, and historic assets) that were shown to be impacted by coastal flooding according to the MC-FRM. Vulnerabilities for each type of highly vulnerable asset are explained in the following sub-sections.

3.3.1. Facilities

There are several Town-owned facilities that have been identified as critically important for their functionality, as well as their historic and/or cultural value, and are at high-risk of flooding:

1) Downtown Fire Station
2) Sandwich Boardwalk
3) Old Town Hall (and Public Water Well & Pump)

The Downtown Sandwich Fire Station has experienced flooding in the past, notably in March of 2018 when two back-to-back winter storms hit the northeast, as shown in Figure 3-17.

Figure 3-17. Past Flooding Event - Fire Station

The roadway grade adjacent to the property (Route 6A) is lower than the building and back edge of the property near Mill Creek and the railway bridge. Therefore, floodwaters migrate from the Creek and pond in the parking lot before reaching the Fire Station garage doors. In at least one instance, floodwaters have been allowed to drain through these garage doors, past the fire engines, and out through the front of the building.

Planning towards 2030, MC-FRM model results indicate that the building is susceptible to coastal flooding during a 5% recurrence event (i.e., 20-year return period event), and that the flood depth at the building's edge during a 1% recurrence storm event (i.e., 100-year return period event) would be 1.5 feet or greater. By 2070, the entire neighborhood is inundated more-or-less annually (100% recurrence event), with large stretches of State Route 6A underwater. The Downtown Sandwich Fire Station is subject to upwards of 5 feet of flooding in a 2070 1% chance event, as shown in Figures 3-18 and 3-19.

Table 3-2. Risk Assessment Results – Fire Station Assets

Asset Name	Conseq. Score	Prob. Present	Risk Present	Prob. 2030	Risk 2030	Prob. 2070	Risk 2070	Composite Risk
Fire Station	24	0.5%	50	5.0%	500	100.0%	10000	2175
Fire HQ Parking Lot A	16	3.3%	220	9.8%	656	75.1%	5005	1308
Fire HQ Parking Lot B	16	4.5%	302	8.0%	534	73.2%	4880	1287
Fire HQ Parking Lot C	16	1.2%	82	4.1%	270	74.7%	4979	1118
Fire Station Septic	9	0.1%	4	2.0%	75	100.0%	3750	774
Fire Station Outbuilding	8	0.5%	17	5.0%	167	100.0%	3333	725
Fire Station Propane Tank	6	0.5%	13	5.0%	125	100.0%	2500	544
Fire Station Generator	5	0.1%	2	1.0%	21	50.0%	1042	216

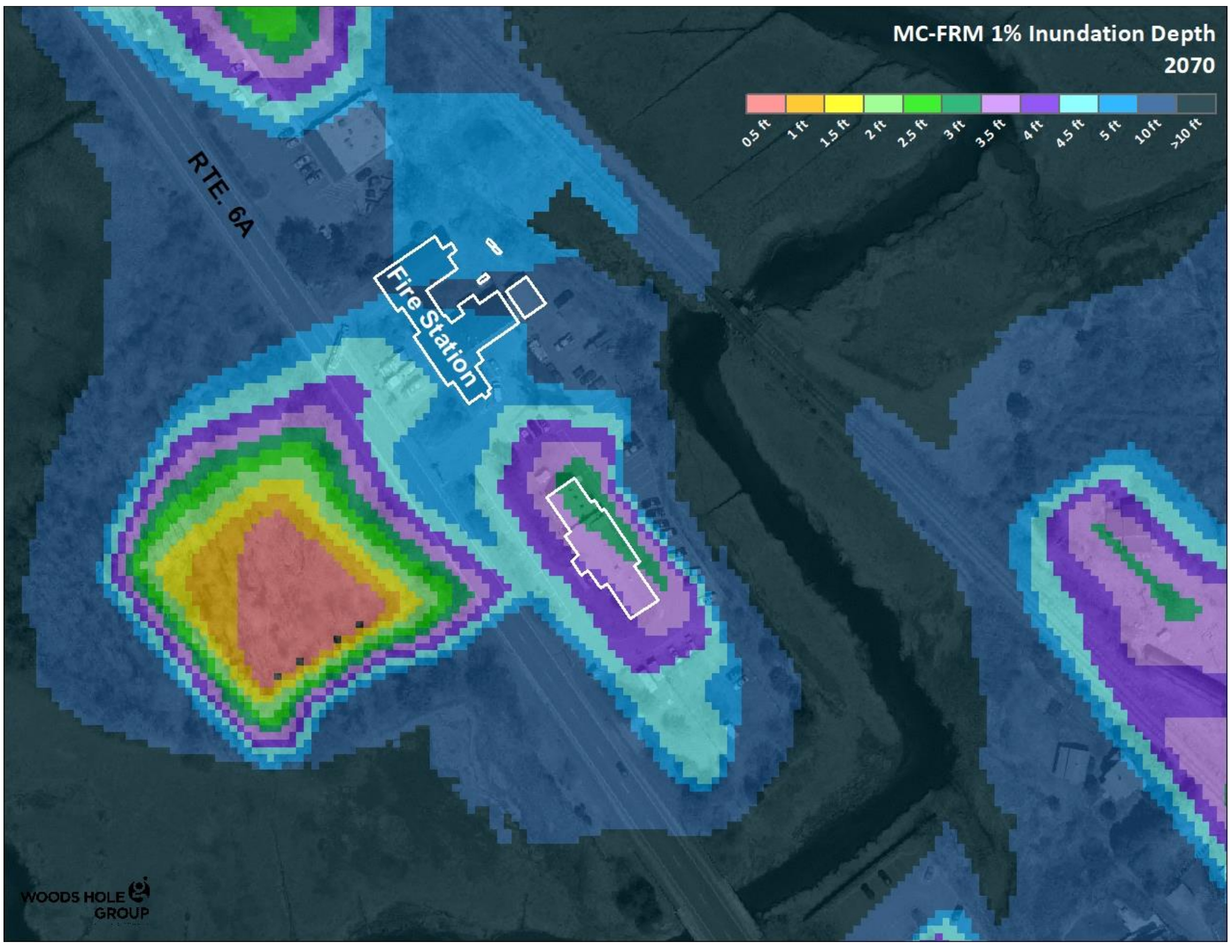


Figure 3-18. Downtown at Fire Station 2070 1% Flood Inundation Depth

Figure 3-19. Rendering of Downtown Fire Station Inundation from 2030 (and 2070 dashed) 1% chance events

3.3.2. Infrastructure

There are a number of municipally owned infrastructure assets that are vulnerable to flooding today, and more so by 2030 and 2070. Based on the Composite Risk scores, the following assets are deemed as High-Risk assets, based upon the risk assessment results, consequence scores, and/or the potential to contribute additional risk to other public and private assets via propagated flooding:

1) Sandwich Marina assets
2) The Boardwalk
3) Roadway assets:
    a. Foster Road
    b. Ploughed Neck Road
    c. State Route 6A / Scorton Creek Bridge
4) Select stormwater outfalls

The process for evaluating boat ramps and stormwater infrastructure followed a vulnerability assessment procedure rather than the standard risk assessment process, as previously described. The vulnerability assessment for boat ramps focused on the long-term usability of the asset in the context of sea level rise. The vulnerability assessment for stormwater outfalls attempted to approximate the potential for storm surge-induced backups of upland drainage areas. These vulnerability assessment procedures are detailed below.

Marina Assets

Boat ramp vulnerability and long-term viability was evaluated by comparing to projected mean high-water elevations. Local mean high-water projections were derived by adjusting the local MHW tidal datum for Sandwich Marina (NOAA Station 8447180, updated tidal epoch) with the relative sea level rise projections developed for the Commonwealth of Massachusetts (refer to Section 2.1.2). The present day MHW elevation for Sandwich Marina is 4.5 feet (NAVD88). Probabilistic projections of MHW elevations for 2030 and 2070 (using the standard High Scenario) at Sandwich Marina are 5.79 feet (NAVD88) and 8.79 feet (NAVD88), respectively. The projected future MHW elevations were compared to the boat ramp critical elevation (top of boat ramp) to assess vulnerability to sea level rise. This assessment concluded that the boat ramp was not vulnerable to sea level rise in the near term or long term.

Table 3-3. Risk Assessment Results - Marina Assets

Asset Name/ No.	Conseq. Score	Prob. Present	Risk Present	Prob 2030	Risk 2030	Prob. 2070	Risk 2070	Composite Risk
Fuel Ball Valves (monitoring)	17	50.0%	3542	100.0%	7083	100.0%	7083	5313
Observation Dock	11	50.0%	2292	100.0%	4583	100.0%	4583	3438
Fuel Monitoring Well - Middle	17	10.0%	708	50.0%	3542	100.0%	7083	2833
Coast Guard Fuel Tank	20	2.0%	167	30.0%	2500	100.0%	8333	2500
Commercial Unloading Pier	20	2.0%	167	25.0%	2083	100.0%	8333	2375
Commercial Fishing Dock (F Dock)	14	0.5%	29	5.0%	292	100.0%	5833	1269
1500 Gallon Pumpout Tank	19	0.0%	0	0.5%	40	50.0%	3958	804
Marina Playground	8	2.5%	84	6.9%	231	75.6%	2520	615
Public Slips (B Dock)	11	0.1%	5	1.0%	46	50.0%	2292	474
Marina Parking Area	14	4.5%	263	4.5%	263	4.9%	287	268
Commercial Fishing Dock (E - Secondary Dock)	14	0.0%	0	0.1%	6	20.0%	1167	235
Coast Guard Dock	20	0.0%	0	0.0%	0	10.0%	833	167
Commercial Fishing Dock (I Dock)	13	0.0%	0	0.0%	0	10.0%	542	108

Asset Name/ No.	Conseq. Score	Prob. Present	Risk Present	Prob 2030	Risk 2030	Prob. 2070	Risk 2070	Composite Risk
Public Slips (H Dock)	11	0.0%	0	0.0%	0	10.0%	458	92
Fuel Tank Leak Sensors	17	0.0%	0	0.0%	0	5.0%	354	71
Fuel Dock (shut off, pumps, monitoring)	17	0.0%	0	0.0%	0	5.0%	354	71
Fixed Pumpout Station	14	0.0%	0	0.0%	0	5.0%	292	58
Commercial Fishing Dock (G Dock)	13	0.0%	0	0.0%	0	5.0%	271	54
Fuel Monitoring Well - Upper	17	0.0%	0	0.0%	0	2.0%	142	28
Marina Parking Area	14	0.4%	21	0.4%	21	0.7%	38	25
Coast Guard Dock (A Dock)	11	0.0%	0	0.0%	0	2.0%	92	18
Public Slips (D Dock)	11	0.0%	0	0.0%	0	1.0%	46	9
Public Slips (C Dock)	11	0.0%	0	0.0%	0	1.0%	46	9
150 Gallon Propane Tank	21	0.0%	0	0.0%	0	0.5%	44	9
Public Slips (E - Main Dock)	14	0.0%	0	0.0%	0	0.5%	29	6
Marina Fuel Tank	22	0.0%	0	0.0%	0	0.2%	18	4
150 Gallon Propane Tank	21	0.0%	0	0.0%	0	0.2%	18	4
150 Gallon Propane Tank	21	0.0%	0	0.0%	0	0.2%	18	4
Emergency Fuel Shutoff	17	0.0%	0	0.0%	0	0.2%	14	3
Compressor Unit	9	0.0%	0	0.0%	0	0.2%	8	2
Harbormaster Office	8	0.0%	0	0.0%	0	0.1%	3	1
Marina Ramp House	7	0.0%	0	0.0%	0	0.0%	0	0
Marina Garage	8	0.0%	0	0.0%	0	0.0%	0	0
Marina Generator	13	0.0%	0	0.0%	0	0.0%	0	0

In the present condition, the location of the Coast Guard Fuel Tank, 1500-gallon Pumpout Tank, and select marina fuel tank/line monitoring equipment make these assets particularly vulnerable to coastal flooding during large storm events, such as the 100-year event. By the 2070 time horizon, the Harbormaster Office building may also be vulnerable to coastal flood inundation during the 0.1% chance event. This building is located at the downstream edge of a large impervious area (boat storage lot, Freezer Road, and Ed Moffitt Drive), and may be susceptible to compounded effects of overland flooding due to restricted gravity drainage.

The Boardwalk

The Sandwich Boardwalk, which has recreational and cultural significance to the Town, extends only a few feet above the coastal marsh. Therefore, this treasured asset has undergone several repairs after numerous past flooding events, including storms in March 2018, as shown in Figure 3-20. The Cape Cod Times and numerous web media sources have documented flooding of this structure during similar past events, which often submerge the majority of the Boardwalk. The top of decking at the low point of the boardwalk is 6.58 ft (NAVD88). In larger storm events, the Boardwalk is also subject to inundation and wave action.

Figure 3-20. Boardwalk Flooding during High Tide – Past Event (March 2018)

Figure 3-21 shows the Boardwalk under sea level rise conditions by 2030. This rendering purposefully omits storm surge and wave action, as this asset is already vulnerable under existing high tides and will only become impassable as tides rise. Additionally, the day to day usage of the Boardwalk will be impacted primarily by nuisance (i.e. sunny day) flooding rather than storm inundation, apart from storm-induced damage. Storm surge and wave action would likely destroy portions of the Boardwalk, as currently constructed.

Figure 3-21. Rendering of the Boardwalk and Parking Area (2030 Sea level Rise Conditions)

Roadways

There are several roadways connecting the barrier beaches of Sandwich with the mainland at Route 6A that are highly vulnerable assets, as illustrated in Figure 3-22. In particular, roadways that provide access in and out of barrier beach neighborhoods such as Spring Hill Beach and East Sandwich Beach via Roos and Foster Roads, and Ploughed Neck Road, respectively, are highly vulnerable. Without the use of these roadways, these coastal neighborhoods become isolated and likely without emergency services or access to food or proper shelter during storm events.

Table 3-4 lists the Town's most highly vulnerable roadway segments that are at risk of damage from storm surge and sea level rise. The table shows the probability of the road segment flooding in 2030 and 2070 modeled conditions and their associated risk scores (highest to lowest). As shown, the most vulnerable segments are primarily located in East Sandwich and either cross a wetland system and/or are within a barrier beach area.

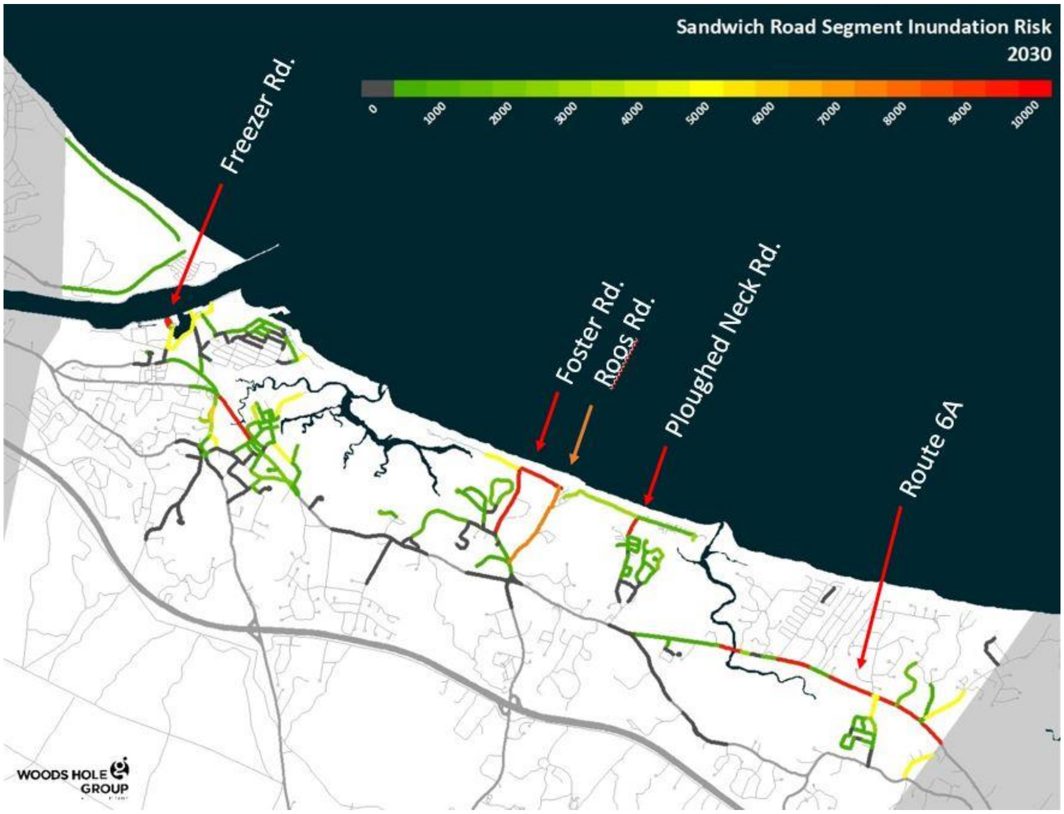


Figure 3-22. 2030 Road Segment Inundation Risk

Table 3-4. Vulnerable Roadway Segments

Road Segment	From	To	Consq. Score	Prob. 2030	Risk 2030	Prob. 2070	Risk 2070	Comp. Risk
PLOUGHED NECK RD.	N Shore Blvd.	Barbara Ln.	22	100%	9167	100%	9167	9167
ROUTE 6A	Scorton Creek bridge	Fort Hill Rd.	22	100%	9167	100%	9167	9167
ROUTE 6A	Tupper Rd.	Jarves St.	22	100%	9167	100%	9167	9167
ROUTE 6A	Beach Plum Cir.	Carlteon Dr.	22	100%	9167	100%	9167	9167
ROUTE 6A	Jones Ln.	Meadow Spring Dr.	22	100%	9167	100%	9167	9167
ROUTE 6A	Meadow Spring Dr.	Sand Neck Rd.	22	100%	9167	100%	9167	9167
ROUTE 6A	Sand Neck Rd.	Barnstable TL	22	100%	9167	100%	9167	9167
ROUTE 6A	Hammond Rd.	Joslin Ln.	22	100%	9167	100%	9167	9167
FOSTER RD.	Foster Rd.	end of road	22	100%	9167	100%	9167	9167
FOSTER RD.	Spring Hill Rd.	Salt Marsh Rd.	22	100%	9167	100%	9167	9167
ROOS RD.	Spring Hill Rd.	Salt Marsh Rd.	17	100%	7083	100%	7083	7083
FREEZER RD.	Marina turnaround	n/a	22	100%	9167	100%	9167	6875

Road Segment	From	To	Consq. Score	Prob. 2030	Risk 2030	Prob. 2070	Risk 2070	Comp. Risk
ROUTE 6A	Joslin Ln.	Wing Blvd.	22	100%	9167	100%	9167	6875
FREEZER RD.	south of Marina turnaround	Ed Moffit Dr.	22	50%	4583	100%	9167	5500
ED MOFFITT DR.	Coast Guard Road	end of road	12	100%	5000	100%	5000	5000
ED MOFFITT DR.	Commercial Unloading Pier	Coast Guard Rd.	12	100%	5000	100%	5000	5000
ED MOFFITT DR.	end of roadway (North end)	Public Slips - H Dock	12	100%	5000	100%	5000	5000
ED MOFFITT DR.	Commercial Unloading Pier	Gallo Rd.	12	100%	5000	100%	5000	5000
ED MOFFITT DR.	Gallo Rd	Public Slips - H Dock	12	100%	5000	100%	5000	5000
GALLO RD.	Ed Moffit Drive	Public Slips - H Dock	12	100%	5000	100%	5000	5000
DEWEY AVE.	Liberty Street	Georges Rock Rd.	12	100%	5000	100%	5000	5000
JONES LN. (bridge)	Route 6A	Jack Kelly Rd.d	12	100%	5000	100%	5000	5000
RIVER ST.	Tupper Road	Main St.	12	100%	5000	100%	5000	5000
ED MOFFITT DR.	Freezer Road	Public Slips - H Dock	12	100%	5000	100%	5000	5000
SALT MARSH RD.	Foster Rd	end of road	12	100%	5000	100%	5000	5000

The stretch of Route 6A approximately from Murkwood Conservation Area over the Scorton Creek Bridge is a critical connector between downtown Sandwich, neighborhoods to the south (Farmersville/Camp Burgess developments), East Sandwich and Barnstable. Without the use of the Bridge or roadway, access to and from East Sandwich becomes very limited. As shown in Figure 3-23, the roadway is still passable in projected 2030 conditions (1% annual chance event). However, by 2070, the roadway becomes completely inundated and virtually impassable (Figure 3-24).

Figure 3-23. Rendering of Scorton Creek Bridge Inundation from 2030 1% chance event

Figure 3-24. Rendering of Scorton Creek Bridge Inundation from 2070 1% chance event

Stormwater System

There are segments of the municipal stormwater system that are vulnerable to sea level rise and storm surges. Again, these vulnerabilities are based upon the elevation of the nearest connected catch basin to the outfall and a comparison of hydraulic heads. If the WSE from the MC-FRM storm surge distribution curve was above the elevation of the nearest connected stormwater inlet, the stormwater outlet was judged to have "certain" vulnerability to back up at the associated probability level. If the WSE from the MC-FRM storm surge distribution curve was below (within 5 feet) the elevation of the nearest connected stormwater inlet, the stormwater outlet was judged to have "potential" vulnerability to back up at the associated probability level. As shown in Table 3-5, the most highly vulnerable outlets are located within the Historic Downtown District.

Table 3-5. Vulnerable Stormwater Outfalls

Stormwater Outlet ID	Location	Critical Elev. (Ft.)*	Certain Backup (%)			Possible Backup (%)			Town Area
			Present	2030	2070	Present	2030	2070	
OU82-258-8	RIVER ST.	5.51	100%	100%	100%	100%	100%	100%	Downtown/ Glass Museum
OU82-54-32-A	CHURCH ST.	7.68	20%	50%	100%	100%	100%	100%	Boardwalk Rd (seaward side)
OU88-300-1	TUPPER RD.	7.83	10%	50%	100%	100%	100%	100%	Town Neck Rd
OU67-500-702	SPRING HILL RD.	8.25	5%	30%	100%	100%	100%	100%	Central/ Spring Hill
OU73-188-189	MAIN ST.	8.96	2%	20%	100%	100%	100%	100%	Downtown/ Town Hall
OU43-501-021	MAIN ST. @ ROUTE 6A	9.01	2%	20%	100%	100%	100%	100%	6A/Fire Station
OU89-344-96-B	WOOD AVE.	11.19	0%	0.5%	50%	50%	100%	100%	Town Neck
OU82-500-771	TUPPER RD.	11.37	0%	0.5%	30%	50%	100%	100%	Downtown/ Glass Museum
OU43-500-805	WATER ST.	11.74	0%	0.2%	30%	50%	100%	100%	Downtown/ Town Hall
OU73-300-1	WATER ST.	12.25	0%	0.1%	10%	30%	50%	100%	Downtown/ Town Hall
OU43-500-810	MAIN ST.	12.58	0%	0%	10%	20%	50%	100%	Downtown/ Town Hall
OU82-316-108	TUPPER RD.	13.16	0%	0%	5%	5%	50%	100%	Downtown/ Glass Museum
OU82-301-1	TUPPER RD.	14.56	0%	0%	0.5%	0.5%	10%	100%	Downtown/ Glass Museum
OU82-316-104	TUPPER RD.	15.18	0%	0%	0.2%	0.2%	2%	50%	Downtown/ Glass Museum
OU67-500-699	NYE RD.	15.87	0%	0%	0.1%	0%	1%	50%	Central/Spring Hill Creek
OU73-188-145	MAIN ST.	16.63	0%	0%	0%	0%	0.2%	30%	Downtown/ Town Hall
OU73-20-14	BEALE AVE.	16.75	0%	0%	0%	0%	0.2%	30%	Dock Creek
OU40-500-862	SPRING HILL RD.	17.80	0%	0%	0%	0%	0%	10%	Central/ Spring Hill

Stormwater Outlet ID	Location	Critical Elev. (Ft.)*	Certain Backup (%)			Possible Backup (%)			Town Area
			Present	2030	2070	Present	2030	2070	
OU43-500-806	TOWN HALL	17.86	0%	0%	0%	0%	0%	5%	Downtown/ Town Hall
OU43-500-807	MORSE RD.	18.08	0%	0%	0%	0%	0%	5%	Dock Creek
OU73-300-2	WATER STREET	18.35	0%	0%	0%	0%	0%	2%	Downtown/ Town Hall
OU68-500-706	SPRING HILL RD.	19.48	0%	0%	0%	0%	0%	0.5%	Central/ Spring Hill Creek
OU68-500-718	SPRING HILL RD.	24.11	0%	0%	0%	0%	0%	0%	Central/ Spring Hill
OU68-500-716	SPRING HILL RD.	24.76	0%	0%	0%	0%	0%	0%	Central/ Spring Hill
OU43-500-813	WATER ST.	27.84	0%	0%	0%	0%	0%	0%	Downtown/ Town Hall
OU40-100-003	QUAKER M.HOUSE RD.	29.64	0%	0%	0%	0%	0%	0%	Central/ Spring Hill
OU94-400-1	DILLINGHAM AVE.	30.70	0%	0%	0%	0%	0%	0%	Town Neck
OU43-500-812	WATER ST.	31.37	0%	0%	0%	0%	0%	0%	Downtown/ Town Hall
OU88-37-18	BURG AVE.	42.86	0%	0%	0%	0%	0%	0%	Town Neck

*NAVD88

Historic Assets

Resilience is fundamental to the preservation of cultural assets because, without adaptation measures, it is likely that historic and cultural assets will suffer material and structural damage due to severe flood impacts in the future. The Historic Downtown District includes a number of important historic assets that are highly vulnerable to coastal flood inundation, particularly between the 2030 and 2070 timeframe, including (Figure 3-25):

- Town Hall
- Town Hall Annex
- Sandwich Glass Museum
- Sand Hill School

A prime example of a key historic asset for the Town is the Sand Hill School. The School was originally built in 1885 and has great cultural significance to the Town, as it was schoolhouse for children of workers from the Sandwich Glass Factory. It was fully rehabilitated in 2018 and is now used for a number of community related activities. While the School building is currently located outside the FEMA 100-year floodplain, updated model results from the MC-FRM show that parts of the property will be subject to inundation during future storm events. By 2070, such events could result in inundation at (and around) the building footprint, with the modeled

2070 0.1% storm event causing 1.5 feet of flooding at the building edge, which could cause flooding of the basement where mechanical equipment is located.

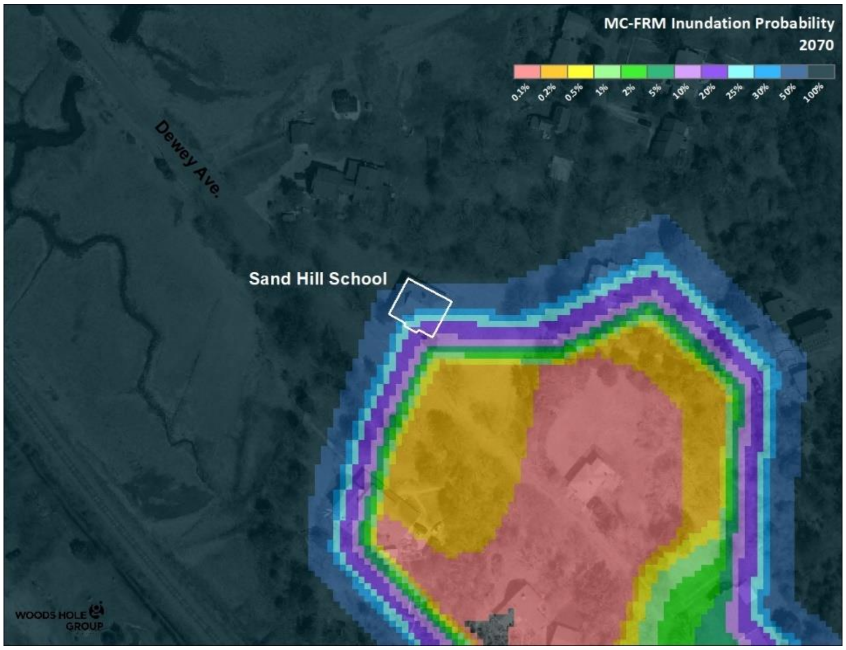


Figure 3-25. Sand Hill School 2070 Inundation Probability

3.4. SUMMARY

It is apparent that neighborhoods across the Sandwich coastline are highly vulnerable to coastal flood inundation due to storm surge and sea level rise. In particular, development along barrier beaches (Sagamore/Scusset, Town Neck/Spring Hill, East Sandwich) are at high risk. However, Sandwich's highly functioning salt marsh systems behind these barrier beaches serve as a strong buffer against coastal flooding to inner coastal neighborhoods.

Table 3-6 below ranks the Town's most highly vulnerable assets ranked by their composite risk scores, and their flood vulnerabilities within the indicated time period between 2030 and 2070. Full risk results for assets, roads, fire hydrants, and stormwater outlets are provided in Appendix C (C-1, C-2, C-3, and C-4, respectively). As previously noted, there are several critical municipal assets in Sandwich that are vulnerable to flooding, as listed in Appendix C. Assets are ranked from highest to lowest according to their consequence score, in order to provide the Town with a starting point for prioritizing adaptation strategies, as described in Section 4. Additionally, Appendix D provides full Asset Risk Profiles for all municipal facilities that are projected to experience some level of inundation by 2070.

Table 3-6. Highly Vulnerable Municipal Assets

Asset Name/ Number	Type	Prob. Present	Risk Present	Prob. 2030	Risk 2030	Prob. 2070	Risk 2070	Composite Risk
Boardwalk	Ped. Bridge	50.0%	3958	100.0%	7917	100.0%	7917	5938
Fuel Ball Valves (monitoring)	Marina Assets	50.0%	3542	100.0%	7083	100.0%	7083	5313
Observation Dock	Marina Docks	50.0%	2292	100.0%	4583	100.0%	4583	3438
Boardwalk Rd. Parking Lot	Parking	33.8%	1970	60.6%	3533	82.5%	4815	3008
Fuel Monitoring Well - Middle	Marina Assets	10.0%	708	50.0%	3542	100.0%	7083	2833
Coast Guard Fuel Tank	Marina Assets	2.0%	167	30.0%	2500	100.0%	8333	2500
Commercial Unloading Pier	Marina Docks	2.0%	167	25.0%	2083	100.0%	8333	2375
Town Neck Parking Lot	Parking	23.4%	1365	37.8%	2203	75.6%	4409	2225
Fire Station	Facility	0.5%	50	5.0%	500	100.0%	10000	2175
Sandwich Police/ Fire Headquarters	Parking	3.3%	220	9.8%	656	75.1%	5005	1308
Sandwich Police/ Fire HQ.	Parking	4.5%	302	8.0%	534	73.2%	4880	1287
Commercial Fishing (F Dock)	Marina Docks	0.5%	29	5.0%	292	100.0%	5833	1269

4.0 ADAPTATION STRATEGIES

There are generally three types of adaptation strategies that may be applicable, individually or in combination, to adapt to the risks of flooding from sea level rise and storm surge:

- Avoid Risk,
- Accommodate (Adapt),
- Protect, and
- Retreat (Managed).

These types of strategies are conceptually illustrated and described in Figure 4-1, from CoastAdapt (NCCCARF, 2019).

Figure 4-1. Conceptual Illustrations of Adaptation Options

Avoidance strategies typically include the adoption of laws and policies that no longer allow for development within a highly vulnerable area. Generally, this is accomplished through the employment of zoning (typically an overlay), where new development is not allowed to occur. A local example of this was put into place by the Town of Chatham. Chatham's zoning bylaw designates "conservancy districts" encompassing all land in the town's 100-year floodplain as mapped in its most recent town-approved Flood Insurance Rate Maps. The goal of the bylaw is to protect people, property, and resources. The bylaw clearly delineates three types of activities in designated conservancy districts—permitted uses, special permit uses, and prohibited uses—examples are shown in Figure 4-2. This type of regulatory measure is further explained in Section 4.3.2.

Permitted uses

- Fishing, cultivation, and harvesting of shellfish (including excavation of areas for cultivation and harvesting of marine foods); various horticulture activities
- Outdoor recreation activities, provided that related structures do not destroy beneficial character of district
- Floats
- Maintenance of existing raised roadways
- Installation of utilities
- Agriculture
- Government dredging of navigation channels
- Construction and maintenance of town landings and public boat launching ramps; nourishment of town beaches
- Mosquito control by Cape Cod Mosquito Control Project
- Maintenance of existing channels and marine facilities

Special permit uses

- Construction of certain structures, including catwalks, piers, ramps, stairs, boat shelters, tennis courts
- Construction of structures or buildings used in conjunction with a marina or boatyard
- Construction and maintenance of driveways or roadways of minimum legal length and width
- Construction and maintenance of private boat launches and beaches
- Installation of submerged pipes or cables used for swimming pools or commercial fishing operations

Prohibited uses

- Filling of land
- Draining of land
- Discharging of hazardous substances, treated sewage, or thermal effluent
- Construction of residential units or use of houseboats or barges as dwellings
- Building of any structure in V and V1-30 Zones
- Construction of pipelines to carry crude oil or unprocessed natural gas
- Actions that destroy natural vegetation, alter existing tidal flow, or otherwise alter the character of the land
- Destruction of natural growth that prevents erosion or storm damage
- Draining, damming, or relocating water courses except for aquaculture, agriculture, or flood or mosquito control

Figure 4-2. Chatham Conservancy District Uses

Accommodation strategies accept that vulnerable areas, infrastructure, and buildings will flood, but aim to minimize and control physical damage and unsafe conditions. Accommodation strategies may include physical, operational, or regulatory measures (Table 4-1).

Table 4-1. Examples of Accommodation Strategies

Type of Measure	Examples		
Physical	Construct an artificial floodway to convey flood water away from roadways and homes to a natural area or flood-tolerant green space that can store the water with limited damage.	Raise new and existing structures, for example on stilts or piles, above flood elevations with additional freeboard to provide a safety factor.	Implement wet floodproofing measures such as raising occupied spaces and utilities above flood elevations, building with flood damage resistant materials, or using flood-resilient structural design.
Operational	Improve flood evacuation and emergency planning by updating scenarios and plans, training first responders, or providing education and resources to residents and businesses in high flood risk areas.		
Regulatory	Strengthen building codes and zoning to require or encourage projects in high flood risk areas to implement increased setbacks, physical accommodation measures, onsite flood storage, or protection or enhancement of existing natural systems (e.g., dunes, wetlands).		

Sea walls, beach dunes, dikes, bulkheads, levees, revetments, flood gates, temporary flood protection barriers, dry floodproofing, and hurricane barriers are all examples of protection strategies that aim to prevent flood water from reaching sensitive areas.

