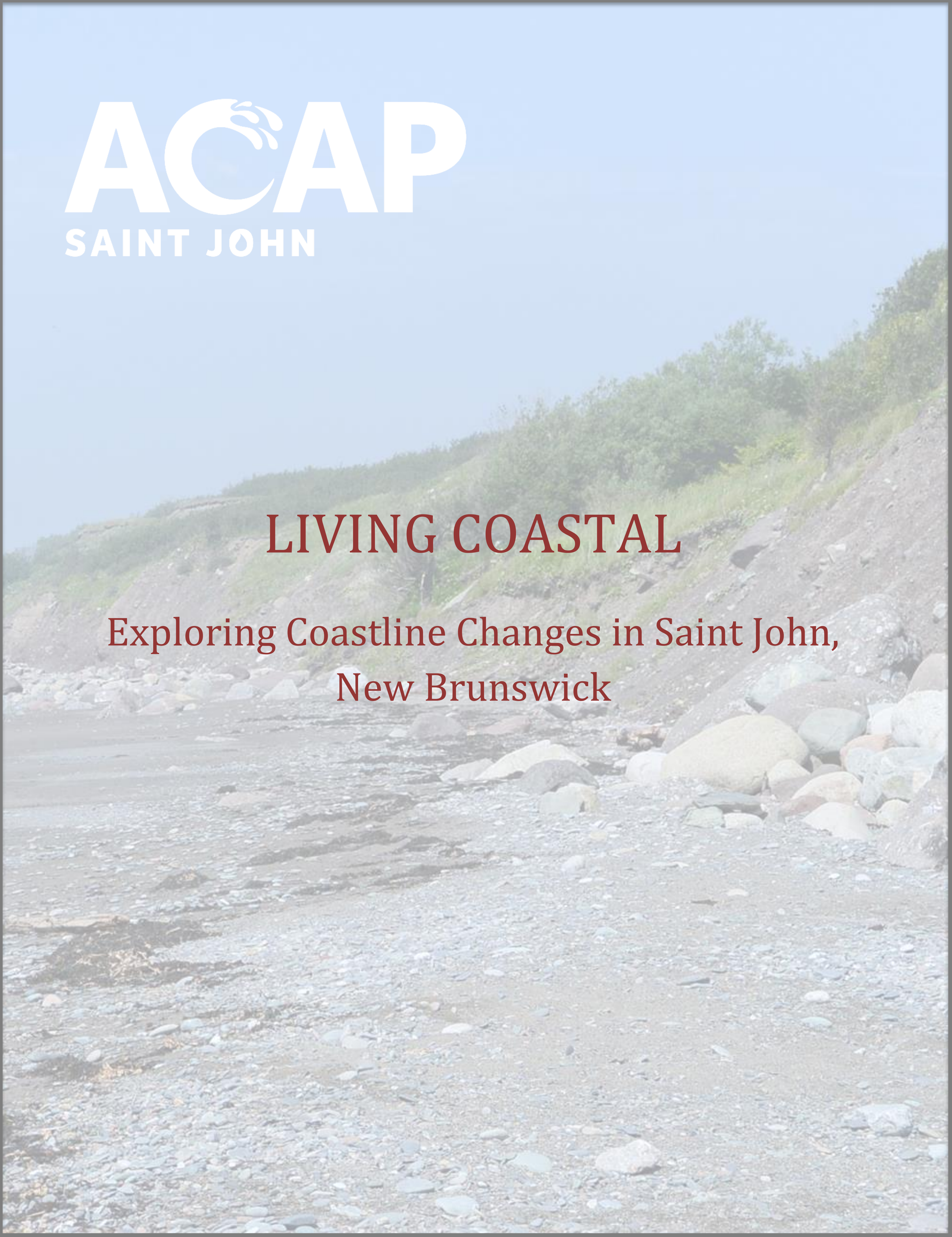

ACAP SAINT JOHN

LIVING COASTAL

Exploring Coastline Changes in Saint John, New Brunswick

Living Coastal: Exploring Coastline Changes in Saint John, New Brunswick

ACAP Saint John 2022

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New Nouveau Brunswick

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Executive Summary

The City of Saint John, New Brunswick is located on the Bay of Fundy at the mouth of the Wolastoq [St. John River]. As a municipality, many actions have been taken to address climate change impacts including increasing precipitation and temperatures, sea level rise, and increased storm severity. The City of Saint John's Climate Change Adaptation Plan, adopted in November 2020, formalizes several objectives that aim to increase resilience and protect the city in the future. Objective 2 of this plan is focused on adaptations to sea level rise which is identified as a high risk for the municipality. Monitoring, infrastructure relocation, and information sharing are recognized as opportunities to protect and enhance communities at risk. This research intends to support the actions outlined in Objective 2 and can be used by municipal staff, stakeholders, and community members to protect, preserve, and restore the beautiful coastline that surrounds the city.

In 2020, sea level rise estimates for the province of New Brunswick were updated, reinforcing the severity of the issues and the urgency that climate change poses. The rising sea level is not the only threat to coastlines, as erosional processes are a function of marine, terrestrial (i.e., land use), and atmospheric (weather) systems. ACAP Saint John has collected data from ten sites throughout the city to inform adaptation measures and highlight the need for action. This report includes an overview of coastal erosion, historical analysis, results from site assessments, and information to guide adaptation.

There is no single solution for erosion, however preventative strategies can be taken to slow down the process, allow infrastructure to be relocated or supported, and protect the community. A large part of prevention is monitoring the changes that occur over time and building awareness about effective strategies that may help stabilize and enhance coastal areas. This report builds off research completed in 2016 and aims to provide a baseline for future monitoring of coastlines in the area.

Living Coastal: Introducing Coastal Erosion

The City of Saint John is familiar with challenges of coastal erosion, as the city lies within the Bay of Fundy, where the world's highest tides have played a critical role in shaping the landscape. Along the Fundy Coast, the rates of erosion are variable, however the sensitivity of the coastline to erosional processes is recognized as an issue for the province. Through the adoption of the *City of Saint John Climate Change Adaptation Plan (2020)*, the municipality has made a commitment to becoming more resilient to climate change impacts like coastal erosion.

In 2016, ACAP Saint John released the *Coastal Hazards Characterization Report* which identified areas where erosion has been experienced. The report highlights multiple locations in the municipality and describes the hazards that may be associated with the observed shorelines. In 2021, ACAP received funding from the New Brunswick Environmental Trust Fund to complete an assessment of coastline change to complement the 2016 report, and provide adaptation information to the municipality, stakeholders, and the community.

Erosion is defined as the geologic process where materials are worn away or moved by natural forces such as wind and water (National Geographic Society, 2018). The forces that contribute to erosion can be grouped into three categories:

- Marine systems (i.e., waves and tidal fluctuations);
- Terrestrial systems (i.e., land use and vegetation); and,
- Atmospheric systems (i.e., wind, precipitation, temperature).

Within each of these systems there are several processes that can influence the rate of erosion. The systems do not act independently and when combined, can cause severe impacts. During extreme weather events, the City of Saint John can be faced with high volumes of urban runoff, high winds, and storm surge. The timing of storm events can significantly alter the severity of erosion due to the tidal variation in Saint John, where an extreme event occurring during low tide may have a lesser impact on the coastline. If the same storm were to occur at high tide, the combination of erosional forces (wind and storm surge) may result in more severe impacts.

In areas where infrastructure is present, erosion creates challenges for the municipality and for homeowners. Although coastline changes happen overtime, the unpredictable nature of erosion creates fear for individuals working or living along the coast that depend on essential infrastructure such as roadways and utilities. This report has been created to develop a baseline of coastline conditions around Saint John and highlight areas where the impacts of erosion are severe. Overtime, the coastline will naturally change requiring this analysis to be updated and further monitoring to be completed.

Physical Geography of Saint John

The City of Saint John, New Brunswick has a rich geologic history reaching back millions of years into our planets' past. Since the late 1800's, geologists have studied Saint John and southeastern New Brunswick surveying the landscape and unveiling the complex history that exists. This region is home to rocks and fossils that date back to the Precambrian (over 500 million years ago), telling the story of plate tectonics and ancient super continents (Miller, 2014). The landscape has been transformed by environmental processes throughout its long history and is now recognized as part of the Fundy Coast eco-region which stretches from the southernmost point of New Brunswick along the Bay of Fundy to the border of Nova Scotia (Government of New Brunswick, 2003). Although the Fundy Coast is primarily influenced by the tides, the City of Saint John is uniquely situated within the estuary of the Wolastoq which has played an important role in the physical geography of the region. The Wolastoq River Valley has been modified by glacial and melt-water processes leaving behind sand, gravel, and organic deposits. At the coast, glacial sediments are found alongside marine sediments including sand, silt, some gravel, and clay which can range from 0.5-3 meters in thickness (Government of New Brunswick, 2003).

The underlying geology of the area has an important role in understanding erosional processes that occur along the coastline. The province of New Brunswick is actively analyzing erosion issues and adding to a coastal erosion database for the province (Department of Natural Resources and Energy Development, 2017). Studies have determined the coastal migration rates for different landforms around the province providing an overall migration rate of 0.76 meters per year for beaches, and 0.26 meters per year for cliffs (Bérubé, n.d.). Additionally, the province has completed an assessment to categorize the sensitivity of coastlines to storm waves on a scale of very low to very high (O'Carroll & Bérubé, n.d.). The Saint John region has variable sensitivity to storm waves ranging from low on the city's west side to high on the eastern coastline (Figure 1).

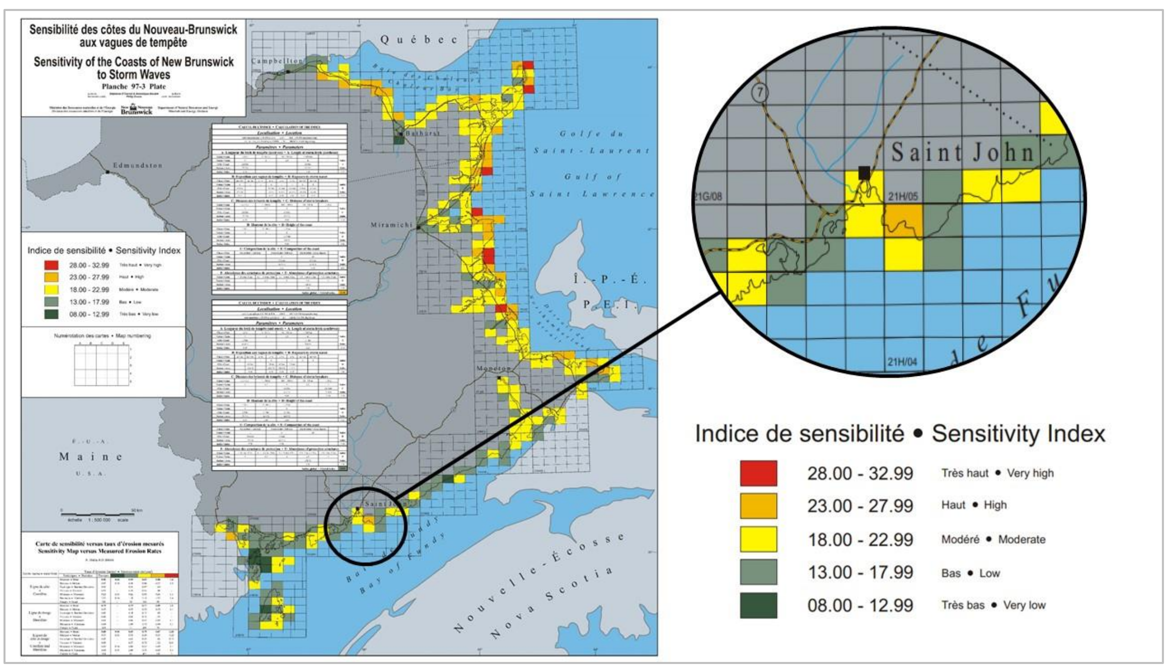

Figure 1: Sensitivity of the coasts of New Brunswick and Saint John region to storm waves (Adapted from O'Carroll & Bérubé, n.d.).

The soil texture in the region has a significant role on the rates of erosion and sensitivity to erosional processes. Soil texture refers to the relative proportions of sand, silt, and clay that are present, and determines the porosity (ability of water to flow through) and stability of the soil. For example, sandy soils have large pores between particles allowing water to flow more freely and increasing the susceptibility to erosion compared to clay soils which have smaller pore spaces, allowing them to form more cohesively and restricting the flow of water (Environmental Agency, 2008).

A variation in soil texture is observed along the coast ranging from solid clay formations to loose sand and granular textures. Each of these soil textures will interact differently with erosional forces and can create variability in the rates of erosion around the coastline. Table 1 provides a summary of the soil textures observed and their relationship with erosional forces.

Table 1: Soil textures observed in Saint John and qualities related to erosional processes (Environmental Agency, 2008; Arp, 2011).

Soil Texture		**Description**	**Relation to Erosion**
Light soils	Sand	Loose and single-grained with large spaces between particles.	- Allows water to flow through and will disperse easily resulting in movement in areas with high volumes of urban runoff. - Highly vulnerable to wind erosion.
	Sandy Loam	Contains mostly sand but a has silt and clay content.	
Medium soils	Loam	Relatively even mixture of sand, silt and clay.	- Clay content increases soil stability - Where clay content is low, water flows easily, and soil is less susceptible to movement. - When clay content is high, soils are prone to waterlogging (saturation) which can result in movement of material. - Highly susceptible to movement in areas with high rainfall on slopes.
	Sandy Clay Loam	Mostly sand with more clay than silt.	
	Clay Loam	Fine textured containing mostly clay with some sand and silt content.	
Heavy soils	Clay	Fine textured with small to no space between particles.	- Slow draining soils can generate runoff and have low risk of erosion. - Waterlogging can occur where drainage is restricted, and soils may reach saturation resulting in mass movement.

The Role of Vegetation

For decades researchers have studied the role that vegetation has in the stability of landforms. The exact modelling of sediment movement and rates of erosion in relation to the presence of vegetation continues to be explored, however there is a common acceptance that vegetation and landforms are interconnected (Osterkamp et al, 2011). Coastal landforms are not only shaped by marine and atmospheric systems but also by terrestrial functions including vegetation and urban runoff, both of which contribute to sediment transport. The effects of vegetation on erosion will depend on the vegetation type and the erosional processes involved. Overall, research has shown that vegetation can help to stabilize slopes while the removal of vegetation can accelerate rates of erosion and increase the likelihood of slope failure (Menashe, 1998). The relation between vegetation and erosion is explored in Table 2 below.

Table 2: Specific processes involving the presence of vegetation and erosion (Menashe, 1998).

Process	Explanation
Infiltration	Roots and vegetation absorb rainfall.
Interception	Vegetation absorbs rainfall energy preventing soil compaction.
Restraint	Soil particles are physically bound in place by root systems while above ground, vegetation filters and captures sediments from urban runoff.
Retardation	Vegetation slows down the velocity of urban runoff.
Transpiration	Vegetation uses water, reducing soil moisture and preventing saturation.

Climate Change and Coastal Erosion

Around the world the anticipated impacts of climate change are leading to the adoption of adaptation plans that utilize climate projection data to create opportunities that build resilience and strength within municipalities. The City of Saint John has acknowledged the risks that a changing climate poses and is actively engaged in the opportunities that adaptation strategies can offer. In the case of coastal erosion, there are multiple climate change impacts involved, adding to the complexity of the issue.

Changes in precipitation, temperature, and extreme weather

By 2080 and 2100, the weather in Saint John will vary from the current conditions. In Table 3 below, the data is presented to quantify the anticipated changes. As atmospheric processes play an important role in erosional processes, climate change will have a direct influence on rates of erosion.

Table 3: Summary of Projected Climate Changes for Saint John (ACAP Saint John, 2020a).

Temperature

- Mean annual temperature increases by 3.5°C by 2071-2100 compared to 1970-2000 with up to 70 annual hot days (25°C +) by 2071-2100.
- Average winter temperature above -1°C by 2071-2100.
- Annual freeze-thaw days increase from 82 to 87 by the year 2070.

Precipitation

- Annual rainfall increases by 85 mm by the year 2100 compared to 1970-2000.
- Precipitation patterns become more erratic and rainfall intensity will increase by 10%.
- Approximately 21 more rain days by 2070-2100.

Extreme Weather

- Increased severity and frequency of summer convective storms and ice storms.
- Increased severity and frequency of flooding from extreme rainfall and mid-winter thaws.
- Higher severity of drought: water deficit of 110% by the year 2080.
- Windstorm frequency increases by 8-15% (by the year 2050).

Increasing annual temperatures will reduce soil moisture content resulting in less soil loss, however an increase in winter temperatures and freeze-thaw cycles will lead to an increase in soil loss (Wang et al, 2018). Increases in precipitation will result in larger volumes of urban runoff accelerating erosion on slopes by creating large channels and cuts allowing for rockfalls. Saturation of coastline material will increase the potential for slides and slumping events (ACAP Saint John, 2016). The increased frequency and intensity of storms will accelerate erosion due to wind and storm surge in combination with heavy precipitation and extreme temperatures. **Overall, research suggests that an increase in material loss is expected** with higher rates of loss during winter when temperature variations and moisture are high, compared to summer when soil moisture is decreased and drought conditions may be experienced (Wang et al, 2018).

Sea level rise

The rising sea level has a direct impact on the erosion of coastlines. Sea level rise is a result of several factors including the melting glaciers, crustal subsidence in the region, as well as warming ocean temperatures (ACAP Saint John, 2020b). Projections show that compared with 2010 levels, the sea level in **Saint John is estimated to rise 86 cm by 2100,** with an increase in storm surge level of 0.8 m (Table 4). Flood mapping allows for development of adaptation measures that address infrastructure (roads, building, utilities) and habitats at risk, however these projections do not predict the accelerated rates of erosion. New tools and technologies are being developed to predict the rates of erosional processes overtime with consideration for climate change and sea level rise.

Table 4: Summary of projected sea level rise impacts (ACAP Saint John, 2020a).

- Saint John sea level rise of 86 cm +/- 38 cm from 2010 to 2100.
- Annual storm surge levels increase by 0.8 m compared to 2010.
- 1 in 100-year storm levels increase by 1.3 m by 2100 compared to 2010.
- Current coastal erosion rates of 0.59-0.99 m/yr.

The effects of sea level rise will have a direct impact on shoreline habitat resulting in coastal squeeze. This is the process where habitat is forced to move inland as environmental factors such as wind or waves alter the landscape (ACAP Saint John, 2020b). The migration of coastal habitats can be a natural process where the habitat expands inland as the environment changes (Figure 2-a), however the presence of barriers (natural or anthropogenic) can result in the loss or "squeezing" of habitat (Figure 2-b, c). When structural protection is installed as a defense to erosion it may be protecting the coastline from high water erosional processes however, these strategies can restrict habitat migration resulting coastal squeeze (Pontee, 2013).

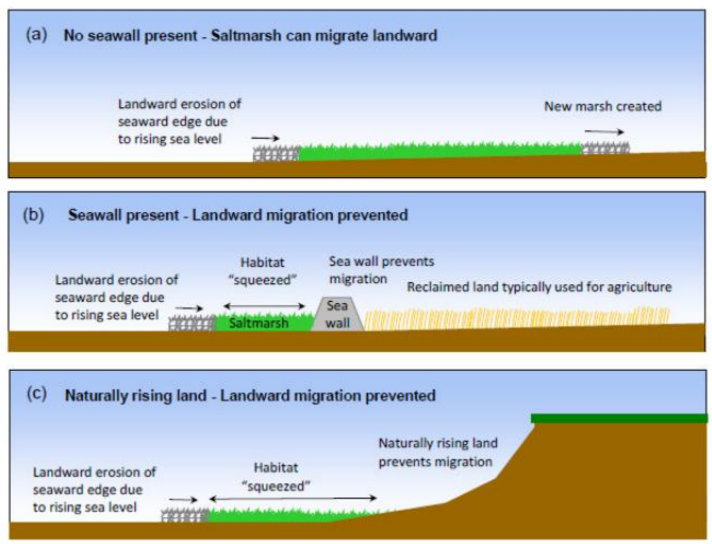

Figure 2: Examples of coastal habitat migration due to sea level rise (a) without barriers, (b) with built or anthropogenic barriers in place, and (c) with natural barriers (Pontee, 2013).

Historical Analysis

The City of Saint John is familiar with the challenges of coastal erosion. News archives and historical photographs convey the stories of landslides, slumping, and infrastructure damage or loss (Figure 3). ACAP Saint John reviewed reports previously completed for areas around the city including Red Head and McLarens Beach, where the challenges of erosion have been ongoing for several decades. These reports are referenced in the individual sites assessment sections. The role of historical analysis in this research is to provide a basic understanding of the project area and compare coastline changes using aerial photos and mapping software.

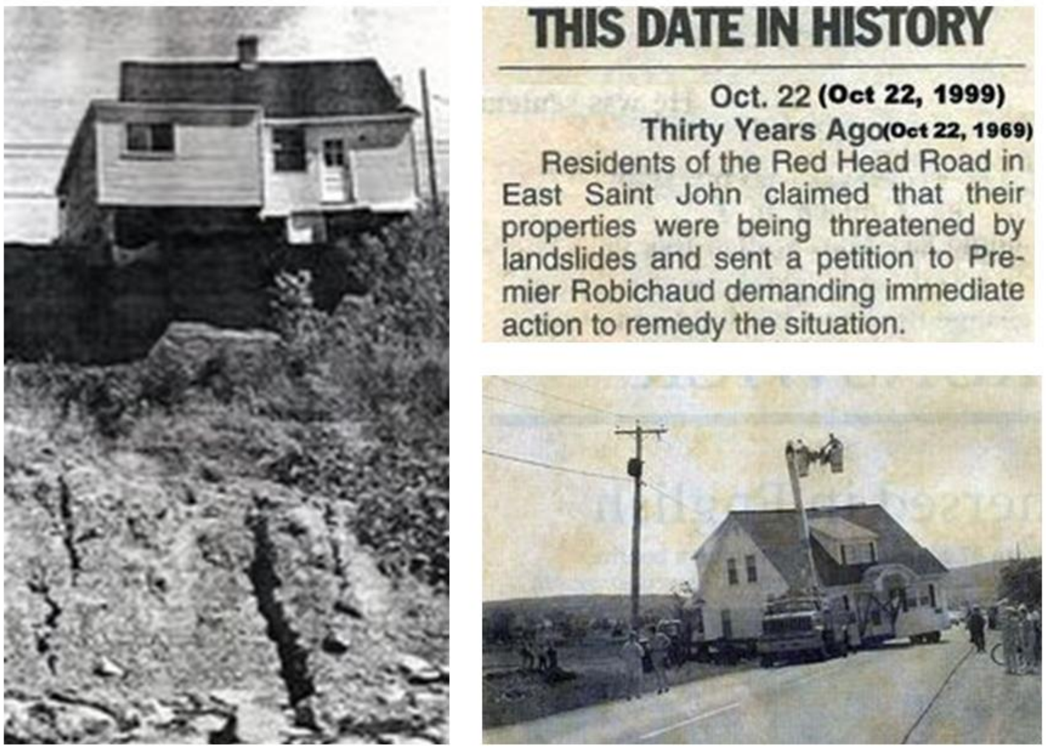

Figure 3: Historical photographs and news clippings demonstrating the challenges of erosion in Saint John. Left, a house on the cliffs edge. Top right, news clipping referring to action taken in 1969. Bottom right, example of homes being relocated (Images courtesy of G. Prosser).

