Coastal Environments and Erosion in Southwest St. Georges Bay, Antigonish County

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Introduction

There has been a recent surge in interest in the rates of sea-level rise and coastal erosion in Nova Scotia, especially the potential of climate change to increase these rates and the related risks. A number of projects have been initiated by government departments and universities to collect and distribute the information needed for adaptation planning throughout the province. These projects need a base of accurate scientific data, coupled with the involvement of local land-use planning authorities that are willing to apply the scientific conclusions to formulate sound government policy.

A project to plan for adaptation to climate change was completed by Nicol (2006) for the Antigonish area, but that project had some self-identified data limitations, such as the lack of a Light Detection and Ranging (LiDAR) survey for precise elevations, storm-surge modelling, or any data about past rates of erosion (Nicol, 2006). The provincial surficial geology map (1:500 000 scale; Stea *et al.,* 1992) was also used, which omits significant (to coastal erosion) geomorphic features such as drumlins. The Antigonish area is the only part of the province not covered by 1:100 000- or 1:50 000-scale surficial geology mapping.

To resolve these geoscience data limitations, the Department of Natural Resources has acquired a LiDAR survey of the area, in collaboration with Applied Geomatics Research Group, Nova Scotia Department of Economic Development, and Nova Scotia Department of Environment. This survey and the resulting digital elevation model will be used to prepare flood models and a new surficial geology map. This report presents some initial results of two other project components that will be expanded in 2009: (1) examination of present day coastal processes and (2) determination of historical rates of erosion based on archival aerial photographs.

Project Area

The study area lies in the southern Gulf of St. Lawrence, on the southwest coast of St. Georges Bay (Fig. 1). The coastal area (the focus of this report) is generally low-lying, characterized by a series of barrier beaches anchored by drumlin- or bedrock-headlands.

Bedrock of the area is composed of Devonian to Carboniferous sedimentary strata that onlap the Hadrynian to Devonian igneous-metasedimentary rocks of the Antigonish Highlands (Boehner and Giles, 1993). The sedimentary units range from continental clastics (conglomerate, mudstone and sandstone) to marine deposits (carbonates and evaporites). These rocks vary in their resistance to erosion, with the evaporites being moderately susceptible to erosion and karstification compared to the highly resistant granitoid rocks.

The area was last glaciated in the Late Wisconsinan. Ice flow was first to the east-southeast, but later the ice flowed to the northeastward (Stea *et al.,* 1998; Shaw *et al.,* 2006), resulting in basal till deposits containing reddish sandstone and conglomerates, capped by drumlin-forming tills near the surface containing mixed rock types including metasiltstone, volcanic rocks, diorite and amygdaloidal basalt (Stea and Myers, 1990). Where eroded, these drumlins can provide abundant sediment supply to beaches down current (to the east). During deglaciation, parts of the coastal area may have been inundated by an ice-dammed lake during the Younger Dryas re-advance (Stea and Mott, 2005). Deposits from this former lake may contribute to fine-grained sediment in the area, although none has been mapped.

The offshore bedrock geology is a continuation of onshore units. The bathymetry of troughs and depressions represents preglacial, fluvially eroded valleys and ridges that were over-deepened by

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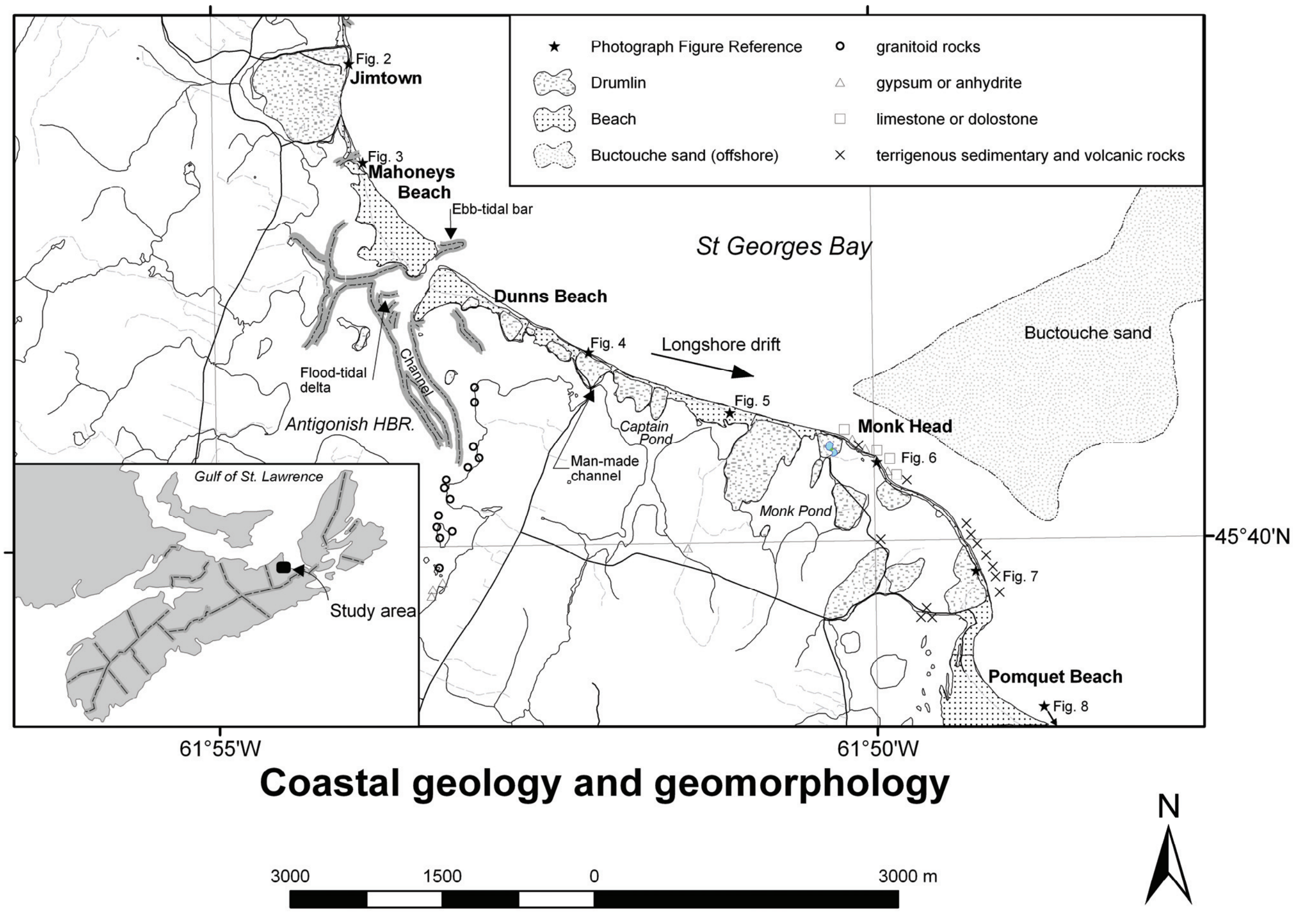

