Tremont Climate Vulnerability Assessment

A technical input to Tremont's
Climate Resilience Planning Process

COMMUNITY RESILIENCE PARTNERSHIP

TOWN OF TREMONT MAINE

Gulf of Maine Research Institute

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1. Introduction

Climate change is a global phenomenon, but its effects are felt locally. Climate change drives a range of impacts in Maine including rising temperatures, sea level rise, ocean acidification and warming, shifting precipitation patterns, and species shifts.[1] These changes have far-reaching consequences, not only for Maine's environment but also for its economy and communities. "Maine Won't Wait," the state's four-year climate action plan, is a testament to Maine's commitment to taking swift and meaningful action to mitigate the drivers and adapt to the impacts of climate change. Maine also provides grants and direct support to municipal governments to address climate change, emphasizing the significant role to be played by local communities.

Understanding climate vulnerability at the local level is pivotal for Maine's communities. It equips them to plan, build resilience, and adapt, thereby enabling them to continue to flourish in the face of change. An analysis that simultaneously considers communities' interconnected environmental, economic, and social strengths and vulnerabilities serves as one tool to equip local decision-makers and community members with the information they need to identify areas and populations that are most susceptible to climate impacts. This knowledge can be leveraged, along with community priorities, to inform climate and resilience planning efforts.[2]

This report assesses potential impacts to Tremont from a range of climate hazards, including sea level rise and increased coastal flooding; warming temperatures; changes in precipitation; changes to the Gulf of Maine's marine environment; vector-borne diseases; saltwater intrusion into coastal aquifers; and wildfires. This assessment leverages both quantitative data and the Tremont community's local knowledge to identify climate impacts to infrastructure and services that are a priority for the town. It draws upon existing datasets, scientific literature, and reports to assess climate risk. It also considers how climate hazards interact with Tremont's social and economic conditions to create variable risk among community members.

What is Climate Vulnerability?

Vulnerability is a measure of potential harm caused by a human or ecological system's exposure and sensitivity to hazards.[3] Here, climate vulnerability is assessed by examining how the Tremont community may be impacted by the adverse effects of climate change (which can include both variability and extremes in climate) through consideration of the "hazards of place,"[4] or the location of climate hazards relative to the location of community infrastructure, assets, and populations.

Why Assess Climate Vulnerability?

Weather and climate significantly impact the quality of life and safety of communities. Rising land surface and ocean temperatures, sea-level rise, increased wildfire risk, and species migration impact Tremont's economic sectors, as well as the infrastructure that connects residents to key social and emergency services in town and throughout Mount Desert Island. Climate impacts can exacerbate existing economic and health challenges faced by at-risk populations while increasing residents' exposure to unsafe living and working conditions.

This assessment can support Tremont in identifying and prioritizing adaptation actions, such as upgrading physical infrastructure and building out local planning capacities, by identifying when the community will experience specific impacts under a range of climate change scenarios. Translating these results into actions that include community values, priorities, and future visions requires a robust and engaged community process. In many instances, responding to climate change impacts may not require an overhaul of existing infrastructure, planning processes, or municipal functions. Instead, Tremont may adapt its existing plans and actions to leverage its strengths, enabling the community to better care for one another and actually thrive in the face of climate change.

2. The Town of Tremont

The Town of Tremont is located on the southwest of Mount Desert Island and includes Tinker's, Moose, Hardwood, Gott's, and Longley Islands. The town includes the villages of Bass Harbor, Bernard, Seal Cove, and West Tremont. Almost one-third of the Town of Tremont lies within the boundary of Acadia National Park.[5]

Land Area (square miles)	35.63
Population	1,914
Population Density (per square mile)	53.7
Households	852
Housing Units	1,811
Median Age	49.9

Table 2.1: *Tremont at a glance (source: ACS 2017-2021 5-year estimate)*

2.1 Priorities and Values

Tremont's 2023 comprehensive plan update identifies issues and opportunities facing the town and sets goals, policies, and implementation strategies to guide future planning and growth. Priorities for the town, as identified in the 2023 plan, include:

Goal #1: Promote a diversified local economy that provides for stable and sustainable year-round jobs
Goal #2: Provide housing options to support a year-round community while protecting rural character and small-town Tremont
Goal #3: Invest in improved public access to water, conserving natural resources and climate change resilience
Goal #4: Prioritize safe transportation for everyone along Route 102 and support island-wide transit

Climate change impacts pose potential barriers to achieving the community-defined goals in Tremont. During the comprehensive planning process, community members were asked about the extent to which they had observed climate change impacts in the town over the last three years. A majority of community members observed changes in marine and non-marine habitats, an increase in coastal water temperatures, and shifts in coastal erosion patterns, all of which they attributed to climate change. It's worth mentioning, however, that a significant number of respondents also expressed uncertainty as to whether their observations accurately represented climate driven changes taking place. There were no responses that highlighted other observed climate impacts, and provides part of the motivation for focusing this analysis on sea level rise and coastal flood risk. Notably, more than 85% of respondents indicated that the town should incorporate considerations of climate change into its future planning efforts.[5] This includes ensuring that waterfront access is both maintained and expanded and that an emergency management plan is developed to support year-round residents. Planning for a resilient future in Tremont necessitates taking stock of the climate-related vulnerabilities that the community faces.

2.2 Existing Policies and Ordinances Related to Climate Impacts

Tremont has a series of existing town ordinances and policies that are valuable for addressing the effects of climate change impacts, even though they do not explicitly outline efforts to enhance climate change resilience.[6] These ordinances and policies include a Floodplain Management Ordinance, emergency management plans, and erosion control standards. Tremont does not have municipal building codes, underscoring the importance of these policies and ordinances in encouraging best practices for infrastructure, and ensuring that residents are safe during times of emergency.

2.2.1 Flood Hazard Management

Tremont adopted a Floodplain Management Ordinance during a Town Meeting in July 2020. The town actively participates in the Federal Emergency Management Agency National Flood Insurance Program (FEMA NFIP), which enables property owners to purchase flood insurance and mandates the implementation of floodplain management measures in designated Special Flood Hazard Areas. It is important to note that coastal Special Flood Hazard Areas describe flood risk at a specific moment in time and do not account for increases in coastal flood risk due to sea-level rise over the lifetimes of structures.

Tremont's Floodplain Management Ordinance establishes a system for Flood Hazard Development Permits and outlines a review procedure for development activities within the designated Special Flood Hazard Areas of the town. The ordinance is enforced by the Code Enforcement Officer, and the Planning Board is responsible for reviewing site plans, subdivisions, and conditional use applications. Tremont's Floodplain Management Ordinance adheres to state and federal standards, ensuring consistency with broader regulatory frameworks.

A well-implemented floodplain management ordinance can reduce climate vulnerability by minimizing exposure to flood risk and encouraging resilient development practices that preserve natural flood defenses and promote informed decision-making at the individual and community levels. Tremont's 2023 Comprehensive Plan Update further outlines several recommendations for flood hazard management, including avoiding development in areas vulnerable to current and future hazards, and ensuring that decisions are made using models and projections that account for climate change.

2.2.2. Emergency Management

Tremont has a volunteer fire department with a roster of 21 active members, a fleet of five engines, and a cold water rescue boat. There are two firehouses, one at the north and south ends of the town. While the Tremont Volunteer Fire Department used to rely on fundraising efforts for its budget, it is now supported by the town, with an annual budget of approximately $130,000 as of 2023.[5] The 2023 Comprehensive Plan Update noted that the number of volunteer firefighters is generally insufficient, even though Tremont is part of a mutual aid agreement with other towns in Hancock County. Listening sessions noted that the fire department's roles and responsibilities extend beyond fire protection, and include the need to check in upon community members during times of emergency such as extreme weather events or power outages– a need residents felt the fire department was not adequately equipped to address.

2.2.3 Erosion Control

Tremont's Land Use Ordinance also adopts measures to protect buildings and lands from coastal erosion through the creation of resource protection zones that limit development in areas that are at risk of extreme erosion such as coastal bluffs. Additionally, the Planning Board requires that all construction activities that involve filling or grading create an erosion and sediment control plan to be submitted for review, with requirements that drainage ways be designed and constructed to carry water from a 25-year storm or greater (a storm that has a 1-in-25, or 4% chance of occurring in a given year; see Article VI of ref. 6). Erosion control methods articulated within the land use ordinance include constructing rip rap and retaining walls, avoiding excessive grading, and limiting vegetation removal. Finally, Tremont's Land Use Ordinance ties erosion control methods to the Best Management Practices in the Maine Erosion and Sediment Control Handbook from 1991.

2.3.4 Groundwater and septic systems

Tremont's Land Use Ordinance further outlines requirements for septic systems in accordance with the minimum standards set in the State of Maine's plumbing code. The State of Maine Plumbing Code requires that septic systems must be designed and installed by licensed professionals after obtaining the necessary permits. These systems are sized based on factors like the number of occupants and undergo soil and site evaluations to determine the appropriate size. The code enforces setback requirements to maintain safe distances from property lines, buildings, wells, and water bodies to prevent contamination. Notably, Tremont's Septic Ordinance does not include requirements around septic pump-outs or inspections, which would be beneficial in preventing septic system failure and protecting coastal water quality and clean water supply.[7]

3. Methodology

Much of the analysis presented in this report derives from NOAA's Climate Explorer, the Maine Climate Council Scientific & Technical Subcommittee's *Scientific Assessment of Climate Change and Its Effects in Maine*[1] (and its 2021 Update Report[8]), and the Maine Climate Impact Dashboard.[9] Methodologies for the service area and property impact analyses can be found in section 4.

For this assessment, the project team followed a five-step process:

1. **Identification Climate Concerns:** We identified priority climate concerns through conversations with the town manager, referencing the Comprehensive Plan, and review of notes from A Climate to Thrive's climate resilience planning community listening sessions.
2. **Review of Climate Risks:** We conducted a review of existing research and reports on climate risks to Tremont. This encompassed a range of factors, including sea level rise, coastal flooding, coastal erosion, temperature, precipitation, marine conditions, tick-borne diseases, saltwater intrusion, and wildfires.
3. **On-site Investigation:** Our team visited Tremont to engage with residents, gaining insights into observed climate impacts and priority concerns. We also measured elevations of critical infrastructure such as bridges, tidal crossings, and utilities at the town landing and MaineDOT Bass Harbor Ferry Terminal. This effort included the collection of community photos and videos capturing coastal flooding events.
4. **Coastal Flooding Impacts Assessment:** Recognizing coastal flooding as a key concern voiced by town residents, we examined future flood impacts on water-dependent sites like the town landing; road access to key community assets and emergency services; and the municipal tax base. Detailed methods used for this analysis can be found in Appendix A, and sections 4.3 and 4.5.
5. **Vulnerable Populations Analysis:** Building on existing research, reports, and community conversations, our project team assessed how climate hazards might disproportionately impact vulnerable populations.

4. Sea Level Rise and Coastal Flooding

4.1 Coastal Flooding Hazard in Tremont

Sea level rise is driving more frequent coastal flooding globally.[9] Along Maine's coast, sea level has risen 7.5 inches (or 0.6 feet) since 1910 (the year Maine's oldest tide gauge was installed in Portland), and the rate of rise has doubled in the past two decades.[1] Although a change in sea level of less than a foot may seem small, particularly relative to Tremont's tidal range, an incremental increase in sea level can drive rapid increases in the frequency—and severity—of flooding. Many of Tremont's low-lying roads, coastal properties, and water-dependent infrastructure currently sit just above the elevation reached by present day's highest tides and storm surges. Thus, even small increases in sea level put these sites at risk of recurrent flooding during high tides and surges in the coming years.

The combined impacts of rising sea level, high tides, storm surge, and waves all contribute to coastal flooding (Figure 4.1). Natural planetary cycles cause tidal range to vary over daily-to-decadal timescales, and the highest tides can cause minor flooding, even in the absence of stormy weather. In Tremont, the average tidal range (the distance between daily higher high and lower low water) is 10.6 feet, but the highest tides can raise water level an additional 2.1 feet above mean higher high water. Storm surge is the prolonged rise in water level above the predicted tide, caused by strong and persistent winds driving ocean water toward land. Storm surges from extratropical cyclones rather than tropical cyclones (hurricanes) have driven the vast majority of extreme coastal floods in the Gulf of Maine because they are more common and larger, slower-moving storms that cause longer-duration surges more likely to intersect with high tide.[10,11] There is also not statistically significant evidence that climate change will drive higher or more frequent storm surges in the Gulf of Maine in the future.[12,13] Southeasterly winds drive the largest storm surges both in Tremont[14] and at the nearby Bar Harbor tide gauge.[1] Eleven storms have produced storm surges over 3 ft since the Bar Harbor gauge was installed in 1947, and the largest surge of 4.9 ft was recorded during the Groundhog Day Storm of 1976.[1] Two of these surges exceeding 3 feet occurred back-to-back on January 10 and 13, 2024. These events are discussed in greater detail in Focus Box 4.3. Finally, waves cause additional flooding along Tremont's wind-exposed coastlines outside Bass Harbor and, to a lesser extent, within southern Bass Harbor.

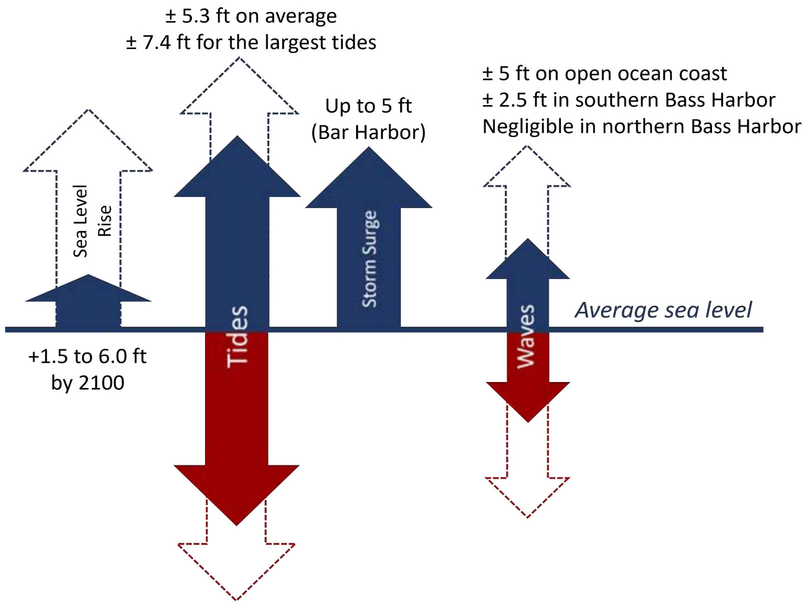


Figure 4.1: *Processes that raise and lower coastal water levels in Tremont.*

Tables 4.1.a and 4.1.b show estimates of current and future high water levels for Tremont. These estimates combine the latest U.S. Interagency Task Force sea level rise projections (see Focus Box 4.1)[15] with estimates of mean higher high water (MHHW), which is exceeded half of days; highest astronomical tide (HAT), which is exceeded 2-10 times per year; and the 1% annual chance stillwater elevation (1% SWEL), which has an average 1% chance of being exceeded each year. Focus Box 4.2 provides definitions of these terms, and Appendix A contains a detailed explanation of calculations. High water elevations and wave impacts vary spatially as a function of local coastal characteristics (coastline orientation, water depth, etc.), and the values in Tables 4.1.a and 4.1.b most accurately reflect flood hazard on the open ocean coastline and within southern Bass Harbor in the absence of waves. Waves may raise water level an additional 2.5 feet in southern Bass Harbor and along the open ocean coastline, whereas northern Bass Harbor is sheltered from wave impacts (Figure 4.2).[14]

Shallow waters also likely reduce the height of high waters in northern Bass Harbor north of John's Island, so the Table 4.1.a and 4.1.b flood heights represent high-end flood hazard estimates for sites such as Crockett Point Road, Cousins Creek Bridge, Clark Bridge and Archie's Lobster (Figure 4.2). The tidal crossing under Clark Bridge further reduces the height of high waters on the landward side of the bridge. A 2014 USGS study found that high water elevations landward of Clark Bridge (relative to NAVD88) were 60% of high water elevations at the Bar Harbor tide gauge.[C] We use this result to adjust high water elevations in assessing flood risk to Marsh Bridge and the marsh landward of Clark Bridge (see Appendix A for details).

An ideal characterization of flood hazard would be a relationship between water level and all frequencies of occurrence that varies spatially to account for varying coastline characteristics. In other words, one would know the elevations of high waters that range in frequency from daily to a 1% annual chance of occurrence (or rarer) at all locations. MaineDOT is currently funding the development of a statewide flood risk model that will provide this type of spatially continuous flood risk information for present and future conditions. Results that can be used to update this analysis will likely be available around 2025.

Year	Sea Level Height (ft above NAVD88)					
	Mean Higher High Water (MHHW)		Highest Astronomical Tide (HAT)		1% Annual Chance Stillwater Elevation	
	Int.	High	Int.	High	Int.	High
2023	5.2	5.2	7.3	7.3	9.5	9.5
2030	5.6	5.6	7.7	7.7	9.9	9.9
2040	5.8	5.9	7.9	8	10.1	10.2
2050	6.1	6.4	8.2	8.5	10.4	10.7
2060	6.5	7.1	8.6	9.2	10.8	11.4
2070	6.9	7.9	9	10	11.2	12.2
2080	7.4	8.9	9.5	11	11.7	13.2
2090	7.9	9.9	10	12	12.2	14.2
2100	8.6	11	10.7	13.1	12.9	15.3

***Table 4.1.a**: High water levels seaward of Clark Bridge. Future tidal and extreme water high water levels under the U.S. Interagency Task Force Intermediate and High sea-level rise scenarios in southern Bass Harbor and along Tremont's open ocean coastline (in other words, everywhere seaward of Clark Bridge). Waves may also raise water level an additional 2.5 feet at sites along the open ocean coastline and in southern Bass Harbor (Figure 4.2).*

Year	Sea Level Height (ft above NAVD88)					
	Mean Higher High Water (MHHW)		Highest Astronomical Tide (HAT)		1% Annual Chance Stillwater Elevation	
	Int.	High	Int.	High	Int.	High
2023	3.4	3.4	4.7	4.7	6.1	6.1
2030	3.6	3.6	5.0	5.0	6.4	6.4
2040	3.7	3.8	5.1	5.2	6.5	6.6
2050	3.9	4.1	5.3	5.5	6.7	6.9
2060	4.2	4.6	5.5	5.9	7.0	7.4
2070	4.5	5.1	5.8	6.5	7.2	7.9
2080	4.8	5.7	6.1	7.1	7.5	8.5
2090	5.1	6.4	6.5	7.7	7.9	9.2
2100	5.5	7.1	6.9	8.5	8.3	9.9

***Table 4.1.b:** High water levels landward of Clark Bridge. High water levels landward (northeast) of Clark Bridge (Figure 4.2), calculated following the equation in Appendix A.*

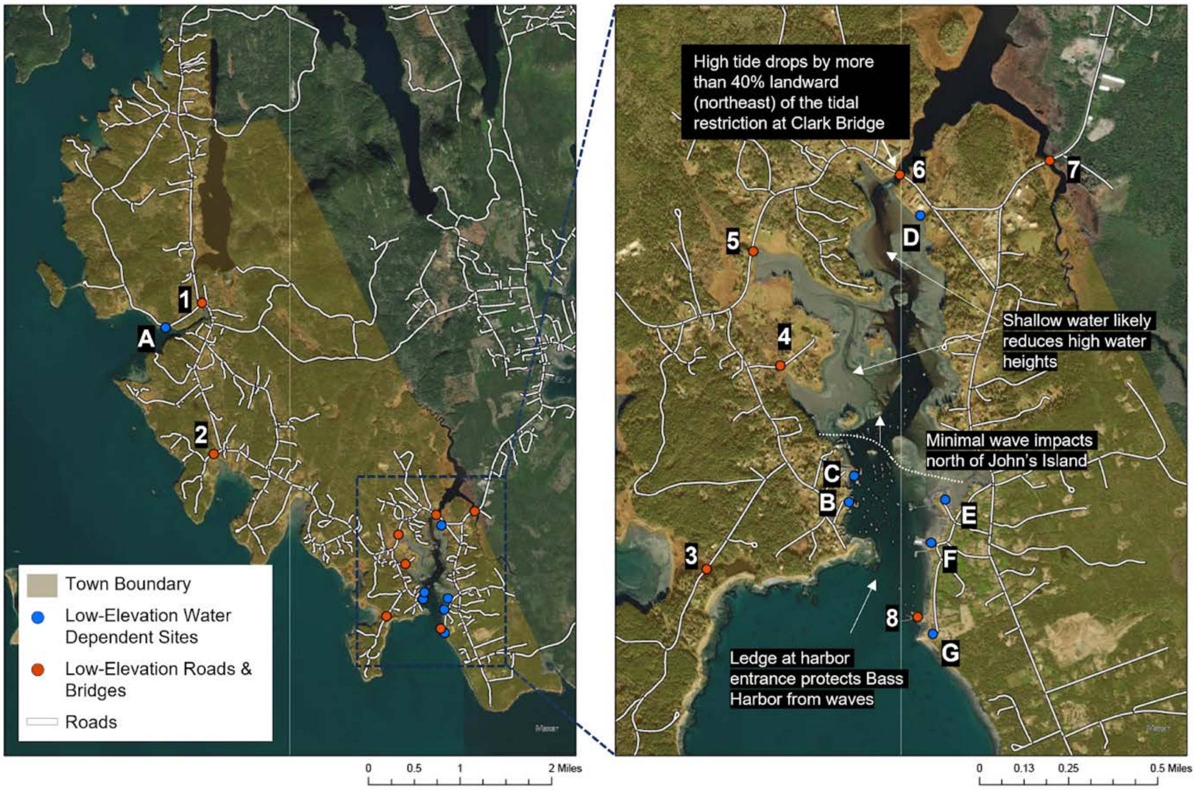
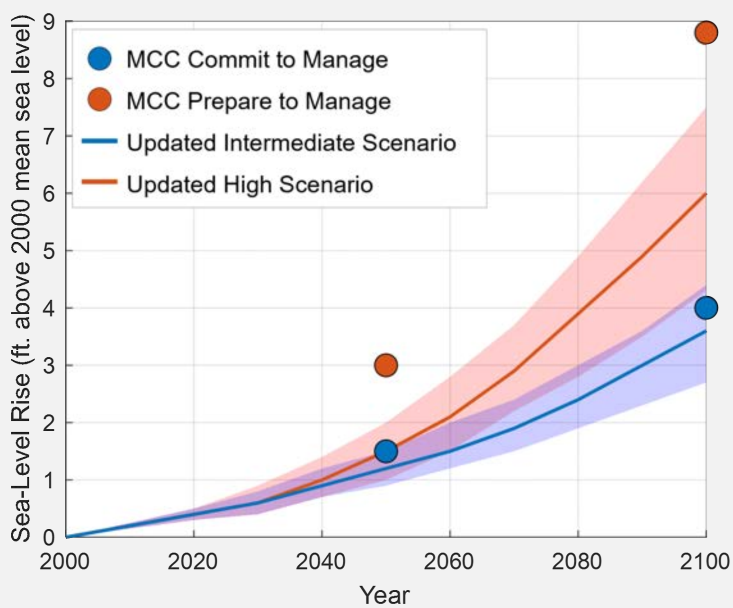


Figure 4.2: *Locations of low-elevation roads, bridges, and water-dependent sites that are vulnerable to coastal flooding. Text in the right-hand figure describes spatial variation in high water elevations and wave impacts. Numbered labels of low-lying roads and bridges correspond to Tables 4.2 and 4.3. Lettered labels of water-dependent sites correspond to Table 4.10.*

Focus Box 4.1: Sea Level Rise Scenarios

In 2020, the Maine Climate Council's Scientific and Technical Subcommittee (MCC STS) recommended that Maine commit to manage 1.5 feet of sea level rise in 2050 and 4.0 feet in 2100.[1] These values are relative to mean sea level in the year 2000, and sea level rose roughly one-quarter foot between 2000 and the early-2020s. Subsequently, Public Law Ch. 67 *Resolve, To Analyze the Impact of Sea Level Rise* was enacted June 16, 2021, and it directs seven state agencies to incorporate consideration of 1.5 and 4.0 ft of sea level rise into administration of their laws and rules. The MCC STS also recommended that Maine prepare to manage 3.0 ft of sea level rise in 2050 and 8.8 ft in 2100 (relative to 2000 mean sea level).

