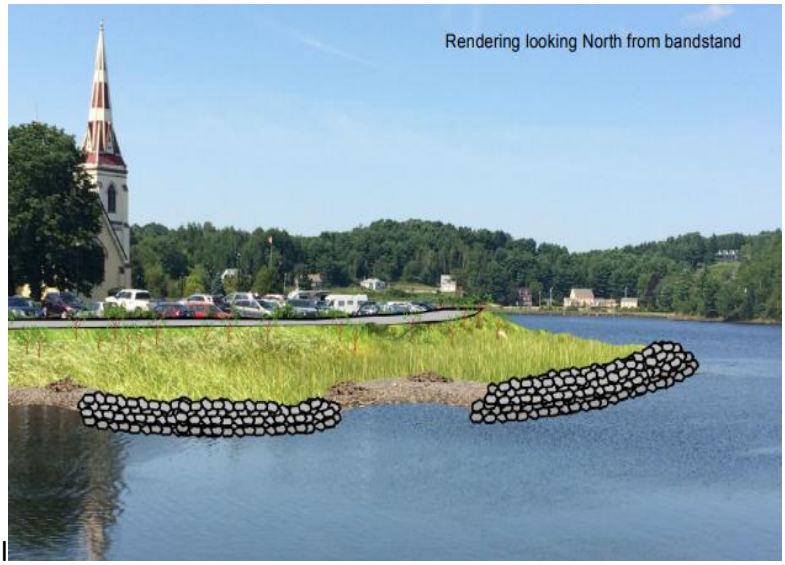

Image credit: CBCL Ltd.

Mahone Bay Living Shoreline Project

A Case Study of Nature-based Coastal Adaptation in Nova Scotia

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Team members from the School of Planning at Dalhousie University compiled the cased studies. Other members of the Making Room for Movement Team provided content and insight to one or more of the studies, including Kirsten Ellis, CBWES, Inc.; Nancy Anningson, Ecology Action Centre; Dr. Kate Sherren, Dalhousie University; Dr. Danika van Proosdij, Saint Mary's University; Dr. Tuihedur Rahman, McGill University; and Tony Bowron, CBWES, Inc.

Case study project participants contributed to documenting the projects by providing project descriptions and technical information. For this case study, the Mahone Bay Living Shoreline Project, the School of Planning project team thanks staff with the Town of Mahone Bay.

This project was undertaken in Mi'kma'ki, the unceded ancestral territory of the Mi'kmaq. We acknowledge and pay respect to the traditional stewards of the land on which we live and have conducted this work.

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Case Study Context and Purpose

The town of Mahone Bay on Nova Scotia's South Shore needs to address the threat of coastal flooding and erosion along its coastline. Successive studies have made it clear that the risks to many of the town's assets, including historic buildings, will worsen with climate change. Its traditional solutions of armouring and infilling are becoming part of the problem. The town decided to examine the risk from a fresh perspective and then decided to try a new approach: use the advantage of its sheltered location for a living shoreline thereby protecting the shore, creating habitat, and enhancing the natural beauty of the harbour.

This case study of nature-based coastal adaptation draws on technical reports, municipal documents, median reports, and input from project proponents to describe the project site; local climate change hazards and risks and social vulnerability; governance, policy, and planning context; project development, design, and implementation, and benefits, challenges, and lessons

Figure 1: Town of Mahone Bay, Nova Scotia (adapted from Google Images and Google Earth)

Background

The town of Mahone Bay is a small municipality of approximately 1036 people (Statistics Canada, 2021) on Nova Scotia's South Shore, situated at the head of Mahone Harbor on Mahone Bay (Figure 1). The town covers 3.21 km^2 and stretches along the western and southern shoreline of Mahone Harbour. Ernst Brook flows into the harbour from the west. The town has developed on either side of the small estuary. Much of the town is situated in the Ernst Brook floodplain or directly at the harbour shoreline. Mushamush River flows into the harbour, north of Ernst Brook.

The Mi'kmaq People were the First Peoples in Mahone Bay. The Mi'kmaq call Mahone Bay Mushamush, from which the Mushamush River got its name (Town of Mahone Bay, 2020a). The river that forms the town's eastern boundary with the neighbouring Municipality of the District of Lunenburg.

Mahone Bay was colonized in 1754 and converted to farm lots, followed by mills, homes, and shops constructed near the harbour (Town of Mahone Bay, 2020a). In the mid-1800s, the town's European economy thrived, dominated by agriculture, forestry, milling, fishing, shipbuilding, and shipping (Town of Mahone Bay, 2020a). In the mid to late 1800s, the iconic Three Churches were built on the Mahone Bay waterfront (Figure 2). In 1903, a railway was built, connecting Mahone Bay to the City of Halifax, increasing visits to the area (Town of Mahone Bay, 2020a). Today, the coastal town is a popular tourist destination, known for its historical charm and waterfront vistas.

The bayfront is important to the character, history, and appeal of Mahone Bay. Tourism is a key economic driver in Mahone Bay and protection of the historic waterfront has long been a priority for the community. The town has traditionally used rock armouring to manage flooding and erosion problems along its shore and at Ernst Brook. For example, Ernst Brook was reconstructed into a concrete-walled channel, beginning at the Hwy 3 (Lighthouse Route/Mainstreet) bridge to the river outlet (CBCL, 2016). Edgewater Street is reinforced by a rock wall (CBCL, 2016) which slows erosion at specific locations, such as in front of the three historic churches – collectively referred as the Three Churches (CBCL, 2016) (Figure 2).

However, there is evidence that the sea wall would likely suffer significant damage during a large storm event, resulting in washouts (CBCL, 2016). Mahone Bay also has residential and commercial properties located on the waterfront, particularly on the southeast shore. The properties are protected by round-stone arnouring, similar to the armouring on the shoreline across from the Three Churches, separated by wharves and boat launches (CBCL, 2016).

Figure 2. The Three Churches along Edgewater Street, and the parking lot, protected by round-stone armouring (Photo: "Three Churches"Jeff Power is licensed under CC BY-NC-ND 2.0)

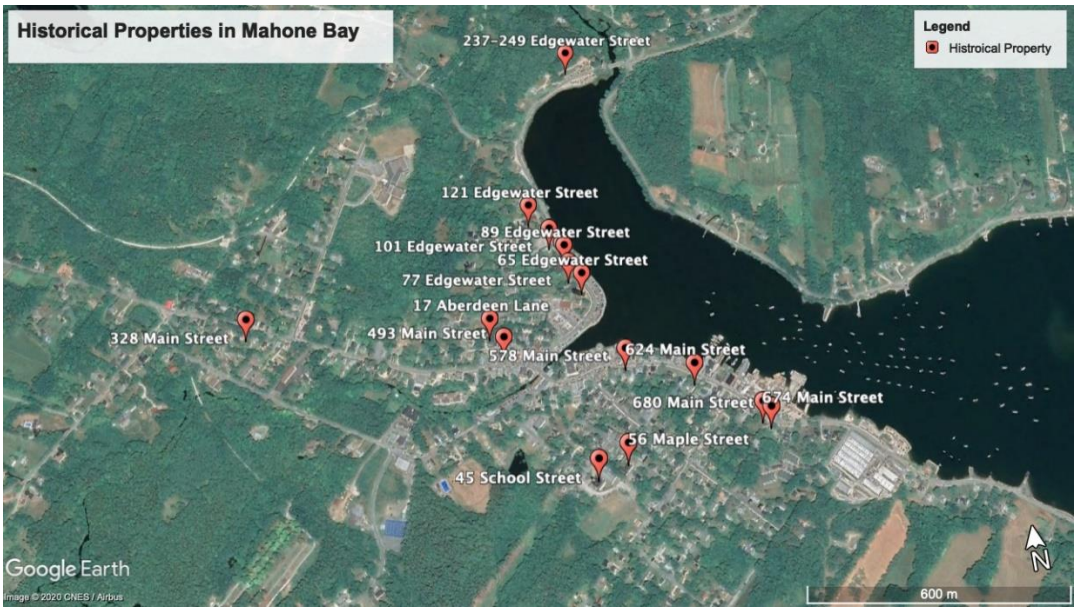

Figure 3. Registered historic properties in Mahone Bay (adapted from Google Earth, 2020)

There are 18 registered historic properties in Mahone Bay, the majority of which are located on Main Street and Edgewater Street (Town of Mahone Bay, 2020b) (Figure 3). These streets are particularly prone to flooding and erosion.