Protection strategies try to prevent unsafe conditions and physical damage from occurring by creating a barrier between flood water and vulnerable areas, infrastructure, and buildings. To be truly effective over the longer term, existing protective structures may need to be raised incrementally, in response to sea level rise, and strengthened to withstand the forces of increasingly powerful storms. New structures may also be needed to protect areas that have not historically flooded.

Retreat strategies recognize the fact that in some areas it may be too costly, technically not feasible, or politically unrealistic to prevent damage from rising sea levels and storm surge, and that the best strategy is to remove vulnerable infrastructure, buildings, or populations from high risk flood zones. These areas can then be transformed back to more natural states to provide protective, recreational, or other functions that are compatible with occasional or regular flooding. Retreat strategies require significant planning to relocate infrastructure and buildings or resettle populations in areas outside of high-risk flood zones.

Examples of retreat strategies include property buyouts, relocation of roads and infrastructure, implementation of new zoning or other regulations that limit new construction, reconstruction, or expansion of structures in high risk flood areas, and policies and programs that steer development towards areas that are safe from flood risks.

Each type of adaptation strategy has been applied geographically, as follows:

1) Site-level strategies: property or facility itself;
2) Regional strategies: strategic locations to protect neighborhoods or multiple neighborhood areas; and
3) Town-wide strategies: policy and regulatory-based strategies.

These strategies are explained further throughout the following sections.

4.1. NATURAL RESOURCE ADAPTATION

Strategies to adapt and protect the Town of Sandwich's natural resources in the face of rising tides and increasing storm intensity should be multi-layered, and will focus on maintaining the enabling conditions that allow coastal resource areas to thrive, restoring degraded systems to enhance existing coastal resource areas, implementing green infrastructure and living shoreline solutions to fortify existing natural resource features, and accommodating the migration of natural resources over time, both vertically and horizontally. It should be noted that while wetlands are projected to migrate and convert over the time horizons of this study (to 2070) without significant anthropogenic barriers (development in Sandwich is generally outside of marsh migration pathways with the exception of some roadways and parking lots), longer term migration may be impeded by the natural topography of the region. Glacial features rise steeply in many parts of Sandwich, and will eventually prevent the lateral migration of wetlands.

Underpinning any efforts to maintain, restore, fortify, or accommodate coastal resource areas is the protection and maintenance of Sandwich's barrier beach and dune systems. Not only do these barrier systems provide flood protection for inland development, but they also create the enabling conditions (depth, tidal exchange, wave dissipation, etc.) for salt marsh systems to thrive in the basins behind them. Significant effort and study has been expended to date maintaining and enhancing the beach and dune system at Town Neck. These important efforts must continue so that salt marsh habitat in Old Harbor and Mill Creek can survive in the present, and have a chance to adapt/migrate in the future. It will be similarly imperative to ensure the long-term sustainability of Spring Hill and East Sandwich Beaches in order to support enabling conditions within the Old Harbor/Mill Creek system as well as in Scorton Creek. Both salt marsh systems are projected to have a moderate level of resilience, but that projection is predicated on the existence of the barrier landforms.

Scusset Beach

The Scusset Beach and Dune system is accreting due to trapping of longshore sediment transport against the canal jetty. Rates of accretion at the beach may be sufficient to keep pace with sea level rise and maintain the existing beach berm width and profile for the foreseeable future. The coastal processes study in the Section 111 will provide more specific analysis. Efforts at Scusset Beach should focus on monitoring the beach and dune, and increasing the health of the dune by consolidating walking paths and/or developing walkovers. Bypass of sediments to downdrift Town Neck Beach, at quantities deemed prudent by the Section 111 sediment budget, would be a responsible use of accumulated material going forward.

Scusset Marsh

As the restored Scusset Marsh continues to transition in the future with shifting tides, it will migrate laterally within the low-lying basin between the beach and the canal. Lateral migration should be allowed to evolve naturally, as it will result in transitions that are ecologically beneficial. However, deeper segments of the marsh near the main tidal stem are projected to experience a large conversion from low marsh to tidal flat, resulting in loss of salt marsh resource in this region (though offset by migration overall) by 2070. These lower elevation areas may be due to historic subsidence in the marsh area before the USACE restoration began, as well as the absence of a natural sediment supply due to the unnatural location of the tidal connection (in the Canal). Marsh elevations in this area could be made more resilient by thin-layer deposition to allow the low marsh to keep pace with sea level rise.

Town Neck Beach

As discussed above, the Town Neck Beach and Dune system plays a major role in providing enabling conditions for the existence of the salt marsh resource area behind it. Ongoing work to protect and enhance the eroding beach and dune in this area is critical, not only for the long-term preservation of the coastal barrier system itself, but also for the valuable salt marsh resource it protects.

Old Harbor and Mill Creek

The coastal wetland resource area at Old Harbor and Mill Creek is moderately resilient to sea level rise, meaning there is room for some lateral migration and the relationship between elevation and tidal range facilitate a transition from high marsh to low marsh over a time period when other marshes in the region may convert to predominantly tidal flat or open water. However, as the system transitions to predominantly low marsh, deeper areas are lost to tidal flat and/or open water by 2070. A targeted strategy of ditch filling and thin-layer deposition could be utilized here to bolster the overall integrity of the current high marsh resource (to reduce ponding and sloughing), and to enable the future transition to a more continuous low marsh resource unit rather than one fractured by tidal flats and open water channels. Additionally, there are many roadway and railway crossings within the inland reaches of the wetland where flow may be restricted by undersized culverts. A site-specific inventory of these culverts and upstream wetland conditions would facilitate the identification and prioritization of salt marsh restoration opportunities. Such wetland restoration projects would also be designed to accommodate future tidal ranges and marsh migration. All wetlands projections and related adaptation measures discussed for the Old Harbor and Mill Creek system depend entirely on the overall resiliency of the Town Neck barrier beach system, which must be maintained to support the enabling conditions for salt marsh habitat. Without the barrier beach system, the salt marsh will become a harbor with tidal flats as the dominant bottom condition.

Spring Hill Beach

As with Town Neck Beach, the Spring Hill Beach and Dune system plays a major role in providing enabling conditions for the existence of the Old Harbor / Mill Creek salt marsh resource area behind it, and would be an important precursor for any restoration at Long Creek. Adaptation for Spring Hill Beach should focus on dune restoration, consolidating access paths, and potentially developing overpass walkways in certain areas to enhance dune integrity. With dense development along the shore-parallel Salt Marsh Road and North Shore Boulevard, living shoreline solutions may provide a reasonable amount of flood protection and erosion control on the backside of the dune system adjacent to the tidal creek and wetland area, while enhancing the resource area and its long-term resilience.

Scorton Creek

The coastal wetland resource area at Scorton Creek is moderately resilient to sea level rise, meaning there is room for some lateral migration and the relationship between elevation and tidal range facilitate a transition from high marsh to low marsh over a time period when other marshes in the region may convert to predominantly tidal flat or open water. However, as the system transitions to predominantly low marsh, deeper areas are lost to tidal flat and/or open water by 2070. It would be prudent to implement a monitoring program in the near term to observe whether the marsh is keeping up with sea level rise, and determine if/when any action is warranted.

If thresholds established in the monitoring plan are triggered, a targeted strategy of ditch filling and thin-layer deposition could be utilized here to bolster the overall integrity of the current high marsh resource (to reduce ponding and sloughing), and to enable the future transition to a more continuous low marsh resource unit rather than one fractured by tidal flats and open water channels. Additionally, there are a few roadway crossings, particularly at the eastern reaches of the creek, where tidal flow may be restricted by undersized culverts. A site-specific inventory of these culverts and upstream wetland conditions would facilitate the identification and prioritization of salt marsh restoration opportunities. Such wetland restoration projects would also be designed to accommodate future tidal ranges and marsh migration.

The existing tide gate on Long Creek at Ploughed Neck Road is a major barrier to salt marsh migration, since it restricts normal tidal exchange and has impounded the (now freshwater) wetland area between Ploughed Neck Road and Roos Road, with portions of that area having been converted historically to cranberry bogs. Removal of the tidal restriction on Long Creek would catalyze a large-scale ecological restoration and associated water quality benefits. However, the decision to replace the tide gate with an appropriately sized culvert (or operable gate) would have to consider existing agricultural uses and flood protection provided by the barrier. If determined feasible, the retoration project could also include raising a section of Ploughed Neck Road to maintain emergency access for North Shore Boulevard (see Section 4.4.2).

East Sandwich Beach

As with Town Neck and Spring Hill, the East Sandwich Beach and Dune system plays an important role in providing enabling conditions for the existence of the Scorton Creek salt marsh resource area behind it. East of Hammond Road, the coastline transitions from beach/dune to a beach and coastal bank system with a high upland area (Scorton Neck) between Cape Cod Bay and Scorton Creek. Adaptation for East Sandwich Beach should focus on dune restoration in scarped areas, and living shoreline toe protection for the coastal bank. Otherwise this system should be left to transition naturally and supply sediment to downdrift beaches. There may be opportunities on the backside of the dune system adjacent to the Scorton Inlet for living shoreline interventions to enhance the resource area along Scorton Harbor and increasing its long-term resilience.

4.2. REGIONAL ADAPTATION STRATEGIES

Regional or coast-wide adaptation strategies aim to reduce flood risks across a geographical area that may contain multiple critical municipally owned assets as well as privately-owned assets including buildings, roadways, and other infrastructure. Some of the large areas at risk of coastal flooding in Sandwich are at risk because of “flood pathways”, which are low-lying strips of land that permit coastal flood waters to flow further inland into other (often much larger) low-lying areas where there is existing development (areas that are usually dry). Solutions to close these flood pathways, or otherwise address them, are referred to in this report as regional strategies. In other cases, regional strategies may be related to improving the protective value of existing natural protections (e.g., dunes, beach) or man-made coastal structures along an entire stretch of coastline.

Regional strategies can be expensive to implement. However, the benefits of regional strategies are that they can be relatively cost-effective and straightforward to implement and provide significant reduction in flood risk for a large number of beneficiaries through a single project, compared to a site-by-site approach of many independent projects. Implementation of regional strategies to address flood risks in the 2070-time horizon, when most of the Town will face significant risks, may face higher technical, political, and financial challenges than the less extensive near-term regional solutions or site-specific adaptations.

Opportunities for addressing sea level rise and storm surge inundation in Sandwich from a regional perspective are limited due to a few factors:

1. Geologic processes shaped the landform of Sandwich in such a way that elevation gradients are often steep, causing low-lying areas (typically salt marshes that experience regular flooding) to back up to relatively high elevation glacial deposits (which may be subject to little, if any, present or future inundation). Thus, most flood patterns in Sandwich projected by MC-FRM are not conducive to regional solutions because flooding mostly occurs along the entire fringe of wetland areas rather than through a specific flood pathway.

2. The extensive and open nature of the marsh systems behind the Town's barrier beaches and dunes does not provide strategic intervention points for regional solutions since there are few constriction points at which to leverage an intervention.

3. With a few exceptions, notably roads and the Downtown area, Sandwich's municipal infrastructure (and private development to a somewhat lesser degree) has not been constructed in flood prone areas. The vast majority of municipal infrastructure occurs in upland areas of Town, outside of the study area of this project, and therefore outside of areas at risk of inundation.

The flood pathway affecting the Downtown district – including the Fire Station, Old Police Station, Route 6A, development around Jarves Street and Willow Street, and the Town Hall area – is somewhat constricted by the landform and existing development. A regional solution for the Downtown District would be comprised of a phased series of elevated living shoreline and vegetated berm installations to address the 1% event flooding in Present, 2030, and 2070 conditions (Figure 4-3). The phased berm features would be installed first to address Present day inundation levels, then expanded both laterally and vertically to address 2030 and 2070 inundation levels (as needed). The living shoreline would front the railway, and be tied into the sides of the rail bridge (with a tide gate and adjustable wall to address flooding above and below the bridge). The solution would enhance resource areas along the shoreline and allow normal tidal activity to continue under the railway and under the Route 6A bridge (maintaining a healthy estuarine ecosystem upstream of the bridge and facilitating marsh migration over time), but would be operable during storm events in order to impede storm surge as needed.

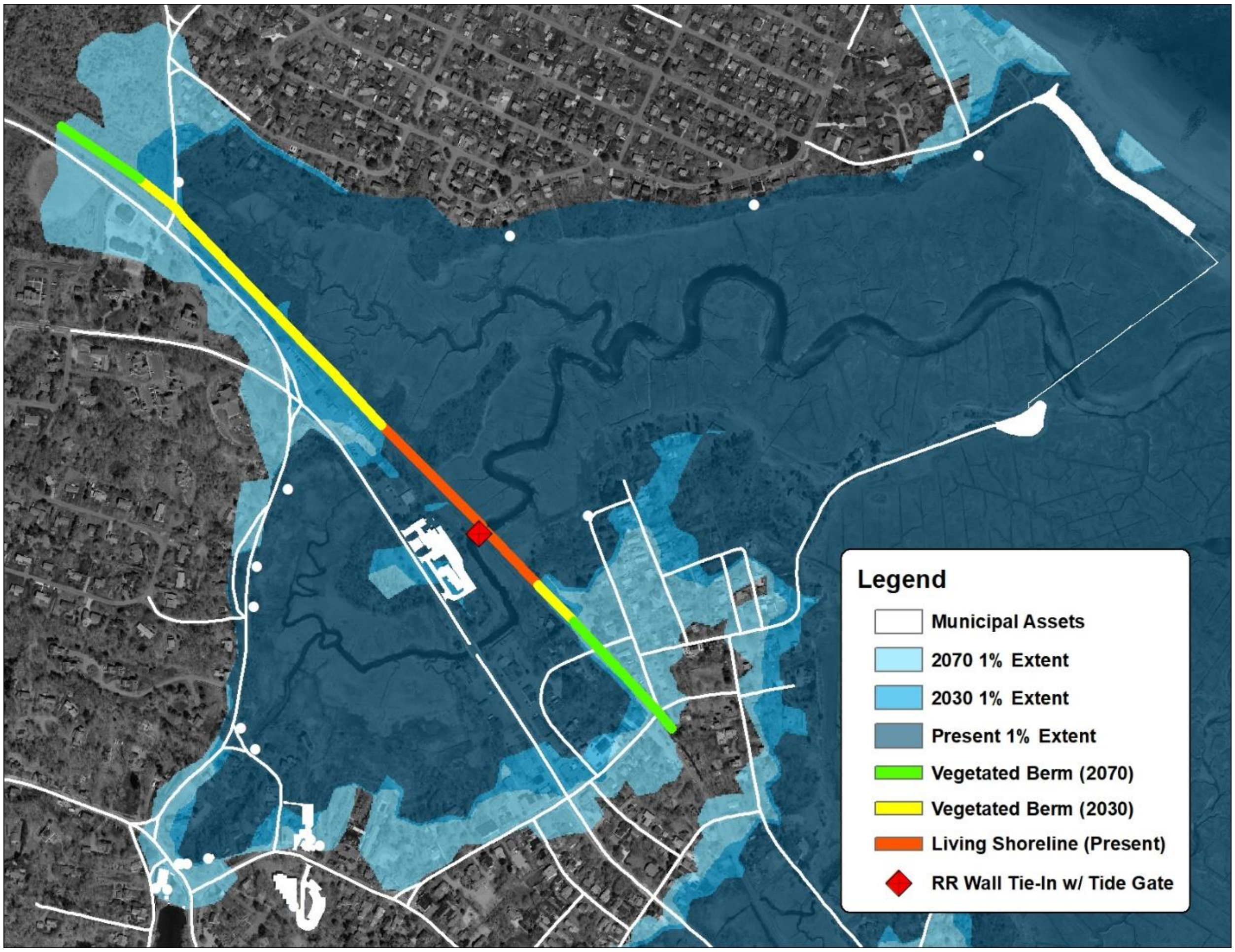


Figure 4-3. Proposed Downtown District Regional Solution

The flood pathway affecting the Route 6A, Main Street, and the Sandwich Fish Hatchery (a Massachusetts Division of Fisheries and Wildlife asset) is also constricted by the adjacent landforms. A regional solution at Dewey Street would be comprised of a phased series of elevated living shoreline and vegetated berm installations to address the 1% event flooding in Present, 2030, and 2070 conditions (Figure 4-4). The phased berm features would be installed first to address Present day inundation levels, then expanded both laterally and vertically to address 2030 and 2070 inundation levels (as needed). The living shoreline would front Dewey Road, and be tied into the roadway at the creek crossing (with a tide gate and adjustable wall to address flooding above and below the road). The solution would enhance resource areas along the shoreline and allow normal tidal activity to continue under Dewey Street, the railway and

Route 6A (maintaining a healthy estuarine ecosystem upstream and facilitating marsh migration over time), but would be operable in order to impede storm surge as needed. A possible alternative configuration of this regional solution would be to elevate Dewey Avenue along the same alignment and install an operable tide gate under the roadway.

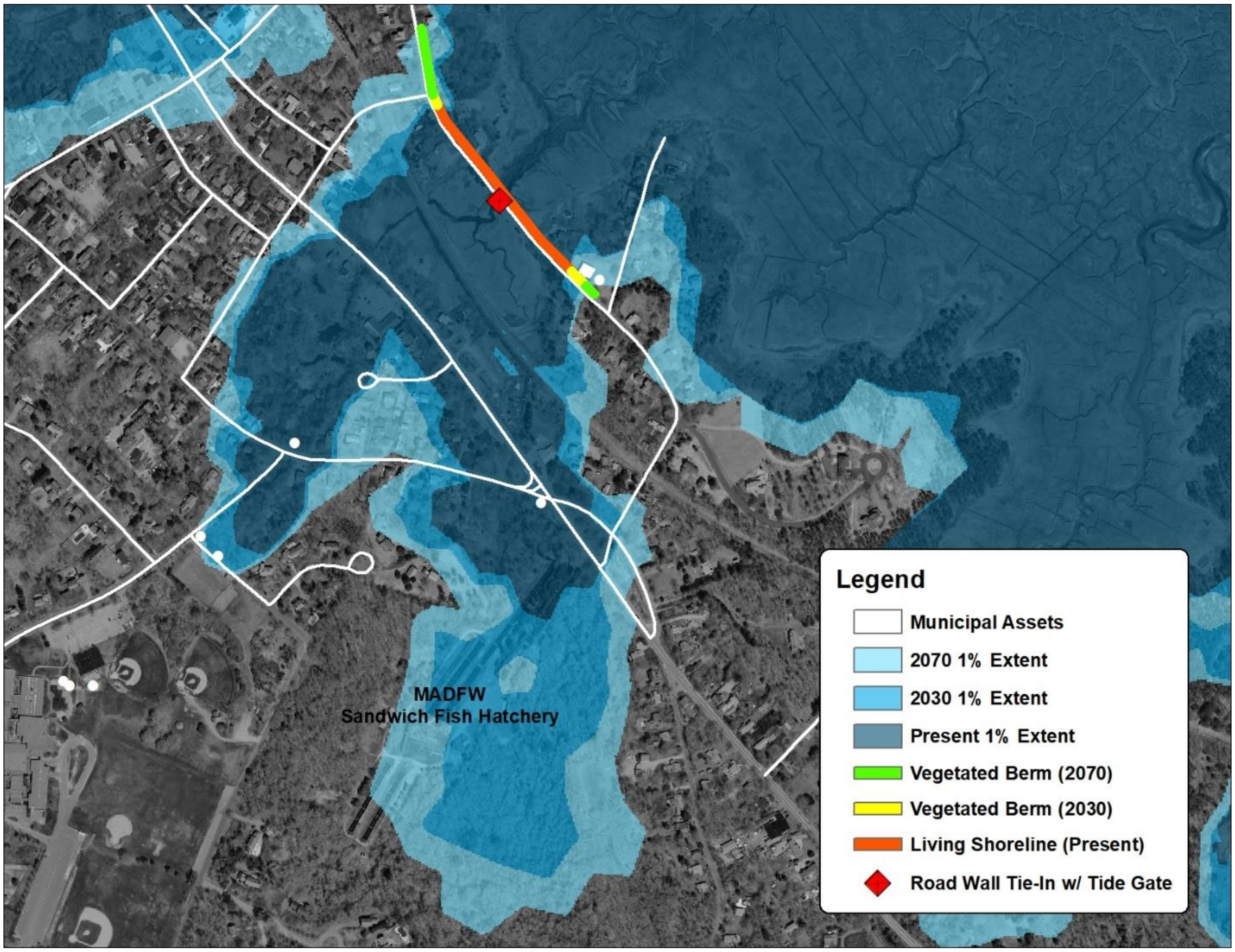


Figure 4-4. Dewey Street Regional Solution

As mentioned in Section 4.1, the most important regional solution the Town of Sandwich can undertake to support coastal resilience and protect inland developed areas is to continue to support the maintenance of the Town's barrier beach and dune systems – most critically the Town Neck Beach and Dune restoration project. This coastal barrier system is essential to reducing vulnerability to sea level rise and storm surge as it greatly reduces wave action on the inner shorelines of the Town, thereby reducing erosion and flood impacts, and also provides suitable habitat conditions for salt marsh to exist within the Old Harbor / Mill Creek area. Salt marsh habitat buffers inland areas from storm surge and wave action, and is a natural storm defense system with multiple ecosystem services and co-benefits. For these reasons, work to maintain and enhance Town Neck is vitally important to building coastal resilience in Downtown Sandwich. Likewise, other efforts to maintain and enhance Sandwich's barrier beach and dune systems should be supported as critical to regional adaptation throughout the Town. These barrier systems and the adjacent high glacial deposit landforms (e.g. Town Neck, Spring Hill, Ploughed Neck, Scorton Neck) are naturally protective features that form the backbone of coastal green infrastructure – the first line of defense – for the Town.

4.3. STRATEGIES FOR HIGH-RISK DEVELOPMENT

Prior to developing adaptation strategies, it is important to select a Design Flood Elevation (DFE) that will be the level to which structures are adapted to, whether it a public or private structure. For the purposes of this study, DFEs do not include “freeboard” (height often added above the expected flood level for additional safety). However, we recommend that the Town consider additional freeboard height, which can vary from site-to-site reflecting local conditions, criticality of the structure in question, and the owner’s tolerance for risk. Building-level adaptation measures must also take code-required minimum Base Flood Elevations (BFE) elevations into account. The DFEs suggested herein do not supersede the minimum base flood elevations legally established by the Massachusetts State Building Code or other applicable codes for the design of buildings and infrastructure. The DFEs in this report are presented for the purpose of establishing a reference elevation by which to evaluate various strategies to address flooding impacts from sea level rise and storm surge. During the preliminary design stage of a project, site-level investigations, such as wave run-up and overtopping analyses and code reviews, should be completed where applicable (e.g., seawalls and dunes) to determine actual design flood elevations.

The typical difference between the 1% and 0.2% flood elevations in 2030 and 2070 is approximately 1.1 to 1.3 ft.

Tables 4-2 and 4-3 list the draft proposed DFEs for each primary high-risk areas of Sandwich. These DFEs should be considered draft to be used for discussion purposes, as more detailed investigations into model node flooding profiles may warrant refining the flood elevation exceedance curves for each region.

Table 4-2. Flood Elevations: Old Harbor/Mill Creek (Town Neck/Downtown)

EXCEEDANCE PROBABILITY	FLOODWATER ELEVATION (2030)	FLOODWATER ELEVATION (2070)
(%)	(Ft. - NAVD88)	(Ft. - NAVD88)
0.1	12.5	16.6
0.2	12.1 (DFE)	16.0 (DFE)
0.5	11.5	15.3
1	11.0 (DFE)	14.7 (DFE)
2	10.5	14.2
5	9.9	13.4
10	9.4	12.8
20	8.9	12.2
25	8.7	12.0
30	8.5	11.8
50	8.0	11.1
100	6.8	9.7

Table 4-3. Flood Elevations: Scorton Creek (East Sandwich)

EXCEEDANCE PROBABILITY	FLOODWATER ELEVATION (2030)	FLOODWATER ELEVATION (2070)
(%)	(Ft. - NAVD88)	(Ft. - NAVD88)
0.1	12.6	16.9
0.2	12.2 (DFE)	16.3 (DFE)
0.5	11.6	15.6
1	11.1 (DFE)	15.0 (DFE)
2	10.7	14.5
5	10.1	13.7
10	9.6	13.1
20	9.1	12.5
25	8.9	12.2
30	8.8	12.0
50	8.2	11.3
100	7.1	9.9

Selecting a more conservative DFE, such as the 0.2% probability elevation (500-year recurrence interval), may be prudent if the criticality of the area or asset to be protected is very high, but it has some impacts on the feasibility and cost of adaptation strategies to modify what exists today in vulnerable areas.

4.3.1. Building Adaptation

The strategies recommended at the building scale are intended to reduce repetitive losses from property damages caused by flooding and reduce harm to residents living in properties at risk of flooding. The strategies range from full building modifications that involve elevating the structure above the base flood elevation to interior modifications that strive to protect individual, critical elements from flood damages. There are a series of retrofit options available for property owners to consider and/or for the Town to either mandate or incentivize, depending on the property's repetitive loss history and location within the projected flood area.

The Town could also consider establishing an assistance program for subsidized home improvements. This would allow interested property owners to renovate their residences to reduce the negative impacts of flooding without a significant cost-burden. FEMA has grant programs like the Flood Mitigation Assistance program that provides federal funding to property owners, through municipalities, the designated grant applicant. "FMA provides funding to States, Territories, federally-recognized tribes and local communities for projects and planning that reduces or eliminates long-term risk of flood damage to structures insured under the NFIP." (https://www.fema.gov/flood-mitigation-assistance-grant-program).

Reducing the cost-burden to property owners encourages building-scale adaptations that will contribute to the safety of residents without forcing them to relocate upfront. However, in doing so and reducing the amount of repetitive loss the owner might experience, the property owner can build equity which would facilitate their ability to relocate outside of the floodplain in the future.

Full Building Elevation

If a property has a high probability of flood inundation risk, the owner should consider elevating the entire structure above the DFE to avoid critical damages from sea level rise, storm surge, and increased precipitation. Based on the construction type and architectural style of the building, the structure might either be elevated on to stilts, which allows water to pass under the structure without putting lateral pressure on the base of the building, or the structure can be elevated onto a concrete plinth (*see diagram below*).

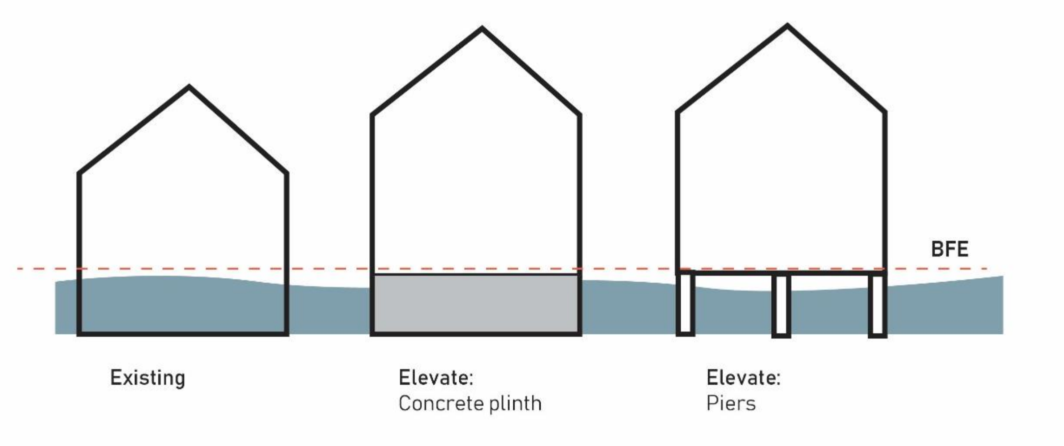


Figure 4-5. Full Building Elevation

Both strategies require that additional stairs or a ramp are added in order to access the new elevated entryway. The design should consider ways to maintain a visual and accessible physical connection to the public right of way. These considerations should also include maintenance of the street rhythm and common architectural vernacular. Without these design considerations, elevated buildings can negatively impact the street design, particularly in commercial settings.

A common residential building type in Sandwich is the single-family, one-story– this type of structure is most suitable for full building elevation, rather than an interior elevation due to the limited floor to ceiling heights. The Town of Hull provides a freeboard incentive that rebates $500 in Building Department fees for homes that elevate 2.0 ft. higher than what is required by code.

The Town can create a special permit process to allow property owners to exceed local building height limitations when elevating for flood protection. Exceedance can include extra height for vertical additions to accommodate for lost first-floor space if necessary.

Interior Elevation

If a property has a high probability of flood inundation risk, the owner can also consider elevating the first floor from the interior, if a full building elevation is not possible. An interior elevation may be appropriate if the building is masonry or non-porous, flood-resistant material, and the most significant flood risk comes from inundation of the building openings. An interior elevation is also appropriate when historic preservation regulations prohibit alterations to the exterior façade of a building. Considering the historical context of Sandwich's Town Center, interior elevation may be appropriate for some publicly owned and commercial buildings. This strategy only works if there is an adequate floor to floor height to accommodate the elevation in addition to an adequate windowsill height so that the floor elevation does not obstruct existing openings.

This building adaptation requires new exterior stairs for access to the elevated interior first floor which can be on the exterior or the interior of the building. If they are on the interior, a flood-proof vestibule is necessary (*see diagram below*).

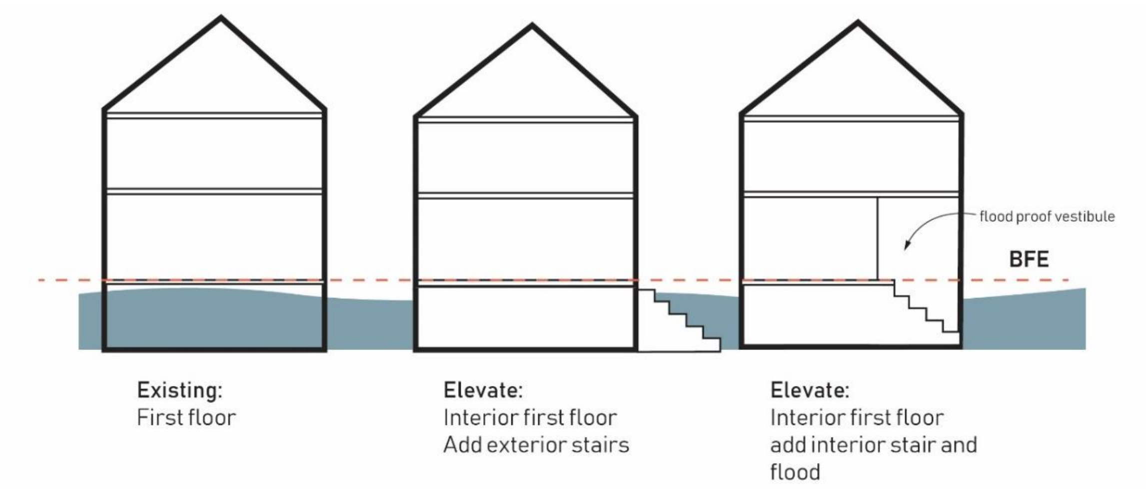


**Figure 4-6.	Interior Building Elevation**

Dry Floodproofing

If a full building or interior elevation is not feasible, structures can be dry flood-proofed at the area below the Base Flood Elevation. This involves using multiple strategies to ensure that no floodwaters enter through the exterior envelope, the basement, or any openings such as windows and doors.

Dry floodproofing might involve installing deployable flood shields at the doors or any windows below the BFE. Often flood shields require permanent hardware to be installed on the frame of the opening so that barriers can be easily deployed in the case of a flood event. However, flood barriers can also include more 'light-footprint' site strategies such as sandbags or Tiger Dam system. These systems do not ensure that the structure itself is sealed from flooding but can lessen the damages suffered from flood impacts. It also involves sealing the existing exterior façade material with an impervious coating that stops floodwaters from penetrating pre-existing porous materials. To mitigate stormwater flood damages, a backflow valve can be installed to prevent sewer and drain backup from flooding the basement.

Wet Floodproofing

Wet floodproofing aims to reduce flood damages by allowing water to pass through the structure so that the loads of the water do not cause permanent damage to the structure. Wet floodproofing also requires that the interior of the space is retrofitted to have 'floodable' materials that will not suffer permanent damage when water passes through. FEMA summarizes the strategy as, "including properly anchoring the structure, using flood resistant materials below the Base Flood Elevation (BFE), protection of mechanical and utility equipment, and use of openings or breakaway walls." https://www.fema.gov/wet-floodproofing.

Mechanical Systems

Whenever possible, mechanical systems should be elevated above the base flood elevation. For low flood inundation probabilities, or if it is not feasible to relocate the mechanical system outside of the lower level, systems should be elevated on a platform to protect from subgrade flooding. Systems should always be anchored so as not to shift during a flood event, damaging other areas.

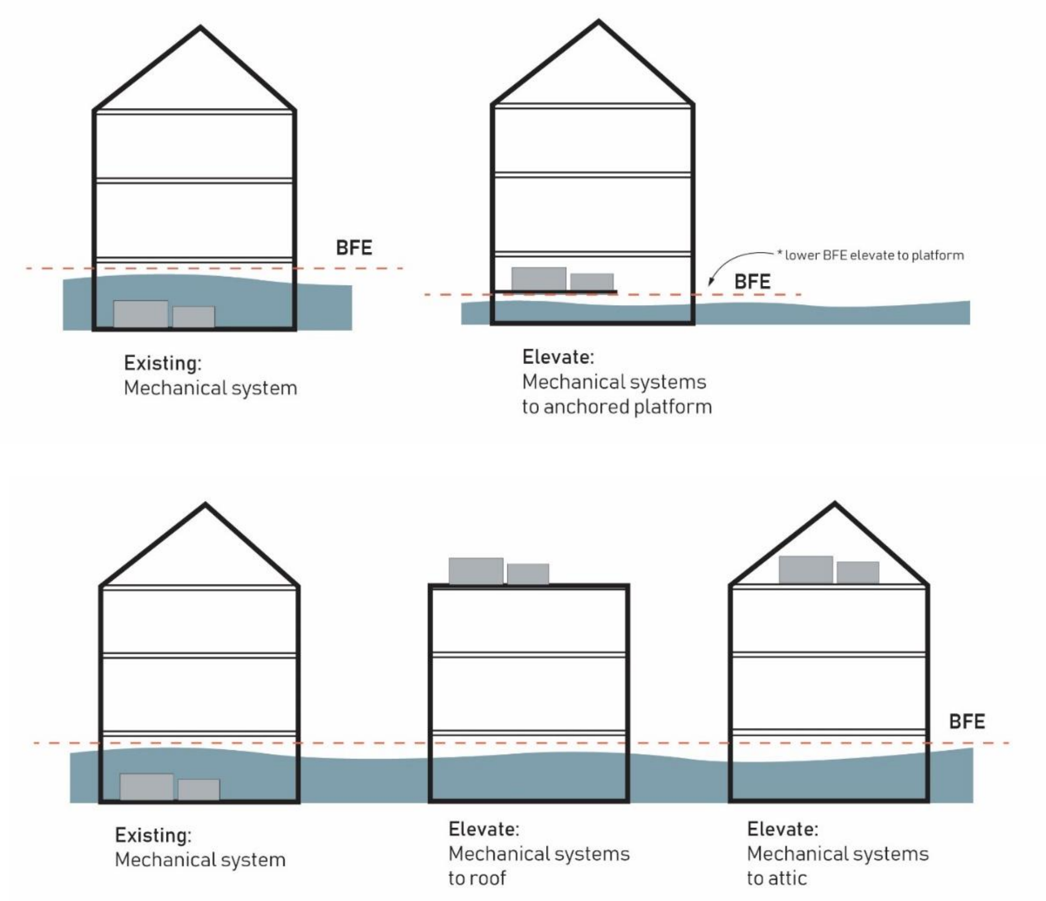


Figure 4-7. Elevation of Mechanical Systems

4.3.2. Managed Retreat

Managed Retreat is an adaptation strategy that involves both land use changes and relocation of residents or critical facilities from the floodplain. Retreat, "is one of the most adaptive responses to climate change," because it reduces foreseeable predicted risk by moving residents from dangerous, high-risk flood areas (Koslov, 2016). Residents receive the current value of their home pre-storm, meaning they avoid potential losses associated with flood damages.