There is a significant range in future sea level projections, driven primarily by uncertainty in future global greenhouse gas emissions and the response of ice sheets to warming temperatures.[9] The "commit" and "prepare" to manage values selected by the MCC STS correspond to statewide averages for Intermediate and High scenarios developed by the National Oceanographic and Atmospheric Administration (NOAA) in 2017.[16] Of the six scenarios developed by NOAA, Intermediate is the third highest, and High is the fifth highest. A U.S. Interagency Task Force updated NOAA's projections in 2022, and sea level rise projections in Maine slightly decreased for the Intermediate and High scenarios due to a delay in meltwater contributions from ice sheets and a change in relative contributions from Greenland and the Antarctic ice sheet.[15] In this assessment, we use the Intermediate and High scenarios from the updated 2022 U.S. Interagency Task Force projections at the Bar Harbor Tide gauge (Tables 4.1.a and 4.1.b). They are equivalent to the MCC STS commit and prepare to manage scenarios, but they are localized to the Tremont area and reflect the latest science.



Focus Box Figure: *Comparison of updated U.S. Interagency Task Force sea level scenarios for Bar Harbor used in this report[15] to the Maine Climate Council (MCC) scenarios,[1] which are on the 2017 NOAA report.[16]*

Year	Sea Level Rise (ft above 2000 mean sea level)			
	Intermediate		High	
	Central Estimate	Likely range	Central Estimate	Likely Range
2030	0.6	0.4 to 0.8	0.6	0.4 to 0.9
2040	0.9	0.7 to 1.2	1.0	0.7 to 1.4
2050	1.2	0.9 to 1.5	1.5	1.0 to 2.0
2060	1.5	1.2 to 2.0	2.1	1.5 to 2.8
2070	1.9	1.5 to 2.4	2.9	2.2 to 3.7
2080	2.4	1.9 to 3.0	3.9	2.8 to 4.9
2090	3.0	2.3 to 3.6	4.9	3.5 to 6.2
2100	3.6	2.7 to 4.4	6.0	4.3 to 7.5

Focus Box Table: *Sea-level rise projections at the Bar Harbor tide gauge, developed by the U.S. Interagency Task Force.[15] These Intermediate and High scenarios are equivalent to the Maine Climate Council Scientific and Technical Subcommittee's "commit" and "prepare" to manage scenarios.*

Focus Box 4.2: Water level terms and datums

Mean higher high water (MHHW): The average of the higher high water height observed each day (the Gulf of Maine has two high tides per day) over a 19-year period (19 years includes the longest-period lunar cycle that significantly influences tide range).

Mean lower low water (MLLW): The average of the lower low water height observed each day over a 19-year period.

Highest astronomical tide (HAT): The highest predicted astronomical tide (or the rise in water level from tides alone, without the influence of weather) expected to occur at a location over a 40-year period. Due to wind and currents, water levels exceed HAT roughly 2-10 times per year.

1% annual chance stillwater elevation (1% SWEL): The peak water level that has a 1% chance of occurring in a given year from the combined influence of high tide and storm surge (commonly called the "100-year" water level). It does not include periodic rise and fall (over seconds) of water from wind waves.

North American Vertical Datum of 1988 (NAVD88): The land-based reference point, assigned a value of zero, relative to which elevations of structures and coastal water levels can be measured.

Focus Box 4.3: Coastal storms on January 10 & 13, 2024

Back-to-back coastal storms with strong winds out of the southeast drove extensive coastal flooding and damage along Maine's coast on January 10th and 13th. The southeasterly winds generally caused the most severe impacts on southeast-facing shorelines such as Ship Harbor, Lopaus Point, Nutter Point, and Dix Point. Lopaus Point Road was inundated and impassable at high tide, isolating residences on Lopaus Point, and the road sustained damage. The Bernard town landing was damaged and remained closed for repairs several weeks after the storms. The road to the Bass Harbor Ferry Terminal, Little Island Marine, Route 102 near Archies, and Cape Road near the Seal Cove Picnic Area were also all inundated.

The January 13 storm led to the highest water level recorded at the Bar Harbor tide gauge since it was installed in 1947. The January 10 storm led to the second highest. Sea level rise is the reason that these two storms broke flooding records. If sea level rise and variability are removed from the Bar Harbor tide gauge record (in other words, if we re-examine high water levels as if annual mean sea level were the same every year), six other storms since 1947 would have led to the same water levels as the two January storms. This is an indication that the January storms represent the new type of severe event that communities can expect, and that impacts will continue to become more severe as sea level rises.

Sea level in January 2024 was higher than it has ever been, in part due to the long-term rise in sea level, and in part due to an abrupt increase in sea level that occurred between 2022 and 2023. At the Bar Harbor tide gauge, average sea level over the year 2023 was 0.26 feet higher than it was in 2022. For context, over the past 30 years (1993-2023), sea level has been rising 0.12 feet **per decade**. The cause of this abrupt increase in sea level remains unknown. There was a high sea level anomaly in the Gulf of Maine in 2010 that has been attributed to wind patterns associated with a strongly negative North Atlantic Oscillation and a reduction in Atlantic Meridional Overturning Circulation slowing the Gulf Stream.[A,B] The 2010 high sea level anomaly lasted one year, and it is unknown whether the current high sea level will lower again.

In terms of other factors that contribute to flooding (tides, storm surge, and waves), the January 13 storm was an example of moderate storm surge combining with high astronomical tides, whereas the January 10 storm drove extreme storm surge and waves on top of a near-average high tide. On January 10, strong winds out of the southeast raised offshore waves heights to nearly 30 feet (NERACOOS Buoy E01, NDBC Buoy 44032), bringing particularly devastating impacts to Maine's southeast-facing open ocean coastal areas, including those in Tremont. It is also currently unknown whether climate change is affecting the timing of wind direction associated with coastal storms in the Gulf of Maine.

4.2 Salt marshes and coastal bluffs

Tremont's coastline includes bluffs and salt marshes that may be vulnerable to enhanced erosion rates or inundation as sea level rises. The roughly 90-acre Bass Harbor Marsh is partially within Tremont, and there are an additional 40 acres of salt marsh around Mitchell Cove and the Bernard Cemetery.[17] Healthy salt marshes are important to people and communities. They buffer against erosion and flooding;[18] maintain fish and wildlife populations;[19,20] contain sweetgrass, which the Wabanaki use for medicine and basket making;[A,B] support commercially harvested species;[21] filter pollutants and excess nutrients;[22] and store carbon.[23] Bass Harbor marsh is significant to Wabanaki communities, in part for harvesting sweetgrass,[B] and Tremont's 2023 Comprehensive Plan Update identifies the marsh as a critical natural area and scenic resource that is "an important part of what it means to live in Tremont."[5] Tremont's shoreline also includes bluffs of unconsolidated sediment along the open ocean coast and within Bass Harbor, Duck Cove, and Goose Gove.[24]

The assessment of coastal flooding impacts in the following sections does not estimate changes in the shoreline due to bluff erosion or salt marsh degradation, as they are difficult to quantify. Salt marshes exist within a specific elevation range relative to high tides, so in order to survive as sea level rises, they need to build elevation by producing organic material and capturing mineral sediment or migrate inland to higher ground. The maximum rate that salt marshes can build elevation depends on local factors such as tidal range, sediment availability, health of marsh vegetation, and human modifications to the coastal environment.[25] A 2014 study by the U.S. Geological Survey and National Park Service found that sediment accumulation on the Bass Harbor Marsh platform kept pace with sea level rise 1980-2011 but did not investigate whether this would continue as the rate of sea level rise accelerates in the future.[C] Road crossings that restrict tidal flow into and out of Bass Harbor Marsh (locations 6 and 7 on the map in Figure 4.2), as well as the marshes landward of Crockett Point Road and Cousins Creek Bridge (locations 4 and 5 in Figure 4.2), may hinder the ability of Tremont's salt marshes to remain healthy as sea level rises. This is discussed further in Section 4.3.2.

The National Park Service, Indigenous scientists and gatherers, Friends of Acadia, and Maine Coast Heritage Trust continue to conduct research in Bass Harbor Marsh that is critical to informing marsh restoration practices and any potential future modifications to Clark Bridge. Specifically, they are investigating how past human modifications to the marsh, such as construction of ditches and berms, have impacted marsh hydrology; how to facilitate sweetgrass growth by studying habitat preferences; best management practices for invasive species such as the glossy buckthorn; and how sea level rise and the tidal restriction impact sediment delivery and nutrient budgets.

There is also little quantitative information on how sea-level rise will impact bluff erosion rates. Even in the absence of sea-level rise, however, bluffs gradually and naturally erode, often at rates of inches per year.[1,26] The sediment eroded from bluffs can also be a critical sediment supply for adjacent marshes; thus, armoring bluffs can have negative unintended consequences for marsh resilience.[27]

4.3 Impacts to Roads, Bridges, and Tidal Crossings

4.3.1 Road surface flooding

In Tremont, cars are the most commonly used mode of transportation. Of particular significance is Route 102, as it serves as a primary entry and exit route for Tremont, connecting the town to neighboring Mount Desert Island (MDI) communities and services. More than 80% of Tremont's residents also depend on the town's road network to go to work, whether it's for their daily commute within the town or to travel in and out of Tremont.[28] To put it in perspective, 287 residents leave Tremont for work, while an additional 160 people who live outside Tremont commute into the town for their jobs.[5] This reliance of Tremont's population and its workforce on the functionality and maintenance of roadways highlights just how crucial it is to keep the town's roads in good condition, especially considering the potential challenges posed by coastal flooding.

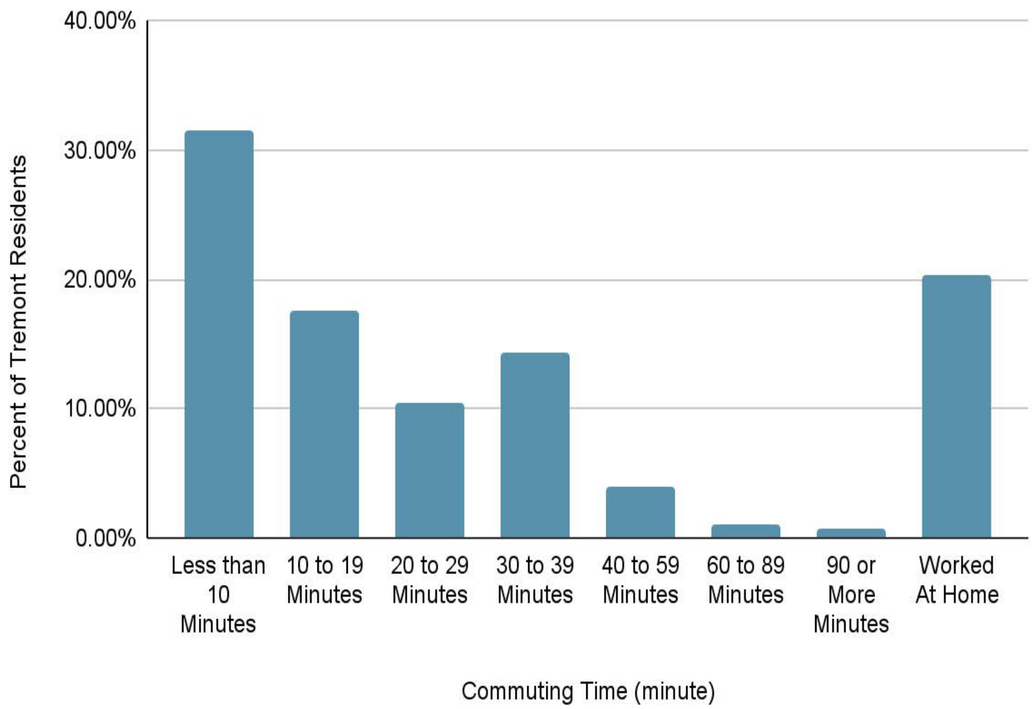


Figure 4.3: *Commuting time for residents in Tremont (ACS 2017-2021 5-year estimate)*[28]

Table 4.2 describes flood impacts to Tremont's low-lying coastal roads and bridges through the year 2100 (see Figure 4.2 for locations). Currently (in 2023), Lopaus Point Road, Crockett Point Road, Marsh Bridge, the MaineDOT Bass Harbor Ferry Terminal bridge, and the lowest-elevation section of the Rt. 3 Bridge connecting MDI to Trenton (the southernmost part of the bridge just north of the intersection with Rt. 102) are vulnerable to flooding from the 1% SWEL. Lopaus Point Road and the ferry terminal bridge are also exposed to higher water levels and erosion from wave impacts. All these locations will be flooded at water levels that are exceeded every year (HAT and MHHW) by mid-to-late century under both the Intermediate and High sea level-rise scenarios. Dix Point Road Bridge and Cousins Creek Bridge are at higher elevations and will be vulnerable to flooding from the 1% SWEL mid-to-late century.

Clark Bridge, which was reconstructed in 2019, may be flooded at the 1% SWEL around 2030 and HAT around 2090 for the Intermediate scenario and 2070 for the High scenario. We note that these are conservative estimates, given that high water elevations are likely reduced by friction from the shallow water depths in northern Bass Harbor. Although Marsh Bridge is at low elevation, it is likely at least 1.4 ft above the present-day 1% SWEL due to the Clark Bridge tidal restriction lowering high water landward of the bridge. Future flood risk to the bridge depends on changes to Clark Bridge and the evolution of Bass Harbor marsh with sea level rise.

Bass Harbor Ferry Terminal

This information can be used along with the tidal restriction information (Section 4.3.2.) and service area analysis (Section 4.3) to prioritize adaptation projects for specific roads and bridges. Table 4.2 also includes the years that most of Tremont's bridges were built, and the MaineDOT bridge design guide estimates that bridges need to be replaced after 75 to 100 years.[29] The Tremont Public Works Department is responsible for maintaining 49 miles of local roads and state aid highways, while MaineDOT is responsible for the maintenance of Cousins Creek Bridge, Clark Bridge, Marsh Bridge, MaineDOT Bass Harbor Ferry Terminal Bridge, and the Rt. 3 bridge in Trenton. This analysis, along with narratives and documentation of road flooding, could serve as a starting point for engaging local and state emergency management agencies and surrounding municipalities for support with requesting upgrades to state-maintained infrastructure.

No. on Map	Name	Lat	Long	Road elev, ft NAVD88	Year built	Inundation Impacts			Additional rise in water level from wave crests
						Present (2023)	Intermediate SLR through 2100	High SLR through 2100	
1	Seal Cove Bridge	44. 287	-68. 4004	34.9	1969	None	No anticipated coastal flooding impacts. Could be impacted by precipitation flooding, particularly if the culvert were blocked.		Likely none
2	Dix Point Road Bridge	44. 263	-68. 398	10.2	unknown	None	Flooded at 1% SWEL around 2050 and HAT in the 2090s	Flooded at 1% SWEL around 2040, HAT in the 2070s, and MHHW in the 2090s	Likely none
3	Lopaus Point Road	44. 237	-68. 3604	8.4	unknown	1.1 ft below the 1% SWEL	Flooded at HAT in the 2050s and MHHW around 2100	Flooded at HAT around 2050 and MHHW in the 2070s	2..5+ ft
4	Crockett Point Road	44. 245	-68. 356	8.1	unknown	1.4 ft below the 1% SWEL	Flooded at HAT around 2050 and MHHW around 2100	Flooded at HAT in the 2040s and MHHW in the 2070s	Likely none
5	Cousins Creek Bridge	44. 25	-68. 3575	11.6	1969	None	Flooded at 1% SWEL around 2080	Flooded at 1% SWEL around 2060 and HAT in the 2080s	Likely none
6	Clark Bridge	44. 253	-68. 3494	9.9	2019	None	Flooded at 1% SWEL around 2030 and HAT around 2090	Flooded at 1% SWEL around 2030, HAT around 2070, and MHHW around 2090	Likely none
7	Marsh Bridge	44. 253	-68. 3407	7.5	1931	1.4 ft above the 1% SWEL	Future impacts depend on changes to the tidal restriction at Clark Bridge and marsh evolution with sea level rise		Likely none
8	MaineDOT Bass Harbor Ferry Terminal	44. 235	-68. 3483	8.9	1997	0.6 ft below the 1% SWEL	Flooded at HAT around 2070 and MHHW around 2100	Flooded at HAT in the 2050s and MHHW around 2080	Up to 2.5 ft
not shown	Rt. 3 bridge over Mt. Desert Narrows	44. 423	-68. 3642	9.5	1958	At 1% SWEL	Flooded at HAT around 2080	Flooded at HAT in the 2060s and MHHW in the 2080s	Unknown

Table 4.2: *Coastal flooding impacts to low-lying roads and bridges (see Figure 4.2 for locations).*

4.3.2 Tidal Restrictions

In addition to considering flood risk to the road surface, it is important to determine whether roads that cross tidal environments allow for unimpaired flow between their landward and seaward sides. When tides flow through undersized bridges and culverts, flow is accelerated and/or redirected, causing structural wear or damage to the bridge or road and impairing the natural processes that sustain tidal wetlands.[25] For example, tidal restrictions can reduce the inundation of salt marshes during the highest tides and surges, which are critical times for delivering sediment that sustains marshes. [27,31-32]

The CoastWise approach was recently developed at the recommendation of the Maine Climate Council to provide “a voluntary set of science-based best practices, tools, and sequences to encourage the design of safe, cost-effective, ecologically supportive, and climate-resilient tidal crossings."[30] Following CoastWise principles, six tidal crossings in Tremont were identified as tidal restrictions in January 2020: Crockett Point Road, Cousins Creek Bridge, Clark Bridge, Marsh Bridge, Dix Point Road Bridge, and Seal Cove Bridge (Table 4.3).[33] These six crossings are, therefore, all susceptible to damage during high water events, and likely restrict the flow of water and sediment into and out of salt marshes.

CoastWise provides detailed guidance on the sequence of steps to take in planning, designing, and constructing crossings. Under their framework, crossings should be designed to accommodate flows during the 1% annual chance flood event, plus relative sea-level rise over the crossing's lifespan, plus 0-2 feet of freeboard (i.e. 0-2 ft of extra clearance). The exact amount of recommended freeboard depend on the risk consequence of the crossing (see Tables 3.2 and 5.2 of the Coastwise Manual). Opening tidal restrictions and restoring full tidal exchange also has implications for the marsh that should be investigated ahead of restoration. Unrestricting tides raises the high tide water surface elevation landward of restrictions, increasing tidal inundation of marsh platforms while they build elevation and reach a new steady-state. In cases where a salt marsh is already highly impaired, the marsh may not be able to adapt to increased inundation, and rapidly reestablishing tidal exchange can further damage the marsh.[30] Increasing tidal flow into an estuary also alters the flow of nutrients among the uplands, estuary, and ocean, and this has implications for vegetation health and macro-algal blooms.[C]

MaineDOT replaced Clark Bridge in 2019. The geometry of the bridge underpass may have been maintained due to concern that unrestricting tides may increase the concentration of nutrients that cause macro-algal blooms in the estuary (note that there is also a bedrock sill near Clark Bridge that naturally restricts tides, so the precise impact of opening the bridge underpass remains unknown).[C] At the time, marsh accretion was also keeping pace with sea-level rise,C and the road surface was not flooding. As sea level rise increases the risk of road surface flooding and damage to Clark Bridge, potentially necessitating further modifications to the structure, it will be critical to understand how higher sea level and tidal exchange impact sediment and nutrient delivery to the marsh.