Development and land use change along the shoreline have impacted the coast's ability to adapt to changing conditions. The waterfront development of Mahone Bay was made possible by hardening the shoreline and draining and 'infilling' coastal areas. In preparing the background study and design recommendations for the Mahone Bay living shoreline project, engineering and environmental design company, CBCL, Ltd. (2016), studied the evolution of the Mahone Bay shore. Historical photos illustrate infilling and shore hardening in Mahone Bay (Figures 4, 5 and 6). Infill likely occurred on natural salt marshes (CBCL, 2016). For example, Edgewater Street's modern construction was made possible by infilling the harbour (CBCL, 2016). Infill has extended the natural coastline seaward. Mahone Bay's shoreline has a documented history of erosion. However, from 1965-2011, the shoreline appears to be growing (Figure 7) because armouring has prevented erosion and infilling has advanced the shoreline. These approaches to shoreline management have steepened the shoreline and decreased the available space for estuaries and salt marshes to mitigate coastal hazards naturally (CBCL, 2016).

Today, the town's main roads, parking lots, and commercial buildings dominate the estuary shoreline along with wharves and a marina south of the commercial area. Parking lots and other 'low risk' development including a boatyard and industrial storage are on infilled land. The development of impermeable surfaces such as roads and parking lots has impacted the coast's ability to absorb rainwater, increasing overland flow. Increased runoff near coastal banks can increase bank erosion. The addition of wharves and boat launches on the coast has likely affected natural erosion and sediment retention patterns, impacting the coast's ability to evolve naturally.

Some of shoreline protection structures are now deteriorating, and coastal hazards are increasing (CBC Radio 2020; CBCL 2016). For example, several stone walls are showing evidence of wave overtopping and are at risk of being washed out (CBCL, 2016). In December 2014, flooding effects were felt widely among the community. In a 2015 news report, one resident said, **"Did you experience any flooding last December? No? Well, you were one of the few."** (Bower, 2015).

Figure 4. Pond located on Main Street that was later drained and developed (Mahone Bay Museum, 2020)

Figure 5. Shore armouring, late 1800s (exact date unknown) (Mahone Bay Museum, 2020)

Figure 6. Shore armouring, late 1800s (exact date unknown) (Mahone Bay Museum, 2020)

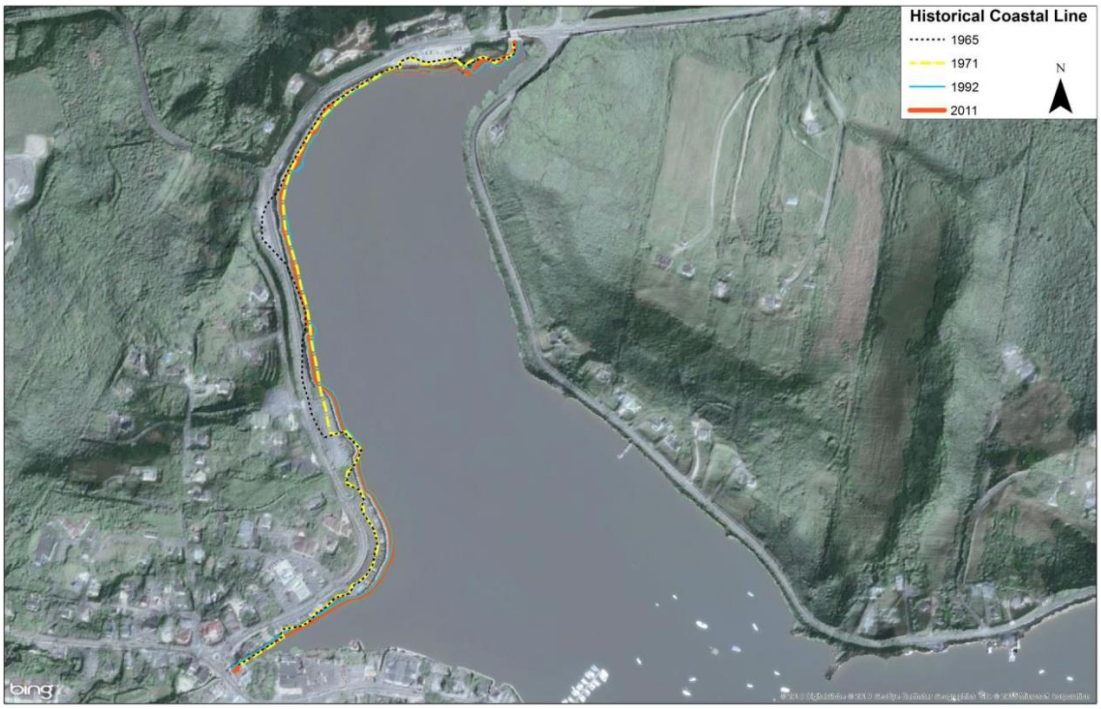

Figure 7. Historical shoreline evolution in Mahone Bay (CBCL, 2016)

Climate change and changing land use have challenged the effectiveness of the infrastructure built at a time of lower sea-levels, without accounting for climate change. Despite historical and modern efforts to maintain and even extend the coastline, flooding and erosion continue to be major concerns in Mahone Bay. Several properties and road infrastructure are located within meters of the coast. They are exposed to increasing hazards making them highly vulnerable.

Hazards and Risks in Mahone Bay

Climate change is creating warmer and wetter conditions in Nova Scotia, creating more frequent and intense rainfall events (ECCC, 2019). As sea levels rise, coastal flooding is becoming more common, negatively impacting coastal communities such as Mahone Bay. Rising sea levels magnify high tides and storm surges (ECCC, 2019). Researchers and the town council have examined the climate change hazards, principally flooding, for the town.

In 2012, Mahone Bay was the focus of a coastal flood risk mapping project, undertaken by the Atlantic Geomatics Research Group (AGRG) of the Nova Scotia Community College (Webster,

et al, 2012), through of the Atlantic Climate Adaptation Solutions Association (ACASA). ACASA was the Atlantic Provinces program of Natural Resources Canada (NRCan) Regional Adaptation Collaboratives (Province of Nova Scotia, n.d.). The AGRG researchers used high resolution terrain mapping (LiDAR) to map the flood elevation of storm surge along the shoreline of Mahone Harbour south to Princess Inlet for the 1-in-25-year and 1-in-100-year storms with the projected increase in sea level by 2100. The projections show that the town's shoreline commercial and service infrastructure is almost entirely in the flood zone. The mapping project did not incorporate an increase in extreme weather intensity and frequency.

In their study investigating the vulnerability of seniors to coastal impacts of climate change in rural Nova Scotia, Rapaport, *et al*. (2013) mapped the spatial relationship between coastal flooding and health, security and emergency, and daily needs services in Mahone Bay (Figure 8). They used published projections for relative sea level rise to 2025, highest high tides, and benchmark storm surge. The projected flood level for sea level rise and highest high tide was 1.81m; adding the benchmark storm surge flooding increased the projected flood elevation to 3.44m. The spatial analysis showed that 12 services would be directly impacted by storm surge flooding, two would by impacted by highest high tide flooding, combined with sea level rise. Five additional locations are indirectly impacted because access would be interrupted.