Retreat also benefits natural resource areas by removing human development and opening the area for conservation and restoration efforts. By increasing open space, there is an opportunity to enhance the resilience of both human and natural systems by creating a larger 'buffer' area between developed and non-developed areas to accommodate sea level rise. As the likelihood of storms increase and sea level continues to rise, residents may be forced to relocate as the coastline becomes a more hazardous place to live. Because these changes will happen over a multi-decade time horizon, there is time for the Town to plan for this process as a gradual retreat, rather than immediate or forced retreat (although major storm events may alter this scenario). This section of the report recommends a 50-year phased planning process (2020-2070) considering short-term, near-term, and long-term actions that will shift current development patterns from the floodplain to the upland areas of the Town.

Ultimately, this strategy intends to eliminate risk for the Sandwich community. "A long-term policy of managed retreat can limit a community's exposure to coastal hazards, save lives, and limit the expenditure of public funding on vulnerable infrastructure and response mechanisms" (Siders, 2013). (A long-term managed retreat policy may become necessary in Sandwich due to the 2070 inundation probability indicated in the Massachusetts Coastal Flood Risk Model (MC-FRM). Building footprints are shown in black below (Figure 4-8), with a significant number located within high probability flood areas.

When considering the relationship of infrastructure, development, and natural resources flood risks, it becomes clear that the 2070 inundation probabilities indicate a need for a regional adaptation strategy that accounts for severe accessibility issues due to frequent flooding and marsh migration. With these constraints in mind, the Town should consider actions that 'retreat' residents from these areas to upland areas.

The Town's current development patterns are characterized by higher densities along route 6A and the parallel coastline, and more spread out pockets of development upland, bound by Routes 130, 149 and 6. To the west of Route 130, area is largely undeveloped. (The topographic range between these areas is ~0'-~240') Sandwich is an ideal locale for managed retreat tools because of this undeveloped land. Residents 'retreating' from flood-risk properties could relocate within the Town boundaries, preserving the existing tax base and allowing residents to maintain community networks. Having an opportunity for Town-led managed retreat with the input of residents is a major benefit for this adaptation response because retreat is often contested because it is initiated at the state or federal level as a response to a disaster, rather than as a proactive and positive adaptation mechanism.

Open space areas indicated in Figure 4-8 in light green represent areas that may be suitable for redevelopment based on the following baseline criteria: flood probability in 2070 scenario, topographic elevation, and designation of open space as not for conservation purposes. Further analysis of specific sites is necessary to understand other factors that would affect development opportunities.

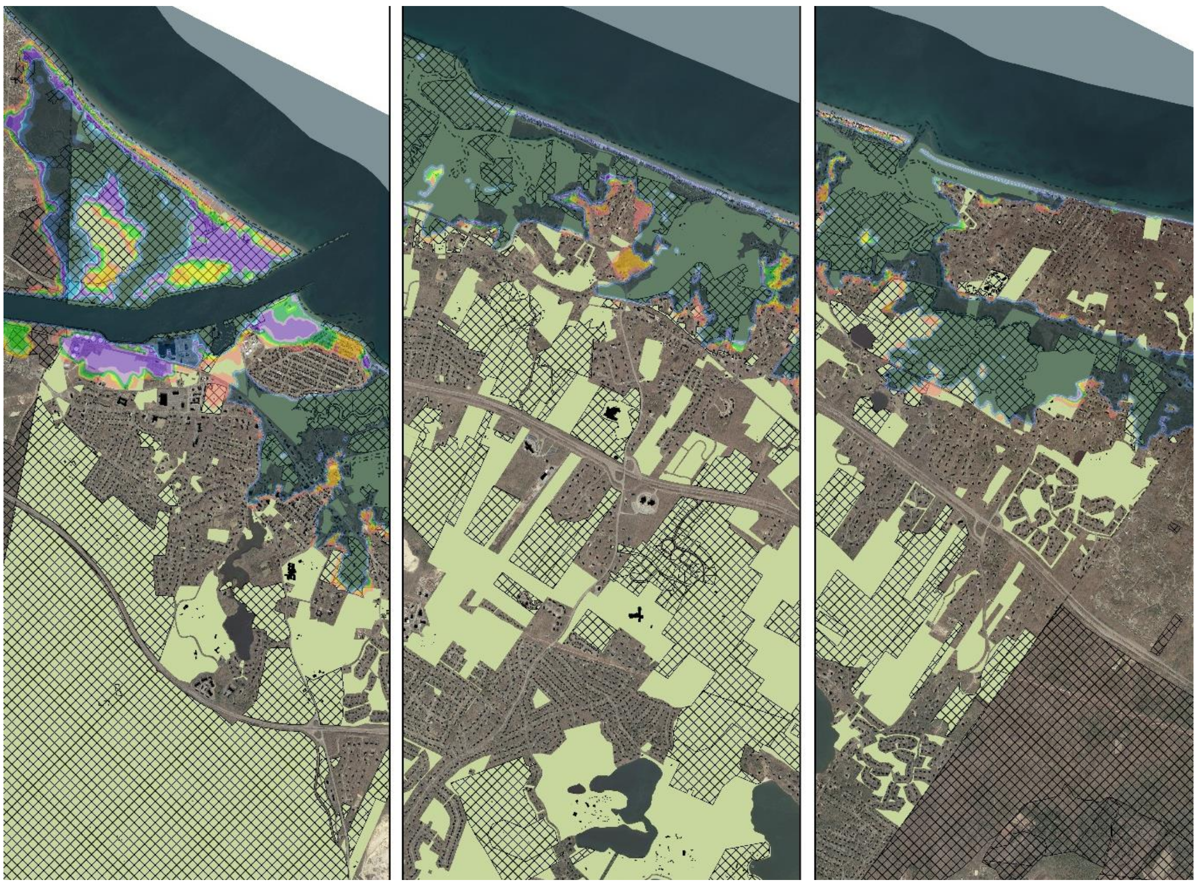


Figure 4-8. Managed Retreat and Potential Migration in Each High-Risk Area

The following section introduces land-use regulations that support gradual 'retreat' by placing limits on development within high probability inundation areas. The strategies are organized based on the timeline at which they should be implemented (short-term, near-term, long-term) with the long-term strategies supporting the most aggressive 'managed retreat' outcomes (Figure 4-9). These tools are meant to provide stringent regulations on land use that do not displace current residents but instead shift the trajectory of coastal development. It is this type of development that contributes to the Town's vulnerability to climate change and its associated impacts.

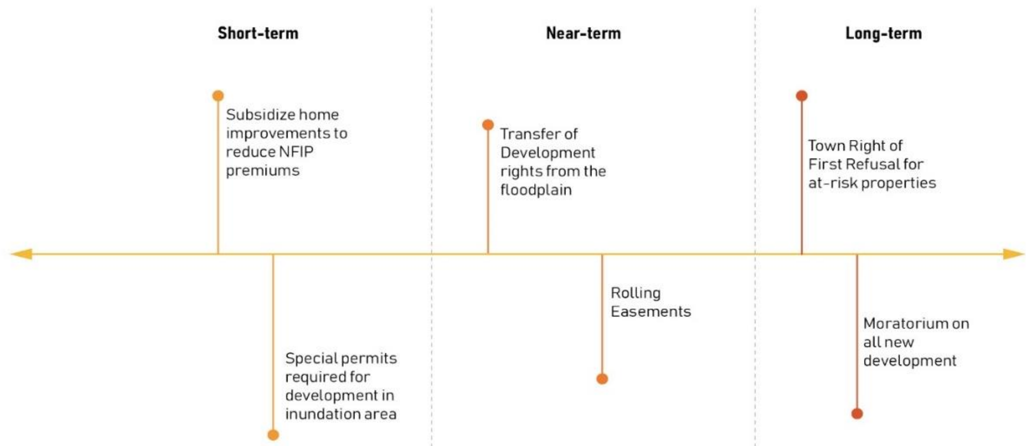


Figure 4-9. Managed Retreat Timeline

Town Right of First Refusal (Short-Term)

A Town Right of First Refusal allows current residents to maintain ownership through their 'end of life.' ((*https://www.landthink.com/what-is-a-right-of-first-refusal-and-how-does-it-work/*) This strategy ensures that current residents are not displaced from their home, while also ending a generational cycle of coastal homeownership. A Town Right of First Refusal is a property-level approach to incrementally eliminating at-risk structures. This timeframe will vary for residents based on their willingness to relocate or the length of their lifetime.

A 'Town Right of First Refusal' prohibits current property owners from selling their at-risk property to a private owner. The Town must provide just compensation to the owner but then has full ownership rights. The Town can transition the acquired property into a restored flood plain. The First Refusal acts as a more flexible form of eminent domain in which property owners are not forced to surrender their property.

The Town could provide incremental payments to the owner so that they receive the benefit of building equity from their property and are not denied the opportunity to build wealth through property ownership. The goal is to acquire land gradually in order to maintain the self-determination of residents. The Town should offer residents in all circumstances, the pre-storm market value of the property.

The Town might consider applying to one of three federal grant programs that support the acquisition of flood-prone properties: FEMA's Hazard Mitigation Grant Program (HMGP), HUD's Community Development Block Grant for Disaster Recovery (CDBG-DR), or the Natural Resources Conservation Services Emergency Watershed Protection Program (EWP). There are also state precedents for acquisition programs like New Jersey's Blue Acres Program. However, a state-led buyout program is outside the realm of the Town's jurisdiction.

Benefits:

- A Town Right of First Refusal supports a more gradual retreat process that allows residents to make decisions about relocation according to their personal needs and timeline.
- This strategy might reduce possible feelings of displacement.
- A Town Right of First Refusal allows the Town more time to generate funding for the purchase of private properties.

Challenges:

- The 2070 flood inundation probabilities suggest severe flooding. This approach is not aggressive in terms of mitigating negative impacts in the near-term.
- The Town must manage the program for multiple decades which may create planning challenges if only some properties are acquired, and then the entire area cannot function efficiently as a working floodplain.
- Litigation is possible.

Transfer of Development Rights (Long-Term)

The Town could incorporate a transfer of development rights overlay district into their current zoning in order to shift development trends from high probability inundation areas to areas with lower risk. Transfer of Development Rights (TDR) is a land use regulation tool that uses incentives as compensation for stripping property owners of their current development potential and 'sending' the rights to other, 'receiving' areas deemed more suitable for development.

The Rhode Island Government Planning Agency defines TDR as "a voluntary and market-based tool used to direct development away from environmentally sensitive "sending" areas and into "receiving" areas with the desire and capacity for more development."

The Town of Sandwich is an ideal locale for adopting TDR because there is ample open space that could be deemed suitable for future development. Such development could also contribute to the prosperity of the Town through economic and community development. As sea level rise continues to impact the Cape, municipalities will need to consider how to protect their tourism 'assets'. One strategy is to conduct a planning study now to determine a suitable new locus of mixed-use development. At the same time, this proactive regulatory tool adapts the Town to flood impacts on a broader scale. Actions should also be taken to protect the Town's historic center – balancing an armor and retreat approach to climate change planning which emphasizes positive public benefits as well as preservation.

Benefits:

- TDR contributes to new growth and development.
- TDR protects existing natural resource areas from future development.
- TDR opens the area around existing natural resource areas in order to accommodate the migration of those resources due to sea level rise. Wetland migration is one example.
- TDR is a proactive land management strategy that takes into account the encroachment of land caused by sea level rise.
- TDR helps to reduce financial losses caused by flood damages to new developments.
- TDR can reduce Town-wide National Flood Insurance Premiums by reducing the number of properties in the FEMA Special Flood Hazard Area.
- Protects future residents from flood risks associated with living in new developments in the high probability inundation area.
- TDR can mitigate negative feelings that profit is being 'taken' from developers and landowners by providing new opportunities through incentivized development.

Challenges:

- Coastal properties are often valued higher due to beach access, viewsheds, and tourism.
- TDR requires a market for new development – if the Town is already struggling to bring in developers, it will be difficult to incentivize developing 'inland' areas.
- TDR may face resident opposition due to negative perceptions of new development and an 'armor in place' mindset common to beachfront communities.

Moratorium on New Development (Long-Term)

The Town could put a moratorium on all new development in the high probability inundation area. This is the most progressive approach to 'managed retreat' without acquiring existing properties. This strategy does not mitigate risk for current property owners, but it reduces future risk for new residents and decreasing financial losses from flood damages.

Putting a moratorium on development in flood vulnerable areas shifts development opportunities to inland areas in a similar fashion to the Transfer of Development Rights Strategy. However, the moratorium does not have to rely on voluntary participation or the award of incentives to developers. This type of strategy may be necessary if there is not a strong interest in development.

Benefits:

- A moratorium ensures that no new residents are put at risk.
- A moratorium is simple to implement in that it does not require ongoing administration.
- De facto shifts development opportunities to lesser risk areas.

Challenges:

- A moratorium requires state enabling legislation.
- A moratorium limits potential for growth of local tax base from coastal development.
- A moratorium can be contentious.

Rolling Easements (Perpetual)

The Town should consider a rolling easement program. This program would be part of a long-term and/or phased managed "retreat" program to be implemented in areas subject to severe and repeated flooding. Rolling easements are a potential way to provide cash to a property owner today with the understanding that when the property is substantially damaged, it will not be rebuilt and will be turned over to the Town. Based on information provided in the latest Town of Sandwich Hazard Mitigation Plan Update dated January 2012, there are 235 total "repetitive loss" properties in Sandwich, each having had at least two or more flood claims of $1,000 or more in any given 10-year period since 1978. These properties might be ideal candidates for such a program as they have already experience repeated flood damage in the past. It is likely that these properties will experience more claims in the future unless they have been elevated or otherwise protected from flooding. Four of these properties have experienced five or more claims related to flooding.

The Natural Resources Conservation Services (NRCS) Emergency Watershed Protection Program EWP – permanent floodplain easements program is a useful case study. The primary function of EWP is restoration of natural resources: "Restoration may include both structural and non-structural measures to bring back floodplain functions such as water storage and flow, control erosion, and establish native vegetation" (USDA, NRCS).

Benefits:

- Rolling easements allow property owner to maintain ownership until substantial damage occurs.
- Rolling easements allow the Town to be the permanent stewards of the natural resource area in order to best preserve or restore its function.
- Rolling easements respond to direct impacts rather than projected impacts, which may reduce a property owner's resistance to acquisition.

Challenges:

- It may be hard to implement a comprehensive restoration plan if all land is not acquired at the same time.
- The 'rolling' nature of the program requires overview over multiple decades.

- The 'rolling' nature of the program may undermine the near-term resilience benefits if there is a limited amount of land available for restoration.

4.4. STRATEGIES FOR MUNICIPAL ASSETS

For specific critical municipal infrastructure assets and buildings, it may be necessary or preferable to implement strategies at the asset level to adapt to flooding. Asset level strategies are particularly needed for assets located in high flood risk areas for which regional strategies have been rejected for technical, political, or financial reasons. It is also necessary for assets that are outside of the scope of regional flood protection strategies. Asset level adaptation is also preferable for very critical assets that cannot afford to wait until regional solutions are implemented.

In the following sections, adaptation options are recommended for assets in each High-Risk area, with additional guidance for decision makers and designers. Order-of-magnitude cost estimates, in 2019 dollars are provided, where possible, for long-term planning purposes. These costs in no way are meant to represent actual estimates of total project costs as no surveying, subsurface exploration, engineering design, permitting and escalation of costs was performed as part of this project, all of which are necessary to establish true project costs required to design and construct a project.

4.4.1. Facilities

The suite of options for building adaptations was presented in Section 4.3.1. These strategies may be applied as needed to vulnerable facilities in the Town of Sandwich, considering further site-specific investigations and suitability analyses.

MC-FRM results indicate that the Downtown Fire Station complex (station, outbuilding, generator, propane tank, and parking lot) is the most vulnerable municipal facility in the Town of Sandwich. It is also the only municipal facility that is at risk of inundation under present day conditions; in fact, 2018 Nor'easters flooded the parking lot and Route 6A surrounding the Fire Station, impeding operations and forcing the crew to park essential vehicles at a high spot across the street. For these reasons, and due to the increasing risk of inundation in the future, the Fire Station (Sandwich Fire Station No. 1) was selected for conceptual-level site adaptation planning.

Fire Station No. 1 Conceptual Level Adaptation

The MC-FRM model results at the 2030-time horizon indicate that the Fire Station No. 1 building is susceptible to coastal flooding during a 5% recurrence event (i.e., 20-year return period event), and that the flood depth at the building's edge during a 100-year storm event would be 1.5 feet or greater. By 2070, MC-FRM model results show that inundation is experienced more-or-less annually (i.e., 100% recurrence event) at this location. In the absence of a regional solution to protect this area, the 2070 flood depth during a 100-year storm event is 5 feet or more across the entire property.

The Town has been in discussions regarding the transfer of operations from this station to the newly constructed emergency service center at 255 Cotuit Road in central Sandwich. Currently, the Downtown Fire Station only serves as a satellite (or local) service center. Operations staff have been moved to the new emergency center. The Downtown station is staffed by essential crew required to respond to an emergency. However, the Downtown Station remains the only maintenance center for all emergency vehicles within the Town. The maintenance garage, as shown in Figure 4-10, contains oils and greases and numerous hazardous waste materials that would create a significant release of pollutants if flooded. It is strongly recommended that the Town work with the Massachusetts Office of Technical Assistance and Technology (OTA) to help the Town comply with the Toxics Use Reduction Act.

Figure 4-10. Fire Station – Maintenance Garage

It is recommended that a phased retreat (i.e., migration of remaining operations and equipment to the centralized Fire Department site) occur in the near-term. As part of this strategy, some of the Department's uses for this building could remain operational and be protected using dry-floodproofing strategies at the building edge. For example, the building's garage doors and entryways could be equipped with deployable flood barriers such as Presray stackable "stop log" systems (Figure 4-11). Additional building floodproofing would be required to elevate outdoor mechanical equipment (HVAC units), protect low air vents, and repair deteriorating masonry pointing and concrete block walls.

For other assets, such as the generator and propane tank (located behind the Station in the back of the property), deployable barriers – such as AquaFence products – could be installed to reduce near-term vulnerabilities.

Costs to implement a suite of building floodproofing interventions and deployable barriers to protect Fire Station No. 1 facility equipment during a storm (while allowing flooding on the Site) would be on the order of $265,000.

Figure 4-11. Stackable Flood Barrier Example.

Other strategies could include a perimeter landscape berm along the north and east property edges to funnel floodwaters (or surge) away from the building edge. Such a strategy may reduce the frequency (or magnitude) of the flooding inside the building but would not be an effective flood mitigation solution (in isolation) beyond 2030.

Costs to construct a 3 ft. high protective berm approximately 460 ft. around the marsh-facing edges of the parcel tied into a high point near the Old Police Station (at the southeast) and into Route 6A (at the northwest) would be on the order of $300,000. This would provide protection for the Fire Station No. 1 complex against all 2030 storm levels, and up to a 10% chance 2070 event, but given site constraints would likely require additional sandbagging or deployable barriers across Route 6A to be fully protective. Costs to implement long-term resilience strategies for the Fire Station would likely be prohibitive for this location, and road access to Route 6A will be a compounding factor. Long term, the Town of Sandwich should develop a plan to relocate this Fire Station to a location that is less vulnerable within the service area.

4.4.2. Infrastructure

For specific critical municipal infrastructure assets and buildings, it may be necessary or preferable to implement strategies at the asset level to adapt to flooding. Asset level strategies are particularly needed for assets located in high flood risk areas for which regional strategies have been rejected for technical, political, or financial reasons. It is also necessary for assets that are outside of the scope of regional flood protection strategies. Asset level adaptation is also preferable for very critical assets that cannot afford to wait until regional solutions are implemented.

In the following sections, adaptation options are recommended for assets in each high-risk area, with additional guidance for decision makers and designers. Order-of-magnitude cost estimates, in 2019 dollars are provided, where possible, for long-term planning purposes. These costs in no way are meant to represent actual estimates of total project costs as no surveying, subsurface exploration, engineering design, permitting and escalation of costs was performed as part of this project, all of which are necessary to establish true project costs required to design and construct a project.

Marina Assets

The Coast Guard fuel tank and elements of the Marina fuel system, such as ball valves and monitoring wells, are vulnerable under present day conditions. By 2030 and 2070, flooding frequency and depth will increase, making these assets susceptible to leakage and failure. Similarly, the Pumpout Tank, Maintenance Garage propane tanks, Emergency Fuel Shutoff, and various fueling infrastructure on G Dock are susceptible at (or before) the 2070-time horizon. It is recommended that all fueling activities be moved toward the Boat Ramp edge of the Marina, near the Harbormaster Office which is situated at higher grade. If this is not feasible, ways to floodproof the system and fortify the fueling dock should be investigated.

For Marina assets attached to docking structures (including Fuel Dock shut off, pumps, monitoring equipment, Fuel Tank Leak Sensors, and Pumpout Station), it is recommended that all equipment is secured to a level that accounts for additional effects of wave action.

The docking structures, themselves, should be assessed to confirm that any floating elements have sufficient vertical room to migrate (during large storm events), without becoming unanchored.

Roadways

Roadways are by far the most vulnerable infrastructure features in the Town of Sandwich. Road segments in low-lying areas (adjacent to or crossing over salt marsh areas) received the highest Risk scores in this assessment. In general, there are a variety of options for adapting roadways to sea level rise and storm surge impacts. These adaptation measures range in intensity based on the criticality of the road as well as the type of inundation that needs to be addressed (e.g. non-essential roads may be allowed to overwash in storms if emergency access is not necessary, but should be designed to be resilient to storm surge impacts and resistant to future daily tidal flooding). MassDOT is currently developing a roadway adaptation handbook, which can be consulted for a variety of adaptation strategies. Strategies can include simple raising of the roadbed, resilient side slope green infrastructure treatments to reduce undermining, causeway installation, or bridge construction. Specifics of the site and environmental conditions will inform the selection of appropriate interventions.

Ploughed Neck Road was identified as a high-risk roadway in this assessment, and advanced for conceptual-level adaptation since it is a north-south roadway crossing a marsh that serves as the only access point for dense coastal development on the barrier beach. It is therefore a critical roadway for emergency services, and solutions developed for it may also be leveraged at other similar low-lying coastal neighborhood access roads in Sandwich.

Route 6A between Sandy Neck Road and Howland Road was also identified as a high-risk roadway in this assessment, and advanced for conceptual-level adaptation since – although it is a State-owned roadway – it is a major corridor and critical emergency access route for Sandwich Police and Fire. Solutions developed for this segment of Route 6A, which crosses an insufficiently connected marsh system, may also be leveraged at other similar low-lying marsh crossings in Sandwich.

Ploughed Neck Road Conceptual Level Adaptation

The critical elevation for Ploughed Neck Road is 10.2 ft. NAVD88, based on the 2016 DEM. MC-FRM results indicate that there is potential flooding over the roadway in current conditions beginning at the 0.5% level, with about 1 foot of water on the roadway in a 0.1% chance event. By 2030, inundation probability increases to 2% (i.e. the 50-year return period event), and projected flood depths are about 1 ft. for the 1% chance event, and almost 2.5 ft. for the 0.1% chance event. The probability of inundation at Ploughed Neck Road by 2070 increases to 50% (on average every other year), and flood depths are almost 5 ft. for the 1% chance event, and over 6.5 ft. for the 0.1% chance event.

Over the near- to mid-term, adaptation options for Ploughed Neck Road are limited, but feasible. Construction of a causeway approximately two feet higher than current conditions with an operable tide gate would drastically reduce flooding in the near term – a 2030 0.1% chance event storm surge would overtop the roadway with less than six inches of water. The increased elevation would reduce 2070 inundation probability to 20% (i.e. the 5-year return period event, but flood depths would exceed 1 ft. for anything greater than the 10-year return period event. The reconstructed roadway would eliminate future tidal (sunny day) flooding, reduce the occurrence and severity of storm inundation, and should be constructed with green infrastructure hybrid side slopes to be resilient to storm surge impacts.

Long-term planning for the roadway should focus on maintaining everyday access, as long as it is feasible to maintain residential homes on the barrier beach and dune system, and ensuring the roadway is resilient to storm impacts. At some point, it may make sense to discuss managed retreat. This roadway adaptation also presents an opportunity to complete a salt marsh restoration in the upstream reaches of Long Creek (west of Ploughed Neck Road). An operable tide gate could allow for restored tidal flow in the future, provided concerns about cranberry agriculture can be resolved. The operable gate could remain open, providing ecological benefits and encouraging salt marsh migration, but could also be closed on occasion to limit storm surge propagation up Long Creek.

Costs to construct a causeway across the low-lying segment of Ploughed Neck Road (between North Shore Boulevard and Barbara Lane) 2 ft. higher than the existing roadbed (to 12.2 ft. NAVD88) approximately 800 ft., with an operable tide gate at the Long Creek crossing, would be on the order of $750,000. This would provide protection for emergency access up to and including the 2030 0.2% chance event (i.e. the 500-year return period event) and reduce road inundation to manageable levels for the high probability 2070 events. The strategy would likely *require additional roadbed elevation along North Shore Boulevard to tie into the grade, which would add to these costs. A discussion of risk tolerance and long-term planning for this vulnerable area would inform the design elevation of such a strategy, if implemented, which would influence cost.*

Route 6A (Sandy Neck to Howland) Conceptual Level Adaptation

The critical elevation for Route 6A between Sandy Neck Road and Howland Road is 7.9 ft. NAVD88, based on the 2016 DEM. MC-FRM results indicate that there is potential flooding over the roadway in current conditions beginning at the 10% level, with almost 2 foot of water on the roadway in a 1% chance event. By 2030, inundation probability increases to 50% (on average every other year), and projected flood depths are over 3 ft. for the 1% chance event, and over 4.5 ft. for the 0.1% chance event. The probability of inundation on this segment of Route 6A by 2070 increases to 100% (annual), and flood depths are over 7 ft. for the 1% chance event, and 9 ft. for the 0.1% chance event.

Since Route 6A is a critical roadway for the Town and the Region, adaptation designs are necessary to maintain emergency access during storms and to get the low-lying roadway out of the future tidal inundation zone. Since roadway infrastructure have long design life expectancy, it makes sense to plan to the 2070 1% inundation level (assuming no major land use changes occur in that timeframe that would reduce the criticality of Route 6A). The 2070 1% water surface elevation is 15.0 ft. NAVD88. Given the approximate 7-foot rise needed to get the roadway out of the risk zone, a bridge span is necessary. The bridge over the Scorton Creek wetland area would span approximately 550 feet, and then transition to elevated roadway segments on either end that tie in to high spots in the landform at #680 MA-6A (Mrs. Mugs Gift Shop) on the western end and #85 Main Street in Barnstable on the eastern end. The segment of roadway elevation to tie into the 15.0 ft. NAVD88 design elevation of the bridge would be approximately 1,050 feet long.

In addition to preserving daily access into the future and accommodating increasing storm surge for emergency access, the conversion of the roadway to a bridge span would have ecological benefits by restoring the full tidal connection between the Barnstable and Sandwich upper reaches of Scorton Creek.

Costs to construct a 550 ft. bridge span across Scorton Creek and elevate the roadbed tie-ins (to Sandy Neck Road and to Howland Road) approximately 3 ft. over 1,080 ft. would be on the order of $12,150,000. This would provide protection for emergency access up to and including the 2070 1% chance event (i.e. the 100-year return period event). Since this is a State-owned roadway spanning the Sandwich/Barnstable line, cost sharing would need to be coordinated.

4.4.3. Historic Assets

The Town should consider a Cultural Hazard Mitigation Plan, which is a district-level plan that specifies adaptation strategies for protecting and preserving the Town's most vulnerable historic assets within the Downtown. The Plan also outline a new, or mimic existing historic landmark districts, but these districts are designated based on predicted climate change impacts. The Town should involve community stakeholders to identify specific assets, which may go beyond historic structures, which may illuminate other public or economic values. A potential district that encompasses Town Hall, the Grist Mill, the Shawme Pond Natural Spring, and Town Hall Annex is recommended for consideration as these assets are at risk of future flooding stemming from Mill Creek. The Shawme Pond Spring is a prime example of a unique, community-identified vital asset that, albeit not a traditional historic asset, should be included in the district for protection. The spring's drinking water is at risk of salination due to flood inundation probabilities in this area, thus needing protection in the future.

The City of Annapolis provides a useful case study of this type of cultural hazard mitigation planning process. The City identified the risk of flooding on its historic landmarks district. The Annapolis Cultural Hazard Mitigation Plan (CHMP) emphasized the need to coordinate adaptation measures at a variety of scales including land use and environmental law, public realm strategies, and property level actions in order to adequately protect these historic structures. The CHMP also highlighted that these actions needed to be implemented by the City of Annapolis and private stakeholders. The City conducted extensive public outreach to increase awareness of increasing flood risk, as well as involve the community in the identification of vulnerable, cultural assets. This engagement process helped increase support for the CHMP. Annapolis' plan is proactive, incorporating both a disaster plan to facilitate a more efficient recovery process as well as a resilience plan for decreasing negative impacts. The plan highlights the following objectives:

- Enhance the public's awareness and understanding of potential flood risks. Quantify economic losses to local businesses and incentivize adaptation measures
- Assign field team to property owners to provide technical assistance to develop adaptation strategies
- Develop preservation-sensitive options for a post-disaster regulatory response
- Integrate risk reduction measures into building permitting process
- Adapt publicly owned buildings

The following design considerations could be incorporated into a Cultural Hazard Mitigation Plan with regard to historic building adaptations. These design considerations are intended to help preserve the character of the built environment, while also enhancing the safety of Town residents, as listed below.

1) **Circulation**: if buildings are elevated, ensure that there is a physical and visual connection to the sidewalk and street. Maintain ADA accessibility as necessary.
2) **Character**: The 'street wall' rhythm should be preserved, despite elevated structures. Additions should be in the same architectural style and have a minimal visual impact on the overall aesthetic of the street. When multiple structures are being elevated, they should be elevated in the same style and to the same designated BFE to create continuity.

3) **Maintain historic site features**: Historic hardscaping materials, site design, and planting should be preserved despite building changes. These site elements may include paving, fencing, decorations, outdoor living spaces, etc. When the building is fully elevated, the ground floor space should be used as an extension of this outdoor area and should not be used for parking.
4) **Flood barriers**: When employing flood barrier systems, necessary hardware should have minimal impact on opening frames. Measures should be taken to protect historic materials from damages from salinized water.

Town Hall

The vulnerability assessment for Town Hall (see Appendix D) indicates that storm surge may crest the rear basement entry elevation (12.16 ft. NAVD88) in a 0.1% chance event in 2030. By 2070, the model projects storm surge could come up Mill Creek and flood the Town Hall basement, which houses the building's mechanical equipment, in a 20% chance event (i.e. the 5-year return period event). In a 2070 1% chance event, storm surge could reach the height of the main floor, which currently houses Town administrative offices. A 2070 0.1% chance event could flood the first floor of Town Hall with almost two feet of water (4.4 feet above the critical elevation of the rear basement entry). There are several adaptation strategies the Town can consider, as listed below.

1) **Floodproof Basement:** The critical elevation for Town Hall was established as the basement entry at the southeast corner of the building because the basement contains significant mechanical equipment. Measures to floodproof the basement, including barriers at the basement entrance and measures to cover the vents along the eastern foundation wall, will be the single most important measure to take in the mid- to long-term, since storm surge is not projected to crest the first floor until a 2070 1% storm, and is only projected to start flooding the basement mechanical room at the 2030 0.1% level.
2) **Temporary Programming**: The first floor of Town Hall can be repurposed as a temporary, event space that the Town rents out for community events. Because the Town plans on relocating the everyday activities of Town Hall for municipal governance, this historic structure is available as a community asset. By transitioning the first floor to temporary uses programming, there is less likelihood of flood damage because space remains free of permanent fixtures, furniture, and equipment that could be damaged in a flood event. This is the lowest impact strategy in terms of cost and effort and does not mitigate damages to the structure or materials of Town Hall.
2) **Elevate the first floor from the interior**: Because the exterior, masonry basement enclosure is semi-above grade and the current first-floor entrance is already elevated above grade, the first floor would need to be elevated less than two feet to account for the predicted 2070 0.1% inundation depth. Given the building's floor to floor height, it would be possible to elevate from the interior, leaving the historic façade in place. The

Town would need to add several additional stairs to the entryway to maintain a circulative connection to the sidewalk.

3) **Change grading around the building**: A site-scale option requires adjusting the grading around the building to reduce the amount of flooding that is accumulating on the East side of the building where the grade dips down toward the Shawme Pond outlet. Use of cut and fill strategies to level the area at the building base to direct floodwater towards the waterway. Heighten the raceway wall to hold back new fill on the building side and increased water on the Shawme Pond outlet side. The Town will also need to consider the impacts of reservoir overtopping.
4) **Partial building elevation**: The Town might consider expanding the masonry plinth of the existing building and elevating the wood frame construction above the BFE. By expanding the masonry wall, there is an increased, impervious buffer to mitigate flood damages.

