Town of Marshfield Long-Term Coastal Resilience Plan

FINAL REPORT

July 2022

PREPARED FOR:
Town of Marshfield
Planning Department
870 Moraine St
Marshfield, MA 02050

PREPARED BY:
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A CLS Company
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Table of Contents

List of Figures and Tables

EXECUTIVE SUMMARY

The goal of the Marshfield Long-Term Coastal Resiliency Plan is to develop recommended policies and zoning to proactively reduce future vulnerabilities and, if necessary, rebuild in a more resilient way after a future catastrophic event. These policies, which would largely affect private property owners, should in principle be cost-effective (i.e., benefits outweigh costs).

Public Involvement

As part of the planning process, Town departments, elected officials, board/commission/committee members, residents (including high school students), and businesses were engaged through interviews, a public workshop, public meetings, and an online survey. Engagement activities focused on learning from local knowledge, educating and raising public awareness about future coastal flooding threats and gathering ideas, feedback, and preferences on different mitigation strategies, policies, and draft recommendations. Project information is publicly available on the Town's Planning Department website.

Economic Impacts of Coastal Flooding

Sea level rise and increased storm intensity are projected to worsen coastal flooding in Marshfield. This will have severe economic impacts on residents and businesses, for example:

- Average losses from coastal flooding are estimated to increase to $11 million per year in 2030 and $16 million per year in 2050.
- Losses from individual floods are estimated to cost from $100 million (1,101 buildings) in the 2030 10-year storm to $400 million (1,737 buildings) in the 2050 500-year storm.

These estimates include the cost to repair or replace damaged buildings, contents, and business inventories, as well as temporary relocation expense, rental income loss, capital related loss, income loss, and business interruption loss. They do not include the cost of replacing damaged infrastructure, like seawalls and roads.

Mitigation Strategies

Three primary coastal flood risk mitigation strategies were considered: elevation, voluntary acquisition, and dry floodproofing. These are typically eligible for grant funding through FEMA and USACE. In addition, regulatory taking and eminent domain were considered. Like acquisition, these strategies result in buildings being removed from or prevented from being built or rebuilt in the floodplain. Unlike acquisition, participation is involuntary. The plan explicitly does not focus on engineering strategies like seawalls or beach nourishment, which the Town has been addressing through other projects.

Policy Evaluation

A variety of policies were evaluated for cost-effectiveness using a Benefit-Cost Analysis (BCA).

- ***Higher elevation standard:*** A regulatory policy to require that substantially damaged residential buildings rebuild to a higher standard of the 2050 100-year flood elevation plus 1 foot (13 ft NAVD88 ± 0.5 ft). Substantial damage means the cost to repair is 50% or more of the pre-flood building value. This policy was found to be cost-effective across the board.
- ***Elevation and dry floodproofing grant program:*** A large elevation and dry floodproofing grant program for non-substantially damaged buildings, with no requirement that mitigation is cost-effective to participate. How many and which properties participated was based on community survey results and random selection. The dry floodproofing grant program was shown to be cost-effective, while the elevation grant program was found to be cost-ineffective.
- ***Voluntary acquisition grant program:*** A limited voluntary acquisition program targeting properties with buildings that are in areas of projected daily high tide flooding in 2030. In one scenario, only substantially damaged properties would be targeted for acquisition, and in the others only non-substantially damaged properties, but in all scenarios individual cost-effectiveness was not required for eligibility. This policy was found to be cost-ineffective across the board.
- ***No rebuild zones:*** A regulatory policy prohibiting rebuilding of substantially damaged buildings that are in areas of projected daily high tide flooding in 2050. This policy was found to be cost-ineffective.
- ***Elevation, dry floodproofing, and acquisition programs with cost-effectiveness eligibility standards:*** The cost-effectiveness of elevation, dry floodproofing, and acquisition was evaluated for all applicable buildings in the project area to estimate the total number of buildings that would potentially be eligible for FEMA or USACE grant funding. It is important to note that funding available to Marshfield in any given year would be well below the total costs to implement the full portfolio of potentially eligible projects. Federal grant programs are competitive, have limited funding, and may be difficult for the Town to administer at a large scale. In addition, based on community survey results, not all eligible residents are likely to participate. Results show that 113-403 elevation projects ($48-83 million in avoided loss), 27-71 dry floodproofing projects ($36-40 million in avoided loss), and 18-37 acquisition projects ($15-51 million in avoided loss and environmental benefits) could be considered cost-effective and potentially eligible, depending on the program and cost-effectiveness calculation method.
- ***Oceanfront eminent domain and large no build zones:*** The cost-effectiveness of using eminent domain or large no build zones covering the entirety of first row of properties behind the seawalls to mitigate risks from wave overtopping and seawall failure was evaluated. Due to the high property values and relatively low and highly uncertain

average annual buildings and contents losses from these hazards, these policies were found to be cost-ineffective for all individual buildings.

Importance of Flood Insurance

Under every policy scenario, even if all cost-effective mitigation strategies were implemented, the community would still be left with tens of millions of dollars in residual unmitigated losses over the next 50 years. However, if all buildings at risk were insured to the maximum available through NFIP, most of those losses would be covered by flood insurance.

Even with no mitigation, in the most extreme flood scenario modeled (2050 500-year flood):

- 97% and 93% of residential buildings would have damages less than the maximum NFIP flood insurance coverages for buildings ($250k) and contents ($100k), respectively.
- If 100% of buildings at risk were insured to the max, 89% ($133 million) of total building damages and 84% ($62 million) of total contents damages would be covered by insurance, less deductibles.
- If 100% of substantially damaged buildings had Increased Cost of Compliance coverage, up to an additional $49 million ($30k per structure) would be available to owners to help elevate upon rebuilding.

Yet, as of 2018, only about 50% of Marshfield buildings in the FEMA floodplain were insured. In the community survey, only 55% of respondents stated they had adequate flood insurance. This is a red flag that the community at-large and hundreds of households are not financially prepared for future coastal flooding.

Recommendations

The plan includes eight recommendations, with various sub-components, for the Town to implement regulatory changes, policies, programs, and projects that serve the goal of building resilience to long-term coastal flooding risks.

Recommendation #1 – Promote Flood Insurance (More)

The Town should continue and increase Community Rating System (CRS) participation to maintain or improve flood insurance discounts and make coverage more affordable. That includes updating the Town's CRS Program for Public Information and Flood Insurance Coverage Assessment and Coverage Improvement Plan. The Town should create additional flood insurance outreach projects: direct mailings of brochures, flood insurance meetings, better advertise free technical assistance, incorporate damage and loss estimates, and promote Increased Cost of Compliance coverage, host flood insurance clinic for one-on-one support. Finally, the Town should investigate a parametric community wide flood insurance option.

Recommendation #2 – Establish Higher Elevation Standards

The Town should update its bylaws and regulations, particularly for Wetlands Protection and Floodplain Zoning, to incorporate coastal resilience to sea level rise within their purposes and definitions. A 100-ft Buffer Zone should be added to Land Subject to Coastal Storm Flowage (LSCSF) – the FEMA 100-year floodplain – to approximately cover areas that will be affected by floodplain expansion due to sea level rise. Standards should be added prohibiting habitable and utility uses below the approximate future flood elevation of 13 ft NAVD88 and prohibiting high risk uses altogether. In the future, after MassDEP updates its regulations, the Town should consider adopting a new Coastal Resilience Article following Cape Cod Commission model. The Town should also create a set of building elevation case studies to help contractors understand how to construct elevation projects in Marshfield's coastal context.

Recommendation #3 – Increase Building Heights for Elevation Projects

Currently, only the difference between older and newer FEMA base flood elevations can be added to building height for flood mitigation projects. The Town should modify the building height definition for elevation projects:

- To be measured from minimum flood elevation in State Building Code, including required freeboard, OR 13 ft NAVD88, whichever is higher
- For all new construction, substantial improvements, expansions and new/expanded uses in Floodplain Zoning Overlay, LSCSF and Buffer Zone
- Only for the portions of new or modified structures and uses that meet flood-resistant design and construction standards and Wetlands Protection restrictions on habitable space and utilities below 13 ft NAVD88

Recommendation #4 – Pursue Federal Grants for Elevation and Dry Floodproofing

There are hundreds of elevation and dry floodproofing projects in Marshfield that would be potentially eligible for federal grant funding. That funding must be pursued by the Town, as the sub-applicant for FEMA grants or non-federal sponsor for USACE projects. The Town should:

- Publicize and recruit participants for the FEMA Flood Mitigation Assistance and Hazard Mitigation Grant Program targeting the list of potentially cost-effective structures.
- Request US Army Corps of Engineers (USACE), New England District, to conduct a Hurricane and Storm Damage Reduction Feasibility Study for elevation and dry floodproofing in the entire Planning Area under Section 103 continuing authorities.
- Create a low-interest revolving loan fund for property owners in Marshfield to help finance the non-federal match for federal elevation and dry floodproofing grant projects.

Recommendation #5 – Create a 30-foot setback from public [and private] seawalls

Most repetitive loss properties in Marshfield are located along the seawalls, and damage has historically been caused mostly by wave overtopping and seawall failure. Elevation alone will not mitigate these causes of damage, and raising seawalls is not a feasible long-term strategy. The Town should modify Bylaws Chapter 217 (Seawalls) to prohibit structures "…on, over, or within 30 feet of seawalls and revetments…" without approval by the Select Board. The Town should also consider rescinding the exemption for private seawalls, since the risks are the same. Zoning in the project area already requires a 30-ft rear yard requirement, which may or may not align with the proposed seawall setback, but this may be waived or varied through the Zoning Board of Appeals. To offset some impacts on developable space, the Town could consider also reducing the minimum front yard setback for parcels subject to the 30-ft seawall setback from 15 to 5 ft.

Recommendation #6 – Prepare a Substantial Damage Management Plan

As demonstrated through the BCAs, a key cost-effective strategy for rebuilding more resiliently is to tie substantial damage to higher elevation standards. However, the success of that policy depends on effective and efficient management of substantial damage determinations and enforcement of the State Building Code and local regulations in the rebuilding process.The Management Plan should describe the community's process for evaluating damage to buildings and addressing those that have been substantially damaged, as required by NFIP. It should also outline community responsibilities, identify available data about buildings in the floodplain, describe the community's approach to damage estimation, and list steps the community will take if buildings are determined to be substantially damaged. Community Rating System credits are available for this activity.

Recommendation #7 – Develop Flood Warning and Response Capabilities

Damage and loss estimates prepared for this project indicate that it is increasingly likely that over the coming years and decades people and property in the planning area will be exposed to dangerous coastal flood hazards, the likes of which have not recently or ever been seen. A flood warning and response system would help residents and businesses make timely decisions and take appropriate actions to avoid property damage, injury, and even loss of life. It would also help the Town make efficient use of limited disaster response resources, take timely actions to protect critical facilities (and reduce downtime and associated economic impacts) and improve the safety of first responders. Community Rating System credits are available for this activity.

Recommendation #8 – Pursue Federal Grants for Dyke Road

While it was explicitly not within the scope of this project to evaluate infrastructure strategies to mitigate coastal flood risks, the concentration of losses upstream of Dyke Road could not be responsibly ignored. In the 2030 100-year coastal flood, 41% of the losses and 90% of the substantially damaged buildings are upstream of Dyke Road. It is possible that enhancing the flood control capacity of Dyke Road is more cost-effective and/or more efficient than raising all the vulnerable buildings behind it. There are significant benefits (avoided damage and loss) against which to budget costs for improving Dyke Road. The Town should develop and submit a FEMA Building Resilient Infrastructure and Communities (BRIC) grant application for FY22, and, if construction costs appear to be less than $15 million, consider adding Dyke Road to the scope of the requested USACE Hurricane and Storm Damage Reduction Feasibility Study (Recommendation #4).

INTRODUCTION

The goal of the Marshfield Long-Term Coastal Resiliency Plan is to develop guiding principles and recommended policies and zoning to proactively reduce future coastal flooding and erosion vulnerabilities and, if necessary, rebuild in a more resilient way after a future catastrophic event. This includes accounting for the impacts of sea level rise and increased storm intensity due to climate change, using the best available future projections. The plan explicitly does not focus on engineering strategies like seawalls or beach nourishment, which the Town has been addressing through other projects. The Town received Municipal Vulnerability Preparedness Action Grant funding support for the plan from the Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs.

The planning area consists of approximately 2.5 square miles, further delineated into sectors shown on **Figure 1**. An asset inventory was developed for the planning area and risk factors affecting each sector were evaluated. This involved reviewing existing plans, studies, and data sets, as well as records and accounts of previous storm damage due to coastal flooding and/or erosion to develop a full understanding of the existing risk and existing assets within the coastal area. A separate memorandum evaluates and documents the present and projected future coastal hazards, including flooding from wave overtopping, high tides, sea level rise, and storm surge, and coastal erosion, for each sector. The memorandum provides data on likely scenarios and degrees of potential impact in vulnerable areas to inform development and economic analysis of policy and zoning strategies to mitigate risks to the community.

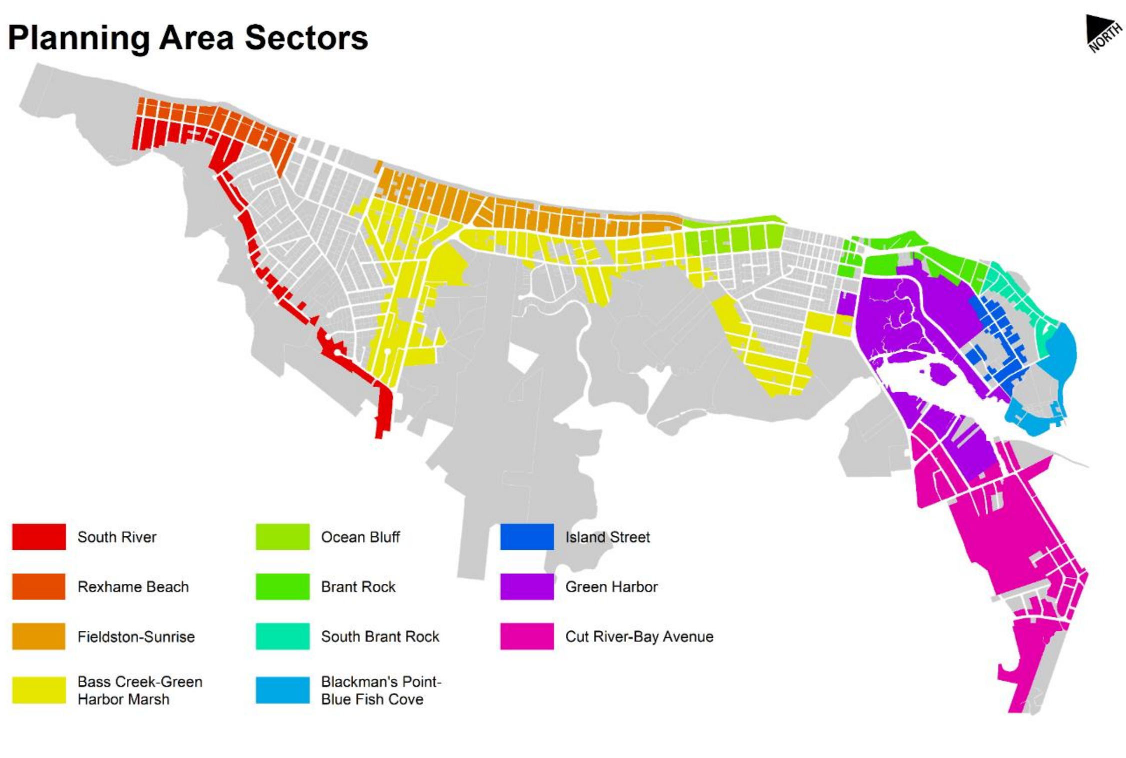


Figure 1. Map of planning area and sectors.

This report describes the methods and results of economic analyses carried out to estimate the impacts from long-term coastal flooding if no action is taken and if alternative mitigation strategies and policies are implemented. It identifies cost-effective strategies and policies to help mitigate coastal flooding risks and make the community more resilient to climate change, both before and after a catastrophic flooding event. Finally, it provides recommendations for the Town to act on the findings of the planning process, including potential implementation funding sources.

The report is organized as follows:

- **1.0 Benefit-Cost Analysis** describes the overall framework used to evaluate the cost-effectiveness of coastal flood mitigation strategies and policies and application of results.
- **2.0 Damage and Loss Estimation** describes the methods used to estimate future long-term economic impacts from coastal flooding and reports the baseline damages and losses expected if no action is taken.
- **3.0 Mitigation Strategies** describes the physical actions (i.e., elevation, voluntary acquisition, regulatory taking and eminent domain, dry floodproofing) considered as part of the economic analysis, their costs, and how they were applied.
- **4.0 Policy Scenarios** describes three policy scenarios, including their different combinations of mitigation strategies and levels of implementation (limited to aggressive), and the cost-effectiveness analysis results for each, along with limitations.
- **5.0 Additional Policy Analyses** describes the results of specific analyses evaluating the number of elevation, dry floodproofing, and voluntary acquisition projects that have the potential to meet federal grant eligibility criteria, as well as the cost-effectiveness of eminent domain and large no build zones along the waterfront to mitigate wave overtopping risks.
- **6.0 Policy and Zoning Recommendations** describes eight recommendations, with various sub-components, for the Town to implement regulatory changes, policies, programs, and projects that serve the goal of building resilience to long-term coastal flooding risks.