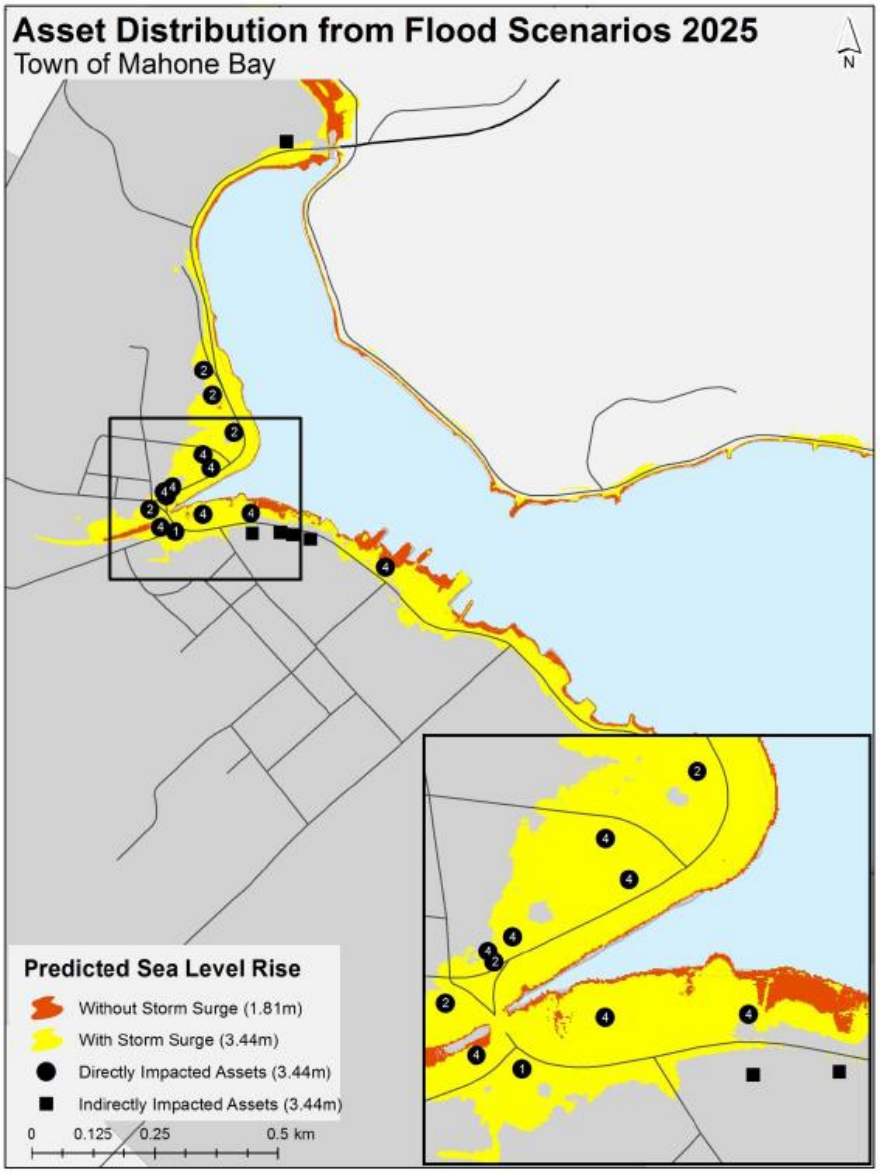

Figure 8. Intersection of projected flooding and service assets in 2025 combining sea level rise, highest high tide and benchmark storm surge. (Rapaport, et al. 2013)

In 2013, the town of Mahone Bay produced a *Municipal Climate Change Action Plan* (MCAPP) (Town of Mahone Bay, 2013). The plan identified 13 hazards and risks associated with changes in climate. Hazards specifically relating to flooding include coastal flooding, inland flooding, hurricanes, extreme weather events, and forest cover changes. The MCCAP also acknowledges secondary hazards, such as erosion.

Inland and coastal flooding meet at Mahone Bay, the result of a complex interaction between rising sea levels, coastal erosion, increased intense rainfall events, river flow, tides, and storm surge (CBCL, 2016). The intensity of flooding risks is also influenced by the presence (or lack) of vegetation, slope, and natural space for flood water storage. Mahone Bay's history of armouring, infilling, and implementing impermeable surfaces on the coast, significantly influences the coast's natural ability to mitigate flooding and erosion. For example, replacing vegetation with parking lots and roadways, increases overland flow. Overland flow occurs when the land cannot absorb water and it continues to flow over the surface (Kampf & Mirus, 2013). Overland flow increases with impermeable surfaces such as pavement because there is no vegetation to slow down the flow of water and absorb it. Furthermore, due to the engineering of natural waterways, inland flooding and overland flow are often exacerbated when an intense storm occurs at high tide (CBCL, 2016).

In its engineering report for the living shoreline project, CBCL (2016) describes the interaction between storms, inland flooding, storm surge and tidal flooding. Ernst Brook often backs up during storms. During a storm, rainwater naturally collects in a pond to the west of Pond Street (CBCL, 2016). The rainwater drains through a narrow pipe into the Ernst Brook (CBCL, 2016). At the same time, high tidal waters are pushing upstream. Storm surge further exacerbates coastal flooding. Storm surge refers to waters that rise above normal tidal levels during a storm event. Strong winds push water onto the shoreline during a storm surge, increasing the water level (NOAA, 2020). Low air pressure during storms also contributes to higher sea-levels during storm events. As a result, Ernst Brook quickly reaches capacity, water overtops the concrete banks and, unable to percolate into the ground, floods the adjacent developed areas.

Mahone Bay's MCCAP (Town of Mahone Bay, 2013) identifies current or predicted locations, infrastructure, and populations affected by climate change hazards and risks. Residents and commercial building owners between the shoreline and 6 metres elevation could be affected by coastal flooding. The infrastructure of concern includes power lines, the town wharf, sewage pumping stations, Ernst Brook and Mushamush Bridges, and EHS ambulance stations. Highway 3 is also of major concern. Damage to the highway could potentially isolate the community.

“ …at the next big storm parts of Highway 3 will wash away on the Mader’s Cove side, which would isolate the town…” (Wilson, in Lighthouse Now, Bower, 2015)

“If the town was isolated even for a few weeks while road repairs were done, it would really damage the tourist industry. Some people wouldn't be able to afford to continue.” (Wilson, in Lighthouse Now, Bower, 2015)

In the background work for the living shoreline project, CBCL found that the areas at the greatest risk of flooding in Mahone Bay are located along Edgewater Street, Main Street, and Ernst Brook (CBCL, 2016). Coastal flooding has already damaged the foundations of each one of the Three Churches and is impacting adjacent infrastructure during stormy weather (CBC Radio, 2020).

Despite recognition that Mahone Bay’s coast is at considerable risk, there are several ongoing development agreements for structures in known hazardous areas, including converting existing uses for residential purposes, expanding buildings, constructing apartment buildings and multi-unit dwellings, and a shipyard/marina. In 2015, a controversial commercial and residential development was proposed along Main Street (Town of Mahone Bay, 2016a) The proposal raised many concerns about its vulnerability to climate change and sea-level rise hazards, and its impact on the coastline. Following the motion to enter a development agreement with the developer, the Town received several letters of concern. The letter raised several points, including (Town of Mahone Bay, 2016a):

1. The new structure will be longer than the original building, extending towards the waterfront
2. Though the development has raised the ground level to the 2 m required by the Province, the ground floor of the building is still likely to flood
3. The building is in very close proximity to a busy street, where several accidents have already occurred. Increased congestion from the exit parking lot could increase hazards and inhibit access for emergency services.

In October 2016, the town of Mahone Bay agreed to enter a development agreement with the developer (Town of Mahone Bay, 2016b). The development agreement includes the requirement for floodproofing measures.