Figure 4-12. Town Hall – BFE 12.16 ft. NAVD88 / DFE 16.0 ft. NAVD88

Sand Hill School

The vulnerability assessment for Sand Hill School Community Center (see Appendix D) indicates that storm surge may reach the basement windows and rear basement hatch critical elevation (14.88 ft. NAVD88) in a 0.5% chance event in 2070 (i.e. the 200-year return period event). A 2070 0.1% chance event could flood the first floor (1.5 feet above the critical elevation). The overall approach for the Sand Hill School building should be to adopt a wait and see approach, as there is no risk of flooding until the 2070 horizon. When appropriate, there are several adaptation strategies the Town can consider, as listed below.

1) **Deployable Flood Barriers**: The 2070 0.1% flood inundation depth is around 1.5 feet, so the school could invest in deployable flood barriers to be installed across the main entry vestibule, as well as to protect basement windows and the basement hatch at the rear of the building.
2) **Building Elevation**: Although the Sand Hill School was recently renovated, elevating the entire structure would be relatively simple due to the construction type (granite block foundation, with wood frame construction). The existing foundation could be left in place and the wood frame walls elevated. If the building were to be elevated, the first floor should be elevated approximately 1.5 feet.

Figure 4-13. Sand Hill School – BFE 14.88 ft. NAVD88 / DFE 16.4 ft. NAVD88

4.5. POLICY AND REGULATORY CHANGES

Changes in municipal practice are important for the successful implementation of climate resilience measures. In particular, planning and implementing actions for, climate resilience takes coordinated, concerted effort. Therefore, it is important for all municipal departments and committees (e.g. finance, selectmen, natural resources, open space, emergency, public works, planning) to work collaboratively on this issue. The function actions of each and every department will eventually be affected by climate changes and will need to rely on each other to conduct their work and implement resiliency measures described herein and recommendations to come. While this overarching recommendation may require additional strategic planning and coordination efforts, short-term strategies could include the following:

- Create a climate committee comprised of representatives from each municipal department, and possibly community stakeholder groups, to meet regularly to discuss the findings herein, and future actions needed (focused on mitigation *and* adaptation);
- Develop policies for public projects that incorporate the anticipated effects of long-term sea level rise and promote more sustainable practices throughout the community via:
    - Requiring that all Town-funded projects take predicted impacts of long-term sea level rise into account, and
    - Developing a regular (perhaps bi-annual) inventory/report of actions taken by the community to improve resilience to climate change and sea level rise.

The Town should consider acquiring land adjacent to coastal resource areas to accommodate changing conditions of natural resource areas due to climate change. Areas of particular interest are those identified in this study as areas of potential resource change and/or migration. Specific actions that the Town should complete, via leadership by the Town's Open Space Committee, include (but are not limited to):

- Use the natural resource information provided in the Climate Change Vulnerability Assessment and Plan to identify priority areas for acquisition through easements, fee interest or purchase of development rights to address the projected effects of sea level rise; and
- Include the above priorities in the next update to the Town's Open Space and Recreation Plan.

It is important for the Town to also develop policies for public projects that incorporate the anticipated effects of climate change and sea level rise and promote more sustainable practices throughout the community, such as:

- Require that all Town-funded projects take into account predicted impacts of climate change and sea level rise;

- Evaluate the Town's Hazard Mitigation Plan in the context of this study and amend as appropriate. Include a documentation requirement/goal to build data on the impacts of coastal storms to inform implementation of future adaptation measures;
- Develop a regular (perhaps bi-annual) inventory/report of actions taken by the community to improve resilience to climate change and sea level rise;
- Consider installing an automated tide gauge in Old Sandwich Harbor to help monitor actual sea level rise locally and provide important data for the design and implementation of future adaptation projects (approximate cost = $5,000);
- Consider developing a Coastal Flood Operations Plan to prepare for and minimize flood damage due to coastal flooding as a result of extreme weather events. The plan will help to institutionalize flood prevention actions that need to be performed before, during and after a major storm. Specific elements of this Plan should include:
    - Utilization of actual maximum predicted water elevations for a storm,
    - Clearly define what the sources of data are and who makes the decision to implement the plan,
    - Clearly define actions to be taken based on the maximum predicted water elevations, parties responsible to perform the actions and timelines required to implement the actions,
    - Include actions relating to pre-storm mobilization, monitoring during the storm, and post-storm recovery,
    - Identify training, storage, and maintenance needs for any specific equipment such as temporary flood barriers,
    - Facility-specific instructions located on-site for easy access during pre-storm mobilization, and
    - Incorporation into the Town's overall emergency response planning documents.

A thorough review of the Town's by-laws and regulations relevant to climate change and resiliency was conducted to gain an understanding of the purpose and scope of these laws and potential limitations with respect to the implementation of climate resilience measures. In cases in which existing laws and regulations restricted public or private property owners from adopting climate-resilience measures, recommended changes have been offered. For the purpose of this analysis, climate-resilient measures are those that:

- Protect natural resources and land uses from the impacts of climate change;
- Accommodate existing land uses by making required adjustments and adaptations to the impacts of climate changes; and/or
- Manage Retreat from extremely vulnerable areas using laws, policies, and procedures that account for the impacts of climate changes.

These measures intend to reduce adverse impacts to public or private property owners by supporting environmental protection, public health and safety, and economically feasible and sustainable growth in appropriate locations. Specific regulatory changes are explained in Appendix E.

4.6. SUMMARY

The adaptation recommendation in this section are a menu of strategies, some general and some specific, that the Town of Sandwich may consider for future implementation to build coastal resilience to future sea level rise and storm surge hazards. In many cases, these strategies are preliminary in nature and would need further refinement in the design phase. Monitoring for implementation thresholds as well as adjusting risk and vulnerability assessments over time given evolving projections will be important elements in the Town's coastal resilience program. Additionally, these coastal resilience initiatives would benefit from a cross-departmental discussion of risk tolerance and cumulative risk. This vulnerability assessment and adaptation plan defaults to the 1% and 0.2% chance inundation events (i.e. the 100-year and 500-year return period events), but certain assets may be better designed to higher or lower risk thresholds.

The analyses conducted for this project and described in this document are also a resource for conducting Town-wide vulnerability assessments (for non-municipal assets) and other planning efforts. The supporting MC-FRM, SLAMM, and asset data accompanies this report in a digital deliver.

5.0 REFERENCES

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APPENDIX A COASTAL INUNDATION MAPS