As part of the planning process, Town departments, elected officials, board/commission/ committee members, residents (including high school students), and businesses were engaged through interviews, a public workshop, public meetings, and an online survey. Engagement activities focused on learning from local knowledge, educating and raising public awareness about future coastal flooding threats and gathering ideas, feedback, and preferences on different mitigation strategies, policies, and draft recommendations. Members of the public were notified about opportunities to participate in the planning process through the Town's website, printed flyers, and email. Specific outreach to neighborhood organizations, Town board/commission/committee members, high school students, and individuals who participated in prior project engagement activities was conducted. Public presentations, meeting summaries, and a summary of survey results are publicly available on the Town's Planning Department website. Video of the first community workshop is also available on Marshfield Community Television's Vimeo website.

1.0 BENEFIT-COST ANALYSIS

The cost-effectiveness of a range of coastal flood risk mitigation policy scenarios was evaluated to inform long-term resiliency recommendations for the Town. Cost-effectiveness was evaluated using a Benefit-Cost Analysis (BCA) framework. Federal Emergency Management Agency (FEMA) defines a Benefit-Cost Analysis as "a method that determines the future risk reduction benefits of a hazard mitigation project and compares those benefits to its costs. The result is a Benefit-Cost Ratio (BCR). A project is considered cost-effective when the BCR is 1.0 or greater." In other words, the benefits must equal or be greater than the costs. BCAs were performed and BCRs calculated for each mitigation policy scenario.

The primary benefits quantified and included in the BCAs were avoided damage and loss (i.e., flood risk reduction) and environmental benefits (for acquisition policies only). Other benefits that can be quantified but were not included in the BCAs are avoided emergency response and cleanup costs and insurance cost-savings. Because these benefits are not included, it is likely that the cost-effectiveness of mitigation policy scenarios evaluated in this project is underestimated.

The BCAs included all key costs, such as the costs of constructing mitigation improvements; the costs of associated engineering, planning, project management, construction management, and other professional services (e.g., legal); and loss of tax revenue (for acquisition policies only).

BCAs are useful for a variety of purposes in mitigation planning:

- To compare the relative cost-effectiveness of different mitigation strategies for an individual structure to inform property owner decisions (e.g., should a commercial building owner elevate the building or dry floodproof it – which strategy would be most cost-effective?).
- To compare the relative cost-effectiveness of mitigation for multiple buildings (e.g., which buildings are the most cost-effective to mitigate – which should be prioritized with limited resources to get the most bang for the buck?).
- To evaluate the overall social and economic outcomes of a mitigation program and help identify a portfolio of mitigation projects that is cost-effective overall.

BCAs are also required to determine eligibility for federal mitigation grant programs. To be eligible, projects must be cost-effective (BCR of 1.0 or greater). This ensures federal funding is responsibly invested. For example, FEMA's Flood Mitigation Assistance (FMA) and the Hazard Mitigation Grant Program (HMGP) provide funding for mitigating flood risks to individual or groups of buildings. If applying as an individual structure, each building's BCR must be greater than 1.0 to be eligible. If multiple buildings are included in a grant application, their aggregate BCR must be 1.0 or greater. FEMA's Building Resilient Infrastructure and Communities (BRIC) grant program and the US Army Corps of Engineers' (USACE) Coastal Storm Risk Management

(CSRM) grant program generally target mitigating flood risks to larger project areas with multiple buildings. Individual buildings in USACE CSRM project areas can have mitigation BCRs as low as 0.9 and still be eligible for funding if the broader project has a BCR greater than or equal to 1.0 and if their inclusion would improve community cohesion with other eligible buildings.

To be used for determining individual projects' FEMA grant eligibility, a FEMA-specific methodology must be used following procedures in the latest version of the FEMA BCA Toolkit. The BCA conducted for this project did not follow that methodology because the aim was to evaluate the overall social and economic outcomes for the community, not individual properties. However, many elements of the analysis were consistent with the FEMA methodology.

2.0 DAMAGE AND LOSS ESTIMATES

Most of the quantified benefits in a BCA typically come from avoided damages and losses. To account for these potential benefits, damages and losses must be estimated both with and without mitigation. For this project, FEMA's Hazus program – a geographic information system (GIS) software – was used to estimate damages and losses from storm surge flooding, accounting for the increased flood risk caused by projected relative sea level rise. FEMA's Hazus Program provides standardized tools and data for estimating physical, social, and economic impacts from floods and other hazards.

In addition, this project used creative methods to overcome challenges with quantifying the risk associated with wave overtopping and related seawall failure in the planning area. Because these are not peer-reviewed or standard methods, wave and seawall failure damages and losses and strategies to mitigate them were not integrated in the broader BCAs. However, results are reported here to provide an estimate of the potential risks.

2.1 Storm Surge and Sea Level Rise

Hazus can perform an "out of the box" analysis at the Census Block level without specific building locations or characteristics. The out of the box methodology uses area-weighted analysis, whereby, in general terms, the percent of the Census Block that is flooded is assumed to be equal to the percent of buildings flooded, and damages and losses are calculated for a generalized building stock based on regional characteristics. This is a relatively high-level analysis.

Alternatively, Hazus can perform a "site level" analysis, which models the impacts to each individual building within a defined planning area based on site-specific building location, characteristics, and flood depths. Hazus requires users to input data on local conditions to carry out a site level analysis, including a building inventory and flood depth maps. The results are more site-specific, detailed, and accurate than an out of the box analysis. For this project, site level analyses were carried out in Hazus.

The building inventory for the planning area was developed using the following data sources:

- State GIS information on building locations and footprints – only buildings in areas that fall within the 2050 0.1% annual chance (1,000-year return period) flood boundaries from the Massachusetts Coast Flood Risk Model (described below) were included
- Marshfield Assessors data on building occupancy, area, number of stories, and assessed values
- Field data collected by Town staff on estimated foundation type, basement presence and type, and first floor height above ground – this data was collected in a high-level visual survey of buildings in the planning area using the number of stairs up to the front door as an estimate of the first floor height above ground
- RS Means – an industry standard cost estimating data provider and software – for regionally appropriate building replacement values based on standard costs per square foot by building occupancy
- Content replacement values based on a standard percentage of building replacement value identified in the Hazus software
- Other data derived from US Census data, such as the number of occupants and average income

The flood depth maps for the planning area account for present and future coastal flood risk from sea level rise and coastal storms. The Massachusetts Coast Flood Risk Model (MC-FRM) was used to develop site-specific, GIS-based flood depth maps. The MC-FRM is a probabilistic, hydrodynamic model that assesses present and future coastal flood risk throughout the Commonwealth of Massachusetts. It was developed by Woods Hole Group and other partners for MassDOT's use in coastal vulnerability assessments, adaptation planning, and resilient design. The MC-FRM has been adopted by the State's Resilient Massachusetts Action Team (RMAT) for use by all state agencies as part of their Climate Resilience Design Standards and Guidelines for coastal projects. The MC-FRM helps coastal communities prioritize adaptation investments over time using a strategic risk-based framework.

The MC-FRM incorporates the "High" relative sea level rise (RSLR) projections developed by the State. Selecting the "High" scenario reduces the risk of under-preparing and under-designing for the future, while providing flexibility to move the timeline for adaptation actions further into the future if observed RSLR follows lower trajectories. **Figure 2** plots the observed monthly mean sea level at Boston Harbor tide gage through 2020, the four State RSLR scenarios for 2020-2100, and the selected values (and sea level rise increments from 2008 baseline) used in MC-FRM's for the 2030 (blue), 2050 (pink), and 2070 (purple) time horizons. The "High" results in 2030 are similar to "Intermediate" results in 2050 (blue), the "High" results in 2050 are similar to the "Intermediate" results in 2070 (pink), and the "High" results in 2070 are similar to the "Intermediate" results in 2100 (purple), as indicated by the dashed lines in **Figure 2**.

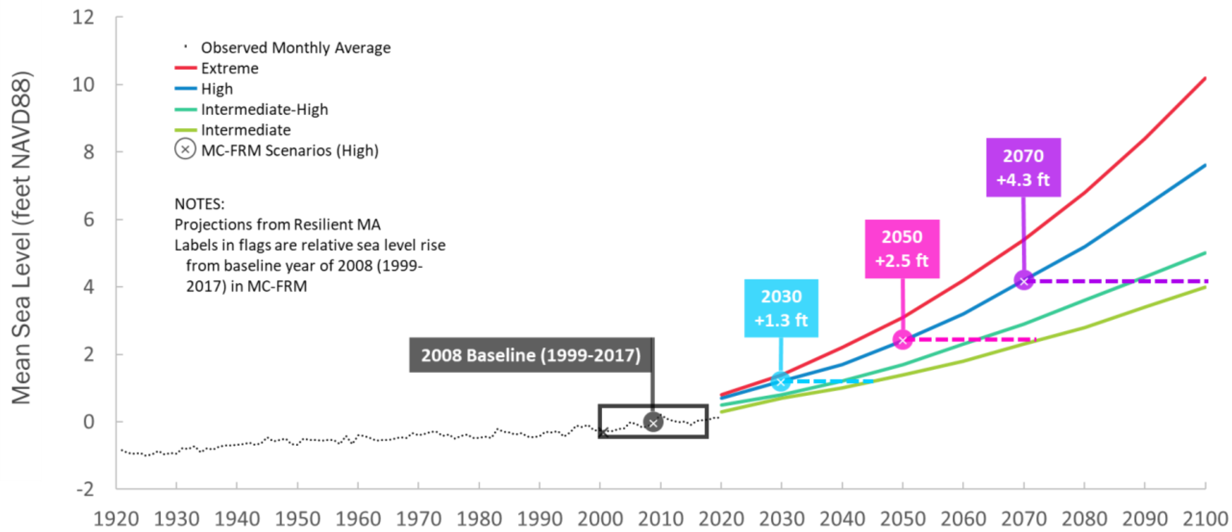


Figure 2. Observed relative mean sea level (ft-NAVD88) and State projections for the Boston Harbor tide gage.

The depth of inundation above ground during the 10%, 2%, 1%, and 0.2% annual chance water levels (i.e., the 10-, 50-, 100-, and 500-yr return periods) was mapped for the 2030 and 2050 time horizons. The flood depth maps were generated by subtracting LiDAR ground elevations from MC-FRM water surface elevations for each storm recurrence and time horizon. While the MC-FRM probability of inundation maps for the planning area do account for wave overtopping, flood depths from wave overtopping were not mapped due to limitations in available technical methods to do so.

The building inventory and flood depth maps were used in Hazus to estimate the direct damages within the planning area. Direct damages include the cost to repair or replace damaged buildings, contents, and business inventories. For each building, Hazus calculates the depth of flooding relative to the first floor height above ground using depth-damage functions. Specific functions are used according to each building's characteristics. In addition, Hazus was used to estimate time-dependent losses where the amount of loss is related to how long it takes to recover to pre-disaster conditions. These included temporary relocation expense, rental income loss, capital related loss, income loss, and business interruption loss.

Losses for each future flood scenario and time horizon were estimated as if no mitigation actions will be taken. These losses served as the baseline against which to compare residual, or remaining unmitigated losses, under different mitigation policy scenarios. The difference between losses with and without mitigation is the avoided loss, or benefit.

Out of 2,271 buildings in the building inventory, the number with flood losses (i.e., greater than $0.00) ranged from 1,101 (48%) in the 2030 10-year storm to 1,737 (76%) in the 2050 500-year storm. **Figure 3** shows the number of buildings impacted in each scenario. The value of total flood damage and loss ranged from just over $100 million in the 2030 10-year storm to nearly $400 million in the 2050 500-year storm. **Figure 4** shows the total value of losses in each scenario, broken down by type of loss. The largest categories of losses, in order, are building losses, contents losses, and business interruption losses.

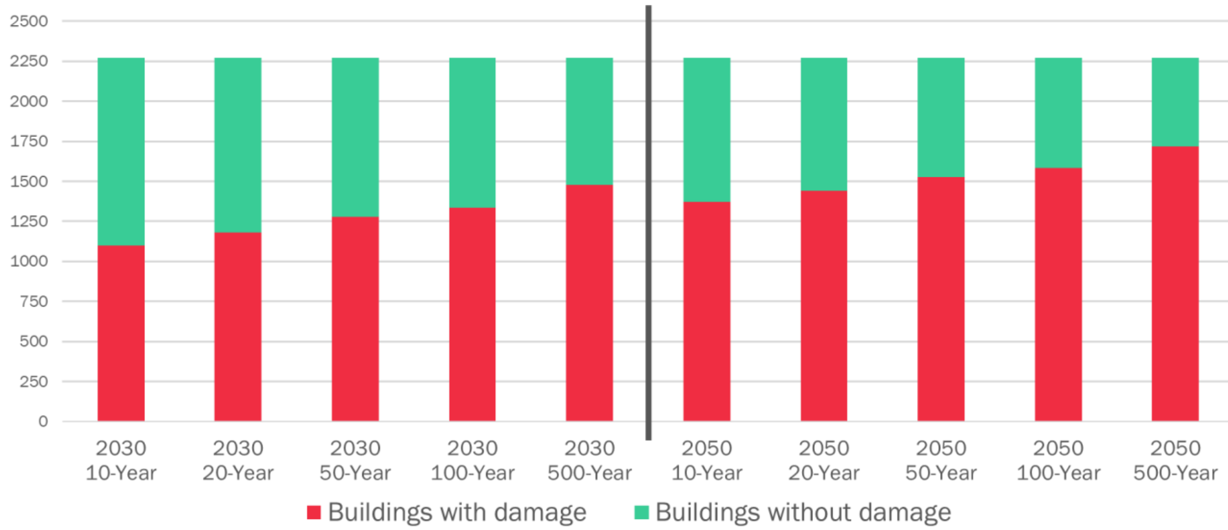


Figure 3. Number of buildings with and without flood damage and loss by storm return period and time horizon.

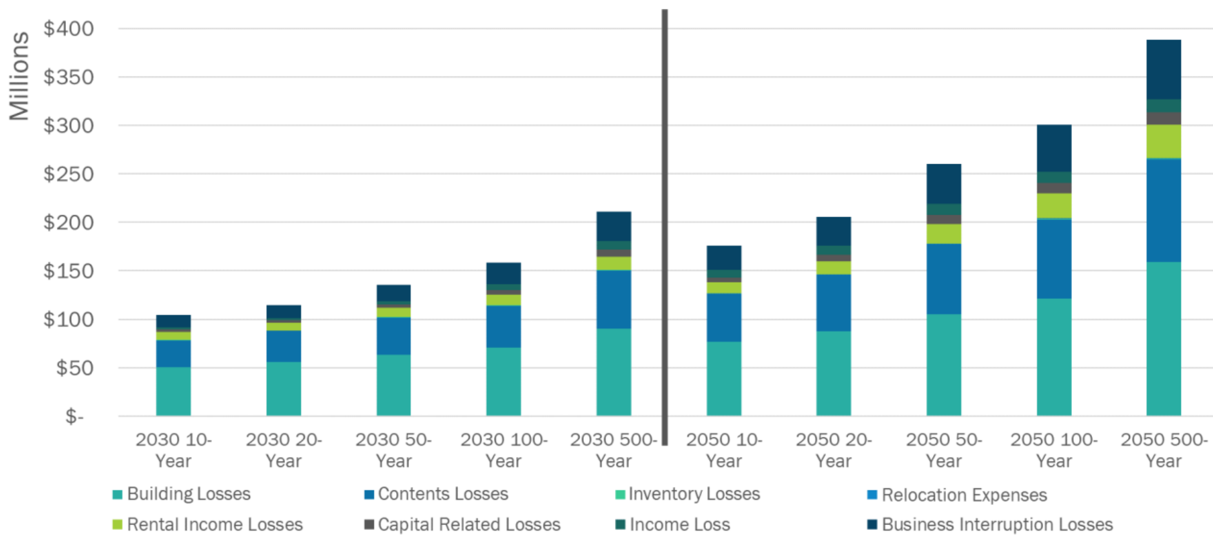


Figure 4. Value of flood damage and loss by type, storm return period, and time horizon.

The results presented in **Figure 3** and **Figure 4** are for single events. It is possible for multiple events to occur in the same year, and it is expected that high recurrence events will occur multiple times over longer periods of time (e.g., a 10-year event is expected to occur twice over a 20-year period, on average). To account for the differing probability of each single event loss occurring, another summary metric was calculated – average annual loss. This is the expected loss per year, on average, from coastal flooding. The average annual loss is not the actual amount of loss that will occur in every single year, as this will vary and be influenced by natural variability. It is just an estimate. Average annual losses were estimated to be over $11 million for the 2030 time horizon and about $16 million for the 2050 time horizon. **Figure 5** shows these results, broken down by type of loss.