Figure 1. Location of the study area with geology and geomorphology of the coastline between Jimtown and Pomquet Beach. Bedrock outcrop observations from Boehner and Giles (1993) and distribution of Buctouche sand from Kranck (1971). Locations of drumlins are based on aerial photography interpretation. Only drumlins along the coast of St. Georges Bay appear on this map.

glacial erosion (Kranck, 1971). Following the deglacial low-stand there has been a marine transgression that formed marine terraces of Buctouche sand and gravel, with discontinuous patches of sandy Pugwash mud (Krank, 1971). The terraces of Buctouche sand in the study area are generally about 3 km offshore, oriented sub-parallel to the present coastline. One terrace of Buctouche sand forms a submarine spit offshore from Monk Head (Krank, 1971; Fig. 1). Pugwash mud also fills in some lower areas (Krank, 1971).

Sea-level Changes

Relative sea-level changes following deglaciation for the region have been significantly affected by migration of a glacial forebulge inward from the paleo-ice margin at the shelf edge (Quinlan and Beaumont, 1981). The resulting subsidence, combined with global eustatic rises in sea level, can be calculated from tidal records. The nearest tidal records are from locations to the west at Pictou and to the east at Point Tupper (Canso Causeway), with relative sea-level rises calculated at 36.8 and 43.1 cm/100 yr, respectively (Carrera *et al.,* 1990).

Historical Notes

Preliminary assessment of archival aerial photographs shows that barrier beaches have been continually changing morphology and size with time, notably with a breach that formed on the west end of Mahoneys Beach in late December 2004 (Susan Cameron, personal communication, June 16, 2008). Dredging was carried out recently landward of that breach in Antigonish Harbour; dredging was also completed in the 1920s on the eastern side of the harbour toward Captain Pond

(Public Works Canada, 1925). Sometime before then Captain Pond was connected to Antigonish by an apparently man-made channel several metres wide and 125 m long, which would have significantly changed currents in the harbour. Growth of a delta in the harbour near Antigonish by as much as 370 m occurred between 1954 and 1964, based on aerial photograph analyses (Critchley, 1976), suggesting that the harbour is filling with terrestrially derived sediment. The Canso Causeway was built in 1955, cutting off the two-way tidal flow between the Gulf of St. Lawrence and the Atlantic (Buckley, 1977).

Although St. Georges Bay is relatively sheltered from wave activity compared to other stretches of coastline in Nova Scotia (Owens and Bowen, 1977), storm surges are modelled with a relatively higher repeatability, especially compared to the Atlantic coast (Bernier *et al.,* 2006). A couple of historically significant storm events include a hurricane reported in 1862 that uprooted trees and damaged property (Antigonish Casket, 1862). "The August Gale" in 1873 resulted in the destruction of barns and crops by winds, as well as the wharf; a schooner tied up to the wharf was driven onshore (New York Times, 1873). On August 15, 1971, Hurricane Beth made landfall near Antigonish (Canadian Hurricane Centre, 2009), causing flooding in some areas along the harbour (Antigonish Planning Advisory Council, 2005).

A key difference between this area and barrier beaches on the Eastern Shore (Atlantic coast of Nova Scotia) is that St. Georges Bay freezes over in winter (Atlas of Canada, 2009). Landfast ice can provide some protection from coastal erosion during winter storms, but sea-ice cover is predicted to decrease in the future (Forbes *et al.,* 2004).

Present Day Observations

The area, despite having a low coastal gradient, still has enough wave energy to erode bedrock and surficial material, and to develop extensive spit and barrier beaches (Owens and Bowen, 1977; Fig. 1). Drumlins anchor barriers and also provide sediment, and more resistant bedrock units also act as anchors. The western portion of St. Georges Bay has higher energy levels, because this area is more exposed to waves from the northeast that hit the shore at an oblique angle, resulting in net sediment transport (i.e. longshore drift) toward the east (Bowen *et al.,* 1975).

At the coastline of Jimtown is a drumlin with man-made armouring on both the northern (Fig. 2) and southern ends. Erosion of the drumlin had threatened several cottages on the northern end, with the resulting action of one cottage being dismantled and the emplacement of a network of boulders with a wood and steel retaining wall as well as boulder groynes. Boulders were also emplaced on the southern end, immediately west of Mahoneys Beach. This area was selected for erosion rate analysis based on archival aerial photographs (see Rates of Erosion).