Research: Coastal Hazards Characterization Report (2016)

The *Coastal Hazards Characterization Report* completed in 2016 by ACAP Saint John provides a strong foundation for understanding the processes and challenges of erosion in New Brunswick. It provides a detailed assessment of the factors that influence stability, types of mass movement, historical data (i.e., storms, extreme weather, infrastructure development) for the province, as well as tips to minimize coastal hazards. Examples of extreme instability are identified highlighting three areas in Saint John: Red Head, Sand Cove Road, and Lorneville. **The observations of the 2021 site assessments align with the conclusions of the 2016 report.** In Table 5, the key findings from the *Coastal Hazards Characterization Report* are summarized.

Table 5: Sites of coastal instability summarized from the Coastal Hazards Characterization Report (ACAP Saint John, 2016).

Conclusions from 2016	Confirmed 2021
Red Head - Clay at base with layer of mixed-grain material above. - Overhanging vegetation with little to none on the exposed clay base. - Evidence that high water breaks at clay base creating overhanging vegetation and saturating clay. - Evidence of protection measures put in place by homeowners. - Highly likely for erosion to continue due to shape of the cove.	✓
Sand Cove Road – McLarens Beach – Sheldon Point Trail - Further studies to be completed regarding the road which was reduce to one lane in early 2016. Reporting in 2004 confirms high erosion rate for the area. - McLarens Beach residents have had to relocate homes due to breaking water lines, foundation, or structural failures. - Seawalls and riprap in place to protect homes along McLarens Beach, with evidence of a historic wharf. - Coastline section of the Sheldon Point Trail is a very steep slope, highly susceptible to erosion. - Successional slumping observed. - Erosional impacts from waves and rain events.	✓
Lorneville - At risk to erosion following heavy rainfall, as occurred in the 1977 landslide. - Two coves, one at Lorneville Cove and the other off Post Office Road. - Less erosion at Post Office Road. - Protective riprap in place in both coves. - The base of the roadway is being undercut by waves, likely due to storm events.	✓

Mapping: Digital Shoreline Assessment System

ACAP Saint John contracted Flytbot Aerial Solutions to complete a historical analysis of coastlines using the Digital Shoreline Analysis System (DSAS) extension created by the U.S. Geological Survey (USGS). The DSAS extension can be added into ArcMap software to visually compare and calculate the changes in coastlines over time based on digitized aerial images. The system requires georeferencing the images in order to trace the coastline to create an accurate comparison throughout history. Once the coastlines are defined, a baseline is created along with transects that are used to generate a range of variables including the rate of shoreline movement. This analysis used images from 1945, 1984 and 2020 to provide a clear visualization of the coastline changes including erosion and accretion, and to generate a range of variables including net shoreline movement (NSM), the shoreline change envelope (SCE), and the end point rate (EPR) to name a few. Below is the terminology used by the DSAS to describe the coastline changes over time (Figure 4).

Defining DSAS Terminology

- **Net Shoreline Movement (NSM)**: the distance, in meters, between the oldest and newest shoreline. Negative values indicate erosion and positive values indicate accretion.
- **End Point Rate (EPR)**: a measure of erosion or accretion calculated by dividing the NSM by the length of time between oldest and newest shoreline data (rate in meters/year).
- **Shoreline Change Envelope (SCE)**: the greatest distance, in meters, between all shorelines that intersect with a transect. The SCE is always a positive value and may be larger than the NSM if accretion has occurred.

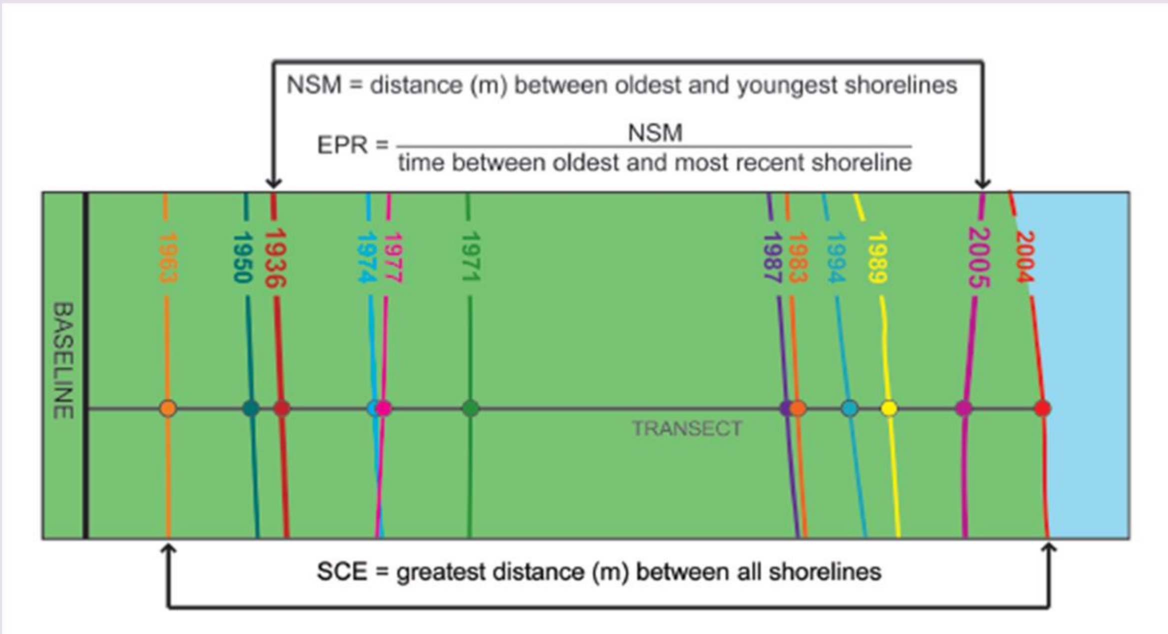

Figure 4: Example of DSAS data from the User Guide included to explain DSAS variables that are explored below (Himmelstross et al, 2018a).

These variables can provide quantitative context to the changing coastline and are presented in Table 6 for six of the sites assessed in the Living Coastal project (see Figure 8 for a map of the sites assessed).

Table 6: Quantification of coastline change at sites around Saint John showing average values for erosion (negative values) and accretion (positive values) (Himmelstross et al, 2018b).

Site Name	Average of Net Shoreline Movement (m)	Average End Point Rate (m/year)	Maximum Shoreline Change Envelope (m)
1. Mispec Beach	1.63	0.02	27.3
2. Anthony's Cove	-13.08	-0.17	48.76
3. Red Head	-11.35	-0.15	39.14
5. Bayshore Beach	-9.98	-0.13	24.33
6. Duck Cove	0.59	0.01	25.03
7. McLarens Beach	-4.97	-0.07	16.32

Overall, majority of the sites show a negative NSM confirming that erosion has been occuring throughout the region. At Mispec Beach and Duck Cove, the average shoreline movement suggests that accretion of material is the dominant process occuring, however the average EPR suggests that accretion is happening at a very slow rate of 0.02 and 0.01 meters per year, respectively. The data suggests that Red Head and Anthony's Cove have seen the largest changes in shoreline movement followed by Bayshore Beach. These quantifications are supported by current and historical observations in the region.

The historical trend at Anthony's Cove is predominantly erosion with the largest change appearing at the outlet of Bean Brook between AC7 and AC8 (Figure 5). The NSM in this area is the highest at this site, at -48.76 meters. Recently, a culvert has been installed in this area, altering the watercourses along the coastline. These changes may correspond with the high degree of erosion as well as the accretion of material that is shown at AC9-AC11 at the former mouth of Bean Brook. The erosion highlighted along AC3-AC6, provides the second highest NSM values for Anthony's Cove averaging -30.25 meters of net shoreline movement. Where riprap is installed along Anthony's Cove Road, the average of NSM is calculated at -3.3 meters with an EPR of -0.05 meters per year suggesting that riprap is effectively slowing the rate of erosion but not preventing it completely.

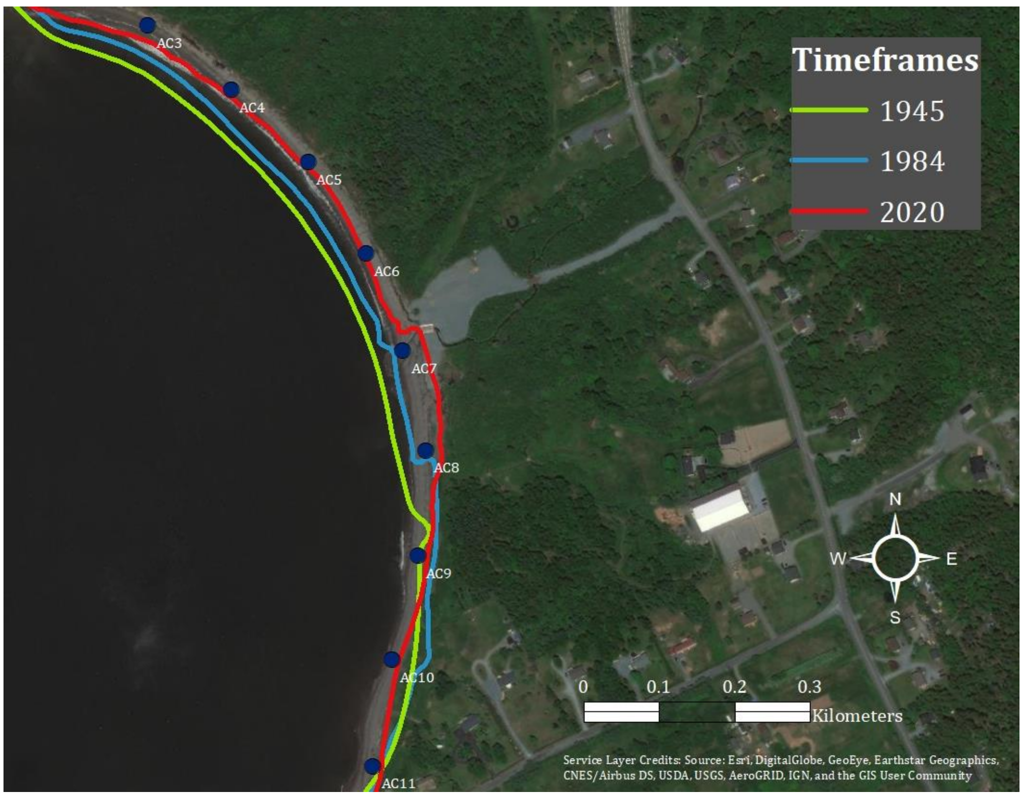

Figure 5: Coastline changes at Anthony's Cove showing areas of erosion through most of the site and accretion at AC9-AC11 (Himmelstross et al, 2018b). The points represent the sections of the Living Coastal site assessments.

At Red Head, the shoreline changes are apparent along the coast, particularly between the 1945 and 2020 shorelines (Figure 6). While Table 6 presents the average of NSM at Red Head to be -11.35 meters, there are several areas that have a higher degree of shoreline change including the outlet of

Beyea Brook at RH20 which shows -36.27 meters of net shoreline movement. Beyond RH21 the coastline appears stable (where the timeframes appear to overlap) however further into the cove, a higher degree of erosion is observed around RH24 and RH25. At the tip of Cranberry Point (RH27-END) it appears that very little shoreline movement has occurred throughout the timeframes analyzed.

The province has observed erosion along the coastline and measured the rate of erosion to be 0.5 meters per year, which totals 5 meters in 10 years (Department of Energy and Resource Development, 2017). The DSAS analysis provides an average EPR of -0.15 meters per year however there are sections along the coastline where the EPR was higher, with a maximum of -0.48 meters per year, in alignment with the provincial findings. Discrepancies in the findings between the province and the DSAS analysis may be attributed to the specific locations in which measurements are taken, the baseline data used, as well as the shoreline delineation and georeferencing of aerial images.

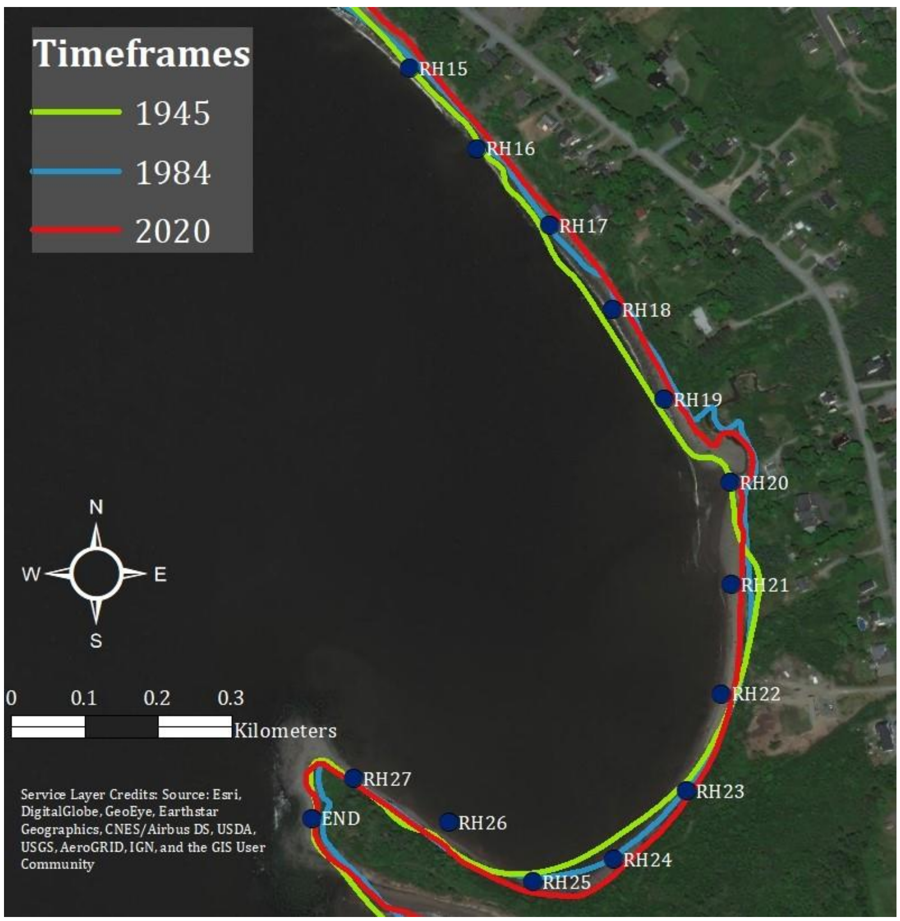

Figure 6: Coastline changes at Red Head (Himmelstross et al, 2018b). The points represent the sections of the Living Coastal site assessments.

The historical analysis of Bayshore Beach shows some stability along the coastline where the timeframes appear to overlap (Figure 7). At BB7 and BB8, a higher degree of erosion is confirmed as the 2020 shoreline has retreated from the 1945 and 1984 shorelines. At the parking lot, the historical trend shows erosion between 1945 and 1984, and then material accumulation is observed at the 2020 timeframe. This accretion of material could be from development in the area including paving of the roadway and installation of the culvert in BB11.

Studies completed by the province of identify the rate of erosion to be approximately 0.46 meters per year, equal to almost 5 meters over 10 years (Department of Energy and Resource Development, 2017). The DSAS analysis generated an average EPR of -0.13 meters per year with a maximum EPR of -0.36 meters per year. This variation may indicate that erosional processes have slowed down but may also be attributed to the specific location of measurements, baseline data, shoreline delineation and georeferencing of aerial images.

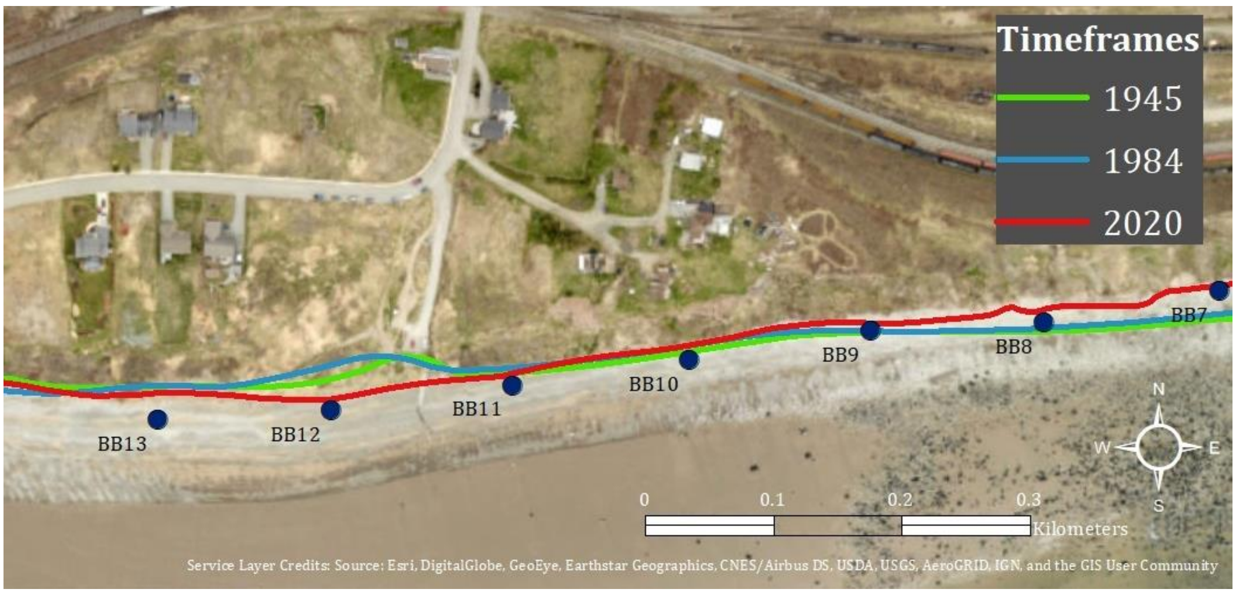

Figure 7: Coastline changes at Bayshore Beach showing areas of erosion and accretion (Himmelstross et al, 2018b). The points represent the sections of the Living Coastal site assessments.

The analysis provides quantification of erosion and accretion along coastlines around Saint John. It is important to note that the shorelines in this analysis are recreated from aerial photos and have a bias from the technician who completed the georeferencing and defined the shorelines. This is recognized as a limitation to the DSAS extension and must be considered when comparing the data to similar analyses. To recreate this analysis and increase accuracy, higher resolution historical imagery would be required. Additionally, future analysis may use the functions of ArcMap and ArcPro in conjunction to reduce the uncertainty and save time for technicians as some of the ArcMap limitation may be resolved more readily using ArcPro.

In addition to the data outputs presented in this report, the DSAS extension can be used to produce projections of shoreline change. The data inputs required to generate the projections were not available during this project, however further investigations with a larger data capacity may be interested to explore this output. The analysis completed for this report used three data sets to compare and quantify historical coastline changes, whereas four data sets are required to generate projections. In the future, the collection of additional data may allow for further exploration with the DSAS extension and provide estimated projections of shoreline change for sites around Saint John.

Living Coastal: Site Assessments

From June 2021 - September 2021 ACAP Saint John completed site assessments at 10 coastal areas around the city (Figure 8). These assessments cover over 10 kilometers of coastline and create a baseline of conditions that can be used to evaluate adaptation options, monitor changes, and prioritize actions in the future. The following sections provide a description and assessment details for each site (full data sets can be accessed upon request). Property and land ownership is acknowledged and more details regarding ownership can be found in Appendix B.