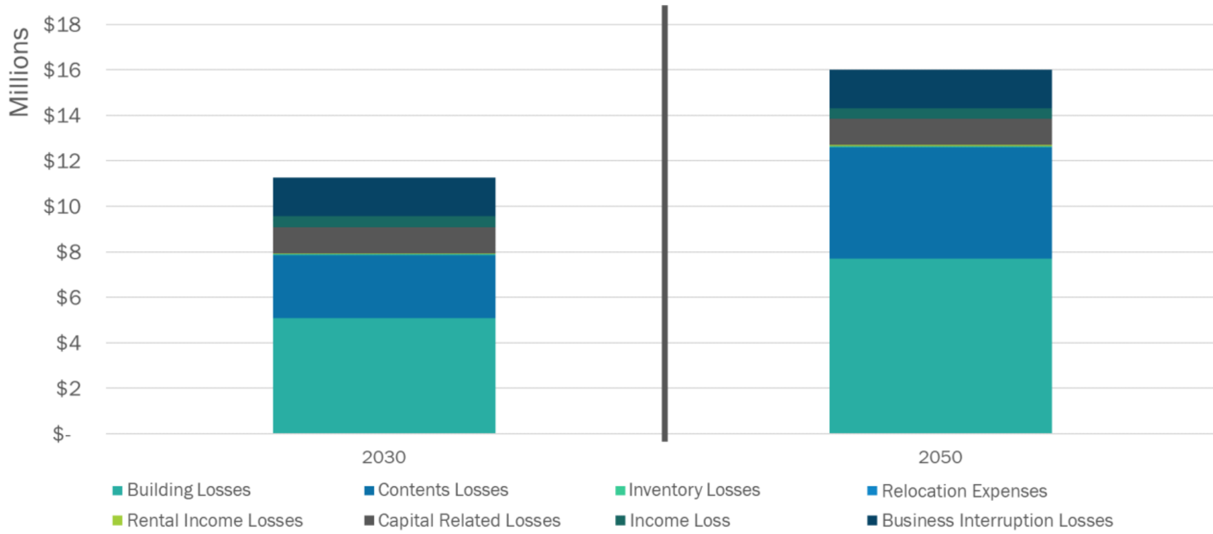


Figure 5. Value of average annual flood damage and loss by type and time horizon.

2.2 Wave Overtopping and Seawall Failure

Wave overtopping occurs when waves runup and splash over coastal structures, launching water, sediment (including large stones), and debris onto land and structures on the landward side. This can cause flooding as water accumulates behind the structure, erosion as water impacts the ground and drains away from the seawall, and direct damage to buildings as water and other materials impact buildings. Seawalls can also fail due to wave overtopping, beachfront erosion, and structure conditions.

Most of the repetitive loss properties in the planning area, and many of the National Flood Insurance Program (NFIP) insurance claims from the planning area, are located just inland of seawalls and revetments. The damages and losses to these properties and safety risks to their occupants has historically been due to a combination of wave overtopping and storm damage and seawall failures. Some of these properties are in FEMA Velocity Zones (Zone VE), denoting exposure to wave hazards. However, the existing seawalls and revetments in combination with topography limit the type of wave hazards in most of these areas. Waves are not generally propagating inland, breaking over land, and crashing into building foundations and walls. Rather, most of these areas are mapped in the VE Zone because they are in the 30-50 foot "splash zone" exposed to wave overtopping. The potential for coastal structure failure or the discontinuity of coastal structures may also factor into the VE Zone mapping extents in some areas (e.g., Rexhame Beach).

Existing damage estimation methodologies in Hazus and the broader literature do not address the specific types of damage caused by wave overtopping in splash zones. Use of VE Zone damage estimation methodologies, which are focused on the impacts of waves crashing directly into structures (which is likely to cause catastrophic damage), would overestimate the risks in these areas. As such, reasonable scenarios were developed to attempt to quantify future risk of these types of damages.

Wave overtopping rates were calculated by Woods Hole Group for cross-shore transects located along the planning area shoreline, shown on the left of **Figure 6**, as part of the Town's 2019 study into beach nourishment and alternative shoreline flood mitigation strategies. Rates were calculated for the 10-year and 50-year water level and wave conditions in Present day, as well as with 2 feet of relative sea level rise approximated for the 2050 time horizon. Rates were compared with US Army Corps of Engineers (USACE) wave overtopping damage thresholds for buildings and seawalls, shown on the right of **Figure 6**.

As opposed to depth-damage functions used in Hazus, the USACE damage thresholds do not provide a quantified estimate of the percent damage to a building or its contents at increasing overtopping rates. The increments between USACE damage thresholds are relatively large and the damage occurring at each threshold is described in simple and qualitative terms. For example, for buildings, "minor damage to fittings, sign posts, etc." is estimated to occur between rates of 0.001 and 0.03 liters/second per meter, while "structural damage" is estimated to occur at rates of 0.03 liters/second per meter or greater. These thresholds also do not account for differences in coastal structure or beachfront conditions.

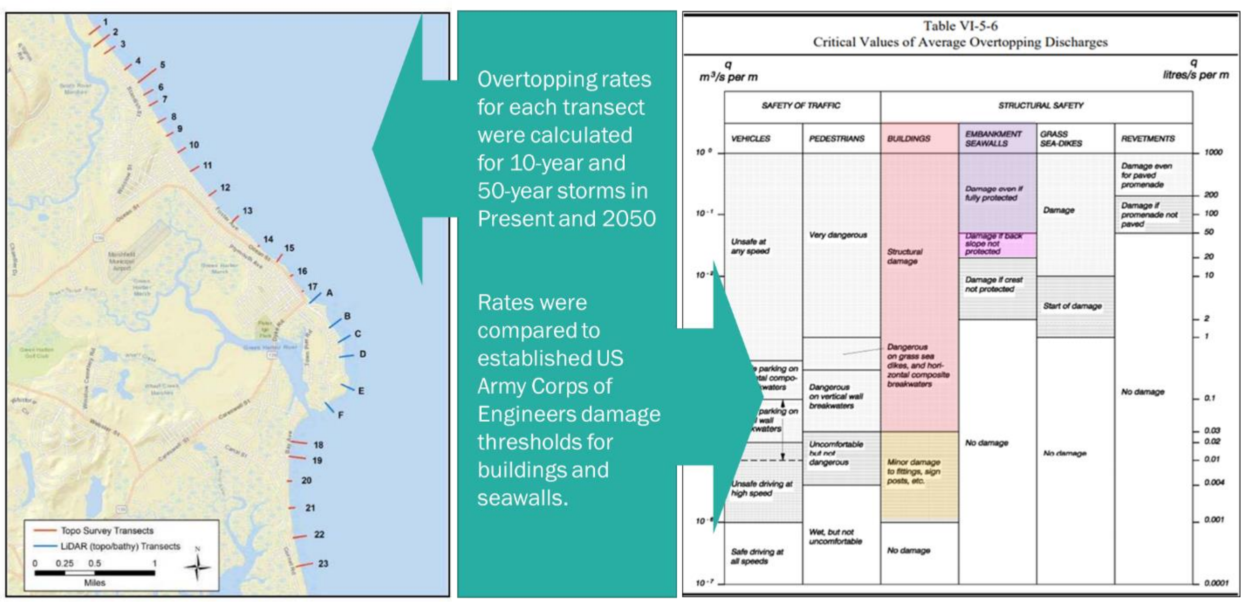


Figure 6. **Wave overtopping transects (left) and USACE overtopping rate damage thresholds (right).**

The calculated wave overtopping rates at different transects for Present and 2050 conditions are reported in the graphs of **Figure 7** and **Figure 8**, respectively. On the left of each figure, the vertical scale is larger to encompass the upper bounds of wave overtopping rates and their relation to the higher seawall damage thresholds, and on the right the vertical scale is smaller to show their relation to the much lower building damage thresholds.

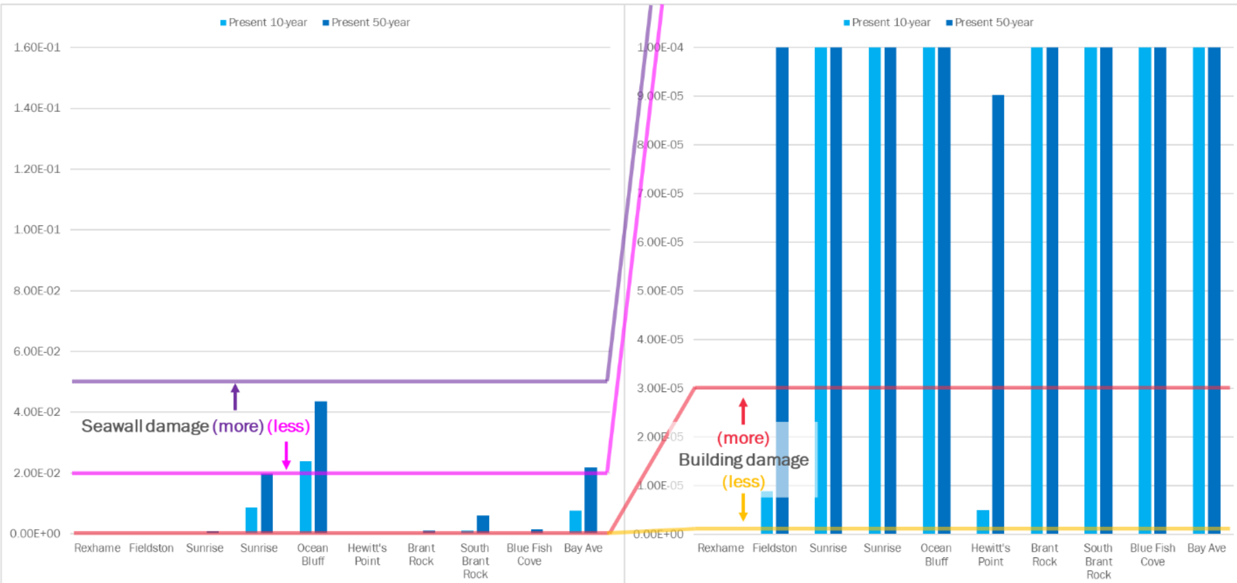


Figure 7. **Present wave overtopping rates compared to USACE damage thresholds for seawalls and buildings.**

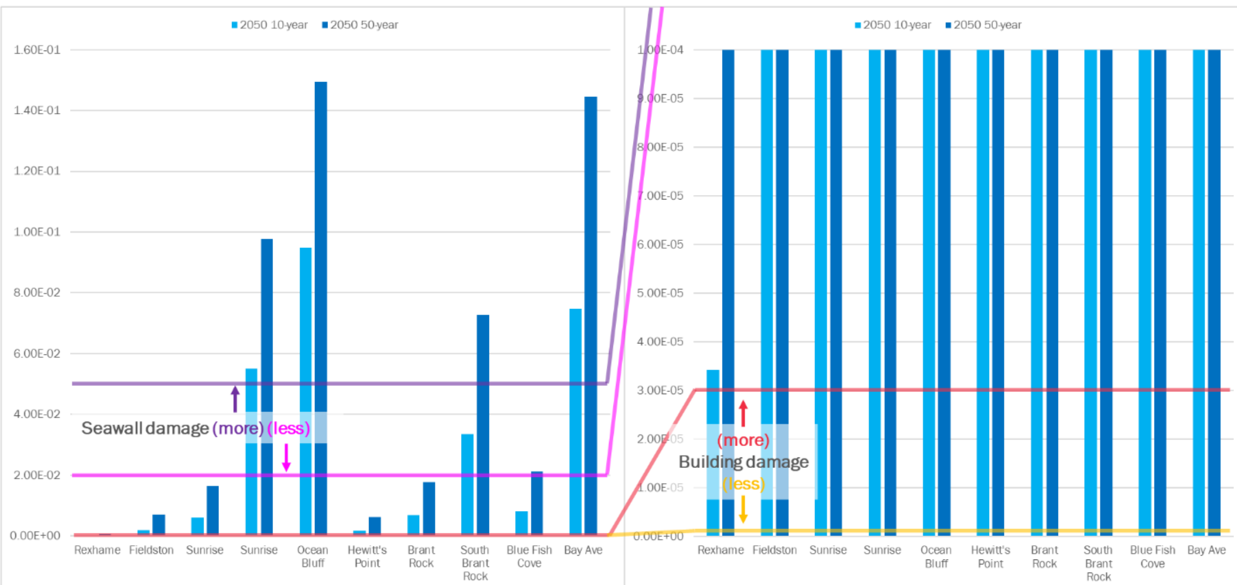


Figure 8. **2050 wave overtopping rates compared to USACE damage thresholds for seawalls and buildings.**

In Present conditions, wave overtopping exceeds the structural damage threshold for buildings (red line) in the 50-year storm at every transect except Rexhame Beach, and in the 10-year storm at every transect except Rexhame Beach, Hewitt's Point, and Sunrise. Overtopping exceeds the minor building damage threshold in the 10-year storm at every transect except Rexhame Beach. In 2050, overtopping exceeds the higher threshold in the 10-year and 50-year storms for all transects. The magnitude by which structural damage threshold is exceeded is significant, validating the historical concentration of repetitive losses among oceanfront properties and raising significant concern for future risks under a changing climate.

The same 2019 study evaluated the feasibility and effectiveness of raising Town-owned seawalls higher to mitigate the 2050 structural damage risks to oceanfront buildings from overtopping. It found that to mitigate just the 2050 10-year storm overtopping below this threshold, most Town-owned seawalls would need to be raised by 8 feet or more (5 feet for Fieldston, 7.5 feet for Sunrise north, and 4 feet for Hewitt's Point). It further stated, "Based on existing elevations of the infrastructure landward of the seawalls, and the design of the seawalls themselves, it is likely that crest increases greater than 4 ft would not be practical without significant modifications to the sites (i.e., roadway modifications, building redesign/relocation to landward edge of property, raise grade behind the seawalls)." Costs to construct maximally sized seawalls were estimated in the order-of-magnitude range of $100-200 million.

In Present conditions, wave overtopping exceeds the lower threshold for seawall damage "if back slope is not protected" (pink line) at Ocean Bluff in both 10-year and 50-year storms, and at Sunrise (south) and Bay Ave in 50-year storms. Present overtopping rates do not exceed the higher threshold for "damage even if [back slope is] fully protected" (purple line) at any transect. In 2050, with 2 feet of relative sea level rise, the higher threshold is exceeded at these same three transects in both the 10-year and 50-year storms. In addition, the higher threshold is exceeded at South Brant Rock in the 50-year storm, and the lower threshold is exceeded at South Brant Rock in the 10-year storm and at Blue Fish Cove in the 50-year storm, in 2050.

The relatively low Present day risk of seawall failure from overtopping does not account for differences in structure condition. Coastal structure condition ratings used to inform the same 2019 study indicated that the Ocean Bluff, Bay Ave, and South Brant Rock seawalls were in fair or poor condition and their beachfronts were highly eroded. Sunrise, in contrast, has recently upgraded seawalls which were mostly in good or excellent condition – however the beachfront was also highly eroded. Considering these factors, most damages from seawall failure could reasonably be expected to occur in the Ocean Bluff and Bay Ave areas in Present, and expanded to include Sunrise (after which time the condition may be degraded) and South Brant Rock in 2050.

Informed by the analyses described above and a review of VE Zone FEMA NFIP Redacted Claims database information for properties in the planning area Census Tracts, judgement was used to develop a basis for estimating potential damages from wave hazards. The method uses consistent time horizons and storm recurrences as the Hazus analysis. For each recurrence and time horizon, the approximate number of buildings assumed to incur damage and the percent of building and contents assumed to be damaged were estimated. The approximate number of buildings with claims in higher and lower recurrence events was summed from the historical claims data and multiplied by a factor of three, assuming that about half of property owners are uninsured and a third of the insured property owners did not file claims to avoid higher insurance costs and therefore would not be captured in the claims data. Approximate percent damages for buildings and contents were based on the approximate ratio of claims values to insured values for properties with claims in higher and lower recurrence events. It was assumed that overtopping and seawall failure would cause differing levels of damage, with seawall failure being the more likely to cause substantial damage. The more extreme storm recurrences lack historical analogies in the claims data, including almost all the 2050 scenarios. Therefore, assumptions were made regarding the magnitude of increase in number of buildings damaged and associated percent damages. The parameters derived from the analysis above are reported in **Table 1**.

The building inventory used for the Hazus analysis was narrowed to oceanfront properties with buildings located within 100 feet of existing coastal structures. A random selection of the number of buildings indicated in **Table 1** was made from the oceanfront building inventory, and overtopping damages were applied for each recurrence and time horizon. A smaller subset of buildings located in areas of higher risk of seawall failure was identified based on the threshold and condition analysis above. A random selection of the number of buildings indicated in **Table 1** was made from this subset, and seawall failure damages were applied for each recurrence and time horizon. The rules of the random selection were such that the same building could not be counted towards both overtopping and seawall failure damages. Time-dependent losses were not estimated.

Table 1. Wave overtopping and seawall failure damage estimation parameters.