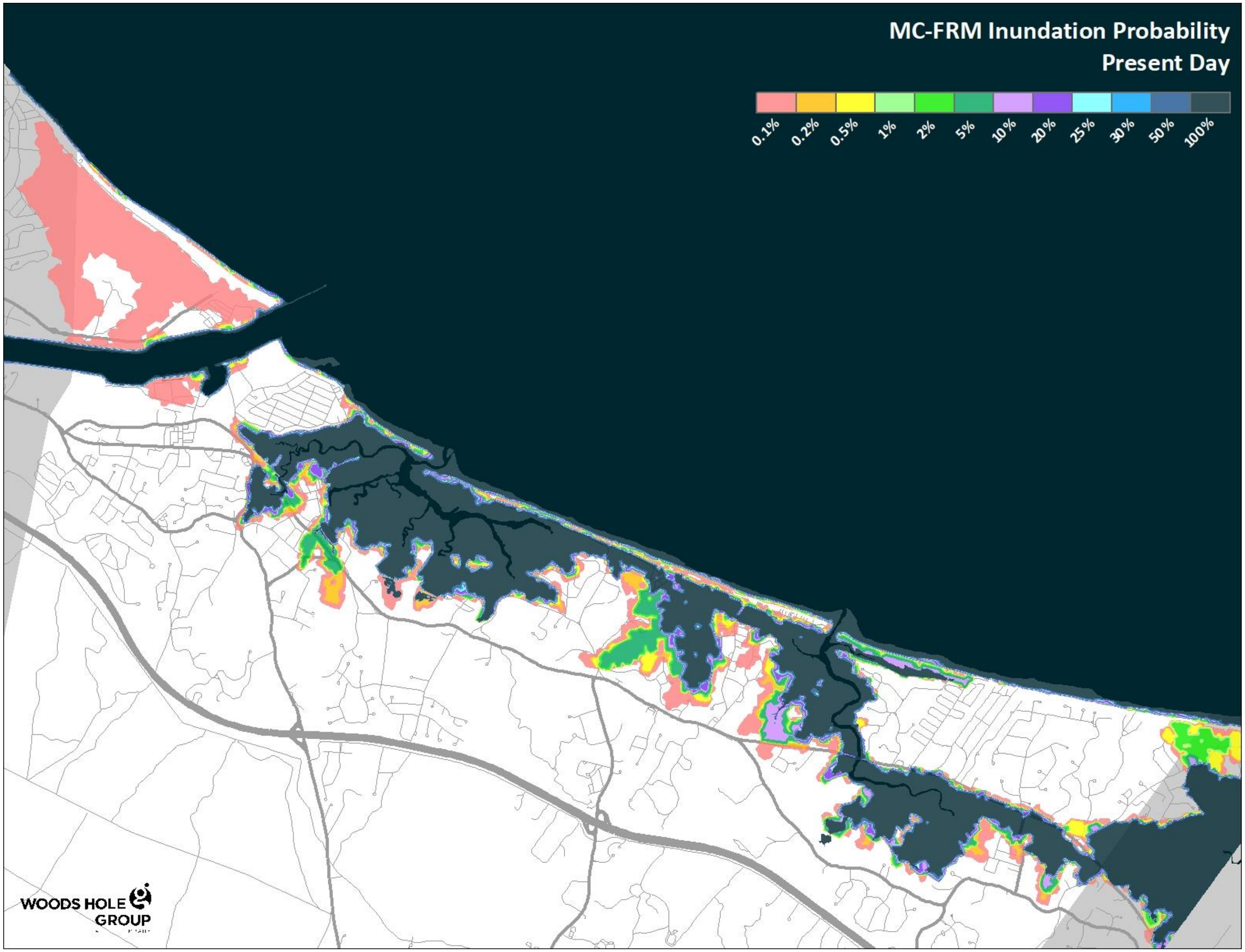


Figure A-1. MC-FRM Present Day Inundation Probability

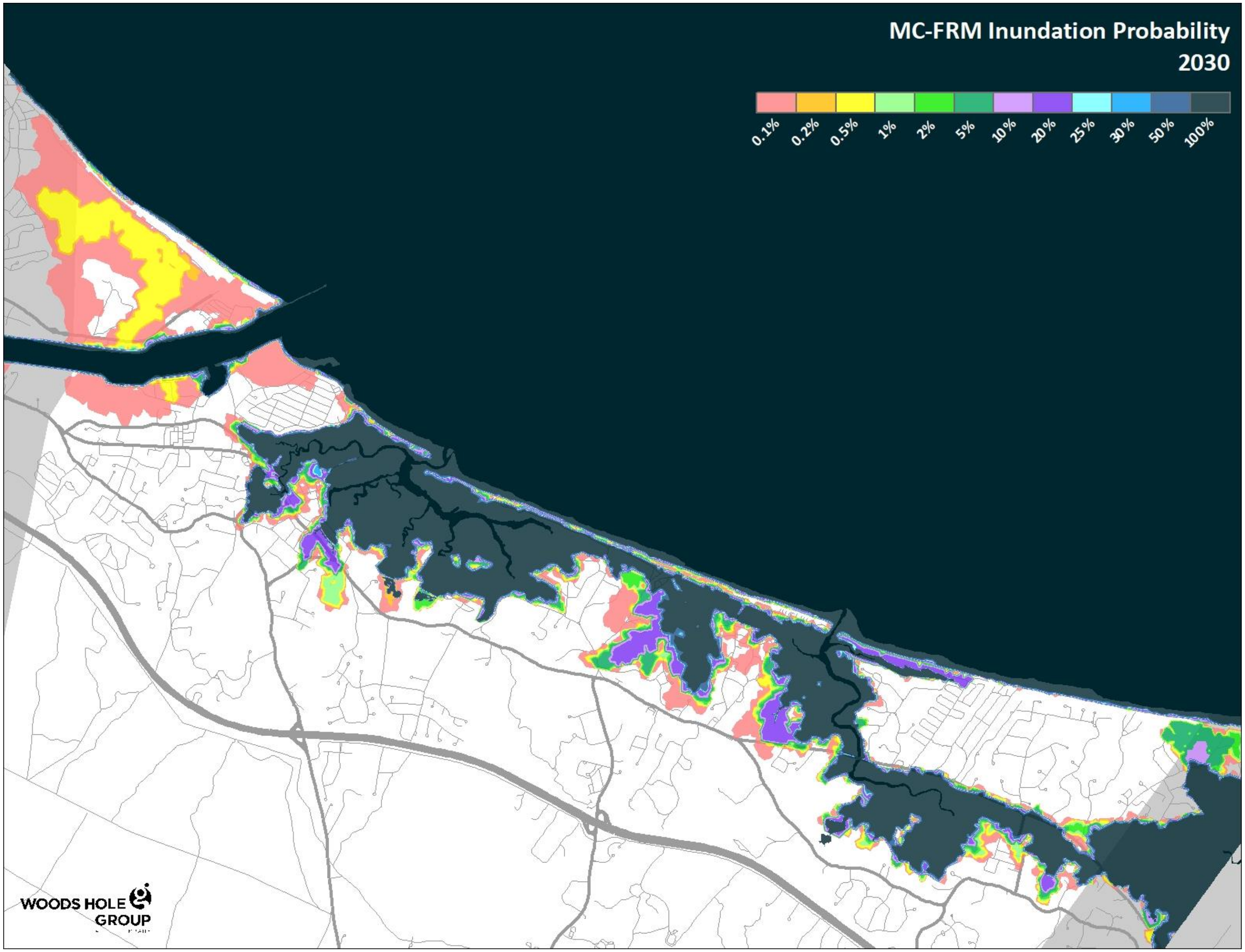


Figure A-2. MC-FRM 2030 Inundation Probability

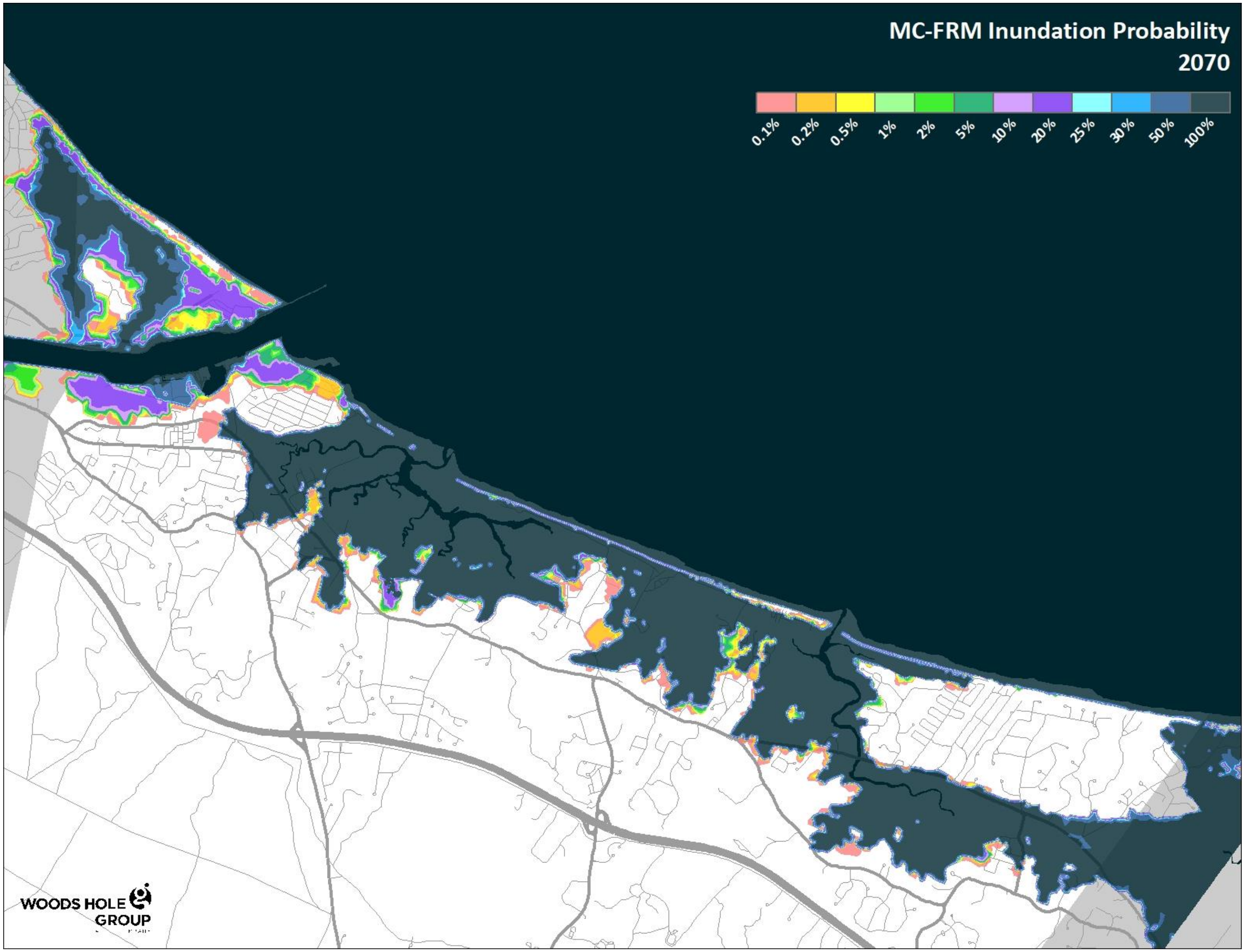


Figure A-3. **MC-FRM 2070 Inundation Probability**

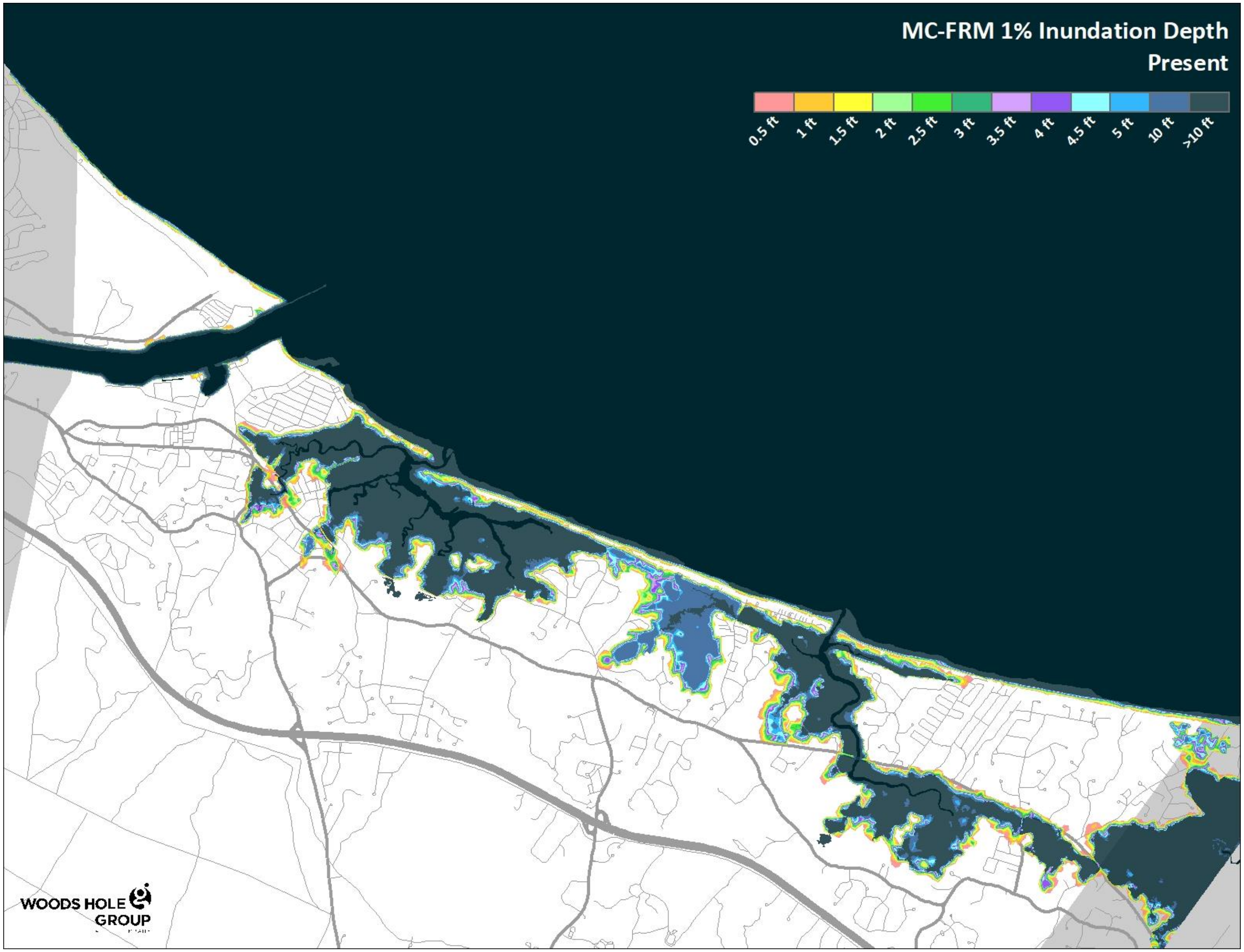


Figure A-4 MC-FRM Present Day 1% Inundation Depth

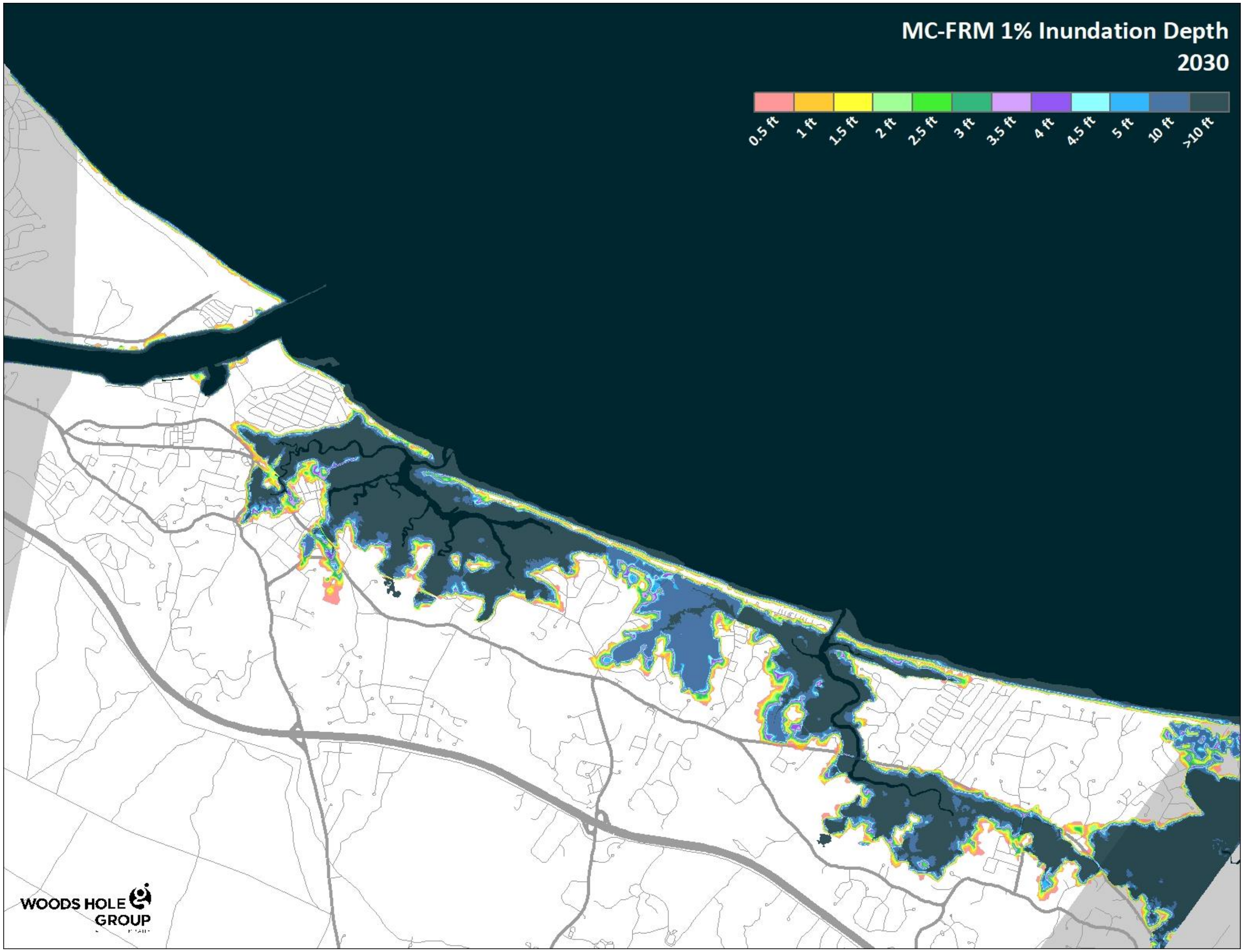


Figure A-5. MC-FRM 2030 1% Inundation Depth

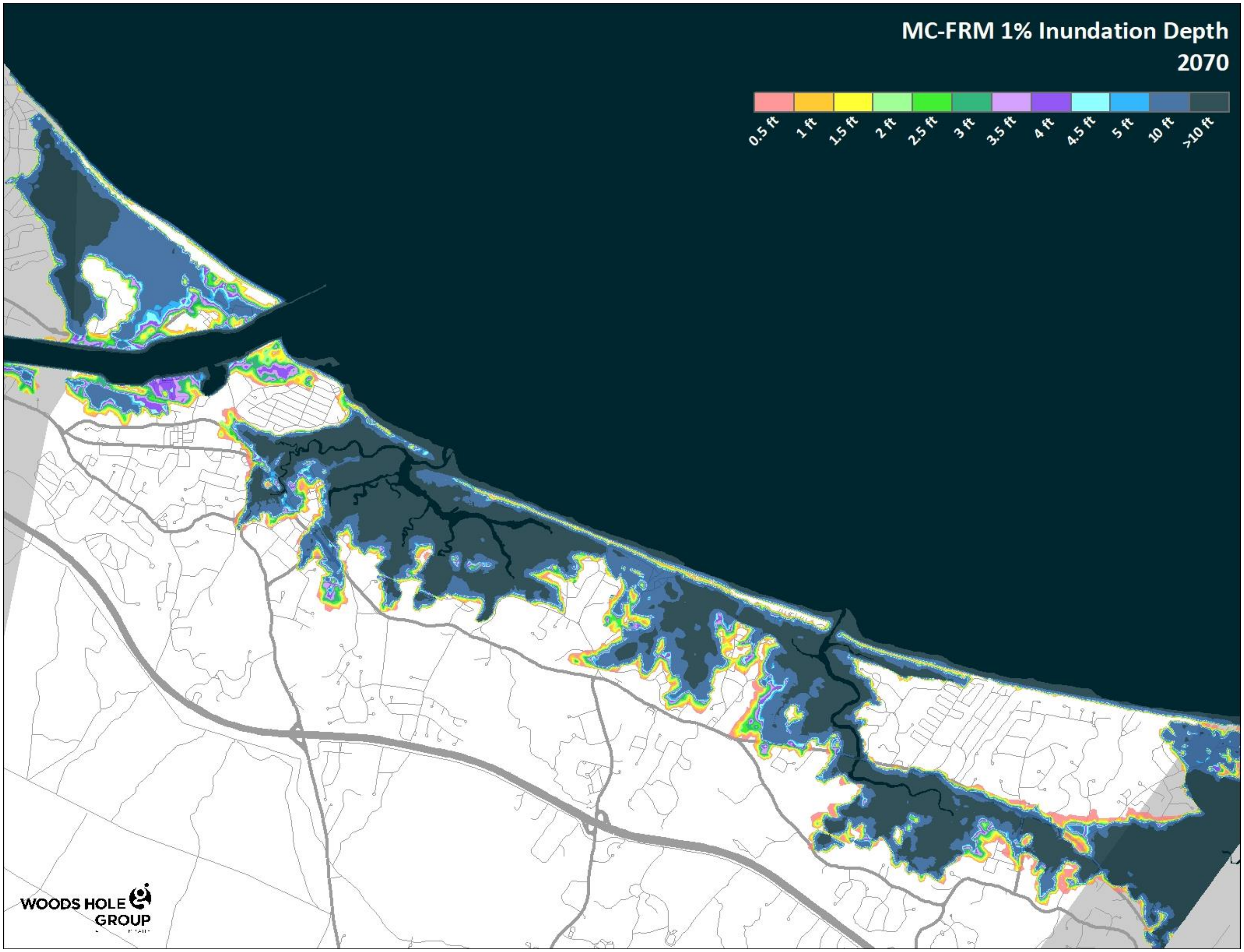


Figure A-6. MC-FRM 2070 1% Inundation Depth

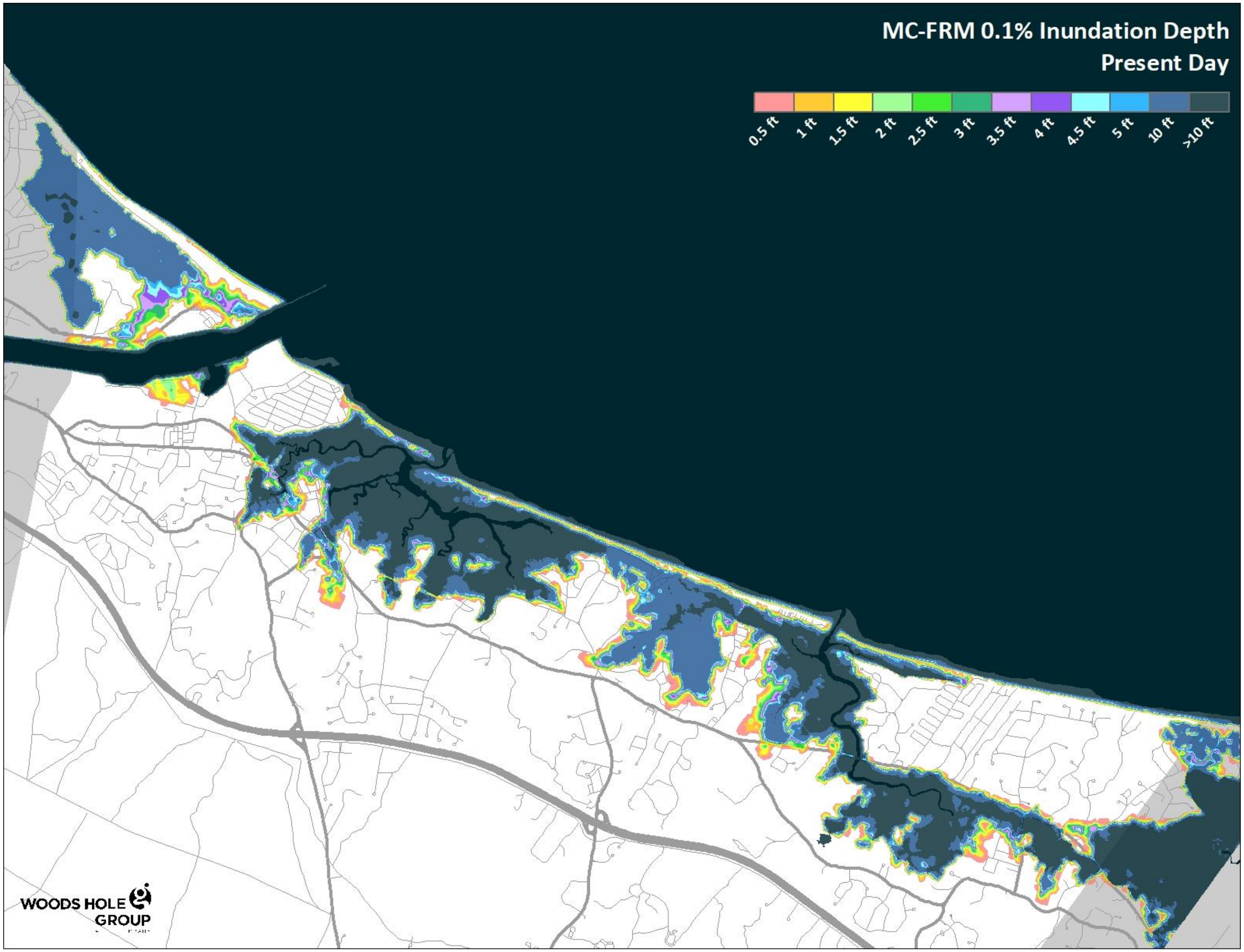


Figure A-7. MC-FRM Present Day 0.1% Inundation Depth

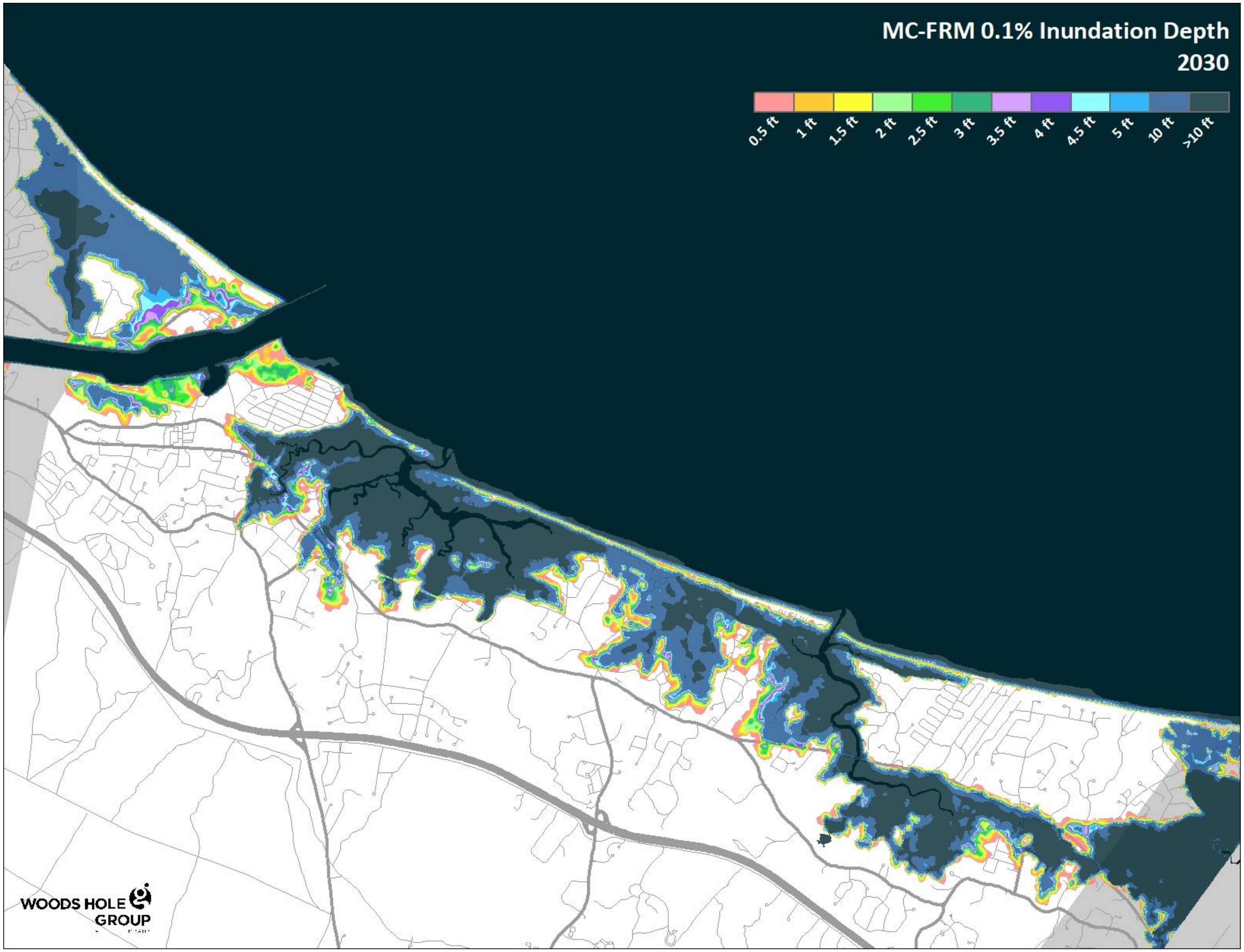


Figure A-8. MC-FRM 2030 0.1% Inundation Depth

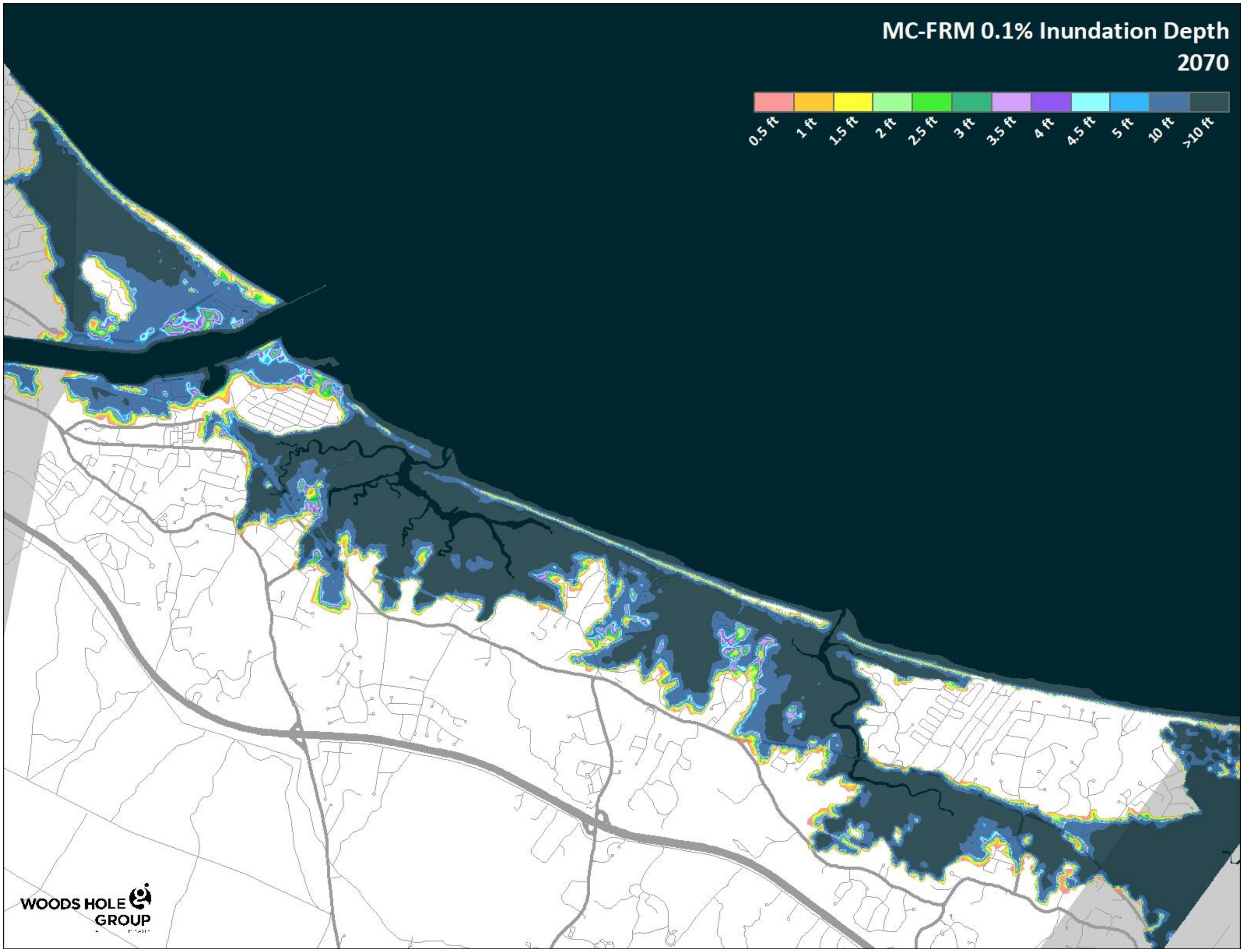
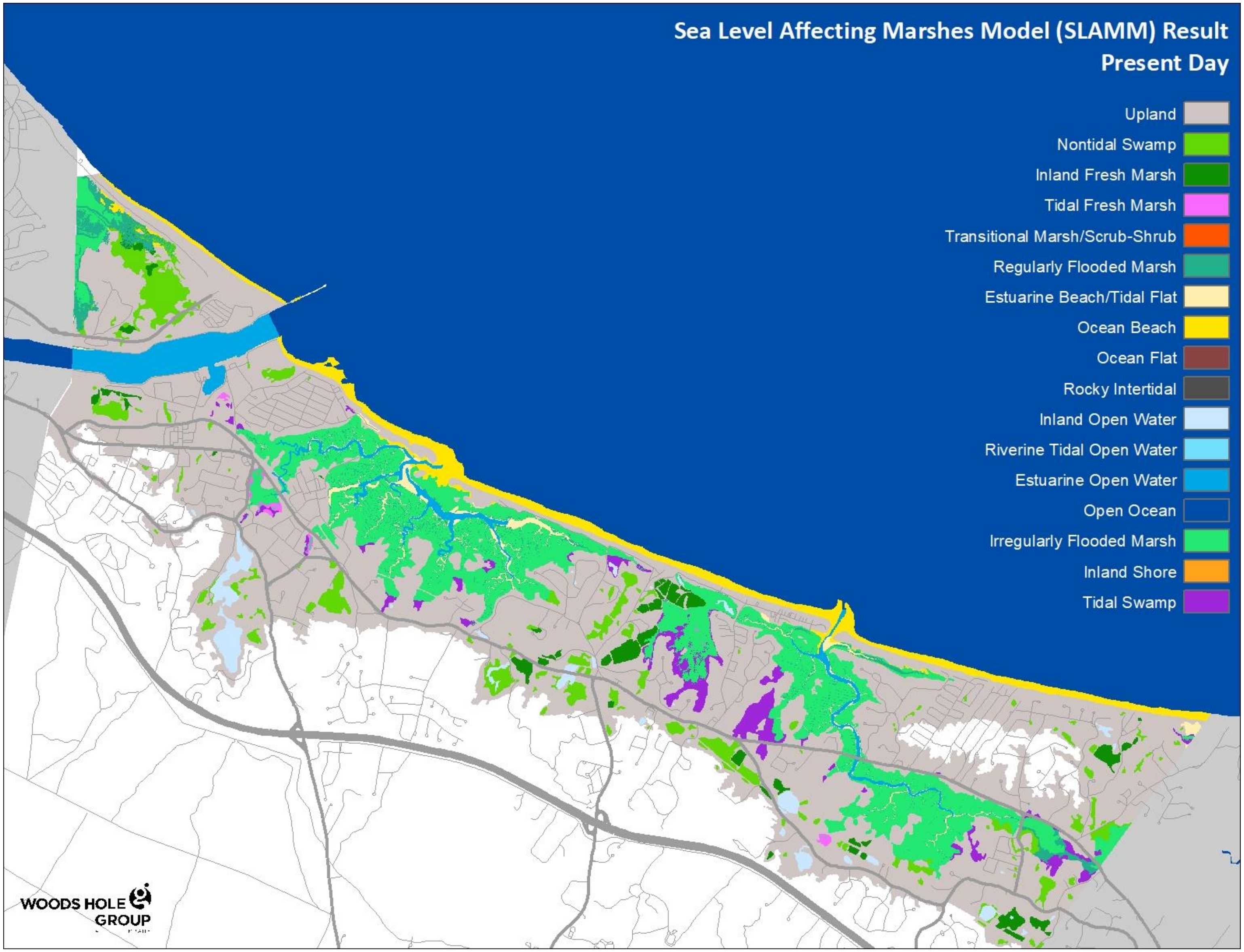
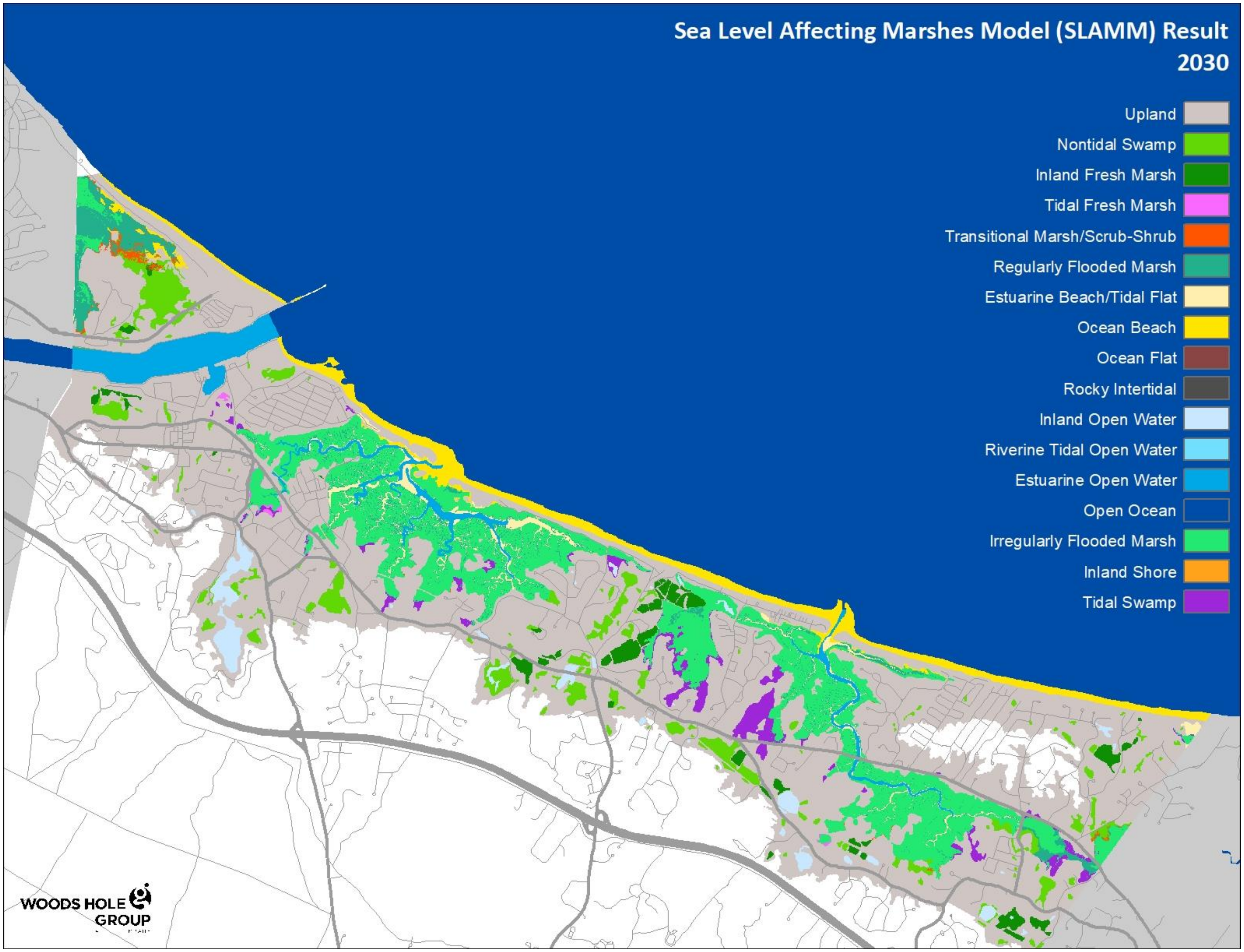


Figure A-9. MC-FRM 2070 0.1% Inundation Depth

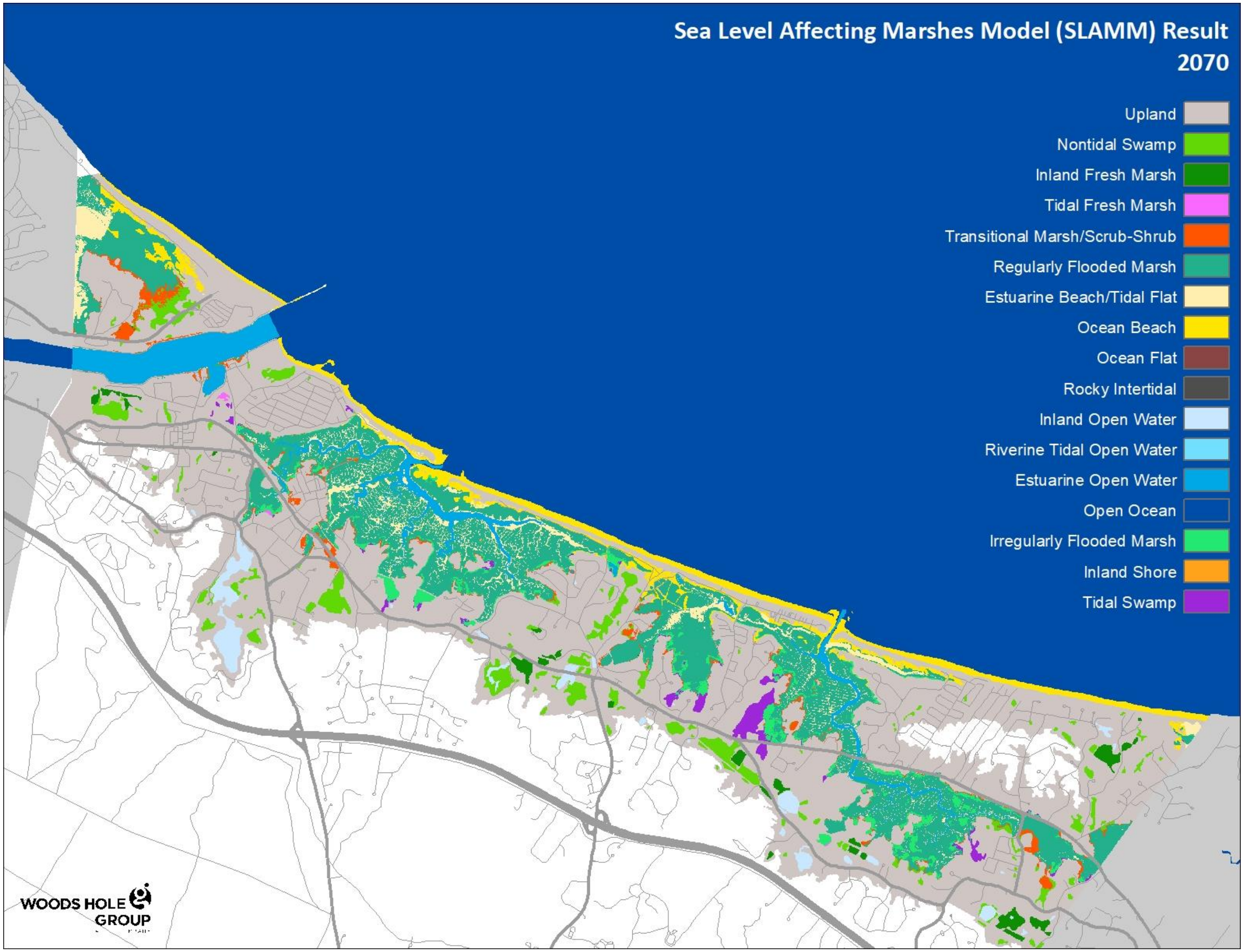
APPENDIX B WETLAND CLASSIFICATION



B1: 2011 – Wetland Classification Areas in Town of Sandwich



B2: 2030 – Wetland Classification Areas in Town of Sandwich



B3: 2070 – Wetland Classification Areas in Town of Sandwich

APPENDIX C RISK DATA AND CONSEQUENCE SCORING

Table C-1. Vulnerable Municipal Assets' Consequence Scores, Probabilities of Flooding, and Risk Scores

(Colors indicate which risk score quartile the asset is in for the given time horizon. Red = High, Orange = Moderate-High, Yellow = Moderate-Low, Green = Low. In addition, Pink = High risk score with very low consequence)

Asset Name/ Asset Number	Asset Type	Consq. Score	Prob. Present	Risk Present	Prob. 2030	Risk 2030	Prob. 2070	Risk 2070	Composite Risk
Boardwalk	Ped. Bridge	19	50.0%	3958	100.0%	7917	100.0%	7917	5938
Fuel Ball Valves (monitoring)	Marina Assets	17	50.0%	3542	100.0%	7083	100.0%	7083	5313
Observation Dock	Marina Docks	11	50.0%	2292	100.0%	4583	100.0%	4583	3438
Boardwalk Road Parking Lot	Parking	14	33.8%	1970	60.6%	3533	82.5%	4815	3008
Fuel Monitoring Well - Middle	Marina Assets	17	10.0%	708	50.0%	3542	100.0%	7083	2833
Coast Guard Fuel Tank	Marina Assets	20	2.0%	167	30.0%	2500	100.0%	8333	2500
Commercial Unloading Pier	Marina Docks	20	2.0%	167	25.0%	2083	100.0%	8333	2375
Town Neck Beach Parking Lot	Parking	14	23.4%	1365	37.8%	2203	75.6%	4409	2225
Fire Station	Facility	24	0.5%	50	5.0%	500	100.0%	10000	2175
Sandwich Police and Fire Headquarters Parking Lot	Parking	16	3.3%	220	9.8%	656	75.1%	5005	1308
Sandwich Police and Fire Headquarters Parking Lot	Parking	16	4.5%	302	8.0%	534	73.2%	4880	1287
Commercial Fishing Dock (F Dock)	Marina Docks	14	0.5%	29	5.0%	292	100.0%	5833	1269
Sandwich Police and Fire Headquarters Parking Lot	Parking	16	1.2%	82	4.1%	270	74.7%	4979	1118
East Sandwich Fire Station Parking Lot	Parking	16	0.1%	4	0.3%	21	73.3%	4887	986
Police Station (septic tank)	Facility Septic	9	5.0%	188	10.0%	375	100.0%	3750	956
1500 Gallon Pumpout Tank	Marina Assets	19	0.0%	0	0.5%	40	50.0%	3958	804
Fire Station (septic tank)	Facility Septic	9	0.1%	4	2.0%	75	100.0%	3750	774
Fire Station Outbuilding	Facility	8	0.5%	17	5.0%	167	100.0%	3333	725
East Sandwich Fire Station (septic tank)	Facility Septic	8	0.1%	3	0.1%	3	100.0%	3333	669
Marina Playground	Open Space	8	2.5%	84	6.9%	231	75.6%	2520	615
Town Hall Annex Parking Lot	Parking	12	1.3%	66	2.2%	110	52.4%	2619	590
Fire Station Propane Tank	Facility	6	0.5%	13	5.0%	125	100.0%	2500	544
Public Slips (B Dock)	Marina Docks	11	0.1%	5	1.0%	46	50.0%	2292	474
Seasonal Bathrooms (septic tank)	Facility Septic	8	1.0%	33	5.0%	167	50.0%	1667	400
Old Police Station	Facility	22	0.0%	0	0.1%	9	20.0%	1833	369
East Sandwich Fire Station	Facility	22	0.0%	0	0.1%	9	20.0%	1833	369
Marina Parking Area	Parking	14	4.5%	263	4.5%	263	4.9%	287	268
Town Hall Annex	Facility	14	0.0%	0	0.1%	6	20.0%	1167	235
Town Hall	Facility	14	0.0%	0	0.1%	6	20.0%	1167	235
Commercial Fishing Dock (E - Secondary Dock)	Marina Docks	14	0.0%	0	0.1%	6	20.0%	1167	235
Fire Station Generator	Facility	5	0.1%	2	1.0%	21	50.0%	1042	216
Town Hall Annex (septic tank)	Facility Septic	10	0.1%	4	0.1%	4	25.0%	1042	212
Grist Mill Ticket Booth	Facility	8	0.0%	0	0.2%	7	30.0%	1000	202
Footbridge - Rt. 130 (Town Hall)	Ped. Bridge	12	0.0%	0	0.1%	5	20.0%	1000	202
Coast Guard Dock	Marina Docks	20	0.0%	0	0.0%	0	10.0%	833	167
Commercial Fishing Dock (I Dock)	Marina Docks	13	0.0%	0	0.0%	0	10.0%	542	108
Town Hall (septic tank)	Facility Septic	11	0.1%	5	0.1%	5	10.0%	458	95

Asset Name/ Asset Number	Asset Type	Consq. Score	Prob. Present	Risk Present	Prob. 2030	Risk 2030	Prob. 2070	Risk 2070	Composite Risk
Public Slips (H Dock)	Marina Docks	11	0.0%	0	0.0%	0	10.0%	458	92
Clark Haddad Building (septic tank)	Facility Septic	10	0.0%	0	0.1%	4	10.0%	417	85
Murkwood Conservation Area Barn	Facility	9	0.0%	0	0.0%	0	10.0%	375	75
Fuel Tank Leak Sensors	Marina Assets	17	0.0%	0	0.0%	0	5.0%	354	71
Fuel Dock (shut off, pumps, monitoring)	Marina Assets	17	0.0%	0	0.0%	0	5.0%	354	71
Fixed Pumpout Station	Marina Assets	14	0.0%	0	0.0%	0	5.0%	292	58
Commercial Fishing Dock (G Dock)	Marina Docks	13	0.0%	0	0.0%	0	5.0%	271	54
Town Neck & Freeman Avenue Parking Lot	Parking	12	0.0%	1	0.1%	6	4.6%	232	49
Fuel Monitoring Well - Upper	Marina Assets	17	0.0%	0	0.0%	0	2.0%	142	28
Marina Parking Area	Parking	14	0.4%	21	0.4%	21	0.7%	38	25
Coast Guard Dock (A Dock)	Marina Docks	11	0.0%	0	0.0%	0	2.0%	92	18
Dexter Grist Mill	Facility	12	0.0%	0	0.0%	0	1.0%	50	10
Footbridge - Rt. 130 (Grist Mill)	Ped. Bridge	12	0.0%	0	0.0%	0	1.0%	50	10
Footbridge - Rt. 130 (Grist Mill)	Ped. Bridge	12	0.0%	0	0.0%	0	1.0%	50	10
Harbor Master Office & Bathrooms (septic tank)	Facility Septic	10	0.0%	0	0.1%	4	1.0%	42	10
Public Slips (D Dock)	Marina Docks	11	0.0%	0	0.0%	0	1.0%	46	9
Public Slips (C Dock)	Marina Docks	11	0.0%	0	0.0%	0	1.0%	46	9
150 Gallon Propane Tank	Marina Assets	21	0.0%	0	0.0%	0	0.5%	44	9
East Sandwich Fire Station Generator	Facility	5	0.0%	0	0.0%	0	2.0%	42	8
Sandwich Water District Building	Facility	14	0.0%	0	0.0%	0	0.5%	29	6
Sand Hill School Building	Facility	14	0.0%	0	0.0%	0	0.5%	29	6
Public Slips (E - Main Dock)	Marina Docks	14	0.0%	0	0.0%	0	0.5%	29	6
Marina Fuel Tank	Facility	22	0.0%	0	0.0%	0	0.2%	18	4
Lower Shawme Dam	Dam	22	0.0%	0	0.0%	0	0.2%	18	4
150 Gallon Propane Tank	Marina Assets	21	0.0%	0	0.0%	0	0.2%	18	4
150 Gallon Propane Tank	Marina Assets	21	0.0%	0	0.0%	0	0.2%	18	4
Marina Landscapers Shed	Facility	4	0.0%	0	0.0%	0	1.0%	17	3
Emergency Fuel Shutoff	Marina Assets	17	0.0%	0	0.0%	0	0.2%	14	3
Footbridge - Rt. 130 (Fountain)	Ped. Bridge	12	0.0%	0	0.0%	0	0.2%	10	2
Compressor Unit	Marina Assets	9	0.0%	0	0.0%	0	0.2%	8	2
Harbormaster Office	Facility	8	0.0%	0	0.0%	0	0.1%	3	1
Sandwich Water Authority Parking Lot	Parking	12	0.0%	0	0.0%	0	0.0%	1	0
Sandwich Public Library Parking Lot	Parking	13	0.0%	0	0.0%	0	0.0%	1	0
Seasonal Bathrooms	Facility	10	0.0%	0	0.0%	0	0.0%	0	0
Deacon Eldred House	Facility	11	0.0%	0	0.0%	0	0.0%	0	0
Sandwich Public Library	Facility	14	0.0%	0	0.0%	0	0.0%	0	0
Marina Ramp House	Facility	7	0.0%	0	0.0%	0	0.0%	0	0
Marina Garage	Facility	8	0.0%	0	0.0%	0	0.0%	0	0
Marina Generator	Facility	13	0.0%	0	0.0%	0	0.0%	0	0
Shawme Pond Band Stand	Facility	8	0.0%	0	0.0%	0	0.0%	0	0

Asset Name/ Asset Number	Asset Type	Consq. Score	Prob. Present	Risk Present	Prob. 2030	Risk 2030	Prob. 2070	Risk 2070	Composite Risk
Old Town Cemetery	Open Space	5	0.0%	0	0.0%	0	0.0%	0	0
Library (septic tank)	Facility Septic	9	0.0%	0	0.0%	0	0.0%	0	0
Deacon Eldred House (septic tank)	Facility Septic	11	0.0%	0	0.0%	0	0.0%	0	0
Wing School (septic tank)	Facility Septic	6	0.0%	0	0.0%	0	0.0%	0	0
Wing School (septic tank)	Facility Septic	6	0.0%	0	0.0%	0	0.0%	0	0
Wing School (septic tank)	Facility Septic	6	0.0%	0	0.0%	0	0.0%	0	0
Water District Office Building (septic tank)	Facility Septic	6	0.0%	0	0.0%	0	0.0%	0	0

Table C-2. Roadways Risk Table

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
FOSTER ROAD	Spring Hill Rd	Salt Marsh Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
FOSTER ROAD	Spring Hill Rd	Salt Marsh Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	9167	9167	9167	9167
ROOS ROAD	Foster Rd	Spring Hill Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	7083	7083	7083	7083
FREEZER ROAD	Tupper Rd	Canal Service Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	50.0%	100.0%	100.0%	4583	9167	9167	6875
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	50.0%	100.0%	100.0%	4583	9167	9167	6875
FREEZER ROAD	Tupper Rd	Canal Service Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	50.0%	50.0%	100.0%	4583	4583	9167	5500
FREEZER ROAD	Tupper Rd	Canal Service Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	50.0%	50.0%	100.0%	4583	4583	9167	5500
ED MOFFITT DRIVE	Freezer Rd	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
ED MOFFITT DRIVE	Freezer Rd	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
ED MOFFITT DRIVE	Freezer Rd	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
ED MOFFITT DRIVE	Freezer Rd	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
ED MOFFITT DRIVE	Freezer Rd	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
GALLO ROAD	Town Neck Rd	Ed Moffit Dr	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
DEWEY AVENUE	Main St	Liberty St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
JONES LANE	Route 6A	Old County Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
RIVER STREET	Main St	Tupper Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
ED MOFFITT DRIVE	Freezer Rd	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
SALT MARSH ROAD	Foster Rd	Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	25.0%	50.0%	100.0%	2292	4583	9167	4354
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	20.0%	50.0%	100.0%	1833	4583	9167	4125
HOWLAND LANE	Old County Rd	Barnstable TL	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	50.0%	100.0%	100.0%	2500	5000	5000	3750
BOARDWALK ROAD	Harbor St	Parking Area	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	50.0%	100.0%	100.0%	2500	5000	5000	3750
JONES LANE	Route 6A	Old County Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	50.0%	100.0%	100.0%	2500	5000	5000	3750
RIVER STREET	Main St	Tupper Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	50.0%	100.0%	100.0%	2500	5000	5000	3750
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	20.0%	100.0%	100.0%	1167	5833	5833	3500
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	20.0%	25.0%	100.0%	1833	2292	9167	3438
FREEZER ROAD	Tupper Rd	Canal Service Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	20.0%	20.0%	100.0%	1833	1833	9167	3300
JONES LANE	Route 6A	Old County Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	25.0%	100.0%	100.0%	1250	5000	5000	3125
RIVER STREET	Main St	Tupper Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	50.0%	50.0%	100.0%	2500	2500	5000	3000
WOOD AVENUE	Knott Ave	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	100.0%	100.0%	1000	5000	5000	3000
WOOD AVENUE	Knott Ave	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	100.0%	100.0%	1000	5000	5000	3000
SANDY NECK ROAD	Route 6A	Barnstable TL	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	100.0%	100.0%	1000	5000	5000	3000
NORTH SHORE BOULEVARD	North Shore Blvd Ext.	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	2917	2917	2917	2917
HOLWAY ROAD	North Shore Blvd	South to Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	2917	2917	2917	2917
NORTH SHORE BLVD EXT	North Shore Blvd	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	2917	2917	2917	2917
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	20.0%	50.0%	100.0%	1167	2917	5833	2625
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	458	1833	9167	2613
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	30.0%	30.0%	100.0%	1750	1750	5833	2567
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	10.0%	10.0%	100.0%	917	917	9167	2567
GALLO ROAD	Town Neck Rd	Ed Moffit Dr	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	50.0%	50.0%	50.0%	2500	2500	2500	2500
CHURCH STREET	Jarves St	State St	2	2	2	1	1	1	9	37.5	Ground	Use MC-FRM %	25.0%	100.0%	100.0%	938	3750	3750	2344
JACK KELLY ROAD	Jones Ln	Andersen Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	50.0%	100.0%	1000	2500	5000	2250
JONES LANE	Route 6A	Old County Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	50.0%	100.0%	1000	2500	5000	2250
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	2.0%	5.0%	100.0%	183	458	9167	2063
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	20.0%	50.0%	50.0%	1167	2917	2917	2042
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	1.0%	5.0%	100.0%	92	458	9167	2017
BOULDER BROOK ROAD	Spring Hill Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	25.0%	25.0%	100.0%	1250	1250	5000	2000
FREEZER ROAD	Tupper Rd	Canal Service Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	46	458	9167	1994
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	46	458	9167	1994
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	30.0%	100.0%	1000	1500	5000	1950
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	1.0%	2.0%	100.0%	92	183	9167	1934
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	1.0%	2.0%	100.0%	92	183	9167	1934
SCUSSET BEACH ROAD	Bourne TL	Parking lot	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.5%	2.0%	100.0%	46	183	9167	1911
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.2%	2.0%	100.0%	18	183	9167	1898
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	2.0%	100.0%	9	183	9167	1893
STONEFIELD DRIVE	Boulder Brook Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	25.0%	100.0%	1000	1250	5000	1875
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.2%	1.0%	100.0%	18	92	9167	1870
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	9	46	9167	1852

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	9	46	9167	1852
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	9	18	9167	1843
MAIN STREET (ROUTE 130)	Route 6A	Town Hall Square	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	9	18	9167	1843
MAIN STREET (ROUTE 130)	Route 6A	Town Hall Square	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	9	9	9167	1841
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	9	9	9167	1841
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	9	9	9167	1841
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	9	9	9167	1841
FREEMAN AVENUE	Town Neck Rd	Wood Ave	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	5.0%	10.0%	100.0%	354	708	7083	1806
WILLOW STREET	Jarves St	Church St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	20.0%	100.0%	1000	1000	5000	1800
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	10.0%	50.0%	50.0%	583	2917	2917	1750
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	10.0%	50.0%	50.0%	583	2917	2917	1750
SCORTON CIRCLE	Marshview Cir	Cul-de-sac	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	10.0%	30.0%	100.0%	500	1500	5000	1700
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	10.0%	30.0%	100.0%	500	1500	5000	1700
BEALE AVENUE	Route 130	Main St	2	3	3	3	1	2	14	58.3	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	292	1167	5833	1663
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	10.0%	10.0%	50.0%	917	917	4583	1650
MOODY DRIVE	Tupper Rd	Moody Dr	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	10.0%	50.0%	50.0%	500	2500	2500	1500
JARVES STREET	Factory St	Main St	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.2%	2.0%	100.0%	14	142	7083	1466
JARVES STREET	Factory St	Main St	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.2%	2.0%	100.0%	14	142	7083	1466
JARVES STREET	Factory St	Main St	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.1%	1.0%	100.0%	7	71	7083	1441
JARVES STREET	Factory St	Main St	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	7	35	7083	1431
KENNETH STREET	Jack Kelly Rd	Betty Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	250	1000	5000	1425
JACK KELLY ROAD	Jones Ln	Andersen Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	250	1000	5000	1425
CLAYTON STREET	Route 6A	Cul-de-sac	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	250	1000	5000	1425
MEADOW SPRING DRIVE	Route 6A	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	25.0%	50.0%	100.0%	729	1458	2917	1385
ARROWHEAD CIRCLE	Marshview Cir	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	20.0%	50.0%	100.0%	583	1458	2917	1313
KENNETH STREET	Jack Kelly Rd	Betty Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	5.0%	10.0%	100.0%	250	500	5000	1275