**Note: for these assessments, the term "coastline" is used to refer to the entire form type which might be a slope, cliff, or anthropogenic. The term "shoreline" is used to describe the area where the water extends to, which might be at the base of a steep slope or cliff form.*

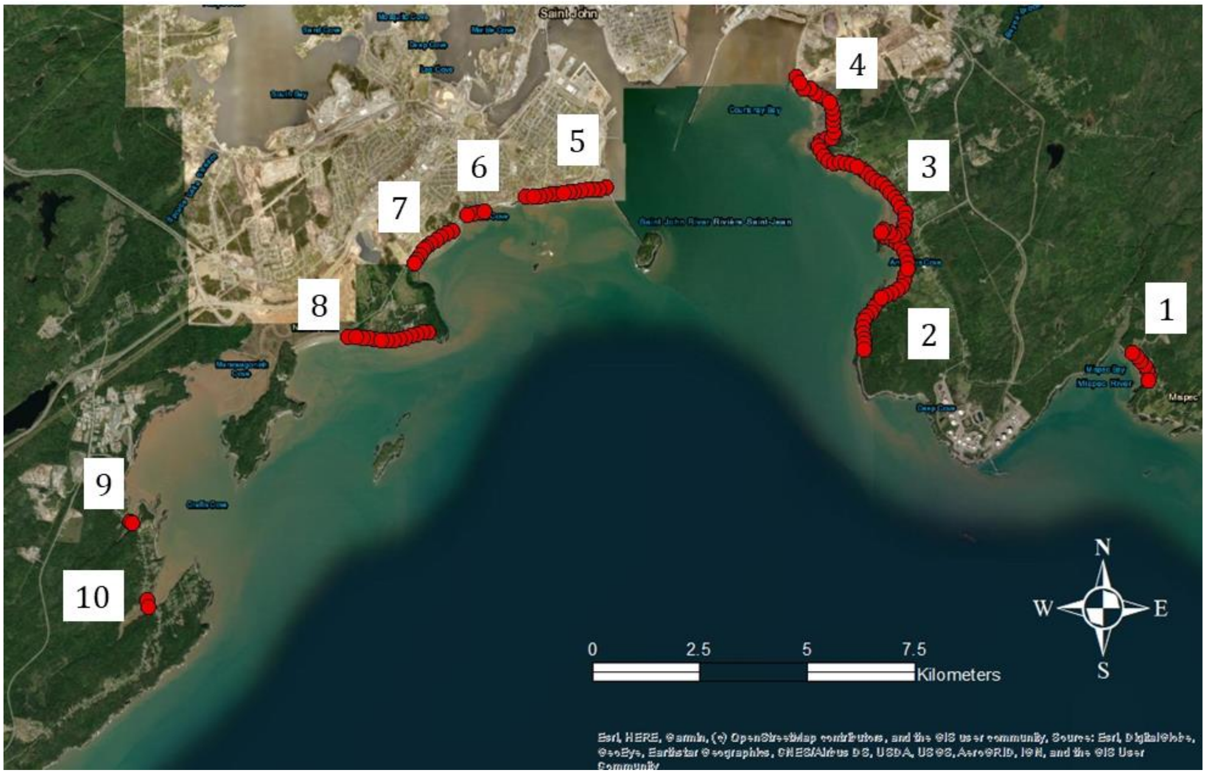

Figure 8: Sites assessed in the Living Coastal research include: (1) Mispec Beach, (2) Anthony's Cove, (3) Red Head, (4) Hazen Creek, (5) Bayshore Beach, (6) Duck Cove, (7) McLarens Beach, (8) Sheldon Point, (9) Lorneville Cove 1, and (10) Lorneville Cove 2.

The methodology was repeated at each site beginning at one end of the coast and completing the field assessment sheet every 100 meters (see Appendix A for the detailed methodology and field assessment data sheet). Notable erosion was observed within each section to provide an accurate representation of the conditions throughout the entire site. Observations included land use, form type, stability, height, and slope, areas of erosion height and slope, presence of vegetation, soil texture, and backshore and foreshore form type and composition. The assessment methodology was based on studies completed by the Atlantic Climate Adaptation Solutions Association (ACASA) and the relevant work in Nova Scotia along the Bay of Fundy coastlines (Piertersma-Perrott & Van Proosdij, 2012).

Table 7 provides an overview of the terminology and qualifiers used throughout the site assessment process.

Table 7: Field assessment guidelines and qualifiers (Adapted from Piertersma-Perrott & Van Proosdij, 2012).

Variable	Definition and/or Qualifier
Predominant Observation of Stability	Highly stabilized: No visible signs of erosion. Partially stabilized: Visible signs of erosion but no active movement or slumping. Not stabilized: Visible signs of erosion including active movement, cliffing, and/or slumping
Land Use	Observed on-site. May be recreational, residential, anthropogenic, undeveloped.
Vegetation	Ranked on a scale 1-5 as no vegetation, little, partial, mostly, and fully vegetated. Vegetation observed by percent of shrubs, grasses, trees.
Soil Textures	Feel tests completed in the field using guides on hand to determine.
Primary Form Type	Vertical cliff where slope equal to or greater than 50 degrees. Steep slope where slope is between 20-50 degrees. Smooth slope where slope is less than 20 degrees. Other forms may include bedrock outcrop, dune, waterbody, and wetland.
Slope Range	Slope measured in degrees using a clinometer. Slope converted to percent during data analysis.
Height	Height of the form in meters calculated using data collected with a clinometer. A height profile is included to demonstrate the variation along the coast. Note: variability in height may not always be the result of erosion and can also be associated with changes in land use, form type, and infrastructure.
Backshore	The area between the high tide and the coastline. Material types observed by percent of cobble, boulder, gravel, and fines.*
Foreshore	The area between the low tide and the high tide line. Form type observed as consolidated or unconsolidated. Material types observed by percent of cobble, boulder, gravel, and fines.*

*Material types categorized in the field based on approximate size: boulder material 25 cm or larger; cobble material 6-25 cm; gravel material 0.2-6 cm; fines are the smallest granular material visible (<0.2 cm).

1. Mispec Beach (MB)

Mispec Beach is a municipal park owned and maintained by the City of Saint John and has experienced storm damage and erosion in the past. Along the beach the land ownership includes sections of privately ownership including the unnamed brook that is owned by Irving Oil Limited (Appendix B).

At the beach access point, the slope is steep, and a staircase is in place (Figure 9B). The staircase has been damaged in multiple storm events forcing visitors to walk down the adjacent slope accelerating erosion at the access point. During winter months the staircase is removed to avoid damage from winter storms. At the edge of the parking lot overlooking the beach, a slope has been partially reinforced with riprap to slow erosion from waves (Figure 9C). A full summary of observations is presented in Table 8.

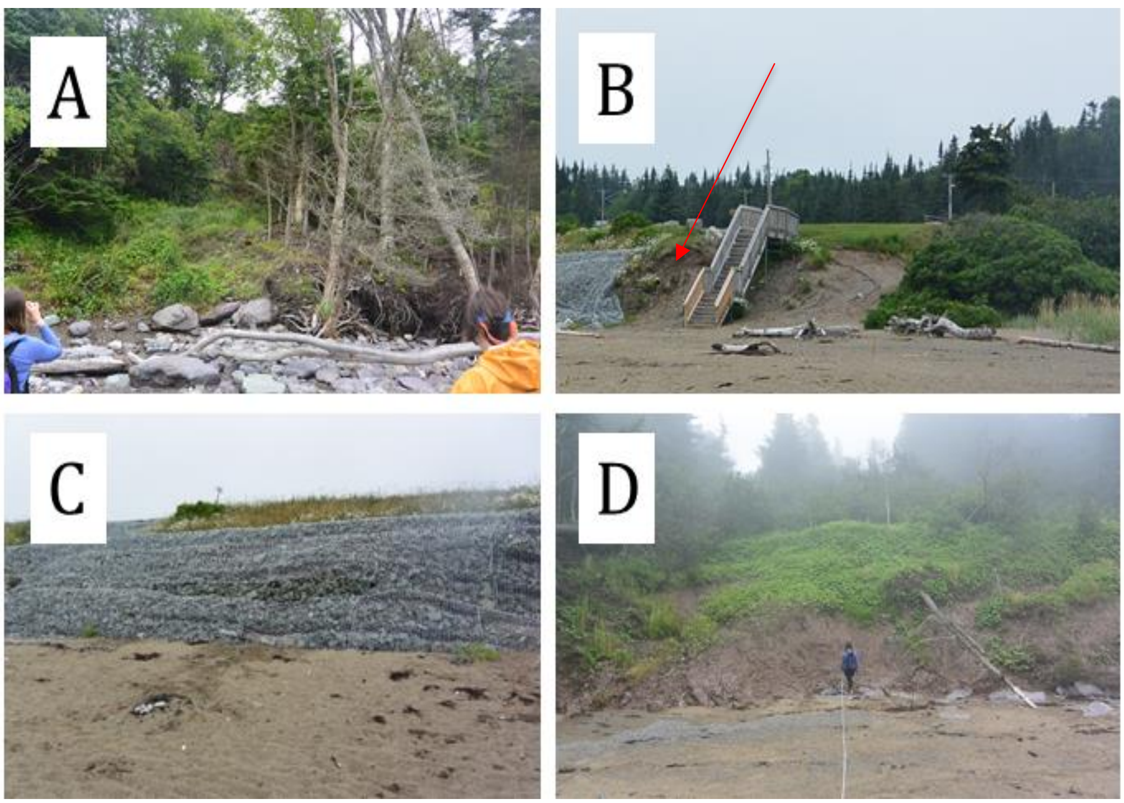

Figure 9: Sites of erosion observed summer 2021 at Mispec Beach. (A) MB1 where fallen trees and debris are found on steep slopes. (B) Beach access at the end of MB3 showing the slope (58%) beside the staircase and the new material from repairs at the base of the the steps. Red arrow highlighting a culvert that outlets onto the backshore. (C) Riprap section in MB4 and MB5 where parking area overlooks the beach. (D) Successional slumping in MB7 where vegetation has grown on previously slumped material.

KEY OBSERVATIONS

- Overall, the site is partially stabilized except in one section where riprap is in place allowing the shoreline to be highly stabilized (Figure 10).

- Riprap and caging is used to stabilize MB4 and MB5. Tearing is noted and repairs may be required to maintain stability of this section (Figure 11).

- Partially stabilized areas have fallen trees and overhanging vegetation, but no active erosion was observed.

- Soil type is mainly sand over clay with loamy sand observed in some sections.

- Predominant form type is steep slope with a waterbody in MB3 where an unnamed brook outlets into the backshore (Figure 11). Smaller stream outlets are observed in MB5 and MB6.

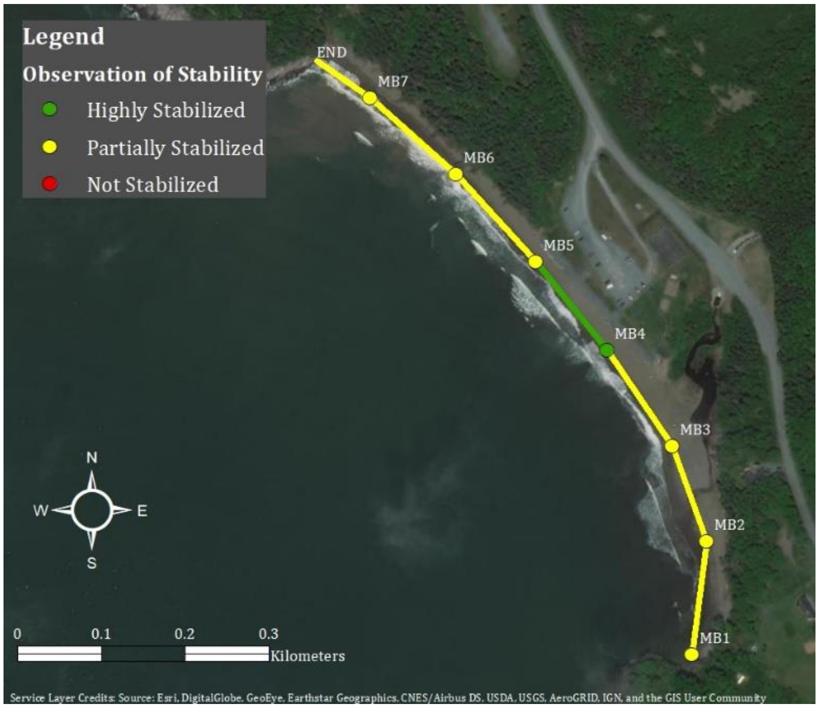

Figure 10: Observation of stability at Mispec Beach observed summer 2021.

- Anthropogenic installation of riprap in place in MB4 and MB5 and piping observed in MB5 (Figure 11).

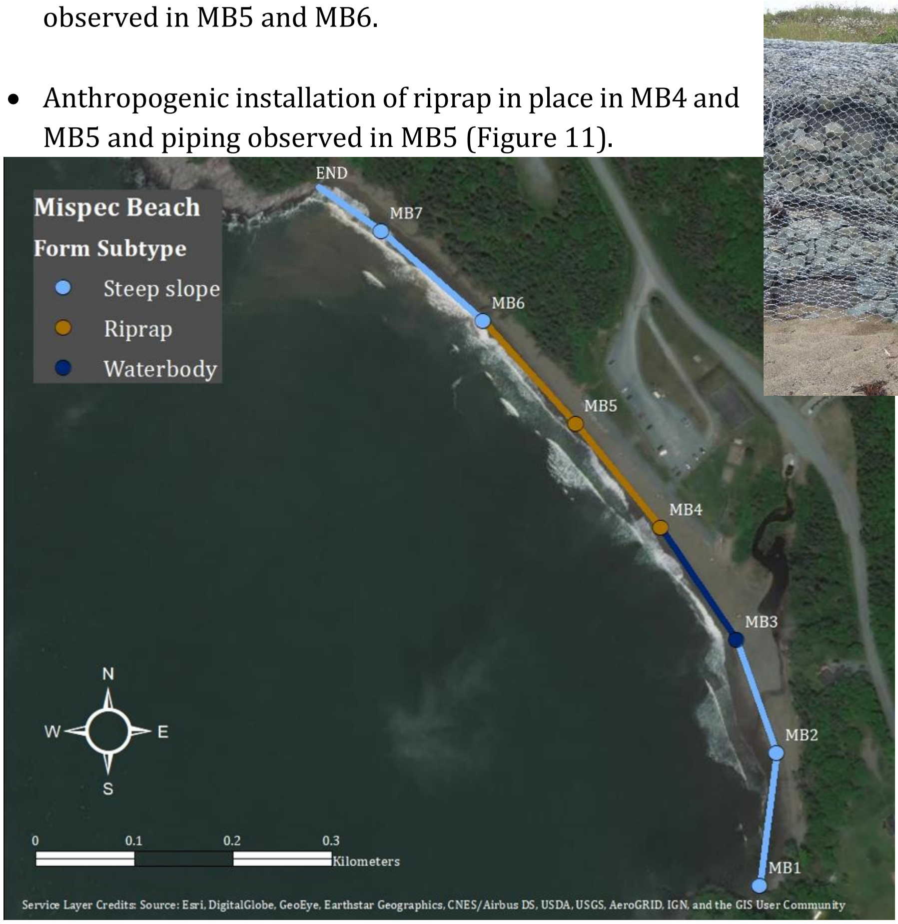

Figure 11: Left, form types along Mispec Beach observed summer 2021. Image above, showing a drainage channel in the riprap where repairs may be required.

Table 8: Mispec Beach site assessment data summary.

Assessment Variable	**Observation**	**Notes**
Predominant Observation of Stability	Partially stabilized	Only one section is highly stabilized (MB4). This is where protection is in place and will require maintenance and repairs.
Land Use	Recreational	Residential area starting in MB1 and transitioning quickly to recreational.
Vegetation	Fully or mostly vegetated	Trees and grasses are the dominant vegetation.
Soil Textures	Clay and clay with sand layer overtop	Typical for this area. Some loamy sand observed.
Primary Form Type	Steep slope	Predominantly steep slopes with anthropogenic installation of riprap to stabilize slope in MB4 and MB5. Waterbody at MB3 where unnamed brook outlets onto the beach.
Slope Range and Average	40-100% slope range with an average of 71%	Greatest slope is where riprap is installed in MB4 and at the easternmost point MB1. Slope at beach access in MB3 is approximately 58%.
Backshore	Predominantly fines with gravel as secondary material type	Cobble and some bedrock found in sections MB1/MB2 and at END.
Foreshore	Unconsolidated beach	Predominantly fines. Gravel and cobble make up 20-40% in some sections.

2. Anthony's Cove (AC)

Anthony's Cove is a residential area beyond Red Head in East Saint John. The site is predominantly private ownership apart from two land parcels owned by Irving Oil Terminals & Pipelines G.P. (Appendix B). The area has a history of erosion where roads have been lost and the main access road, Anthony's Cove Road, is currently protected by riprap. The stretch of riprap is stabilizing the roadway however the culvert allowing Anthony's Brook to pass underway is impacted by the eroding road where blocks put in place for support have slumped overtime (Figure 12A). During spring melt and heavy rainfall, residents have observed the culvert to be extremely full and in combination with a high tide event, the infrastructure is highly vulnerable to erosion. Residents have seen changes in the waterways along the coastline due to rising sea levels and erosion, as well as the construction of a large culvert at Bean Brook about halfway down the main cove towards Cranberry Point (Figure 12B).

The assessment begins at Cranberry Point where the coastline is not stabilized and is directly exposed to wind and wave action during storms. Homeowners in Anthony's Cove have experienced damages, flooding, and loss of land during extreme weather events. At the end of Anthony's Cove Road, a utility pole has been relocated on multiple occasions and will require further attention as the roadway that is supporting the infrastructure is eroded due to wave action and overland runoff (Figure 12D). A full summary of observations is presented in Table 9.

Figure 12: Example of form types at Anthony's Cove. (A) Anthony's Cove culvert in AC10 showing cracking of Anthony's Cove Road. (B) Bean Brook culvert in AC7. (C) Riprap protecting roadway ends in AC14 and begins again in AC17. (D) Erosion near utility pole at AC23.

KEY OBSERVATIONS

- Appears highly stabilized, however residents are highly vulnerable to extreme weather, storm surge, and sea level rise (Figure 13).

- Stability is gained by presence of riprap, vegetation, and rock material in the foreshore.

- In AC23, privately installed riprap stretches approximately 40 m, however as a whole, this section is not stabilized.

- Coastline is a mix of forms with a large section of riprap along Anthony's Cove Road (AC12-AC18) (Figure 14).

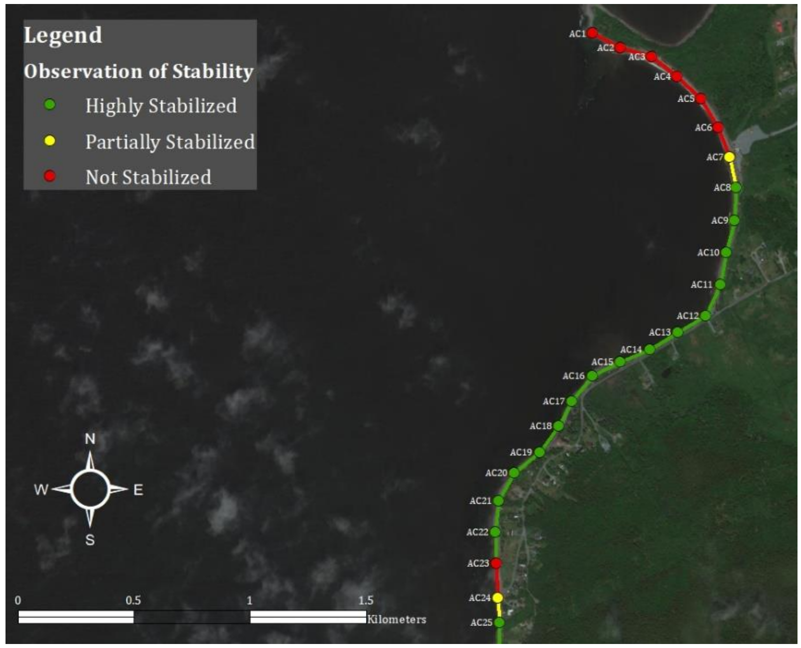

Figure 13: Stability of Anthony's Cove observed in summer 2021. A large section of the coastline is highly stabilized but highly vulnerable to the impacts of extreme weather, storm surge, and sea level rise.

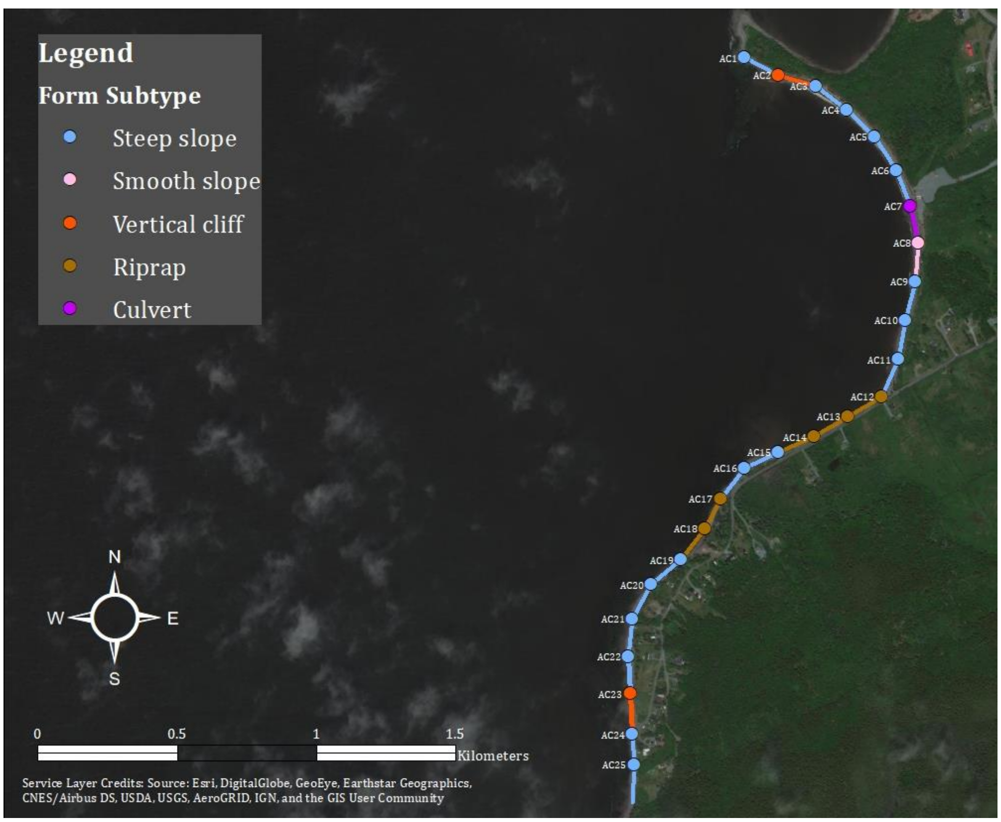

Figure 14: Form types along Anthony's Cove observed in summer 2021.

- High degree of variation in vegetation with a large portion of the coastline partially, mostly, or fully vegetated with grasses. Loss of vegetation due to erosion is observed (Figure 15).

- Engineered culvert at Bean Brook (end of AC6) and evidence of old culvert in AC7 (Figure 16).