Storm recurrence	Cause of Damage	2030			2050		
		Number Damaged	Building % Damage	Contents % Damage	Number Damaged	Building % Damage	Contents % Damage
10-year	Overtopping	15	10	15	20	35	55
	Seawall Fail	NA	NA	NA	40	50	75
20-year	Overtopping	25	15	20	25	40	60
	Seawall Fail	5	50	75	45	50	75
50-year	Overtopping	20	20	30	30	50	75
	Seawall Fail	25	50	75	50	50	75
100-year	Overtopping	20	35	55	40	80	100
	Seawall Fail	40	50	75	60	80	100
500-year	Overtopping	30	50	75	60	100	100
	Seawall Fail	50	50	75	80	100	100

Out of the 180 buildings in the oceanfront building inventory, the estimated number of buildings with flood losses ranged from 15 (8%) in the 2030 10-year storm to 140 (78%) in the 2050 500-year storm. **Table 1** reports the estimated number of buildings to be impacted by wave overtopping and seawall failure in each scenario. The estimated value of total flood damage and loss ranged from just over $0.6 million in the 2030 10-year storm to nearly $53 million in the 2050 500-year storm. **Figure 9** shows the estimated total value of damages in each scenario. Estimated average annual damages were about $0.5 million in 2030 and $1.8 million in 2050. The cost of replacing or repairing existing seawalls and revetments that are in poor or fair condition based on Town estimates is approximately $30-40 million, not including additional costs of raising them higher. As noted above, maximally raising Town-owned seawalls was estimated to cost in the order of magnitude of $100 million to $200 million.

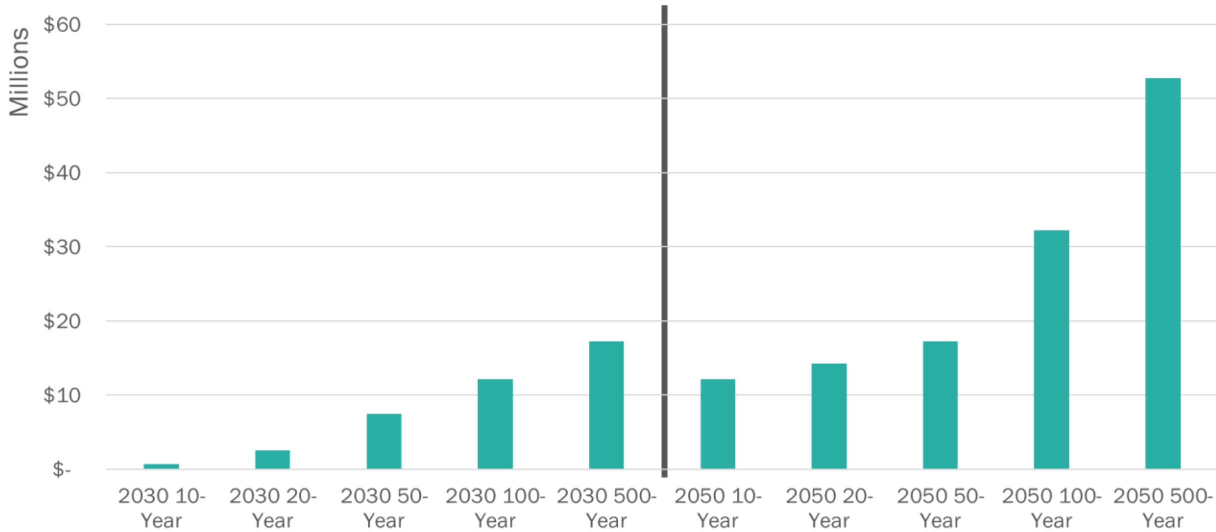


Figure 9. Estimated total value of wave and seawall failure damage and loss by storm return period and time horizon.

3.0 MITIGATION STRATEGIES

The cost-effectiveness of three primary coastal flood risk mitigation strategies was evaluated, namely elevation, acquisition, and dry floodproofing. These are the three non-structural mitigation strategies that are typically eligible for grant funding as part of FEMA hazard mitigation assistance programs and USACE flood risk reduction projects. In addition, regulatory taking and eminent domain were evaluated, which, like acquisition, result in buildings being removed from or prevented from being built or rebuilt in the floodplain. Simple illustrations of these strategies are shown in **Figure 10**. These strategies are described in the sections that follow.

Figure 10. Simple illustrations of mitigation strategies evaluated in this study.

Cost estimates were developed for each strategy, including base costs, technical and administrative costs (markup percentages of base costs), and contingencies. Contingencies like those used in recent USACE studies with similar scope from the New England region were applied to base and technical/administrative costs. Costs were applied to individual buildings in the building inventory based on their spatial location and other selection criteria described in the Policy Scenarios section that follows.

Figure 11 shows the impact zones within which different strategies were considered for application. Buildings potentially exposed to the 0.1% annual chance (1,000-year) storm flooding (red outlined parcels) were considered for elevation. Buildings potentially exposed to daily tidal flooding in 2050 (bright blue) or 2030 (purple parcels) or to structural damage from wave overtopping or seawall failure in 2050 (yellow parcels) were considered for acquisition, regulatory takings, or eminent domain. Details on these policies and how they were applied are described in the following sections.

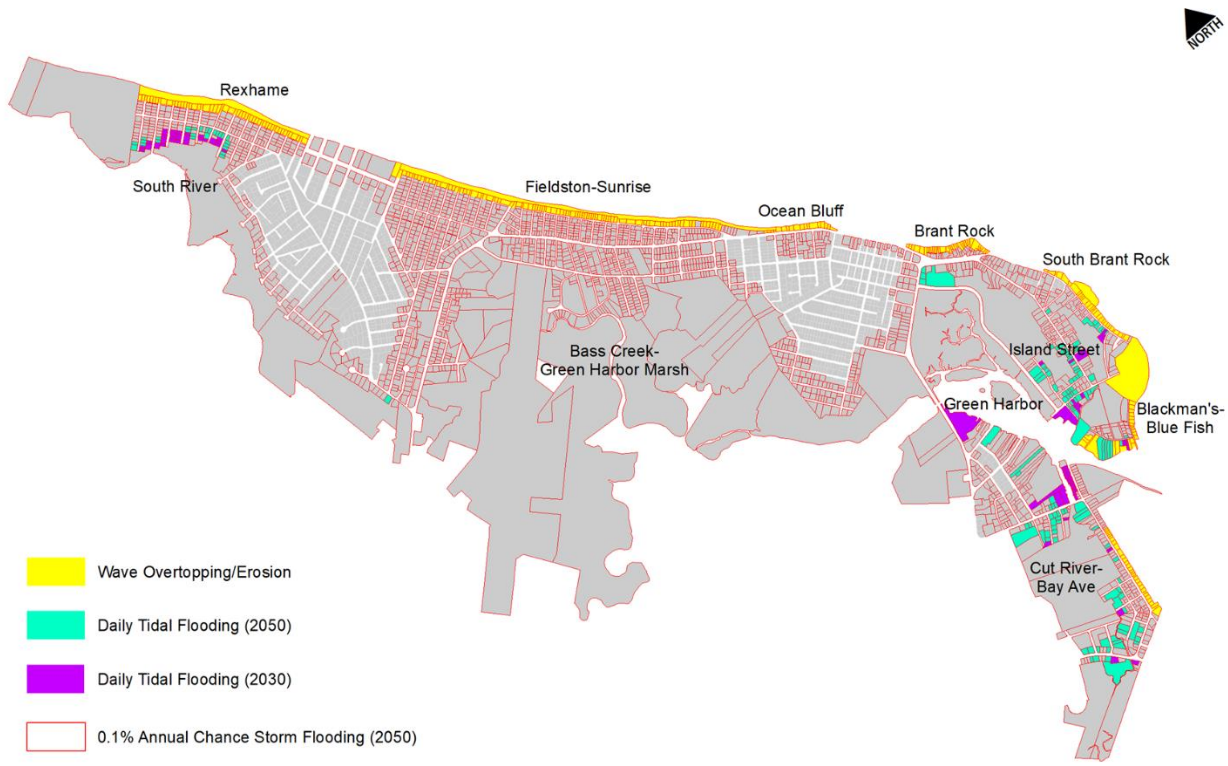


Figure 11 Impact zones within which mitigation strategies were considered for application.

Individual buildings were not structurally assessed to determine whether it is feasible to elevate or dry floodproof them, and bottom-up cost estimates were not prepared for individual buildings. Those analyses and estimates would be required as part of future implementation (grant applications, etc.). For the purposes of this study, elevation and dry floodproofing were assumed to be technically feasible and follow typical costs for all buildings.

3.1 Elevation (Residential)

Elevation is a common mitigation strategy in coastal communities, including Marshfield. FEMA's *Homeowner's Guide to Retrofitting* provides guidance on the design and construction process of home elevation projects, along with considerations and factors that can affect the feasibility and cost.

For the purposes of this study, elevation means a residential building is raised up to or above the projected 2050 100-year flood elevations identified in the MC-FRM flood maps plus 1 foot of freeboard. For areas in existing FEMA AE Zones, this minimum elevation is approximately 13 feet

NAVD88 though it varies spatially by ±0.5 ft. Future damages and losses from storms evaluated in Hazus for the 2030 and 2050 time horizons would be eliminated for properties elevated to this level. Damage to landscaping and vehicles were not accounted for in the Hazus estimates and could still occur after a home is elevated. It may be feasible to elevate non-residential buildings, depending on the way they are constructed. However, for this project, elevation of non-residential buildings was not evaluated.

A property owner can elevate their home voluntarily at any time, subject to local approvals (e.g., zoning), but the State Building Code requires elevation in the FEMA Special Flood Hazard Area for new construction, substantial improvement, and as part of the rebuilding process if a building or its foundation is substantially damaged by a flood. The latter is referred to for FEMA grant purposes as "mitigation reconstruction." This study assumes that one or more policies are put in place to require that new and substantially damaged or improved homes to be elevated to a higher standard than the existing minimum requirements including in areas beyond the FEMA Special Flood Hazard Area to which the floodplain is projected to expand. As with other mitigation strategies evaluated, cost-effective elevation projects are generally eligible for federal grants through FEMA or USACE. FEMA elevation grants are competitive, with repetitive loss and severe repetitive loss properties being prioritized, and the funding must pass through the State (as the applicant) and Town (as the sub-applicant) before reaching property owners. Specific policy recommendations are provided later in this report.

Typical residential elevation cost estimates from the 2018 USACE *Pawcatuck River Coastal Storm Risk Management Feasibility Study, Final Integrated Feasibility Report & Environmental Assessment* were used as a starting reference for home elevation costs. The table provides elevation costs for typical structures with different combinations of structural features, such as footprint shape (simple vs complex), foundation type, presence of basement, and number of stories.

The planning area building inventory had some buildings with structural feature combinations that differed from the typical structures covered by the USACE cost table. For these, additional typical costs were developed. For example, the table provides costs for simple and complex 1-story buildings with no basement, but only simple 2-story buildings with no basement. To create a cost for complex 2-story buildings with no basement, the simple 2-story costs were multiplied by the ratio of complex to simple 1-story buildings with no basement. Base costs for six new typologies were created following this approach and cross walked with the building inventory.

The resulting base costs for 12 building typologies were increased to account for typical construction cost differences between Rhode Island and Massachusetts and to account for cumulative inflation since 2018. In addition, technical and administrative costs were added based on percent of base costs used by the USACE for the 2021 *Rhode Island Coastline Coastal Storm Risk Management (CSRM) Project Feasibility Study*. These included 11.5% for lands and damages (20% contingency); 18.5% for Planning, Engineering, and Design (30% contingency); and 3.3% for Construction Management (30% contingency). A 30% contingency was also added to base costs.

Base costs for home elevation ranged from about $85,000 ($110,000 with contingency) for a simple 1-story building with no basement to about $167,000 ($217,000 with contingency) for a complex 2-story building. Total costs ranged from about $146,000 to $288,000, including technical and administrative costs and contingencies.

3.2 Voluntary Acquisition

Voluntary acquisitions, sometimes called "buyouts," are a less common coastal flood mitigation strategy. Residential and non-residential properties can participate in acquisition programs. In a voluntary acquisition, an eligible property owner sells their property for the pre-disaster fair market value to a public or non-profit entity. Any existing building is then demolished and turned into open space, which must be maintained and kept as open space in perpetuity. Voluntary acquisitions are voluntary – no property owner is forced to sell their property. It is also a lengthy process. The pre-disaster fair market value is determined by a certified appraiser. As with other mitigation strategies evaluated, cost-effective acquisition projects are generally eligible for federal grants through FEMA and USACE. FEMA acquisition grants are competitive, with repetitive loss and severe repetitive loss properties being prioritized, and the funding must pass through the State (as the applicant) and Town (as the sub-applicant) before reaching property owners. Voluntary acquisition projects are costly in high property value markets, such as Marshfield and, as such, tend to be less cost-effective than other mitigation strategies.

The cost of acquisition was estimated for each building in the planning area. Total value of each property including building, land, and other values, was obtained from the Marshfield's Assessors database. A $100,000 demolition cost was added for each building. A 30% contingency was added to the total value and demolition cost. Finally, technical and administrative costs were added, based on USACE's 2021 Rhode Island study, including 8% for Planning, Engineering, and Design (30% contingency) and 3.5% for Construction Management (30% contingency). In addition, for the purposes of the BCAs, the net present value of property tax revenue loss over the next 50 years was calculated based on the current tax rate of $12.95 per $1,000 of total assessed value. The net present value of open space created by the acquisition over the next 50 years was also calculated for each property and accounted for in the benefits for the purposes of the BCA, using the FEMA standard rate of $8,308 per acre per year.

3.3 Regulatory Taking and Eminent Domain

The last clause in the Fifth Amendment to the US Constitution states "…nor shall private property be taken for public use, without just compensation." Two mitigation strategies are relevant in the context of private property rights versus public projects or policies.

Regulatory taking is when government regulations limit the use of a private property to such a degree that the landowner is effectively deprived of all economically reasonable use or value of their property. One may think that if a community creates zoning or wetlands regulations that prohibit building or rebuilding homes on private properties in a flood prone area, without compensating the owners for the lost property value, that would be considered a regulatory taking or be unconstitutional. However, the Massachusetts Supreme Court and US Supreme Court have consistently ruled that when floodplain zoning is created in the public interest (e.g., public safety, wetlands resource protection) and does not render a property economically worthless, no compensation is due. See MA Office of Coastal Zone Management's *Fact Sheet 3. A Cape Cod Community Prevents New Residences in Floodplains* for an example.

For the purposes of the BCAs, the cost-effectiveness of "no build zones" wherein new construction, substantial improvement, and rebuilding of substantially damaged buildings would be prohibited was evaluated. Such regulatory restrictions were evaluated as if they were in fact regulatory takings, even though they technically are not. This was done, in line with the project's objectives, to account for the lost value to private property owners as part of the overall community costs and benefits. If the cost-effectiveness of such regulations were evaluated accounting only for the Town's cost (lost tax revenue) and public benefits (open space), the results would be very different.

Eminent domain is when private property is taken by the government for a proper public purpose and the private property owner is compensated for the fair market value of the taken property. It has been used, for example, in flood control projects where land that is currently owned by private individuals is needed by a public entity to construct the flood control infrastructure. USACE coastal storm risk mitigation projects, can use eminent domain to acquire flood prone properties if it is cost-effective to do so. FEMA hazard mitigation assistance cannot be used for eminent domain, only voluntary acquisition.

For the purposes of this project eminent domain was evaluated as a potential long-term strategy to mitigate persistent risks to private property and public infrastructure from wave overtopping and seawall failure. In the future, there may be a need to build larger or different, more resilient, potentially more natural types of coastal infrastructure than the existing seawalls and revetments. Upland areas may be needed for this infrastructure, since building out further into already eroded beaches would face steep environmental permitting challenges. This was more of a thought experiment than an actual policy the Town would like to pursue.

Base costs for regulatory takings and eminent domain were the same as for voluntary acquisitions, except that an additional $10,000 per property cost was added to account for legal services. The same technical and administrative costs and contingencies were applied as for acquisitions. As with acquisitions, property tax revenue losses and open space benefits were calculated and accounted for in the BCAs.

3.4 Dry Floodproofing (Non-Residential)

Dry floodproofing is when a structure is modified to be substantially impermeable to water up to a given flood elevation. The State Building Code only allows non-residential buildings and non-residential portions of mixed-use buildings to use dry floodproofing to meet requirements for flood-resistant design and construction in Special Flood Hazard Areas. Dry floodproofing can also be used to protect specific interior areas, like utility rooms, rather than an entire building or first floor. Dry floodproofing is not permitted in VE Zones. FEMA's *Floodproofing Non-Residential Buildings* publication provides guidance on the design and construction of dry floodproofing projects, along with considerations and factors that can affect the feasibility and cost.