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
WOOD AVENUE	Knott Ave	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	5.0%	10.0%	100.0%	250	500	5000	1275
CANARY STREET	State St	Harbor St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	5.0%	10.0%	100.0%	250	500	5000	1275
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.1%	5.0%	100.0%	6	292	5833	1257
GEORGE'S ROCK ROAD	Dewey Ave	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	25.0%	30.0%	100.0%	729	875	2917	1210
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.2%	2.0%	100.0%	12	117	5833	1208
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.1%	2.0%	100.0%	6	117	5833	1205
CANARY STREET	State St	Harbor St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	5.0%	5.0%	100.0%	250	250	5000	1200
JACK KELLY ROAD	Jones Ln	Andersen Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	5.0%	5.0%	100.0%	250	250	5000	1200
CLAYTON STREET	Route 6A	Cul-de-sac	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	2.0%	10.0%	100.0%	100	500	5000	1200
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.1%	1.0%	100.0%	6	58	5833	1187
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.1%	1.0%	100.0%	6	58	5833	1187
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.1%	1.0%	100.0%	6	58	5833	1187
TOWN NECK ROAD	Tupper Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	1.0%	10.0%	100.0%	50	500	5000	1175
LIBERTY STREET	Main St	Dewey Ave	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	6	6	5833	1171
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	6	6	5833	1171
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	6	5833	1168
STATE STREET	Harbor St	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	10.0%	50.0%	100.0%	292	1458	2917	1167
BRANT HILL ROAD	Great Island Rd	Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	25.0%	25.0%	1000	1250	1250	1125
STONEFIELD DRIVE	Boulder Brook Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	2.0%	5.0%	100.0%	100	250	5000	1125
DEWEY AVENUE	Main St	Liberty St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	2.0%	5.0%	100.0%	100	250	5000	1125
FREEMAN STREET	Canary St	Harbor St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	2.0%	5.0%	100.0%	100	250	5000	1125
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	2.0%	5.0%	100.0%	100	250	5000	1125
SPRING HILL ROAD	Route 6A	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	20.0%	20.0%	30.0%	1000	1000	1500	1100
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	10.0%	10.0%	20.0%	917	917	1833	1100
SPRING HILL ROAD	Route 6A	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	1.0%	5.0%	100.0%	50	250	5000	1100
SPRING HILL ROAD	Route 6A	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	25	250	5000	1088

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
BAYBERRY LANE	Marshview Cir	Marshview Cir	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	25	250	5000	1088
KENNETH STREET	Jack Kelly Rd	Betty Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	25	250	5000	1088
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	25	250	5000	1088
JUNE LANE	Route 6A	June Ln	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.5%	2.0%	100.0%	25	100	5000	1043
CRANBERRY TRAIL	Sandy Neck Rd	Windmill Bog Way	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.5%	2.0%	100.0%	25	100	5000	1043
STONEFIELD DRIVE	Boulder Brook Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	2.0%	100.0%	5	100	5000	1033
BETTY AVENUE	Jones Ln	Jack Kelly Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.2%	1.0%	100.0%	10	50	5000	1020
SANDY NECK ROAD	Route 6A	Barnstable TL	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.2%	1.0%	100.0%	10	50	5000	1020
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.2%	1.0%	100.0%	10	50	5000	1020
SPRING HILL ROAD	Route 6A	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	5	25	5000	1010
BARBARA LANE	Ploughed Neck Rd	Roberts Way	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	5	10	5000	1006
ROBERTS WAY	Ploughed Neck Rd	Ploughed Neck Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	5	10	5000	1006
SCORTON CIRCLE	Marshview Cir	Cul-de-sac	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	5	10	5000	1006
BETTY AVENUE	Jones Ln	Jack Kelly Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
JONES LANE	Route 6A	Old County Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
ROBERTS WAY	Ploughed Neck Rd	Ploughed Neck Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
RICHARDS WAY	Ploughed Neck Rd	Ploughed Neck Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
SANDY NECK ROAD	Route 6A	Barnstable TL	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
FACTORY STREET	Harbor St	Liberty St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	5	5000	1002
SANDY NECK ROAD	Route 6A	Barnstable TL	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	5	5000	1002
JONES LANE	Route 6A	Old County Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	5	5000	1002
ANDERSEN AVENUE	Jones Ln	Edward Kelly Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	5	5000	1002
DEXTER AVENUE	Town Neck Rd	Wood Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	100.0%	0	0	5000	1000
TOWN NECK ROAD	Tupper Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	100.0%	0	0	5000	1000
TOWN NECK ROAD	Tupper Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	100.0%	0	0	5000	1000

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
DEXTER AVENUE	Town Neck Rd	Wood Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	100.0%	0	0	5000	1000
HARBOR STREET	Church St	Dead end	1	2	3	3	1	1	11	45.8	Ground	Use MC-FRM %	0.2%	5.0%	100.0%	9	229	4583	990
NORTH SHORE BOULEVARD	North Shore Blvd Ext.	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	10.0%	25.0%	100.0%	292	729	2917	948
ARROWHEAD CIRCLE	Marshview Cir	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	10.0%	25.0%	100.0%	292	729	2917	948
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	50.0%	9	9	4583	924
HARBOR STREET	Church St	Dead end	1	2	3	3	1	1	11	45.8	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	5	9	4583	922
HARBOR STREET	Church St	Dead end	1	2	3	3	1	1	11	45.8	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	4583	920
MAIN STREET (ROUTE 130)	Route 6A	Town Hall Square	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	50.0%	0	0	4583	917
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	50.0%	0	0	4583	917
SUNRISE LANE	Factory St	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	146	583	2917	831
CHURCH STREET	Jarves St	State St	2	2	2	1	1	1	9	37.5	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	4	8	3750	754
CHURCH STREET	Jarves St	State St	2	2	2	1	1	1	9	37.5	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	4	4	3750	753
GROVE STREET	Town Hall Square	Pocasset Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.1%	0.1%	50.0%	7	7	3542	714
JARVES STREET	Factory St	Main St	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.1%	50.0%	0	7	3542	710
OLD COUNTY ROAD	Route 6A	Barnstable TL	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	50.0%	0	0	3542	708
OLD COUNTY ROAD	Route 6A	Barnstable TL	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	50.0%	0	0	3542	708
OLD COUNTY ROAD	Route 6A	Barnstable TL	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	50.0%	0	0	3542	708
ARROWHEAD CIRCLE	Marshview Cir	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	2.0%	10.0%	100.0%	58	292	2917	700
ARROWHEAD CIRCLE	Marshview Cir	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	2.0%	10.0%	100.0%	58	292	2917	700
STATE STREET	Harbor St	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	1.0%	10.0%	100.0%	29	292	2917	685
QUAKER ROAD	Spring Hill Rd	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	15	146	2917	634
STONEFIELD DRIVE	Boulder Brook Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	1.0%	5.0%	50.0%	50	250	2500	600
QUAKER ROAD	Spring Hill Rd	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	3	15	2917	589
QUAKER ROAD	Spring Hill Rd	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	3	15	2917	589
STATE STREET	Harbor St	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	3	3	2917	586
LIBERTY STREET	Main St	Dewey Ave	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.1%	50.0%	0	6	2917	585

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
DEWEY AVENUE	Main St	Liberty St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.5%	2.0%	50.0%	25	100	2500	543
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.5%	2.0%	25.0%	46	183	2292	536
MORSE ROAD	Beale Ave	Route 130	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	2.0%	50.0%	5	100	2500	533
CROSS STREET	Jarves St	Liberty St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.5%	50.0%	5	25	2500	510
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	1.0%	2.0%	20.0%	92	183	1833	468
HARBOR STREET	Church St	Dead end	1	2	3	3	1	1	11	45.8	Ground	Use MC-FRM %	0.0%	0.1%	50.0%	0	5	2292	460
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.5%	20.0%	9	46	1833	385
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.5%	20.0%	9	46	1833	385
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	20.0%	9	9	1833	374
SCUSSET BEACH ROAD	Bourne TL	Parking lot	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	20.0%	9	9	1833	374
SCUSSET BEACH ROAD	Bourne TL	Parking lot	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	20.0%	9	9	1833	374
PLEASANT STREET	Jarves St	Liberty St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.1%	0.1%	30.0%	6	6	1750	355
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.1%	30.0%	0	6	1750	352
FERN AVENUE	Ploughed Neck Rd	Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	30.0%	5	5	1500	304
TOWN NECK ROAD	Tupper Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	30.0%	0	0	1500	300
DEXTER AVENUE	Town Neck Rd	Wood Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	30.0%	0	0	1500	300
WATER STREET (ROUTE 130)	Town Hall Square	Shawme Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.1%	0.1%	20.0%	7	7	1417	289
JARVES STREET	Factory St	Main St	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.1%	0.1%	20.0%	7	7	1417	289
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	1.0%	2.0%	10.0%	92	183	917	284
PHILLIPS ROAD	Culver Rd	Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.5%	25.0%	5	25	1250	260
BRANT HILL ROAD	Great Island Rd	Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.5%	25.0%	5	25	1250	260
GALLO ROAD	Town Neck Rd	Ed Moffit Dr	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	25.0%	0	0	1250	250
BOULDER BROOK ROAD	Spring Hill Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.5%	20.0%	5	25	1000	210
BRANT HILL ROAD	Great Island Rd	Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.2%	20.0%	5	10	1000	206
PHILLIPS ROAD	Bourne TL	Culver Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	20.0%	5	5	1000	204
PHILLIPS ROAD	Culver Rd	Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	20.0%	5	5	1000	204

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
FACTORY STREET	Harbor St	Liberty St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	20.0%	0	5	1000	202
PHILLIPS ROAD	Bourne TL	Culver Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	20.0%	0	5	1000	202
PHILLIPS ROAD	Bourne TL	Culver Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	20.0%	0	5	1000	202
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	10.0%	9	9	917	191
SCUSSET BEACH ROAD	Bourne TL	Parking lot	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	10.0%	9	9	917	191
SCUSSET BEACH ROAD	Bourne TL	Parking lot	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.1%	0.1%	10.0%	9	9	917	191
FREEMAN AVENUE	Town Neck Rd	Wood Ave	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.1%	10.0%	0	7	708	144
JARVES STREET	Factory St	Main St	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	10.0%	0	0	708	142
COAST GUARD ROAD	Town Neck Rd	Marina Access Rd	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.1%	0.2%	20.0%	3	6	583	120
LIBERTY STREET	Main St	Dewey Ave	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.1%	10.0%	0	6	583	118
TOWN NECK ROAD	Tupper Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	10.0%	0	5	500	102
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	9	458	94
HARBOR STREET	Church St	Dead end	1	2	3	3	1	1	11	45.8	Ground	Use MC-FRM %	0.0%	0.1%	10.0%	0	5	458	93
FREEMAN AVENUE	Town Neck Rd	Wood Ave	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	7	354	73
FREEMAN AVENUE	Town Neck Rd	Wood Ave	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	7	354	73
EDWARD KELLY ROAD	Andersen Ave	Andersen Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	5.0%	5	5	250	54
KNOTT AVENUE	Freeman Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
KNOTT AVENUE	Freeman Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
KNOTT AVENUE	Freeman Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
KNOTT AVENUE	Freeman Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
CHADWELL AVENUE	Freeman Ave	Knott Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
TOWN NECK ROAD	Tupper Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
ALMY AVENUE	Town Neck Rd	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
FACTORY STREET	Harbor St	Liberty St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	5.0%	0	0	250	50
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.1%	2.0%	0	9	183	39
GROVE STREET	Town Hall Square	Pocasset Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.1%	0.1%	2.0%	7	7	142	34

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
BOULDER BROOK ROAD	Spring Hill Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	2.0%	5	5	100	24
ANDERSEN AVENUE	Jones Ln	Edward Kelly Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	2.0%	5	5	100	24
FEAKE AVENUE	Knott Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	2.0%	0	5	100	22
DILLINGHAM AVENUE	Town Neck Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	1.0%	0	5	50	12
FREEMAN AVENUE	Town Neck Rd	Wood Ave	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.1%	0.5%	0	7	35	9
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.5%	0	0	46	9
WATER STREET (ROUTE 130)	Town Hall Square	Shawme Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.5%	0	0	35	7
KNOTT AVENUE	Freeman Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	0.5%	0	5	25	7
SHAWME AVENUE	Chadwell Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	0.5%	0	5	25	7
BAKSIS ROAD	Briarwood Ave	L & R - Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	0.5%	0	5	25	7
GALLO ROAD	Town Neck Rd	Ed Moffit Dr	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.5%	0	0	25	5
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	18	4
FREEMAN AVENUE	Town Neck Rd	Wood Ave	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	14	3
FREEMAN AVENUE	Town Neck Rd	Wood Ave	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	14	3
FREEMAN AVENUE	Town Neck Rd	Wood Ave	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	14	3
LIBERTY STREET	Main St	Dewey Ave	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	12	2
CHADWELL AVENUE	Freeman Ave	Knott Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	10	2
FEAKE AVENUE	Knott Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	10	2
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	9	2
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	9	2
FREEZER ROAD	Tupper Rd	Canal Service Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	9	2
FREEZER ROAD	Tupper Rd	Canal Service Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	9	2
JARVES STREET	Factory St	Main St	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	7	1
OLD COUNTY ROAD	Route 6A	Barnstable TL	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	7	1
OLD COUNTY ROAD	Route 6A	Barnstable TL	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	7	1
OLD COUNTY ROAD	Route 6A	Barnstable TL	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	7	1

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
BEALE AVENUE	Route 130	Main St	2	3	3	3	1	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	6	1
SPRING HILL ROAD	Route 6A	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
LAND'S END LANE	Route 6A	Cul-de-sac	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
LAND'S END LANE	Route 6A	Cul-de-sac	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
BOULDER BROOK ROAD	Spring Hill Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
WOOD AVENUE	Knott Ave	Parking Lot	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
JONES LANE	Route 6A	Old County Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
SHAWME AVENUE	Chadwell Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
TOWN NECK ROAD	Tupper Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
SUMMER STREET	Main St	Pleasant St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GROVE STREET	Town Hall Square	Pocasset Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GROVE STREET	Town Hall Square	Pocasset Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
PLOUGHED NECK ROAD	Route 6A	North Shore Blvd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
PLOUGHED NECK ROAD EXTENSION	Ploughed Neck Rd	Dead end	0	2	0	0	0	0	2	8.3	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
DILLINGHAM AVENUE	Town Neck Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	Route 6A	Barnstable TL	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
WATER STREET (ROUTE 130)	Town Hall Square	Shawme Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
STONEFIELD DRIVE	Boulder Brook Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	Route 6A	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	Route 6A	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
TOWN NECK ROAD	Tupper Rd	Freeman Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	Route 6A	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
JUNIPER HILL ROAD	Spring Hill Rd	Cul-de-sac	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
QUAKER MEETINGHOUSE ROAD	Route 6A	Route 130	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	Route 6A	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
JUNE LANE	Route 6A	June Ln	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
PLEASANT STREET	Jarves St	Liberty St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
BEALE AVENUE	Route 130	Main St	2	3	3	3	1	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
BODFISH AVENUE	Town Neck Rd	Knott Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
PHEASANT LANE	School St	Beale Ave	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GROVE STREET	Town Hall Square	Pocasset Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MAIN STREET (ROUTE 130)	Route 6A	Town Hall Square	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	Bourne TL	Barnstable TL	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GULLY LANE	Route 6A	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GALLO ROAD	Town Neck Rd	Ed Moffit Dr	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
JENNIFER ROAD	Morse Rd	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
JENNIFER ROAD	Morse Rd	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
BOULDER BROOK ROAD	Spring Hill Rd	Boulder Brook Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
IDA LANE	June Ln	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
IDA LANE	June Ln	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
IDA LANE	June Ln	Cul-de-sac	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
TUPPER ROAD	Route 6A	Main St	2	2	3	3	2	2	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GILMAN ROAD	Spring Hill Rd	Dead end	1	2	1	1	1	1	7	29.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
QUAKER MEETINGHOUSE ROAD	Route 6A	Route 130	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
QUAKER MEETINGHOUSE ROAD	Route 6A	Route 130	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ACADEMY ROAD	Grove St	House # 8	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
JACK KELLY ROAD	Jones Ln	Andersen Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MAIN STREET	Town Hall Square	Route 6A	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MARSHVIEW CIRCLE	Fleetwood Rd	Fleetwood Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
FLEETWOOD ROAD	Ploughed Neck Rd	Marshview Cir	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
BAKSIS ROAD	Briarwood Ave	L & R - Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
QUAKER MEETINGHOUSE ROAD	Route 6A	Route 130	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
TUPPER AVENUE	Knott Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
BRIARWOOD AVENUE	Tupper Rd	Baksis Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SCHOOL STREET	Main St	Water St	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
NYE ROAD	Spring Hill Rd	Route 6A	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ANDERSEN AVENUE	Jones Ln	Edward Kelly Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ALMY AVENUE	Town Neck Rd	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
KNOTT AVENUE	Freeman Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
KNOTT AVENUE	Freeman Ave	Dillingham Ave	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
WATER STREET (ROUTE 130)	Town Hall Square	Shawme Rd	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	Route 6A	Barnstable TL	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	Route 6A	Barnstable TL	3	2	3	3	3	3	17	70.8	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0

Road Segment Name (From/ To)			Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Pres	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Ri
BRIARWOOD AVENUE	Tupper Rd	Baksis Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
CAPTAIN COLE ROAD	Captain Wing Rd	Captain Wing Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
FOSTER ROAD	Spring Hill Rd	Salt Marsh Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
FOSTER ROAD	Spring Hill Rd	Salt Marsh Rd	4	2	4	4	4	4	22	91.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SHAW STREET	Sandy Neck Rd	Leonard Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SHAW STREET	Sandy Neck Rd	Leonard Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SHAW STREET	Sandy Neck Rd	Leonard Rd	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
UNION BRAIDING ROAD	Grove St	Dead end	2	2	2	2	2	2	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0

Table C-3. Hydrants Risk Tables

Hydrant Location / ID		Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Present	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Risk
ED MOFFITT DRIVE	466-2	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
DEWEY AVENUE	108-13	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
DEWEY AVENUE	108-20	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
SALT MARSH ROAD	354-24	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
FOSTER ROAD	354-95	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
FOSTER ROAD	354-113	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
SALT MARSH ROAD	354-80	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
SALT MARSH ROAD	354-60	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	100.0%	100.0%	100.0%	5000	5000	5000	5000
FOSTER ROAD	354-75	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	50.0%	100.0%	100.0%	2500	5000	5000	3750
SALT MARSH ROAD	354-100	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	50.0%	100.0%	100.0%	2500	5000	5000	3750
SALT MARSH ROAD	354-42	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	50.0%	100.0%	100.0%	2500	5000	5000	3750
BOARDWALK ROAD	036-1	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	25.0%	100.0%	100.0%	1250	5000	5000	3125
FOSTER ROAD	354-57	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	25.0%	100.0%	100.0%	1250	5000	5000	3125
ED MOFFITT DRIVE	466-1	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	50.0%	50.0%	50.0%	2500	2500	2500	2500
BOARDWALK ROAD	036-9	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	25.0%	50.0%	100.0%	1250	2500	5000	2375
NORTH SHORE BOULEVARD	278-37	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	25.0%	50.0%	100.0%	1250	2500	5000	2375
SALT MARSH ROAD	354-114	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	25.0%	50.0%	100.0%	1250	2500	5000	2375
BAY BEACH LANE	024-1	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	20.0%	50.0%	100.0%	1000	2500	5000	2250
ROUTE 6A	350-524	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	25.0%	30.0%	100.0%	1354	1625	5417	2248
ROUTE 6A	350-520	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	25.0%	30.0%	100.0%	1354	1625	5417	2248
ROUTE 6A	404-11	3	1	0	4	1	4	15	62.5	Ground	Use MC-FRM %	20.0%	50.0%	50.0%	1250	3125	3125	2188
FREEZER ROAD	146-36	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	25.0%	25.0%	100.0%	1250	1250	5000	2000
TUPPER ROAD	404-107	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	333	1333	6667	1900
MAIN STREET	257-191	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	333	1333	6667	1900
ROUTE 6A	350-564	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	30.0%	30.0%	50.0%	1625	1625	2708	1842
ROUTE 6A	350-115	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	10.0%	30.0%	100.0%	542	1625	5417	1842
NORTH SHORE BOULEVARD	278-89	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	20.0%	20.0%	100.0%	1000	1000	5000	1800
GEORGE'S ROCK ROAD	151-12	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	20.0%	20.0%	100.0%	1000	1000	5000	1800
ROUTE 6A	350-116	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	10.0%	20.0%	100.0%	542	1083	5417	1679

Hydrant Location / ID		Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Present	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Risk
NORTH SHORE BOULEVARD	278-111	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	10.0%	20.0%	100.0%	500	1000	5000	1550
ROUTE 6A	350-153	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	271	1083	5417	1544
ROUTE 6A	350-159	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	271	1083	5417	1544
FREEZER ROAD	146-20	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	25.0%	25.0%	50.0%	1250	1250	2500	1500
RIVER STREET	343-117	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	250	1000	5000	1425
DEWEY AVENUE	108-15	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	5.0%	20.0%	100.0%	250	1000	5000	1425
MARSHVIEW CIRCLE	260-14	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	10.0%	10.0%	100.0%	500	500	5000	1400
BOULDER BROOK ROAD	041-34	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	10.0%	10.0%	100.0%	500	500	5000	1400
TUPPER ROAD	404-91	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.1%	2.0%	100.0%	7	133	6667	1377
TUPPER ROAD	404-94	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	7	33	6667	1347
TUPPER ROAD	404-121	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	7	7	6667	1339
TUPPER ROAD	404-98	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	7	6667	1335
ROUTE 6A	350-119	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	2.0%	10.0%	100.0%	108	542	5417	1300
CANARY STREET	057-15	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	5.0%	10.0%	100.0%	250	500	5000	1275
ARROWHEAD CIRCLE	013-7	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	5.0%	10.0%	100.0%	250	500	5000	1275
ROUTE 6A	350-492	3	1	0	4	1	4	15	62.5	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	6	31	6250	1263
ROUTE 6A	700-1	3	1	0	4	1	4	15	62.5	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	6	31	6250	1263
ROUTE 6A	350-476	3	1	0	4	1	4	15	62.5	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	6	6	6250	1255
ROUTE 6A	350-454	3	1	0	4	1	4	15	62.5	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	6	6	6250	1255
CLAYTON STREET	074-6	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	2.0%	10.0%	100.0%	100	500	5000	1200
TUPPER ROAD	404-75	4	1	0	4	3	4	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	100.0%	0	0	5833	1167
NORTH SHORE BOULEVARD	278-69	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	2.0%	5.0%	100.0%	100	250	5000	1125
NORTH SHORE BOULEVARD	278-55	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	1.0%	5.0%	100.0%	50	250	5000	1100
	260-018	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	1.0%	5.0%	100.0%	50	250	5000	1100
ROUTE 6A	350-145	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	5	27	5417	1094
ROUTE 6A	350-105	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	5	11	5417	1089
PLOUGHED NECK ROAD	321-107	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	25	250	5000	1088
BOULDER BROOK ROAD	041-24	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	25	250	5000	1088
PINE ROAD	312-51	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	25	250	5000	1088

Hydrant Location / ID		Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Present	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Risk
PINE ROAD	312-020	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.5%	5.0%	100.0%	25	250	5000	1088
HARBOR STREET	176-12	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.2%	5.0%	100.0%	10	250	5000	1080
TOWN NECK ROAD	400-1	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.2%	5.0%	100.0%	10	250	5000	1080
BEALE AVENUE	028-17	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.5%	1.0%	100.0%	25	50	5000	1028
MARSHVIEW CIRCLE	260-40	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.2%	1.0%	100.0%	10	50	5000	1020
OCEAN ROAD	283-012	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	1.0%	100.0%	5	50	5000	1018
QUIET STREET	488-024	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	1.0%	100.0%	5	50	5000	1018
BEACH ROAD	026-12	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.5%	100.0%	5	25	5000	1010
PLOUGHED NECK ROAD	321-91	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	5	10	5000	1006
STATE STREET	386-8	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.2%	100.0%	5	10	5000	1006
MARSHVIEW CIRCLE	260-46	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
FREEMAN ROAD	144-88	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
CHURCH STREET	072-2	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
ROBERTS WAY	344-5	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	100.0%	5	5	5000	1004
MARSHVIEW CIRCLE	260-10	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	5	5000	1002
SCORTON CIRCLE	359-3	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	5	5000	1002
GEORGE'S ROCK ROAD	151-4	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	5	5000	1002
QUAKER ROAD	332-8	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	5	5000	1002
BARBARA LN.	022-003	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	100.0%	0	5	5000	1002
NORTH SHORE BOULEVARD	278-197	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.2%	5.0%	50.0%	10	250	2500	580
OLD MAIN STREET	257-209	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	5.0%	50.0%	5	250	2500	578
ROUTE 6A	350-550	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.0%	0.1%	50.0%	0	5	2708	543
NORSE PINES DRIVE	496-001	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	1.0%	1.0%	50.0%	50	50	2500	540
STONEFIELD DRIVE	387-14	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.5%	50.0%	5	25	2500	510
	496-011	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.5%	50.0%	5	25	2500	510
NORTH SHORE BOULEVARD	278-175	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	50.0%	5	5	2500	504
STONEFIELD DRIVE	387-10	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	50.0%	5	5	2500	504
TOWN NECK ROAD	400-16	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	50.0%	0	0	2500	500
TUPPER ROAD	404-108	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	2.0%	10.0%	10.0%	133	667	667	400

Hydrant Location / ID		Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Present	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Risk
COAST GUARD ROAD	466-3	4	1	0	4	1	4	14	58.3	Ground	Use MC-FRM %	0.1%	1.0%	30.0%	6	58	1750	370
CROSS STREET	090-1	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.5%	30.0%	5	25	1500	310
NORTH SHORE BOULEVARD	278-153	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	30.0%	5	5	1500	304
LIBERTY STREET	224-12	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	30.0%	0	5	1500	302
PLEASANT STREET	319-010	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	30.0%	0	5	1500	302
ROUTE 6A	350-502	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.0%	0.1%	25.0%	0	5	1354	272
TANK FARM	811-003	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.1%	20.0%	0	7	1333	269
NORSE PINES	495-012	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	25.0%	5	5	1250	254
COWSLIP PATH	497-001	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	25.0%	5	5	1250	254
BARBARA LANE	022-007	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	25.0%	0	5	1250	252
STONEFIELD DRIVE	387-3	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	20.0%	5	5	1000	204
FERN AVENUE	134-10	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	20.0%	5	5	1000	204
RICHARDS WAY	340-8	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	20.0%	0	5	1000	202
NORTH SHORE BOULEVARD	278-255	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	1.0%	5.0%	5.0%	50	250	250	150
COAST GUARD ROAD	077-7	4	1	0	4	1	4	14	58.3	Ground	Use MC-FRM %	0.0%	0.1%	10.0%	0	6	583	118
ATWOOD STROLL	499-004	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	10.0%	5	5	500	104
CHURCH STREET	072-20	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	10.0%	0	5	500	102
TUPPER ROAD	811-001	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	7	333	69
SPRING HILL ROAD	382-54	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	5.0%	5	5	250	54
FOSTER ROAD	140-87	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	5.0%	5	5	250	54
STONEFIELD DRIVE	387-9	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
PLOUGHED NECK ROAD	321-45	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
TOWN NECK ROAD	400-74	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
KNOTT AVENUE	231-10	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
FREEMAN ROAD	144-2	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
PLOUGHED NECK ROAD	321-73	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
QUIET ST	488-014	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	5.0%	0	5	250	52
MAIN STREET	257-139	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	2.0%	0	0	133	27
FEAKE AVENUE	133-11	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	2.0%	0	5	100	22

Hydrant Location / ID		Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Present	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Risk
BAYBERRY LANE	025-3	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.1%	0.1%	1.0%	5	5	50	14
FREEMAN ROAD	144-12	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	1.0%	0	5	50	12
MARSHVIEW CIRCLE	260-18	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	1.0%	0	5	50	12
CHADWELL AVENUE	064-11	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	0.5%	0	5	25	7
PLOUGHED NECK ROAD	321-59	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.5%	0	0	25	5
MARSHVIEW CIRCLE	260-32	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.5%	0	0	25	5
OLD MAIN STREET	257-194	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.5%	0	0	25	5
DEWEY AVENUE	108-7	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.1%	0.2%	0	5	10	4
JARVES STREET	207-47	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	13	3
CHADWELL AVENUE	064-35	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	10	2
FREEMAN ROAD	144-28	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	10	2
FEAKE AVENUE	133-33	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	10	2
DEWEY AVENUE	108-9	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.2%	0	0	10	2
TUPPER ROAD	811-002	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	7	1
JARVES STREET	207-10	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	7	1
COAST GUARD ROAD	077-3	4	1	0	4	1	4	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	6	1
TUPPER ROAD	404-72	4	1	0	4	3	4	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	6	1
ROUTE 6A	350-138	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
ROUTE 6A	350-544	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
LANDS END LANE	238-7	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
FEAKE AVENUE	133-23	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
DILLINGHAM AVENUE	110-131	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
FREEZER ROAD	146-10	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
TOWN NECK ROAD	400-52	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
LIBERTY STREET	224-19	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
BOULDER BROOK ROAD	041-54	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
ARROWHEAD DRIVE	014-10	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
OLD COUNTY ROAD	465-1	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
MORSE ROAD	028-10	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1

Hydrant Location / ID		Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Present	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Risk
SPRING HILL ROAD	382-104	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.1%	0	0	5	1
TOWN NECK ROAD	400-42	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
PARSONAGE WAY	493-2	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
PARSONAGE WAY	493-4	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	350-163	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SCHOOL STREET	358-4	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SUMMER STREET	389-3	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MAIN STREET	257-176	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MAIN STREET	257-177	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MAIN STREET	257-154	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
TUPPER ROAD	404-17	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GALLO ROAD	148-9	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MARSHVIEW CIRCLE	260-58	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ALMY AVENUE	004-27	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
TUPPER AVENUE	403-9	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GROVE STREET	169-42	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GROVE STREET	169-48	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GROVE STREET	169-36	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
FLEETWOOD ROAD	137-8	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
TUPPER ROAD	404-65	4	1	0	4	1	4	14	58.3	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
TUPPER ROAD	404-33	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
TUPPER ROAD	404-30	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
TUPPER ROAD	404-45	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
BRIARWOOD AVENUE	046-4	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
WATER STREET	415-3	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GROVE STREET	169-24	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MAIN STREET	257-149	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	350-244	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	350-252	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0

Hydrant Location / ID		Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Present	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Risk
NYE STREET	281-4	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
PUMPHOUSE ROAD	705-1	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	382-22	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	350-330	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	382-36	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	382-56	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	382-90	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
LIBERTY STREET	224-24	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ALMY AVENUE	004-19	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ALMY AVENUE	004-39	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
PLEASANT STREET	319-11	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
BOULDER BROOK ROAD	041-42	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	382-84	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	382-68	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
DEXTER AVENUE	109-17	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
BOULDER BROOK ROAD	041-13	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
QUAKER MEETINGHOUSE ROAD	331-429	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
FOSTER ROAD	140-29	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
BOULDER BROOK ROAD	041-50	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	465-9	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	465-108	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	465-82	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	465-45	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	465-52	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	465-33	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
OLD COUNTY ROAD	465-20	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
SPRING HILL ROAD	382-7	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	800-006	3	1	0	4	1	4	15	62.5	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
PINE TERRACE	315-8	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0

Hydrant Location / ID		Area of Service Area	Duration of Service Loss	Cost of Damage	Safety Impact	Economic Impact	Health / Environment	Consequence Score	Composite Score	Critical Elev. (NAVD88 ft.)	Critical Elev. Note	Prob_Present	Prob_2030	Prob_2070	Risk_Present	Risk_2030	Risk_2070	Composite Risk
PINE TERRACE	315-8	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ROUTE 6A	350-406	3	1	0	4	1	4	13	54.2	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GROVE STREET	169-4	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
MAIN STREET	257-163	4	1	0	4	3	4	16	66.7	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
JENNIFER ROAD	211-1	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
X-COUNTRY	000-0	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
JACOBS MEADOW	495-006	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
ATWOOD STROLL	499-018	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
NORSE PINES DRIVE	496-017	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
NORSE PINES ROAD	496-003	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0
GREAT ISLAND ROAD	162-001	2	1	0	4	1	4	12	50.0	Ground	Use MC-FRM %	0.0%	0.0%	0.0%	0	0	0	0

Table C-4. Stormwater Outfalls Vulnerability Tables

			Present Day Cumulative Probability Distribution (Old Sandwich Harbor / Mill Creek)											
		Critical Elevation (FT. NAVD88)	0.1%	0.2%	0.5%	1%	2%	5%	10%	20%	25%	30%	50%	100%
Stormwater Outlet ID	Location		10.8	10.4	9.9	9.5	9.1	8.5	8.1	7.7	7.5	7.4	6.9	5.8
OU82-258-8	RIVER STREET	5.5	-5.3	-4.9	-4.4	-4.0	-3.6	-3.0	-2.6	-2.2	-2.0	-1.9	-1.4	-0.3
OU82-54-32-A	CHURCH STREET	7.7	-3.1	-2.7	-2.2	-1.8	-1.4	-0.8	-0.4	0.0	0.2	0.3	0.8	1.9
OU88-300-1	TUPPER ROAD	7.8	-3.0	-2.6	-2.1	-1.7	-1.3	-0.7	-0.3	0.1	0.3	0.4	0.9	2.0
OU67-500-702	SPRING HILL ROAD	8.2	-2.6	-2.2	-1.7	-1.3	-0.9	-0.3	0.1	0.5	0.7	0.8	1.3	2.4
OU73-188-189	MAIN STREET	9.0	-1.8	-1.4	-0.9	-0.5	-0.1	0.5	0.9	1.3	1.5	1.6	2.1	3.2
OU43-501-021	MAIN STREET @ ROUTE 6A	9.0	-1.8	-1.4	-0.9	-0.5	-0.1	0.5	0.9	1.3	1.5	1.6	2.1	3.2
OU89-344-96-B	WOOD AVENUE	11.2	0.4	0.8	1.3	1.7	2.1	2.7	3.1	3.5	3.7	3.8	4.3	5.4
OU82-500-771	TUPPER ROAD	11.4	0.6	1.0	1.5	1.9	2.3	2.9	3.3	3.7	3.9	4.0	4.5	5.6
OU43-500-805	WATER STREET	11.7	0.9	1.3	1.8	2.2	2.6	3.2	3.6	4.0	4.2	4.3	4.8	5.9
OU73-300-1	WATER STREET	12.3	1.5	1.9	2.4	2.8	3.2	3.8	4.2	4.6	4.8	4.9	5.4	6.5
OU43-500-810	MAIN STREET	12.6	1.8	2.2	2.7	3.1	3.5	4.1	4.5	4.9	5.1	5.2	5.7	6.8
OU82-316-108	TUPPER ROAD	13.2	2.4	2.8	3.3	3.7	4.1	4.7	5.1	5.5	5.7	5.8	6.3	7.4
OU82-301-1	TUPPER ROAD	14.6	3.8	4.2	4.7	5.1	5.5	6.1	6.5	6.9	7.1	7.2	7.7	8.8
OU82-316-104	TUPPER ROAD	15.2	4.4	4.8	5.3	5.7	6.1	6.7	7.1	7.5	7.7	7.8	8.3	9.4
OU67-500-699	NYE ROAD	15.9	5.1	5.5	6.0	6.4	6.8	7.4	7.8	8.2	8.4	8.5	9.0	10.1
OU73-188-145	MAIN STREET	16.6	5.8	6.2	6.7	7.1	7.5	8.1	8.5	8.9	9.1	9.2	9.7	10.8
OU73-20-14	BEALE AVENUE	16.8	6.0	6.4	6.9	7.3	7.7	8.3	8.7	9.1	9.3	9.4	9.9	11.0
OU43-500-806	TOWN HALL	17.9	7.1	7.5	8.0	8.4	8.8	9.4	9.8	10.2	10.4	10.5	11.0	12.1
OU43-500-807	MORSE ROAD	18.1	7.3	7.7	8.2	8.6	9.0	9.6	10.0	10.4	10.6	10.7	11.2	12.3
OU73-300-2	WATER STREET	18.4	7.6	8.0	8.5	8.9	9.3	9.9	10.3	10.7	10.9	11.0	11.5	12.6
OU68-500-706	SPRING HILL ROAD	19.5	8.7	9.1	9.6	10.0	10.4	11.0	11.4	11.8	12.0	12.1	12.6	13.7
OU68-500-718	SPRING HILL ROAD	24.1	13.3	13.7	14.2	14.6	15.0	15.6	16.0	16.4	16.6	16.7	17.2	18.3
OU68-500-716	SPRING HILL ROAD	24.8	14.0	14.4	14.9	15.3	15.7	16.3	16.7	17.1	17.3	17.4	17.9	19.0
OU43-500-813	WATER STREET	27.8	17.0	17.4	17.9	18.3	18.7	19.3	19.7	20.1	20.3	20.4	20.9	22.0
OU94-400-1	DILLINGHAM AVE	30.7	19.9	20.3	20.8	21.2	21.6	22.2	22.6	23.0	23.2	23.3	23.8	24.9
OU43-500-812	WATER STREET	31.4	20.6	21.0	21.5	21.9	22.3	22.9	23.3	23.7	23.9	24.0	24.5	25.6
OU88-37-18	BURG AVENUE	42.9	32.1	32.5	33.0	33.4	33.8	34.4	34.8	35.2	35.4	35.5	36.0	37.1