The western end of Mahoneys Beach was breached in late December 2004 (Susan Cameron, personal communication, June 16, 2008; Fig. 3). The likely proximate cause of this breach was a reduction in volume of material on the beach. The sediment loss may be related to longshore drift toward the east: downflow at Pomquet the beach is prograding whereas upflow the coast has been armoured following mass wasting that threatened properties. Alternatively, changes in the current in the harbour area have also been noted, and may have contributed to the thinning and ultimate breach of the barrier. The new inlet is similar in morphology to the main inlet. It is asymmetrical, which is consistent with obliquely approaching waves of the longshore current. The flood tidal delta is well developed, but the tidal current is relatively strong, resulting in a deep, ebb-dominated narrow channel with marginal bars.

Farther east along the coast near Dunns Beach are drumlins that have no bedrock present at the base and are exhibiting mass wasting. At one site there is a translational slump (Fig. 4), but in other areas the slump block is transitional to an earthflow, suggesting materials were water saturated at the time of failure. This failure likely occurred as a result of removal of material at the base of the drumlin by coastal erosion. Irrigation on surface, or changing the surface hydrology by removal of vegetation, may have contributed to slope instability by saturating the sediment. This area was selected for erosion rate analysis based on archival aerial photographs (see Rates of Erosion). Seaward of some of these drumlins are shoals of boulders, likely the eroded lag of former drumlins,

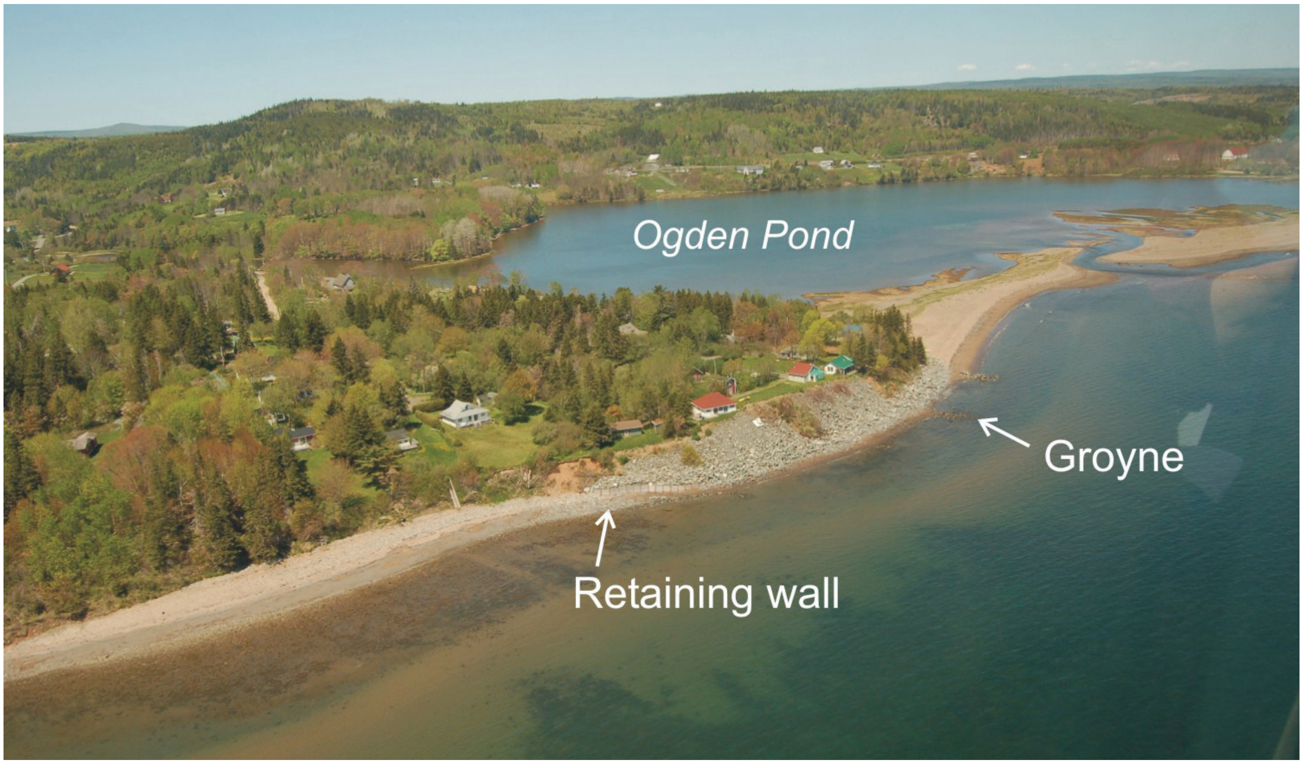

Figure 2. Oblique aerial photograph of amouring and groynes on northern end of a drumlin at Jimtown.