For the purposes of this study, dry floodproofing means a non-residential building is made substantially impermeable to flooding up to or above the projected 2050 100-year flood elevations identified in the MC-FRM flood maps plus 1 foot of freeboard. For areas in existing FEMA AE Zones, this minimum elevation is approximately 13 feet NAVD88 though it varies spatially by ±0.5 ft. Future damages and losses from storms evaluated in Hazus for the 2030 and 2050 time horizons would be eliminated for properties dry floodproofed to this level. Damage to landscaping and vehicles were not accounted for in the Hazus estimates and could still occur after a building is dry floodproofed.

A property owner can dry floodproof their non-residential building voluntarily at any time, subject to local approvals, but the State Building Code requires dry floodproofing, if elevation is not implemented, in the FEMA Special Flood Hazard Area for new construction, substantial improvement, and as part of the rebuilding process if a building or its foundation is substantially damaged by a flood. This study assumes that one or more policies are put in place to require that new and substantially damaged or improved non-residential buildings that are not elevated be dry floodproofed to a higher standard than the existing minimum requirements including in areas beyond the FEMA Special Flood Hazard Area to which the floodplain is projected to expand. As with other mitigation strategies evaluated, cost-effective dry floodproofing projects are generally eligible for federal grants through FEMA and USACE. FEMA dry floodproofing grants are competitive, with repetitive loss and severe repetitive loss properties being prioritized, and the funding must pass through the State (as the applicant) and Town (as the sub-applicant) before reaching property owners. Specific policy recommendations are provided later in this report.

Typical dry floodproofing base costs cited in relevant literature range widely, from as low as $41,500 (2016 USACE *Brant Rock and Fieldston Areas Hurricane and Coastal Storm Damage Reduction Report*) to as high as $250,000 per building (2021 *USACE Rhode Island Coastline CSRM Feasibility Study*). Assuming an average size of commercial buildings in the Brant Rock area of about 3,700 square feet of first floor area, these precedent costs, with regional adjustments and cumulative inflation, range from about $13 to $70 per square foot. A conservative dry floodproofing base cost of $70 per square foot of first floor area was used for this study.

In addition, technical and administrative costs were added based on percent of base costs used by the USACE for the 2021 *Rhode Island Coastline CSRM Feasibility Study*. These included 8.5% for lands and damages (20% contingency); 15% for Planning, Engineering, and Design (30% contingency); and 6% for Construction Management (30% contingency). A 30% contingency was also added to base costs.

4.0 POLICY SCENARIOS

Three policy scenarios were developed and evaluated for cost-effectiveness at mitigating long-term coastal flood risks in the planning area. The scenarios consist of different combinations and levels of policy-supported mitigation strategy implementation. In each policy scenario, a catastrophic flood occurs in 2030 and various policy-supported mitigation actions are fully implemented resulting in mitigation costs being incurred. The benefits of those mitigation policies and actions over their effective lifetime were estimated, and the cost-effectiveness was evaluated. In addition to estimating cost-effectiveness for each policy scenario, the residual unmitigated losses over the effective lifetime were calculated.

When estimating the benefits of mitigation projects and policy scenarios, average annual losses avoided, and environmental benefits attained (where relevant) were added together for each year that a mitigation strategy is assumed to be effective. For this project, a 50-year effective lifetime was assumed. The first 20 years of avoided loss benefits are based on the coastal flood risk profile of the 2030 time horizon and the following 30 years on the 2050 time horizon. Because future money is valued less than money right now, a “discount rate” was applied to future benefits, with the resulting lifetime benefits being converted to a “net present value.” Since mitigation costs used in the BCAs are present costs, converting the benefits to net present value allows for an apples-to-apples comparison in estimating cost-effectiveness (i.e., calculating the BCR). Residual losses were calculated in the same way.

The standard discount rate required for federal hazard mitigation grant BCAs is 7%. Using a 7% discount rate, $100 in 2023 would be equal to a net present value of $93. However, other studies and policy analyses have proposed using a 3% “social” discount rate when evaluating societal benefits and costs of climate change policies. Using a 3% discount rate, $100 in 2023 would be equal to a net present value of $97. Using the lower discount rate can significantly increase the number of cost-effective projects and the net benefits of a mitigation project or policy scenario. For the purposes of this study, a 7% discount rate was used. However, cost-effectiveness based on a 3% discount rate are also provided at a summary level for informational purposes.

The following sections describe the triggering disaster scenario and the policies, mitigation strategies, and cost-effectiveness results for the three policy scenarios. Finally, a summary of results and limitations is provided.

4.1 Triggering Disaster Scenario

The cost-effectiveness analysis of all three policy scenarios is predicated on the occurrence of a triggering catastrophic coastal flood, represented by the 100-year flood in the 2030 time horizon. Without a triggering disaster, new regulatory policies would only affect the relatively small number of properties in the planning area that are redeveloped or substantially improved for other reasons each year. The impact of incentives, like the Town providing administrative support to property owners for federal mitigation grants, would also be limited by the Town’s capacity (historically, 2-5 properties for any given FEMA program year) and the risk perception of area property owners and their motivation to participate in such programs. It was assumed that, with a triggering disaster, regulatory policies and other financial incentives could have more transformational impacts on the long-term physical resilience of the building stock and financial resilience of residents and businesses in the planning area.

A key policy mechanism in all three scenarios, related to the triggering disaster, is that certain regulatory requirements for mitigation are linked to whether a building is substantially damaged. Substantial damage means the total cost of repairs is 50% or more of the building’s value before the flood occurred. When the owner of a building that is substantially damaged seeks a building permit to rebuild, they are already required to upgrade the building to meet the minimum flood resistant design and construction standards in the State Building Code, including elevating or dry floodproofing (for non-residential structures) to the FEMA FIRM Base Flood Elevation plus required freeboard. Substantially damaged buildings that have NFIP flood insurance with Increased Cost of Compliance coverage are eligible for up to $30,000 in extra funding to help meet elevation or dry floodproofing requirements. Substantially damaged buildings may also be eligible for FEMA mitigation reconstruction grants. By similarly linking long-term resilience-focused regulatory policies to substantial damage, the Town can more readily ensure that rebuilding after a future catastrophic event is done in a more resilient way, accounting for long-term risks.

The 2030 100-year coastal flood is estimated to cause some level of damage to 1,335 buildings, with total losses equal to more than $158 million. **Figure 12** shows the geographic distribution of total losses. About $65 million (41%) of total loss occurs in the Bass Creek-Green Harbor Marsh area, which is upstream of the Dyke Road flood control structure. Dense development of this low-lying area was made possible by Dyke Road, however, once Dyke Road is exceeded by coastal flood levels, the result is very deep flooding that causes widespread damage. Losses from wave overtopping and seawall failure are not included in these figures, so values reported for oceanfront areas are under-predictions. Wave overtopping and seawall failure may cause an additional $12 million in building and content losses, based on estimates discussed in Section 2, and $30-40 million in seawall repair and replacement costs.

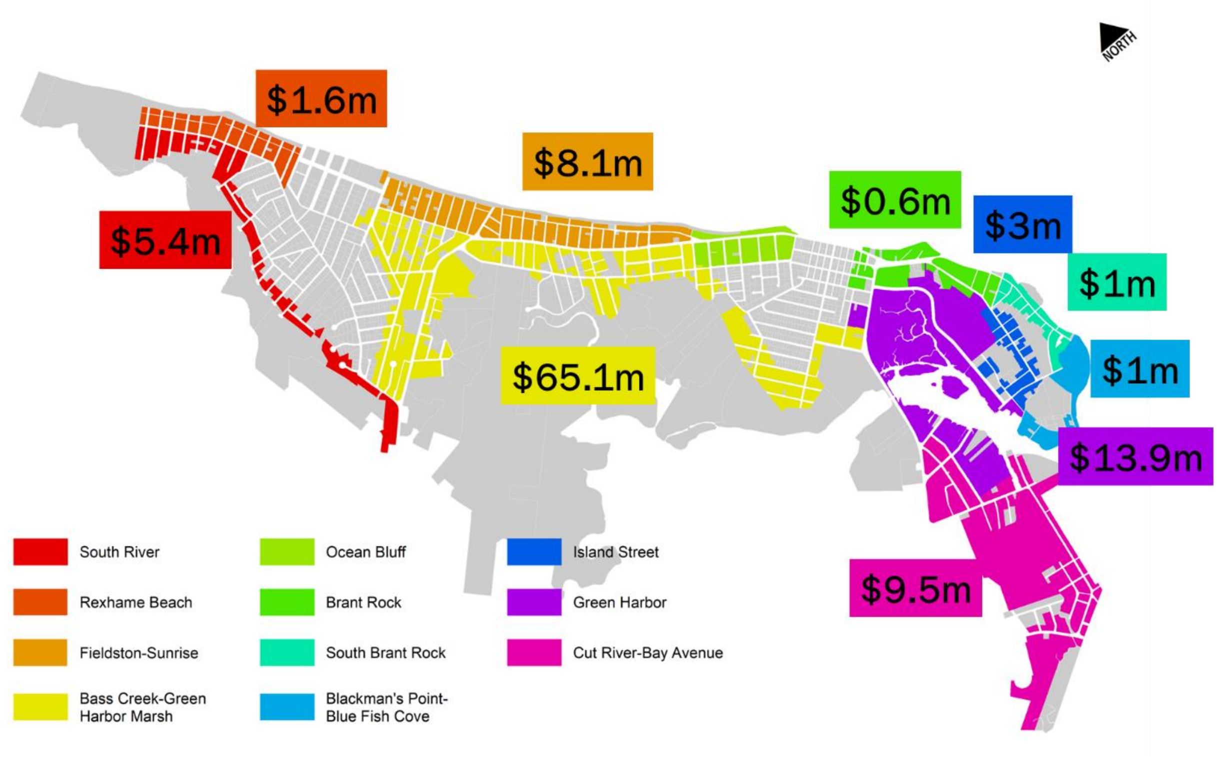


Figure 12. Geographic distribution of total damage and loss in 2030 100-year coastal storm, not including losses from wave overtopping and seawall failure.

There are 245 (18%) out of the 1,335 damaged buildings that are substantially damaged (building damage greater than or equal to 50% of building replacement value). This does not include substantial damage from wave overtopping and seawall failure. Substantially damaged buildings account for about $44 million (27%) of total losses, excluding wave overtopping and seawall failure. **Figure 13** shows the geographic distribution of these buildings. Again, the Bass Creek-Green Harbor Marsh area has a disproportionate concentration of impacts, accounting for 90% of substantially damaged buildings.

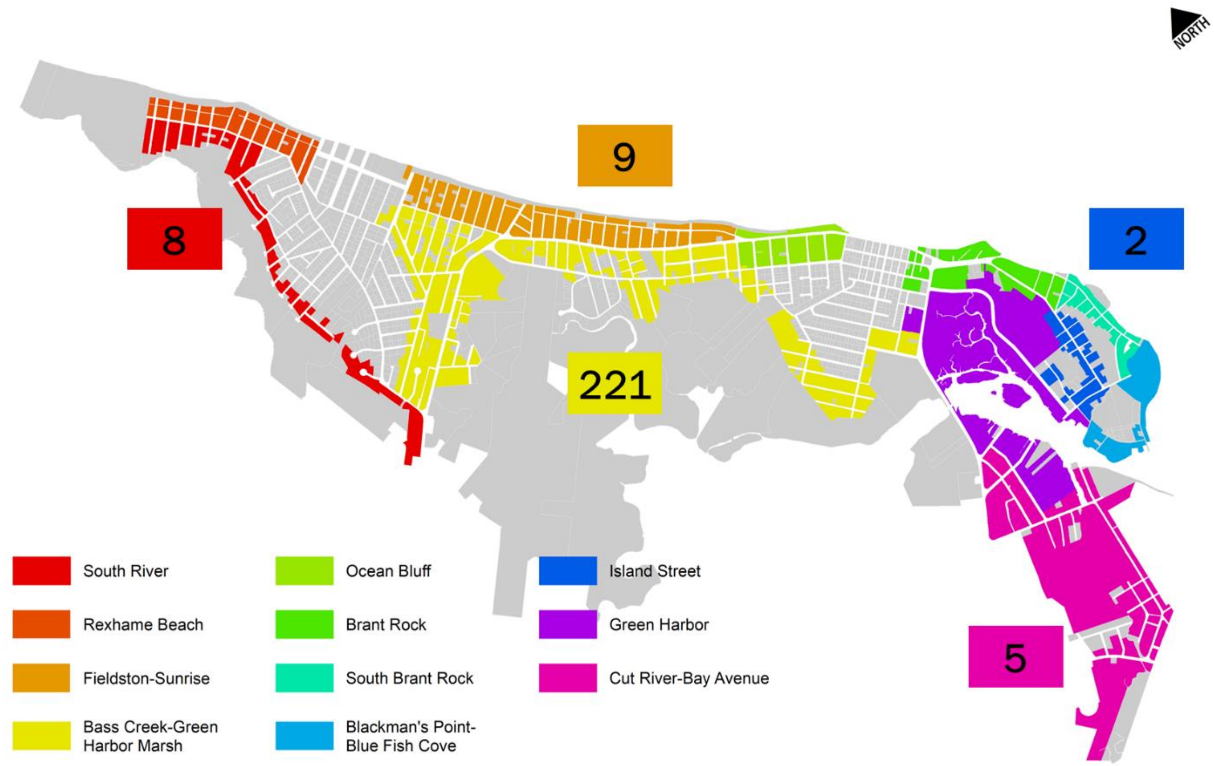
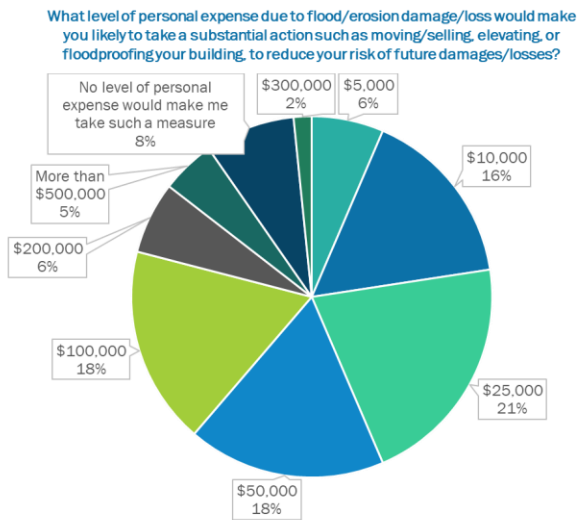


Figure 13. Geographic distribution of substantially damaged buildings in 2030 100-year coastal storm, not including losses from wave overtopping and seawall failure.

The building losses estimated in the triggering disaster scenario were also used to inform levels of participation in voluntary mitigation programs evaluated in the policy scenarios. As part of the community survey conducted for this project, participants were asked what level of personal expense due to flood damage would make them likely to take a significant mitigation action (i.e., elevation, acquisition, dry floodproofing) to reduce future risks. They were separately asked whether they would consider taking different mitigation actions. Summaries of their responses are shown in **Figure 14**. The percentages of people willing to take specific actions after incurring specific thresholds of damage, based on the survey data, and applied to the building damage estimates in the triggering disaster, were used to estimate the percent and number of buildings that would participate in voluntary programs.



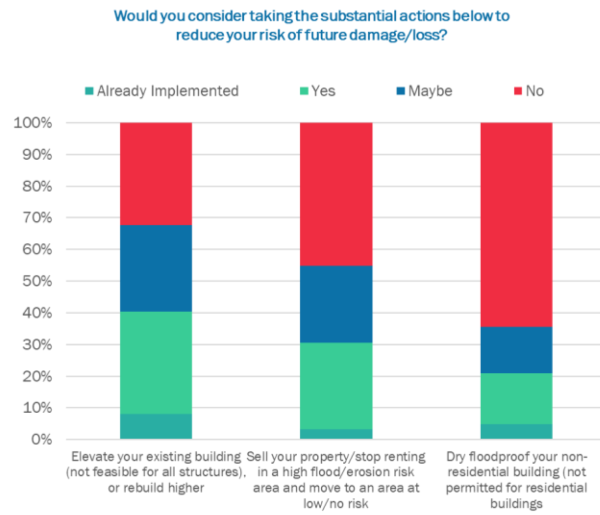


Figure 14 **Community survey results used to inform levels of participation in voluntary mitigation programs.**

4.2 Scenario 1: Limited Policies

Scenario 1 – Limited Policies is the most limited in policy interventions. It includes the following:

- **Higher Elevation Standard:** A regulatory policy to require that substantially damaged residential buildings elevate to higher standard of the 2050 100-year flood elevation plus 1 foot.

- **Voluntary Acquisition Program:** A limited voluntary acquisition program targeting properties with buildings that are in areas of projected daily average highest tide flooding (Mean Higher High Water, MHHW) in 2050. Eligible properties would have to be substantially damaged by flooding. Based on the community survey, it is estimated that 28% of eligible property owners would participate in such a program. Participating properties meeting the above criteria were randomly selected, irrespective of individual cost-effectiveness.

The number of buildings mitigated, costs, benefits, and cost-effectiveness of each policy and all policies in Scenario 1 is summarized in **Table 2**, along with the residual unmitigated number of buildings with future losses and value of residual losses.