			Present Day Cumulative Probability Distribution (Scorton Harbor / Scorton Creek)											
		Critical Elevation (FT. NAVD88)	0.1%	0.2%	0.5%	1%	2%	5%	10%	20%	25%	30%	50%	100%
Stormwater Outlet ID	Location		10.8	10.4	9.9	9.5	9.1	8.6	8.2	7.7	7.5	7.4	6.9	5.8
OU40-500-862	SPRING HILL ROAD	17.8	7.0	7.4	7.9	8.3	8.7	9.2	9.6	10.1	10.3	10.4	10.9	12.0
OU40-100-003	QUAKER MEETINGHOUSE ROAD	29.6	18.8	19.2	19.7	20.1	20.5	21.0	21.4	21.9	22.1	22.2	22.7	23.8

			2030 Cumulative Probability Distribution (Old Sandwich Harbor / Mill Creek)											
			0.1%	0.2%	0.5%	1%	2%	5%	10%	20%	25%	30%	50%	100%
Stormwater Outlet ID	**Location**	**Critical Elevation (FT. NAVD88)**	**12.5**	**12.1**	**11.5**	**11**	**10.6**	**10**	**9.6**	**9.1**	**8.9**	**8.7**	**8.2**	**7.1**
OU82-258-8	RIVER STREET	5.5	-7.0	-6.6	-6.0	-5.5	-5.1	-4.5	-4.1	-3.6	-3.4	-3.2	-2.7	-1.6
OU82-54-32-A	CHURCH STREET	7.7	-4.8	-4.4	-3.8	-3.3	-2.9	-2.3	-1.9	-1.4	-1.2	-1.0	-0.5	0.6
OU88-300-1	TUPPER ROAD	7.8	-4.7	-4.3	-3.7	-3.2	-2.8	-2.2	-1.8	-1.3	-1.1	-0.9	-0.4	0.7
OU67-500-702	SPRING HILL ROAD	8.2	-4.3	-3.9	-3.3	-2.8	-2.4	-1.8	-1.4	-0.9	-0.7	-0.5	0.0	1.1
OU73-188-189	MAIN STREET	9.0	-3.5	-3.1	-2.5	-2.0	-1.6	-1.0	-0.6	-0.1	0.1	0.3	0.8	1.9
OU43-501-021	MAIN STREET @ ROUTE 6A	9.0	-3.5	-3.1	-2.5	-2.0	-1.6	-1.0	-0.6	-0.1	0.1	0.3	0.8	1.9
OU89-344-96-B	WOOD AVENUE	11.2	-1.3	-0.9	-0.3	0.2	0.6	1.2	1.6	2.1	2.3	2.5	3.0	4.1
OU82-500-771	TUPPER ROAD	11.4	-1.1	-0.7	-0.1	0.4	0.8	1.4	1.8	2.3	2.5	2.7	3.2	4.3
OU43-500-805	WATER STREET	11.7	-0.8	-0.4	0.2	0.7	1.1	1.7	2.1	2.6	2.8	3.0	3.5	4.6
OU73-300-1	WATER STREET	12.3	-0.3	0.2	0.8	1.3	1.7	2.3	2.7	3.2	3.4	3.6	4.1	5.2
OU43-500-810	MAIN STREET	12.6	0.1	0.5	1.1	1.6	2.0	2.6	3.0	3.5	3.7	3.9	4.4	5.5
OU82-316-108	TUPPER ROAD	13.2	0.7	1.1	1.7	2.2	2.6	3.2	3.6	4.1	4.3	4.5	5.0	6.1
OU82-301-1	TUPPER ROAD	14.6	2.1	2.5	3.1	3.6	4.0	4.6	5.0	5.5	5.7	5.9	6.4	7.5
OU82-316-104	TUPPER ROAD	15.2	2.7	3.1	3.7	4.2	4.6	5.2	5.6	6.1	6.3	6.5	7.0	8.1
OU67-500-699	NYE ROAD	15.9	3.4	3.8	4.4	4.9	5.3	5.9	6.3	6.8	7.0	7.2	7.7	8.8
OU73-188-145	MAIN STREET	16.6	4.1	4.5	5.1	5.6	6.0	6.6	7.0	7.5	7.7	7.9	8.4	9.5
OU73-20-14	BEALE AVENUE	16.8	4.3	4.7	5.3	5.8	6.2	6.8	7.2	7.7	7.9	8.1	8.6	9.7
OU43-500-806	TOWN HALL	17.9	5.4	5.8	6.4	6.9	7.3	7.9	8.3	8.8	9.0	9.2	9.7	10.8
OU43-500-807	MORSE ROAD	18.1	5.6	6.0	6.6	7.1	7.5	8.1	8.5	9.0	9.2	9.4	9.9	11.0
OU73-300-2	WATER STREET	18.4	5.9	6.3	6.9	7.4	7.8	8.4	8.8	9.3	9.5	9.7	10.2	11.3
OU68-500-706	SPRING HILL ROAD	19.5	7.0	7.4	8.0	8.5	8.9	9.5	9.9	10.4	10.6	10.8	11.3	12.4
OU68-500-718	SPRING HILL ROAD	24.1	11.6	12.0	12.6	13.1	13.5	14.1	14.5	15.0	15.2	15.4	15.9	17.0
OU68-500-716	SPRING HILL ROAD	24.8	12.3	12.7	13.3	13.8	14.2	14.8	15.2	15.7	15.9	16.1	16.6	17.7
OU43-500-813	WATER STREET	27.8	15.3	15.7	16.3	16.8	17.2	17.8	18.2	18.7	18.9	19.1	19.6	20.7
OU94-400-1	DILLINGHAM AVE	30.7	18.2	18.6	19.2	19.7	20.1	20.7	21.1	21.6	21.8	22.0	22.5	23.6
OU43-500-812	WATER STREET	31.4	18.9	19.3	19.9	20.4	20.8	21.4	21.8	22.3	22.5	22.7	23.2	24.3
OU88-37-18	BURG AVENUE	42.9	30.4	30.8	31.4	31.9	32.3	32.9	33.3	33.8	34.0	34.2	34.7	35.8

			2030 Cumulative Probability Distribution (Scorton Harbor / Scorton Creek)											
			0.1%	0.2%	0.5%	1%	2%	5%	10%	20%	25%	30%	50%	100%
Stormwater Outlet ID	**Location**	**Critical Elevation (FT. NAVD88)**	**12.1**	**11.7**	**11.2**	**10.8**	**10.3**	**9.8**	**9.4**	**8.9**	**8.7**	**8.6**	**8.1**	**7**
OU40-500-862	SPRING HILL ROAD	17.8	5.7	6.1	6.6	7.0	7.5	8.0	8.4	8.9	9.1	9.2	9.7	10.8
OU40-100-003	QUAKER MEETINGHOUSE ROAD	29.6	17.5	17.9	18.4	18.8	19.3	19.8	20.2	20.7	20.9	21.0	21.5	22.6

Stormwater Outlet ID	Location	Critical Elevation (FT. NAVD88)	2070 Cumulative Probability Distribution (Old Sandwich Harbor / Mill Creek) 0.1%	0.2%	0.5%	1%	2%	5%	10%	20%	25%	30%	50%	100%
			16	15.5	14.9	14.4	13.9	13.3	12.8	12.2	12	11.9	11.3	10
OU82-258-8	RIVER STREET	5.5	-10.5	-10.0	-9.4	-8.9	-8.4	-7.8	-7.3	-6.7	-6.5	-6.4	-5.8	-4.5
OU82-54-32-A	CHURCH STREET	7.7	-8.3	-7.8	-7.2	-6.7	-6.2	-5.6	-5.1	-4.5	-4.3	-4.2	-3.6	-2.3
OU88-300-1	TUPPER ROAD	7.8	-8.2	-7.7	-7.1	-6.6	-6.1	-5.5	-5.0	-4.4	-4.2	-4.1	-3.5	-2.2
OU67-500-702	SPRING HILL ROAD	8.2	-7.8	-7.3	-6.7	-6.2	-5.7	-5.1	-4.6	-4.0	-3.8	-3.7	-3.1	-1.8
OU73-188-189	MAIN STREET	9.0	-7.0	-6.5	-5.9	-5.4	-4.9	-4.3	-3.8	-3.2	-3.0	-2.9	-2.3	-1.0
OU43-501-021	MAIN STREET @ ROUTE 6A	9.0	-7.0	-6.5	-5.9	-5.4	-4.9	-4.3	-3.8	-3.2	-3.0	-2.9	-2.3	-1.0
OU89-344-96-B	WOOD AVENUE	11.2	-4.8	-4.3	-3.7	-3.2	-2.7	-2.1	-1.6	-1.0	-0.8	-0.7	-0.1	1.2
OU82-500-771	TUPPER ROAD	11.4	-4.6	-4.1	-3.5	-3.0	-2.5	-1.9	-1.4	-0.8	-0.6	-0.5	0.1	1.4
OU43-500-805	WATER STREET	11.7	-4.3	-3.8	-3.2	-2.7	-2.2	-1.6	-1.1	-0.5	-0.3	-0.2	0.4	1.7
OU73-300-1	WATER STREET	12.3	-3.8	-3.3	-2.7	-2.2	-1.7	-1.1	-0.6	0.1	0.3	0.4	0.9	2.3
OU43-500-810	MAIN STREET	12.6	-3.4	-2.9	-2.3	-1.8	-1.3	-0.7	-0.2	0.4	0.6	0.7	1.3	2.6
OU82-316-108	TUPPER ROAD	13.2	-2.8	-2.3	-1.7	-1.2	-0.7	-0.1	0.4	1.0	1.2	1.3	1.9	3.2
OU82-301-1	TUPPER ROAD	14.6	-1.4	-0.9	-0.3	0.2	0.7	1.3	1.8	2.4	2.6	2.7	3.3	4.6
OU82-316-104	TUPPER ROAD	15.2	-0.8	-0.3	0.3	0.8	1.3	1.9	2.4	3.0	3.2	3.3	3.9	5.2
OU67-500-699	NYE ROAD	15.9	-0.1	0.4	1.0	1.5	2.0	2.6	3.1	3.7	3.9	4.0	4.6	5.9
OU73-188-145	MAIN STREET	16.6	0.6	1.1	1.7	2.2	2.7	3.3	3.8	4.4	4.6	4.7	5.3	6.6
OU73-20-14	BEALE AVENUE	16.8	0.8	1.3	1.9	2.4	2.9	3.5	4.0	4.6	4.8	4.9	5.5	6.8
OU43-500-806	TOWN HALL	17.9	1.9	2.4	3.0	3.5	4.0	4.6	5.1	5.7	5.9	6.0	6.6	7.9
OU43-500-807	MORSE ROAD	18.1	2.1	2.6	3.2	3.7	4.2	4.8	5.3	5.9	6.1	6.2	6.8	8.1
OU73-300-2	WATER STREET	18.4	2.4	2.9	3.5	4.0	4.5	5.1	5.6	6.2	6.4	6.5	7.1	8.4
OU68-500-706	SPRING HILL ROAD	19.5	3.5	4.0	4.6	5.1	5.6	6.2	6.7	7.3	7.5	7.6	8.2	9.5
OU68-500-718	SPRING HILL ROAD	24.1	8.1	8.6	9.2	9.7	10.2	10.8	11.3	11.9	12.1	12.2	12.8	14.1
OU68-500-716	SPRING HILL ROAD	24.8	8.8	9.3	9.9	10.4	10.9	11.5	12.0	12.6	12.8	12.9	13.5	14.8
OU43-500-813	WATER STREET	27.8	11.8	12.3	12.9	13.4	13.9	14.5	15.0	15.6	15.8	15.9	16.5	17.8
OU94-400-1	DILLINGHAM AVE	30.7	14.7	15.2	15.8	16.3	16.8	17.4	17.9	18.5	18.7	18.8	19.4	20.7
OU43-500-812	WATER STREET	31.4	15.4	15.9	16.5	17.0	17.5	18.1	18.6	19.2	19.4	19.5	20.1	21.4
OU88-37-18	BURG AVENUE	42.9	26.9	27.4	28.0	28.5	29.0	29.6	30.1	30.7	30.9	31.0	31.6	32.9

Stormwater Outlet ID	Location	Critical Elevation (FT. NAVD88)	2070 Cumulative Probability Distribution (Old Sandwich Harbor / Mill Creek) 0.1%	0.2%	0.5%	1%	2%	5%	10%	20%	25%	30%	50%	100%
			16.1	15.6	15	14.5	14	13.4	12.8	12.3	12.1	11.9	11.3	10
OU40-500-862	SPRING HILL ROAD	17.8	1.7	2.2	2.8	3.3	3.8	4.4	5.0	5.5	5.7	5.9	6.5	7.8
OU40-100-003	QUAKER MEETINGHOUSE ROAD	29.6	13.5	14.0	14.6	15.1	15.6	16.2	16.8	17.3	17.5	17.7	18.3	19.6

APPENDIX D FACILITY RISK PROFILE SHEETS

Dexter Grist Mill

Critical Elevation: 14.56 ft NAVD88
Threshold Description: Top of bottom floor (FEMA Elevation Certificate)

Probability of Exceedance Summary Table

	Present		2030		2070	
% Probability	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	10.34	Dry	12.52	Dry	16.56	2.00
0.2	9.98	Dry	12.06	Dry	16.01	1.45
0.5	9.50	Dry	11.45	Dry	15.28	0.72
1	9.13	Dry	10.99	Dry	14.73	0.17
2	8.77	Dry	10.53	Dry	14.18	Dry
5	8.28	Dry	9.90	Dry	13.43	Dry
10	7.89	Dry	9.41	Dry	12.85	Dry
20	7.48	Dry	8.89	Dry	12.22	Dry
25	7.33	Dry	8.70	Dry	12.00	Dry
30	7.21	Dry	8.54	Dry	11.80	Dry
50	6.77	Dry	7.98	Dry	11.14	Dry
100	5.82	Dry	6.78	Dry	9.70	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	1	4	4	0	3	0	12

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	50	0	0.5	10	#44[a] #201
2030	0%	50	0	0.3		
2070	1%	50	50	0.2		

a. Risk ranking excluding road segments and fire hydrants

Sandwich Fire Station 1

Critical Elevation: 9.44 ft NAVD88

Threshold Description: First floor (slab)

Probability of Exceedance Summary Table

% Probability	Present Flood Elevation	Present Depth Above Critical Elev.	2030 Flood Elevation	2030 Depth Above Critical Elev.	2070 Flood Elevation	2070 Depth Above Critical Elev.
0.1	10.52	1.08	12.44	3.00	16.44	7.00
0.2	10.14	0.70	11.99	2.55	15.90	6.46
0.5	9.63	0.19	11.39	1.95	15.19	5.75
1	9.25	Dry	10.94	1.50	14.65	5.21
2	8.87	Dry	10.48	1.04	14.11	4.67
5	8.35	Dry	9.86	0.42	13.38	3.94
10	7.94	Dry	9.38	Dry	12.80	3.36
20	7.51	Dry	8.86	Dry	12.18	2.74
25	7.35	Dry	8.68	Dry	11.97	2.53
30	7.22	Dry	8.52	Dry	11.78	2.34
50	6.75	Dry	7.97	Dry	11.12	1.68
100	5.75	Dry	6.78	Dry	9.71	0.27

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	4	4	4	4	4	4	24

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0.5%	100	50	0.5	2175	#9[a] #29
2030	5%	100	500	0.3		
2070	100%	100	10000	0.2		

a. Risk ranking excluding road segments and fire hydrants

Sandwich Fire Station 1 Generator

Critical Elevation: 10.55 ft NAVD88
Threshold Description: Top of plinth

Probability of Exceedance Summary Table

% Probability	Present		2030		2070	
	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	10.52	Marginal	12.44	1.89	16.44	5.89
0.2	10.14	Dry	11.99	1.44	15.90	5.35
0.5	9.63	Dry	11.39	0.84	15.19	4.64
1	9.25	Dry	10.94	0.39	14.65	4.10
2	8.87	Dry	10.48	Dry	14.11	3.56
5	8.35	Dry	9.86	Dry	13.38	2.83
10	7.94	Dry	9.38	Dry	12.80	2.25
20	7.51	Dry	8.86	Dry	12.18	1.63
25	7.35	Dry	8.68	Dry	11.97	1.42
30	7.22	Dry	8.52	Dry	11.78	1.23
50	6.75	Dry	7.97	Dry	11.12	0.57
100	5.75	Dry	6.78	Dry	9.71	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	1	1	0	3	0	0	5

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0.1%	20.8	2	0.5	216	#28[a] #161
2030	1%	20.8	21	0.3		
2070	50%	20.8	1042	0.2		

a. Risk ranking excluding road segments and fire hydrants

Sandwich Fire Station 1 Propane Tank

Critical Elevation: 9.68 ft NAVD88
Threshold Description: Ground

Probability of Exceedance Summary Table

% Probability	Present		2030		2070	
	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	10.52	0.84	12.44	2.76	16.44	6.76
0.2	10.14	0.46	11.99	2.31	15.90	6.22
0.5	9.63	Marginal	11.39	1.71	15.19	5.51
1	9.25	Dry	10.94	1.26	14.65	4.97
2	8.87	Dry	10.48	0.80	14.11	4.43
5	8.35	Dry	9.86	0.18	13.38	3.70
10	7.94	Dry	9.38	Dry	12.80	3.12
20	7.51	Dry	8.86	Dry	12.18	2.50
25	7.35	Dry	8.68	Dry	11.97	2.29
30	7.22	Dry	8.52	Dry	11.78	2.10
50	6.75	Dry	7.97	Dry	11.12	1.44
100	5.75	Dry	6.78	Dry	9.71	0.03

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	1	1	1	3	0	0	6

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0.5%	25	13	0.5	544	#22[a] #130
2030	5%	25	125	0.3		
2070	100%	25	2500	0.2		

a. Risk ranking excluding road segments and fire hydrants

Sandwich Fire Station 1 Outbuilding

Critical Elevation: 9.49 ft NAVD88
Threshold Description: Ground

Probability of Exceedance Summary Table

% Probability	Present Flood Elevation	Present Depth Above Critical Elev.	2030 Flood Elevation	2030 Depth Above Critical Elev.	2070 Flood Elevation	2070 Depth Above Critical Elev.
0.1	10.52	1.03	12.44	2.95	16.44	6.95
0.2	10.14	0.65	11.99	2.50	15.90	6.41
0.5	9.63	0.14	11.39	1.90	15.19	5.70
1	9.25	Dry	10.94	1.45	14.65	5.16
2	8.87	Dry	10.48	0.99	14.11	4.62
5	8.35	Dry	9.86	0.37	13.38	3.89
10	7.94	Dry	9.38	Dry	12.80	3.31
20	7.51	Dry	8.86	Dry	12.18	2.69
25	7.35	Dry	8.68	Dry	11.97	2.48
30	7.22	Dry	8.52	Dry	11.78	2.29
50	6.75	Dry	7.97	Dry	11.12	1.63
100	5.75	Dry	6.78	Dry	9.71	0.22

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	1	3	2	2	0	0	8

Risk of Exceedance

Time horizon	Probability of Exceedance	Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0.5%	33.3	17	0.5	725	#18[a] #114
2030	5%	33.3	167	0.3		
2070	100%	33.3	3333	0.2		

a. Risk ranking excluding road segments and fire hydrants

Sandwich Fire Station 2

Critical Elevation: 12.47 ft NAVD88
Threshold Description: First floor (slab) at bay doors

Probability of Exceedance Summary Table

% Probability	Present		2030		2070	
	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	11.32	Dry	12.60	0.13	16.90	4.43
0.2	10.88	Dry	12.16	Dry	16.34	3.87
0.5	10.31	Dry	11.57	Dry	15.60	3.13
1	9.88	Dry	11.13	Dry	15.03	2.56
2	9.44	Dry	10.69	Dry	14.46	1.99
5	8.86	Dry	10.09	Dry	13.70	1.23
10	8.40	Dry	9.62	Dry	13.10	0.63
20	7.90	Dry	9.11	Dry	12.45	Marginal
25	7.73	Dry	8.94	Dry	12.22	Dry
30	7.57	Dry	8.78	Dry	12.02	Dry
50	7.05	Dry	8.24	Dry	11.34	Dry
100	5.92	Dry	7.09	Dry	9.86	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	4	4	4	4	2	4	22

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	91.7	0	0.5	369	#25[a] #144
2030	0.1%	91.7	9	0.3		
2070	20%	91.7	1833	0.2		

a. Risk ranking excluding road segments and fire hydrants

Sandwich Fire Station 2 Generator

Critical Elevation: 13.80 ft NAVD88

Threshold Description: Top of plinth

Probability of Exceedance Summary Table

	Present		2030		2070	
% Probability	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	11.32	Dry	12.60	Dry	16.90	3.10
0.2	10.88	Dry	12.16	Dry	16.34	2.54
0.5	10.31	Dry	11.57	Dry	15.60	1.80
1	9.88	Dry	11.13	Dry	15.03	1.23
2	9.44	Dry	10.69	Dry	14.46	0.66
5	8.86	Dry	10.09	Dry	13.70	Dry
10	8.40	Dry	9.62	Dry	13.10	Dry
20	7.90	Dry	9.11	Dry	12.45	Dry
25	7.73	Dry	8.94	Dry	12.22	Dry
30	7.57	Dry	8.78	Dry	12.02	Dry
50	7.05	Dry	8.24	Dry	11.34	Dry
100	5.92	Dry	7.09	Dry	9.86	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	1	1	0	3	0	0	5

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	20.8	0	0.5	8	#46[a] #203
2030	0%	20.8	0	0.3		
2070	2%	20.8	42	0.2		

a. Risk ranking excluding road segments and fire hydrants

Grist Mill Ticket Booth

Critical Elevation: 11.78 ft NAVD88

Threshold Description: Top of decking

Probability of Exceedance Summary Table

% Probability	Present		2030		2070	
	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	10.34	Dry	12.52	0.74	16.56	4.78
0.2	9.98	Dry	12.06	0.28	16.01	4.23
0.5	9.50	Dry	11.45	Dry	15.28	3.50
1	9.13	Dry	10.99	Dry	14.73	2.95
2	8.77	Dry	10.53	Dry	14.18	2.40
5	8.28	Dry	9.90	Dry	13.43	1.65
10	7.89	Dry	9.41	Dry	12.85	1.07
20	7.48	Dry	8.89	Dry	12.22	0.44
25	7.33	Dry	8.70	Dry	12.00	0.22
30	7.21	Dry	8.54	Dry	11.80	0.02
50	6.77	Dry	7.98	Dry	11.14	Dry
100	5.82	Dry	6.78	Dry	9.70	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	1	3	1	3	0	0	8

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	11.78	0	0.5	202	#30[a] #166
2030	0.2%	11.78	7	0.3		
2070	30%	11.78	1000	0.2		

a. Risk ranking excluding road segments and fire hydrants

Harbormaster Office

Critical Elevation: 15.00 ft NAVD88
Threshold Description: Top of bottom floor (FEMA Elevation Certificate)

Probability of Exceedance Summary Table

% Probability	Present		2030		2070	
	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	10.3	Dry	11.7	Dry	15.3	0.3
0.2	9.9	Dry	11.3	Dry	14.8	Dry
0.5	9.4	Dry	10.8	Dry	14.2	Dry
1	9	Dry	10.4	Dry	13.8	Dry
2	8.6	Dry	9.9	Dry	13.3	Dry
5	8.1	Dry	9.4	Dry	12.7	Dry
10	7.7	Dry	9	Dry	12.2	Dry
20	7.2	Dry	8.5	Dry	11.7	Dry
25	7	Dry	8.4	Dry	11.5	Dry
30	6.9	Dry	8.2	Dry	11.4	Dry
50	6.4	Dry	7.7	Dry	10.8	Dry
100	5.4	Dry	6.7	Dry	9.6	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	1	4	2	1	0	0	8

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	33.3	0	0.5	1	#51[a] #210
2030	0%	33.3	0	0.3		
2070	0.1%	33.3	3	0.2		

a. Risk ranking excluding road segments and fire hydrants

Marina Fuel Tank

Critical Elevation: 14.84 ft NAVD88

Threshold Description: Ground (electrical panel)

Probability of Exceedance Summary Table

% Probability	Present Flood Elevation	Present Depth Above Critical Elev.	2030 Flood Elevation	2030 Depth Above Critical Elev.	2070 Flood Elevation	2070 Depth Above Critical Elev.
0.1	10.3	Dry	11.7	Dry	15.3	0.46
0.2	9.9	Dry	11.3	Dry	14.8	Marginal
0.5	9.4	Dry	10.8	Dry	14.2	Dry
1	9	Dry	10.4	Dry	13.8	Dry
2	8.6	Dry	9.9	Dry	13.3	Dry
5	8.1	Dry	9.4	Dry	12.7	Dry
10	7.7	Dry	9	Dry	12.2	Dry
20	7.2	Dry	8.5	Dry	11.7	Dry
25	7	Dry	8.4	Dry	11.5	Dry
30	6.9	Dry	8.2	Dry	11.4	Dry
50	6.4	Dry	7.7	Dry	10.8	Dry
100	5.4	Dry	6.7	Dry	9.6	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	4	4	2	4	4	4	22

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	91.7	0	0.5	4	#48[a] #207
2030	0%	91.7	0	0.3		
2070	0.2%	91.7	18	0.2		

a. Risk ranking excluding road segments and fire hydrants

Marina Landscapers Shed

Critical Elevation: 13.4 ft NAVD88
Threshold Description: Ground

Probability of Exceedance Summary Table

% Probability	Present		2030		2070	
	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	10.3	Dry	11.7	Dry	15.3	1.9
0.2	9.9	Dry	11.3	Dry	14.8	1.4
0.5	9.4	Dry	10.8	Dry	14.2	0.8
1	9	Dry	10.4	Dry	13.8	0.4
2	8.6	Dry	9.9	Dry	13.3	Dry
5	8.1	Dry	9.4	Dry	12.7	Dry
10	7.7	Dry	9	Dry	12.2	Dry
20	7.2	Dry	8.5	Dry	11.7	Dry
25	7	Dry	8.4	Dry	11.5	Dry
30	6.9	Dry	8.2	Dry	11.4	Dry
50	6.4	Dry	7.7	Dry	10.8	Dry
100	5.4	Dry	6.7	Dry	9.6	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	1	3	0	0	0	0	4

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	16.7	0	0.5	3	#49[a] #208
2030	0%	16.7	0	0.3		
2070	1%	16.7	17	0.2		

a. Risk ranking excluding road segments and fire hydrants

Murkwood Barn

Critical Elevation: 13.00 ft NAVD88
Threshold Description: Lowest mechanical equipment (FEMA Elevation Certificate)

Probability of Exceedance Summary Table

	Present		2030		2070	
% Probability	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	11.32	Dry	12.60	Dry	16.90	3.90
0.2	10.88	Dry	12.16	Dry	16.34	3.34
0.5	10.31	Dry	11.57	Dry	15.60	2.60
1	9.88	Dry	11.13	Dry	15.03	2.03
2	9.44	Dry	10.69	Dry	14.46	1.46
5	8.86	Dry	10.09	Dry	13.70	0.70
10	8.40	Dry	9.62	Dry	13.10	0.10
20	7.90	Dry	9.11	Dry	12.45	Dry
25	7.73	Dry	8.94	Dry	12.22	Dry
30	7.57	Dry	8.78	Dry	12.02	Dry
50	7.05	Dry	8.24	Dry	11.34	Dry
100	5.92	Dry	7.09	Dry	9.86	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	1	3	3	0	0	2	9

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	37.5	0	0.5	75	#36[a] #182
2030	0%	37.5	0	0.3		
2070	10%	37.5	375	0.2		

a. Risk ranking excluding road segments and fire hydrants

Old Police Station

Critical Elevation: 12.17 ft NAVD88
Threshold Description: Ground

Probability of Exceedance Summary Table

% Probability	Present Flood Elevation	Present Depth Above Critical Elev.	2030 Flood Elevation	2030 Depth Above Critical Elev.	2070 Flood Elevation	2070 Depth Above Critical Elev.
0.1	10.52	Dry	12.44	0.27	16.44	4.27
0.2	10.14	Dry	11.99	Dry	15.90	3.73
0.5	9.63	Dry	11.39	Dry	15.19	3.02
1	9.25	Dry	10.94	Dry	14.65	2.48
2	8.87	Dry	10.48	Dry	14.11	1.94
5	8.35	Dry	9.86	Dry	13.38	1.21
10	7.94	Dry	9.38	Dry	12.80	0.63
20	7.51	Dry	8.86	Dry	12.18	0.01
25	7.35	Dry	8.68	Dry	11.97	Dry
30	7.22	Dry	8.52	Dry	11.78	Dry
50	6.75	Dry	7.97	Dry	11.12	Dry
100	5.75	Dry	6.78	Dry	9.71	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	4	4	4	4	4	2	22

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	91.7	0	0.5	369	#25[a] #144
2030	0.1%	91.7	9	0.3		
2070	20%	91.7	1833	0.2		

a. Risk ranking excluding road segments and fire hydrants

Sand Hill School Building

Critical Elevation: 14.88 ft NAVD88
Threshold Description: Ground

Probability of Exceedance Summary Table

	Present		2030		2070	
% Probability	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	11.01	Dry	12.53	Dry	16.36	1.48
0.2	10.58	Dry	12.07	Dry	15.83	0.95
0.5	10.01	Dry	11.46	Dry	15.12	0.24
1	9.58	Dry	10.99	Dry	14.59	Dry
2	9.14	Dry	10.53	Dry	14.06	Dry
5	8.56	Dry	9.90	Dry	13.33	Dry
10	8.10	Dry	9.41	Dry	12.77	Dry
20	7.60	Dry	8.88	Dry	12.16	Dry
25	7.43	Dry	8.69	Dry	11.95	Dry
30	7.28	Dry	8.53	Dry	11.76	Dry
50	6.75	Dry	7.97	Dry	11.11	Dry
100	5.62	Dry	6.76	Dry	9.72	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	4	4	4	0	2	0	14

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	58.3	0	0.5	6	#47[a] #205
2030	0%	58.3	0	0.3		
2070	0.5%	58.3	29	0.2		

a. Risk ranking excluding road segments and fire hydrants

Town Hall Annex

Critical Elevation: 12.12 ft NAVD88
Threshold Description: Rear door threshold

Probability of Exceedance Summary Table

% Probability	Present		2030		2070	
	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	10.34	Dry	12.52	0.40	16.56	4.44
0.2	9.98	Dry	12.06	Dry	16.01	3.89
0.5	9.50	Dry	11.45	Dry	15.28	3.16
1	9.13	Dry	10.99	Dry	14.73	2.61
2	8.77	Dry	10.53	Dry	14.18	2.06
5	8.28	Dry	9.90	Dry	13.43	1.31
10	7.89	Dry	9.41	Dry	12.85	0.73
20	7.48	Dry	8.89	Dry	12.22	0.10
25	7.33	Dry	8.70	Dry	12.00	Dry
30	7.21	Dry	8.54	Dry	11.80	Dry
50	6.77	Dry	7.98	Dry	11.14	Dry
100	5.82	Dry	6.78	Dry	9.70	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	4	4	4	0	2	0	14

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	58.3	0	0.5	235	#27[a] #160
2030	0.1%	58.3	6	0.3		
2070	20%	58.3	1167	0.2		

a. Risk ranking excluding road segments and fire hydrants

Town Hall

Critical Elevation: 12.16 ft NAVD88

Threshold Description: Basement entry

Probability of Exceedance Summary Table

% Probability	Present		2030		2070	
	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.	Flood Elevation	Depth Above Critical Elev.
0.1	10.34	Dry	12.52	0.36	16.56	4.40
0.2	9.98	Dry	12.06	Dry	16.01	3.85
0.5	9.50	Dry	11.45	Dry	15.28	3.12
1	9.13	Dry	10.99	Dry	14.73	2.57
2	8.77	Dry	10.53	Dry	14.18	2.02
5	8.28	Dry	9.90	Dry	13.43	1.27
10	7.89	Dry	9.41	Dry	12.85	0.69
20	7.48	Dry	8.89	Dry	12.22	0.06
25	7.33	Dry	8.70	Dry	12.00	Dry
30	7.21	Dry	8.54	Dry	11.80	Dry
50	6.77	Dry	7.98	Dry	11.14	Dry
100	5.82	Dry	6.78	Dry	9.70	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	4	4	4	0	2	0	14

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	58.3	0	0.5	235	#27[a] #160
2030	0.1%	58.3	6	0.3		
2070	20%	58.3	1167	0.2		

a. Risk ranking excluding road segments and fire hydrants

Water District Building

Critical Elevation: 15.19 ft NAVD88

Threshold Description: Ground

Probability of Exceedance Summary Table

% Probability	Present Flood Elevation	Present Depth Above Critical Elev.	2030 Flood Elevation	2030 Depth Above Critical Elev.	2070 Flood Elevation	2070 Depth Above Critical Elev.
0.1	10.52	Dry	12.44	Dry	16.44	1.25
0.2	10.14	Dry	11.99	Dry	15.90	0.71
0.5	9.63	Dry	11.39	Dry	15.19	Marginal
1	9.25	Dry	10.94	Dry	14.65	Dry
2	8.87	Dry	10.48	Dry	14.11	Dry
5	8.35	Dry	9.86	Dry	13.38	Dry
10	7.94	Dry	9.38	Dry	12.80	Dry
20	7.51	Dry	8.86	Dry	12.18	Dry
25	7.35	Dry	8.68	Dry	11.97	Dry
30	7.22	Dry	8.52	Dry	11.78	Dry
50	6.75	Dry	7.97	Dry	11.12	Dry
100	5.75	Dry	6.78	Dry	9.71	Dry

Consequence of Exceedance

	Area of Service Loss	Duration of Service Loss	Cost of Damage	Impacts to Public Safety	Impacts to Economic Activities	Impacts to Public Health & Environ.	Consequence Score
Scores	4	4	4	0	1	1	14

Risk of Exceedance

Time horizon	Probability of Exceedance	Composite Consequence Score	Risk Score	Weight	Composite Risk Score	Composite Risk Rank
Present	0%	58.3	0	0.5	6	#47[a] #205
2030	0%	58.3	0	0.3		
2070	0.5%	58.3	29	0.2		

a. Risk ranking excluding road segments and fire hydrants

APPENDIX E. REGULATORY RECOMMENDATIONS

Regulatory Review – Achieving Resilience

Prepared for: **Town of Sandwich**

Prepared By: **Julie Conroy, AICP, Kleinfelder**

Revised Aug. 23, 2019

Contents

1. Introduction

Laws and regulations are the foundations upon which Commonwealth cities and towns build their governing principles, land uses, and protection of the environment and public health and safety. These laws and regulations can either support or hinder the short and long-term adaptation and resiliency of a community to climate change impacts. As cited in Climate Ready Boston and other Town reports, studies show that investments in flood hazard mitigation and other resiliency measures can be highly cost-effective. The 2017 report by the National Institute of Building Sciences estimated that, on average, every $1 invested in mitigation saves $6 in damage.[1] Addressing regulatory barriers and constraints to adaptation and identifying opportunities that may exist to achieve greater adaptation will help to make the built environment and essential infrastructure more resilient and less vulnerable to the effects of climate change.