No. on Map	Name	Elev. top of tidal crossing (ft NAVD88)	Presence of Scour	Upstream Marsh	Habitat Discontinuity	Habitat details
1	Seal Cove Bridge	unknown	Insufficient Data	None	Yes	Active alewife habitat, active smelt habitat
2	Dix Point Road Bridge	6.9	Yes	4 acres salt/brackish marsh	No	Active Smelt Habitat; Tidal waterfowl and wading bird habitat within 75 m
4	Crockett Point Road	unknown	Not assessed	2 acres freshwater marsh	Yes	Tidal waterfowl and wading bird habitat within 75 m
5	Cousins Creek Bridge	10.8	Yes	7 acres salt/brackish marsh	Yes	Tidal waterfowl and wading bird habitat within 75 m
6	Clark Bridge	7.9	Insufficient data	38 acres salt/brackish marsh, 25 acres freshwater marsh	Yes	Tidal waterfowl and wading bird habitat within 75 m
7	Marsh Bridge	5.5	Yes	21 acres salt/brackish marsh	No	Tidal waterfowl and wading bird habitat within 75 m

***Table 4.3:** Tremont bridges identified as tidal restrictions based on a January 2020 assessment for the Maine Tidal Restriction Atlas (see Figure 4.2 for locations).[31] Elevations were measured in the field, and information on scour, marsh area, and habitat is from the Maine Tidal Restriction Atlas.*

4.3.3. MaineDOT Bass Harbor Ferry Terminal Utilities

The MaineDOT Bass Harbor Ferry Terminal bridge houses electrical equipment critical to operation of the terminal. Boxes can protect electrical equipment from intermittent splashing from waves, but they often won't protect against prolonged inundation. Figure 4.4 shows elevations of the bottom edges of boxes on the bridge relative to high water elevations over the next 50 years under Intermediate and High sea level rise scenarios. All electrical boxes are high enough to avoid inundation under current conditions, but boxes numbered 4, 5, and 8 should be elevated when they reach the end of their service life and need to be replaced.

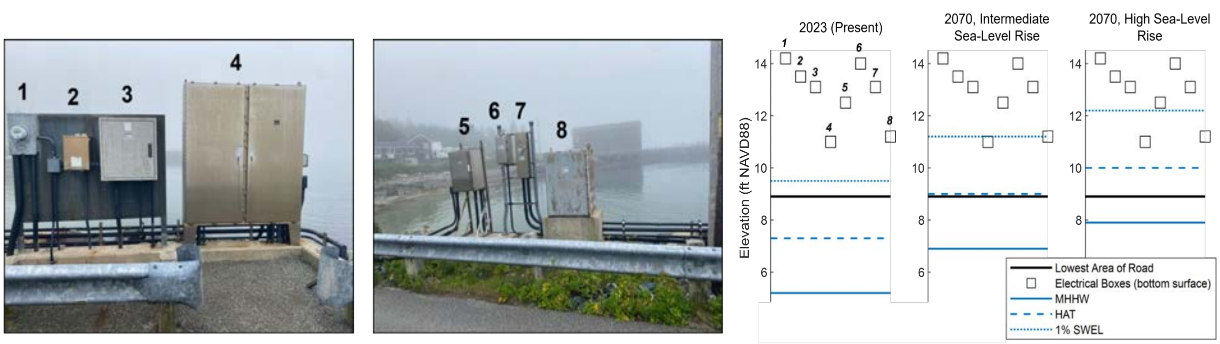


***Figure 4.4:** Elevations of boxes containing electrical equipment on the MaineDOT Bass Harbor Ferry Terminal Bridge, relative to present and 2070 high water elevations.*

4.4 Service Area Impacts

Tremont's large tides cause the water surface elevation to change ~0.5 to 1 ft per hour around high tide, so roads generally will not remain impassable for long periods until rates of sea level rise increases to the point where tides are unable to clear out the water. However, emergency managers consider roads impacted as soon coastal water level reaches the lowest-elevation area of the road surface, as inundation may cause structural damage or bring debris onto the road. One method for determining the impacts of coastal flooding on communities is to understand how road inundation impacts residents' ability to reach community assets and emergency services. To this end, we conducted a service area analysis to define impacted geographic areas in Tremont based on the amount of time it takes to travel to or from community assets and emergency service facilities. Through this analysis, decision-makers will be armed with information that will help them understand how the service scope of community assets and emergency facilities changes under different flood scenarios.

We conducted a service area analysis for community assets under different flood scenarios, using ArcMap. We gathered geographic data, including road networks, community assets, elevation data, and building footprints. First, we used elevation data, sea level rise projections, and flood projections to model potential inundation areas to create flood extents. Next, we created a network dataset from the road network, specifying connectivity and attributes, and created a new network analysis layer for the service areas.

We analyzed different flood scenarios by setting a restriction for flood extent polygons under present-day, 2050, and 2100 HAT Intermediate scenarios, and solved for service areas in 5-minute driving increments. Note that we used the simplified assumption that the Clark Bridge tidal restriction will lower high water by the same amount in the future as it does now. For each flood restriction that was set, the total number of building footprints within 5, 10, 15, 20, 25, and 30+ minute service areas was summarized and used to determine the percentage of the town that was served by community assets under each scenario. The same process was utilized for the emergency preparedness analysis using service areas, but instead of using HAT scenarios, we used a 1% Annual Chance Stillwater Elevation for 2023, 2050, and 2100. Note that the service area analysis was only conducted for flood impacts on road infrastructure in Tremont, and access to services outside of the town's boundaries may be affected by coastal flooding on other roadways on Mount Desert Island.

The service area analysis is closely tied to the road and bridge impact analysis, as it relies upon identifying where the network dataset is disrupted by flood extents. This analysis found that the most at-risk emergency service was healthcare facility access around 2050, due in large part to the need for Tremont residents to cross low-lying roads and bridges in order to reach services outside of town. On the other hand, the presence of two fire stations within Town, means that most residents are within a 10-minute driving distance under 2050 and 2100 scenarios, with the northern section of town being generally more connected that the relatively lower lying southern sections in Bernard and Bass Harbor. In terms of community assets, Tremont Consolidated School may faced some of the biggest impacts around 2100, due to a low density of building footprints that are in close proximity to the school, and projected flood and sea level rise impacts on Clark Bridge to the east of the school and Cousins bridge on the west.

Maps illustrating service area changes under different projected sea level rise conditions can be found in Appendix C.

4.4.1 Community Assets

Community assets consist of resources, infrastructure, and institutions that contribute to a community's functionality, resilience, and overall well-being. These assets encompass a range of components, including both public works-related infrastructure like roads and bridges, as well as infrastructure that supports societal well-being more directly such as schools, community centers, and recreational spaces.[34] Recognizing the location and condition of critical infrastructure aids in identifying areas most vulnerable to flooding, storms, and other climate hazards. The ability to access resources, gathering spaces, and places that foster a sense of identity and connection can support social bonding to promote strong, and healthy relationships and—in the process—cultivate the adaptive capacity of the community. In this section of the vulnerability assessment, we focus on four key town assets—the Town Office, Tremont Consolidated School, Bass Harbor Memorial Library, and Public Waterfront Access points—and the impacts they face as a result of coastal flooding.

Bass Harbor Memorial Library

Located on the eastern side of Bass Harbor in Bernard, the Bass Harbor Memorial Library contributes to Tremont residents' sense of community and well-being. The library is the only municipal library on Mount Desert Island and provides community programming as well as services such as free wifi and computer access. The library also serves as a gathering place for the Tremont community.[5]

In Tremont, the majority of residents have convenient access to Bass Harbor Memorial Library, with more than half residing within a 5-minute drive. Present-day HAT projections do not foresee any inundation affecting the major roads and bridges connecting Tremont to the library. However, under 2050 HAT conditions, road flooding is expected to result in 34 buildings becoming isolated from the library (see Section 4.3). Looking ahead to the 2100 HAT scenario, the percentage of buildings within a 5-minute drive of the library will decrease to 34%, and nearly 40% of buildings will lose all access to the library.

Service Area (minutes driving)	Number (and Percentage) of Buildings in Tremont		
	2023 HAT (count)	2050 HAT (count)	2100 HAT (count)
0-5	1091 (68%)	1066 (66%)	55 (34%)1
5-10	354 (22%)	354 (22%)	282 (17%)
10-15	153 (9%)	153 (9%)	153 (9%)
15-20	14 (1%)	14 (1%)	7 (.5%)
20-25	0	0	0
25-30	0	0	0
30-35	0	0	0
Not connected		34	619

Table 4.4: *Change in the number of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of the Bass Harbor Memorial Library, or that are disconnected entirely, under present day (2023) conditions, as well as HAT projections in 2050, and 2100 under the Intermediate sea level rise scenario.*

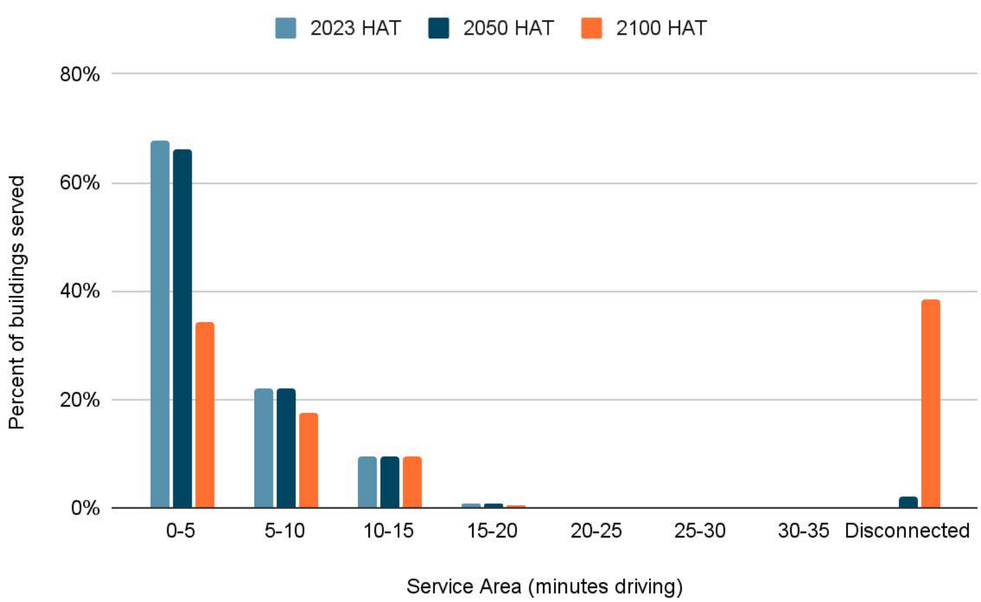


Figure 4.5: *Change in the percentage of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of the Bass Harbor Memorial Library, or that are disconnected entirely under present day (2023) conditions, as well as HAT projections in 2050, and 2100 under the Intermediate sea level rise scenario.*

Tremont Consolidated School

Tremont Consolidated School, a public K-8 school that served 118 students in 2022, is located on the west side of Marsh Bridge. The Island Explorer bus service serves Tremont Consolidated School as a stop from June through October (the tourist season), providing connections to Bass Harbor, Southwest Harbor, and other areas on Mount Desert Island. Due to the seasonal nature of the bus service, it is not a year-round commuting option for students. Tremont Consolidated School stands out in Tremont as one of the limited locations that is connected to a main water line instead of being dependent upon wells, enabling it to provide water to a minimum of 25 individuals for half of the year. Additionally, the school building is attached to a community building, which serves as a gym for the school and houses the only indoor recreational facility in Tremont.

Like Bass Harbor Memorial Library, more than 65% of building footprints within Tremont's boundary are within a 5-minute drive of Tremont Consolidated School, while just over 10% are within a 10-15-minute drive. Present-day HAT conditions do not result in road inundation on the routes connecting the school to the rest of the town, ensuring the service area remains unaffected. However, under 2050 HAT conditions projected under the Intermediate sea level rise scenario, there is a slight change in the number of buildings served, as just under 3% of the town may be unable to access the school.

In contrast, projected 2100 HAT conditions under the Intermediate sea level rise scenario result in significant consequences for Tremont Consolidated School's service area. With over 90% of buildings potentially disconnected from the school due to road and bridge inundation, the school may become isolated (see Section 4.3).

Service Area (minutes driving)	Number and Percentage of Buildings in Tremont		
	2023 HAT (count)	2050 HAT (count)	2100 HAT (count)
0-5	1062 (66%)	1035 (64%)	137 (9%)
5-10	351 (22%)	351 (22%)	0
10-15	199 (11%)	182 (11%)	0
15-20	0	0	0
20-25	0	0	0
25-30	0	0	0
30-35	0	0	0
Not connected	0	44 (3%)	1475 (92%)

Table 4.5: *Change in the number of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of the Tremont Consolidated School, or that are disconnected entirely, under present day (2023) conditions, as well as HAT projections in 2050, and 2100 under the Intermediate sea level rise scenario.*

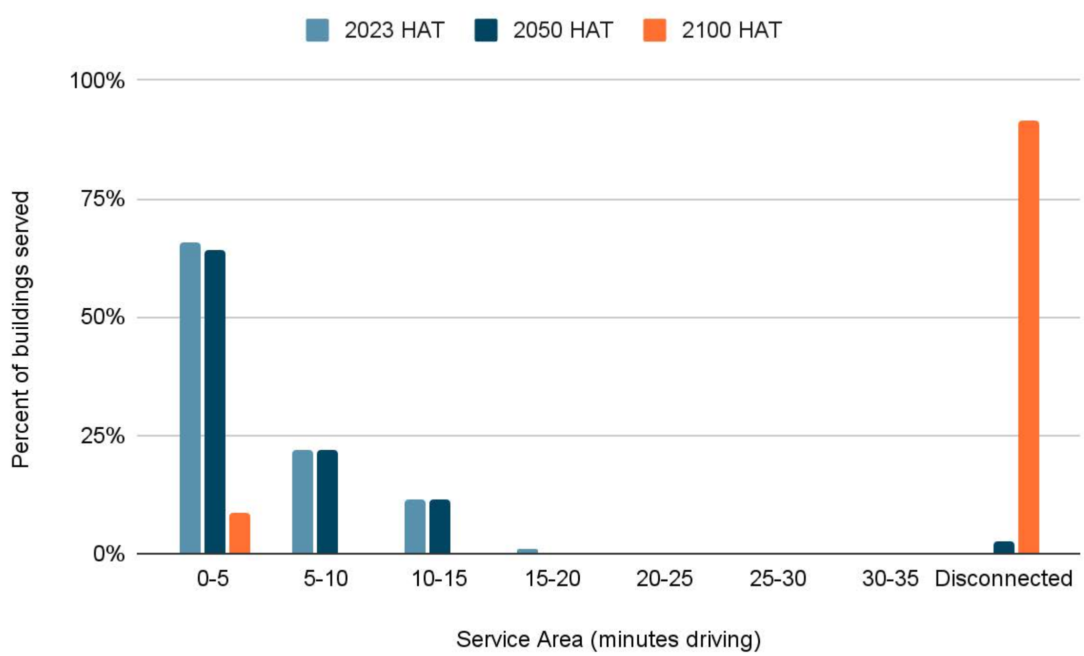


Figure 4.6: *Change in the percentage of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of the Tremont Consolidated School, or that are disconnected entirely, under present day (2023) conditions, as well as HAT projections in 2050, and 2100 under the Intermediate sea level rise scenario.*

Tremont Town Office

The Tremont Town Office is located at the intersection of Route 102, 102A, and Flat Iron Road, an area known as "The Triangle." This area not only houses the Town Office, but also hosts a range of local businesses like Hansens Outpost, automotive repair shops, and restaurants. The Town Office serves as the hub for municipal operations, offering meeting facilities and storage for vital town records. Additionally, the Town Office is home to the only public electric vehicle charging station in Tremont.

Most buildings in the Town of Tremont fall within a 0-5 minute service area of the Town Office, and there are no impacts to adjacent roads that would impact service areas to the Town Office during present-day HAT flooding. However, in the 2050 HAT projection under an Intermediate sea level rise scenario, the intersection of Crockett Point Road and Lopaus Point Road is expected to flood, causing 47 buildings to lose access to the Town Office, accounting for nearly 3% of all Tremont buildings. The projected 2100 HAT flooding impacts under that same Intermediate sea level rise scenario, causes access to the Town Office to be cut off on two sides of the triangle, specifically on Clark Bridge and Marsh Bridge. This will effectively isolate the Town Office from 75% of Tremont's population.

Service Area (minutes driving)	Number and Percentage of Buildings in Tremont		
	2023 HAT (count)	2050 HAT (count)	2100 HAT (count)
0-5	978 (61%)	952 (59%)	402 (25%)
5-10	414 (26%)	411 (26%)	0
10-15	202 (13%)	202 (13%)	0
15-20	18 (1%)	0	0
20-25	0	0	0
25-30	0	0	0
30-35	0	0	0
Not connected	0	47 (3%)	1210 (75%)

Table 4.6: *Change in the number of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of the Tremont Town Offices, or that are disconnected entirely, under present day (2023) conditions, as well as HAT projections in 2050, and 2100 under the Intermediate sea level rise scenario.*

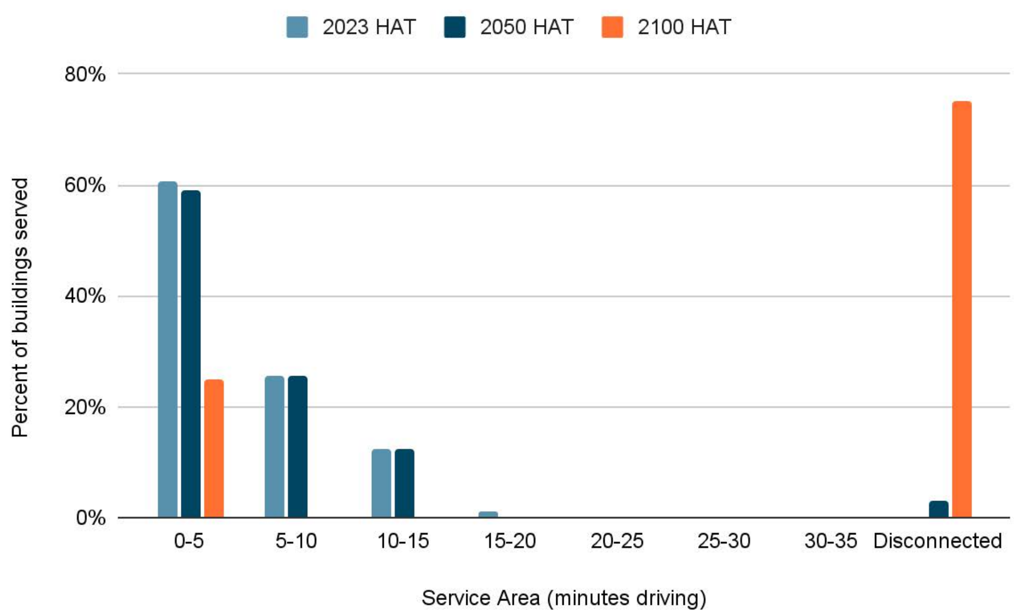


Figure 4.7: *Change in the percentage of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of the Tremont Town Offices, or that are disconnected entirely under present day (2023) conditions, as well as HAT projections in 2050, and 2100 under the Intermediate sea level rise scenario.*

Public Waterfront Access

Improved public access to the water is one of the four goals articulated in Tremont's 2023 Comprehensive Plan Update. The waterfront is a central component of Tremont's identity as a fishing community. Public access to both saltwater and freshwater resources is important for recreation as well as industry, but access points are overcrowded and have inadequate parking.[5] The villages of Bass

Harbor, Bernard, and Seal Cove serve as focal points for fishing activities and water-dependent uses, providing a mix of commercial and recreational boating amenities.

Generally, flooding under HAT conditions does not limit residents' ability to access the waterfront to the same extent that sea level rise-induced coastal flooding impacts the service areas for libraries and schools. This difference is primarily due to the dispersion of public access points between Bass Harbor and Seal Cove, where road flooding is less pronounced under the 2100 HAT projections using the Intermediate sea level rise scenario.

At present, nearly all Tremont residents can reach public waterfront access points within a 5-minute drive. However, projected 2100 HAT water levels under the Intermediate sea level rise scenario, decreases the number of residents with public waterfront access to 62%, with an additional 5% of the population completely unable to access the waterfront.

The roads leading to public waterfront areas in Seal Cove are less flood-prone than those in Bernard and Bass Harbor. While the immediate effects on waterfront access may not appear as severe as those affecting other community resources, the location of projected flooding may intensify pressure on access points in Seal Cove as the accessibility of waterfront areas in Bernard and Bass Harbor declines due to impacts on Dix Point Road and Clark Bridge. These projected flooding impacts on waterfront access may be of concern because a significant portion of the public infrastructure supporting commercial waterfront activities and the working waterfront is located in Bernard and Bass Harbor.