Social Vulnerability to Hazard in Mahone Bay

Flooding and erosion are natural processes that become natural hazards when land development encroaches into flood and erosion prone areas, putting people, infrastructure, and land use activity at risk of flood impacts. Natural hazards affect populations differently. The impacts felt by a population, or a population's vulnerability to a hazard (such as flooding), is evident in the ability of the populations ability to respond to, cope with, and recover from the impact of the hazard. A variety of individual and social factors influence vulnerability of a population including income, employment, gender, age, race, education level, household composition, ability to speak the local language, among others. The greater the proportion of the population experiencing conditions that contribute to vulnerability (such as advanced age, unemployment, being a recent immigrant, for example), the more vulnerable is the population in that area. Vulnerability is described through indices such as the Social Vulnerability Index (Cutter, *et al*., 2003), or a marginalization index (Matheson, *et al*., 2012) or deprivation index such as the Canada Index of Multiple Deprivation (CIMD) (Statistics Canada, 2019). The analysis for this case study uses the CIMD.

The CIMD is an area-based index created by Statistics Canada using variables from the 2016 Census of Population at the Dissemination Area (DA) level (Statistics Canada, 2019). A Dissemination Area is the smallest population unit for which Statistics Canada reports the full set of demographic and social statistics, about 400 to 700 people. DAs are relatively stable geographic areas. Statistics Canada developed CIMD datasets across three geographic scales: national, regional (two, including Atlantic), and provincial (three), referenced to 2106. This case study used the Atlantic Region CIMD data set.

The CIMD comprises four dimensions of deprivation and marginalization, with each dimension incorporating influencing indicators derived from the census data: residential instability;

economic dependency; ethno-cultural composition; and situational vulnerability. The indicators for each dimension are listed in Figures 9 to 12. DA-level factor scores were calculated for each dimension using factor analysis. Scores were then ordered within each dimension into quintiles and the quintiles were assigned a value of 1 through 5, Quintiles represent fifths of a population; the first quintile is the lowest fifth of the data (1% to 20%) and receives the quintile value '1'; the fifth quintile is the highest fifth of the data (81% to 100%) and receives the quintile value '5'. For the CIMD, '1' represents the scores indicating the least deprived fifth of the population; and '5' indicates the most deprived.

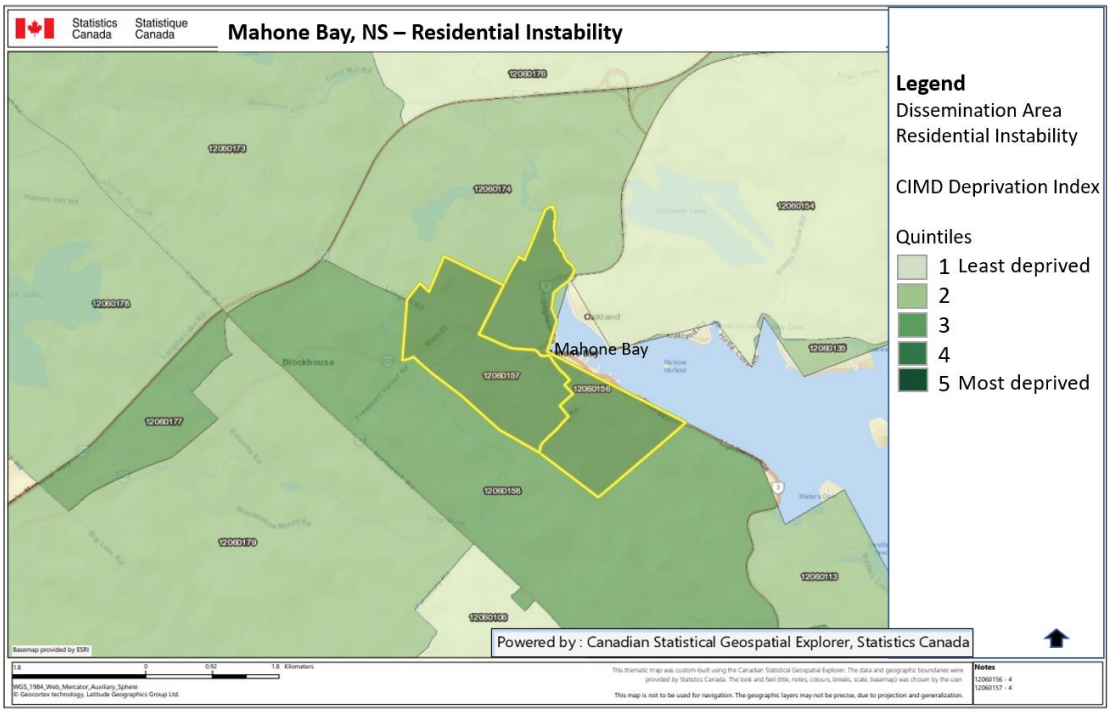

Figure 9. Town of Mahone Bay and surrounding area - Residential Instability* at 2016 Canadian Index of Multiple Deprivation – Atlantic Region -- (Statistics Canada, 2019)
*Proportion of persons living alone; proportion of dwellings that are owned, proportion of dwellings that are apartment buildings; proportion of the population that is married or common-law, proportion of the population that moved in the last five years.

Figures 9, 10, 11, and 12 are maps developed from the Atlantic Region CIMD data set to show the deprivation levels for Mahone Bay and adjacent areas. They allow comparison between the town area – the area of the living shoreline project – and the surrounding rural region. The shades of green on the maps represent lesser (light) to greater (darker) deprivation as indicated by the indices. The higher the deprivation the more vulnerable is the population to hazards.

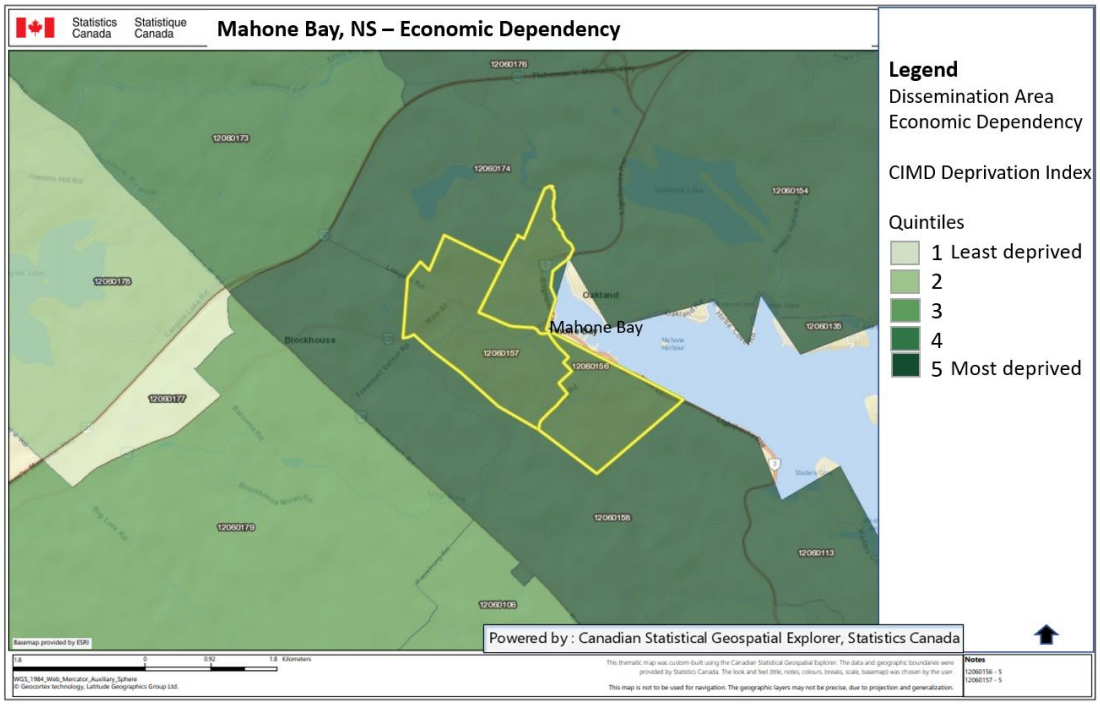

Figure 10. Town of Mahone Bay and surrounding area - Economic Dependency* at 2016 Canadian Index of Multiple Deprivation – Atlantic Region (Statistics Canada, 2019)
*Proportion of population aged 65 and older; proportion of population participating in the labour force -15 and over; dependency ratio (population 0-14 and 65 and over divided by population 15-64; ratio of employment population proportion of population receiving transfer payments.