Table 2. **Benefit-Cost Analysis results and residual risks for Scenario 1 – Limited Policies.**

Policy	Number of Buildings	Cost	Benefit	Benefit-Cost Ratio
Higher Elevation Standard	241	$50,007,680	$51,783,547	1.04
	4	Acquisition:	Avoided Loss:	0.27

Voluntary Acquisition Program		$2,534,016	$458,524	
		Tax Revenue Loss: $240,950	Ecosystem Services: $293,521	
Total	**245**	**$52,782,646**	**$52,535,592**	**0.995**
Residual Loss	1,671	$98,718,957		

4.3 Scenario 2: Moderate Policies

Scenario 2 – Moderate Policies includes expanded but still moderate policy interventions. It includes the following:

- **Higher Elevation Standard:** A regulatory policy to require that substantially damaged residential buildings elevate to higher standard of the 2050 100-year flood elevation plus 1 foot.

- **Voluntary Elevation and Dry Floodproofing Grant Program:** A large elevation and dry floodproofing grant program. Voluntary participation of property owners with less than 50% building damages was assumed to follow the self-reported percentages of residents who said they would be likely to take substantial mitigation actions if they experienced $25,000, $50,000, or $100,000+ in damages and said "yes" they would be likely to elevate their residential building or dry floodproof their non-residential building. It is estimated that of eligible residential property owners, 21% of those with $25,000-$50,000, 28% of those with $50,000-$100,000, and 32% of those with $100,000+ in building damages, would participate in such a program. Participating properties meeting the above criteria were randomly selected, irrespective of individual cost-effectiveness.

- **Voluntary Acquisition Program:** A limited voluntary acquisition program targeting properties with buildings that are in areas of projected daily high tide flooding (Mean Higher High Water, MHHW) in 2030. Eligible properties would not have to be substantially damaged by flooding. Based on the community survey, it is estimated that of eligible property owners 17% of those with $25,000-$50,000, 22% of those with $50,000-$100,000, and 26% of those with $100,000+ in building damages, would participate in such a program. Participating properties meeting the above criteria were randomly selected, irrespective of individual cost-effectiveness.

- **No Rebuild Zones:** A regulatory policy prohibiting rebuilding of substantially damaged buildings that are in areas of projected daily average highest tide flooding (MHHW) in 2050.

The number of buildings mitigated, costs, benefits, and cost-effectiveness of each policy and all policies in Scenario 2 is summarized in **Table 3**, along with the residual unmitigated number of buildings with future losses and value of residual losses.

Table 3. Benefit-Cost Analysis results and residual risks for Scenario 2 – Moderate Policies.

Policy	Number of Buildings	Cost	Benefit	Benefit-Cost Ratio
Higher Elevation Standard	232	$48,279,992	$50,907,121	1.05
Elevation Grant Program	101	$19,388,045	$3,474,541	0.18
Dry Floodproofing Grant Program	13	$8,248,303	$13,400,681	1.62
Voluntary Acquisition Program	6	Acquisition: $4,903,514	Avoided Loss: $275,178	0.08
		Tax Revenue Loss: $497,359	Ecosystem Services: $182,304	
No Rebuild Zones	13	Acquisition: $8,693,231	Avoided Loss: $1,334,950	0.18
		Tax Revenue Loss: $816,284	Ecosystem Services: $420,790	
Total	**365**	**$90,823,728**	**$69,995,566**	**0.77**
Residual Loss	1,551	$81,568,556		

4.4 Scenario 3: Aggressive Policies

Scenario 3 – Aggressive Policies includes the same policy interventions as Scenario 2, but with greater financial incentives and thus higher voluntary participation. It includes the following:

- **Higher Elevation Standard:** A regulatory policy to require that substantially damaged residential buildings elevate to higher standard of the 2050 100-year flood elevation plus 1 foot.

- **Voluntary Elevation and Dry Floodproofing Grant Program:** A large elevation and dry floodproofing grant program. Additional incentives such as low-interest loans and waived permit fees would be available to participants. Voluntary participation of property owners with less than 50% building damages was assumed to follow the self-reported percentages of residents who said they would be likely to take substantial mitigation actions if they experienced $25,000, $50,000, or $100,000+ in damages and said "yes" or "maybe" they would be likely to elevate their residential building or dry floodproof their non-residential building. It is estimated that of eligible residential property owners, 40% of those with $25,000-$50,000, 51% of those with $50,000-$100,000, and 60% of those with $100,000+ in building damages, would participate in such a program. Participating properties meeting the above criteria were randomly selected, irrespective of individual cost-effectiveness.

- **Voluntary Acquisition Program:** A limited voluntary acquisition program targeting properties with buildings that are in areas of projected daily high tide flooding (Mean Higher High Water, MHHW) in 2030. Eligible properties would not have to be substantially damaged by flooding. Based on the community survey, it is estimated that of eligible property owners 32% of those with $25,000-$50,000, 42% of those with $50,000-$100,000, and 49% of those with $100,000+ in building damages, would participate in such a program. Participating properties meeting the above criteria were randomly selected, irrespective of individual cost-effectiveness.

- **No Rebuild Zones:** A regulatory policy prohibiting rebuilding of substantially damaged buildings that are in areas of projected daily average highest tide flooding (MHHW) in 2050.

The number of buildings mitigated, costs, benefits, and cost-effectiveness of each policy and all policies in Scenario 3 is summarized in **Table 4**, along with the residual unmitigated number of buildings with future losses and value of residual losses.

Table 4. Benefit-Cost Analysis results and residual risks for Scenario 3 – Aggressive Policies.

Policy	Number of Buildings	Cost	Benefit	Benefit-Cost Ratio
Higher Elevation Standard	232	$48,279,992	$50,907,121	1.05
Elevation Grant Program	195	$36,507,119	$6,991,832	0.19
Dry Floodproofing Grant Program	16	$10,283,822	$13,651,780	1.33
Voluntary Acquisition Program	10	Acquisition: $7,868,031	Avoided Loss: $445,056	0.08
		Tax Revenue Loss:	Ecosystem Services:	

		$791,389	$232,753	
No Rebuild Zones	13	Acquisition: $8,693,231	Avoided Loss: $1,334,950	0.18
		Tax Revenue Loss: $816,284	Ecosystem Services: $420,790	
Total	**466**	**$113,239,867**	**$73,984,281**	**0.65**
Residual Loss	1,450	$77,630,289		

4.5 Summary and Discussion of BCA Results

The BCA results for the three policy scenarios are summarized in **Table 5**. The policy scenarios are effective at mitigating 15% of buildings damaged and 35% of total losses in Scenario 1, to 24% of buildings damaged and 49% of total losses in Scenario 3, due to projected long-term coastal flooding. Using a 7% discount rate, none of the scenarios are cost-effective, although Scenario 1 is nearly cost-effective with a BCR of 0.995. However, using a 3% social discount rate, all three policy scenarios are cost-effective with BCRs of 1.29 to 1.95. However, the value of unmitigated residual losses is also higher using the lower discount rate.

Table 5. Summary of BCA results for Policy Scenarios 1-3.

Metric	Scenario 1 - Limited	Scenario 2 - Moderate	Scenario 3 - Aggressive
Buildings Mitigated	245	365	466
Total Cost	$52,782,646	$90,823,728	$113,239,867
Total Benefit at 7% Discount Rate	$52,535,592	$69,995,566	$73,984,281
Benefit Cost Ratio at 7% Discount Rate	0.995	0.77	0.65
Buildings Unmitigated	1,671	1,551	1,450
Damage/Loss Unmitigated at 7% Discount Rate	$98,718,957	$81,568,556	$77,630,289
Total Benefit at 3% Discount Rate	$103,311,033	$139,059,442	$147,372,644

Benefit Cost Ratio at 3% Discount Rate	1.95	1.51	1.29
Damage/Loss Unmitigated at 3% Discount Rate	$202,494,874	$167,323,626	$159,104,480

Two specific policies were consistently evaluated to be cost-effective – the higher elevation standard and dry floodproofing grant program. The higher elevation standard has a BCR of 1.04 to 1.05. While this represents only a marginal net project benefit, compared to rebuilding substantially damage structures as-is each time they are damaged, it would avoid significant disruption and impacts on quality of life for hundreds of individual households and the affected neighborhoods at-large. The dry floodproofing grant program has a BCR of 1.33 to 1.62. Even though a limited number of non-residential buildings are assumed to participate in such a program, the avoided losses contribute significantly to an overall reduction in residual losses for the community.

Several other policies were consistently evaluated to be cost-ineffective. They include elevation grant programs, voluntary acquisition programs, and no build zones. The voluntary acquisition program was generally the least cost-effective of these (BCR of 0.08 in Scenarios 2 and 3), owing to both the high property values and the relatively low avoided damages for the properties randomly selected for participation. The elevation grant program and no build zone policy has much higher but still low cost-effectiveness (BCR of 0.18 to 0.19).

A key policy design element that contributed to the lack of cost-effectiveness for elevation grant and voluntary acquisition programs was that there were no individual or aggregate cost-effectiveness requirements for eligibility to participate. In the policy scenarios, participants in these programs were randomly selected based on the value of damages incurred ($25,000 or more), not the ratio of mitigation costs to long-term avoided damages and ecosystem benefits. The lack of cost-effectiveness requirements could be seen as socially equitable in terms of giving community members equal access to public funding support. However, given that competitive federal grant programs do have cost-effectiveness eligibility requirements, it would mean that for projects that are not individually cost-effective the Town or potentially the State would have to cover the grant portion of elevation and acquisition costs that would otherwise be covered by the federal government. This would put a larger strain on fiscal resources and perhaps exacerbate existing sentiment among residents who do not live in coastal areas that Town resources are unfairly distributed. Additional policy analyses were conducted to understand the impact of including cost-effectiveness eligibility criteria in program designs, discussed in the next section.

A methodological factor which could have contributed to the lack of cost-effectiveness for the voluntary acquisition program and no build zones, both of which target buildings subject to daily tidal flood exposure in 2030 or 2050, is that the highest recurrence storm included in the damage and loss estimation was a 10-year storm. It is possible that with inclusion of an annual storm, for example, the cost-effectiveness of these policies (and others) may be improved.

4.6 Limitations

There are several sources of uncertainty inherent in the Benefit Cost Analyses conducted, which warrant acknowledgement. These include, but are not limited to:

- The amount and timing of relative sea level rise by 2030 and 2050
- The resolution and physical processes captured in the flood model
- The accuracy of the building inventory, including building characteristics such as first floor heights above ground, among others
- The depth-damage functions included in the Hazus software
- The feasibility and cost of mitigation strategies
- The discount rate applied to future benefits and residual losses

While the damage and loss estimates presented in this report may seem high, it is much more likely that they are underestimates. There are several sources of damage and loss and other benefits that are unaccounted for in the estimates, which could be avoided or attained through implementation of the mitigation strategies and policy scenarios evaluated and thereby affect the cost-effectiveness results. These include, but are not limited to:

- Insurance cost savings
- Flood damage and loss at higher annual recurrences (daily, monthly, 1-year, 2-year, etc.)
- Damage and loss from wave overtopping and seawall failure
- Emergency response and debris cleanup costs
- Damage to roadways, utilities, and other infrastructure
- Loss of life and injury
- Broader economic and productivity losses (indirect impacts)
- Damage and loss from beach and dune erosion
- Damage and loss from rain-induced flooding

5.0 ADDITIONAL POLICY ANALYSES

Additional policy analyses were conducted to estimate the scale of mitigation programs that would potentially be eligible for federal elevation, dry floodproofing, and voluntary acquisition grants based on program-specific criteria. In addition, the cost-effectiveness of eminent domain and large no build zones to mitigate wave overtopping and seawall failure losses to oceanfront properties was evaluated.

It is important to note that funding available to Marshfield in any given year would be well below the total costs to implement the full portfolio of potentially eligible projects. For example, in FY2021, FEMA's FMA program had $160 million in funding available nationwide. Massachusetts' allocation of FEMA HMGP funding from the COVID-19 disaster declaration was about $110 million statewide. These FEMA grant programs are competitive, so proposed projects in Marshfield must compete with every other proposed project in the State or in some cases the nation. The USACE Section 103 continuing authorities program, which would be the easiest pathway to secure USACE coastal flood risk mitigation funding for Marshfield, has a cap of $10 million in federal share ($15.4 million total project cost) per project. Regardless, there are clearly ample opportunities to pursue federal grants for cost-effective projects, as shown below.

5.1 Elevation Grant Program with Cost-Effectiveness Eligibility Standards

The cost-effectiveness of elevation was evaluated for all individual residential buildings in the building inventory to estimate the total number of properties that would potentially be eligible for FEMA or USACE elevation grant funding. Importantly, mitigation of these properties' long-term coastal flood risks could be pursued as a pre-disaster mitigation strategy (i.e., before a triggering disaster occurs). Otherwise, these properties would represent those that are potentially eligible for elevation or (if substantially damaged) mitigation reconstruction grants, post-disaster.

Two methods were used to assess potential eligibility. The first method compares cost-effectiveness results for individual properties and minimum eligible BCRs for different federal grant programs. FEMA grant applications for individual buildings are required to have a BCR of 1.0. FEMA grant applications for multiple buildings allow the aggregation of benefits and costs to determine cost-effectiveness. Minimum BCRs were adjusted until the portfolio BCR was just above 1.0, with the minimum cutoff being a BCR of 0.35. USACE coastal storm risk mitigation projects allow for the inclusion of buildings with a minimum BCR of 0.9 if the portfolio level BCR is 1.0 or greater and buildings with a BCR lower than 1.0 are in the vicinity of other buildings that will be elevated. The second method is based on FEMA's "pre-calculated benefits." Under this method, elevation projects in the FEMA Special Flood Hazard Area are assumed to be cost-effective if they cost less than or equal to the national average $205,000. Adjustment for regional cost differences is allowed, resulting in a maximum elevation cost of $227,550 per structure in Marshfield. Projects with elevation costs at or below this value were not further screened to determine which were in the FEMA Special Flood Hazard Area.

The results are shown in **Table 6** and indicate that between 113 and 403 buildings are potentially eligible for federal elevation grants based on BCR eligibility criteria, and up to 978 may be eligible based on pre-calculated benefits. The avoided losses (benefits) generated from full implementation of potentially grant-eligible elevation projects would be between $48 million and $83 million. As noted above, FEMA grants are competitive and the total funding available to Marshfield would likely be less than the total costs to implement the full portfolio of cost-effective projects.

Table 6. Potential eligibility for FEMA and USACE elevation grants.

Grant Program Scenario	Eligibility Criteria	Number of Buildings	Cost	Benefit	Benefit-Cost Ratio
Individual Buildings (FEMA FMA and HMGP)	BCR ≥1.0	113	$21,960,482	$48,339,269	2.20

Multi-Building Aggregation (FEMA FMA, HMGP, BRIC)	BCR ≥0.35	403	$78,260,658	$83,388,275	1.07
Multi-Building Aggregation (USACE)	BCR ≥0.9	150	$29,154,543	$55,210,381	1.89
Individual or Multi-Building Aggregation (FEMA FMA, HMGP, BRIC)	$227,550 Maximum Elevation Cost	978	$155,542,606	$58,216,551	0.37

5.1 Dry Floodproofing Program with Cost-Effectiveness Eligibility Standards

The cost-effectiveness of dry floodproofing projects was evaluated for all individual non-residential buildings, following the same process as described above for residential elevations. However, USACE does not appear to allow for BCRs lower than 1.0 for dry floodproofing, and FEMA does not have pre-calculated benefits for dry floodproofing.

The results shown in **Table 7** indicate that between 27 and 71 non-residential buildings are potentially eligible for federal dry floodproofing grants based on BCR eligibility. The avoided losses (benefits) generated from full implementation of potentially grant-eligible dry floodproofing projects would be between about $36 million and $40 million. As noted above, FEMA grants are competitive and the total funding available to Marshfield would likely be less than the total costs to implement the full portfolio of cost-effective projects.

These results imply significantly higher benefits per project than the elevation portfolio. Because the high net benefits of certain individual projects offset the very limited cost-effectiveness of many others, all the non-residential buildings could be theoretically packaged together and still be cost-effective overall. This should be further explored to ensure results are accurate for the high net benefit projects.

Table 7. Potential eligibility for FEMA and USACE dry floodproofing grants.

Grant Program Scenario	Eligibility Criteria	Number of Buildings	Cost	Benefit	Benefit-Cost Ratio
Individual Buildings (FEMA FMA and HMGP, USACE)	BCR ≥1.0	27	$14,301,217	$35,541,343	2.49

Multi-Building Aggregation (FEMA FMA, HMGP, BRIC)	BCR ≥0.0	71	$31,834,293	$40,138,577	1.26

5.1 Voluntary Acquisition Program with Cost-Effectiveness Eligibility Standards

The cost-effectiveness of voluntary acquisition projects was also evaluated for all individual buildings, following the same process as described above for residential elevations. As with dry floodproofing, USACE does not appear to allow for BCRs lower than 1.0 for acquisitions. However, FEMA has pre-calculated benefits for acquisitions in the FEMA Special Flood Hazard Area. The regionally adjusted maximum acquisition cost per structure is $358,530 to be considered cost-effective. Because acquisition projects can be for both residential and non-residential buildings, the number of buildings and benefits identified from acquisition should not be treated as necessarily additive to the elevation and dry floodproofing results.