Service Area (minutes driving)	Number and Percentage of Buildings in Tremont		
	2023 HAT (count)	2050 HAT (count)	2100 HAT (count)
0-5	1582 (98%)	1555 (96%)	994(62%)
5-10	30 (2%)	9 (1%)	404 (25%)
10-15	0	0	129 (8%)
15-20	0	0	0
20-25	0	0	0
25-30	0	0	0
30-35	0	0	0
Not connected		48 (3%)	85 (5%)

Table 4.7: *Change in the number of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of public waterfront access points, or that are disconnected entirely, under present day (2023) conditions, as well as HAT projections in 2050, and 2100 under the Intermediate sea level rise scenario.*

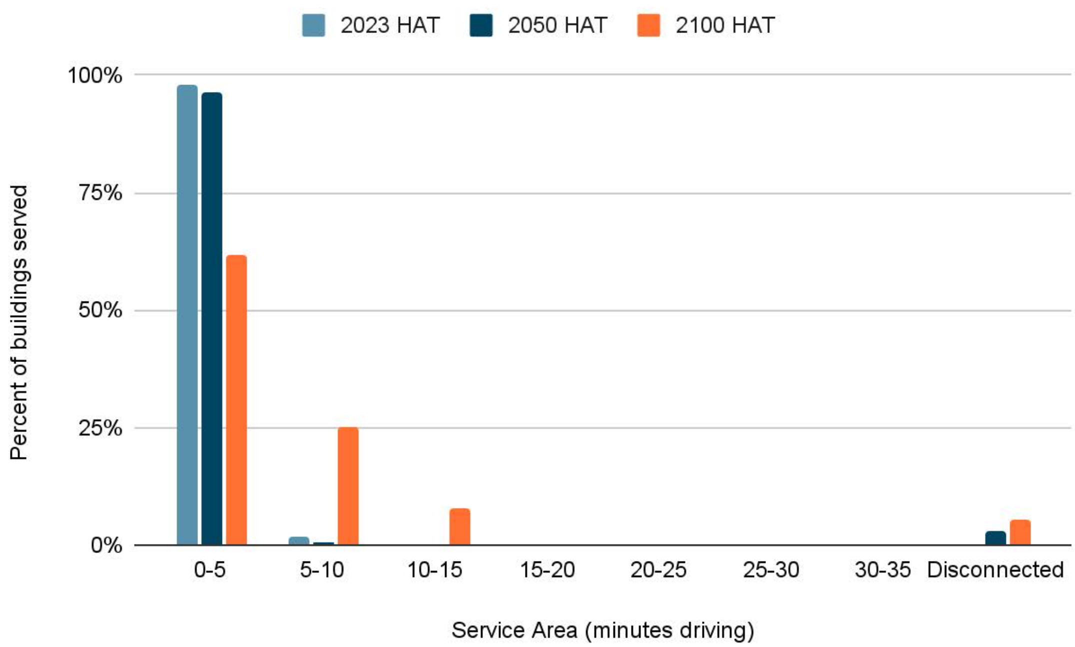


Figure 4.8: *Change in the number of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of public waterfront access points, or that are disconnected entirely, under present day (2023) conditions, as well as HAT projections in 2050 and 2100 under the Intermediate sea level rise scenario.*

4.4.2 Emergency Services

Climate resilience relies on critical components within a community, specifically fire departments and hospitals, as vital assets contributing to a community's adaptive capacity. These essential services ensure the well-being and function of a community during chronic climate-driven impacts as well as extreme weather conditions.

Healthcare

Hospitals and healthcare facilities serve as the backbone of healthcare infrastructure. Climate change can exacerbate poor health outcomes in a community. Examples include heatwaves causing more ER admissions among vulnerable elderly populations, wildfire smoke exacerbating respiratory issues among asthmatics, and longer warm seasons enabling the spread of vector-borne diseases. Hospitals are instrumental in providing medical care and support to individuals impacted by these climate-related health challenges. Understanding health service access is critical for planning for climate-related health impacts, especially for vulnerable individuals.

There are no healthcare facilities like clinics or hospitals in the Town of Tremont. Residents in the town rely on services in Bar Harbor and Southwest Harbor, emphasizing the importance of Route 102 for providing access to and from Tremont.

Currently, under 1% Annual Chance Stillwater Elevation conditions, the service areas for healthcare facilities remain unchanged compared to a scenario without flooding. There are already extant challenges surrounding healthcare access for Tremont residents,[5] yet by 2050, these challenges stand to be significantly exacerbated with conditions resulting from a 1% annual chance flood under the High sea level rise scenario. In the projected conditions for 2050, the number of buildings within a 5-minute service area of healthcare facilities drops to 26%, with 14% of buildings becoming completely isolated from healthcare facilities due to flooding on Lopaus Point Road, Crockett Point Road, Dix Point Road Bridge, and Cousins Creek Bridge. By 2100, projections for 1% Annual Chance Stillwater Elevation under the High sea level rise scenario suggest that the percentage of buildings that become completely isolated from healthcare facilities increases to 44% due to additional inundation impacts Marsh Bridge and Clark Bridge.

Service Area (minutes driving)	Number and Percentage of Buildings in Tremont		
	2023 1% Annual Chance Stillwater Elevation (count)	2050 1% Annual Chance Stillwater Elevation (count)	2100 1% Annual Chance Stillwater Elevation (count)
0-5	948 (59%)	412 (26%)	60 (4%)
5-10	586 (36%)	977 (61%)	835 (52%)
10-15	78 (5%)	0	0
15-20	0	0	0
20-25	0	0	0
25-30	0	0	0
30-35	0	0	0
Not connected	0	223 (14%)	717 (44%)

Table 4.8: *Change in the number of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of healthcare facilities, or that are disconnected entirely, under present day (2023) conditions, as well as 1% Chance Annual Stillwater Elevation projections in 2050, and 2100 under the High sea level rise scenario.*

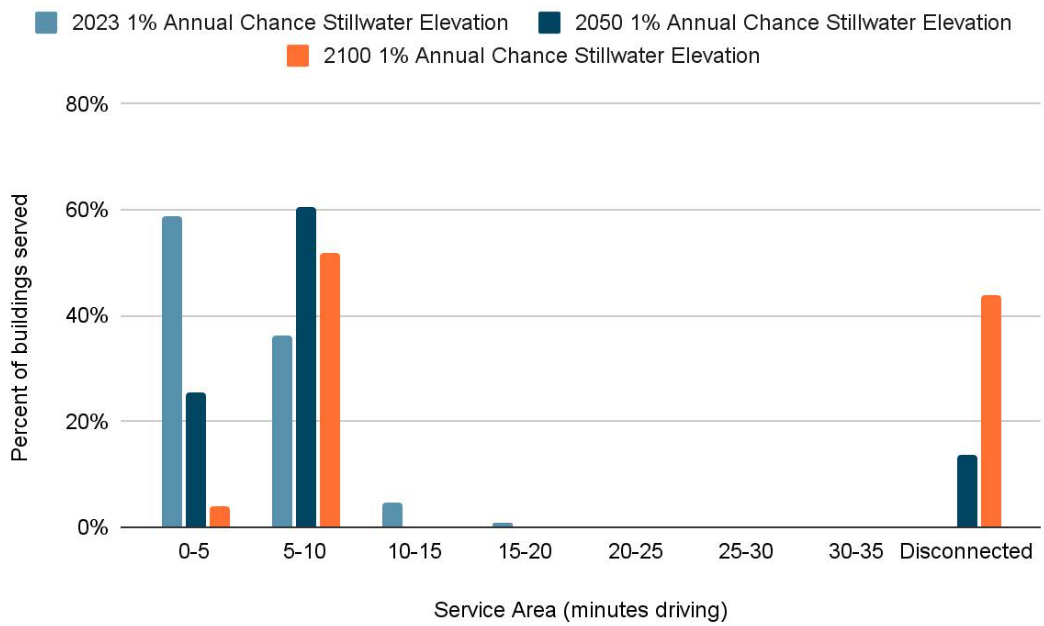


Figure 4.9: *Change in the number of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of healthcare facilities, or that are disconnected entirely under present day (2023) conditions, as well as 1% Chance Annual Stillwater Elevation projections in 2050, and 2100 under the High sea level rise scenario.*

Fire services

Fire departments are critical in responding to and managing climate-induced disasters such as wildfires, extreme weather events, as well as health-related emergencies. Tremont is the only town on Mount Desert Island that does not have a municipal fire department and fire services are often strained (see section 2.2.2). There are two fire stations in town, one at Bass Harbor and the other in Seal Cove.

Currently, most buildings fall within a 0-5 minute service area of at least one of the two volunteer fire stations in Tremont. Presently and under the Intermediate sea level rise scenario in 2050, there are no projected impacts on adjacent roads that would affect fire service areas. However, impacts from the 1% annual chance stillwater elevation flooding realized under the same Intermediate scenario in 2050 and 2100 results in access to fire services being completely severed for 6% and then 21% of buildings in town, respectively. Furthermore, while 92% of the population is within 5 minutes of a fire station during non-flooding and 1% annual chance flooding conditions today, this figure will decrease to 65% in 2050 and to below 50% by 2100 under that High sea level rise scenario. These changes have significant implications for fire response times, especially considering that fire services are already an overburdened service provider.

Service Area (minutes driving)	Number and Percentage of Buildings in Tremont		
	2023 1% Annual Chance Stillwater Elevation(count)	2050 1% Annual Chance Stillwater Elevation (count)	2100 1% Annual Chance Stillwater Elevation (count)
0-5	1481 (92%)	1062 (66%)	805 (50%)
5-10	112 (7%)	450 (28%)	450 (28%)
10-15	0	6 (>1%)	6 (>1%)
15-20	0	0	0
20-25	0	0	0
25-30	0	0	0
30-35	0	0	0
Not connected	19	94 (6%)	35 (22%)

Table 4.9: *Change in the number of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of Tremont's fire facilities, or that are disconnected entirely, under present day (2023) conditions, as well as 1% Chance Annual Stillwater Elevation projections in 2050 and 2100 under the High sea level rise scenario.*

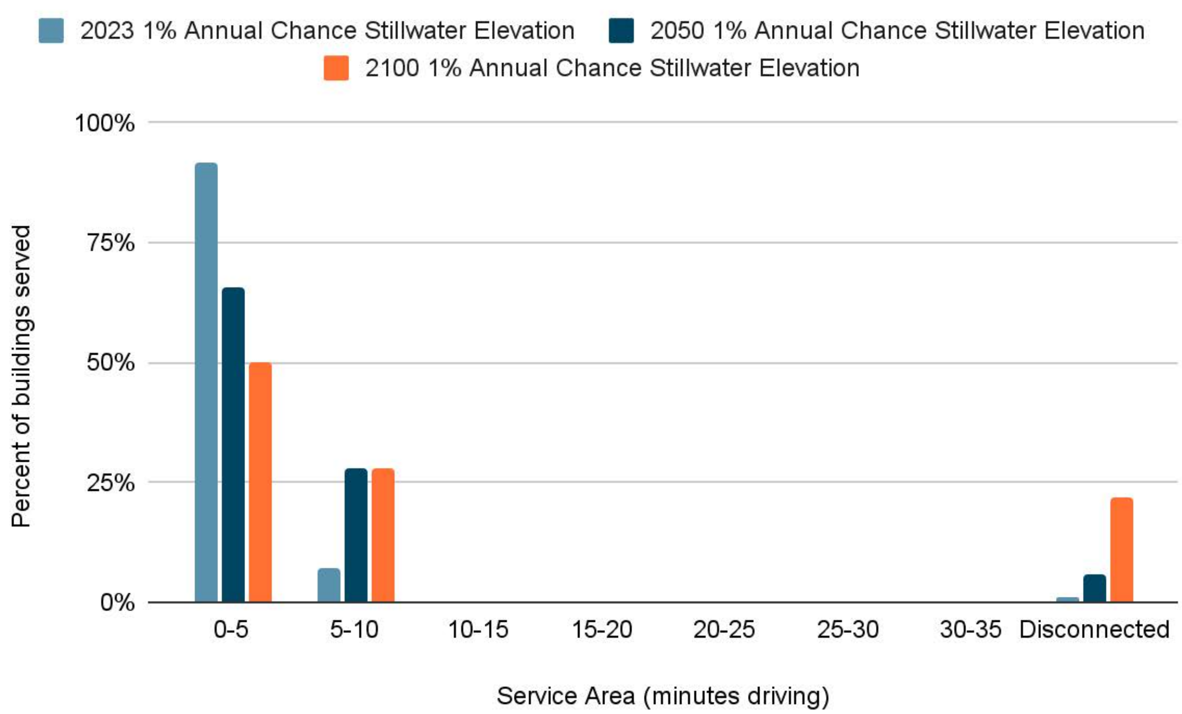


Figure 4.10: *Change in the number of buildings within 5, 10, 15, 20, 25, 30, and 35 minute service areas of Tremont's fire facilities, or that are disconnected entirely, under present day (2023) conditions, as well as 1% Chance Annual Stillwater Elevation projections in 2050 and 2100 under the High sea level rise scenario.*

4.5 Impacts to Water-Dependent Sites

Tremont's working waterfront industry necessitates having infrastructure and businesses that lie close to the sea. Table 4.10 and Figure 4.11 describe present and future coastal flooding impacts through the year 2100 to eight water-dependent public and private sites. The deck of the Town Wharf and the lowest areas of the lower parking lot are less than 1 foot below the present-day 1% SWEL. In fact, peak high water during the December 23, 2022 storm that brought southeasterly winds just barely reached the bottom of the deck's timbers. By 2070, the wharf deck and sections of the parking lot will be inundated at HAT under both the Intermediate and High sea level rise scenarios. With the exception of 1 outlet, electrical equipment on the wharf (outlets, an electrical box, and the lift switch) is high enough to avoid inundation under present-day conditions. However, all utilities except the lift switch will be beneath the 1% SWEL by 2070 under both the Intermediate and High sea level rise scenarios and should be elevated when they reach the end of their service life and need to be replaced.

The Bernard Ramp adjacent to the Town Wharf is currently only submerged during the few highest observed water levels of the year, but it will be submerged at MHHW within 50 years under both the Intermediate and High sea level rise scenarios, representing a significant disruption to water access at high tide. The public ramp at Seal Cove is higher elevation than the Bernard Ramp and is only submerged at MHHW in 2100 under the High sea level rise scenario.

Four working waterfront properties are currently at or below the 1% SWEL: F.W. Thurston Company, Archie's Lobster, Little Island Marine, and C.H. Rich Company. All except Archie's Lobster face additional risk from wave exposure. These properties will all be flooded at HAT by mid-to-late century under both sea level rise scenarios. The former Bass Harbor Boat property is at higher elevation, and likely won't be within the 1% SWEL until about 2040 under the Intermediate sea level rise scenario.

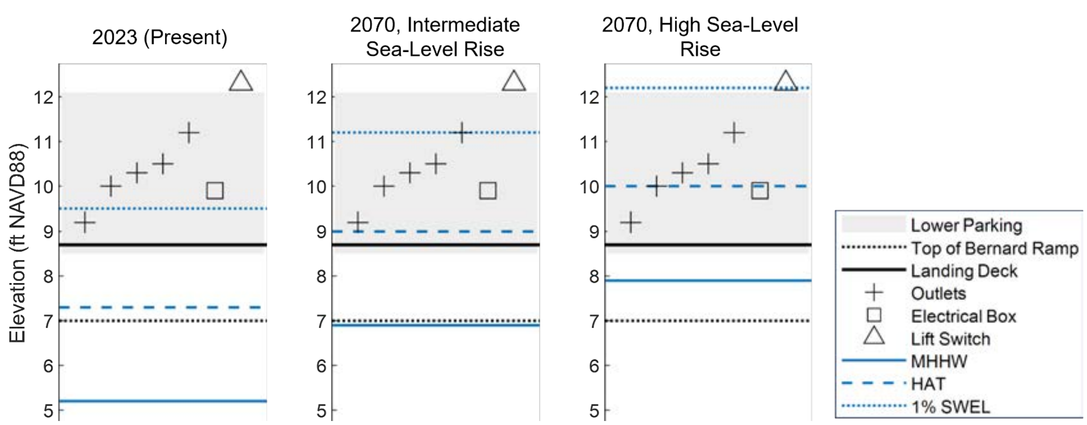


Figure 4.11: *Elevations of the wharf deck (solid black line), lower parking lot (gray area), outlets (+), electrical boxes (square), and lift switch (triangle) at the Town Wharf relative to present day and 2070 high water elevations for the Intermediate and High sea level rise scenarios.*

No. on Map	Name	Elevation, ft NAVD88	Inundation Impacts			Additional increase in water level from wave crests
			Present (2023)	Intermediate SLR through 2100	High SLR through 2100	
A	Seal Cove Boat Ramp	11.5 (top of ramp)	~40 m of ramp above MHHW	~30 m of ramp above MHHW in 2100	Entire ramp nearly submerged at MHHW by 2100	Up to 5 ft
B	Tremont Town Wharf	8.7 (decking)	see Figure 4.11			Up to 2.5 ft
C	F.W. Thurston Company	9.5 ft (decking)	At 1% SWEL	Flooded at HAT around 2080	Flooded at HAT in the 2060s and MHHW in the 2080s	Up to 2.5 ft
D	Archie's Lobster	8.8 (seaward edge of lot)	0.7 ft below 1% SWEL	Flooded at HAT in the 2060s and MHHW around 2100	Flooded at HAT in the 2050s and MHHW around 2080	Likely none
E	Little Island Marine	8.2 (lowest area of causeway)	1.3 ft below 1% SWEL	Flooded at HAT around 2050 and MHHW in the 2090s	Flooded at HAT in the 2040s and MHHW in the 2070s	Up to 2.5 ft
F	C.H. Rich Company	9.0 (decking)	0.5 ft below 1% SWEL	Flooded at HAT around 2070	Flooded at HAT in the 2050s and MHHW around 2080	Up to 2.5 ft
G	Former Bass Harbor Boat Property	10.2 (seaward edge of the lot)	None	Flooded at 1% SWEL around 2040 and HAT around 2090	Flooded at 1% SWEL around 2040, HAT in the 2070s and MHHW in the 2090s	Up to 2.5 ft

Table 4.10: *Coastal flooding impacts to water-dependent infrastructure (see Figure 4.2 for locations).*

4.6 Property Impacts

Both private and public property are threatened by coastal flooding and sea level rise in Tremont. Recurrent inundation can erode property values, with ripple effects on the municipal tax base. Using Tremont's 2023 tax assessment data, we studied the impacts of the three Highest Astronomical Tide (HAT) scenarios and their potential impacts on Tremont's municipal tax base. Appendix B shows the buildings around Bass Harbor that will flood during HAT or storm events, under current conditions as well as the Intermediate sea level rise scenarios in 2050 and 2100. While a single flood event might not always result in substantial property damage, the cumulative effect of repeated nuisance flooding can pose a significant threat to the integrity of a structure, as well as property value, over time.

We conducted a tax base analysis using ArcMap to assess the impacts of coastal flooding on property in Tremont during HAT under the Intermediate sea level rise scenario. First, property boundaries and building footprints were gathered from the Maine Geolibrary and Microsoft Building Footprints dataset and imported into ArcMap. Elevation data was used to model potential inundation areas for each scenario to create flood extents. Assessor data from the Tremont Assessor's Office was joined to tax parcels and building footprints to determine the assessed value of each parcel of land and building in Tremont. Flood extents were overlaid with building footprints with a 15-foot centroid buffer (not parcel boundaries). Where flood extents overlapped with building footprints with the centroid buffer, those both building value and land were considered "impacted".

Additionally, assessor data was coded to determine which of the properties that faced potential flooding are owned by people with primary mailing addresses in the state of Maine versus out of state. The total assessed value of properties in the present day was compared to expected future values at HAT water levels under the Intermediate sea level rise scenario in 2050 and 2100. This enabled a quantification of the potential loss in tax revenue for the Town of Tremont due to sea level rise, assuming that there no additional tax-generating developments over time.

To determine the impacts of HAT flooding on conservation land in Tremont, we used elevation data to model potential inundation areas and overlaid this information with readily available tax data and parcel data to determine the location of conserved parcels that are at risk of coastal flooding, as well as their ownership.

Impacts to the Municipal Tax Base

Most of the properties that stand to be impacted by HAT flooding under the Intermediate sea level rise scenario are located in and around Bass Harbor. According to joined tax data, there are 1441 parcels in Tremont, representing $544,876,300 in total assessed value, and $6,342,360 in tax revenue. During present-day HAT, 27 properties in Tremont are estimated to be at risk of flooding, representing $207,856 in potential tax revenue. In 2050, under HAT conditions with the Intermediate sea level rise scenario, it's projected that 33 properties are at risk of flooding, representing over $270,676 in potential tax revenue. In 2100, under HAT conditions with the Intermediate sea level rise scenario, it's projected that $533,593 of the municipal tax base is projected to be at risk.

	Present Day HAT	2050 HAT	2100 HAT
Number of Properties at risk	27	33	65
Land Value at Risk	9,744,200	13,960,900.00	150537800
Building Value at Risk	8,113,600	9,293,100.00	113225900
Total Assessed Value at Risk	17,857,800	23,254,000.00	45,841,400
Tax Revenue at Risk ($)	207,864	270,676	533,593
Tax Revenue at Risk (%)	3.3	4.2	8.4

Table 4.11: *Summary table showing the number of properties, land value, building value, total assessed value, and tax revenue (in dollar amounts) at risk at HAT water levels under the Intermediate sea level rise scenario throughout the century. This assumes no additional tax-generating development in Tremont over time.*

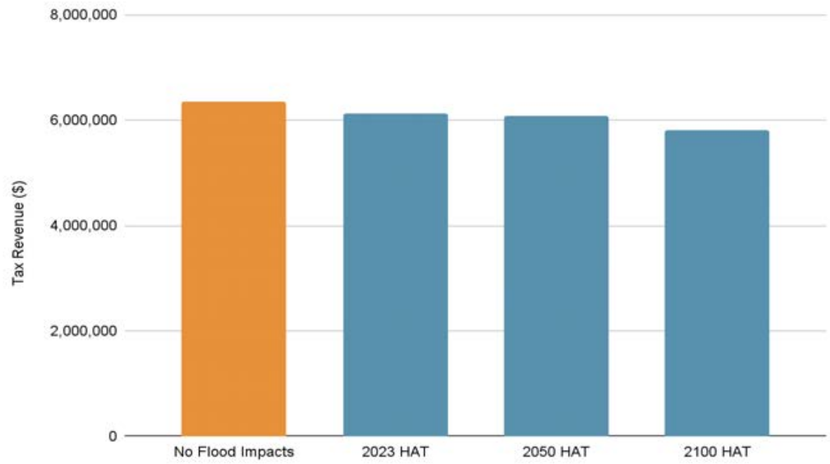


Figure 4.12: *Graph showing potential reduction in municipal tax revenue during Present day HAT, 2050 HAT, and 2100 HAT flooding conditions under the Intermediate sea level rise scenario. This assumes no additional tax-generating development in Tremont over time.*

In the present day (2023) and 2050 HAT condition under the Intermediate sea level rise scenario, these numbers translate into a 3.3% and 4.2% reduction in the tax base, respectively. However, under 2100 HAT conditions using the Intermediate sea level rise scenario, there is a predicted 8.4% reduction from the 2023 tax base. As sea levels and HAT levels increase, the mean property value affected by flooding remains fairly similar, though the average total value of buildings during present-day HAT water levels is higher also – likely due to the concentration of higher-value properties near the coast.