The purpose of this analysis was to examine whether existing Town regulations are a barrier to climate resilience. The analysis focuses on regulatory frameworks affecting the built environment, particularly land use planning, environmental assessment, and building standards.

The overarching goal of this analysis is to provide a summary of the Town's laws and regulations that relate to climate change and its impacts in order to offer recommendations for changes to these laws and regulations that will help the Town better prepare for these impacts. An ideal outcome of the analysis is a set of amendments that are straightforward for Town departments to implement. Long-term outcomes include larger scale changes to land uses, development and redevelopment patterns,

2. Zoning Recommendations

Upon completion of the analysis, a series of recommended changes to existing laws and regulations became apparent to ensure that the Town can become a resilient community in the near and long term, as explained in the following sections.

2.1. Article IV Special Regulations

The Town may select one (or a combination of) recommended options to ensure that areas of coastal flood inundation are protected. The pros and cons of each are explained within each sub-section.

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1 National Institute of Building Sciences, Natural Hazard Mitigation Saves: 2017 Interim Report. See https://www.nibs.org/page/mitigationsaves. FM Global statistics show that every $1 of flood preparedness saves $6 in damage, and every $1 spent on hurricane preparedness saves $105 in damage. In Nov. 2017 Moody's announced that it will take climate readiness into consideration when assessing credit risks for municipal bonds. Without financial stability and a good credit rating, the City could face difficulties financing future climate resilience projects. See: https://www.moodys.com/research/Moodys-Climate-change-is-forecast-to-heighten-US-exposure-to--PR_376056

2.1.1. Option 1: Changes to the Flood Plain District

The first option is to amend the boundaries of the current Flood Plain District (FPD) in Section 4300 to include both existing flood areas defined by FEMA (Special Flood Hazard Areas) and projected coastal flood areas identified in the Sandwich CCVA Project. This approach expands the areas being defined as coastal flood areas to ensure that flood risk is more accurately defined at the property level

The benefit to this approach is that the specific requirements of Section 4300 are not changing, just the defined area that must comply with the Flood Overlay District zoning. The downside of this approach is that it is does not provide innovative lot or building design, and it may not encourage proactive changes to land use and development practices. Additionally, since the Flood Overlay District currently complies with the requirement that the Town participates in FEMA's Community Rating System, care will have to be taken to ensure that proposed changes do not adversely affect the Town's status in this program (if so desired).

It is also recommended that the regulations (Section 4300) clearly state that climate change is being factored into the protective measures. Recommended changes include:

> "*The purpose of these regulations is to ensure public safety by reducing personal injury and threats to life; to eliminate new hazards to emergency response officials; to prevent public emergencies resulting from water contamination ~~due to flooding~~; to avoid the disruption or shutdown of the utility network ~~due to flooding, to the detriment of areas beyond the flooding site;~~ to eliminate costs associated with the response and cleanup; ~~of flooding conditions~~; and to reduce ~~flood~~ damage to public and private property from the impacts of current flooding, and projected coastal flooding associated with sea level rise and increased storm intensity."*

A definition of Sea Level Rise must be added to the Flood Plain District (FPD). The planning team recommends the following definition to ensure clarity and legal defensibility: "Sea Level Rise refers to the future increase in mean sea level above the current mean sea level. In the Town of Sandwich, Sea Level Rise was projected using the Massachusetts Coastal Flood Risk Model (MC-FRM)"

The MC-FRM defines the elevation of predicted flooding within different areas of Town based on the best available hydrologic information and modeling.

Under principles of fairness and due process, property owners should receive advance notice of proposed changes that may affect their land and buildings. In addition, there should be a procedure that allows property owners to clarify whether their land and buildings are affected.

All systems of predicting the extent and risks of future flooding are necessarily imperfect. For that reason, it is standard practice that flood hazard zoning overlays contain a warning and disclaimer notifying property owners of the following:

- Assumptions may change,
- Larger and more damaging floods may occur that exceed the overlay protections or reach properties outside the overlay district,
- Properties included in the overlay which were built to more stringent standards may never experience floods, and
- The zoning shall not create liability on the part of the municipality or its officers and employees.

Properties in the Flood Overlay District are subject to specific building requirements defined by Massachusetts State Building Code. It is important to note that the Massachusetts State Building Code, 780 CMR, is administered by the Board of Building Regulations and Standards (BBRS). The current 9th edition of the Building Code came into effect on January 1, 2018.[2] The Building Code provides minimum standards for flood-resistant buildings within the flood zones regulated within the FEMA Special Flood Hazard Area. These standards are based on ASCE 24-14, Flood Resistant Design and Construction and the FEMA requirements set forth in 44 CFR §§60.1-60.3. The following chart summarizes the current State Building Code flood standards.

DFE Standard	**Class 1: Agriculture, temporary and minor storage facilities, etc.**	**Class 2: All other structures and uses not in Classes 1, 3, or 4**	**Class 3: High risk structures Schools, public assembly, water & sewer facilities, etc.**	**Class 4: Essential Facilities (Hospitals, police /fire/emergency, power stations, etc.**
Zone A: DFE of lowest floor	BFE + 1 foot	BFE + 1 foot	BFE + 1 foot	Higher of BFE + 2 feet or BFE for 0.2% flood
Zone A: DFE of utilities and equipment	BFE + 1 foot	BFE + 1 foot	BFE + 1 foot	Higher of BFE + 2 feet or BFE for 0.2% flood
Zone A: DFE of dry floodproofing of residential structures and areas	BFE + 1 foot	BFE + 1 foot	BFE + 1 foot	Higher of BFE + 2 feet or BFE for 0.2% flood
Zone A: DFE of wet floodproofing	BFE + 1 foot	BFE + 1 foot	BFE + 1 foot	Higher of BFE + 2 feet or BFE for 0.2% flood
Zone A: Flood-damage resistant materials below DFE	BFE + 1 foot	BFE + 1 foot	BFE + 1 foot	Higher of BFE + 2 feet or BFE for 0.2% flood
Zone V: DFE of bottom of lowest horizontal structural member	BFE + 2 feet	BFE + 2 feet	BFE + 2 feet	Higher of BFE + 2 feet or BFE for 0.2% flood

2 The BBRS is housed within the Executive Office of Housing and Economic Development under the Division of Professional Licensure. By statute, it is required to update the State Building Code every five years. See Mass. Gen. Laws c. 143.

DFE Standard	Class 1: Agriculture, temporary and minor storage facilities, etc.	Class 2: All other structures and uses not in Classes 1, 3, or 4	Class 3: High risk structures Schools, public assembly, water & sewer facilities, etc.	Class 4: Essential Facilities (Hospitals, police /fire/emergency, power stations, etc.
Zone V: DFE of utilities and equipment	BFE + 2 feet	BFE + 2 feet	BFE + 2 feet	Higher of BFE + 2 feet or BFE for 0.2% flood
Zone V: Flood-damage resistant materials below DFE	BFE + 2 feet	BFE + 2 feet	BFE + 2 feet	Higher of BFE + 2 feet or BFE for 0.2% flood
Zone V: Dry and wet floodproofing are not permitted in.	BFE + 2 feet	BFE + 2 feet	BFE + 2 feet	Higher of BFE + 2 feet or BFE for 0.2% flood

2.1.2. Option 2: Create a Coastal Zone Management District

The Town could consider establishing a Coastal Zone Management District (CZMD) which would combine the Flood Plain Overlay District, Shore District, and Marine District. The purpose of this is to acknowledge the coastal vulnerability of the Town and the importance of a coordinated effort in managing this coastal area.

Overlay districts achieve their objectives without amending the underlying base zoning by employing a technique in which new, and generally more restrictive zoning is “laid over” an existing zone. As the result of the introduction of the overlay district, parcels of land within an overlay district are subjected to two sets of zoning regulations: the underlying base district and the requirements of the overlay. In general, all the provisions of the base zoning for the underlying districts remain in effect, unless they are specifically superseded by the Overlay. Base zoning regulations that would remain in effect include uses, dimensions, density, parking, and relevant project review procedures. However, the Overlay zoning may state that certain provisions of the base district will be superseded. If the zoning does not specify that the base provisions are superseded, then the most restrictive provisions will apply.

Having a CZMD allows for the extension of the minimum flood plain regulations to other flood vulnerable areas of Town, that are not currently in the existing FEMA 1% risk (100-year) limit. It will likely not be possible to eliminate reference to the FEMA FIRM map because doing so would eliminate eligibility under the NFIP for the Town. , The CMZD could incorporate performance standards based on the Boston Harbor Flood Risk Model (BH-FRM) and incorporate higher freeboard standards for structures being rebuilt or substantially renovated that are vulnerable to flooding

Specific performance standards and design guidelines need to be developed for the evaluation of projects in the CMZD during the development review process. Performance criteria in this zone could be developed using No Adverse Impacts principles, as previously described.

The creation of a special purpose overlay district is authorized in Article II of the Town's Zoning Code. A more broadly drafted authorization for a resiliency overlay district would give the Town the authority to introduce future programs, guidelines, and zoning amendments to address the full range of resiliency issues without having to amend this section in the future.

Challenges associated with Overlay zoning include:

- It can require trained planning and engineering staff to develop the initial maps and standards;
- It adds an additional layer of requirements to the development review process;
- To mitigate natural hazards, it requires technical mapping of hazard areas;
- Requires a zoning amendment, which requires formal action by the governing body.

The basic principles upon which a CZMD could be built include the following:

- Resiliency:
    - Proposed designs / renovations should incorporate best practices and standards to reduce or eliminate coastal flood risk or damage resulting from future climate conditions.
    - The coastal flood risk shall be based upon the 1% annual chance flood event, as modeled for 40 inches of sea-level rise (2070).
- Public Realm:
    - Resiliency measures should be designed to support pedestrian connections and enhance the character of the public realm within the Overlay to the greatest extent possible.
    - Resiliency measures should be designed to maintain access to and egress from the building to the public realm during flood conditions for people of all abilities.
- Sustainability Co-benefits:
    - Wherever feasible, proposed flood resiliency upgrades should also enhance a building's energy efficiency, greenhouse gas reduction potential, and passive survivability.
    - Site improvements should improve stormwater retention and infiltration and reduce heat island effects by increasing vegetation and permeable surfaces.

The zoning should contain a clear definition of the physical boundaries of the Overlay. It is presumed that the initial boundaries of the Overlay will correspond to the areas defined by the CIM maps- those affected by the 1% annual chance flood event. The CIM map will further define the elevation of predicted flooding within different areas of the Overlay, based on best available hydrologic information and modeling. The CZMD boundary would be defined as the 1% annual chance flood event, as identified in the CIM 40-inches (3.3 feet) of sea level rise (2070).

2.2. Changes to the Existing Zoning

Changes within the Town's existing Zoning By-Law are required to ensure that definitive statements are made regarding uses permitted in each district, as well as specific standards governing lot size, building height, and required yard and setback provisions.

Before exploring these options, it is important for the Town to be fully aware of the limitations and opportunities presented by the mandatory use of the State Building Code (9th edition).

2.2.1. State Building Code

While the 9th edition of the State Building Code (SBC) did increase the minimum design elevation for occupied structures, it did not change any other design standards for building exposed to flood risks. Although the lifespan of buildings constructed today is at least fifty years, the SBC only applies its flood hazard design standards to structures within the FIRM maps prepared by FEMA, which are based solely on historic data. The SBC does not currently consider the predictable risks of life safety and property damage, based on scientifically founded studies of future sea level rise.

However, there are three potential pathways by which the flood protections of the current State Building Code could be expanded (these are not mutually exclusive; any or all could be pursued at the same time):[3]

1. Expand the scope of the State Building Code's current flood hazard design standards beyond the FIRM maps, to areas of the Overlay that are not within the boundaries of Article 25, through a Section 98 exception;
2. Heighten the protectiveness of the State Building Code's current flood hazard design standards, through a Section 98 exception; or
3. Adopt zoning and other local regulations, independent of the State Building Code, to protect public life safety and property in areas subject to flood risks caused by future sea-level rise.

Pathway 1: Extend the scope of the SBC Flood Hazard Design Standards

There is a process for an exception to the prohibition on local municipalities from adopting standards that vary from the State Building Code. Section 98 of the state building code enabling act allows municipalities to adopt more restrictive standards, upon a determination by the Board of Building

[3] The Massachusetts courts have held that because the State Building Code creates uniform building and construction standards throughout the Commonwealth, it preempts local building regulations. Municipalities are prohibited from adopting more stringent standards unless they seek an exception under Section 98 of the statute, as discussed below. St. George Greek Orthodox Cathedral of W. Mass. v. Fire Dept. of Springfield, 460 Mass. 120 (2012); Shriners' Hosp. for Crippled Children v. Boston Redev. Authy., 4 Mass. App. Ct. 551, 560-561 (1976). Therefore, all three of these pathways may encounter legal and/or political obstacles.

Regulations and Standards (BBRS) that more restrictive standards are "reasonably necessary because of special conditions prevailing within such Town or town and that such standards conform with accepted national and local engineering and fire prevention practices, with public safety and with the general purposes of a statewide building code. . . ." [M.G.L. c.143 §98][4]

The Town, potentially in coordination with other coastal communities, could seek a Section 98 exception to apply the flood hazard standards of the State Building Code more broadly, to areas within the Overlay. In that case, there is a provision of the federal flood insurance system, National Flood Insurance Program (NFIP), that could provide flood insurance incentives for property owners.

FEMA's Community Rating System (CRS) provides discounts on federal flood insurance premium rates for properties located in communities that adopt flood management mechanisms that are more protective than the NFIP minimum requirements. The ratings are based on the extent to which the community meets the goals of the CRS program, which are to: (i) reduce flood damage to insured property; (ii) strengthen and support the insurance provisions of the NFIP; and (iii) encourage a local comprehensive approach to floodplain management. A community that updates its floodplain map to address future flood conditions or establishes more protective building and construction standards will obtain CRS credits and corresponding reductions in local flood insurance rates. [5]

Pathway 2: Heighten the Protectiveness of the SBC Current Flood Hazard Design Standards[6]

In addition to expanding the scope of current flood protections beyond the FIRM maps, heightened standards for construction could be pursued, through a Section 98 exception, including:

- Additional freeboard requirements;
- Updating wet-proofing and dry-proofing requirements and consider extending to existing residential buildings;
- Assigning V-Zone regulations to coastal A-zone construction;
- Raise standards for extreme weather conditions;
- Cumulative substantial improvement calculations;
- Requiring more stringent substantial improvement determinations for repetitive loss structures;
- Aligning design standards that require elevated ground floors with provisions for handicapped access in flood zones;
- Prohibit new basement residential units in flood zones;
- Add standards for elevating mechanical and utility systems;
- Change the definition of "height" to measure from first occupied floor; and

[4] To date, we are not aware of a precedent for the approval of a local exception by BBRS under Section 98.
[5] CRS recognized the uncertainty in estimating future sea levels and adopted a minimum projection for sea level rise for the purposes of allocating CRS credits. The 2017 CRS Coordinator's Manual, page 400-14, requires communities that choose to update floodplain maps to use the "intermediate-high" or a higher projection for 2100, as determined in the Global Sea Level Rise Scenarios for the United States National Climate Assessment Report (NOAA, 2012).
[6] Proposed exceptions to the Building Code could be coordinated with any changes proposed for energy reduction.

- Review building code construction standards to determine if new technologies, including and new wood technologies, with greater fire resistance ratings would allow greater building height without imposing more stringent construction requirements under the building code (e.g. without steel framing or automatic sprinklers)[7]

Pathway 3: Use Zoning and Regulations to Protect Areas Subject to Future Coastal Flooding.

The role of the State Building Code is reflected in the Massachusetts Zoning Act (M.G.L. c. 40A §3). Section 3 of the Zoning Act estates that "[n]o zoning ordinance or by-law shall regulate or restrict the use of materials, or methods of construction of structures regulated by the state building code." There is limited case law interpreting this provision. [8]

Some municipalities have interpreted the precedence of the State Building Code to apply only to buildings developed by right under the local zoning ordinance. As a general matter, because projects that require special permits and other forms of zoning relief are presumed to impose additional impacts, the zoning code may impose additional constraints and conditions upon such developments. Such requirements should focus on issues that are at the core of zoning codes, such as use, dimensions, and performance standards, and avoid regulating construction materials and methods. Since these conditions would arise from a discretionary process, there may be greater room for overlap between local zoning and the State Building Code.

The Hull Zoning Bylaw requires a special permit for construction and renovation of buildings located in the Special Flood Hazard Areas. Approval is conditioned upon elevating the building and providing floodproofing that exceeds the requirements of the State Building Code. (*Hull Zoning Bylaw*, §50-2(a)).

Marshfield's Zoning Code prohibits new construction in the coastal floodplain, and it requires a special permit for new construction in the inland wetland district. In the latter district, the zoning requires the occupied space to be elevated four feet above the seasonal high-water table and to avoid any increased flooding on adjacent properties.[9] (*Marshfield Zoning Ordinance* Chapter 305-13.01(C) and (F) and Chapter 305-13.02 (C)).

Other communities have used wetlands bylaws, rather than zoning bylaws, to establish standards that exceed the standards of the State Building Code. Marshfield's Wetlands Protection Bylaw (Chapter 505-10) requires the top of the floor elevation of any habitable space and all utilities to be located greater than eleven-feet above mean sea level or above the flood surge height.

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[7] See Building Code, Chapter 5, Section 504.3 and Chapter 6, Section 601.

[8] Section 3 codified the holding of Enos v. City of Brockton, 354 Mass. 278 (1968) (invalidated zoning code that required 12-inch masonry walls for multi-family housing), which predates the adoption of this provision. In DeCoulos v. City of Peabody, 360 Mass. 428 (1971), the court limited Enos and allowed a zoning code to require sewer hookups in a particular district, although there was overlap with the State Sanitary Code, based on public health and environmental concerns.

[9] *Marshfield's requirements for elevating buildings in coastal and inland wetland districts may be inconsistent with its Floodplain Zoning requirements (Chapter 305-15.05) which requires all development, whether permitted by right or by special permit to be in accordance with the standards of the State Building code.*

Through these local bylaws and ordinances, communities have begun to impose standards that are more protective than the State Building Code. However, it is generally assumed that until Section 98 exceptions from the State Building Code are granted, or the Code is revised, cities and towns cannot develop comprehensive new construction standards for flood protection that exceed the standards set forth in the current State Building Code. This consensus also seems to have limited the scope and extent of local participation in the FEMA CRS program.

2.2.2. Article I: Administration and Purpose

The Town could consider adding a definition section to Article I in order to begin the Zoning By-law with clarity regarding critical concepts. Alternatively, the Town could make the Definitions section of the By-law a separate article in the beginning of the document. Regardless of approach, it is recommended that the following concepts are defined:

- Sea Level Rise
- Hazards
- Climate Change
- Greenhouse Gasses
- Special Permit Granting Authority

It is recommended that the Town revise the Purpose section (1100 (g)) to include climate resilience, as follows: "Reducing hazards from fire, coastal flooding caused by sea level rise and storm surge, extreme temperatures and precipitation, and other dangers."

The Town should also consider broadening the administration of the Zoning By-Law by revising section 1210 to state: "This by-law shall be administered through collaboration amongst relevant departments and their boards and commissions including, but not limited to:

- Planning & Development
- Natural Resources
- Recreation
- Department of Public Works
- Public Safety
- Building Department
- Health Department
- Human Services.

Specific departmental responsibilities are specified in the relevant Zoning By-law Articles herein."

The Special permit section (1342) specifies considerations that the Board of Appeals provides to the Planning Board and the Town Engineer when they are commenting on a project. These criteria should include climate change through the revision of Section 1342(d) as follows: "*Protection of environmental resources on the site and in adjacent areas, including projected climate changes."* Additionally, reference to the coastal flood projection map BFE should be included on the site plan as specified in Section 1340.

Suggested language could include: *"Site elevation (contours) and flood projection, if located in a flood hazard zone. "*

2.2.3. Article II Use and Intensity Regulations

Recommended changes within this Article include the following:

- Consider allowing higher maximum height restrictions in the case of existing structures being elevated to improve flood protection.
- Consider amending the Zoning By-Law to provide incentives to residential and commercial property owners to raise/protect structures to improve resilience and flood protection of private properties.

2.2.4. Article III General Regulations

Recommended changes within this Article include the following:

- Consider adopting a "freeboard incentive" for residential and commercial building elevation projects or for new construction. As an example, the Town of Hull adopted a "freeboard incentive" that reduces building department application fees by $500 if an elevation certificate is provided to verify that the building is elevated a minimum of two feet above the highest federal or state requirement for the flood zone. Additional fee reductions could apply for additional freeboard.
- Permit the location of bioretention areas, rain gardens, filter strips, swales, and constructed wetlands in required setback areas and in buffer strips.
- Establish limits on the extent of lawn area on residential lots, either area or percentage of lot.
- In low-density areas, establish limits on impervious lot coverage (e.g., 15%.) This strategy is not appropriate for town centers, transit-oriented districts, and moderate density neighborhoods, where compact development should be encouraged.
- Establish regulatory controls over tree clearance and removal of mature trees/forest stands.
- The Town should work with Legal Counsel to determine the most appropriate wording and location within the article to implement these changes.

3. Regulatory Recommendations

There are difficulties associated with zoning changes in terms of process and voting requirements. Therefore, a series of changes and additions to existing regulations are proposed, which are easier to amend, as well as new regulations for zoning sections that do not currently have resilience standards but are important to the Town's overall resilience to climate change impacts (e.g. wetlands).

3.1. Board of Health Regulations

The Sandwich Board of Health Department (BOH) implements policies and regulations as mandated by the Massachusetts Department of Public Health and the Department of Environmental Protection. These policies are aimed at preserving and protecting the health of the community, which directly relates to climate resilience particularly in terms of protecting public health from pollution impacts. For example, flooding may cause the release of hazardous materials during a storm or poor indoor air quality due to mold growth. The BOH developed and implements a series of regulations designed to protect public health, which include the following with direct climate change relevancy, as listed below.

1. Composting Management Regulation: The regulation allows the BOH to provide guidance regarding compost management to ensure that operations are carried out in such a manner to prevent the occurrence of a public health threat. We recommend that outdoor, open-air composting is not allowed within highly vulnerable coastal flood areas, per the Town's CCVA.

2. Exposure to Toxic Pest Control Materials, Herbicides Regulations: These regulations allow the BOH to regulate the application of pest control materials and herbicides, respectively. We recommend that the use of these toxins are prohibited within highly vulnerable coastal flood areas, per the Town's CCVA for public health and safety reasons associated with contamination during a flood event. Additionally, the Town should sponsor a program to work with homeowners in coastal flood projected areas to provide guidance on alternative methods.

3.2. Wetlands Bylaw / Conservation Commission Regulations

The Town has two sets of laws that govern the function and scope of the Conservation Commission's authority: Wetlands Bylaw, and Conservation Commission Regulations. These regulations appear to be mainly duplicative and therefore we suggest that the Town create a separate set of wetlands regulations, inclusive of the Commission Regulations, to eliminate potential contradiction and inconsistencies. Specific recommendations below reflect this overarching proposal.

3.2.1. Regulation No. 13 - Elevate Structures in Coastal Resource Areas

This is an important regulation that provides definitive statements regarding the allowance of elevated structures within the coastal zone and the design and construction of these structures. The Commission has determined that a specific design is deemed the most appropriate to elevate structures within vulnerable areas (i.e. a wood or steel driven pile or a helical screw anchor foundation [Techno Metal Post] or similar). The regulations continue to specify that the lowest horizontal member of the structure must be elevated a minimum of two (2) feet over existing grade. Additional recommend changes to this regulation include the following: "When a foundation structure (any type of foundation, is proposed to be installed in or on a coastal resource area as defined in 310 CMR 10.00, more specifically a Coastal Beach (310 CMR 10.27), a Coastal Dune (310 CMR 10.28), a Barrier Beach (310 CMR 10.29), and, a FEMA velocity zone within a coastal resource area (Barrier Beach, Coastal Dune), and/or a FEMA still-water flood zone within a coastal resource area (Barrier Beach, Coastal Dune), or a projected coastal flood zone per the CIM, as described in the Town's CCVA…"

4. "… The lowest horizontal member of said structure must be elevated above the CIM BFE (see Section XX) according to the ASCE 24 Technical Guidance (excerpts shown below), including new elevated walkways, decks, support structures and sheds."

3.2.2. Wetland Regulations

It is critical for the Town to ensure that natural resources are protected as they serve as the front line of defense in terms of climate change protection through flood absorption, carbon sequestration, heat reduction, and stormwater management. Therefore, we recommend a series of specific additions described in the following sub-sections.

Land Subject to Coastal Storm Flowage

The Massachusetts Coastal Hazards Commission recommended that the state and municipalities revise their wetlands regulations to include best management practices or performance standards for Land Subject to Coastal Storm Flowage (LSCSF). LSCSF are defined within the state Wetlands Protection Act as "land subject to any inundation caused by coastal storms up to and including that caused by the 100-year storm, surge of record or storm of record, whichever is greater" (i.e. coastal floodplain). These areas are significant to storm damage prevention and flood control, protection of wildlife habitat, and the prevention of water pollution. Generally, LSCSF contains areas where the water table is close to the surface, therefore, pollutants in a flood plain, including contents of septic systems and fuel tanks, could affect public health and water supplies, groundwater quality, wildlife, fisheries and shellfish during a storm. For these reasons, the Commission suggests increasing the width of the buffer zone for LSCSF (current buffer zone is 100 ft.). Additionally, we recommend specifying a specific sea level rise elevation rather than using the Commonwealth's Wetland Protection Act's statement: "at a minimum, the historic rate of relative sea level rise in Massachusetts of 1 foot per 100 years….". Based on the results of this CCVA, the results are dramatically different over the long-term life of a project.

Other recommendations related to LSCSF include the items listed below.

1. Buffer Zone: It is strongly recommended that the "no touch zone" is increased to 100 ft of wetlands, or the first foot of projected flooding.
2. Application for permit: The Town should mandate that applicants describe effects on resource areas and their values from climate changes.
3. Include a subsection requiring applicants to submit a discussion on how the effects of sea level rise are being addressed and mitigated for applications affecting Land Subject to Coastal Storm Flowage and Bordering Land Subject to Flooding within the local buffer zone. Also consider that the applicant be required to submit a cost-benefit analysis of mitigation alternatives.

Climate Change Resilience Section:

Several regional towns such as Arlington, MA have included a separate section devoted to discussing the implications of climate change on wetlands resources.

This approach is beneficial to the community because it devotes one unified section to the issues and impacts of concern. It also allows the community to emphasize t the importance of wetland resources as flood controls and storm damage prevention that contributes to the community's overall resilience and adaptation to negative climate change impacts.

Specific recommendations for project proposals that are heard before the Commission should be included in this section, such as:

1. Describe project design considerations to limit storm and flood damage during extended periods of disruption and flooding as might be expected in extreme weather events;
2. Describe projected amount of stormwater surface runoff, which may increase due to storm surges and extreme weather events. Describe how runoff will be managed ormitigated to prevent pollution such as nutrients from fertilizers, roadway runoff, etc. from entering the resource area. Projects should consider eliminate or reduce impervious surfaces as feasible;
3. Describe project vegetation. planting plans, and other measures to improve the resiliency of the wildlife habitat of the resource area to withstand potential temperature and rainfall changes (drought and excess) due to climate change; and
4. Describe measures to protect proposed structures and minimize damage to structures due to the impacts of climate change.

3.3. Sewer Regulations

The purpose of these regulations is to establish a set of rules pertaining to current and future sewer systems. They are intended to protect the public health, safety and welfare and the environment and to ensure proper and safe operation of public and private sewer systems.

The primary recommendation for this set of rules is for the Town to study the use of innovative sewer services to the most vulnerable, developed coastal areas that are zoned to remain as such. The use of a well-designed sewer system provides less impact to coastal resources from leaching septic systems, and greatly reduces the potential for inundation to the system due to coastal flooding. We recognize this is a larger discussion currently underway across all Cape Cod communities due to the EPA-enforced Areawide Water Quality Plan update, per the Clean Water Act. However, changes to the sewer regulations now offers the Town with a mechanism to encouragement and plan for the installation of innovative sewer systems for both climate resilience and nutrient management.

Specific design-related standards should include a requirement that all sewer connections to residential or commercial properties located in an existing or projected flood zone require backflow prevention technology or shut-off valves that will prevent water from entering a building during a flood.

3.4. Subdivision Rules and Regulations

The Town should consider modifying its subdivision rules and regulations as listed below.

1. Definitions: The Town should include the definition for Long-Term Sea Level Rise as described in Section 2 of this document.

2. Contents:

   a. "The base flood elevation contour as shown on the most recent community panel published by the Federal Emergency Management Administration (FEMA) *or a projected coastal flood zone per the BH-FHM described in the Town's CCVA* shall be clearly shown in a heavy solid line clearly differentiated from other contour lines."

   b. Require a written statement describing the effects of long-term sea level rise for developments located in the Floodplain Overlay District, with a discussion on how the proposed project mitigates the effects of long-term sea level rise over a 50-year period, what temporary and permanent measures are proposed to control potential flooding, and any adverse effects these measures may have on adjacent properties.

3. Municipal Services and Utilities:

   c. Consider requiring that all above-ground points of connection to underground utilities located in subdivisions within the Floodplain Overlay District, including power distribution, street lighting, and communications systems (including telephone and Cable TV), be constructed in waterproof enclosures or elevated above the design flood elevation and that all critical elements of such utilities, including transformers, switches and other equipment, be elevated above the design flood elevation, or otherwise protected.

   d. Consider requiring that all critical water and sewer facilities (e.g., pump stations) located in highly vulnerable areas be elevated above the design flood elevation, or otherwise protected.

4. Street Trees:

   a. 5K: Refer to the municipal tree regulations rather than recreating performance standards.

   b. Require newly developed sites to set aside open space for storm water management and to support tree canopy.

   c. Promote the use of trees in stormwater management practices by offering incentives for their use. Incentives may include smaller stormwater retention pond and treatment facilities. Develop street and sidewalk standards to ensure space required for tree planting.

   d. Encourage alternative street design in order to accommodate a larger number of trees.

   e. Include tree, landscaping, and vegetation buffering requirements in the checklist used for the final site plan approval process.

f. Require a tree protection management plan prior to preliminary plat approval that will include proper methods to protect and reduce impact on trees from site planning and construction.

3.5. Special Permitting for Residential Development

The Town may require all new residential development in the high-risk flood area defined by the MC-FRM to undergo a development review approval process. This process would ensure that all new developments located in the flood risk area incorporate adaptive measures to reduce their potential for flood damages. The Town could develop criteria or design guidelines to steer this approval process, emphasizing building the first floor and all critical facilities (e.g.: mechanical systems) to the design flood elevation (base flood elevation + 1-2' of freeboard, dependent on inundation probability). The Town might consider special use permits for non-residential development as well. The benefits associated with this include:

- Consideration of property specific measures (building adaptation, site resilience strategies) in cases where a 'blanket' approach is not applicable;
- A process that is 'politically' contentious because all development rights are not being stripped from the property owner;
- Less chance for litigation issues due to the interpretation of the regulation as "a financial taking;" and
- A discretionary review process that encourages a discussion about climate change impacts between the Town and property owners and developers.

3.6. Stormwater Management Regulations

A vast number of Green Infrastructure (GI) techniques are designed to manage and treat stormwater at the site of its origin in order to maintain the hydrologic cycle. While the Town provides good guidance on stormwater BMP's, it does not appear to have its own stormwater management bylaw or regulations and therefore must rely on the Wetlands By-Law review process and the Massachusetts Stormwater Handbook to address stormwater on public and private properties.

Although the Stormwater Standards included in the Handbook encourage Low Impact Development and Green Infrastructure techniques, they are not mandated and are not cited as required in areas of high climate change risk. Municipalities that do have their own stormwater bylaws ordinance and regulations often are not progressive enough to either incentivize the use of GI or require a long-term funding source such as a drainage fee and/or utility structure. Funds generated can be used to implement or retrofit existing stormwater facilities with new innovative GI. With this in mind, we recommend that the Town consider the following:

1. Establish or revise land use controls and stormwater regulations to promote innovative practices (i.e. GI and better site planning), and promote the importance of updating Capital Improvements Plans to emphasize funding of green infrastructure.
2. Establish a reliable long-term funding source for stormwater management (i.e. drainage fee and/or utility) where funds generated are used to implement GI techniques.