The results shown in **Table 8** indicate that between 18 and 37 buildings are potentially eligible for federal acquisition grants based on BCR eligibility, and up to 18 may be eligible based on pre-calculated benefits. The avoided losses (benefits) generated from full implementation of potentially grant-eligible acquisition projects would be between about $15 million and $51 million. As noted above, FEMA grants are competitive and the total funding available to Marshfield would likely be less than the total costs to implement the full portfolio of cost-effective projects.

Due to the high property values in the planning area, there are relatively few cost-effective acquisition projects that could be pursued individually or packaged together. As with the dry floodproofing portfolio, a small number of highly cost-effective projects offset other cost-ineffective projects. Some of the buildings with high cost-effectiveness are the same as identified in the dry floodproofing portfolio.

Table 8. Potential eligibility for FEMA and USACE dry floodproofing grants.

Grant Program Scenario	Eligibility Criteria	Number of Buildings	Cost	Benefit	Benefit-Cost Ratio
Individual Buildings (FEMA FMA and HMGP, USACE)	BCR ≥1.0	18	$12,222,109	$26,812,412	2.19
Multi-Building Aggregation (FEMA FMA, HMGP, BRIC)	BCR ≥0.65	37	$44,715,409	$50,608,081	1.13

Individual or Multi-Building Aggregation (FEMA FMA, HMGP, BRIC)	$358,530 Maximum Acquisition Cost	18	$4,605,949	$15,193,756	3.30

5.1 Oceanfront Eminent Domain and Large No Build Zones

The cost-effectiveness of using eminent domain or large no build zones covering the entirety of first row of properties behind the seawalls to mitigate risks from wave overtopping and seawall failure was evaluated. Due to the high property values and relatively low average annual buildings and contents losses from these hazards, these policies were found to be cost-ineffective at the societal level, both for the randomly selected portfolio of buildings and all individual buildings (with the seawall failure percent damages in **Table 1** applied to each).

In the case of the large no build zones, if only the costs to the Town of lost tax revenue and the avoided loss and environmental services benefits of new open space are considered, the policy is highly cost effective. As stated earlier, no build zones have been found by the highest courts to be constitutional, with no compensation due to private property owners, when appropriately instituted to protect the public interest. However, the approach taken in this project is to consider societal costs and benefits, not view mitigation policies through the lens of specific parties (i.e., private property owners vs Town vs federal government).

The accuracy of these results is highly uncertain due to the following factors:

- The use of non-standard methods to estimate damage and loss from wave overtopping (no industry standards exist)
- The inclusion of only estimated damages to buildings and contents (no time-dependent losses)
- High uncertainty as to the storm conditions under which seawalls would fail
- High uncertainty as to how many properties would be substantially damaged because of a typical seawall failure.

These results should not be interpreted as evaluating the cost-effectiveness of mitigating wave overtopping damages by constructing new, more resilient coastal infrastructure on the oceanfront, which may include eminent domain costs to acquire land required to construct such infrastructure. The benefits of such projects have not been evaluated.

6.0 POLICY AND ZONING RECOMMENDATIONS

Policy and zoning recommendations were developed considering the findings of the damage and loss estimation, policy benefit-cost analyses, and community engagement described above. Each recommendation is described below, prefaced with contextual information and/or explanations of why the recommendation is being made. As the Town works to update its FEMA Hazard

Mitigation Plan, the relevant recommendations included herein should be included to maximize eligibility and competitiveness for FEMA grants that the Town pursues in the future.

6.1 Promote Flood Insurance

Flood insurance is a critical tool for residents to manage their personal financial risks, protect their investments, and afford to build back better and remain in the community after a flood. The Town already promotes flood insurance and works diligently through participation in the Community Rating System to earn flood insurance discounts for residents to help make it more affordable.

The Town should redouble its efforts to promote flood insurance within the planning area. Catastrophic coastal flooding is expected to become more likely and frequent in the planning area due to climate change. The owners and occupants of more than a thousand homes and businesses are at risk of hundreds of millions of dollars in losses in such events. Even with full implementation of aggressive mitigation policies, there would still be tens of millions of dollars in residual unmitigated expected losses. Most of these losses could be covered by flood insurance.

In the most extreme storm event modeled – a 500-year coastal flood in 2050 – only 3% of damaged residential buildings had more damage than the maximum building coverage available from the NFIP ($250,000), and only 7% of residential buildings with damaged contents had more damage than the maximum contents coverage available from the NFIP ($100,000). If 100% of residential buildings at risk were insured to the maximum NFIP coverage available, 89% ($133 million) of total building damages and 84% (~$62 million) of total contents damages would be covered by insurance, less deductibles. Furthermore, if 100% of the substantially damaged residential structures had Increased Cost of Compliance (ICC) coverage, up to an additional $49 million ($30,000 per structure) would be available to owners to help elevate their homes upon rebuilding.

Yet, as of 2018, only about 50% of multi-family buildings, 45% of single-family buildings, and 50% of commercial buildings in the FEMA Special Flood Hazard Area in Marshfield had flood insurance. Of the 62 people who responded to the community survey, only 55% stated that they had adequate flood insurance. The high level of uninsured and potentially underinsured buildings, along with the results of the damage and loss estimations are a red flag that the community at-large and hundreds of individual households and businesses are not financially prepared.

Residents and business owners should not rely on disaster assistance. In Hurricane Harvey, average flood insurance payouts were $106,000 versus average disaster assistance payouts of $6,000. Furthermore, they should be aware that flooding is not covered under normal home or business insurance – a separate flood insurance policy is required. They should attend a local outreach event to find out the types of flood insurance available to them and contact their local agent to understand flood coverages, how much a flood policy would cost, and buy a flood policy which is separate from their homeowners policy. All these messages are already included in the Town's insurance promotion efforts.

The Town should continue participation and increase investment in Community Rating System activities to maintain or increase flood insurance discounts (i.e., make coverage as affordable as possible) and increase the number and percent of buildings in the planning area that are covered.

Recommendations include the following:

1. **Update Marshfield's Community Rating System (CRS) Program for Public Information (PPI), include an updated Flood Insurance Coverage Assessment and Coverage Improvement Plan, and diligently implement flood insurance outreach.**

   - **Update Flood Insurance Coverage Assessment to include the following:**
     - Assess the change in coverage over years for which data is available.
     - Complete a town-wide flood insurance survey to understand who has flood insurance, is it NFIP or private, and why the uninsured have not obtained coverage.
     - Quantify pre- and post-FIRM structures to understand where vulnerable structures are located and better quantify outreach projects.

   - **Update and create additional flood insurance promotion outreach projects in the Coverage Improvement Plan and PPI, such as:**
     - Updated flood insurance brochures and directly mail twice per year, targeting high risk and uninsured properties.
     - Host additional flood insurance meetings, including technical assistance events during which individuals can meet one-on-one with agents.
     - Create a video or message delivered by a local elected official and play year-round on local access TV.
     - Include messages in outreach targeting common barriers identified by uninsured in the survey responses.
     - Include messages in outreach promoting Increased Cost of Compliance coverage.
     - Include messages in outreach advertising free flood insurance technical assistance.
     - Include messages in outreach using data from the damage and loss estimation.
     - Include a community participation campaign for home and business owners to take photos of their properties to document pre-storm conditions.

2. **Investigate a parametric community wide flood insurance option.** Such a policy would set pre-determined payout levels for pre-determined levels of flooding (e.g., $10 million if peak water elevation in Green Harbor reaches 10 ft NAVD88) and avoid the time-consuming process to document specific damages and go through claims processes that come with normal insurance policies. The main benefit is that this facilitates speedier delivery of post-disaster funds to aid in recovery efforts. Depending on how the policy is structured, funds could be used to pay for Town infrastructure damage and disaster response costs, individual policyholder's costs (if sub-policyholders), or to capitalize a revolving fund for hazard mitigation projects. These benefits would come at a cost of annual premiums and potentially

deductibles paid by the Town, which could be passed through to property owners in high hazard areas or not.

6.2 Establish Higher Elevation Standards

Within the FEMA Special Flood Hazard Area (1% annual chance flood zone), new, substantially improved, and substantially damaged residential buildings, as well as buildings with new or substantially repaired foundations, are already required by the Massachusetts State Building Code to be elevated at least 1 ft above the FEMA Base Flood Elevation (BFE) in A Zones, or 2 ft above the BFE in the V Zones. The Town cannot supersede the State Building Code, but it can use other local zoning and wetlands bylaws and regulations to require that new and substantially improved buildings are built to be resilient to future sea level rise and more intense coastal flooding conditions, to protect public health and safety and the general welfare, and to protect wetland resource values. The BCAs conducted for this project consistently indicate that such policies would be cost-effective.

The Town should consider the following regulatory strategies:

1. Improve the clarity and consistency of language regarding tidal and flood elevations.

- **Base flood elevation.** All references to the "base flood elevation" from the FEMA Flood Insurance Rate Maps (FIRMs) as the controlling elevation for structures should be updated to reference the "minimum elevations required by the Massachusetts State Building Code 780 CMR, including the base flood elevation specified in the FEMA Flood Insurance Rate Maps and any required freeboard," or to that effect. The current text that only references FEMA FIRM base flood elevations wrongly implies that buildings and utilities can be constructed to the base flood elevation only, when the State Building Code requires that most structure and utilities be built to be flood flood-resistant to 1 or 2 feet higher than the base flood elevation. This miscommunicates requirements to Town staff, approving bodies, and project proponents.

- **Mean sea level.** All references to "mean sea level" or NGVD29 regarding the elevation of structures, utilities, and grades required to be shown or described on permit applications should instead reference the North American Vertical Datum of 1988 (NAVD88). NAVD88 is the elevation datum in which all federal tidal and flood elevations are communicated with the public. For example, FEMA FIRMs show base flood elevations in NAVD88, not "mean sea level" or NGVD29 datum. This can lead to confusion and improper datum conversion errors.

2. Strengthen existing Wetlands Protection Bylaw and Regulations.

- **Purpose.** Add "Coastal resilience to sea level rise" to the list of interests protected in the purpose of the Wetlands Protection Bylaw.

- **Regulations Part I (Purpose and Procedures), Article 2 (Purpose).** Modify as follows:

- Add "Coastal resilience to sea level rise" to the list of wetland values.

- **Regulations Part I (Purpose and Procedures), Article 3 (Jurisdiction).** Modify as follows:
    - Move Land Subject to tidal action and Coastal Storm Flowage to above bullet F, so that these areas are included as having 100-foot Buffer Zones.

- **Regulations Part I (Purpose and Procedures), Article 5 (Definitions).** Modify as follows:
    - Add "Coastal Resilience means the ability to minimize the negative impacts of sea level rise; to build capability and ability of a resource area to minimize negative impacts of sea level rise."
    - Add "Sea Level Rise means the relative rise in elevation of the sea surface over time as interpreted by the best available science. Sea level rise may cause greater risk to human safety and development, increased risk to infrastructure, greater and more frequent coastal inundation, elevated storm surge flooding levels, salt water intrusion to water wells and septic systems, loss of coastal recreational resources, increased coastal erosion, and loss of coastal habitats and resources."

- **Regulations Part II (Performance Standards for Resource Areas), Article 4 (Land Subject to Coastal Storm Flowage), Section D (Performance Standards).** Modify as follows:
    - Add "In order to protect coastal resilience to sea level rise wetland values provided by Land Subject to Coastal Storm Flowage resource areas, there shall be no habitable space in any structure and no utilities for any structure located below 13 feet in elevation, referenced to the North American Vertical Datum of 1988 (NAVD88)." A similar performance standard was part of the regulations circa 2018, which referenced a lower elevation (11 feet), Mean Sea Level as the vertical datum, and "flood surge height" from FEMA flood insurance maps.
    - Section D (4) - update as follows, "The predicted [High rate of relative sea level rise in Massachusetts of 3.1 feet by 2050, 4.9 feet by 2070, and 8.3 feet by 2100] [or] [Intermediate rate of relative sea level rise in Massachusetts of 2.1 feet by 2050, 3 feet by 2070, and 4.7 feet by 2100] compared to the baseline year of 1992 (mid-year of the 1983-2001 NOAA National Tidal Datum Epoch) shall be incorporated into the project design and construction.

- **Regulations Part II (Performance Standards for Resource Areas), Article 6 (Buffer Zone).** Modify as follows:
    - Section C (Definitions). Do not exclude Land Subject to tidal action or Coastal Storm Flowage.
    - Section D (Performance Standards). Add "In order to protect coastal resilience to sea level rise values provided by the Buffer Zone of Land Subject to Coastal Storm

Flowage resource areas, within the Buffer Zone of Land Subject to Coastal Storm Flowage, there shall be no habitable space in any structure and no utilities for any structure located below 13 feet in elevation, referenced to NAVD88." The 100-foot buffer zone will include most areas subject to future coastal flood risk that are not presently in the FEMA Special Flood Hazard Area.

- **Integrate the Cape Cod Commission's Model Coastal Resilience Article into the Marshfield Wetlands Protection Regulations after MassDEP finalizes its updated performance standards.** This would create several new zones within and beyond Land Subject to Coastal Storm Flowage, with defined resource values and performance standards for new and substantially improved or damaged buildings and foundations in areas subject to future coastal flooding. The performance standards would require elevation, including freeboard, above future flood levels, referenced to the best available coastal flooding model, and require activities within areas subject to future salt marsh migration to be designed so as not to prevent such migration, among others.

3. Strengthen Zoning Bylaw, Article XV (Floodplain Zoning)

- **Section 15.01 (Purpose).** Add "Increase coastal resilience to sea level rise and increased coastal flooding" or similar.

- **Section 15.05 (Contents of applications).** Modify to include the following:

    - Existing site contours and elevations of existing structures
    - Flood Design Class and associated freeboard height of all new construction, reconstruction, expansion of existing buildings, and new or expanded uses of existing buildings and structures
    - Base flood elevations of all special flood hazard areas delineated on the plan
    - Proposed uses below elevation 13 feet NAVD88 or the minimum elevation required by the State Building Code including the base flood elevation in the effective FEMA FIRM and any required freeboard
    - Minimum elevation of the lowest floor
    - Minimum elevation of the bottom of the lowest horizontal structural member, if in the Zone VE
    - Minimum elevation below which flood damage-resistant materials are used
    - Minimum elevation of utilities and equipment
    - Minimum elevation of dry floodproofing of non-residential structure and non-residential portions of mixed-use buildings (not allowed in Zone VE
    - Minimum elevation of wet floodproofing (not allowed in Zone VE), if permitted by the State Building Code.

- **Section 15.08 (Areas of special flood hazard standards)**

    - Add "Consistent with the Wetlands Protection performance standards for Land Subject to Coastal Storm Flowage, use of areas below elevation 13 feet NAVD88 for any purpose other than access, storage, or parking is prohibited. Areas used for building electrical and mechanical systems are not considered storage."

- Add "New, substantially improved, and enlarged Flood Design Class 3 and 4 buildings and uses are prohibited."
- Section 15.19.B (Special permits) – add "Any permitted structure or use is consistent with the purposes and standards of the Overlay and include measures to mitigate or adapt areas subject to future coastal flooding due to relative sea level rise and increased storm surge."

3. **Create building elevation case studies.** Create a set of building elevation case studies for typical and challenging conditions to help homeowners, contractors, and Town officials (Planning Board, Conservation Commission) understand how to construct elevation projects in Marshfield's coastal context. These could include addressing challenges associated with houses on small lot sizes very close to one another, older structures, and geologic conditions.

6.3 Increase Maximum Building Heights for Elevation Projects

The Town can also make zoning dimensional requirements (e.g., building height, setbacks, lot size and dimensions, lot coverage) more flexible within flood risk areas to facilitate or incentivize building elevation projects. Zoning flexibility may be particularly helpful in the planning area, where many existing homes do not conform with zoning requirements (requiring homeowners to go through approvals processes that add time, cost, and uncertainty) and lot sizes tend to be smaller (limiting opportunities for increased living area and return on investment). The Town already allows for building height to be measured more flexibly for floodproofing projects and allows for encroachment into setbacks for utility elevation bump outs. However, currently, only the difference between older and newer FEMA BFEs can be added to building height for flood mitigation projects.

The Town should modify the definition of building height, as follows:

1. **Article 2 (Definitions), Building Height.** Modify the definition of "Building Height" to the effect of "… For all new construction, substantial improvements, or expansion of existing buildings and new or expanded uses within the Floodplain Zoning Overlay District (Zoning Bylaw, Article XV) and Land Subject to Coastal Storm Flowage and its Buffer Zone (General Bylaws, Chapter 294 and Chapter 505), the maximum building height listed in § 305-6.02, Table of Dimensional and Density Regulations, shall be measured from a) the minimum elevation for flood-resistant design and construction required by the State Building Code, including the base flood elevation in the effective FEMA FIRM and any required freeboard, or b) elevation 13 feet NAVD88, whichever is higher; only for the portions of the new or modified structures and uses that meet the flood-resistant design and construction requirements of the State Building Code and the Wetlands Protection restrictions on habitable space and utility uses below elevation 13 ft NAVD88 shall building height be measured in this way."