An analysis of flood impacts on property that considers seasonality shows that 80% of properties that are impacted by present-day HAT, as well as 2050 and 2100 HAT under the Intermediate sea level rise scenario, are not owned by out-of-state residents, even though roughly 56% of buildings in Tremont list an out-of-state owner address, suggesting that the burden of flood impacts upon buildings may be disproportionately borne by year-round residents who may have no alternative dwelling, or who own working waterfront businesses.

Impacts on Conserved Land and Open Space

In the Town's 2023 Comprehensive Plan Update, the preservation of Tremont's natural resources and conservation lands emerged as a top priority. This focus on conservation becomes a crucial asset in the broader analysis, considering its potential impact on climate resilience. Land conservation proves to be a strategic tool, offering natural barriers to combat extreme weather and storm events, fostering biodiversity, sequestering carbon, and safeguarding water quality. Furthermore, the preservation of coastal lands often plays a pivotal role in maintaining recreational and commercial waterfront access.

Tremont boasts 1688 acres of conserved land spread across 58 parcels, excluding Acadia National Park, which spans over 50,000 acres across Mount Desert Island, the Schoodic Peninsula, and additional outer islands. Acadia National Park, with its diverse ecosystems and vital marsh systems, emerges as a key asset in enhancing resilience to climate impacts.

Within the 58 conserved parcels examined in this study, 35 are situated along the coast. Two of these parcels fall under conservation easements held by Acadia National Park, and five provide waterfront access for the town. Notably, Davis Wharf, a property crucial for commercial use, had a conservation easement imposed in 2009 under the Working Waterfront Access Protection Program, held by the Department of Marine Resources.

The geographical distribution and types of conserved land in Tremont are depicted in Figure 4.13. Moving forward, it is essential to consider the implications of sea level rise on these conserved coastal areas.

Among the 58 parcels, 41, representing 152 acres, are susceptible to flooding during both present-day and projected 2050 conditions under the Intermediate sea level rise scenario.

Mitchell Marsh, owned by Maine Coast Heritage Trust, stands out as having the highest potential area to flood during the Intermediate sea level rise scenario in both 2050 and 2100. Bass Harbor Marsh, much of which lies within Acadia National Park, is another cultural and ecological asset in Tremont that is vulnerable to sea level rise (see Section 4.2 and Section 4.3.2).

Conservation Resources in Tremont

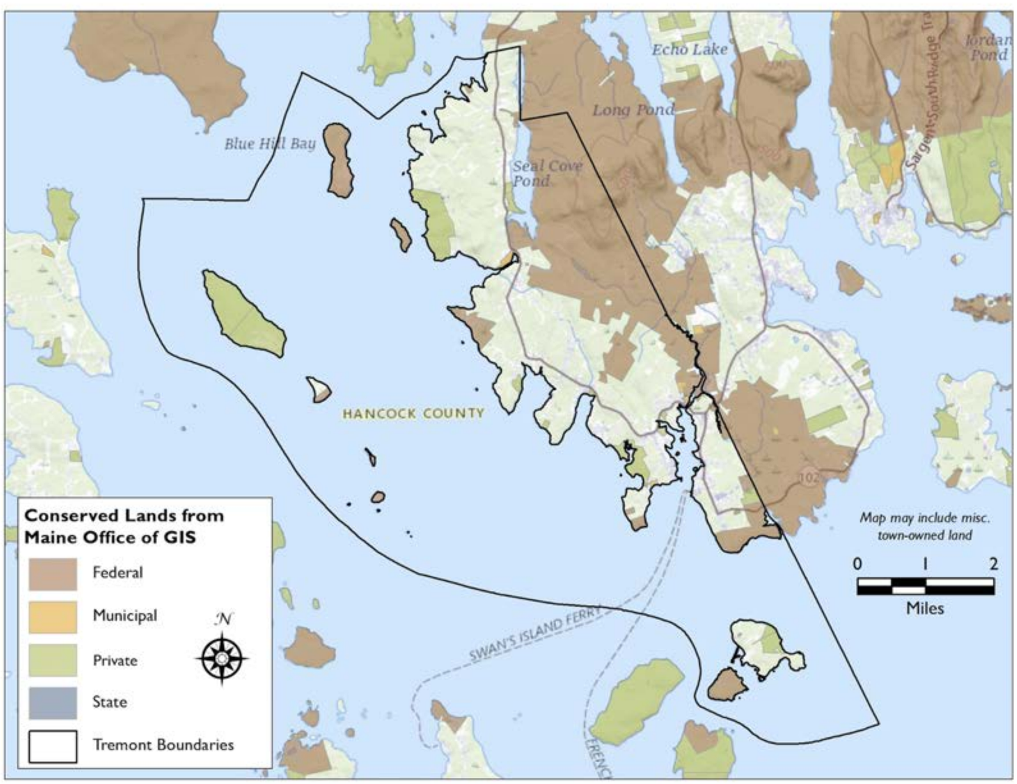


Figure 4.13: *Map showing conservation resources in Tremont. Source: Maine Coast Heritage Trust.*

5. Temperature

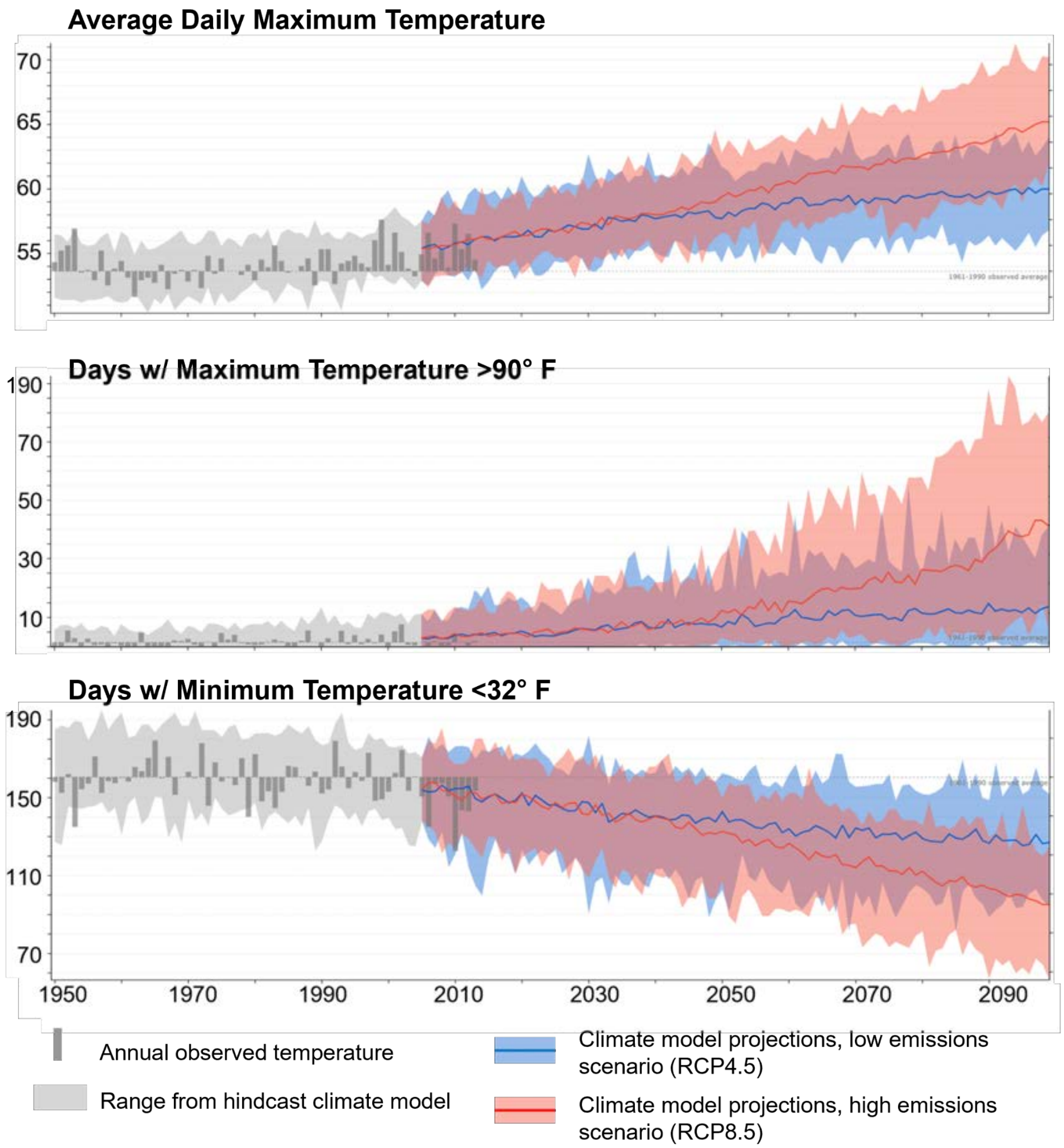


Figure 5.1: *Variation in historical temperatures (1950-2013) and projected temperature from climate models (2006-2100) for Hancock County.[35] Shaded regions show projections from a range of climate models, and lines show a weighted average of the models.*

The federal government's Climate Explorer tool allows users to investigate historical and projected temperatures for any region in the country; Figure 5.1 shows results for Tremont (at the scale of Hancock County).[35] We consider future temperatures under two scenarios: 1) a low emissions future in which humans stop annual increases in global emissions of heat-trapping gasses by 2040 and then dramatically reduce them through 2100 (this scenario is named "RCP4.5" in climate models); and 2) a high emissions future in which global emissions of heat-trapping gasses continue increasing through 2100 (RCP8.5).

From 1961 through 1990, the annual average daily maximum temperature (T_{max}) in the Tremont area was 53.6°F. By mid-century, T_{max} is projected to rise to 58.4°F (model range: 55.1°F – 61.7°F) under a lower emissions scenario, or nearly 5°F warmer than the long-term average; under the higher emissions scenario mid-century T_{max} is projected to be 59.8 °F (model range: 56.4°F – 63.4°F), or more than 6°F warmer than the long-term average. By the end of the century, T_{max} is projected to be 59.8°F (56°F – 63.5°F) under the lower emissions scenario and 64.6°F (59.9°F – 69.7°F) under the higher emissions scenario, more than 10°F hotter than the historical average.

From 1961 through 1990, the Tremont area experienced, on average, 1.5 days per year where the maximum temperature exceeded 90°F. By mid-century, the number of 90+°F days is projected to be 8.4 per year (model range: 0.3 – 26.9) under a lower emissions scenario and nearly two weeks per year (13 days, model range: 1.6 – 35) under a higher emissions scenario. At the end of the century, these occurrences of extremely hot days are projected to increase to 12.8 days per year (model range: 0.8 – 38) under the lower emissions scenario and 38.2 days per year (model range: 7.3 – 81.1)—more than a month's worth—under the higher emissions scenario.

The "Shifting U.S. Cities" analysis by Climate Central[36] illustrates how climate change could make summer feel in nearly 250 cities across the country under a higher emissions scenario (Figure 5.2). Bangor, the nearest city to Tremont in Climate Central's database, is projected to have summertime temperatures more akin to Manchester, NH by midcentury and conditions more like Trenton, NJ at the end of the century under that higher emissions scenario.

Figure 5.2: *Graphic from Climate Central's "Shifting U.S. Cities" analysis, illustrating that summertime temperatures in Bangor will feel like Manchester, NH in 2060 and Trenton, NJ in 2100 under a high emissions scenario.*

Another important metric when assessing the impact of climate change in a community is understanding the change in the number of days below freezing (32°F). While there has been significant variability in the number of days below freezing in any given year since 1950, over the past 30-40 years, a noticeable decline in the number of below-freezing days annually has begun to emerge. From 1961 through 1990, the Tremont area averaged almost 55 days per year where temperatures dropped below 32°F. By mid-century, that number is projected to decrease to 31.5 days per year (model range: 11.2 – 52.1) under a lower emissions scenario and 25.7 days per year (model range: 7.8 – 45.7) under a higher emissions scenario. By the end of the century, the number of below freezing days is projected to be under a month for both scenarios: 26 days per year (model range: 8 – 47.3) under the lower emissions scenario and 11.5 days per year (model range: 0.3 – 30.3) under the higher emissions scenario.

Heat Island Effect in Tremont

In our study of Tremont, we utilized USGS 2023 land satellite data to investigate the heat island effect. A heat island is a localized area within the town where temperatures are significantly higher than the surrounding areas, primarily due to human activities and the prevalence of impervious surfaces such as roads, buildings, and pavements (and, usually, the lack of tree cover). Understanding this phenomenon is critically important for understanding how localized environmental factors can exacerbate broader scale patterns of warming to adversely impact public health, energy consumption, and the overall quality of life in urban areas. Since there was no accurate land surface temperature data immediately available for Tremont, land surface temperatures were estimated using land cover classification and thermal band extraction using USGS 2023 LandSat Data, and then used to calculate a temperature contrast (deviation of temperatures from the average temperature for all of Tremont).

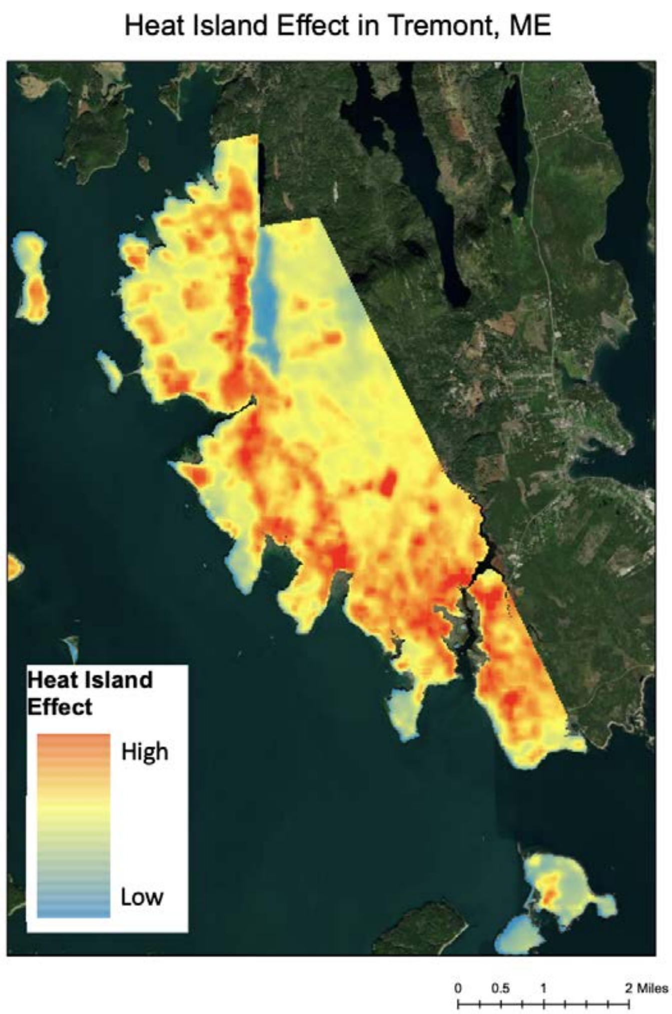


Figure 5.3: Map showing the locations of temperature variations from the mean land surface temperature in Tremont Maine.

Our analysis revealed there are temperature range of 8°F, which falls within the typical range for urban heat islands during the daytime.[37] The areas with the most substantial deviations towards higher temperatures (up to 3.5°F hotter than the mean temperature) in Tremont were closely associated with higher percentages of impervious surfaces, building footprints, and urban development, emphasizing the role of land cover in exacerbating the heat island effect. One area with a particularly pronounced heat island effect is the downtown area of Bass Harbor. Cooler areas include Seal Cove Pond and the area of Tremont occupied by Acadia National Park, which is highly vegetated, and may contribute to the overall resilience of Tremont in terms of a cooling effect. Importantly, the planned growth areas for the Town of Tremont as laid out in the 2023 Comprehensive Plan Update are in areas that are also shown to have an existing heat island effect. Increasing development in already populated areas with existing amenities and road access provides many economic opportunities for the Town of Tremont, even as additional plans could be made to try to manage heat impacts associated with development (e.g., increasing tree cover or otherwise providing shade structures).

6. Precipitation

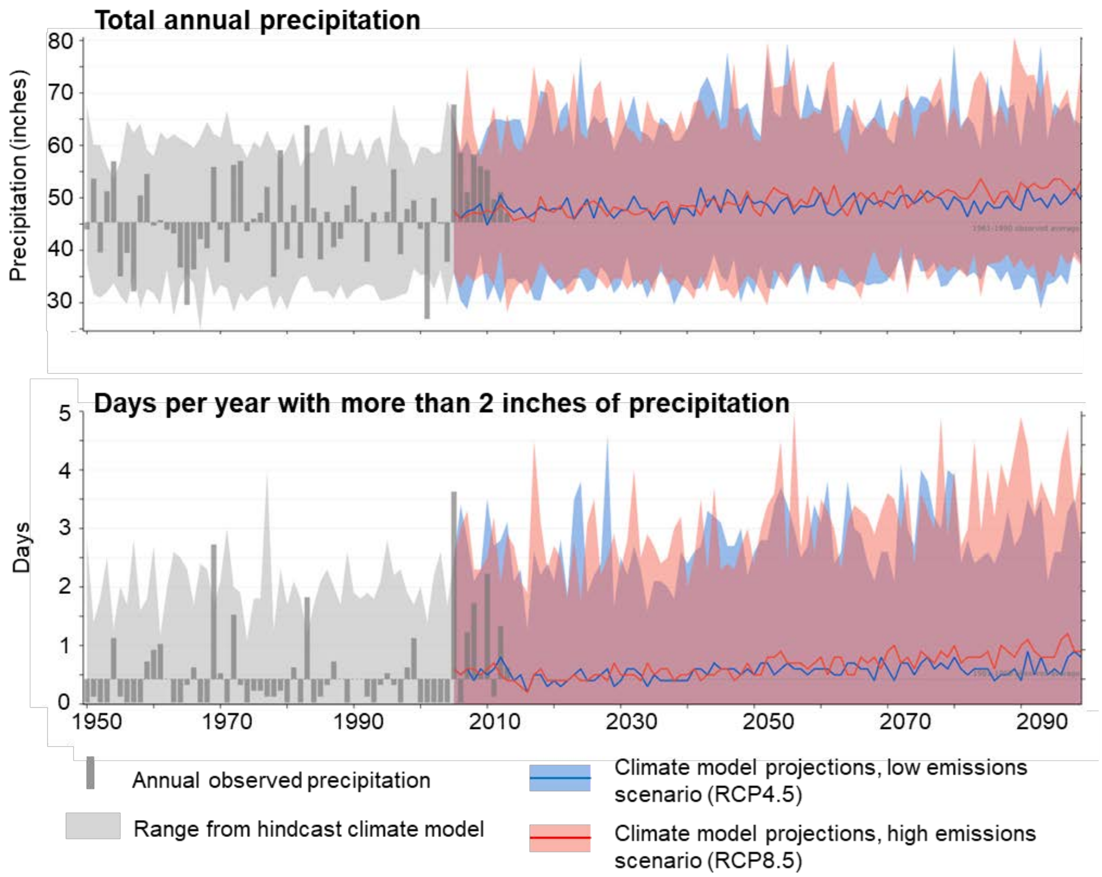


Figure 6.1: *Variation in historical precipitation (1950-2013) and projected precipitation from climate models (2006-2100) for Hancock County.[35] Shaded regions show projections from a range of climate models, and lines show a weighted average of the models.*

6.1 Total Precipitation

Generally speaking, the warmer air that we are observing as a result of climate change has the capacity to "hold" larger amounts of water vapor, which can lead to more precipitation (rain and snow). Statewide annual precipitation has increased by 6" since 1895. An unusually wet interval spanning 2005 to 2014 and observed increases in summertime and early fall rainfall all significantly influence this trend.[1] Significant uncertainty remains in projections of localized precipitation with climate models given the complexity of the meteorological processes governing precipitation. Still, projections of precipitation can be useful in providing a coarse understanding of the direction of the trends and a general sense of their magnitude. The federal government's Climate Explorer provides historical and projected precipitation for Hancock County.[35]

Maine is part of a large area in the higher mid-latitudes that is projected to see increases in winter and spring precipitation. Historically, the Tremont area has experienced approximately 45" of precipitation annually. By mid-century, that number is expected to grow modestly to ~48.5 inches per year (model range: 34.5 – 68.6) under a lower emissions scenario and to almost 50 inches per year (model range: 34.6 – 68.9) under a higher emissions scenario. By end-of-century, those numbers are expected to grow even further to ~50 inches per year under a lower emissions scenario and almost 52.5 inches per year under the higher emissions scenario—nearly 8 inches more precipitation annually than historical conditions. With the projected declines in days where temperatures are below freezing, we can conclude that more precipitation will fall in forms other than snow, such as sleet, freezing rain, or rain.