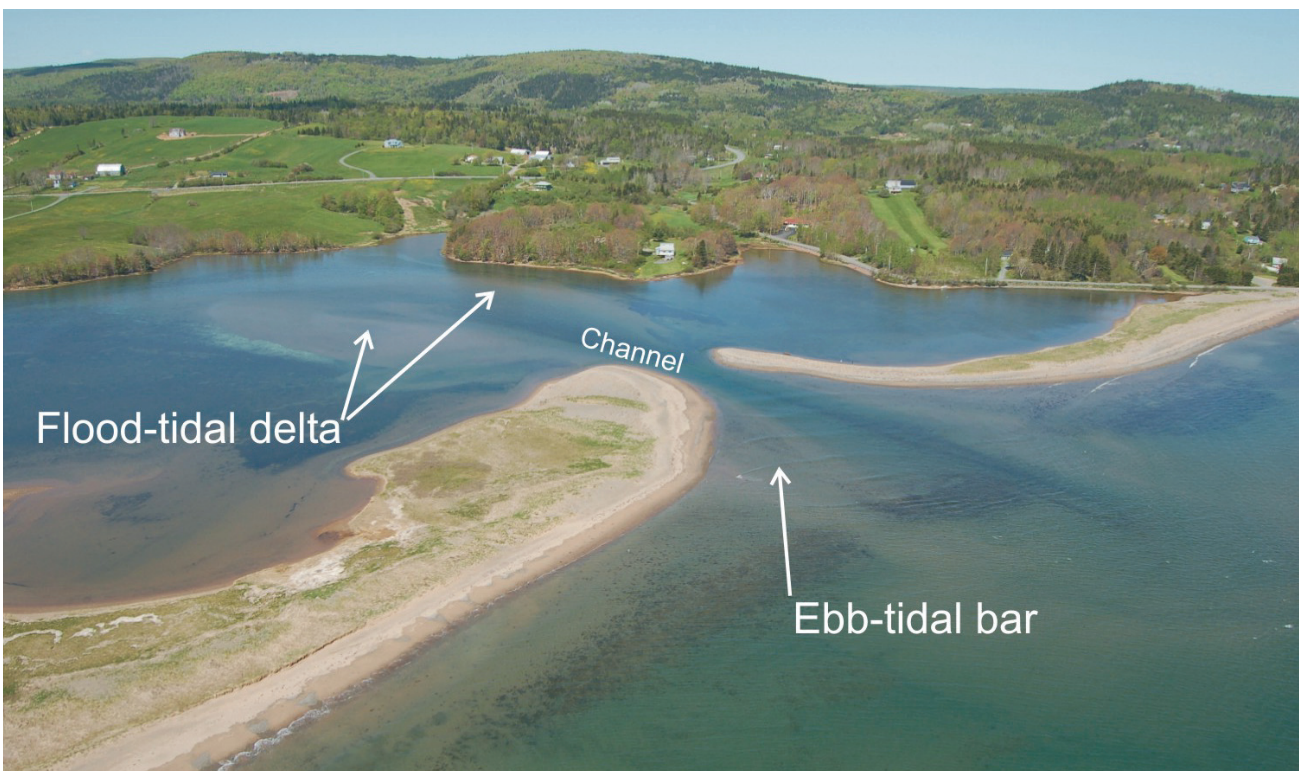

Figure 3. Oblique aerial photograph of a wave-dominated tidal inlet, with a flood tidal delta at Mahoneys Beach. This inlet breached the barrier beach in late December 2004 (Susan Cameron, personal communication, June 16, 2008). The inlet is asymmetrical, consistent with obliquely approaching waves that result in a longshore current, also mapped from aerial photographs (Fig. 1).

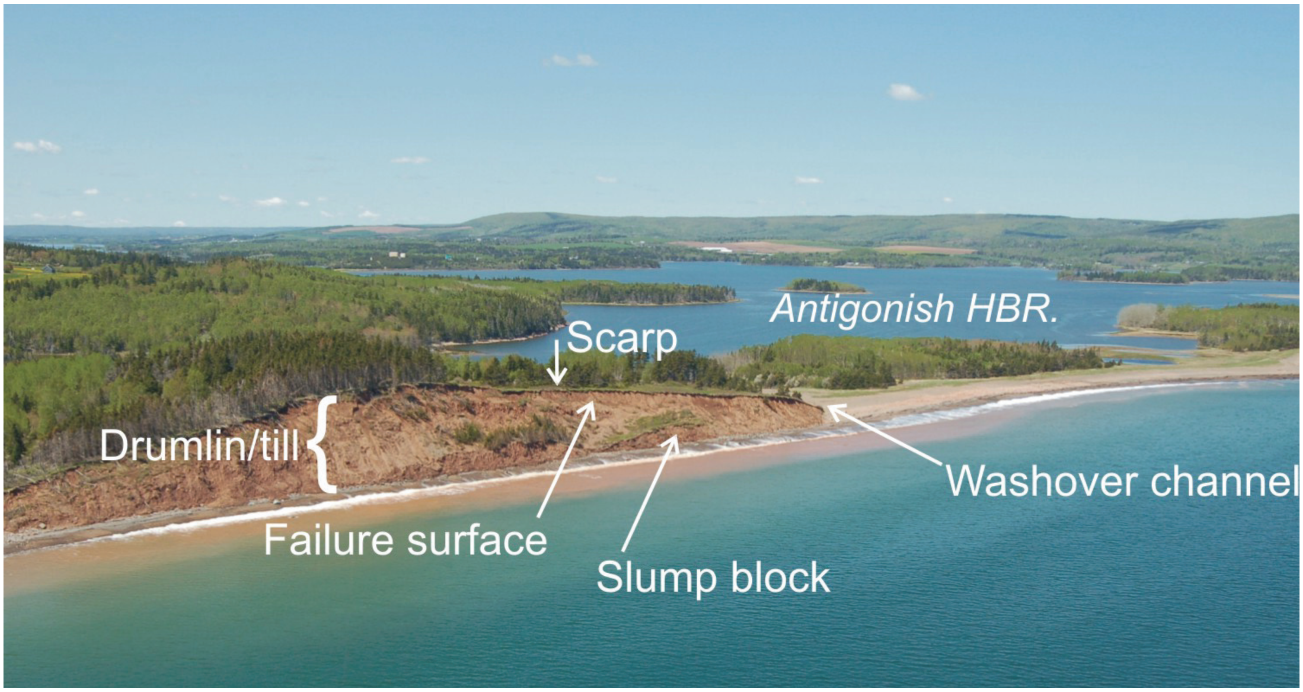

Figure 4. Oblique aerial photograph of translational slump on the coastal face of a drumlin. Scarp erosion is mapped in Figure 10.

that might reduce wave energy hitting the shoreline.

Eastward along the coast is Captain Pond, a lagoon protected by a barrier beach (Fig. 5). The barrier has a vegetated aeolian dune ridge, with washover fan deposits of thin, sheet-like sand beds. Only one dune ridge is present, possibly an indication that the barrier is transgressing, although there are extensive barrier flats on the lagoonal side, suggesting a degree of stability (Oertel, 1985).