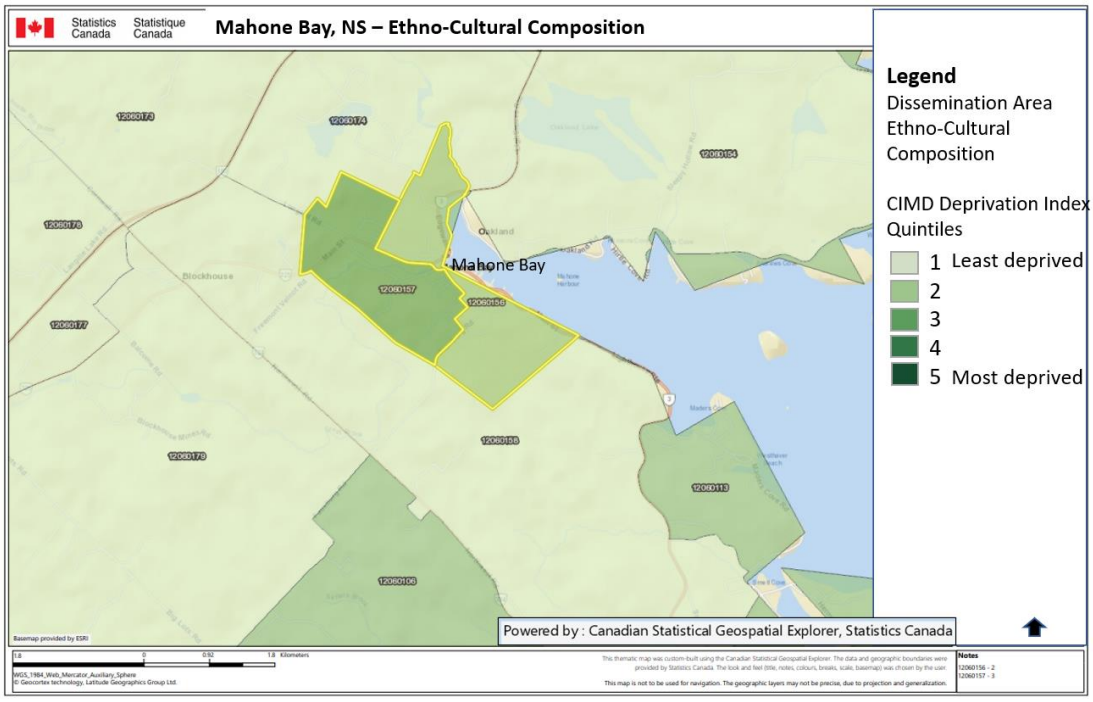

Figure 11. Town of Mahone Bay and area - Ethno-Cultural Composition* at 2016 Canadian Index of Multiple Deprivation– Atlantic Region (Statistics Canada, 2019)
*Proportion of population that is recent immigrants; proportion of population that has no knowledge of either official language.

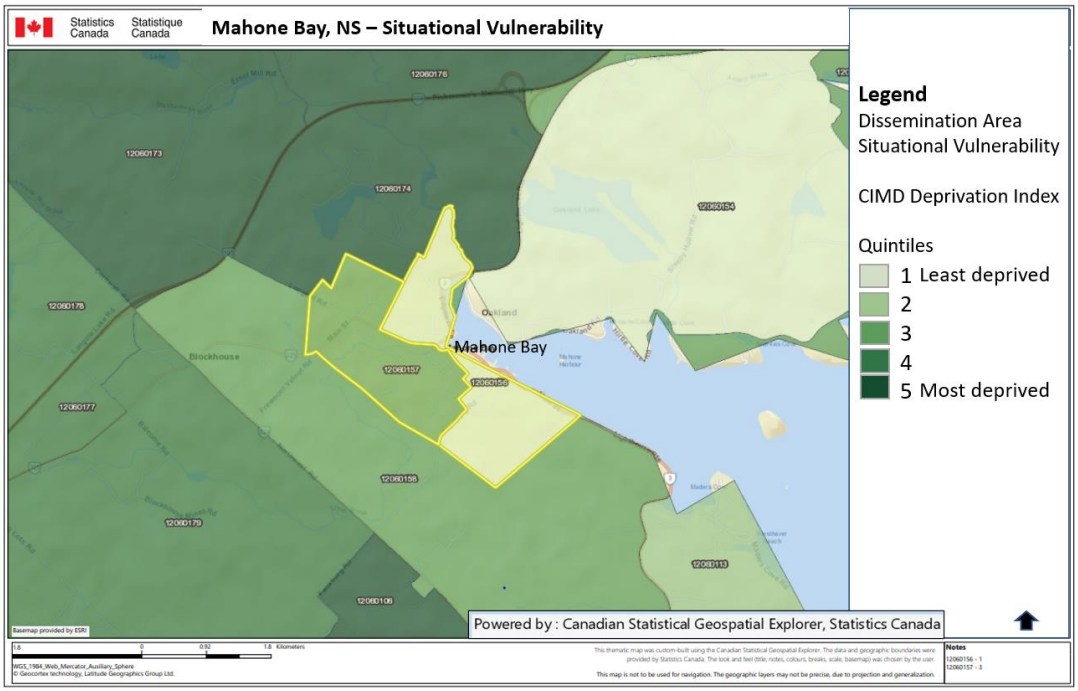

Figure 12. Town of Mahone Bay and surrounding area - Situational Vulnerability* at 2016 Canadian Index of Multiple Deprivation – Atlantic Region (Statistics Canada, 2019)
*Proportion of the population that identifies as Aboriginal; proportion of dwellings needing major repairs; proportion of population aged 25 to 64 without a high-school diploma.

The largest contributors to social vulnerability as indicated by multiple deprivation indices for the town of Mahone Bay are Economic Dependency and Residential Instability, both with deprivation scores of '4' for the three DAs covering the town. One of the three DAs for the town has a deprivation score of '3' for Situational Vulnerability and '4' for Ethno-Cultural Composition. However, the town has less vulnerability in Economic Dependency than the immediately adjacent rural area, and the two waterfront DAs have the lowest deprivation score for Situational Vulnerability, along with the rural DA to the east of the town. The deprivation vulnerability patterns are complex in and around the town of Mahone Bay.

Economic Dependency includes senior populations and other indicators relating to their economic dependence. This could explain the higher deprivation scores in this dimension of multiple deprivation indicators. Seniors (those 65+), are the fastest-growing demographic in Nova Scotia, and rural regions experience this more intensely than cities (CBCL, 2009). Seniors make up 15% of the population in Nova Scotia, and 25-30% in rural areas (CBCL,

2009). Rapaport et al. (2013) explain how the senior populations are a vulnerable population group to climate change impacts. In the Mahone Bay region approximately 31% of the population are 65 or older. The proportion of seniors in Mahone Bay is rapidly increasing. In 2001, 29% of the population was senior, and in 2011, 33% of the population was senior. Infrastructure designed to assist seniors in Mahone Bay is at risk of sea-level rise climate change related risks. For example, nursing homes and care facilities are permitted to be developed directly on the waterfront. Risk to these essential facilities further increases senior vulnerability.

Situational vulnerability includes education level and state of repair of dwellings. The low deprivation score in the town DAs suggests higher education levels and/or dwellings in good repair. Town of Mahone Bay is attracting retirees which is why its population structure is aging. But, the deprivation statistic could indicate that they are also well-educated. The Situational Vulnerability scores may be pointing to characteristics that lower vulnerability to climate change impacts and could enhance success for climate change adaptation.