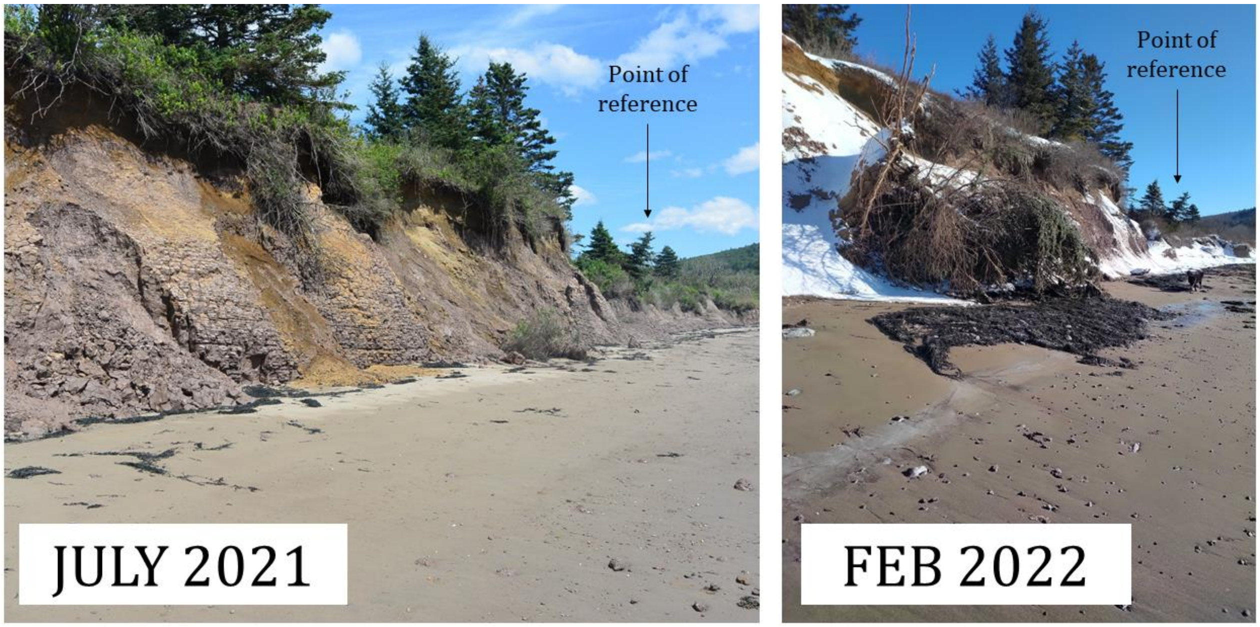

Figure 15: Observed loss of vegetation in AC2 over the course of the project. Trees along the coast can be used as reference points to compare the images. The newly fallen tree in February 2022 can be seen intact during the site assessment completed in July.

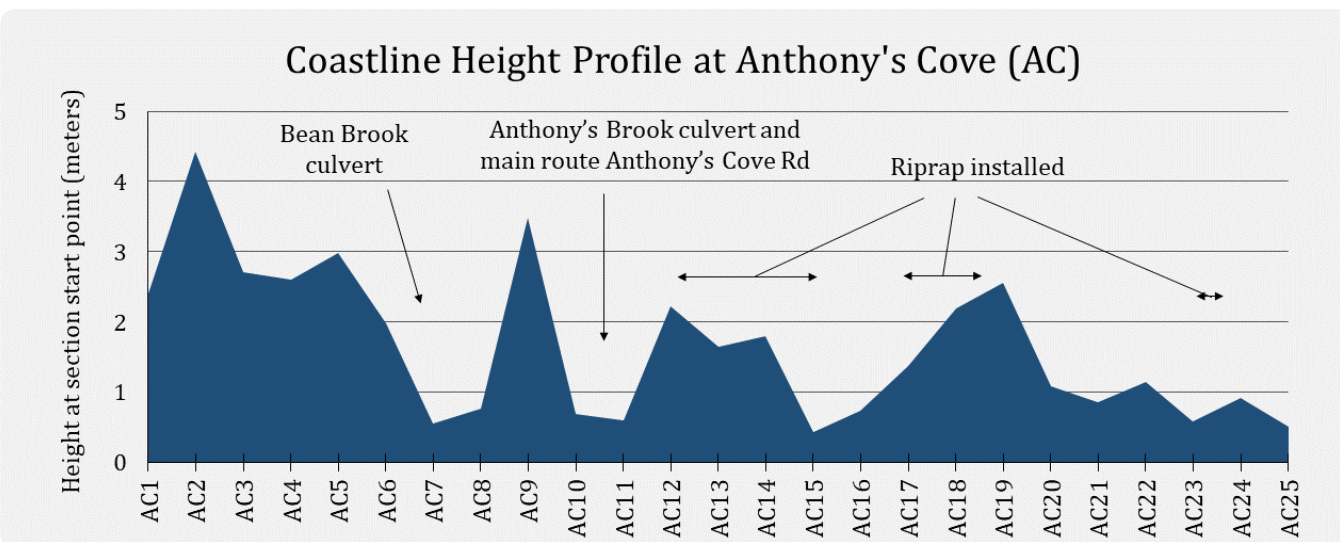

Figure 16: Height profile for Anthony's Cove observed in summer 2021 highlighting changes in form type and locations of infrastructure. AC9 and AC19 were both observed as steep slopes with full vegetation. Runoff was observed in several sections as a large contributor to erosion. At AC15 and AC16 riprap is disrupted and a parking lot lookout is observed.

Table 9: Anthony's Cove site assessment data.

Assessment Variable	Observations	Notes
Predominant Observation of Stability	Highly stabilized	Riprap protection, foreshore rock material, and vegetation creates highly stabilized coastline, however AC1 to AC7 along Cranberry Point is not stabilized and at AC23 and AC24 (the end of Anthony's Cove Road) stability is lost. Where stable, homeowners are highly vulnerable to storm events and sea level rise.
Land Use	Residential	Recreational uses in the main cove (AC1-AC12) accessed through private but shared access point on Anthony's Cove Road. Culverts in place at AC6-AC7 and in AC11. A parking lookout is used by visitors in AC15 and AC16, where many tidal pools are found in the exposed foreshore.
Vegetation	Partially to fully vegetated predominantly with grasses	No to little vegetation is found where riprap is installed and on the cliff in AC2. Overhanging vegetation on cliffs AC1-AC4. Partial vegetation in AC23 where privately installed riprap is observed.
Soil Textures	Sandy loam and sand layer over clay	Some sections are predominantly sand (AC8-AC10).
Form Type	Steep slope	Some cliffs are observed but steep slope is the predominant form type.
Slope Range and Average	0-100% slope range with an average of 61%	Slope is highly variable with highest slopes found along AC2-AC5 and at AC23 to END. Riprap sections have estimated slope of 59%.
Backshore	Material type varies, gravel is consistent throughout but not always predominant	At AC1 material is mostly fines and gravel but changes to being mostly gravel and cobble, and ending with a mix of gravel, cobble, and boulder material.
Foreshore	Unconsolidated beach, variation in material types	Predominant foreshore material changes throughout the coastline. AC1-AC8 is mostly fines but changes to be predominantly cobble until it changes again at AC16 to boulders and bedrock material.

3. Red Head (RH)

The community of Red Head has been faced with challenges of coastal instability for decades (Figure 17). The area is predominantly private land, and many of the homes built along Red Head Road have been lost, relocated, or abandoned due to instability. Along this stretch of coastline, the city owns three parcels of land, and Biron Engineering has ownership of a section at the northwestern tip (Appendix B). The history of erosion includes a large slumping event in 1995 where two homes were torn down due to structural damage and one was relocated (ACAP Saint John, 2001). Various measures have been taken to slow down erosional processes including the community effort to install tires as protection however, none have proven successful. ACAP Saint John has worked with the Red Head Community Association to clean up the tire debris, yet many are still observed along the shoreline (see ACAP Saint John Report *Operation Red Head, 2017)*.

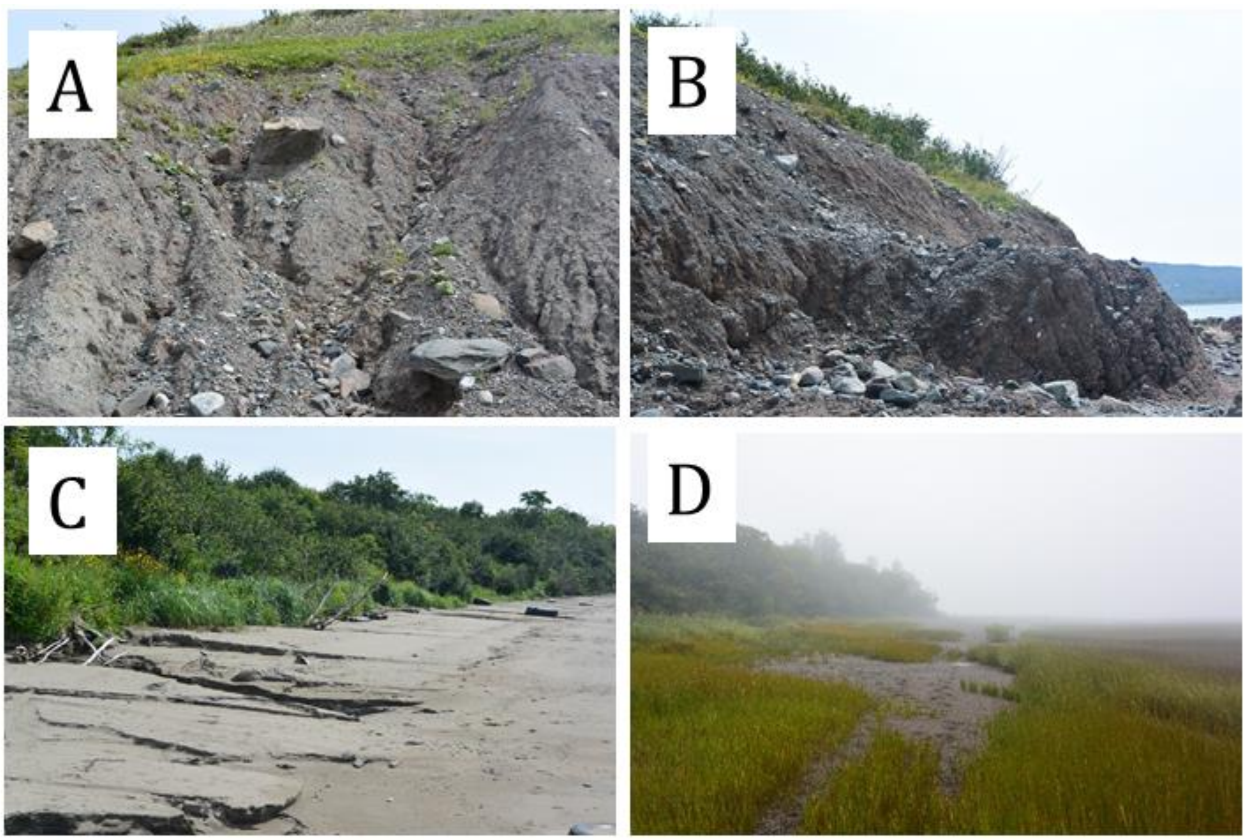

Figure 17: Observations of stability at Red Head. (A) Loose boulder material in RH2 where slope is not stabilized. (B) Slumped material in RH3. (C) Overland drainage channels in the backshore at RH22 where coastline is highly stabilized. (D) Vegetation in the backshore and foreshore at RH25.

Researchers have determined that relocation and setbacks are the best option for residents in this area, and that the installation of hard armouring will not be sufficient to protect the coastline long term (ACAP Saint John, 2001). The observations at Red Head confirm the severity of erosion and the need for setback regulations and enforcement of coastal development policies. A full summary of observations is presented in Table 10.

KEY OBSERVATIONS

- The largest section of Red Head is not stabilized, and previous slumping events are observed. Areas with partial stability may be due to protective installations put in place (Figure 18).

- The coastline is highly stabilized at RH20-END due to the geography where the cove is sheltered from erosional elements and the presence of vegetation (Figure 18).

Figure 18: Stability of Red Head observed in summer 2021. Images: Top left, majority of the coastline are steep slopes that are not stabilized. Bottom left, overhanging vegetation is observed.

- Steep slopes are the predominant form type (Figure 19).

- Debris and damaged protection efforts are observed (Figure 20).

- Homes are observed close to the edge of the slope and many areas where debris has fallen into the backshore (Figure 20A/C).

Figure 19: Form types observed at Red Head in summer 2021.

- Erosion is observed beyond installed protection suggesting that high water events have surpassed protective measures.

- Coastline is high from RH1-RH16 and then slowly declines toward Beyea Brook (Figure 21).

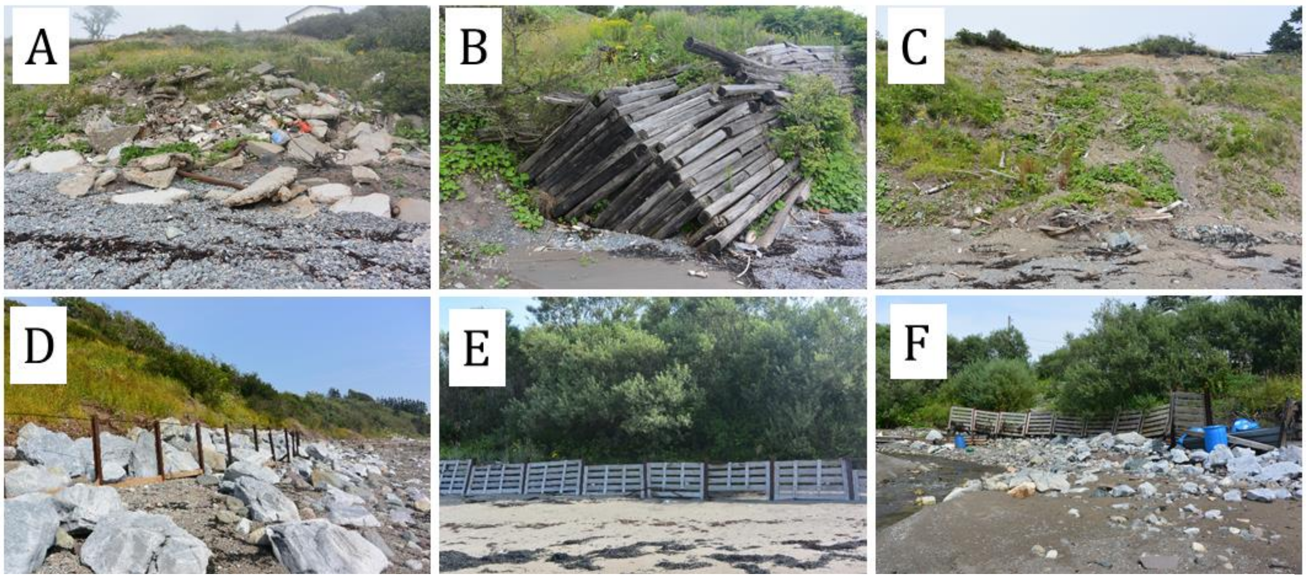

Figure 20: Debris and damaged protective measures at Red Head. (A) Debris along the slope in RH9 and a structure in the top right corner on the slope edge. (B) Damaged wooden seawall in RH10. (C) Additional debris scattering the slope in RH11 with structure at the top of the slope. (D) Protection in RH12 where riprap and seawall installments are ineffective to protect the coastline. (E) Coastal fencing in RH15, relatively intact and fully vegetated. (F) Damaged fencing with debris at RH20 alongside the outlet of Beyea Brook.

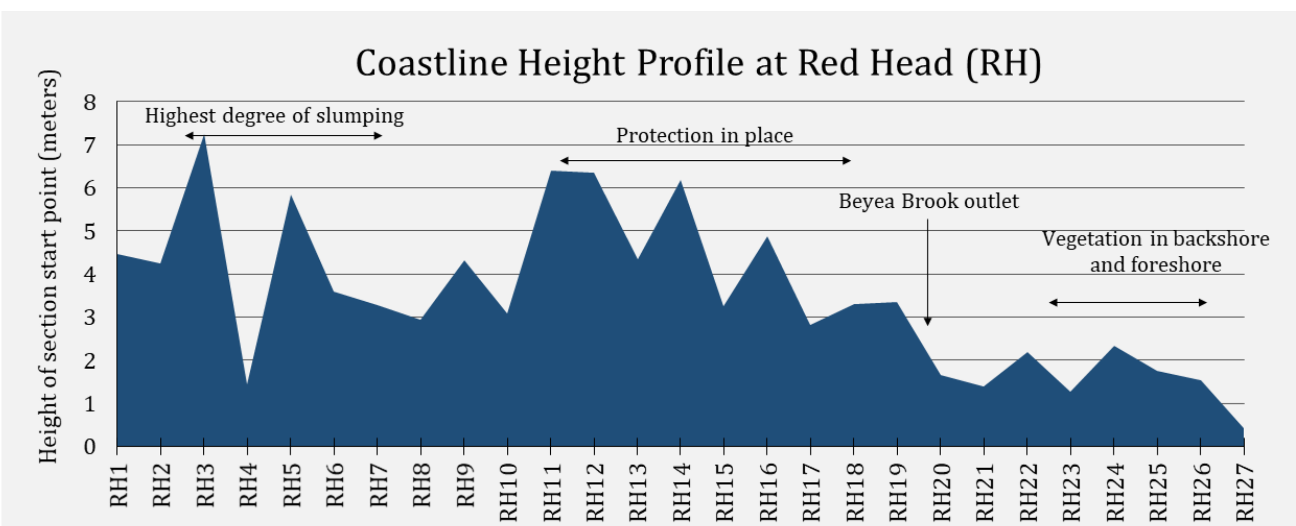

Figure 21: Height profile for Red Head observed in summer 2021 highlighting changes in form type and key infrastructure. Slumping is observed throughout the coastline. Debris littering the backshore in RH9 and RH11.

Table 10: Red Head site assessment data summary.

Assessment Variable	Observations	Notes
Predominant Observation of Stability	Not stabilized	The largest section of Red Head is not stabilized however partial stability is observed beginning at RH14. This partial stability may be due to protective installations put in place. The coastline is highly stabilized at RH20-END due to the geography where the cove is sheltered from erosional elements and the presence of vegetation.
Land Use	Residential	The coastal beaches are used primarily by landowners who have private access down to the beach. Channels from overland runoff observed throughout. Beyea brook outlet stretching approximately 5 m across the backshore in RH19. Tires scattered in the backshore.
Vegetation	Fully or mostly vegetated	The steep slopes are fully or mostly vegetated in many sections with grasses and shrubs including Japanese Knotweed and Willow. Few trees are observed until RH18 to RH26. Wave action reduces vegetation at the slopes base and creates overhanging vegetation in many sections.
Soil Textures	Sand layer over clay, horizons visible on steep slopes	Clay is predominant is some areas. Sandy clay loam and sandy loam present where soil transitions from clay to sand.
Form Type	Steep slope	Anthropogenic protection (intact and damaged) is observed in RH13-RH18 including riprap, wooden seawalls, and gabion baskets.
Slope Range and Average	0-100% slope range with an average of 74%	The slope is predominantly 80-100%, with some sections being completely vertical. The average is reduced significantly by few sites that have considerably smaller slopes than the rest of the coastline.
Backshore	Variable material types	RH1-RH5 predominantly boulders, changing to cobble and gravel until RH12 where boulders are the primary material again. Vegetation in the backshore at RH23-RH26. Backshore is reduced in RH25 to END.
Foreshore	Unconsolidated beach, variable material types	RH1-RH5 predominantly boulders, changes to fines and cobble as primary material. Gravel is predominant in RH8-RH10. At END foreshore is has consolidated bedrock material and unconsolidated cobble and gravel. RH22-RH26 significant vegetation (grasses) in the foreshore.

4. Hazen Creek (HC)

The area where Hazen Creek outlets into the Bay of Fundy is primarily used as a recreational spot for beach walking and sea glass combing but is also residential with homes located on the south-eastern and northernmost part of the coastline (AC1-AC3, and AC15-END). The land ownership varies including private owners, the city, JD Irving Limited, and NB Supply and Services (Appendix B). The site includes a large section of riprap that protects Red Head Road from storm surge flooding during extreme weather (Figure 22C). Along with the roadway, a bridge and utility infrastructure are at risk to the rising tides and although riprap has effectively protected these assets, a long-term strategy for this site may be necessary. Field work completed throughout summer 2021 observed additional riprap being added to raise the breakwater. A full summary of observations is presented in Table 11.

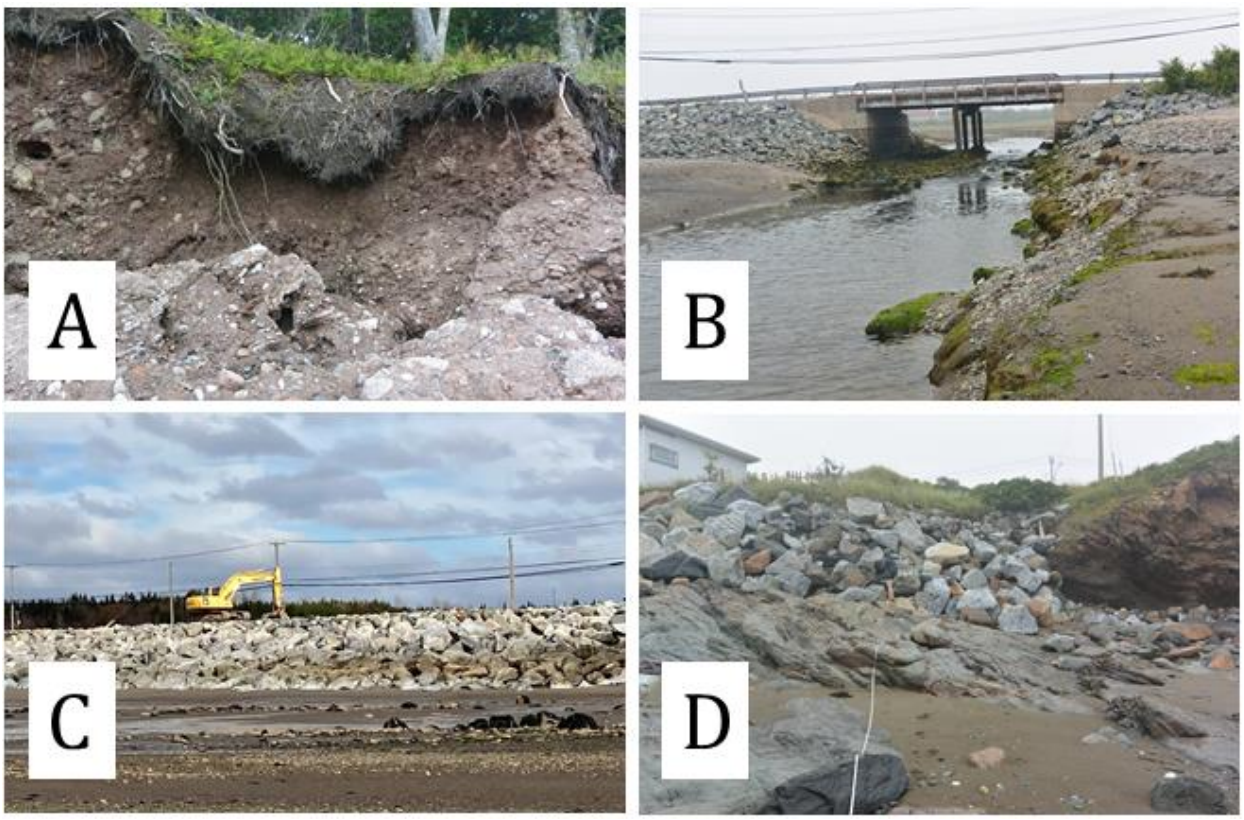

Figure 22: Observations of stability and key infrastructure at Hazen Creek. (A) Overhanging vegetation at HC5. (B) Bridge at Red Head Road crossing over Hazen Creek. (C) Maintenance of riprap in November 2021. (D) Home (left) at HC14 where some riprap is observed along with bedrock outcrops in the backshore and on the right.