Farther east along the coastline near Monk Head, the coastal cliffs are predominantly bedrock, with only a thin cover of till (Fig. 6). The bedrock here is resistant carbonate and sandstone of the Hood Island and Addington formations (Windsor Group). These units are interbedded with siltstone, gypsum and anhydrite. The evaporites are much more susceptible to erosion and solution weathering. At the time of field work (ca. June 2008) the coastline was undercut (Fig. 6), with some small caves eroded into the evaporites.

West of Pomquet Beach (Fig. 7) the coastline is typified by a drumlin bluff, which overlies resistant silicilastic bedrock. Although the bedrock is resistant, it is only present to near the high tide level, the bluff is composed entirely of till. Erosion here might be less severe than for other drumlins along the coast because of the presence of this resistant unit at the base. Bowen *et al.* (1975) speculated that because the bedrock strikes roughly perpendicular to the coastline it acts as a natural groyne. The bedrock prevents fine material from being deposited immediately down current (east) of the drumlin, where the foreshore is predominantly cobbles and boulders, and fine sediment is instead deposited farther downflow at the eastern end of Pomquet Beach. Bowen *et al.* (1975) suggest this process may explain the curve in the coastline, and the thin west end of Pomquet Beach.

The erosion of this drumlin, nevertheless, results in high sediment loads that contribute to a prograding beach at Pomquet (Bowen *et al.,* 1975; Fig. 8). Numerous, vegetated dune ridges are present on the surface. On the landward side the dunes are lower and some of the interdune areas are flooded, indicating that sea level was lower when these ridges were formed (Bowen *et al.,* 1975).

Rates of Erosion

Rates of erosion of two sections of the coastline were calculated by comparing aerial photos from different years (Figs. 9 and 10). Aerial photographs from 1939, 1971, 1990 and 1997 were scanned and georeferenced in ArcMap 9.2®, based on the

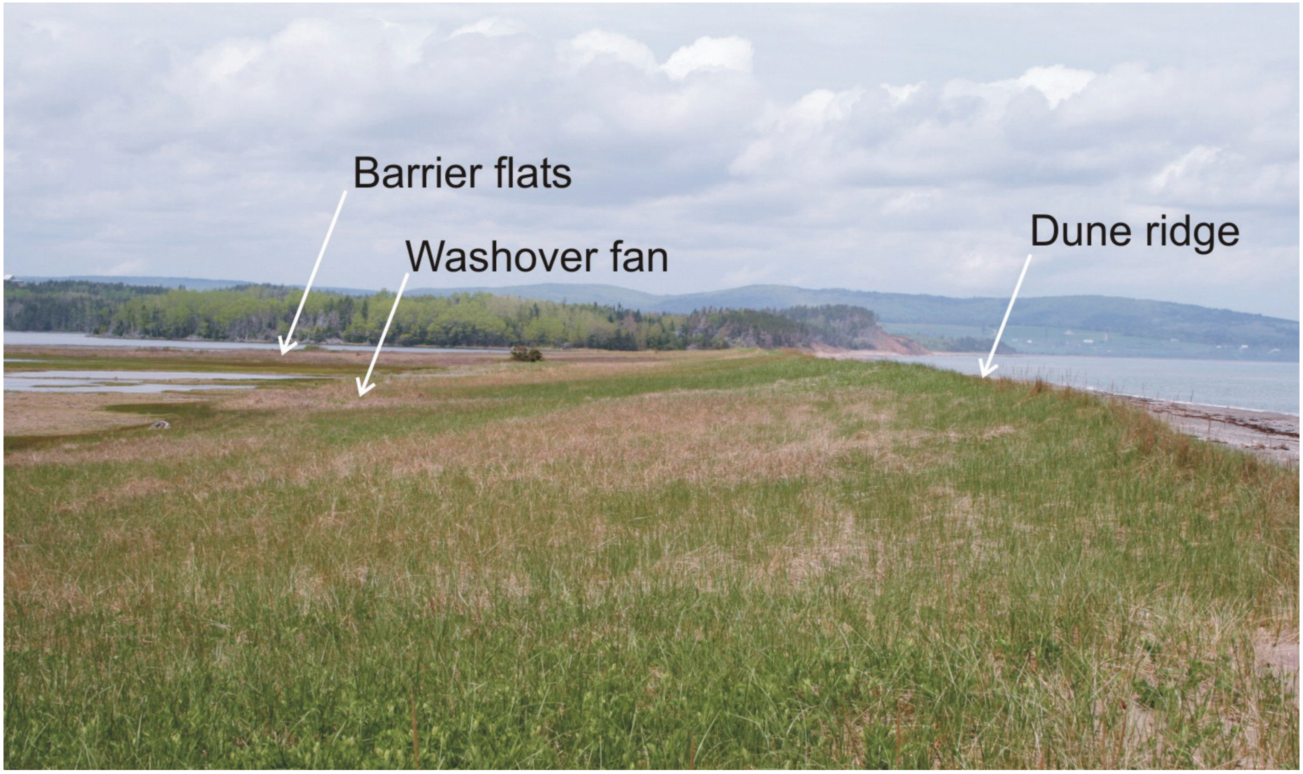

Figure 5. Photograph of vegetated aeolian dune ridge on a barrier beach, with washover fan deposits of thin, sheet-like sand beds. Captain Pond lagoon is at left of the photograph, eroding drumlin from Figure 4 in the background.

Figure 6. Oblique aerial photograph of Monk Head. Till overlies a bedrock cliff of interbedded resistant limestone and erosive evaporites.