6.2 Days with Greater than 2 Inches of Precipitation

Large amounts of rain falling over a short period of time can be particularly problematic for emergency managers and municipal service providers because heavy rain can trigger flash flooding along streams and creeks, complicate wastewater treatment, and flood roadways to hospitals and schools. A common metric used in climate science to analyze frequency of "extreme precipitation" is the number of days with more than 2 inches of precipitation. Maine has experienced an increase in the average number of heavy precipitation events per year, particularly since the mid-2000s, a trend that has emerged across the Northeast, particularly in winter and spring.[1] The frequency of extreme precipitation events is projected to increase as warming continues, potentially resulting in increased flooding risks and the degradation of surface water quality as greater runoff from more intense storms carries pollutants into freshwater resources. Historically, the Tremont area has experienced only ~0.4 days per year where more than 2 inches of precipitation has fallen (meaning there's roughly 1 day every other year where that much rain falls). Projections range from no change in heavy rainfall days to an increase to ~3-4 days per year at the end of the century. The weighted model average for the high emissions scenario shows an increase to 1 day per year by 2100, which represents a more than doubling in the occurrence of extreme precipitation events by the end of the century.

7. Marine Conditions in the Gulf of Maine

7.1 Temperature

The Maine Climate Impact Dashboard[9] provides long-term records of marine temperature at five locations in the Gulf of Maine. One of those locations is near Mt. Desert Island (see inset of Figure 7.1). Historically, annual average sea surface temperatures at this location hovered around 46°F, but in the past decade, conditions have largely stayed at about 49°F.

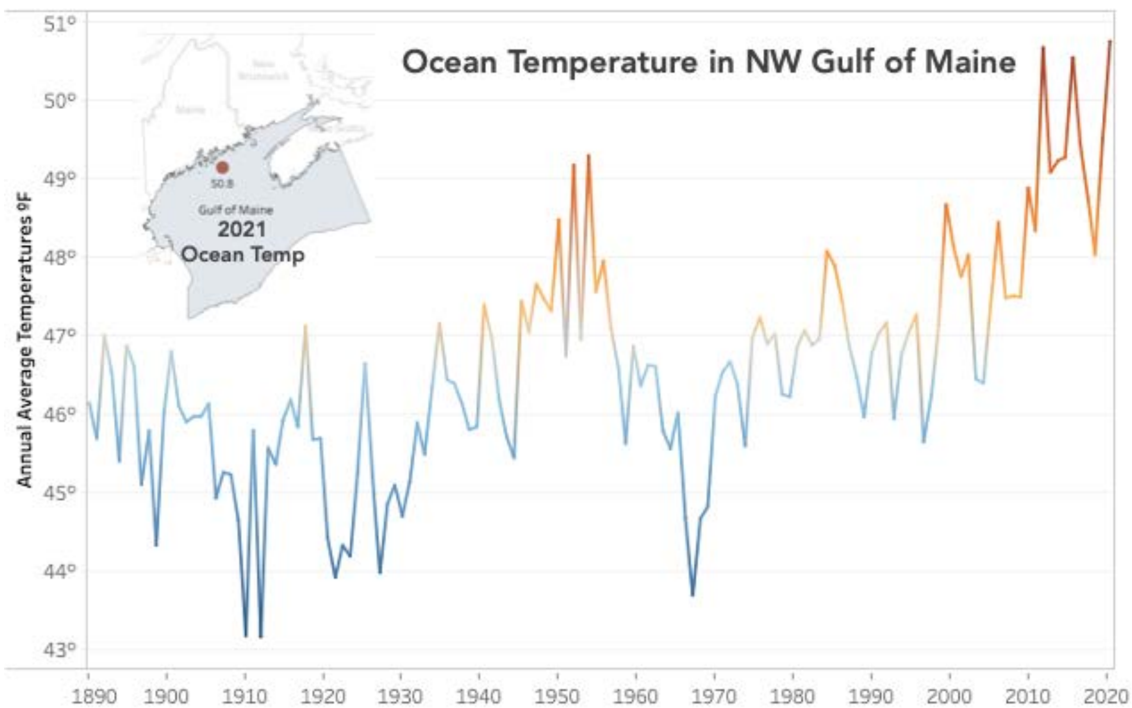


Figure 7.1: *Observed annual average sea surface temperature for a site in the north-northwest region of the Gulf of Maine, denoted by the red dot in the inset. This figure is reproduced from the Maine Climate Impact Dashboard,[9] based on data provided by NOAA.*

The Gulf of Maine Research Institute publishes seasonal and annual warming updates for the entire Gulf of Maine region (see area denoted with a dotted line in the inset of Figure 7.2) going back to the early 1980s when reliable satellite data became available.[38] Although there is significant interannual variability in temperatures, the long-term warming trend in the Gulf of Maine is nearly 3.5 times faster than the global average. As in Figure 7.2, which shows a more localized long-term temperature record, the regional temperature record also shows that 2021 was the warmest year on record for the Gulf of Maine. This sustained warming trend has consequences—many of which remain an area of active research—for individual species, as well as for broader food web and ecosystem dynamics.

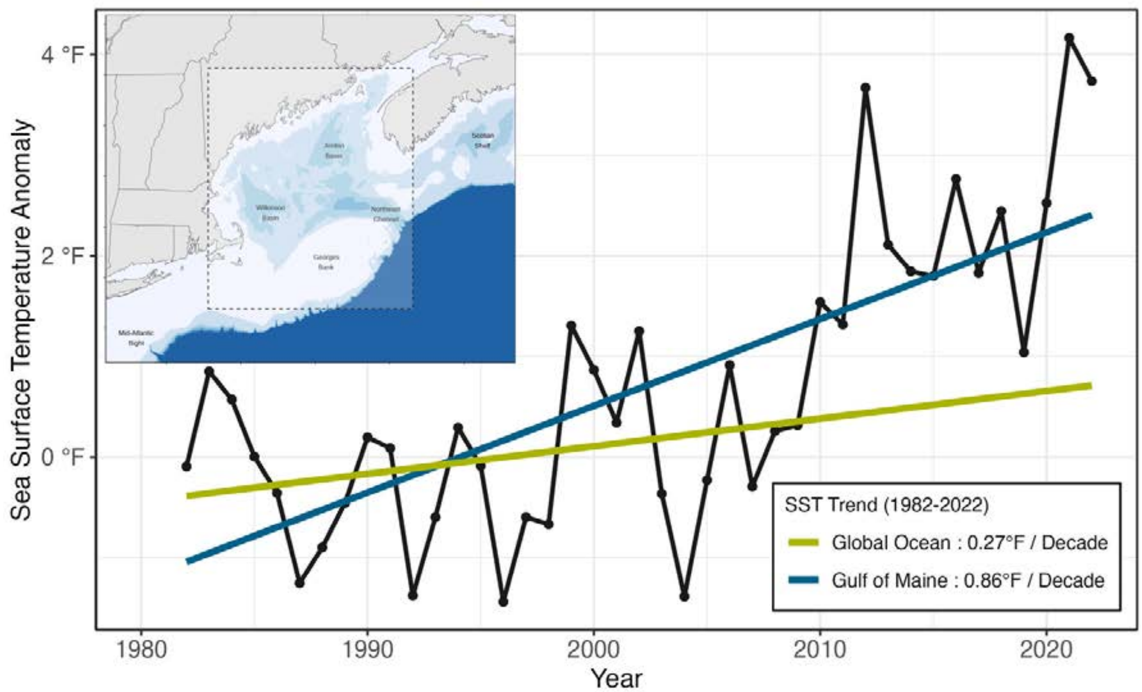


Figure 7.2: *Time series of annual average sea surface temperature (SST) anomalies (i.e., deviations from the long-term average over 1982-2011) for the Gulf of Maine (solid black line) from 1982 through 2022, illustrating that 2022 was the second warmest year on record. Long-term trendlines for the Gulf of Maine (blue) and the entire globe's ocean surface (green) show how much more quickly the Gulf of Maine is warming compared to the rest of the world's oceans. The dashed box in the inset figure denotes the region for which data was analyzed; colors denote 100 m depth intervals up to 600 m. SST data is derived from NOAA's Optimum Interpolation Sea Surface Temperature Dataset and was obtained from NOAA's National Center for Environmental Information.*[39]

The aforementioned Maine Climate Impact Dashboard also provides localized climate projections based on recent globally coordinated climate model experiments.[9] Figure 7.3 shows projections of average annual ocean temperature for the entire Gulf of Maine across three different scenarios: lower emissions (yellow), medium emissions (orange), and higher emissions (dark red). Under all scenarios, warming in the Gulf of Maine is expected to continue through mid-century. At that time, sea surface temperatures are projected to be somewhere between 52.5°F and 54.5°F depending on what emissions pathway humanity follows. Under the lower emissions scenario, sea surface temperatures plateau by mid-century and do not increase much beyond that. Under the medium scenario, end-of-century sea surface temperatures reach 55°F (~3°F above present-day levels) and under the higher scenario, they are projected to reach 61°F, with continued warming thereafter.

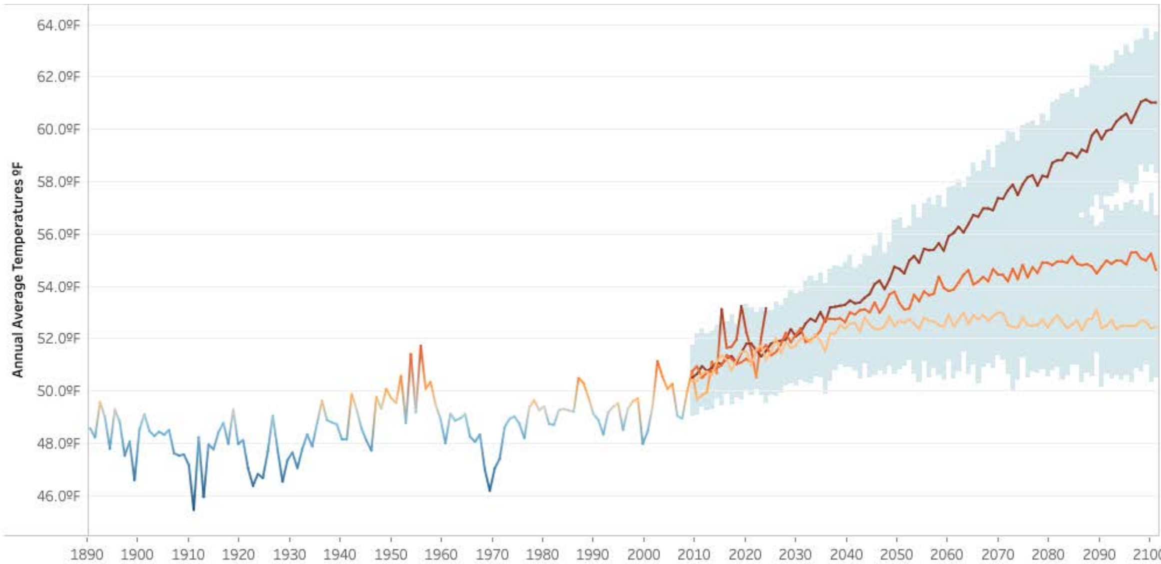


Figure 7.3: *Observed (1890-2021) and projected (2010-2100) annual average sea surface temperature for the Gulf of Maine. The figure is from the Maine Climate Impact Dashboard.[9] Observations are from NOAA, and projections are from the 5th Coupled Model Intercomparison Project (CMIP5) archive. Model projections come from three different greenhouse gas emissions scenarios: (light orange) represents a very aggressive global decarbonization consistent with limiting global average temperatures to 2°C above pre-industrial levels; (orange) and (deep red) represent RCP 4.5 and RCP8.5, respectively—scenarios which are described in the caption of Figure 5.1. Light blue shading around the individual scenario lines represents the spread in model results.*

7.2 Acidification

One of the key ecosystem services provided by the world's oceans is the role they play in serving as a "carbon sink". That is, the ocean naturally absorbs carbon dioxide (CO_2) from the atmosphere. To date, the oceans have absorbed more than a quarter of the CO_2 emissions humanity has released since the dawn of the Industrial Era.[40] The downside to this ecosystem service, however, is that this excess CO_2 in the ocean has led to an acidification of marine waters. Ocean acidification poses risks to a range of marine species, including corals and shellfish, as the more acidic waters can inhibit shell growth. Not only has the globally averaged surface ocean pH declined from 8.2 to 8.1 (a 30% decline) since the late 19th century, but the *rate* of change is at least 100 times faster than at any other time in the last 200,000 years (scientists only began regularly collected pH measurements in the Gulf of Maine a little over a decade ago, so we do not have a long-term localized dataset to analyze).[1] According to the Maine Climate Council, ocean pH is projected to decline by an additional 0.05-0.33 by the end of the century, depending on the emissions pathway humanity follows.[1] While there are generally no significant differences in ocean pH over large spatial areas, it is not clear how ocean acidity in the Gulf of Maine will deviate from these global projections. Moreover, pH levels can vary widely in coastal zones, where shellfish aquaculture can be significantly affected by changes in acidity (i.e., more acidic conditions can inhibit shell growth, particularly in early life stages when shellfish are most vulnerable). If shellfish aquaculture in the coastal zone around Tremont is deemed to be an important economic driver, it may be worth considering the deployment of low-cost sensors to monitor localized ocean water conditions in real-time.

7.3 Species Shifts

Marine temperature changes in the Gulf of Maine have already begun to alter the region's subarctic ecosystem characteristics, introducing more temperate conditions that are conducive to a variety of new species, while posing threats to others.[1] Warming waters can also lead to stratification, inhibiting the vertical mixing of nutrients, while also creating more anoxic conditions (i.e., through the process of deoxygenation), which can be detrimental to the vitality of marine species. When coupled with the still-largely-unknown effects of ocean acidification on commercially valuable species at all life stages, these shifts present both challenges and opportunities for wild harvest fishermen and fisheries managers, alike. For example, reductions in *Calanus finmarchicus*—a large zooplankton species at the heart of North Atlantic food webs—herring, and cod have been well-documented in recent years. Indeed, half of the commercial finfish and shellfish species—including cod and American lobster—in the Northeast have high or very high climate sensitivity and are expected to be negatively impacted by future warming.[1] Conversely, species such as longfin squid, silver hake, black sea bass, and even blue crab are becoming more frequently observed and could represent new commercially valuable fisheries for the region if the regulatory regime evolves in a manner that can keep pace with the changes brought about by climate change.[41]

Projecting how climate change will affect any given fishery—particularly over a specified timescale (e.g., by 2050)—is quite challenging. In addition to the uncertainty associated with the emissions scenario humanity will pursue, much remains poorly understood (and, therefore, only coarsely modeled) about how climate will affect a given species and its ecosystem interactions. It is also unknown whether there are tipping points or thresholds in the system, and at what rate species may be able to adapt to changing conditions. All that said, the preponderance of studies that have looked at population projections of American lobster suggest a likely decline in abundance in the Gulf of Maine, with the effects being sooner and more acute in southern Maine and shallower waters compared to Downeast Maine and deeper, offshore waters (where "thermal refuges" may provide improved habitability).[41]

This very brief assessment focuses primarily on how ocean temperature affects commercially valuable marine species, but changes in precipitation, especially the timing and intensity of spring runoff, also have a strong influence on salinity conditions along the coast.[1] Understanding how coastal circulation will be affected by all of these factors remains an active area of complex research. Coastal circulation influences the supply of nutrients and phytoplankton into estuaries and determines how the larvae of scallops, mussels, and lobsters spread along the coast.[1] Detailed, localized modeling would be needed to more fully characterize how coastal circulation around Tremont would change under various warming scenarios—and what consequences that might bring to the region's ecosystem, and, ultimately, to the wild harvest fishing and aquaculture farming practices of the area, as well as the vitality of working waterfront industries.

8. Tick-Borne Diseases

Generally, Maine has high rates of vector-borne diseases transmitted by deer ticks, including Lyme disease, *Anaplasmosis,* and *Babesiosis.* The Maine Center for Disease Control and Prevention and Maine Climate Impact Dashboard provide data on vector-borne diseases including tick-borne disease totals and emergency department visits for tick-borne disease for the state.[9,42]

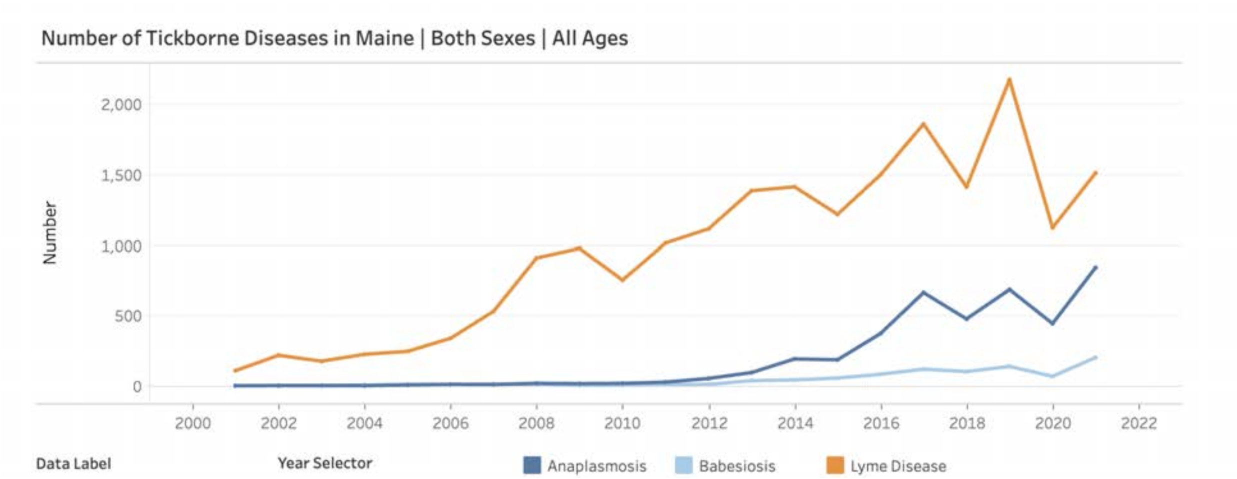


Figure 8.1: *Changes in the number of tickborne diseases recorded in Maine over the last 20 years. Source: The Maine Environmental Public Health Tracking Program.*[43]

Over the last 20 years, the rate of tickborne diseases has steadily increased in the state of Maine, with Lyme disease remaining the most prevalent among the tickborne diseases observed in the state. In 2017, Maine experienced a record number of Lyme disease cases, and between 2015 and 2017, it had the highest three-year incidence average of Lyme disease in the entire United States.[1]

The rise in tickborne diseases is closely linked to the growing population of deer ticks in the state and their expanding geographic range. This expansion is partly attributed to a warming climate, which allows deer ticks to have longer life cycles and reproduce more.[1] Given the ongoing trends of increasing relative humidity and warmer winter temperatures, the Maine Climate Council anticipates that vectorborne illnesses will continue to rise in the region, potentially becoming a chronic problem, particularly in Southern Maine. According to 2023 data, Hancock County stands out as a hotspot for tickborne diseases within the state, with a Lyme disease incidence rate of 406.6 per 100,000 people, compared to 13.4 per 100,000 people in 2001.[42] In comparison to other towns on Mount Desert Island, Tremont had a lower Lyme incidence rate from 2016 to 2023, with an incidence rate of 276.8 per 100,000 people. Southwest Harbor, the Town of Mount Desert, and Bar Harbor, on the other hand, had incidence rates of 364.6, 501.4, and 357.2, respectively.[42]

While it remains uncertain whether the rate of tickborne diseases will continue to increase, the Maine Climate Council projects that the Lone Star Tick (*Amblyomma americanum)*, a vector for ehrlichiosis, which is currently uncommon in the state, may become more abundant in Maine.[1]

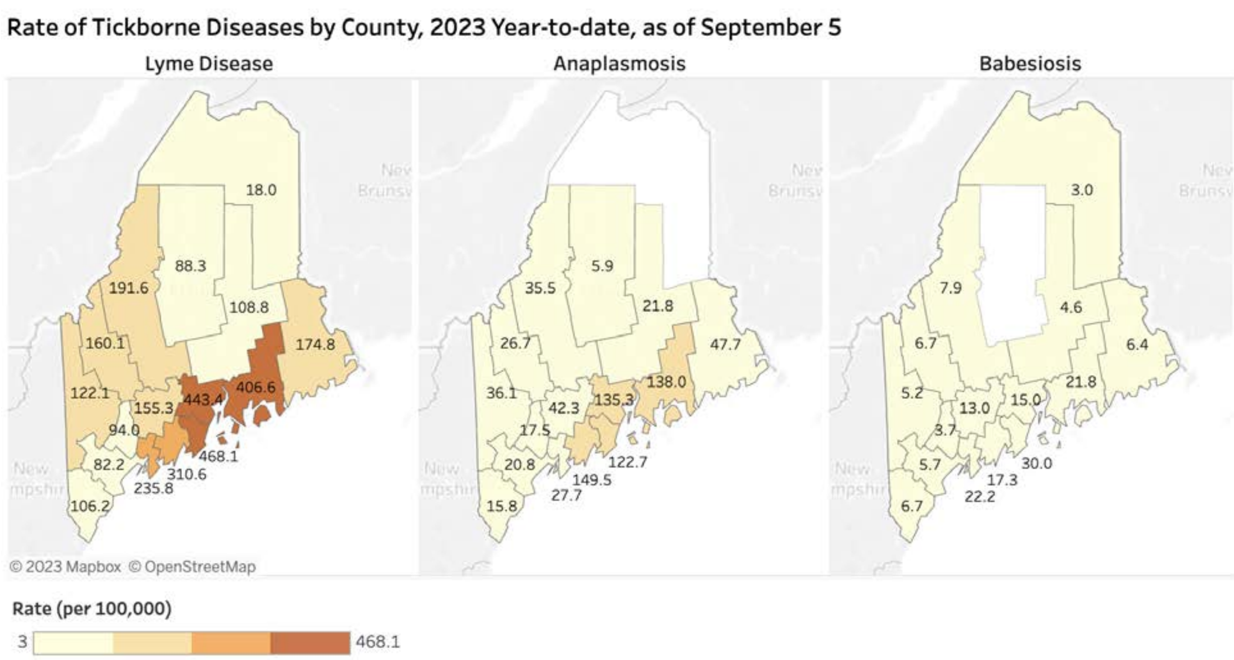


Figure 8.2: *Rate of tickborne diseases in Maine, summarized by county and disease type. Source: The Maine Environmental Public Health Tracking Program.*[43]

9. Drinking Water

Sea level rise and changes in precipitation both pose risks to Tremont's drinking water resources. Residents and businesses in Tremont acquire water from privately owned wells that provide nearly all drinking, household, and commercial freshwater resources. Private wells on Mt. Desert Island range in depth from 50 to 500+ feet and tap into underground lenses of freshwater within fractured bedrock. Near the coastline, this underground freshwater resource transitions to saline groundwater. The depth of the freshwater-saltwater boundary is determined by bedrock characteristics, the amount of freshwater present underground, the amount of freshwater extracted through wells, and local sea level. Typically, the fresh-saltwater boundary slants inland with increasing depth (Figure 9.1).