KEY OBSERVATIONS

- This site is highly stabilized due to the presence of riprap stretching through HC9-HC14 (Figure 23).

- Residential areas at HC1-HC3 and HC15 may be partially stabilized but are highly vulnerable to sea level rise and storm surge.

Figure 23: Observation of stability at Hazen Creek in summer 2021. Images: Top right, riprap and powerlines observed in HC13. Bottom right, trees falling from slopes in HC6. Both images show the highwater mark, resulting in a reduced backshore along the coastline.

- Where present, vegetation is predominantly shrubs and grasses (Figure 24).
- Overhanging vegetation is observed in HC2-HC5.

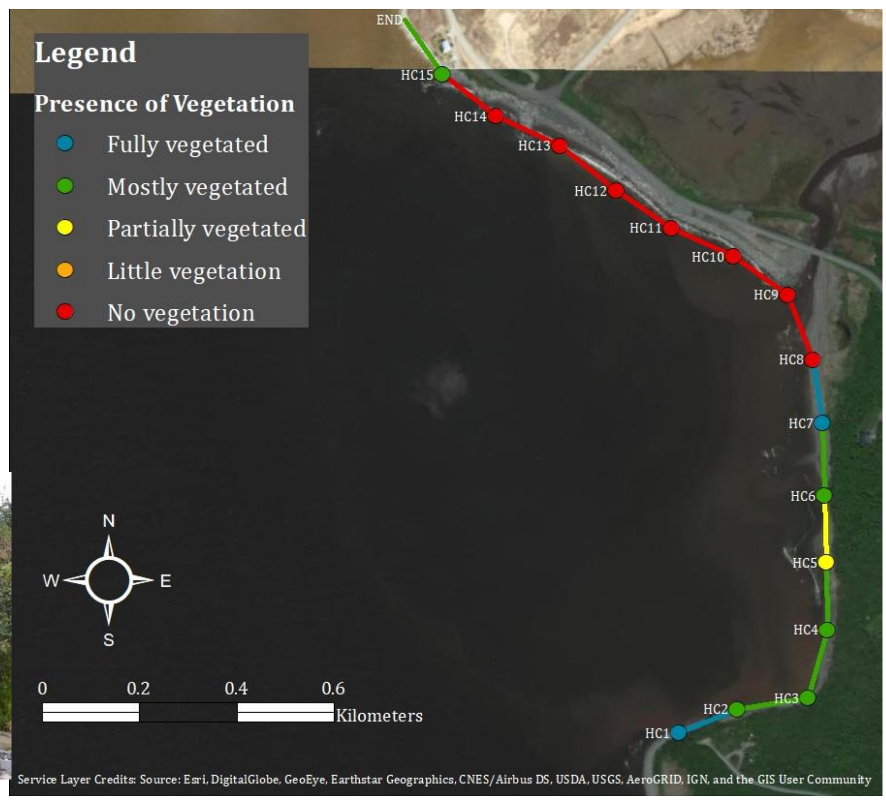

Figure 24: Vegetation observed summer 2021 at Hazen Creek. Image left, showing shrubs and grasses with some overhanging vegetation on the slope in HC4.

- Riprap is the largest section of the coastline however steep slopes and vertical cliffs are observed (Figure 25).

- Riprap is protecting utility infrastructure along the roadway.

- Hazen Creek outlet and bridge at the end of HC8. Parking area at the start of HC9 (Figure 26).

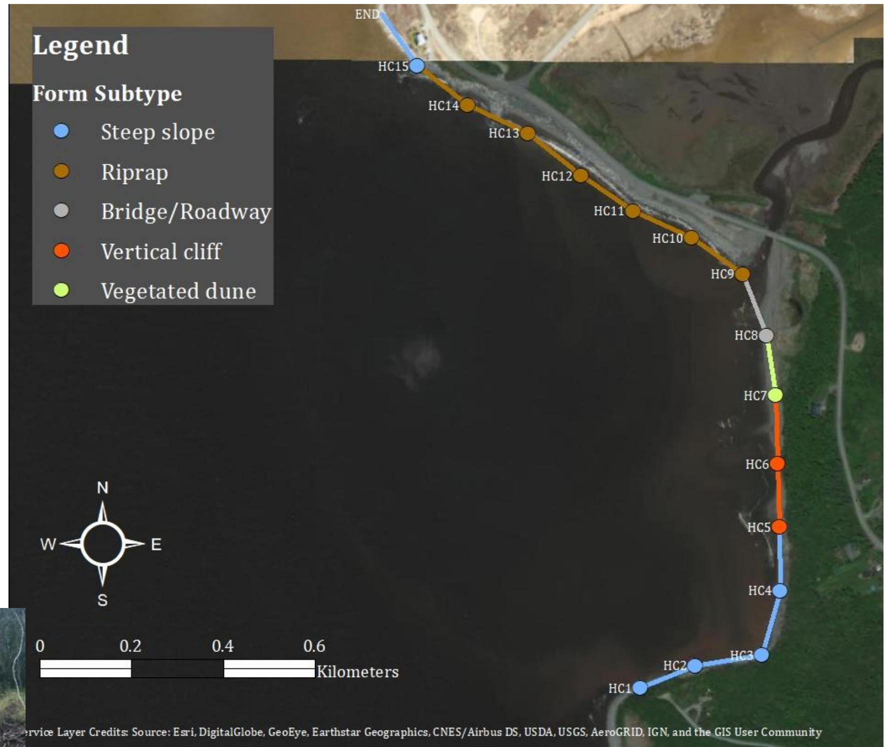

Figure 25: Form types observed at Hazen Creek during summer 2021. Image left, exposed bedrock material in HC5 with falling trees and overhanging vegetation.

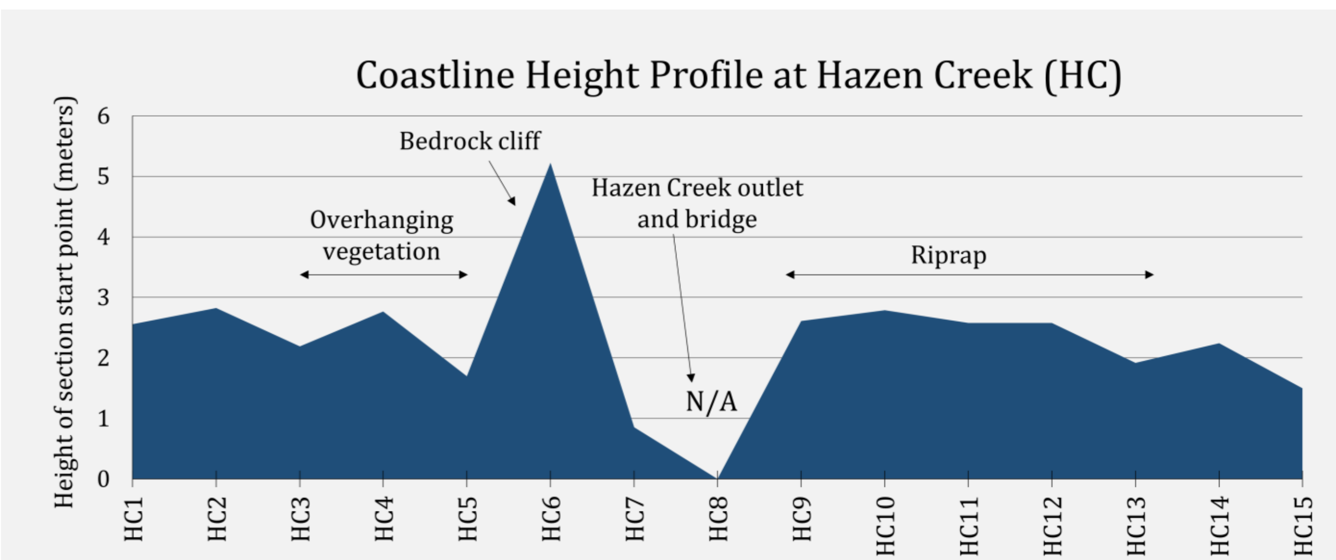

Figure 26: Height profile for Hazen Creek observed in summer 2021 highlighting changes in form type and key infrastructure. Homes in HC1-HC3 and HC15. Culvert outlet at HC13.

Table 11: Hazen Creek site assessment data.

Assessment Variable	**Observations**	**Notes**
Predominant Observation of Stability	Highly stabilized	This site is highly stabilized due to the presence of riprap stretching through HC9-HC14. Areas of partial stability include the residential area at HC15. Residential areas at HC1-HC3 may be stabilized but are highly vulnerable to storm surge and sea level rise.
Land Use	Recreational / Residential	The beach accessed by the parking lot on Red Head Road is recreational but residential areas are observed at HC1-HC3 and HC15. At HC8 Hazen Creek outlets below a bridged roadway. The roadway with utility poles and powerlines continues parallel to the coastline protected by riprap (HC9-HC14). Culvert in HC13 outlets onto the backshore.
Vegetation	Where present, predominately shrubs and grasses	Where most of the coastline is riprap (HC9-HC14), the coastline has no vegetation. In sections HC1-HC7 and at HC15-END vegetation is predominantly shrubs and grasses.
Soil Textures	Rock, sand layer over clay	Clay is observed along with sandy clay loam layers, however rock is predominant including both bedrock and riprap. Bedrock material is present in HC4-HC6 and at HC15 to END.
Form Type	Riprap, Steep slope	Riprap is the largest section of the coastline however steep slopes and vertical cliffs are observed in HC1-HC7. A dune is present where the coastline approaches the roadway and Hazen Creek outlets.
Slope Range and Average	0-100% slope range with an average of 60%	The highest slopes are observed in HC3-HC8 where steep slopes and cliff forms are observed. Along the riprap HC9-HC14 slope is an average of 46%.
Backshore	Variable material types	Gravel and cobble are dominant from HC1-HC8. Fines, gravel, and cobble are distributed throughout the coast. Boulders are observed at HC15-END. Backshore is reduced throughout the coastline where the high tide mark reaches the cliff in HC4-HC6 and the riprap in HC9-HC14.
Foreshore	Unconsolidated beach, variable material types	Material types shift from being predominantly cobble (HC1-HC7) to fines (HC10-END). Gravel is present consistently.

5. Bayshore Beach (BB)

Bayshore Beach is a popular recreational space in Saint John where visitors can enjoy the tidal flats, walk their dogs, and comb for sea glass. There is a residential community living along Sea Street and Seal View Lane as well as a train yard spanning a large section of the coastline. Ownership of this area is split between New Brunswick Southern Railway Co., Canadian Pacific LTD, McNulty Cartage (1987) LTD, and the City of Saint John (Appendix B). The beach is at the base of a steep roadway and stretches west from the Partridge Island breakwater until bedrock cliffs create a natural barrier.

Along the coastline evidence of infrastructure loss and slumping events are observed (Figure 27). In 2019 a slumping event occurred moving material into the backshore and creating a barrier for walking the beach during hightide (in section BB7). A full summary of observations is presented in Table 12.

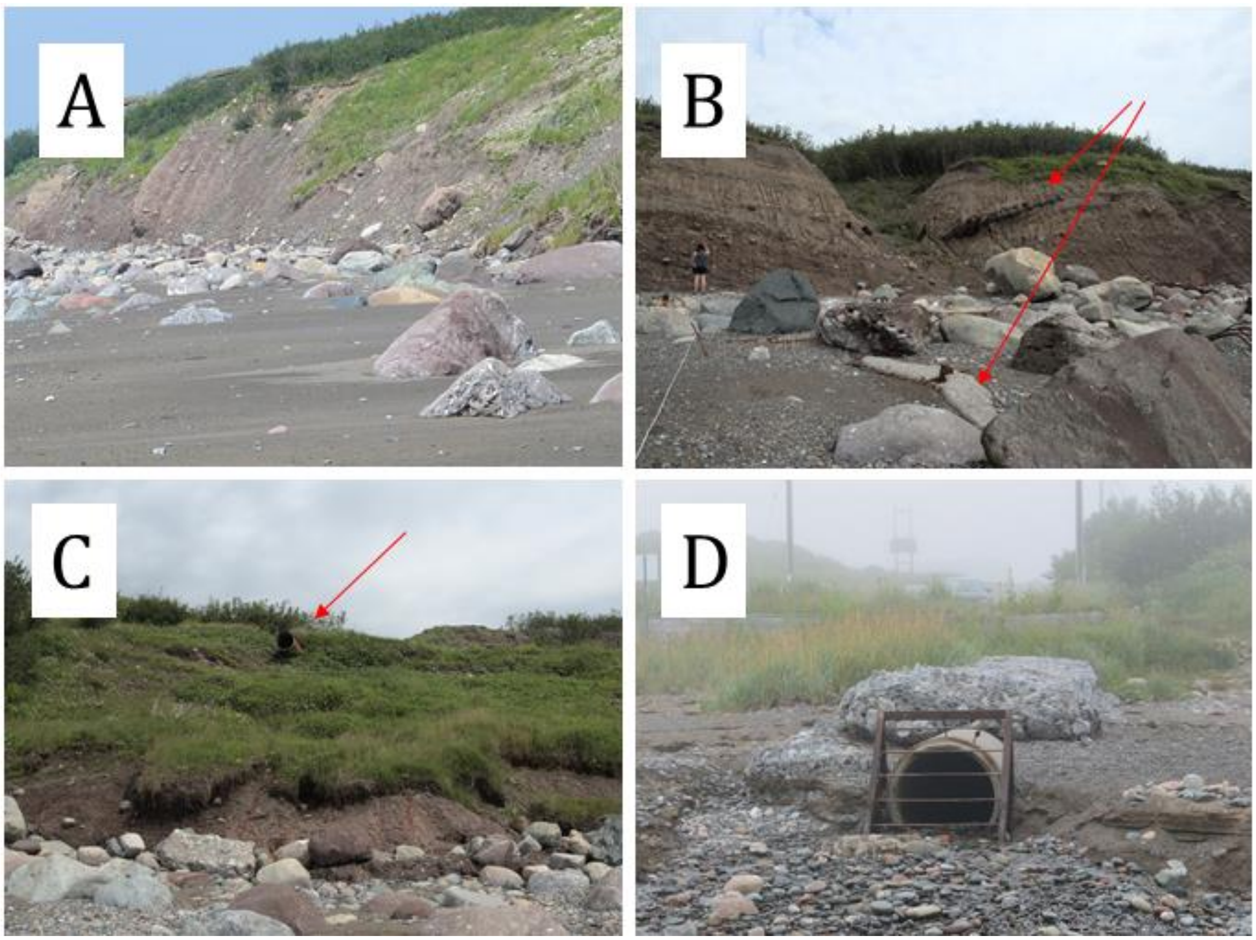

Figure 27: Highlighting form types and infrastructure at Bayshore Beach observed 2021. (A) Steep slope in BB3 with many boulders observed in the backshore. (B) Infrastructure and debris along the coastline and backshore in BB5. (C) Piping outlet at BB6 with vegetated slumps observed along the slope. Overhanging vegetation at the base. (D) Stormwater outlet and gabion support structures in BB11.

KEY OBSERVATIONS

- Falling boulders and slumping material are observed in areas with least stability (BB2-BB7) (Figure 27B).
- Infrastructure and debris observed including piping outlet in BB6 where large slump is observed (Figure 27C).
- Beach access and parking area in BB11 where a stormwater outflow pipe is supported by gabion structures (Figure 27D).
- Sections BB11-END are observed to be highly stabilized, but residents and infrastructure are highly vulnerable to storm surge and sea level rise (Figure 28).
- Slumping event in 2019 has created a blockage during hightide (Figure 29).

Figure 28: Observation of stability at Bayshore Beach in summer 2021. Images: left, vegetated slopes observed from BB12-END creating natural protection for residential infrastructure. Right, vegetation around public beach access in BB11 before slope increases where residential development is observed.

- Majority of the coastline is vegetated including steep slopes and slumped areas creating a high degree of variation in the height profile (Figure 30).

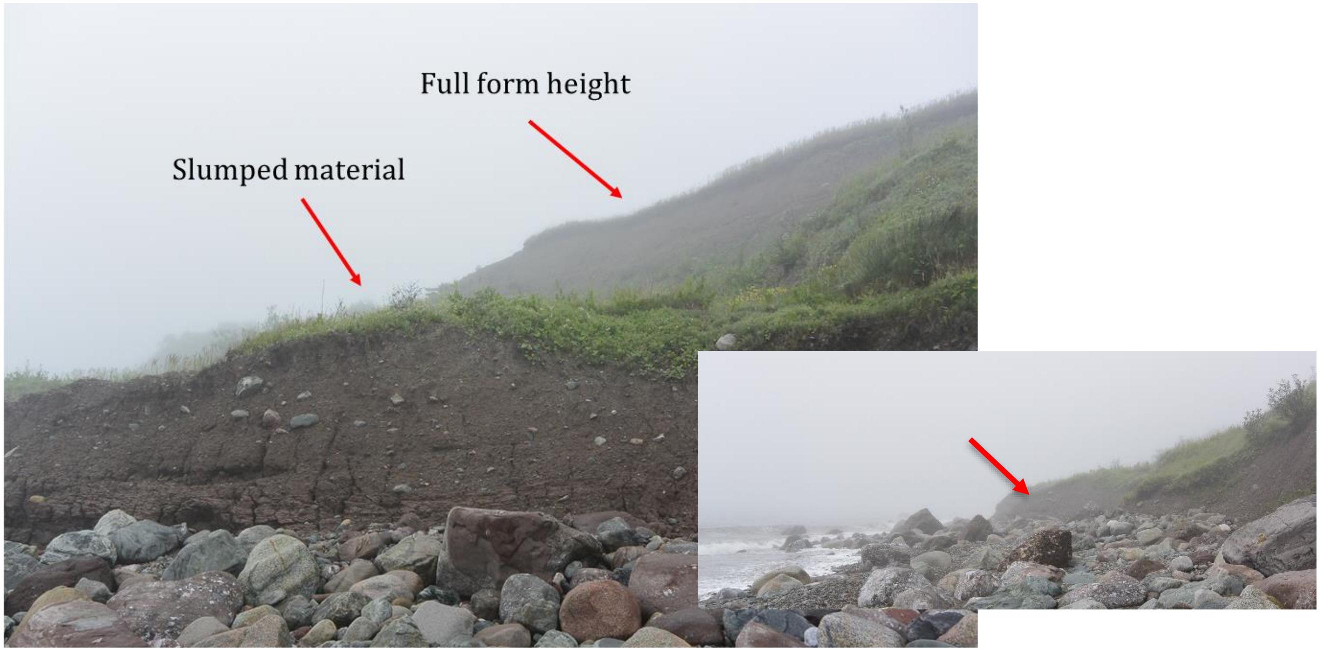

Figure 29: Left, large slump in BB7. Drainage channels are observed on the exposed slopes. Vegetation has grown on the slumped material. Right, material is blocking a section of the backshore creating a carrier to the beach during high tide. Note, many boulders in the backshore and along the shoreline.

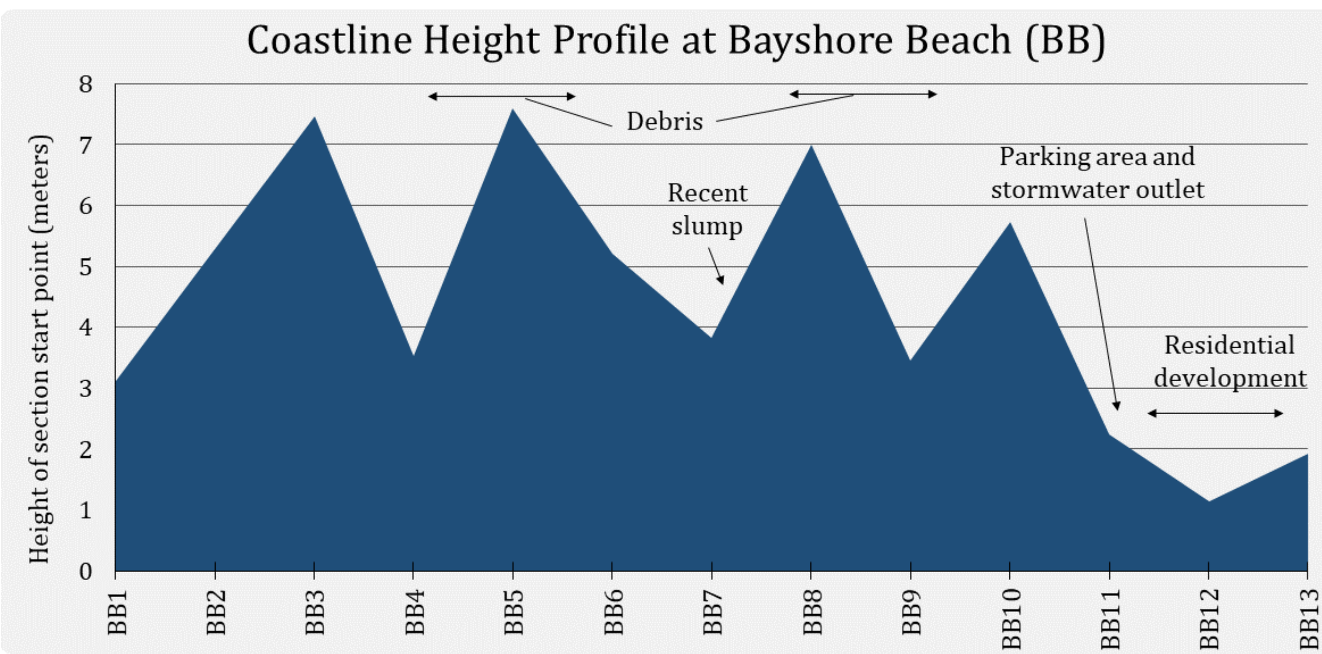

Figure 30: Height profile observed at Bayshore Beach in summer 2021 highlighting form changes and key infrastructure. Successional slumping is observed throughout the coastline.