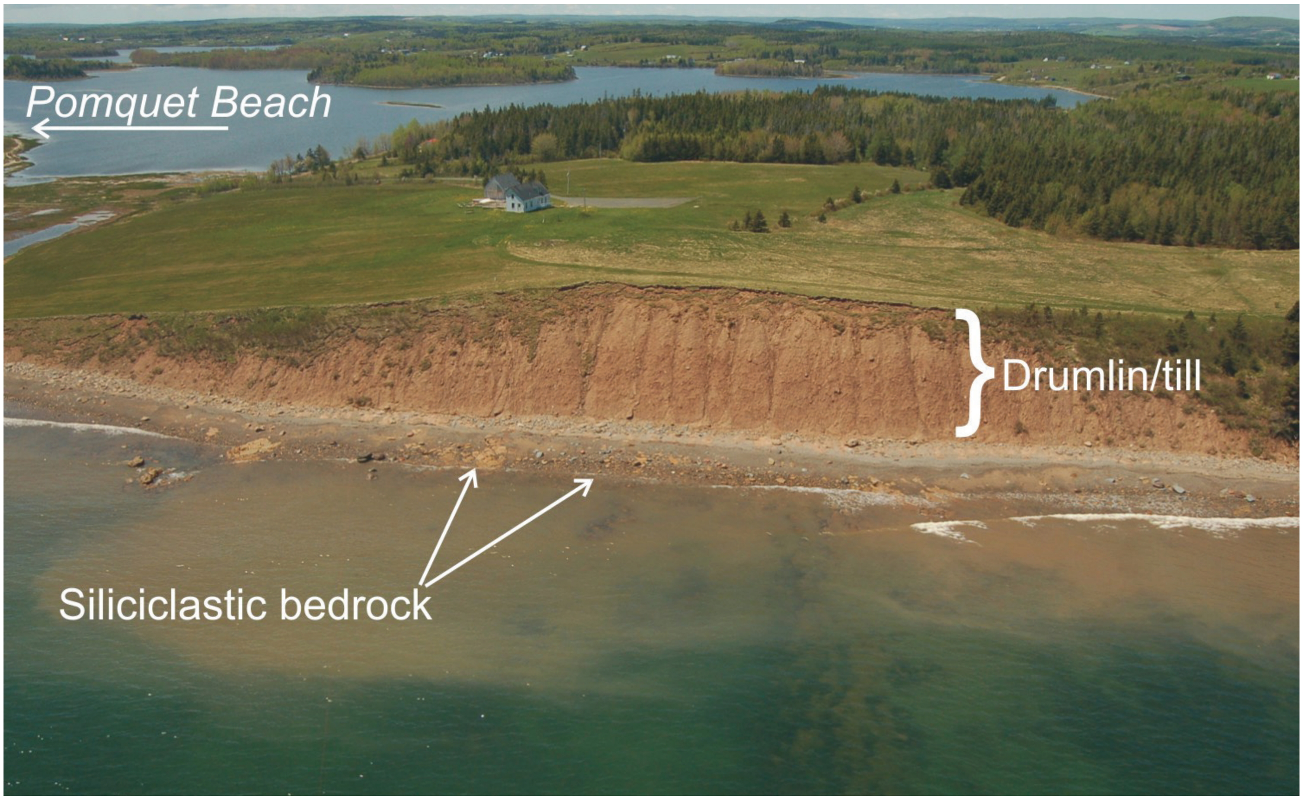

Figure 7. Oblique aerial photograph of drumlin cliff over sedimentary bedrock.