6.4 Pursue Federal Grants to Incentivize Mitigation

The Town should aggressively pursue federal grants to incentivize property owners to voluntarily elevate their homes or dry floodproof their businesses to higher levels or voluntarily sell their property to the Town.

In the past, the Town has helped homeowners compete for and obtain federal elevation grants from FEMA's Flood Mitigation Assistance program and Hazard Mitigation Grant Program. With FEMA grants, the Town must act as the sub-applicant for the grant, with the State being the applicant. The Town's role is typically limited to providing application and other administrative support – it does not provide the non-federal funding (typically 25%) required to match the federal grant portion (typically 75%) of the total project costs. The non-federal funding typically comes from the property owner. Competitive FEMA grants are also available for mitigation reconstruction projects, to help rebuild substantially damaged buildings to higher standards.

FEMA prioritizes elevation, non-residential dry floodproofing, and voluntary acquisition projects for structures insured by the National Flood Insurance Program. This further supports the need to increase flood insurance coverage to enhance the community's competitiveness for future FEMA grants. FEMA also prioritizes mitigation grants and provides a greater federal cost share percentage for repetitive loss structures (up to 90%) and severe repetitive loss structures (up to 100%).

FEMA grant programs are not a universal solution – the total funding available each year is limited, Marshfield's projects need to compete with others nationally and in Massachusetts, and the Town's capacity to support grant applications and administration is limited up to a few projects per year. Factors negatively affecting Marshfield's competitiveness include that most structures vulnerable to future coastal flooding are not yet repetitive loss structures (there are many, but they are concentrated along the oceanfront), and that FEMA is now prioritizing communities with high social vulnerability (Marshfield's demographics indicate low social vulnerability relative to the national index). Cost-effectiveness eligibility criteria must factor into which properties the Town supports, and the analysis carried out for this project can help identify a pool of competitive cost-effective projects.

The Town has also worked with the US Army Corps of Engineers (USACE) on a Hurricane and Storm Damage Reduction Project feasibility study, under continuing authorities in Section 103 of the 1962 River and Harbor Act. The study area was limited to portions of the Fieldston, Sunrise, and Brant Rock and only included 265 buildings, most of which were not surveyed. The portfolio of buildings identified and evaluated in the study was not cost-effective to elevate or dry floodproof, according to the study. However, that is because the study was focused on mitigating risks from wave overwash, not storm surge and sea level rise, and it was based on older FEMA FIRMs which had lower base flood elevations and therefore less damage and loss to avoid.

There are pros and cons of working with the USACE versus FEMA. One of the pros is that USACE manages the implementation of the program, overcoming the bottleneck of the Town's limited capacity. As stated earlier, the Town's existing capacity for support FEMA elevation projects is up to a few buildings per year – USACE could manage a much higher throughput. The main downside is that USACE only provides 65% federal cost share, compared with FEMA's 75%. That means for a $200,000 elevation project the property owner would need to come up with $20,000 more working with USACE versus FEMA. USACE Section 103 projects federal share is capped at $10 million (total project cost of $15.4 million). Our analysis indicates that there are nearly $30 million in potentially cost-effective elevation projects in the planning area under USACE eligibility criteria.

Alternatively, or in parallel, the Town could pursue new Congressional authority for a coastal storm risk feasibility study the outcome of which, if implemented, would not be subject to the $10 million cap. That would require Congress to both authorize and appropriate funds for the study, either through the annual Water Resources Development Act or specific disaster relief bills.

The Town should implement the following actions related to federal mitigation grants for elevation, dry floodproofing, and acquisition:

1. **Publicize and recruit participants for the FEMA Flood Mitigation Assistance and Hazard Mitigation Grant Program targeting the potentially cost-effective structures identified in this study.** These programs offer 75% federal cost-share. Applications for the Hazard Mitigation Grant Program, from which Massachusetts has record funding due to the COVID-19 disaster, are due October 9, 2022. If demand from planning area property owners is high, the Town should consider hiring a contractor to provide application and administrative support, given its limited capacity.

2. **Request USACE New England District to conduct a Hurricane and Storm Damage Reduction Feasibility Study for elevation and dry floodproofing in the entire Planning Area under Section 103 continuing authorities.** If approved, up to $100,000 would be federally funded, with costs in excess shared 50% federal and 50% non-federal. Implementation costs, if approved, would be split 65% federal and 35% non-federal, with a $10 million cap on federal costs (total project costs of max $15.4 million). USACE manages these projects, helping overcome limitations of Town staff capacity.

3. **Create a low-interest revolving loan fund for property owners in Marshfield to help finance all or a portion of the non-federal match for federal elevation and dry floodproofing grant projects**. This would be a departmental revolving fund to be managed by an appropriate department. The Town should establish eligibility criteria. Income and owner-occupancy should be among the criteria considered to make equitable allocations of limited public funds.

6.5 Create a 30-Foot No Build Setback from Seawalls

The vast majority of existing repetitive loss structures affected by coastal flooding in Marshfield are located on the first row of parcels along the oceanfront, just landward of existing seawalls. The damages and losses to these properties and safety risks to their occupants has historically been due to a combination of wave overtopping and storm damage and erosion induced seawall failures. Elevating structures within proximity to the Town's seawalls will reduce certain risks from wave overtopping (e.g., inundation of lower floors and foundation erosion), but, alone, it will not mitigate the prevalent damage and safety risks from water, stones, and debris that are launched over the seawalls during storm events or the risk of structural damage due to seawall failures. To reduce these prevalent damage and safety risks, buildings need to be set back further from the seawalls. In general, FEMA's risk mapping procedures delineate the wave overtopping splash zone as approximately 30-50 feet inland of seawalls.

The Town should consider prohibiting new construction and substantial improvement, reconstruction, and enlargement of existing structures within a setback at least 30 feet from the any Town-owned seawall or revetment, or any seawall or revetment regardless of ownership. An enforced 30-foot setback, in combination with other zoning relief, would still provide property owners with the potential to gain approval for new construction, substantial improvements, and other activities on oceanfront lots, thereby avoiding significant societal costs, including impacts on the tax base. The Town could reduce the 15-foot front yard setback for properties subject to the seawall setback to minimize such costs.

The R-3 (Residential Waterfront) district already requires a 30-foot wide rear yard, though the yard would be measured to the lot line which may not coincide with the seawall alignment. However, most oceanfront lots are already non-conforming with the dimensional and density requirements in the Zoning Bylaw (e.g., only 26 out of 214 parcels within 30 feet of a Town seawall or revetment meet minimum lot size requirements for the R-3 district) and therefore require zoning relief for new construction, substantial improvement, and enlargement. Through the zoning relief process, the rear yard setback could be waived or varied by the Zoning Board of Appeals. To add a second layer of approvals to minimize such outcomes, the power to approve such activities within the seawall setback could be vested with the Board of Selectmen, as it is for building on or over Town-owned seawalls.

Wider setbacks of 50 or 100 feet could be considered since the splash zone can extend well beyond 30 feet and a 30-foot setback will not mitigate all risks of structural damage due to seawall failures. However, large no build zones along the oceanfront were evaluated to not be cost-effective (though there are high uncertainties embedded in the analysis). The remaining potentially developable space on many oceanfront lots would be eliminated or very limited, raising the likelihood of legal challenges claiming that the setback is a regulatory taking. As mentioned earlier in this report, courts have consistently sided with public entities in regulatory takings challenges related to floodplain development restrictions, given the primacy of public interests in public safety and the strong likelihood that other economically reasonable uses and values of the property generally persist without residential or commercial development.

The Town should consider the following bylaw modifications:

1. **General Bylaws, Chapter 217 (Seawalls).** Modify to prohibit structures "…on, over, or within 30 feet of seawalls and revetments…" The Town should consider rescinding the existing exemption of privately owned and maintained seawalls from these restrictions, since

structures built in the splash zones of these private structures would be subject to continued risk.

2. **Article 6 (Dimensional and Density Regulations), Section 6.08. (Other dimensional and density provisions).** Add "The minimum front yard within R-3 districts for a parcel where the rear yard is limited by a 30-foot setback from an existing seawall or revetment, the minimum front yard setback shall be 5 feet, provided that no new or existing structure is located within the 30-foot setback from the existing seawall or revetment." This could also be clarified with an asterisk and note in the table of dimensional requirements.

6.6 Prepare a Substantial Damage Management Plan

As demonstrated through the triggering disaster and policy scenarios, a key cost-effective strategy for rebuilding more resiliently is to tie substantial damage to higher elevation standards. Again, substantial damage means the total cost of repairs is 50% or more of the building's value before the flood occurred. However, the success of that policy depends on effective and efficient management of substantial damage determinations and enforcement of the State Building Code and local regulations in the rebuilding process. In the 2030 100-year storm scenario, there are an estimated 1,335 damaged buildings, 245 of which are estimated to be substantially damaged. That implies a lot of effort being required of Town staff, boards, and commissions immediately following a disaster. A Substantial Damage Management Plan, developed pre-disaster, can help make that post-disaster process smoother and increase the effectiveness of proposed resilience policies.

The Community Ratings System (CRS) was updated in 2021 to offer new and substantial points (up to 140) to communities that develop a Substantial Damage Management Plan. By implementing this recommendation according to the CRS requirements, the Town will help maintain or improve its CRS standing and the significant associated flood insurance discounts for Marshfield's NFIP policyholders. By helping to make flood insurance affordable and taking other actions identified in Recommendation 1, it is possible to increase the number and proportion of vulnerable properties that have flood insurance coverage.

The Substantial Damage Management Plan describes in detail the community's process for evaluating damage to buildings and addressing those that have been substantially damaged, as required by NFIP. It outlines community responsibilities, identifies available data about buildings in the FEMA Special Flood Hazard Area (or beyond it, if desired), describes the community's approach to damage estimation, and lists steps the community will take if buildings are determined to be substantially damaged.

1. The Town should follow the six-step process described in the CRS manual, summarized below:

    - **Step 1. Assess the community's vulnerability to substantial damage.** This step requires the review of all buildings in the SFHA to determine those that are likely to be substantially damaged.

- **Step 2. Identify the community's team for the management of substantial damage to properties.** A committee is not required for the development of the management plan, but a team would be helpful for all the steps. This should include the floodplain administrator and the necessary staffing to carry out the work effort post-flood, as well as other departments and boards/commissions responsible for issuing relevant permits or approvals for rebuilding.

- **Step 3. Identify the post-event efforts related to substantial damage.** For this step, the community should contact the State NFIP Coordinator to obtain any substantial damage guides or templates that have been developed by the state for communities. The plan must include post-event coordination and communications efforts, damage estimate and substantial damage determination procedures, and post-substantial damage determination procedures for compliance.

- **Step 4. Build a property database for substantial damage estimates.** In Step 1, a list of properties that could be substantially damaged was prepared. This step requires developing a database for that list that includes the building, building value, and flood information. Pre-populating the FEMA Substantial Damage Estimator database will earn extra points.

- **Step 5. Identify actions the community can take to address potential substantial damage.** The plan must include at least one action the community will take to educate the community about substantial damage/substantial improvement and the requirements of the NFIP. Considering mitigation alternatives for areas in which building have the potential to be substantially damaged will earn extra points.

- **Step 6. Determine implementation steps and procedures for updating the plan.** This must include an annual evaluation report, information sharing with elected officials, and an update process and/or schedule.

The property database, damage and loss estimations, and mitigation alternatives analysis carried out as part of the present project will provide a good starting point, or could even help earn partial credit, towards Steps 1, 4, and 5.

6.7 Develop Flood Warning and Response Capabilities

Damage and loss estimates prepared for this project indicate that it is increasingly likely that over the coming years and decades buildings and their occupants in the planning area will be exposed to dangerous coastal flood hazards, the likes of which have not recently or ever been seen. The development and use of an effective flood warning and response system would help residents and businesses make timely decisions and take appropriate actions to avoid property damage, injury, and even loss of life. It would also help the Town make efficient use of limited disaster response resources, take timely actions to protect critical facilities (and reduce downtime and associated economic impacts) and improve the safety of first responders.

Residents who participated in community meetings and surveys for this project pointed out that in a recent more modest coastal flood in the Brant Rock area that occurred over night, they did not receive a notification and they did not think flood gates were properly managed. Several residents were unable to move their vehicles ahead of time and their cars were totaled. Other experiences shared by participants included vehicle rescues when motorists tried to drive through flood waters and got stuck. Scaling up these kinds of experiences from a modest flood to the magnitude of a catastrophic flood, and the need for improved flood warning and response systems is made even more plain.

As with flood insurance promotion and substantial damage management planning, the Community Rating System offers significant points for Flood Warning and Response activities (up to 365 points). Implementation of these activities according to the CRS requirements will help the Town make flood insurance as affordable as possible and, along with flood insurance promotion activities, increase flood insurance coverage which is important for the community's long-term resilience.

A Flood Warning and Response Plan creates the capabilities to recognize an imminent threat to the community, provide warning to the affected populations, activatecommunity emergency response efforts, and give special attention to critical facilities.

1. The Town should develop and formally adopt a Flood Warning and Response Plan that includes the elements described in the CRS manual, summarized below:

    - **Flood threat recognition system.** The Town should develop a "Level 3" automated flood warning system that provides information such as the timing and potential elevation of a forecasted flood. The system must be able to receive or provide flood warnings 24 hours a day, 7 days a week, and 365 days a year. The system must be correlated to a flood inundation map, so that emergency managers can see what areas will be affected by the predicted flood. There are existing publicly available National Weather Service coastal flood forecast services that can be accessed online, including water level forecasts such as the Advanced Hydrologic Prediction Service and Extratropical Water Level Forecast (ESTOFS) and mapping products such as Probabilistic Tropical Storm Surge (P-Surge) and Extra Tropic Storm Surge (ET-Surge). A consultant could help the Town create a program and notification system that pulls forecast information from these sources and sends alerts to emergency managers when different triggers are reached. Alternatively, proprietary models and services could be contracted.

    - **Emergency warning dissemination.** The plan must include early warning alerts and pre-scripted messages that are disseminated to the public when a flood is imminent and identify the channels through which they will be disseminated. The warning messages should state when flooding is predicted to occur, its expected severity, and appropriate response actions (e.g., evacuation routes, safe shelters, protective actions). Appropriate channels for disseminating early warnings to those with special needs should be included. Reverse-911 alerts, audible sirens from the nuclear plant, and signs warning drivers of flooded roadways have been identified as potential warning notification channels for Marshfield.

- **Flood response operations.** The plan must describe the actions to be taken, identify those responsible for the action, define the time needed to carry out the activity, and contain other critical information that partners will need to perform their assigned responsibilities. The plan should also list the personnel, equipment, facilities, supplies, and other resources needed to complete each task, including what is available in the community versus from the private sector or other jurisdictions. The plan should also identify potential mitigation opportunities that may arise in the aftermath of a disaster, as repairs are needed, funding is available, and awareness is high. Finally, the plan should identify response and recovery measures to take that support property protection, such as a high-ground site to relocate vehicles, sandbag distribution, or others.

- **Critical facilities planning.** Flood warning and response planning must be coordinated with critical facility operators. The plan must list the vulnerable facilities considered critical in a flood or needed to support flood response. These facilities must be contacted to determine if they need any special warning arrangements (e.g., timing, method of notification). Any needed arrangements should be included in the plan. Ideally, these facilities should be part of the plan development and review and have their own plans which are accepted by the community.

6.8 Pursue Federal Grants for Dyke Road

While it was explicitly not within the scope of this project to evaluate the cost-effectiveness of infrastructure strategies to mitigate coastal flood risks, the concentration of losses upstream of Dyke Road could not be responsibly ignored. As shown in **Figure 12** and **Figure 13**, 41% of the losses and 90% of the substantially damaged buildings in the 2030 100-year coastal flood would be in the Bass Creek-Green Harbor Marsh area upstream of Dyke Road. It is possible that enhancing the flood control capacity of Dyke Road is more cost-effective and/or more efficient than raising all the vulnerable buildings behind it.

There are significant potential benefits (avoided damage and loss) against which to budget costs for increasing the flood protection provided by Dyke Road. The Town has begun to evaluate the feasibility and cost of raising Dyke Road or otherwise improving its flood control capacity. Information available from the BCA could be used to help assess the cost-effectiveness of such projects prior to developing a grant application. If it appears that the project meets cost-effectiveness criteria, the Town should develop and submit a FEMA Building Resilient Infrastructure and Communities (BRIC) grant application for FY22. If construction costs appear to be less than $15 million, the Town could also consider adding the evaluation of elevating Dyke Road to the request for USACE to conduct a Hurricane and Storm Damage Reduction Feasibility Study. However, this would put it at competition for elevation and dry floodproofing funding.