Table 12: Bayshore Beach site assessment data summary.

Assessment Variable	**Observations**	**Notes**
Predominant Observation of Stability	Not stabilized	Predominantly not stable and partially stabilized. From BB11- END the coastline is highly stabilized, but residents and infrastructure are highly vulnerable to sea level rise and storm surge.
Land Use	Recreational/Residential	Primarily recreational with public parking lot and access in BB11. At the top of the coastline's steep slopes an active rail yard runs from BB3 to BB9. In BB9 and BB10 homes along Seal View Lane are also built at the top of the slope. Homes along Sea Street BB12-END are elevated atop a smooth slope. Infrastructure in BB11 where a stormwater outflow pipe is supported by gabion structures.
Vegetation	Partially to fully vegetated	Majority of the coastline is vegetated including the steep slopes and slumped areas. Predominant vegetation type is shrubs in BB1-BB5 and transitions to being grasses in BB6-END. No trees were observed.
Soil Textures	Sandy clay loam	Variations in soil texture with observations of sandy clay, clay, and sand throughout the coastline. Layering of sand above clay and sandy clay are observed.
Form Type	Steep slope	Steep slopes and vertical cliffs are predominantly observed. Beyond the parking area BB11-END the slope becomes smooth.
Slope Range and Average	0-100% slope range with an average of 59%	The highest slopes are observed in BB5 and BB6. Debris from infrastructure (concrete and rebar) are present in these sections.
Backshore	Variable material types	BB1-BB10 has relatively equal parts cobble, gravel, and boulder. BB11-END is predominantly fines and gravel with little to no boulder or cobble. Slumped material in BB7 showing multiple slumping events.
Foreshore	Unconsolidated beach, variable material types	BB3-BB9 is relatively equal in cobble, boulder, gravel, and fines. At BB1-BB2 no boulders observed. Beyond BB9, fines become predominant with gravel and little to no cobble and boulder.

6. Duck Cove (DC)

Duck Cove is a privately accessed beach located off Duck Cove Lane in west Saint John. The land is owned by private owners and the Duck Cove Recreation and Heritage Association Inc (Appendix B). The beach is approximately 350 meters in length with bedrock at each end creating a natural barrier (Figure 31A). The Shoreline Trail runs along the top of the coastline where steep slopes overlook the beach. A metal staircase has been installed to allow access to the beach where residents can walk along the waters edge. Apart from the staircase, the beach is free from infrastructure and only a small section of debris is observed (Figure 31C). Although locals are familiar with the area and may visit on occasion, the beach is primarily used by community members living in and around Duck Cove. A full summary of observations is presented in Table 13.

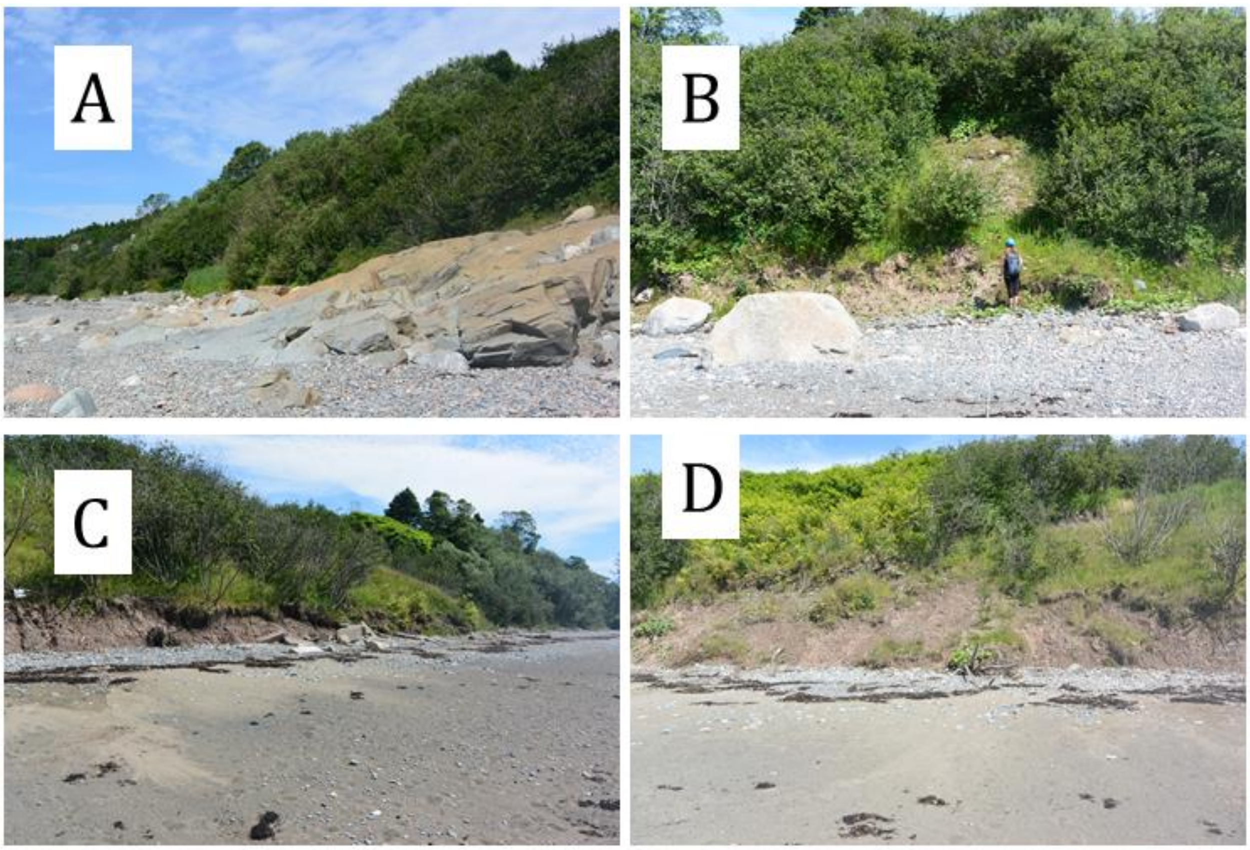

Figure 31: Highlights of erosion and form type at Duck Cove observed 2021. (A) Bedrock at DC1 looking west down the coast. (B) Steep slope in DC3 with shrubs as the dominant vegetation. Note the gap in vegetation where erosion is observed. (C) Debris at the base of the slope in DC3. Erosion from wave action and overhanging vegetation is observed. (D) At the end of DC3 before the height and erosion of the slope increase at DC4. The slope is mostly vegetated with erosion at the base. Note the shoreline washup in both (C) and (D) at the base of the slope.

KEY OBSERVATIONS

- No active erosion was observed until DC4-END where coast is not stabilized (Figure 32).
- Where stability is reduced, sand is the observed soil texture (Figure 32).
- Piping outlets observed in DC3 and runoff drainage and erosion in DC4.
- Fully to mostly vegetated with prominent vegetation type being shrubs (Figure 33).

Figure 32: Observation of stability at Duck Cove summer 2021. Image left: Eroded section at DC4 where coastline in not stabilized and sand is the predominant soil texture. Staircase access is on the left where vegetation returns but erosion is observed around the access point.

Figure 33: Presence of vegetation observed at Duck Cove in summer 2021. Image top, predominantly shrubs and grasses observed throughout the coastline. Note the home in the distance of DC3.

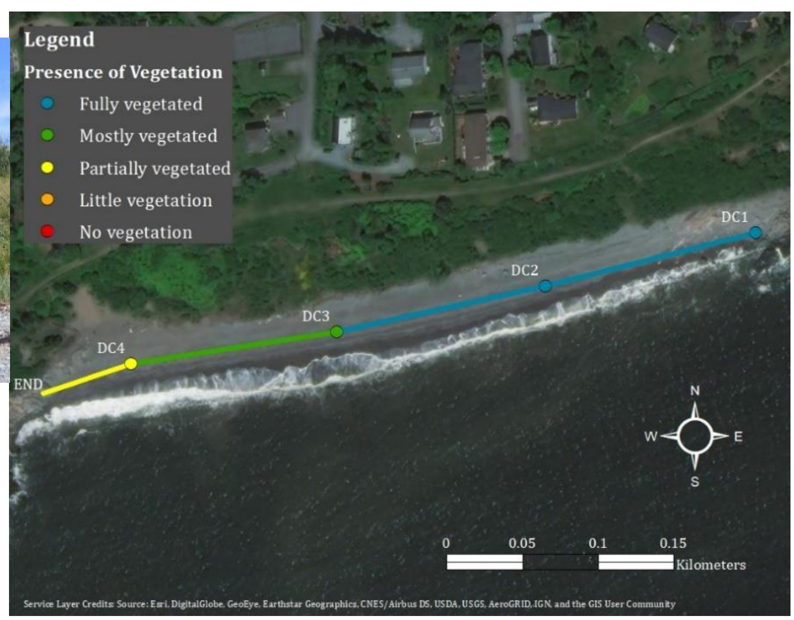

Table 13: Duck Cove site assessment data summary.

Assessment Variable	Observations	Notes
Predominant Observation of Stability	Partially Stabilized	The coastline shows evidence of erosion such as overhanging vegetation and slumping, but no active erosion was observed until DC4-END where coast is not stabilized.
Land Use	Residential	Private beach with access installed by homeowners. The Shoreline Trail runs along the top of the slope between the coastline and residential areas. Piping outlets observed in DC3 and drainage erosion in DC4.
Vegetation	Fully vegetated	DC4-END has the least amount of vegetation. DC1-DC3 vary from fully to mostly vegetated with the predominant vegetation type as shrubs (i.e., willows). Grasses are the secondary vegetation with only a few trees observed.
Soil Textures	Variable textures observed	A mix of sandy clay loam, clay loam, loamy sand, and sand along the coastline. Where stability is reduced the observed soil texture is sand.
Form Type	Steep slope	The entire coastline is categorized as a steep slope.
Slope Range and Average	20-80% slope range with an average of 57%	The slopes vary throughout the coastline with a greatest slope of 70% in DC4-END.
Backshore	Gravel and fines are predominant	Bedrock observed in DC1 and at END. In DC1 and DC2 cobble is predominant with some boulder. Transition in DC3 to becoming predominantly gravel and fines. Large concrete debris in DC3.
Foreshore	Unconsolidated beach, predominantly gravel and fines	In DC1 a wider range of materials, gravel, and fines with small amounts of cobble and boulder. DC2-END is primarily fines.

7. McLarens Beach (MCB)

A history of erosion and infrastructure challenges is observed at McLarens Beach where roads, homes, and utilities have been impacted due to erosion. The land is owned by multiple entities including the city, private owners, Saint John Diocesan Cemetery Co Inc. (ownership of cemetery), and NB Supply and Services (Appendix B). The beach is a recreational spot and for many years visitors and residents have been witness to the transformation of this coastline including the loss of land and park structures.

A study by Fundy Engineering in 2015 identifies homes at risk including residents living close to the beach on Morton Lane (off McLarens Beach Road) and along Sand Cove Road where elevation has dropped over 2 m at the property (Fundy Engineering, 2015). Additionally, at the end of Gregory Lane residents have installed protection methods to reduce wave erosion and slow erosional processes (Figure 34). As a result of erosional processes, Sand Cove Road (a primary access road to west side communities and the Irving Nature Park) has been reduced to one lane and utility infrastructure has been relocated. Work was completed in 2014 to stabilize the potable water line that services homes along McLarens Beach (Fundy Engineering, 2015). The challenges created by erosion will continue to impact the residents and infrastructure in this area. A full summary of observations is presented in Table 14.

Figure 34: Images (A) Wooden seawall in MCB4. Staircase shows signs of wave damage and wall is angled towards the shoreline indicating erosion is occuring beyond the protection. (B) Concrete seawall and riprap in MCB5 to protect homes.

KEY OBSERVATIONS

- Majority of the coastline is stabilized but highly vulnerable to sea level rise and storm surge (Figure 35).

- Impacts from erosion in the parking area in MCB8 where structural and asphalt debris are observed.

- Shrubs are the most predominant vegetation type, with willow and Japanese knotweed observed.
- A large section of debris is observed in MB6 where the cemetery is at the top of the coastline (Figure 36).

Figure 35: Observation of stability at McLarens Beach in summer 2021.

Figure 36: Image left, MCB6 looking southwest where debris is covering the slope. Right, debris in MCB6 could be from old infrastructure or infill used to extend and protect the coastline. Riprap observed along the shoreline leaving a gap between the water and debris.

Figure 37: Form types observed at McLarens Beach summer 2021.

- Seawalls and riprap are in place along the coastline (Figure 37).
- Form heights are lowest where the seawalls are in place and at the beach access (Figure 38).

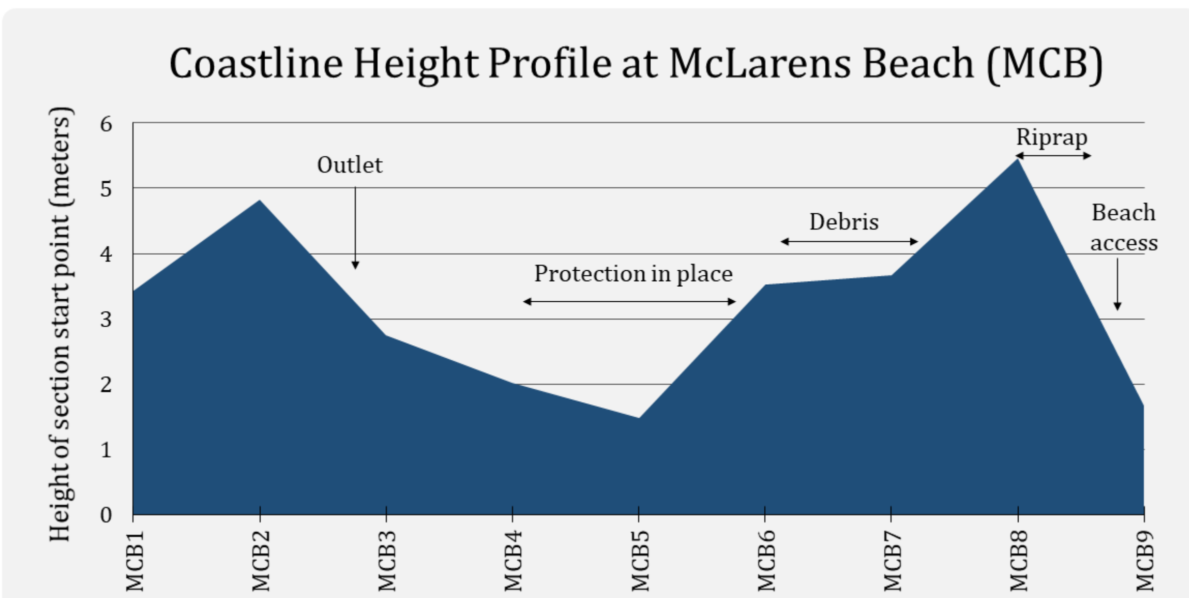

Figure 38: Height profile at McLarens Beach observed summer 2021 highlighting key infrastructure.

Table 14: McLarens Beach site assessment data summary.

Assessment Variable	Observations	Notes
Predominant Observation of Stability	Highly Stabilized	Majority of the coastline is stabilized but highly vulnerable. Areas with partial stability observed at MCB6-MCB7.
Land Use	Residential/ Recreational	Recreational access at McLarens Beach Road in MCB8-END however private residents along the coastline MCB9-END and MCB1-MCB5. Private residents have seawalls and riprap in place. Impacts in the parking area in MCB8 where structural and asphalt debris are observed. Runoff/stream outlet onto beach in MCB2. Impacts of erosion continue up to Sand Cove Road.
Vegetation	Fully or mostly vegetated	For most of the coastline vegetation is present. In MCB5 and MCB6 little vegetation is observed. Shrubs are the most predominant vegetation type. In MCB1 trees are dominant however there is a transition starting at MCB2-END where shrubs (willow and Japanese knotweed observed) become the primary vegetation type. Grasses present throughout.
Soil Textures	Sandy clay loam	Sandy clay loam is more frequently observed but clay loam, loamy sand, sandy loam, and sand are also observed.
Form Type	Steep slope	Steep and smooth slopes are predominant along the coastline. Seawalls and riprap are in place to protect homes in MCB4, MCB5 and MCB9.
Slope Range and Average	20-100% slope range with an average of 67%	The slopes vary throughout the coastline. Areas of partial instability (MCB6 and MCB7) are within the 80-100% slope range. Lowest slope at MCB1.
Backshore	Variable material types	MCB1-MCB4 predominantly cobble and gravel, with some bedrock. Transition in MCB5 until END to having boulder as primary material with cobble secondary, except for MCB8 where cobble is primary. Movement of material in the backshore due to wave action.
Foreshore	Unconsolidated beach, unconsolidated slope	Some areas of foreshore are highly sloped. Material types vary throughout, predominantly fines and cobble.

8. Sheldon Point (SP) at Saints Rest Beach

The Sheldon Point site is a recreational area with a hiking trail, coastal lookouts, and a direct link to Saints Rest Beach and the Irving Nature Park. The site is owned by JD Irving Limited and Voyageur Properties Limited (Appendix B). Access to the beach is found at the first parking lot of the Irving Nature Park or at the end of the Sheldon Point trail that begins off Sand Cove Road. Many residents explore this beach admiring the waves, steep slopes, and beautiful views. The area has experienced erosion in the past and both drainage channels from urban runoff and impacts from waves are observed. This site is part of a monitoring program with the New Brunswick Department of Energy and Natural Resources who continue to observe and measure changes along the coastline. As a recreational area, there is little infrastructure at risk however this area is highly vulnerable and with a high frequency of visitors, erosion may present a different set of hazardous challenges including rock falls and isolation due to mass movement. A full summary of observations is presented in Table 15.

KEY OBSERVATIONS

- No area is highly stabilized (Figure 39).
- Signs of active and historical erosion observed including falling rocks and trees, large erosional channels from urban runoff, and slumped material (Figure 40).
- Vegetation is observed on previously slumped material revegetated the coastline.

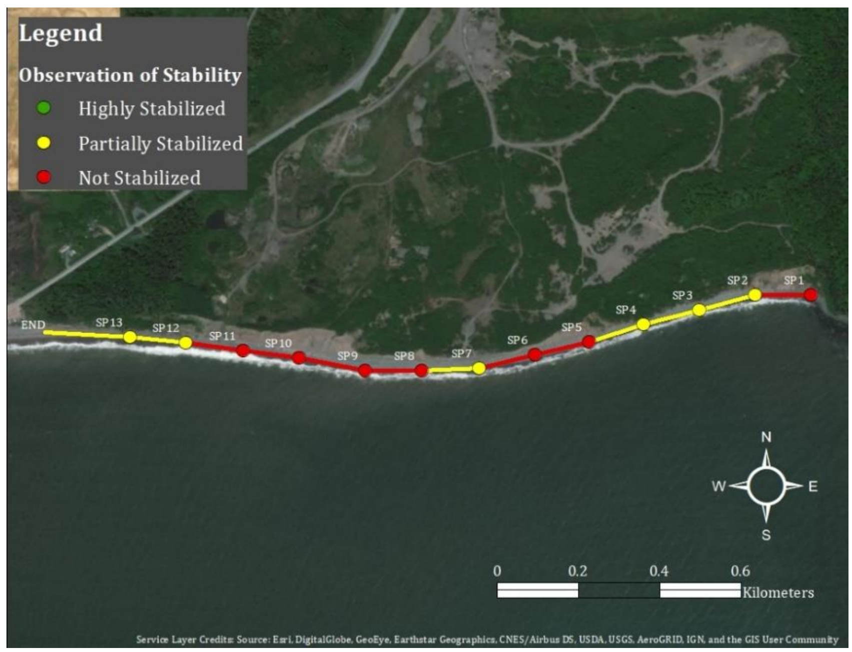

Figure 39: Observatiobn of stability at Sheldon Point in summer 2021.

Figure 40: Images: left, drainage channels and loose boulder material in SP10. Soil layers visitble at the top of the slope. Right, multiple slumps in the backshore at SP11.

- None of the sections are fully vegetated (Figure 41).
- Predominant vegetation type varies between grasses and shrubs.
- Steep slopes and cliffs are the predominant form types observed (Figure 42).

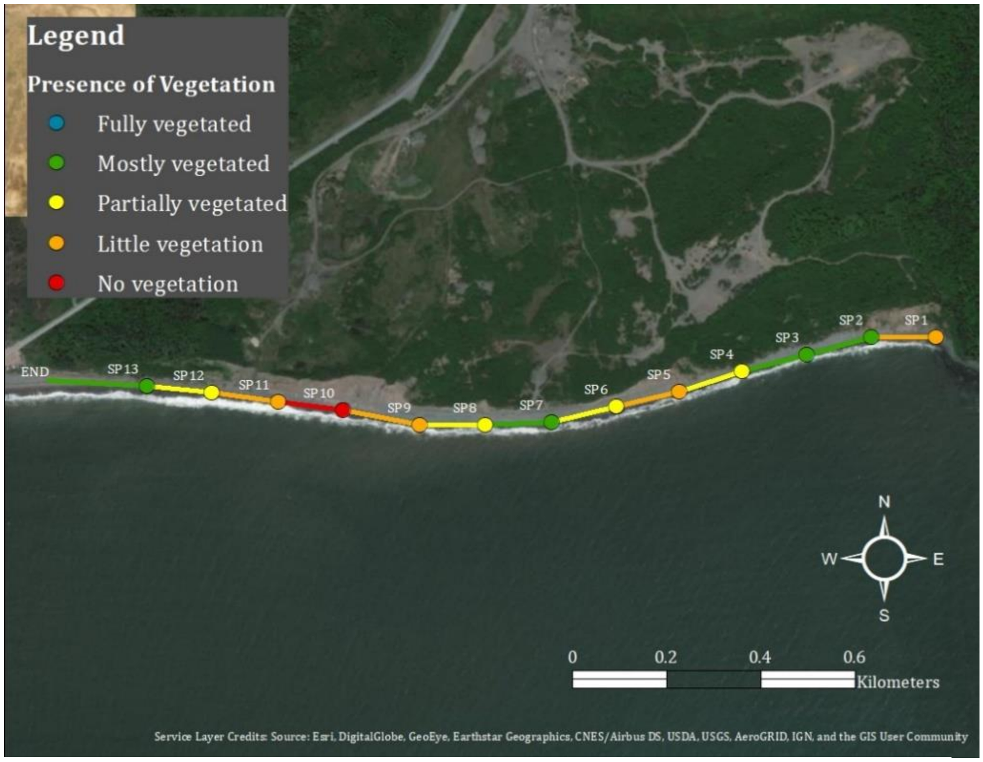

Figure 41: Presence of vegetation observed at Sheldon Point in summer 2021.