The Mahone Bay Living Shoreline Project

Historically, Nova Scotia has addressed flooding by maintaining the "status quo" (Finck, 2006; Finck, 2012). Traditional fixes in Mahone Bay include sea walls, round stone armouring, and infilling (CBCL, 2016). Today, the town recognizes that the upkeep of these traditional mitigation measures will be significant in cost and resources. Mahone Bay's Mayor, David Devene, stressed that traditional approaches are no longer protecting Mahone Bay.

"…it was determined that armour stone is not going to really last because you're washing away what's behind the armour stone. (Devene, in CBC, 2020)**"**

"Although we've had surge tides in that area since the 1960s, they've been infrequent and not nearly as severe as we've been experiencing in more recent years. Council quickly understood...that we needed to take action. (Devene, in Metcalfe, 2019)**".**

As the studies previously described show, the coastal infrastructure and assets in Mahone Bay are at high risk of coastal flooding now and into the future.

In 2014, the Mahone Bay Harbour Development Committee initiated conversations concerning development projects on the northern shore of Mahone Harbour (Town of Mahone Bay, 2014). The Shoreline Reconstruction Project, later titled the Flood Prevention and Shoreline Enhancement Project, was voted a priority initiative (Town of Mahone Bay, 2015). In 2015, the town hired CBCL Limited to conduct a study of coastal flooding and erosion and to identify adaptation options for Mahone Bay including standard and nature-based approaches (Town of Mahone Bay, 2015). In 2016, CBCL completed the *Mahone Harbour Flood Prevention and Shoreline Enhancement Plan for Mahone Bay.* CBCL prepared designs and completed a cost-benefit analysis, comparing traditional hard protection infrastructure with a living shoreline. The consultants developed concept designs for Main Street and Edgewater Street and detailed design for Edgewater Street. The armoured seawall had an estimated cost of $3,289,00, and the living shoreline was estimated at $2,488,000 (CBCL, 2016). Based on recommendations, consultation with the community, and project feasibility the municipality chose the living shoreline.
The living shoreline proposed by CBCL is a hybrid design that combines rock-based erosion mitigation (marsh sill) and a vegetated salt marsh between the barriers (CBCL, 2016). The vegetation reduces wave energy, lessening erosion and negative impacts on protected infrastructure (CBCL, 2016). Living shorelines have been shown to be more effective at mitigating erosion and are more durable than traditional hard structures (Gittman *et al*., 2014; Gittman *et al*., 2016). They also can increase and support biodiversity (Gittman *et al*., 2014; Gittman *et al*., 2016). The goal of a living shoreline is to create an environment that self-adapts to changing conditions (Mitchell & Bilkovic, 2019). Although not maintenance-free, the level of maintenance for a living shoreline should decrease over time (Figure 13).

"As a landowner … I would strongly push our church to opt for the living shoreline. For our part, it obviously enhances the sense of our being part of a created order, and it's much more beautiful than a simple wall." (Wissler, in Lighthouse Now, Bower, 2015)

Figure 13. Example of a living shoreline (CBCL, 2016)

The analysis conducted by CBCL indicated that Mahone Harbour at Mahone Bay has the right conditions for a living shoreline (CBCL, 2016). The Mahone Bay shoreline experiences moderate waves and has a wide intertidal mudflat, supportive of a living shoreline. The municipality chose to focus efforts on Edgewater Street because land ownership is more consistent, and there is more socially available space to complete the project (Town of Mahone Bay, personal communication). The historic Three Churches located on Edgewater Street, are highly vulnerable and highly valued by the town.

Edgewater Street is an eroding bluff with tidal flats (CBCL, 2016). The recommended design is a living shoreline with breakwaters and an elevated waterfront trail/berm (CBCL, 2016) (Figures 14 and 15). The project will extend the shoreline seaward with coarse sand at a slope appropriate to establish a salt marsh. It aims to reduce wave energy reaching the paved waterfront trail on the landward side of the fill. The design includes rock breakwaters strategically placed to mitigate

fill erosion. Once built to the full extent, the project will be approximately 700 m in length from the Mushamush River mouth to the Ernst Brook Bridge and, at most, 10-15 m wide extending seaward (Figure 15) (CBCL, 2016).

The Mahone Bay Living Shoreline Project aims to meet four goals (CBCL, 2016):

1. Minimize erosion
2. Minimize coastal flooding risks and hazards
3. Provide habitat for fish and aquatic species
4. Maintain the connection between land and water ecosystems

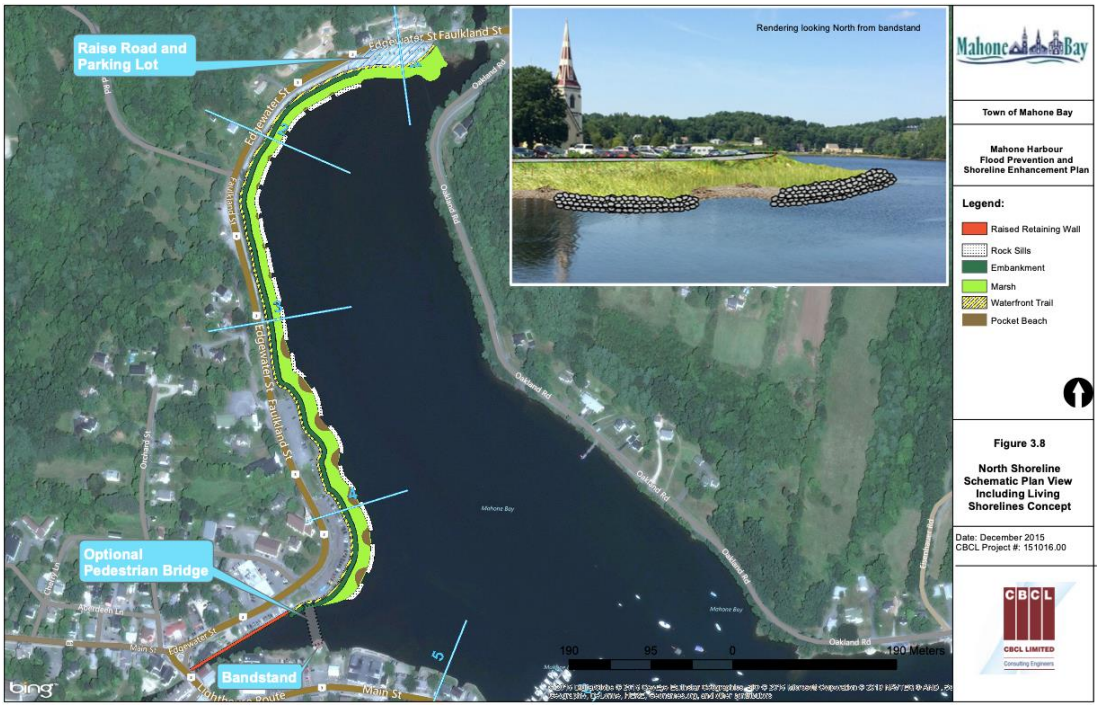

Figure 14. Project design for Edgewater Street (CBCL, 2016)

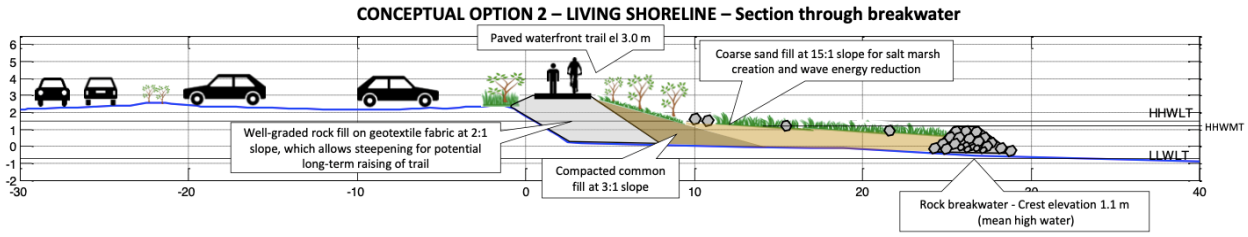

Figure 15. Schematic for one of the living shoreline options (CBCL, 2016)

Project funding

CBCL estimated that a living shoreline for the northern shore would cost approximately $2,488,000 (total construction, engineering design, and contingencies) (CBCL, 2016). In June 2014, an application was submitted to the NSDE for funding to develop and design the project and collect baseline data (Town of Mahone Bay, 2014b). In September 2014, the application for a Flood Assessment Grant to protect Highway 3 was approved by NSDE (Town of Mahone Bay, personal communication). The town was awarded $87,500 as a part of the remediation plan, specifically for design (Town of Mahone Bay, 2014b). A funding application was also submitted to the Build Canada Fund (Town of Mahone Bay, 2015). In 2015, Nova Scotia Municipal Affairs notified Mahone Bay that they did not receive the funding. In 2020, the federal government was still encouraging the municipality to apply for federal funding (Town of Mahone Bay, personal communication). So far, Mahone Bay is still waiting for provincial and federal funding participation, which is necessary to implement the full scale of the living shoreline. As a result, Mahone Bay turned to other partners to fund sections of the project, taking an incremental approach to implementation (Town of Mahone Bay, personal communication). This will result in a demonstration site that can be visible to the local community.