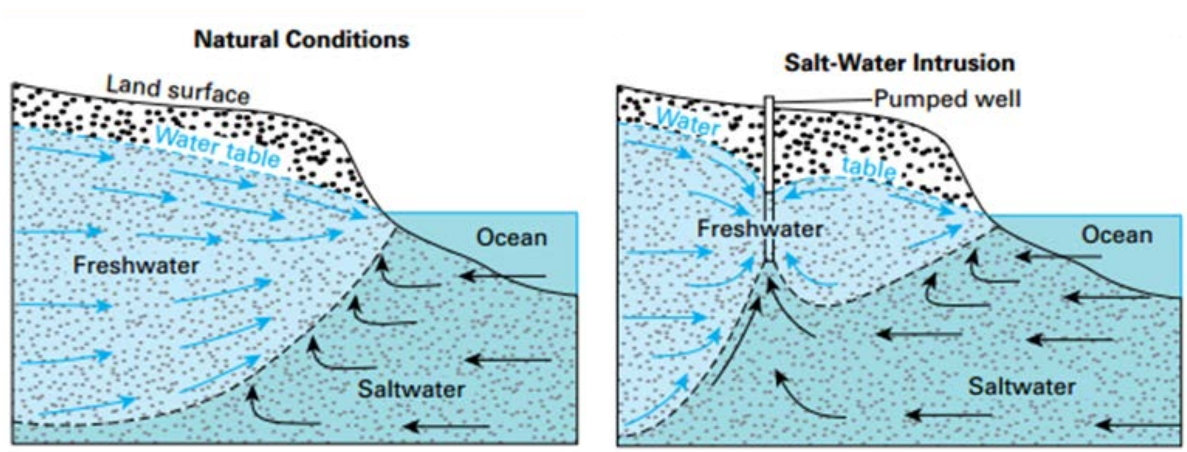


Figure 9.1: *Groundwater extraction schematic for natural conditions and saltwater intrusion conditions. Source: U.S. Geological Survey.*[44]

Saltwater intrusion is the contamination of underground or surface freshwater resources by saltwater. Salt-contaminated water is unsafe for consumption and can lead to costly plumbing damage. Well contamination is also irreversible and would create a challenge in acquiring freshwater resources at contaminated properties. Tremont's low development density, wet climate, and coastal wells that are generally intermediate in depth and set back from the coast all diminish the town's vulnerability to saltwater intrusion.[45] However, the impact of climate change on drought in Maine is uncertain,[1] and prolonged drought would increase the risk of saltwater intrusion. Rising sea levels will also slowly force the freshwater-saltwater boundary upward as the greater volume of ocean water exerts more force (Figure 9.1).[46] The shallowing boundary will eventually lead to saltwater intrusion events at the deepest coastal wells.[47-48]

It is difficult to quantify this risk without a detailed hydrogeologic study, but monitoring the deepest coastal wells is a way to receive early indications of heightened risk of saltwater intrusion. A complete database of well location and depths in Tremont is available through the Maine Geological Survey.[49]

If there is an increase in heavy rainfall days (see section 6.2), more heavy rainfall would also drive more erosion and nutrient loading into surface water that can lead to eutrophication and algal blooms. This effect can be particularly severe if heavy rain events follow dry periods. Pollutants and septic effluent accumulate on and in soil during drought, and the next rainfall flushes pollutants from the soil, leading to runoff with a larger than normal pollutant load.[A] A final precipitation-related risk is that warming driving more mixed precipitation (sleet, for example) can increase use of road salt and negatively impact water quality.[A]

10. Wildfires

The Great Fire of 1947, which burned nearly half of Mount Desert Island, persists deeply in the cultural history of the region, and altered forest stands are still visible today.[50] Wildfires play a unique role in forest ecology and are carefully monitored and managed by the Maine Forest Service and National Park Service on MDI. The Maine Forest Service maintains an observation station at the Acadia National Park Headquarters on McFarland Hill and provides the island's residents and visitors with real-time fire risk analysis and warnings.[51]

Despite the poignant local wildfire history, wildfires, especially large outbreaks, are relatively uncommon in coastal Maine, where the wet climate limits the amount of available fuel (dry kindling, sticks, logs). Spring rain showers prevent fuel from drying out, keeping fire outbreaks relatively small and manageable. An increased risk of late-season (September-November) wildfires may thus follow particularly hot and dry summers.

The risk of wildfire in Tremont will likely continue to be low over the coming decades. Two risk modeling tools, the Northeast-Midwest State Foresters Alliance[52] and First Street Foundation's Fire Factor®[53] show Tremont as having low-moderate risk of wildfire, where the risk is driven primarily by the woodland setting and periodic exposure to high winds in the fall. High wind can cause excessive drying of fuel and carries the risk of downed power lines and accidental ignition. The greatest risk of wildfires occurs in time periods of extreme drought paired with abundant fuel source presence. This risk is only manifested with an ignition source, which could be lightning, downed power lines, or, as is most common, human negligence. Ensuring proper outdoors stewardship through signage and education as well as safe disposal of flammable materials is necessary to reduce the risk of accidental ignition.[54]

The current firefighting capacity of Tremont includes a volunteer-based fire department that has cooperation agreements with the other fire services on the island, including Southwest Harbor, Somesville, Mt. Desert, and Bar Harbor.

The hazards posed by wildfires are multifold. The fire itself poses a great and obvious risk to human safety and infrastructure. Additionally, wildfire smoke contains particulate matter: microscopic particles of soot, heavy metals, volatile organic compounds (VOCs) and other carcinogens that can be dangerous to human health if inhaled.[55] This particulate-laden wildfire smoke diminishes air quality and poses heightened outdoor risk to the elderly, young children, and individuals with respiratory illnesses.[56] Smoke may originate from nearby fires where smoke is readily mixing with the local air, or distant, massive fires that create large pockets of poor-quality air that can traverse the entire country.[57] In recent years, as wildfires have raged across the American West and Canada, winds have brought the resulting smoky air to Maine skies. Air Quality Indices fell into the "Moderate" (AQI 51-100) or "Unhealthy for Sensitive Groups" (AQI 101-150) category for several days during the summer of 2023 due to Canadian wildfires,[58] leading Maine DEP to declare an 'Air Quality Alert'.[59] Weather patterns are impossible to decipher over long time scales, but a predicted climate-induced increase in wildfires in Canada and the American West may lead to more occurrences of particulate-filled air in coastal Maine in the future.[60] Another potential consequence of wildfires is the impact it has on the land cover. For example, if a fire clears out a stand of trees, the remaining barren land—particularly if a hill- or mountain-side—can be more prone to landslides, rockslides, or contribute to heightened flood risk during heavy precipitation events.

11. Vulnerable Populations & Other Drivers of Vulnerability

The following section outlines how social, economic, and demographic factors may increase Tremont residents' exposure and sensitivity to climate change hazards and their resulting consequences. Climate vulnerability is assessed by considering populations' exposure, sensitivity, and adaptive capacity in relation to climate hazards. Some populations are more exposed to climate hazards based on their locations. Some groups of people, influenced by socio-economic factors like income, age, and housing type, are more sensitive to the health, safety, and economic consequences of climate change.[2] In particular, rural areas may struggle to cope with climate hazards due to aging infrastructure and dispersed populations, leading to longer travel distances for accessing resources and care during or after extreme weather events.[61]

Not all groups of vulnerable individuals face the same level of vulnerability to a given risk or hazard. Vulnerability results from an intricate interplay of factors operating on systemic, community, and individual scales.[62] Consequently, different aspects of an individual's vulnerability may render them more susceptible to certain risks or hazards while simultaneously enhancing their resilience to others.[63] Thus, engaging with higher-risk populations to understand existing strategies for managing climate-related hazards is critical for climate resilience planning and improving a community's overall adaptive capacity.

In developing this analysis, demographic and social characteristics for Tremont were obtained from the American Community Survey 2021 (ACS, 2021, 5-year estimates) dataset,[26] as well as from the Town of Tremont's 2023 Comprehensive Plan Update.[5] For each social vulnerability factor analyzed, additional climate risks are noted. This data was further aggregated in a "summary of findings" to estimate the population that faces heightened sensitivity to particular climate hazards.

11.1 Children under the age of 5

Climate change hazards pose more immediate risks to children due to their developing physiology, distinctive exposure pathways (such as extended time outdoors), and limited capacity to adjust to shifting environmental conditions. For example, young children's limited ability to regulate their temperature reduces their capacity to adapt to hazards such as extreme heat.[64] Additionally, young children's higher consumption of air, food, and water relative to their body mass heightens their exposure to environmental pollutants compared to older children or adults.[65] Lastly, children below the age of 5 rely on adults for their safety and well-being, magnifying their vulnerability during weather-related disasters.

Climate Hazards:

- Extreme Temperature
- Vector Borne Disease
- Drinking Water Quality
- Wildfire Smoke

Observations for Tremont:
The estimated total population of children under the age of 5 in Tremont is 68. This demographic constitutes 4.4% of Tremont's entire population and closely aligns with the proportion of the population on Mount Desert Island that falls under the age of 5 (4.5%). Within Tremont, children under 5 years old comprise 5.62% of the estimated total portion of the vulnerable population. Specific assets within the community of Tremont that may be important to the 5-and-under population include Bass Harbor Memorial Library as well as Tremont Consolidated School. Finally, there are no Pre-K childcare services offered within the Town of Tremont, with the nearest preschool childcare option located in Southwest Harbor via Route 102 (see Section 4 for a description of flood risk to Route 102).

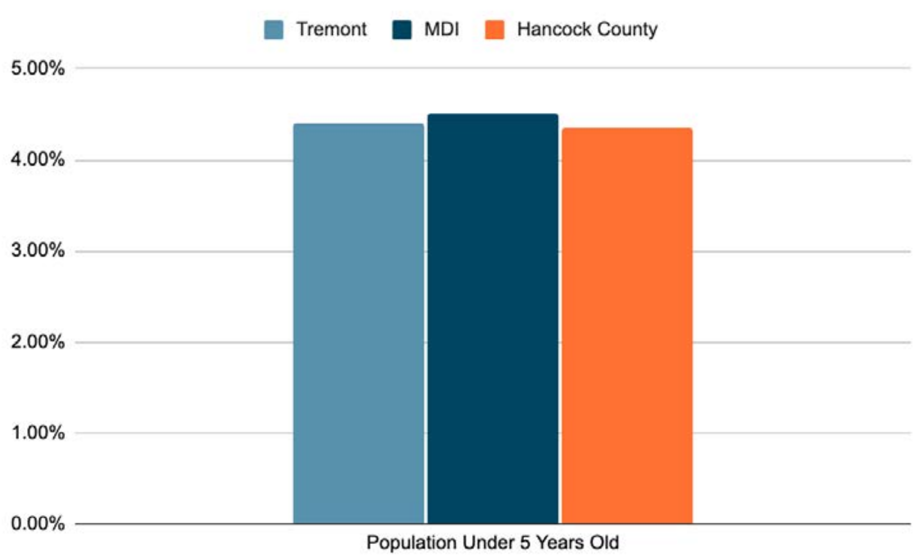


Figure 11.1: *Graph showing the percentage of children under the age of 5 in Tremont, compared to all Mount Desert Island Communities and Hancock County. Source: American Community Survey 2017-2021 5-year Estimates. (2022)*[26]

11.2 Elders aged 65 and over

Climate extremes are associated with health impacts that disproportionately affect older adults.[66] This diverse demographic comprises distinct sub-populations, resulting in variable vulnerabilities depending on factors such as race, income, physical health, disability status, and the presence of social support networks. Furthermore, elderly individuals are more likely to have pre-existing health conditions that can worsen due to climate-related events, such as extreme heat. They may also rely more on medical equipment and require frequent access to medical care, which can be disrupted by extreme weather, leading to power outages or interrupted access to medical facilities or caregivers due to impacts such as flooded roadways. Lastly, some elderly adults might experience social isolation, which can limit their capacity to seek prompt assistance during severe weather events.[66]

Climate Hazards:

- Extreme Temperatures
- Coastal Flooding
- Wildfire Smoke
- Drinking Water Quality

Observations for Tremont:

The estimated total population of adults aged over 65 in Tremont is 360. This demographic comprises 23.2% of Tremont's entire population, slightly lower than the proportion of the population on Mount Desert Island aged over 65 (25.0%). Adults over 65 in Tremont constitute 29.8% of the total estimated vulnerable population. Currently, Tremont has not established options for home-based elderly care. Consequently, elderly residents might be isolated from in-home support systems and reliant on emergency services, such as ambulances and EMT services, during times of distress or disaster. Given that elderly residents constitute a significant portion of the population, emergency services could become overwhelmed during severe weather events, such as heatwaves or extreme flooding. Additionally, the social services provided for elderly residents (e.g., the Mount Desert Island and Ellsworth Housing Authority, and Island Connections) are located outside of Tremont in Bar Harbor and Ellsworth. This situation makes individuals utilizing these services reliant on easy access both within and off Mount Desert Island (refer to Section 4).

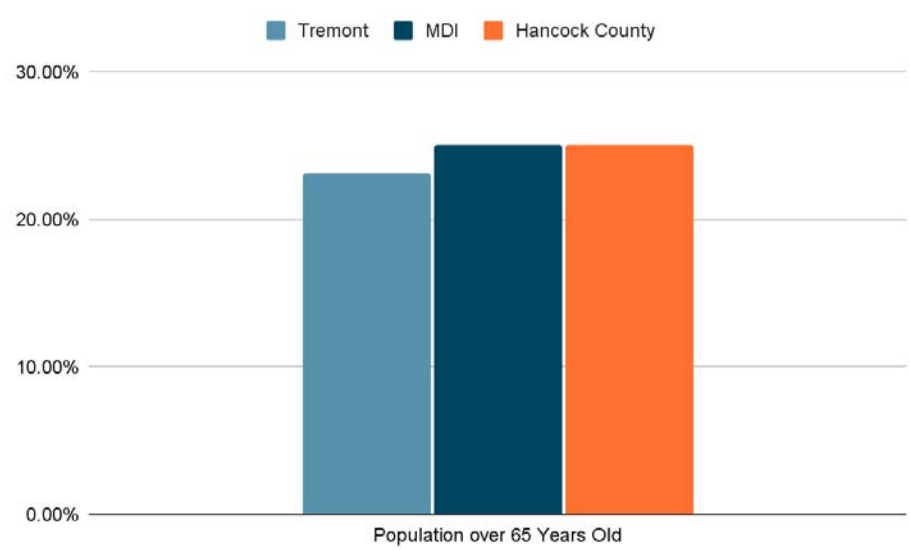


Figure 11.2: *Graph showing the percentage of population age 65 and older in Tremont, compared to all Mount Desert Island Communities and Hancock County. Source: American Community Survey 2017-2021 5-year Estimates. (2022)*[26]

11.3 People with Disabilities

People with disabilities frequently experience elevated rates of social risk factors that can contribute to poor health outcomes in the aftermath of extreme weather events and climate-related emergencies.[67] Limited mobility, inaccessible infrastructure, and non-inclusive disaster preparedness strategies can impede their access to evacuation routes and shelter choices during such occurrences. Furthermore, individuals with disabilities frequently experience higher poverty rates, constraining their capacity to adapt to and recover from climate hazards. Communication and information dissemination methods that lack inclusivity can also restrict their ability to access crucial and timely information during emergencies.[68]

Climate Hazards:

- Extreme Temperature
- Coastal Flooding
- Wildfire (and Wildfire Smoke)
- Drinking Water Quality

Observations for Tremont:

In Hancock County, approximately 14.6% of the population experiences a disability, and individuals with disabilities report a scarcity of provider training and care within their communities.[69] In Tremont, the population living with disabilities is 23%, constituting 36.4% of the total at-risk population. Similar to resources for those aged 65 and over, resources for Tremont residents with disabilities are located either in Bar Harbor or off Mount Desert Island in Ellsworth. This underscores the importance of accessible transportation options for this at-risk population during emergencies. During extreme flood events, the availability of care might be compromised due to flood impacts on major roads leading both into and out of Tremont, as well as off MDI (refer to Section 4).

11.4 Low-Income Populations

Low-income populations and households grappling with economic challenges frequently exhibit heightened adaptive capacity due to navigating daily life with added resource limitations.[70] However, this adaptive capacity can become overwhelmed during severe weather events or instances of climate change-induced illnesses. For economically vulnerable populations, weather-related disasters can impose enduring economic strains, including escalated costs stemming from storm damages. The financial burdens of preparing for extreme weather or climate-related disasters can be substantial, such as retrofitting housing for cold conditions or procuring flood insurance.[71] Economic stress often compounds preexisting vulnerabilities linked to housing, health, age, disability, and work disruptions. This makes individuals and households confronting economic strain particularly sensitive to hazards related to extreme weather, temperatures, intense precipitation, floods, and wildfires.

Climate Hazards:

- Extreme temperatures
- Coastal Flooding
- Wildfire Smoke
- Drinking Water Quality
- Extreme precipitation

Observations for Tremont:

Levels of economic stress at the household level were determined using ACS 2021 poverty and income indicators, which ascertain poverty status through a ratio of income to the official poverty threshold established by the U.S. government in 2020. The estimated total population of households with an income-to-poverty ratio under 2.00, categorized as "poor or struggling," constitutes 13.3% of Tremont's entire population. In comparison to Hancock County, fewer households in Tremont are grappling with economic challenges, although the proportion of Tremont households facing financial difficulties surpasses that of MDI as a whole. Within Tremont, households categorized as poor or struggling account for 16.9% of the total vulnerable population. Climate change hazards stand to heighten economic uncertainty and inequality. Critically, the expected economic consequences will be distributed unevenly, with the most economically disadvantaged 10% facing the likelihood of experiencing 5 to 10 times more negative economic repercussions compared to the wealthiest 10% within the community.[72]

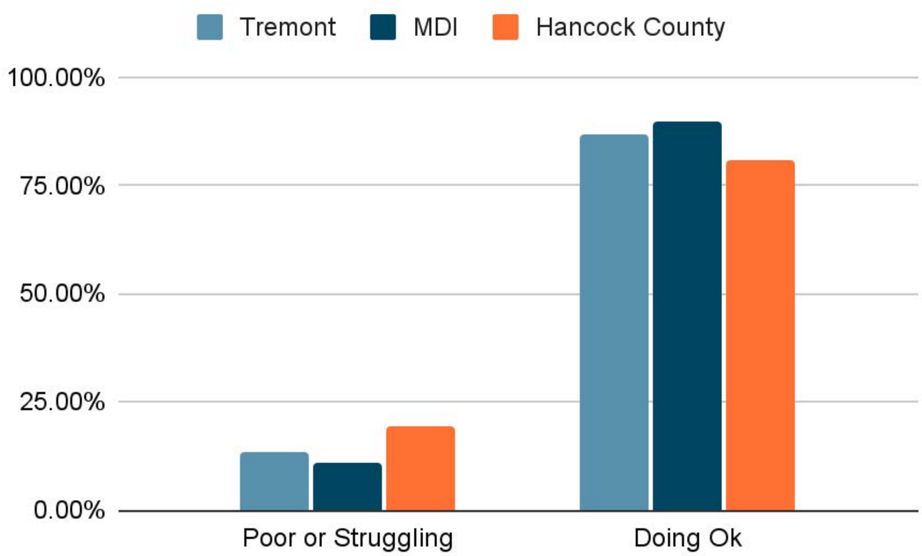


Figure 11.3: *Graph showing the economic hardship faced by Tremont residents compared to all Mount Desert Island Communities and Hancock County based on an income-poverty ratio. Source: American Community Survey 2017-2021 5-year Estimates. (2022)*[26]

11.5 Natural Resource-based Workforce

Climate change has the potential to introduce new work-related risks, increase susceptibility to occupational hazards, and influence the long-term viability of vocations within the natural resources industry.[73] Outdoor workers, particularly in the agricultural and fisheries sectors, are projected to face health impacts from temperature extremes, poor air quality, extreme weather, and vector-borne diseases. Changes in precipitation patterns, temperatures, wildfire risk, and occurrences of extreme weather events have the potential to disrupt the availability and operations of natural resources.[74] Moreover, while not necessarily natural-resource-based employment, outdoor workers, generally (e.g., construction, public works) face an increased risk of heat stress from projected increases in extreme temperatures. Additionally, rural communities' identity is often intertwined with the natural resources economy that the workforce participates in. As a result, climate stressors can also introduce challenges within a community that are tied not only to physical and economic well-being but also to emotional well-being and sense of place.[73]

Climate Hazards:

- Extreme Temperature
- Vector Borne Disease
- Coastal Flooding
- Wildfire (including Wildfire Smoke)
- Extreme Precipitation
- Ocean Warming
- Species Shifts

Observations for Tremont:

The natural resources sector employs a higher percentage of the population in Tremont compared to Hancock County (9% vs. 5%). Specifically, Tremont's economy relies heavily on marine-based activities, evident in recent marine licensing data that shows an increase in the issuance of marine licenses from 2019 to 2022. By 2022, 203 commercial fishing licenses had been granted, primarily for lobstering. The population engaged in the natural resources sector constitutes 6.9% of the vulnerable population in Tremont. Climate change impacts on the fishing industry (see Section 7) and coastal flooding hazards that impact crucial working waterfront infrastructure (see Section 4.4) mean that the marine resource sector in Tremont stands to be highly affected by climate change, with additional implications for the overall economic resilience of Tremont.