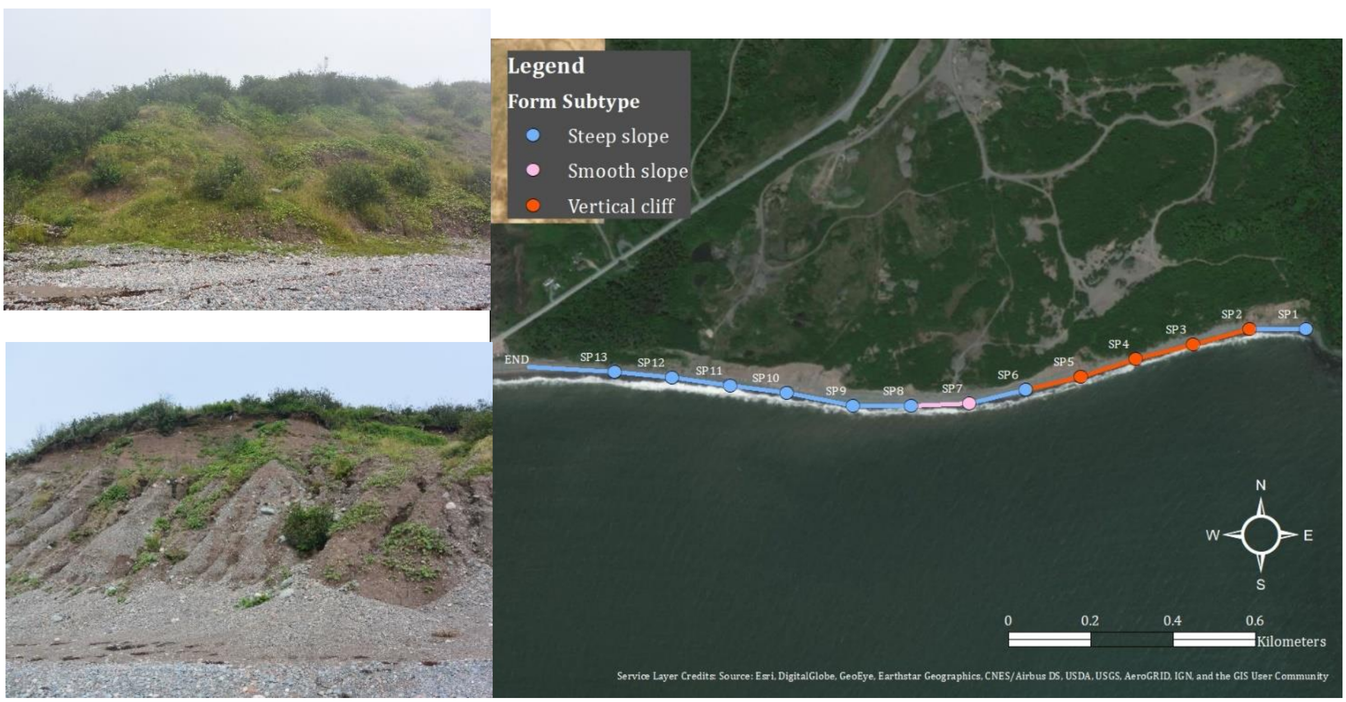

Figure 42: Form types observed at Sheldon Point in summer 2021. Only one section is categorized as a smooth slope. Images left: Top, in SP2 vegetation, predominantly grasses have grown onto the cliff face. Bottom, drainage channels and overhanging vegetation on a steep slope in SP5.

- Clay loam and sandy loam on top of clay are observed throughout the site (Figure 43). This soil texture is highly vulnerable to erosion from runoff and wave action.

- High variation in slope heights is observed with lowest points at SP7 where trail access is observed, and at SP12-END where the parking lot is located (Figure 44).

Figure 43: Observations throughout Sheldon Point. (A) Changing soil layers and fallen boulders in the backshore at SP6. (B) Trail access point in SP7 is mostly vegetated and predominantly sand. (C) Increase in form height and vegetation in SP9. Loose material is highly vulnerable to erosion from runoff.

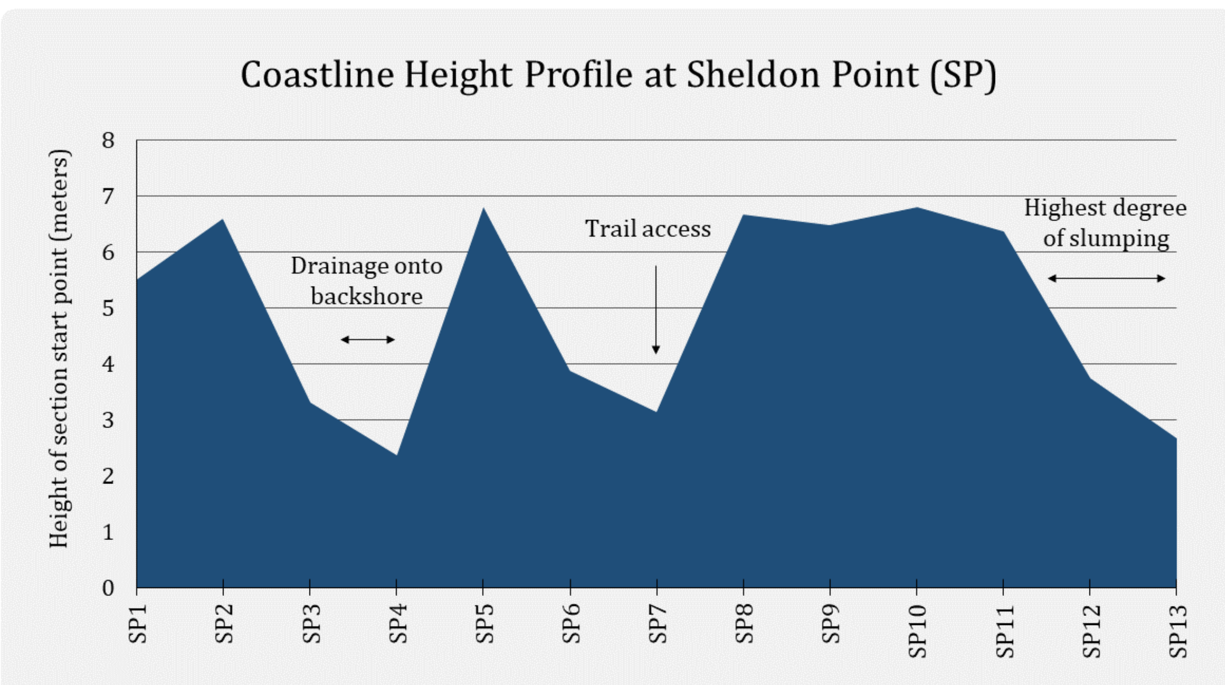

Figure 44: Height profile for Sheldon Point observed in 2021 highlighting for changes and key features. Slumping is observed throughout the entire coastline. Little to no infrastructure was observed with the exception of debris in SP7 and SP11, and a pipe outlet on the slope of SP11.

Table 15: Sheldon Point site assessment data summary.

Assessment Variable	Observations	Notes
Predominant Observation of Stability	Not Stabilized	Some sections are partially stabilized however majority of this coastline is not stabilized with signs of active and historical erosion including falling rocks and trees, large erosional channels from urban runoff, and slumped material.
Land Use	Recreational	The site is used for recreation with trail access at SP7 and beach access at the parking lot at the END point. A sand pit is observed at the top of the steep slopes where a range of debris is found including brick and concrete.
Vegetation	Variable levels of vegetation	No sections are observed to be fully vegetated. The predominant vegetation type varies between grasses and shrubs. Little to no trees are observed. Overhanging vegetation observed in SP5, SP6, SP9 and SP13. Vegetation is observed on previously slumped material revegetated the coastline.
Soil Textures	Clay	Clay loam and sandy loam also observed. Transition of soil type visible in the slope, clay with sand layers on top.
Form Type	Steep slope	Steep slopes and cliffs are predominant along the coastline. A smooth slope form is observed in SP7 where the Sheldon Point trail access is located however within the section, the form transitions back to a steep slope.
Slope Range and Average	20-100% slope range with an average of 80%	Lowest slopes are observed at SP7 (trail access) and at SP12-END (leading to the parking area). Slope is predominantly in the 80-100% range.
Backshore	Variable material types	Predominantly gravel from SP1-SP8. SP9-END fines are predominant. Cobble is present throughout the entire coastline. Bedrock at SP1. Boulders are observed in several sections, some have fallen from the slope due to erosion.
Foreshore	Unconsolidated beach	Relatively equal distribution of material types. Gravel is observed as predominant in most sections, followed by cobble and fines. The exception is SP1 which is predominantly cobble, followed by gravel and boulder.

9. Lorneville Cove 1 (LVCC) at Lorneville Community Centre

Lorneville Cove 1 is located just before the Community Centre in Lorneville and is the first cove that Lorneville Road passes over on the way into the community. This roadway, owned by the City of Saint John, is a direct transportation corridor for access into the area and is used by many residents travelling to and from Saint John (Appendix B). Historically, the region has experienced landslides following heavy rainfall events and the roadway has been reinforced by rock armouring to protect the infrastructure from erosion. The site assessment was completed along both sides of the roadway where the impacts of erosion are observed. LVCC1 is the coastal side and LVCC2 is upstream (Figure 45). A full summary of observations is presented in Table 16.

KEY OBSERVATIONS

- Rock armouring is providing partially stability of LVCC1 (Figure 45).
- Buckling and cracking of the roadway is observed in both LVCC1 and LVCC2 (Figure 46B).
- The culvert in place at LVCC2 is blocked by organic debris limiting flow of water below the roadway (Figure 46C).
- LVCC1 is partially vegetated with grasses and few shrubs. LVCC2 has little vegetation present and is all grasses.
- Rock armouring is a combination of riprap and smaller rocks (Figure 46A).

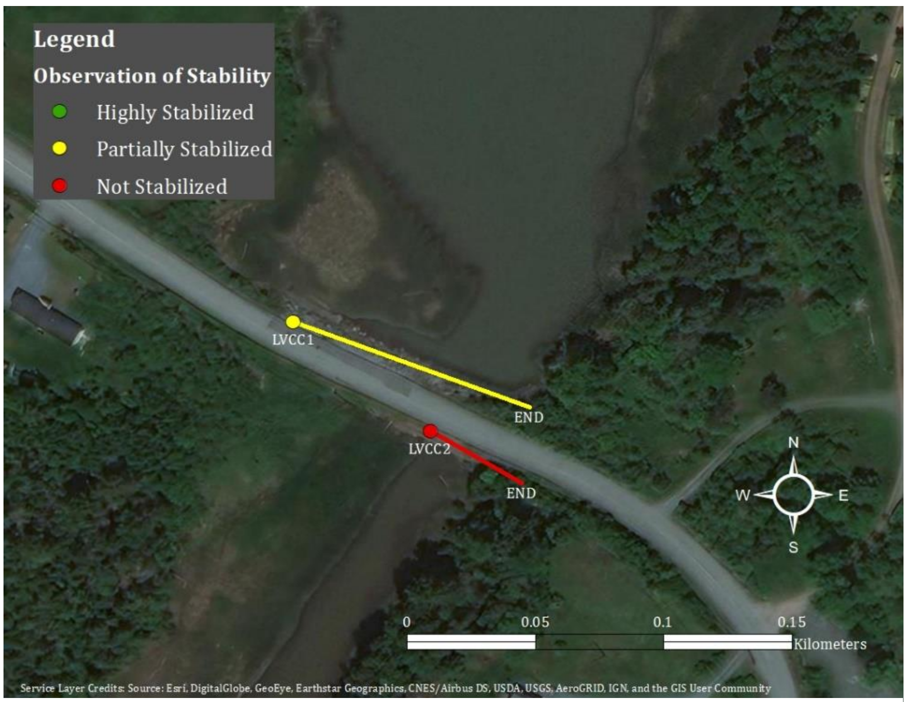

Figure 45: Observation of stability at Lorneville Cove 1 at Lorneville Community Centre observed in summer 2021.

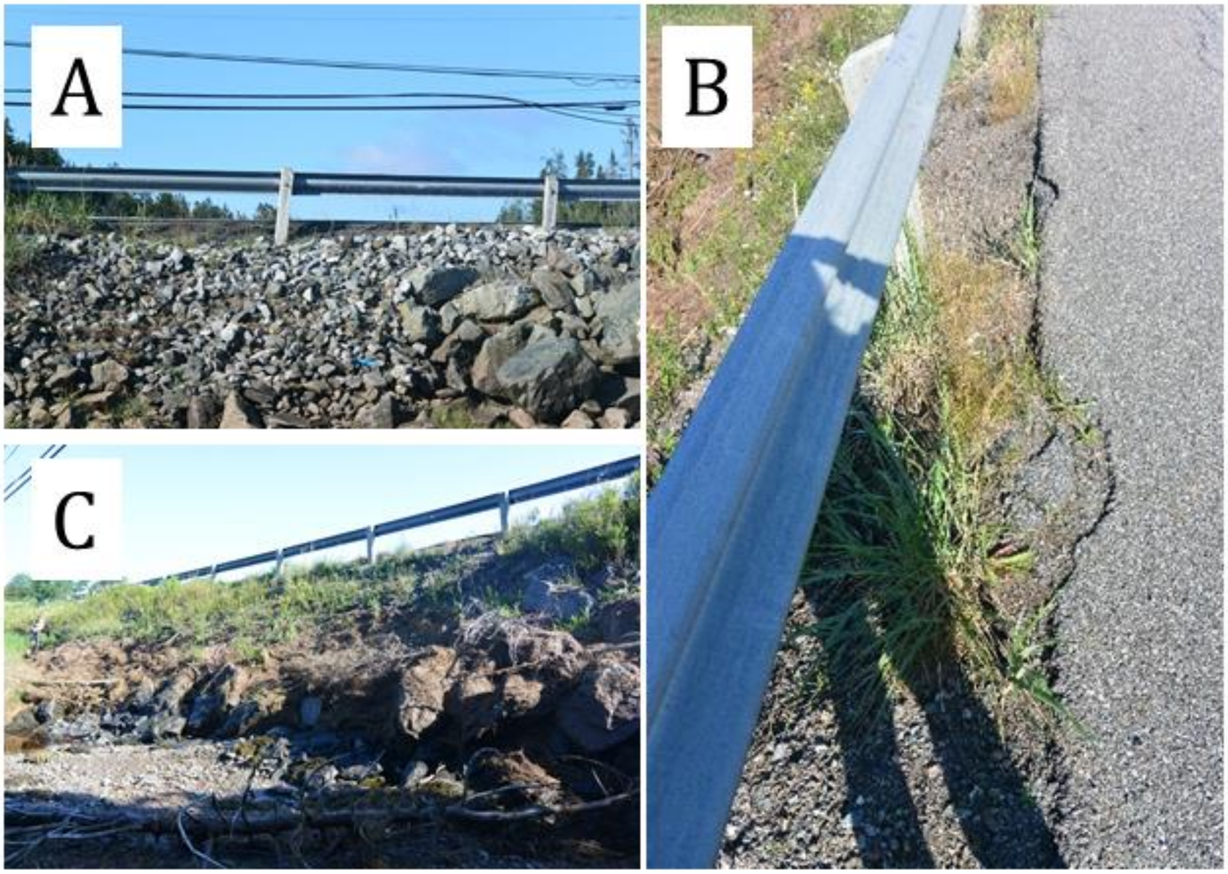

Figure 46: Highlights at Lorneville Cove 1 at the Lorneville Community Centre. (A) Erosion at the road shoulder in LVCC1. (B) Road buckling along the guardrail of Lorneville Road. (C) Debris built up over riprap in LVCC2 blocking a culvert from flowing below the roadway.

Table 16: Lorneville Cove 1 at Lorneville Community Center site assessment data summary.

Assessment Variable	Observations	Notes
Predominant Observation of Stability	Partially Stabilized	Rock armouring is helping to stabilize LVCC1. At LCVV2 the observation is not stabilize but rock armouring is observed at the base of the slope and organic debris is built up. Buckling and cracking of the roadway is observed in both LVCC1 and LVCC2.
Land Use	Roadway	Both LVCC1 and LVCC2 are part of the Lorneville Cove with Lorneville Road crossing through. The road is an access route into Lorneville. The culvert in place at LVCC2 is blocked by debris limiting flow of water below the roadway.
Vegetation	Partial to little vegetation	LVCC1 is partially vegetated predominantly with grasses and few shrubs. LVCC2 has little vegetation present and is all grasses.
Soil Textures	Rock armouring in place	Rock armouring is a combination of riprap and smaller rocks.
Form Type	Riprap	LVCC1 and LVCC2 are slopes with riprap installed for protection. At LVCC2 riprap is at the lower part of the slope and hidden beneath organic debris.
Slope Range and Average	80-100% with an average of 100%	The protected slope is steep in LVCC1 and LVCC2 and both sites are observed at 100% slope.
Backshore	Predominantly boulder	At LVCC1 boulder and cobble make up the rock armouring with some gravel observed. LVCC2 has less cobble and is predominantly boulder and gravel. Smaller materials like cobble and gravel are more likely to be movement by wave action and urban runoff.
Foreshore	Unconsolidated, estuary	At LVCC1 boulder and fines are predominant with smaller amounts of gravel and cobble. LVCC2 has no boulder and little to no cobble but is relatively equal parts fines and gravel.

10. Lorneville Cove 2 (LVPO) at Post Office Road

Lorneville Cove 2 at the Post Office Road is another coastal roadway and access route at risk to the impacts of erosion. The ownership of this site is shared due to the infrastructure present whereby the roadway and culvert are owned by separate entities (the city and the province respectively; Appendix B). Rock armouring is used to protect the roadway and culvert infrastructure. Similar to Lorneville Cove 1, the assessment was completed on both sides of the roadway to observe the level of erosion and notable impacts. LVPO1 is the coastal side and LVPO2 is inland (Figure 47). The inland site is identified as an area which may be at risk to coastal squeeze and habitat migration as the sea level rises. A full summary of observations is presented in Table 17.

KEY OBSERVATIONS

- Riprap is providing stability at both LVPO1 and LVPO2 (Figure 47).
- A large concrete culvert allows water to flow below the roadway (Figure 48).
- Updates made to infrastructure in the last five years.

Figure 47: Observation of stability at Lorneville Cove 2 at Post Office Road in summer 2021.

Figure 48: Images: left, culvert at LVPO1 on the coastal side of the roadway. Bottom, at LVPO2 on the inland side. Culvert appears to be in good condition.

- No vegetation is observed on the slopes where riprap is in place, but grasses are present along the edge of the roadway before and after riprap (Figure 49A/C).

- Marsh observed inland of LVPO2 is vulnerable to coastal squeeze (Figure 49D).

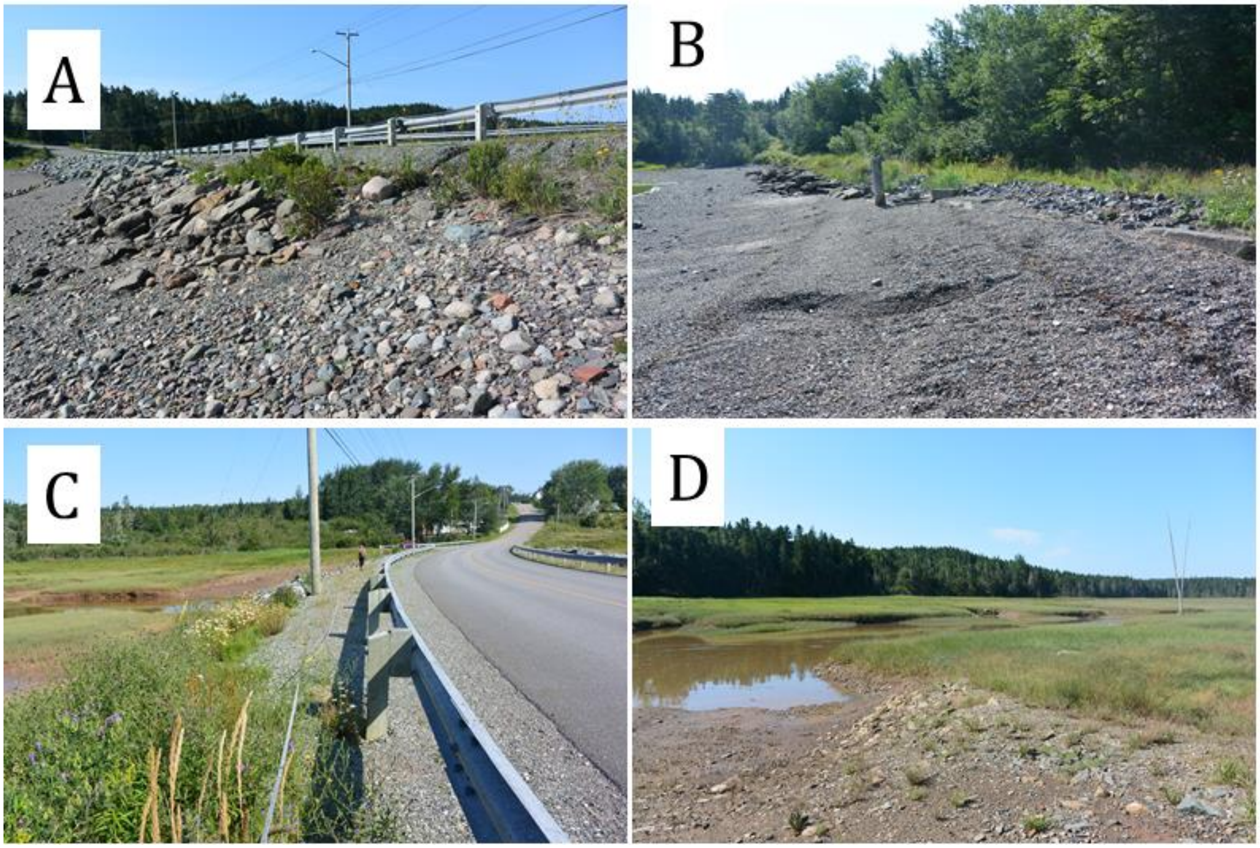

Figure 49: Highlights at Lorneville Cove 2 at Post Office Road. (A) View from the start of LVPO1. (B) Beyond the roadway at LVPO1 where the coastline flattens out and vegetation is present. (C) View from the roadside at LVPO2. (D) Looking inland at LVPO2.