Mahone Bay partnered with Coastal Action, a charitable organization that works with communities on the South Shore of Nova Scotia to address environmental concerns. Coastal Action applied for and received funding from the INTACT foundation, a private sector environmental funding program. Coastal Action is the lead for this portion of the project and TransCoastal Adaptations/Saint Mary's University, CBCL, and CB Wetland and Environmental Specialists are collaborators on the project (personal communication, 2020). Detailed baseline design and monitoring began in Summer 2021 after CoVID-19 pandemic restrictions were eased.

GOVERNANCE, POLICY, AND PLANNING

The town of Mahone Bay is gaining recognition for green initiatives and plans for sustainability in cultural, economic, social, and environmental sectors (Town of Mahone Bay, 2020a). The town spearheaded the Living Shoreline Project with significant community support (Town of Mahone Bay, personal communication). Mahone Bay has recognized its shortcomings in terms of land use planning and inaction to address coastal hazards. As a result, the municipality creatively leveraged its jurisdiction through land use planning to develop a strategy to address coastal and inland flooding and erosion. In addition to the Living Shoreline Project, Mahone Bay has the power to protect buildings and other infrastructure, people, and the environment by establishing setbacks and standard lot sizes that consider climate change projections and are adaptive to changing conditions. Current and future coastal land use and development will influence the living shoreline project capacity to mitigate coastal hazards. For example, if wharves were permitted to be constructed on Edgewater Street, this could influence erosion patterns and negatively impact the project.

Installing a living shoreline is considered shoreline alteration and therefore may require permits and approvals depending on its position at the shore. A living shoreline that extends below the normal highwater mark is considered habitat alteration under the *Fisheries Act* (CBCL, 2016) and would require federal government permitting through Department of Fisheries and Oceans. The provincial government has permitting requirements for construction work that extends into the intertidal zone since this is usually Crown land that is under the administration and control of the Minister of Natural Resources (Province of Nova Scotia, 2017). Permits would also be necessary for work that interferes with a stream course or wetland. There are also site management requirements for sediment control. Regulations under the provincial Coastal Protection Act (Government of Nova Scotia, 2019; 2021), once introduced, will regulate construction impacts and the impacts of structures such as wharves, boat ramps, and shoreline armouring in the tidal zone. Restrictions will not apply to permitted projects or activities like living shorelines, undertaken to conserve or improve ecosystem function, however (Province of Nova Scotia, 2021). Projects with a footprint above the highwater mark must also take into consideration requirements of municipal land use zoning bylaws.

Town of Mahone Bay	Municipal Development Approvals
Nova Scotia Department of Lands and Forestry (NSDLF)	Permits for coastal infilling, rock sills and breakwaters, armouring below the highwater mark
Nova Scotia Department of Environment (NSDE)	Environmental Assessment
Federal Department of Fisheries and Oceans	Fish habitat considerations
Transport Canada	Canadian Navigable Waters Act Approval for alteration to waterways

Table 1: Permitting and other regulatory considerations that may be needed for a living shoreline

Municipal land use, planning and regulation in Mahone Bay

The living shoreline can only meet its full potential if it is complemented by smart land use planning. Currently, restrictions and floodproofing measures are enforced through development agreements (Town of Mahone, personal communication). At the time of preparing this case study, Mahone Bay is updating its Municipal Planning Strategy to formalize and regulate this process (Town of Mahone, personal communication). In general, Mahone Bay recognizes that development can have negative impacts on the coastal zone. For example, altering drainage patterns decreases the natural absorption of floodwaters and increases flooding risks and hazards (Warren, 2020). The Municipal Planning Strategy (Town of Mahone Bay, 2008b) aims to protect the beauty of the waterfront and commit to environmental issues (Warren, 2020). Zoning on the Mahone Harbour Waterfront (Figure 18) is predominantly (Town of Mahone Bay, 2008a):

- Restricted Commercial (RC)
- Commercial Shoreline (CS)
- Harbourfront Commercial (HC)
- Open Shoreline (OS)
- Institutional (IN)
- Park (P)
- Residential (R)

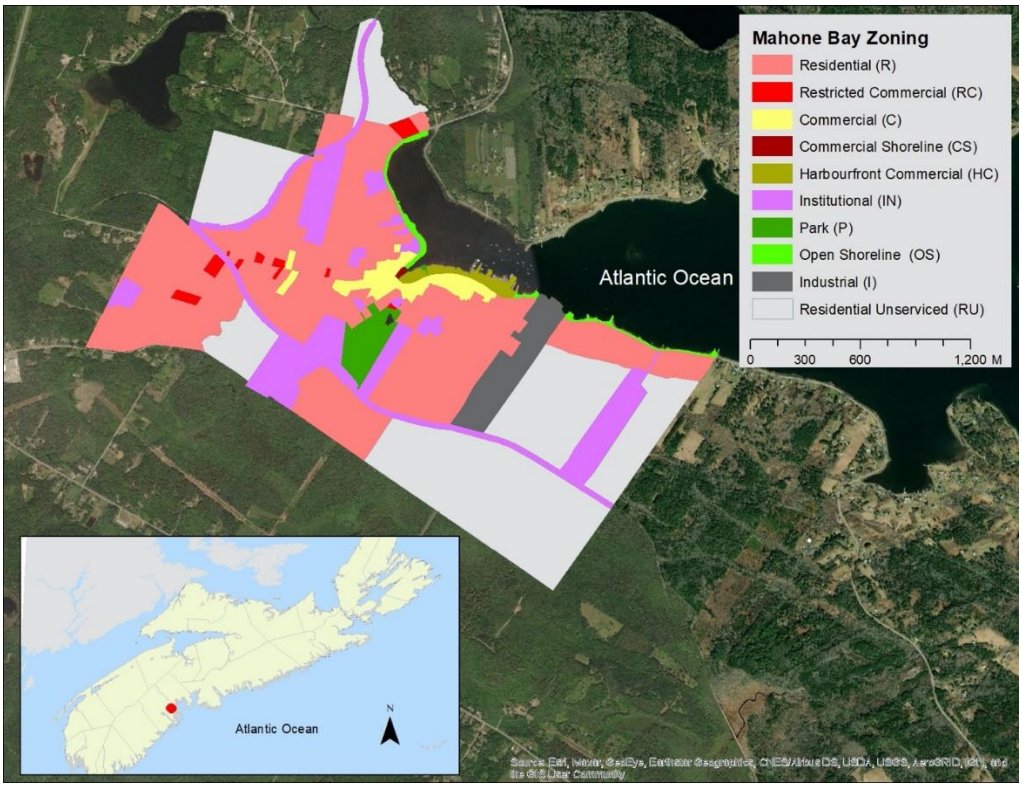

Figure 18. Land use zoning, town of Mahone Bay (Town of Mahone Bay, 2008. Map created by E. Rapaport, 2020)

The Open Shoreline zone permits low intensity uses, such as marine activities, playgrounds, parks, open spaces, parking lots, wharves, piers, slipways, and launch ramps (Warren, 2020). No new residential development is permitted within the Open Shoreline zone. However, many of these uses, such as wharves and piers, could negatively impact erosion and sediment retention and are subject to flooding risks. The Park zone also permits low intensity uses parks, playgrounds, open spaces, sports fields, and pavilions. However, the Park zone permits parking lots and other developments (Warren, 2020). Commercial zones permit a variety of medium intensity uses such as hotels, retail services, and tourist establishments. The Harbourfront Commercial and Commercial Shoreline zones are designated for new commercial developments on the waterfront. Several residential units are currently within the commercial zones and are permitted as an existing use.