11.6 Housing Quality

Housing quality contributes significantly to climate vulnerability due to its role in shaping the extent to which individuals can manage climate impacts at home. Inadequate housing conditions can heighten residents' exposure to risks during extreme temperature and rainfall events.[75] Housing that lacks proper ventilation and insulation can become excessively hot during extreme heat, and homes that are poorly constructed or situated in floodplains are more susceptible to water damage (and subsequent mold issues) during precipitation and flooding events.[76] After major climate incidents, people living in low-quality housing face an elevated risk of displacement.[77] Moreover, substandard housing quality can exacerbate existing vulnerabilities tied to income, as low-income residents may need to allocate a higher percentage of their income to repairs or flood insurance. Home heating type can also increase climate vulnerabilities with inefficient or outdated heating systems resulting in higher energy bills that increase the financial burdens placed on households and making it more challenging to adapt to extreme weather events or invest in climate resilience measures.

Furthermore, the choice of home heating system can influence a household's vulnerability during power outages. Electric heating systems, for example, may leave households more exposed to power disruptions, while fossil fuel-based systems can be susceptible to supply chain disruptions and price volatility. Lastly, the type of heating system can have a significant impact on indoor air quality. Systems like wood-burning stoves and fireplaces release fine particulate matter (PM2.5), which can contribute to respiratory problems. Additionally, kerosene and oil-fired heating systems can produce carbon monoxide and sulfur dioxide, leading to a decrease in indoor air quality

Climate Hazards:

- Extreme Temperature
- Coastal Flooding
- Wildfire (including Wildfire Smoke)
- Extreme Precipitation

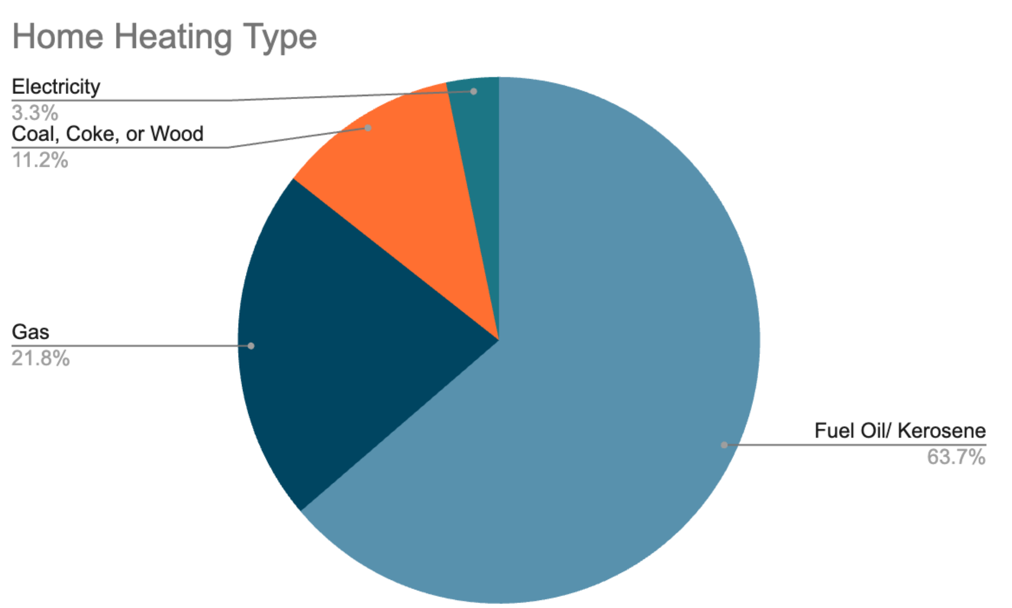


Figure 11.4: *Graph showing percentage breakdown of home heating type in Tremont, Maine. Source: American Community Survey 2017-2021 (five-year estimates) 2022. Source: American Community Survey 2017-2021 5-year Estimates. (2022)[26]*

Observations in Tremont:
Approximately 3.8% of housing units in Tremont consist of mobile homes, which may lack the insulation and ventilation needed to withstand extreme temperatures. Generally, housing quality is not a significant concern in Tremont, with only 0.4% of housing units considered 'substandard,' as reported by the US Census Bureau. The median year of construction for houses in Tremont is 1976, slightly later than the Maine state average of 1975. This suggests that many homes in Tremont may have inefficient heating or ventilation systems, making it more challenging and costly for residents to maintain comfortable temperatures during extreme weather conditions.

Regarding home heating fuel sources, 21.4% of homes use gas, 3.2% rely on electricity, 62.6% use fuel oil or kerosene, 11% employ coal, coke, or wood for heating, and 0.4% of homes report having no home heating source. For the 62% of households that depend on fuel oil or kerosene, coastal flooding that hinders road access for heating oil transportation could have significant health and safety impacts during the winter months, or when coastal flooding events coincide with cold temperature extremes. Electric heating, while representing only a small portion of the heating sources, may also face challenges during power outages.

Furthermore, households using non-electric heating sources may experience reduced indoor air quality, impacting not only residents' comfort but also increasing their risk of respiratory issues, especially when heating systems are not properly maintained.

11.7 Vehicle Access

Given the limited availability of public transportation and the constrained capacity of emergency services, having restricted access to personal vehicles can be critical during emergencies requiring evacuation. In such scenarios, the absence of transportation options creates additional challenges for residents, hindering their mobility. This limitation could impede residents' ability to reach essential resources such as cooling stations during intense heatwaves or access hospitals and clinics. It's important to note that individuals experiencing limited vehicle access are often part of economically burdened or elderly demographics—both of which are vulnerable groups in which increased mobility challenges and health constraints can exacerbate the impacts of climate-related vulnerabilities. Conversely, high reliance upon personal vehicles can also contribute to climate vulnerability, as a result of heavy reliance upon roadways that are subject to hazards such as coastal flooding.

Climate Hazards:

- Extreme Temperature
- Coastal Flooding

Observations for Tremont:
Only 3% of households, or approximately 54 residents in Tremont, do not have access to a vehicle, representing 4.5% of the total vulnerable population. While this number is relatively low, the reliance of

a significant number of Tremont residents on personal vehicle access heightens their vulnerability to hazards that can affect roadways.

A majority of Tremont's residents depend on vehicle access not only in emergencies and evacuations but also for everyday activities such as commuting to work and buying groceries. This heavy reliance on personal vehicles has several implications for climate vulnerability. Climate change hazards, particularly coastal flooding, can disrupt roadways, making them impassable. In such situations, residents who rely on vehicles may find their transportation options severely limited, hindering their ability to access essential services, evacuate when necessary, or conduct routine activities (see Sections 4.2 & 4.3).

11.8 Seasonal Residents

For this analysis, we utilized tax assessor data to identify properties with primary mailing addresses located outside of the state, which served as a proxy for determining seasonal occupancy. This data was then integrated with existing parcel data for the Town of Tremont to determine the number of parcels owned by individuals residing outside the state and their respective locations. It's important to note that this method does not account for seasonal residents who may maintain a primary residence within the state of Maine.

Tremont boasts a total of 1,811 housing units, with the majority being owner-occupied, comprising 80% of the residences, while the remaining 20% are rented. The overall full-time occupancy rate stands at 47.1%, leaving approximately 53.0% of homes that appear to serve as seasonal residences. A map illustrating the locations of seasonal and year-round properties can be found in Appendix D.

The presence of seasonal residents in Tremont introduces specific challenges and opportunities related to climate vulnerability. Seasonal residents may be particularly susceptible to certain hazards due to their limited familiarity with local emergency protocols and disaster preparedness measures, especially during climate-related emergencies like extreme storms, wildfires, or flooding. The influx of residents during the peak summer months can strain already under-resourced services due to increased demand as the population fluctuates throughout the year. Simultaneously, the seasonal distribution of Tremont's residents throughout the town provides opportunities to consolidate resources on a seasonal basis, enabling better targeting and servicing of the year-round community during the winter months. For instance, the coastal flood hazard is greatest during the winter storm season, while the wildfire hazard is most significant during the early fall months.

Furthermore, seasonal residents' awareness of long-term climate change hazards and their active participation in the implementation of adaptation strategies can significantly strengthen local efforts to promote climate resilience within the community as a whole. This collective knowledge-building process can serve as a bridge between seasonal and year-round residents, fostering a sense of shared responsibility for climate-related challenges in Tremont.

By encouraging the exchange of insights, experiences, and expertise among residents, the Tremont community can collectively develop an elevated awareness of climate vulnerabilities and the most effective ways to address them. This knowledge-sharing not only eases the demands on emergency services during the summer months but also enhances the community's capacity to prepare for and respond to climate-related emergencies. Additionally, the process of knowledge exchange and relationship building fosters social bonding between seasonal and year-round residents, enhancing their sense of belonging within the community and providing the foundation for cooperative, community-based initiatives aimed at reducing vulnerabilities and enhancing resilience. This empowerment enables residents to collaborate on disaster preparedness, local climate adaptation, and other community projects, ultimately fostering a more resilient and tightly-knit community better equipped to face the challenges posed by climate change.

11.9 Summary of Findings

In total, there are an estimated 1,209 individuals in Tremont who could be considered as having a heightened risk of being adversely affected by climate change impacts. As noted in Section 11.8, social vulnerability to climate change hazards can be co-occurring (i.e., individuals over the age of 65 may also have disabilities or lack access to a vehicle), meaning that some individuals may be counted more than once in the estimate, leading to an inflated total count of vulnerable individuals.

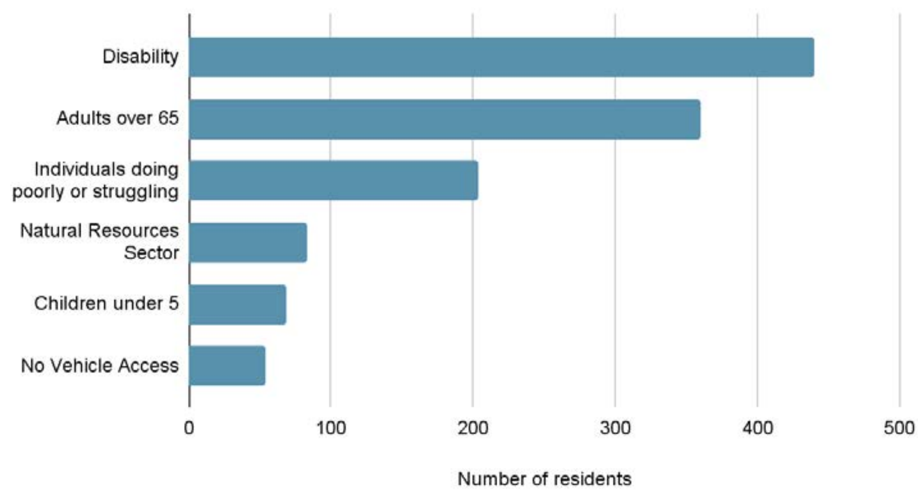


Figure 11.5: *Estimate of populations with heightened sensitivity to climate hazards.*

Of the estimated vulnerable population (n = 1,209 people), more than one-third is made up of disabled Tremont residents, followed by elderly residents (over 65 years old), and households and individuals facing economic hardship (with an income-to-poverty ratio of >2.00). The co-occurrence of social vulnerabilities can vary significantly depending on regional context, though elderly adults often have higher rates of existing medical conditions and disability, with 6% of the population that is 65 and over experiencing poverty.

Figure 11.6: *Percentage of populations living in poverty in Tremont by age*

The Socio-demographic Sensitivity Matrix shown below in Table 11.1 tabulates the instances of vulnerable populations that are particularly sensitive to each of the climate hazards outlined in Sections 4 through 10 and discussed in Section 11. The top of the chart enumerates the primary climate risks that Tremont residents face while the column to the far left of the table indicates which populations are impacted by each risk.

	Extreme Temperature (Count)	Vector Borne Disease (Count)	Drinking Water Quality (Count)	Wildfire (Count)	Coastal Flooding (Count)	Extreme Precipitation (Count)	Ocean Warming (Count)	Species Shifts (Count)
Children under 5	68 (6%)	68 (6%)	68 (6%)	0	0	0	0	0
Adults over 65	360 (30%)	0	360	360(30%)	360 (30%)	0	0	0
Individuals doing poorly or struggling	204 (17%)	0	204	204 (17%)	204 (17%)	204 (17%)	0	0
Natural Resources Sector	83 (7%)	83 (7%)	0	83 (7%)	83 (7%)	83 (7%)	83 (7%)	83 (7%)
Disability	440 (36%)	0	440 (46%)	440 (46%)	440 (36%)	0	0	0
No Vehicle	54 (4%)	0	0	54 (4%)	54 (4%)	0	0	0
Instances of vulnerability	1209 (100%)	151 (12%)	1072 (89%)	1141 (94%)	1141 (94%)	287 (24%)	83 (7%)	83 (7%)

Table 11.1: *Socio-demographic sensitivity matrix, showing the number of individuals that are sensitive to climate hazards by count and, in parentheses, as a percentage of the total vulnerable population.*

Considering the estimated population count of each vulnerable group and taking into account the hazards that each demographic is particularly sensitive to, we can rank population vulnerabilities for the Town of Tremont from the highest sensitivity (involving more vulnerable individuals) to the lowest sensitivity (involving less vulnerable individuals). It's important to emphasize that risks with lower sensitivity levels should not be dismissed as irrelevant to the community, particularly due to Tremont's cultural and economic ties to the working waterfront and marine resources industry, which stand to be impacted by ocean warming and species shifts.

Based on this preliminary analysis of climate risks and sensitivity, resilience planning efforts may be most effective if they prioritize temperature extremes, coastal flooding, and wildfires. However, climate change hazards will affect everybody in Tremont, and climate resilience planning options need to consider the ways in which sensitivity to hazards are intertwined, and impacts the adaptive capacity of the entire population. Further discussion among Tremont residents is essential in prioritizing which climate impacts and/or populations to plan for (including those that are not necessarily categorized as "vulnerable").

Tremont Climate Risk Sensitivity Ranking

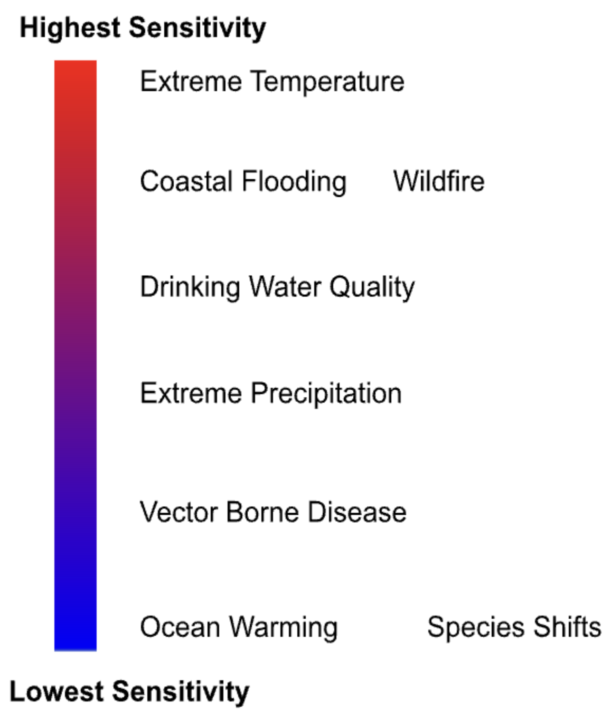


Figure 11.7: *Ranking of climate hazards based on population sensitivity as tabulated in the socio-demographic sensitivity matrix. Note that this matrix is based on the number of vulnerable people exposed to hazards, and does not include the associated risk (for more, see: Conclusions).*

12. Conclusions

Tremont is currently grappling with a complex web of climate vulnerabilities that stem from the interplay between its demographic makeup and various climate hazards. The town's commitment to addressing these challenges is vividly exemplified in its 2023 Comprehensive Plan Update and existing policies, which underscore the paramount role of local action in bolstering climate resilience. A thorough vulnerability assessment has considered an array of climate hazards and how they intersect with social and economic variables.

Foremost among these challenges is the growing concern of coastal flooding, driven by rising sea levels and tidal fluctuations. In Tremont, transportation plays a pivotal role in the town's infrastructure, with road networks serving as a lifeline for both residents and commuters. Coastal flooding poses a significant threat to these transportation routes, resulting in disruptions to essential community assets and critical resources, including fire and medical services. It is at this juncture that social vulnerabilities become heightened. Elderly residents, children, individuals with disabilities, and low-income households are particularly at risk, underscoring the need for resilience planning to address the impact of coastal flooding not only on properties, but on the ability of the Tremont to continue to offer critical amenities and services.

Beyond its effects on roads, the influence of coastal flooding on public and private property requires attention. Coastal flooding has the potential to diminish municipal tax revenue by up to 5.84%, with impacts predominantly concentrated in and around Bass Harbor. While this potential reduction in municipal tax base is not too severe it is critical to note that many of the properties impacted by coastal flooding constitute Tremont's working waterfront infrastructure and businesses. They play a vital role in the local economy, and contribute significantly to the town's identity and sense of community. Beyond coastal flooding, Tremont's working waterfront economy also faces challenges from changing marine conditions, including warming sea surface temperatures, ocean acidification, and shifting species.

Vulnerable populations in Tremont face numerous climate-related challenges – heat risk, coastal flooding, and wildfires chief among them. Moving forward, it is crucial to address these climate-related challenges with a focus on equity and the specific needs of vulnerable populations to safeguard the well-being of the Tremont community, as a whole.

"Climate Risk" refers to the potential negative consequences of climate hazards for communities, economic systems, ecological systems, or human health. One of the most common ways of assessing risk is by considering the "likelihood of occurrence" multiplied by "magnitude of impact" or vulnerability level. Tables 12.1 and 12.2 present a qualitative assessment of climate risk, taking into consideration the likelihood of occurrence and the magnitude of potential impacts on infrastructure and vulnerable populations. They represent the expert judgment of this assessment's authors based on the analysis presented herein coupled with their broader experience with and knowledge of climate science, community engagement, and municipal climate action planning. These tables serve as a starting point for understanding risks and developing a list of prioritized climate actions. However, continued conversations with Tremont community members and municipal staff are critical for further contextualizing this assessment's findings with the values, perspectives, experiences, and priorities of Tremont residents and workers.

	Likelihood of Occurrence	Potential Impact Level (population vulnerability)	Timeframe	Risk (likelihood x impact)	Expected Impacts
Extreme heat	Likely	High	Medium Term	High	Increased demand for cooling; increase in heat-related health emergencies
Coastal Flooding	Likely	High	Short term	High	Damage to private property; flood related health impacts; roadway, infrastructure, and ecosystem impacts
Wildfire	Low	High	Uncertain	Moderate	Damage to public and private property; health related impacts, damage to natural environments; landslide & rockslide risk, along with increased flood risk
Extreme Precipitation	Possible	Medium	Long-term	Moderate	Road inundation; infrastructure impacts (e.g. stormwater); health impacts
Vector Borne Disease	Likely	Medium	Long Term	Moderate	Increase instances of lyme and other tick-borne diseases
Water Quality Impacts	Likely	Medium	Medium-term	Moderate	Saltwater intrusion to wells and septic systems
Species Shifts	Possible	Low	Medium Term	Low	Impacts on commercial fisheries, working waterfront economy
Ocean warming	Likely	Low	Medium Term	Moderate	Impacts on commercial fisheries, working waterfront economy

Table 12.1: Matrix describing the risks posed by specific climate impacts to Tremont's population, as a function of their likelihood of occurrence and their potential impact on vulnerable populations.

	Likelihood of Occurrence	Potential Impact Level	Timeframe	Risk (likelihood x impact)	Expected Impacts
Buildings	Likely	Moderate	Medium-term	Medium	Increased demand for cooling; flood damage
Roads	Likely	High	Medium-term	High	Road inundation; disruption to emergency services and access to amenities
Working Waterfront	Possible	High	Short term	High	Reduced ability to access the water; labor impacts; infrastructure inundation
Groundwater	Likely	High	Medium-term	Moderate	Water quality impacts; saltwater intrusion
Conserved Land	Likely	Low	Long term	Low	Increased disease vectors; ecosystem impacts

Table 12.2: *Matrix describing the risks posed by several climate impacts to Tremont's infrastructure, as a function of their likelihood of occurrence and their potential impact on town infrastructure.*

In summary, Tremont's climate vulnerability results from the intricate interplay between climate hazards and the vulnerabilities of its diverse population. The "hazards of place" and demographic variations fundamentally shape the town's unique vulnerability landscape. Effective climate resilience planning calls for a community-driven approach that addresses the specific needs of each demographic group, ensuring that Tremont can adeptly confront evolving climate impacts while preserving the well-being and long-term sustainability of its community. Collaboration between seasonal and year-round residents is vital for building a closely-knit community resilient to climate challenges. Building a resilient Tremont entails addressing climate change threats and harnessing the collective strength and expertise of the entire community.

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A. Appendix A
B. Appendix B
C. Appendix C
D. Appendix D