Table 17: Lorneville Cove 2 at Post Office Road site assessment data summary.

Assessment Variable	**Observations**	**Notes**
Predominant Observation of Stability	Highly Stabilized	Rock armouring is stabilizing LCPO1 and LCPO2.
Land Use	Roadway	Both LVPO1 and LVPO2 are part of the Lorneville Creek inlet with Lorneville Road crossing over. The road is an access route into Lorneville. A large culvert is installed to allow flow below the roadway.
Vegetation	No vegetation	LVPO1 and LVPO2 have no vegetation present. Some grasses are present at either end of the section where the riprap ends.
Soil Textures	Rock armouring in place	Riprap is in place to stabilize the roadway. Larger rocks are used at both LCPO1 and LVPO2. At the base of the large rocks gravel and cobble are observed.
Form Type	Riprap	LVPO1 and LVPO2 are slopes with riprap installed for protection.
Slope Range and Average	80-100% with an average of 92%	LVPO1 and LVPO2 both have a high slope percentage.
Backshore	Boulder	At LVPO1 boulder is the only material observed. LVPO2 is predominantly boulder but small amounts of gravel and cobble are present.
Foreshore	Unconsolidated, estuary	Beyond riprap in LVPO1 gravel is predominantly observed with some fines and little cobble. At LVPO2 fines are predominant with more boulder and cobble.

Additional Sites of Erosion in Saint John

Irving Nature Park

The Irving Nature Park is a popular destination for tourists and residents looking to experience the natural beauty of Saint John. The park has a history of erosion and has developed a monitoring program to provide information for planning future trail maintenance. ACAP Saint John reviewed reports from 2000 and 2011 that addressed seven sites along the coastline of Taylors Island (specifically along the Seal Trail) and Sheldon Point.

The initial reporting completed in 2000 was to establish a baseline and develop a preliminary set of data. The 2011 report builds from the previous data and identifies annual rates of erosion by site as well as changes in undercut banks at each site. Photographs are included to provide a visual comparison between 1999 and 2011. For the analysis, researchers returned to a previously determined measurement point and calculated the distance lost from the test point. Some sites were not measured as they were considered unsafe due to instability, and the sites at Sheldon Point could not be located due to the changing landscape, highlighting the erosional processes that have occurred within the study timeframe. Overall, the report concludes that erosion is occurring at all sites and the priority of trail maintenance may require additional information such as proximity of the trail and road to the edge. Continued monitoring is recommended to further explore the coastline changes and rates of erosion within the park (Irving Nature Park, 2011).

Coastal and Inland Erosion

The sites identified in this report were selected based on previous research conducted and the capacity of the project team, however there are many other sites around the city that are facing erosion challenges and could not be examined in this report including:

- **Courtenay Bay** where the causeway is currently protected by riprap and is highly vulnerable to storm surge and sea level rise.
- **Tin Can Beach** and the **historic Lantic Sugar site** where dilapidated seawalls are present, and riprap is in place along the coastline of the potash terminal.
- The **Digby Ferry terminal** and beach leading to **City Line** where riprap has been put in place.
- **Additional west side coves**, along the Shoreline Trail between Bayshore Beach and Duck Cove, as well as Sand Cove which extends beyond McLarens Beach.

Beyond coastal erosion, there are challenges of inland erosion. Studies similar to this may be useful to address areas where infrastructure is at risk including:

- **Riverview Drive** along the Wolastoq where homes are close to the sloping riverbank, and across the river at Chesley Drive where Ocean Steel is located.
- The **trailway accessed from Riverview Ave West to Riverview Drive** where erosion is occurring as well as the homes on **Lancaster Drive** that are located atop the slope.
- Stretches of **Manawagonish Road** where homes are at risk to inland erosion.
- **Loch Lomond Road at Silver Falls** and around the industrial area where sandy slopes are vulnerable to erosional processes.

Adaptation Options and Opportunities

Adaptation in the City of Saint John

In 2020 the City of Saint John adopted a Climate Change Adaptation Plan that formalizes several objectives and actions that can be taken to protect the community and build resilience to the impacts of climate change. **The impacts of sea level rise are rated as a high risk for the municipality** and the plan addresses these challenges in Objective 2 of the Action Register, to reduce shoreline erosion and promote natural infrastructure. Specifically, within Objective 2 there are four actions that can utilize the information presented in this report:

- Obj. 2-8: Conduct a study to identify high risk infrastructure that may require relocation in high erosion areas of the city.
- Obj. 2-9: Monitor coastline properties with high rates of erosion.
- Obj. 2-10: Identify areas where possible non-structural protection can minimize storm surge inundation.
- Obj. 2-11: Identify areas where possible structural protection can minimize storm surge inundation.

The data presented directly fulfills Obj. 2-9 by creating a baseline of shoreline conditions that can contribute to the ongoing monitoring and guide future assessments. Additionally, the data presented may be useful for determining areas where non-structural and/or structural protection is required to mitigate the impacts of erosion. Overall, this research is intended to support stakeholders, municipal staff, and researchers alike in their effort to build resilience to storms and sea level rise.

The unpredictable nature of erosion and coastline change creates challenges for adaptation. ACAP Saint John refers to the "protect, accommodate, retreat" strategies that present options for infrastructure at risk (Figure 50). Where possible, ACAP Saint John suggests non-structural or soft armouring as an opportunity to protect both coastal infrastructure and habitat. Additionally, the need for development policies and setback regulations, and strict enforcement of these policies is critical for protecting the community from the impacts of coastal erosion.

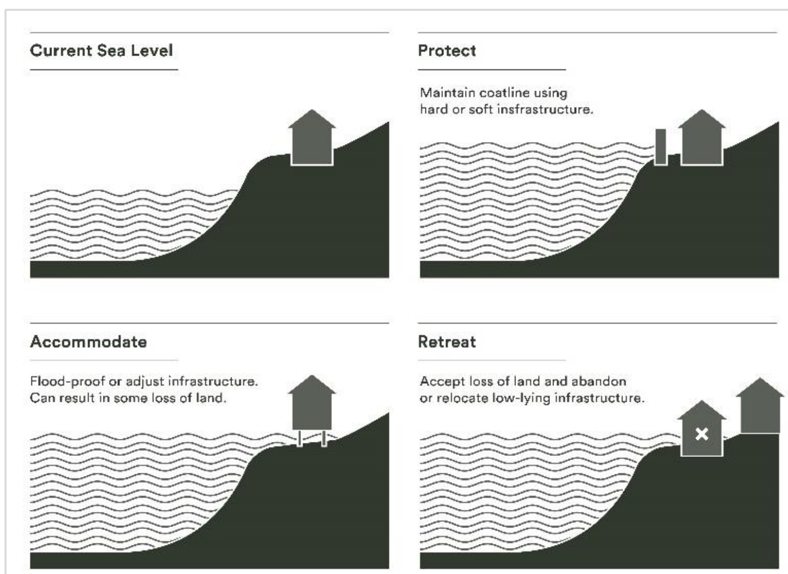

Figure 50: Coastal mitigation strategies for sea level rise (ACAP Saint John, 2020b).

A Coastal Areas Protection Policy for New Brunswick

The province of New Brunswick has defined development regulations and protection measures in the *New Brunswick Coastal Areas Protection Policy*. The purpose of the *Coastal Areas Protection Policy* is to protect sensitive ecological areas and establish development zones based on environmental impact and the likelihood of flooding damage. First established in 2002, and updated in 2019, the document focuses on three key factors: development pressure, climate change, and information sharing. Regarding development, the policy recommends dividing developed coastal zones into three subsections where Zone A represents the foreshore, Zone B is a 30 meter inland coastal buffer, and Zone C lies beyond the 30 meter setback. While not legally binding across the province, the zones have differing restrictions to protect properties and homeowners from sea level rise and the impacts of erosion (Government of New Brunswick, 2019).

The policy identifies Zone A as an area highly vulnerable to storm surge and due to the sensitivity of coastal features, minimal development should occur in this zone. The buffer established in Zone B is recognized as essential in maintaining the integrity of coastlines however there is a higher acceptability for development in this zone. The policy acknowledges that development in Zone B can have a direct impact on coastal features and can expose infrastructure to the impacts of storm surge (Government of New Brunswick, 2019). Identifying these zones and their development limitations is only a partial solution for combating the challenges of coastal erosion. Enforcement and strict setbacks in Zone B are necessary for ensuring the stability and health of coastline features in Zone A. Furthermore, the challenge of adapting to the impacts of increased storm surge and accelerated erosion is beyond structural protection and requires political agency that will carry out the directives outlines in policies created.

Living Shorelines

Research around the world is being conducted to demonstrate successful approaches to combatting the challenges of coastal erosion. The term “living shoreline” refers to a style of coastal protection that incorporates nature and habitat restoration alone or in combination with built structures (Smith et al, 2020). The living shorelines approach is considered a nature-based approach to climate change adaptation and has many benefits to the environment including the creation of coastal habitat and increased biodiversity. Similar to the case of green infrastructure as an adaptation strategy for stormwater management, the implementation of living shorelines has proven to be low maintenance and more cost effective than traditional hard armouring (Smith et al, 2020; Depietri and McPhearson, 2017). Case studies range from green to grey infrastructure, with a common choice being the hybrid option which utilizes vegetation in conjunction with structural material (Figure 51). For areas where hard armouring exists, the hybrid approach is an opportunity to increase resilience to coastal erosion, create shoreline habitat, reduce costs, and restore natural ecosystem processes.

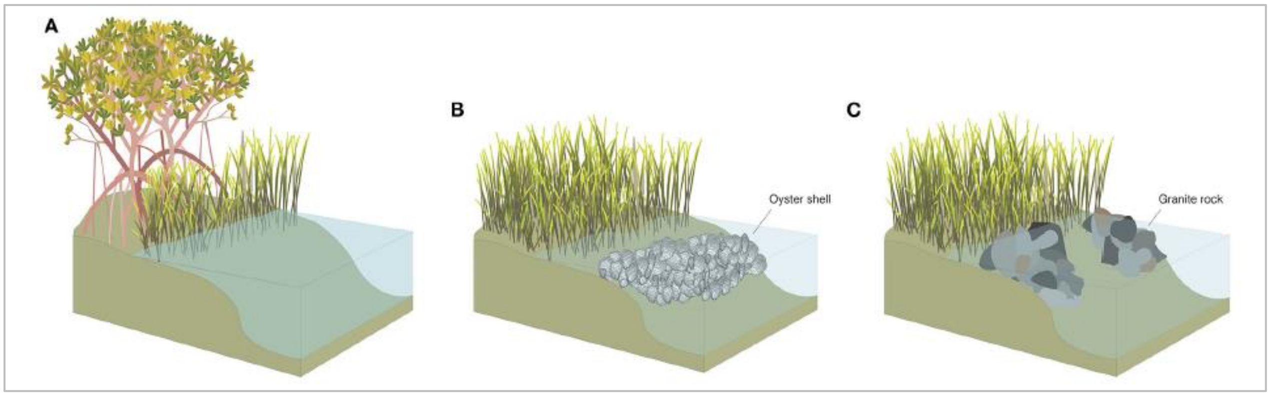

Figure 51: Approaches to living shoreline strategies including (A) vegetation planting only, (B) restoration with soft materials (e.g., oyster shell), and (C) restoration with hard materials (e.g., granite rock). (Smith et al, 2020).

ACAP Saint John is actively promoting the use of natural infrastructure and nature-based solutions as a strategy for combatting climate change impacts. In areas where hard armouring has been installed and is not providing adequate protection, a living shoreline approach can be an affordable and effective method for homeowners and for the municipality. Research has shown that once established, vegetation can provide a prolonged and increasingly effective control for erosion, building support for the implementation of living shorelines in high risk or highly vulnerable areas (Menashe, 1998). Pilot projects can be used as demonstrations to encourage homeowners to revitalize their coastal properties in natural ways that will increase resilience to storms and sea level rise in the future.

LIVING SHORELINES IN ACTION

In 2021, a workshop in Cocagne Community Park in New Brunswick presented several strategies to enhance and protect coastlines at risk (Figure 52). The session involved the hands-on installation of several restoration techniques and upon completion has been awarded the Greener Greenspaces recognition from The Society of Urban Landcare (SOUL). This award highlights restorative and ecological approaches that inspire and empower sustainable land use practices and climate change adaptation. This project can be used to demonstrate the opportunity that living shorelines can provide to communities with infrastructure at risk to erosion and sea level rise.

Figure 52: Living shoreline site in Cocagne Community Park, Cocagne, New Brunswick, completed by Group de development durable du Pays de Cocagne, Shediac Bay Watershed Association, CSR Peninsule acadienne, Vision H20 and Nature NB, in partnership with Helping Nature Heal Inc (2021).

Recommendations and Opportunities

Addressing the challenges presented by coastal erosion will involve immense collaborations between municipal and provincial staff, consultant agencies, and private landowners. In many areas around the city, the property owners are aware of the issues yet lack the information and financial capacity to take action. These barriers create an opportunity for partnership and collaboration where information sharing and local knowledge can be combined to create specific adaptation solutions for individual sites. As partnerships are established and the community gains a sense of familiarity with coastal restoration and adaptation, the level of protection along coastlines vulnerable to sea level rise and storm surge will increase.

Through the assessments completed in 2021, ACAP Saint John has gained a greater sense of the coastal challenges being faced in the region and the recommendations that can be made to ensure stability in the future. Each site is unique, and many opportunities exist including:

- Maintenance and repair of riprap at Mispec Beach.
- Relocation of utility infrastructure at Anthony's Cove.
- Culvert repair at Anthony's Cove Brook.
- Opportunities for partnership to monitor coastal migration at Anthony's Cove.
- Education and development control practices at Red Head.
- Infrastructure and habitat monitoring at Hazen Creek.
- Integration of living shorelines in new development at Bayshore Beach.
- Community involvement with preventative strategies at Duck Cove.
- Landowner/resident partnerships at McLarens Beach.
- Collaboration with Irving Nature Park to monitor and ensure safety along trails.
- Eliminating debris from the culvert at Lorneville Cove 1.
- Repairs to roadway and shoulder at Lorneville Cove 1.
- Monitoring at Lorneville Cove 2 to avoid blockages to the culvert.
- Further exploration of erosion projections for coastal areas using the DSAS technology.

These observations and recommendations can be used to inform future projects, partnerships, and adaptation planning to build resilience to climate change in the region.

Conclusion

There is no solution for erosion however preventative strategies can be taken to slow the process, allow for infrastructure to be relocated or supported, and protect the community from the unpredictable nature of erosional forces. This report provides detailed observations that can be used as a baseline when monitoring coastline changes in the region. Since erosion is a long-term process, ACAP Saint John suggests a five-year monitoring timeframe to ensure that coastline changes are documented, and infrastructure is protected. Overall, the stability of coastal areas in Saint John is variable. Protection measures have been put in place where stability is reduced significantly however the observations suggest that protective installations may not be fully effective to keep infrastructure safe, encouraging contemporary adaptation options such as living shorelines.

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Appendix A: Field Assessment Protocol and Data Sheet

Living Coastal 2021: Shoreline Assessment Methodology

This methodology was based on research conducted by ACAP Saint John to assess the condition of shorelines. The primary reference material was the *Shore Zone Characterization for Climate Change Adaptation in the Bay of Fundy* completed in Nova Scotia (Piertersma-Perrott & Van Proosdij, 2012).

1. Arrive at site and determine starting point for shoreline assessment beginning at one end of the beach. Consult assessment sheet for the next steps.
2. Identify section labelling with ID, GPS information, date, and personnel.
3. Take photos at the start looking first straight at the shoreline and second down the section you are completing. Record photo ID.
4. Determine land use and record weather for the past 24 hours noting storms or weather extremes.
5. Observe the shoreline form and level of stability.
6. Using the clinometer, measure and record the form height and slope.
7. One person holds the rope tape at the starting point while a second person begins to walk down the section observing any erosion. If there is not note-worthy erosion stop at 50 m and record any erosion. Continue another 50 m to complete the 100 m section. Note: 50 m sections were used to allow for detailed observations and reduce tangling of the rope tape.
8. Along the section find a spot to observe soil texture through feel tests using the guides in the field binder (attached below).
9. At the 100 m mark, this is the end of the section. Look back and observe the following: vegetation, backshore material types, foreshore form and material types.
10. Add any additional notes including measurements where infrastructure is observed, changes in form or vegetation, structures, and other notable observations. Sketches may be helpful.
11. Begin the next section on a new data sheet.

Shoreline Erosion Assessment Sheet ACAP Saint John

Section ID:	**Date/Time:** **Personnel:**
GPS Coordinates (at section start):	**Elevation:**
Photos (indicate waypoint ID, photo ID and facing direction):	
Land Use Type:	
Weather (past 24 hours):	

SHORELINE

Form Type: Cliff, outcrop, platform, anthropogenic, slope, dune, wetland, waterbody

Observation of Stability:

Highly Stabilized Partially Stabilized Not Stabilized

Form Type Height (at section start):

Clinometer %	Reading
Top	
Bottom	
Distance	

Form Type Slope (degrees):

Height of Erosion (choose an average spot to take this reading OR at 50m):

Clinometer %	Reading
Top	
Bottom	
Distance	

Slope of Erosion (degrees):

Erosion Photo ID:

Presence of Vegetation on Shoreline

1 (no vegetation)	2	3	4	5 (fully vegetated)

Vegetation types (estimated %)**:**

_____ Grasses _____ Shrubs _____ Trees

Shoreline Soil Texture:

FORESHORE

Form Type: Solid Unconsolidated

Solid: cliff, outcrop, platform, anthropogenic Unconsolidated: cliff, slope, beach, dune

Material Type(s) (estimated %):
____ Boulder ____ Gravel ____ Cobble ____ Fines (sand, clay, etc)

BACKSHORE

Material Type(s) (estimated %):
____ Boulder ____ Gravel ____ Cobble ____ Fines (sand, clay, etc)

Additional Notes (i.e., evidence of runoff, plant ID, built environment features – note distance), Sketch (Optional):

Appendix B: Site Ownership Details

Site ownership details attained from Planet NB by ACAP Saint John February 2022.

Site	PID	Ownership	Comments
Mispec Beach	00360461	City of Saint John	
Mispec Beach	55162218	City of Saint John	
Mispec Beach	00358010	Irving Oil Limited	Includes unnamed stream
Mispec Beach	00359216	Privately owned	Property line goes to high tide mark
Mispec Beach	55152391	Privately owned	Property line goes to high tide mark
Anthony's Cove	55167464	Irving Oil Terminals & Pipelines G.P.	
Anthony's Cove	00338665	Irving Oil Terminals & Pipelines G.P.	
Anthony's Cove	All remaining	Privately owned	
Red Head Beach	00337238	City of Saint John	
Red Head Beach	00338061	City of Saint John	
Red Head Beach	00338020	City of Saint John	
Red Head Beach	00340299	Biron Engineering LTD	NW tip of redhead
Red Head Beach	All remaining	Privately owned	
Hazen Creek	00340745	City of Saint John	From private property in East to beginning of riprap
Hazen Creek	00339044	NB Supply and Services	First section of riprap
Hazen Creek	00337956	City of Saint John	Rest of rip rap until residential property. Part of Sewage treatment facility property
Hazen Creek	55114300	JD Irving Limited	Northernmost portion of the site
Hazen Creek	All remaining	Privately owned	located toward the beginning and end of the site
Bayshore Beach	55110027	New Brunswick Southern Railway Co	
Bayshore Beach	55116495	Canadian Pacific LTD	
Bayshore Beach	55116487	Canadian Pacific LTD	

Bayshore Beach	55109938	New Brunswick Southern Railway Co	
Bayshore Beach	55109912	City of Saint John	Former street ROW
Bayshore Beach	55109920	New Brunswick Southern Railway Co	
Bayshore Beach	00390112	McNulty Cartage (1987) LTD	Section of backshore and coastline
Bayshore Beach	55174700	City of Saint John	Backshore and shoreline from parking lot to W end
Duck Cove	00412320	Privately owned	
Duck Cove	55071146	Duck Cove Recreation & Heritage Association Inc	
Duck Cove	00395046	Duck Cove Recreation & Heritage Association Inc	
McLarens Beach	55047898	NB Supply and Services	Property links McLarens Beach and Duck Cove
McLarens Beach	00395392	Saint John Diocesan Cemetery Co Inc	Cemetery
McLarens Beach	All remaining	Privately owned	
McLarens Beach	3	City of Saint John	McLarens Beach Road property line goes to high tide line
Sheldon Point	55092621	Voyageur Properties Limited	
Sheldon Point	55110910	JD Irving Limited	
Sheldon Point	55092001	Voyageur Properties Limited	
Sheldon Point	55176028	JD Irving Limited	
Lorneville CC 1	3	City of Saint John	
Lorneville CC 2	55231542	City of Saint John	Owner listed as "transportation"
Lorneville PO	55227821	Transportation and Infrastructure	PIDs look misaligned. Likely that the province owns the culvert and city owns the road.
Lorneville PO	55227201	Transportation and Infrastructure	