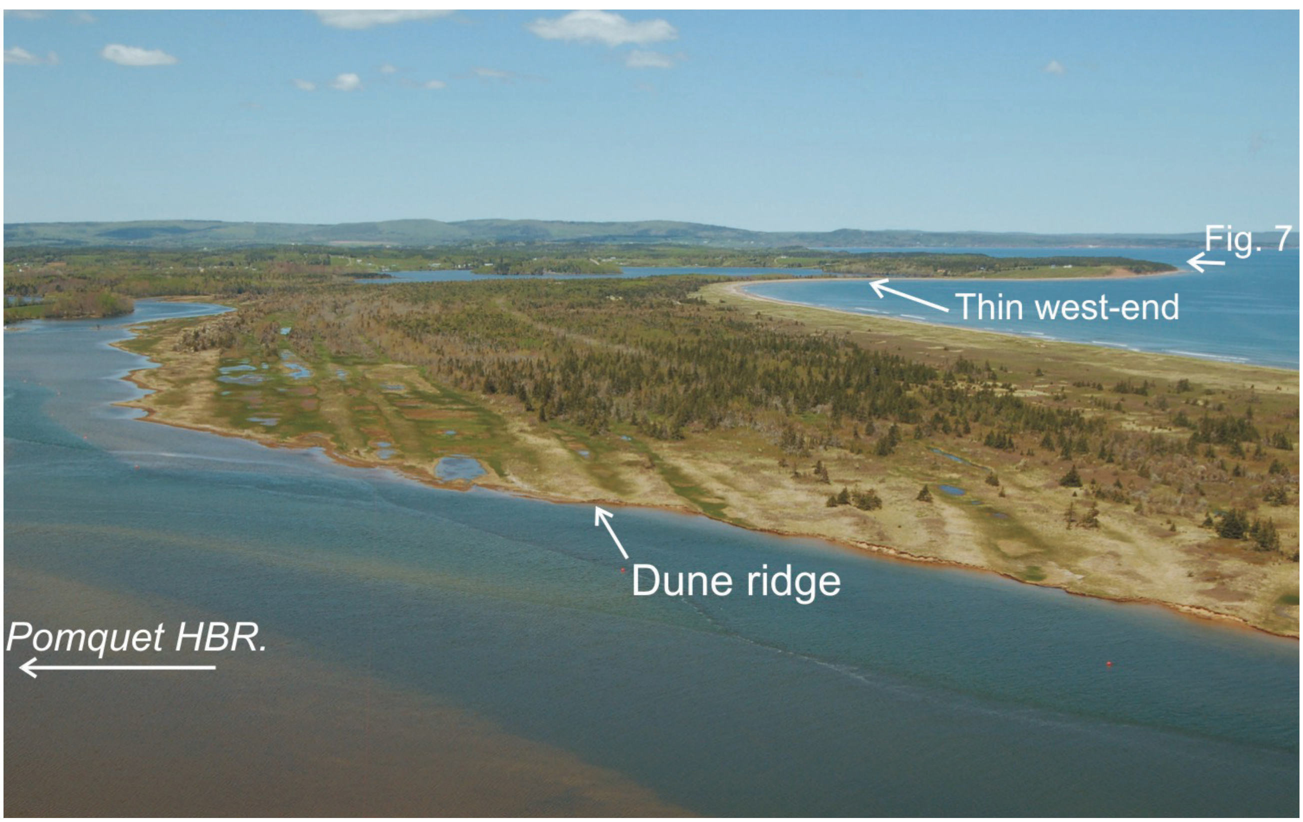

Figure 8. Oblique aerial photograph of prograding barrier beach at Pomquet.

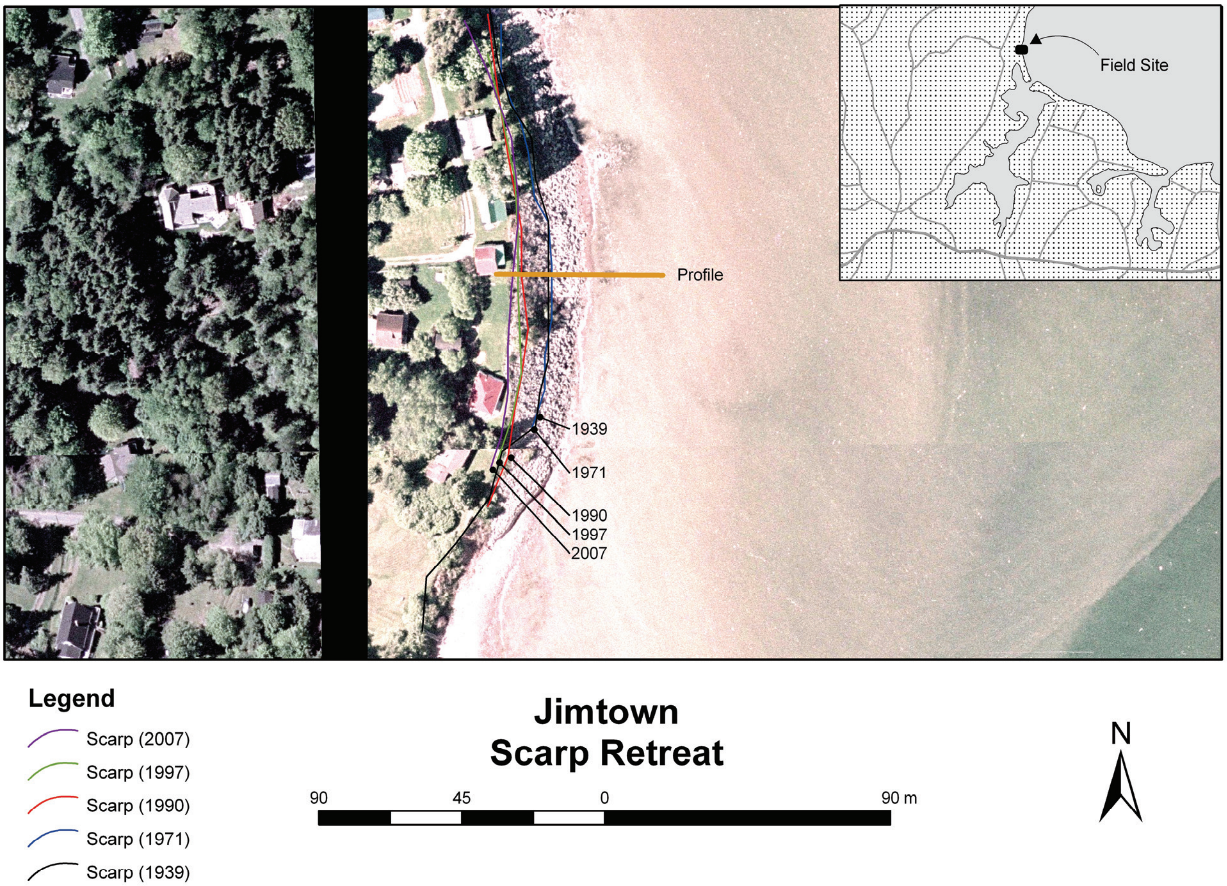

Figure 9. Erosion of drumlin at Jimtown, based on measurements of scarp retreat from 1939, 1971, 1990, 1997 and 2007 aerial photographs. Profile line is 50 m long, oriented approximately perpendicular to the present day scarp. Base aerial photograph is from 2007. Black vertical line marks a boundary of two air photos.

location of roads (especially a road that runs parallel to the scarp at both localities) and cottages. The scarp line for each year was plotted on the 2007 orthorectified aerial photograph, which was used as a base layer and provides the 'present day' scarp location. The distance between scarps of different ages was measured along two profiles oriented roughly perpendicular to the present day scarp at Dunns Beach (Table 1 and 2), and along one profile at Jimtown (Table 3).

At Dunns Beach the rate of scarp retreat has varied from 0.27 to 0.85 m/yr, depending on the time period and the location on the drumlin. This gives an average erosion rate of 0.5 m/yr since 1939, with maximum rates recorded of 0.85 m/yr between 1997 and 2007. This compares with an average erosion rate for the coast near Amherst of 0.4 m/yr (Finck, 2007). The variation of erosion rates in the same year is likely a result of localized mass movements along the length of the coastal face of the drumlin.