Section 4 of the *Land Use By-Law* describes General Provisions for All Zones. Section 4.4.3 describes the Watercourse Protection requirements. Section 4.3.3.1 states that ‘no structure shall

be built within Eight Meters of the protected watercourses shown on Municipal Planning Strategy Map 1'. Section 2.7 (e) of the By-Law identifies watercourse "as a brook, stream, pond, lake, swamp, bog, or other watercourse" in describing site plan requirements. Section 4.5.19 (e) refers to watercourse (as defined by the Environment Act). The Environment Act defines watercourse as i) the bed and shore of every river, stream, lake, creek, pond, spring, lagoon or other natural body of water, and the water therein, within the jurisdiction of the Province, whether it contains water or not, and (ii) all groundwater (Part 1, Section 3, be). The Atlantic Ocean is not included in the definition. There are no elevation setback requirements in the Land Use By-Law.

Section 4.4.3.2 of the By Law, states that "Within 8 Metres (26 feet) of these watercourses, no person shall alter land levels in relation to a development", although under Section 4.5.19 (e) there is provision to increase elevation above the natural ground surface not more than 0.3 metres within 8 metres of a watercourse, except under a variance. The requirement protects the watercourse from increased runoff from a slope introduced to the site. This requirement does have interesting side-effect however, if considering raising land for climate change adaptation using an accommodate option. Filling to raise the land surface above flood level is a technique to enable land use in flood prone areas which, in Mahone Bay include the floodplain of the rivers. In these cases, a developer could apply for a variance.

In all zones, all existing structures that exist prior to the creation of new bylaws are permitted to be enlarged, reconstructed, repaired, renovated, or replaced as long as the setbacks are not reduced. Therefore, structures located on the ocean are solely subject to Front Yard Setbacks, specified in each zone. Required setbacks for zones adjacent to the ocean range from 1.5m-4.5m.

The living shoreline project will occupy the stretch of shoreline from Mushamush River to Ernst Brook. The zoning in this section is Open Space which accommodates all aspects of the project. The location of the pilot section for the living shoreline has adjacent institutional and commercial zoning. The living shoreline and trail along the shore will enhance the aesthetic environment of these public and quasi-public spaces and promote use and more awareness of the project and the benefits of this approach to climate change adaptation.

Other land use, zoning and regulation in Mahone Bay presents challenges for managing coastal impacts of climate change. Though the municipality is supportive of nature-based approaches, there is limited available space to make change; existing commercial activities need accommodation to operate. However, the same businesses are at risk of flooding because of their location on the water. Adapting to flooding and erosion in Mahone Bay will take creative land use planning and Mahone Bay residents' safety must be at the forefront of regulation. A living shoreline will create space for the environment to adapt to changing conditions and decrease coastal squeeze pressures. The town of Mahone Bay including council and residents have committed to exploring a new approach where the location provides the right fit in both environment, existing land use, and regulation.

Lessons, Barriers, and Drivers

Municipalities have a unique role on the coast. Municipalities can permit different types of land use along the coast, through policies and bylaws, which will ultimately impact the coastal zone. Through informed land use planning, municipalities can mobilize climate change adaptations such as nature-based solutions. Municipalities must continue to think critically about land use and how it impacts the natural environment. The town of Mahone Bay is an example of collective municipal and community willingness to innovate with a new approach to adaptation along their shore. Municipalities and other governments should lead in demonstrating these shoreline measures on public land and especially where the public has easy access to see the systems and learn about the benefits. The town of Mahone Bay is a leader for Nova Scotia municipalities.

Education and communication are perhaps the most fundamental piece of nature-based adaptation. Education and communication will encourage successful and proactive adaptation by

1. Providing the necessary tools to practitioners and decision-makers to make informed decisions about how to protect and responsibly use coastal regions
2. Providing the necessary tools to practitioners and decision-makers to make informed decisions about how to support vulnerable populations
3. Building stakeholder engagement and informed citizens

4. Promoting communication of science, climate change, hazards and risks to the general public
5. Encouraging collaboration between multiple groups and all levels of government
6. Creating an opportunity to showcase success stories of nature-based adaptation in Nova Scotia
7. Developing support for the use of nature-based adaptation in the future

The Mahone Bay Living Shoreline project is an example of how partnerships, communication, and education can inspire creative nature-based adaptations. It also allowed for a diverse range of stakeholders to participate in the process, bringing both local and scientific expertise to the project.

Funding is a barrier. The 2015 budget for the installation along the 700 metres of the north and west side of the harbour shore is $2.5 million, well-beyond the ability of a small municipality to finance. While the municipality received a grant to study and then design the solution, it was unsuccessful in securing other federal-provincial cost-shared funding to launch the plan. A community-based NGO partnership opened-up other opportunities through private sector grants, and thanks to the foresight by CBCL to create a project that can be implemented incrementally, a demonstration of the living shoreline will be able to move ahead. Further funding will be required to install the entire project. Mahone Bay is still pursuing provincial and federal funding options. The collaborative has now expanded to include a centre for nature-based solutions, TransCoastal Adaptations at Saint Mary's University, and affiliated groups. The collective builds more capacity and the opportunity to generate more connections.

However, for nature-based systems to be attractive options for municipalities, and eventually mainstream, they need funding commitments through cost-shared agreements to get started. Municipalities are the places where the real-world impacts of climate change affect people and businesses at the property level. In coastal communities, these are properties close to or at the shore. Federal and provincial governments need to support municipalities that are seeking to combine shoreline protection with natural environmental resilience to climate change impacts; the coastal zone is shared jurisdiction and thus shared responsibility; and, nature-based solutions

need to find a place in municipal engineering budgets that cover infrastructure installation that are eligible for cost-shared programs.

Expected Outcomes

The Mahone Bay Living Shoreline Project is advancing to a pilot implementation six years after council gave the approval for its *Mahone Harbour Flood Prevention and Shoreline Enhancement Plan for Mahone Bay*. Following project implementation, it will be important to continue to monitor the living shoreline. Living shorelines as a climate change adaptation approach provide a range of provisioning services based on ecosystem structure. Documented benefits from other living shoreline projects include wave energy dissipation, reduced erosion, habitat, and storm protection (Gittman *et al*., 2014; Gittman *et al*., 2016; Mitchell & Bilkovic, 2019). In addition, living shorelines are potentially self-sustaining under sea-level rise (Gittman *et al*., 2014; Gittman *et al*., 2016; Mitchell & Bilkovic, 2019). They support environmental education, recreation, and enhance the beauty of the coastline.

The Mahone Bay Living Shoreline project was designed based on reducing predicted coastal flooding within the next 50 years to 50% of the total predicted flooding (CBCL, 2016). For the project to be successful in mitigating flooding risks, it is important the finished design includes both coastal and river flooding (CBCL, 2016) The main goals of the project include flood and erosion mitigation, habitat preservation and enhancement, public shoreline access, and aesthetics (CBCL, 2016).

As we watch living shorelines evolve, we may understand natures adaptive capacity to adjust to climate change, and to protect our material assets at the same time. Living shorelines can re-connect us with the natural coastal environment that has disappeared from so many urban shores.

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