At Jimtown there was only one period of erosion recorded, 0.45 m/yr recorded between 1971 and 1990, because following this time the coastline was armoured. A cottage was removed during this period of retreat, possibly related to coastal erosion during Hurricane Beth in 1971. It is unclear if the negligible erosion rates prior to 1971 (and prior to armouring) relate to an error in the aerial photograph rectification process, or a true lack of erosion. The retreat rates at Jimtown highlight both the ability of armouring to slow scarp retreat and the fact that despite a relatively slower retreat rate, cottages constructed near the coast are still at risk.

Summary

The different coastal environments discussed here,

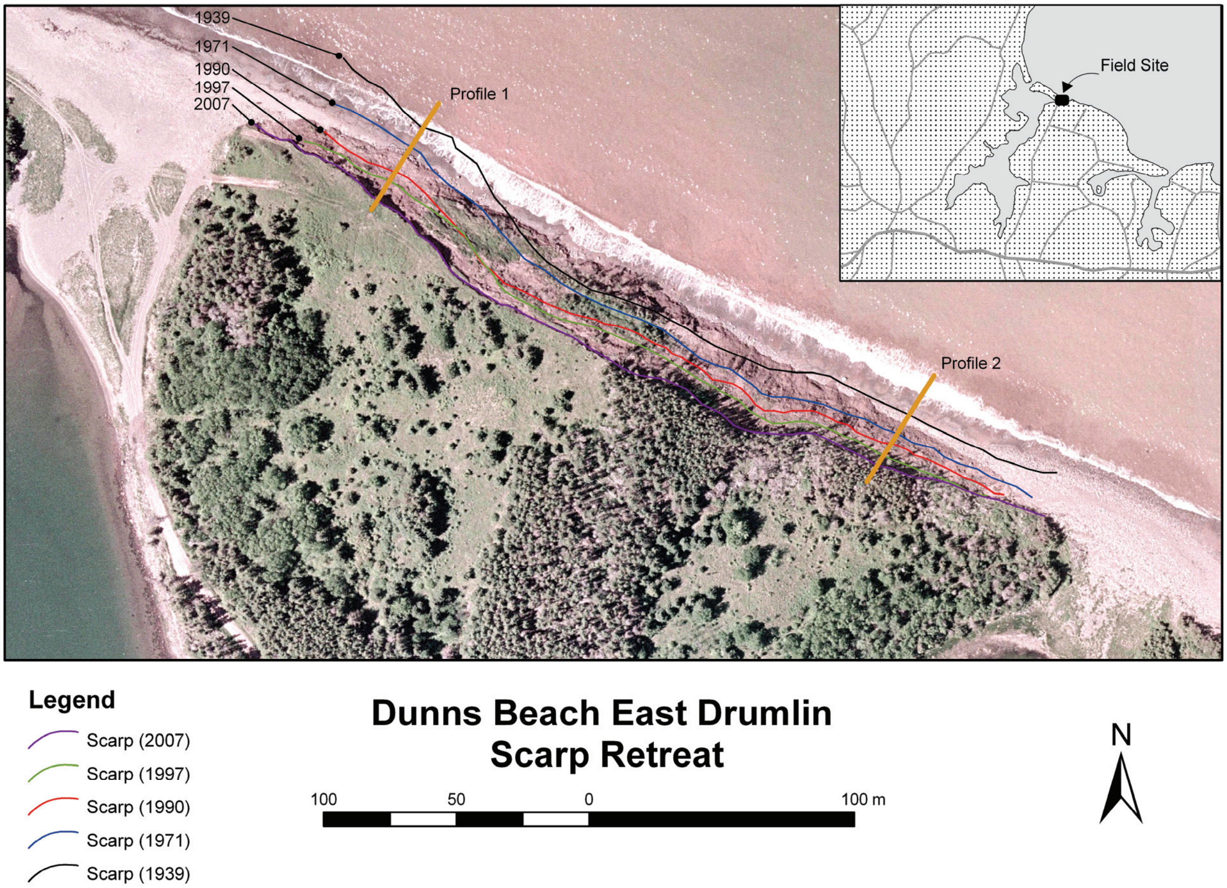

Figure 10. Erosion of drumlin at Dunns Beach, based on measurements of scarp retreat from 1939, 1971, 1990, 1997 and 2007 aerial photographs. Profile lines are 50 m long, oriented approximately perpendicular to the present day scarp. Base aerial photograph is from 2007.

Table 1. Dunns Beach retreat rate at Profile 1.

Years	Scrap Retreat (m)	Retreat Rate (m/yr)
1939-1971	8.5	0.27
1971-1990	11	0.58
1990-1997	4	0.56
1997-2007	8.5	0.85

Table 2. Dunns Beach retreat rate at Profile 2.

Years	Scrap Retreat (m)	Retreat Rate (m/yr)
1939-1971	8.5	0.27
1971-1990	4.6	0.24
1990-1997	5.5	0.79
1997-2007	4.5	0.45

Table 3. Jimtown retreat rate at Profile.

Years	Scrap Retreat (m)	Retreat Rate (m/yr)
1939-1971	Negligible	N/A
1971-1990	8.5	0.45
1990-1997	Negligible	N/A
1997-2007	Negligible	N/A

including an armoured drumlin, an eroding drumlin, a drumlin on bedrock, a bedrock-cliff coastline, and barrier beaches, are all components of a dynamic coastal system that is responding to sea-level rise by erosion and transport of material. Where coastal armouring and groynes have been constructed, or occur naturally, currents and sediment transport respond to these factors. Overlain on these factors are potential effects of climate change, such as increased storm events and winter storms occurring without the protection of shorefast ice. The variability of the coastline reveals that to be effective, projects related to coastal hazard assessment must include examination of the processes that determine coastal geomorphology.

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