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COASTAL MONITORING IN NEWFOUNDLAND AND LABRADOR

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ABSTRACT

Most communities in Newfoundland and Labrador are located adjacent to, or along, the coast. Storm surges and wave run-up can cause erosion and flood low-lying areas, heavy rain can trigger landslides, quarrying in coastal areas can increase erosion rates and waves can undercut the base of slopes, causing rock falls or other types of slope movement. Since 1863, as a result of coastal flooding, there have been at least thirty recorded deaths, and costly economic damage from flooding, slope movement and erosion.

Sea level is projected to rise during the next century, and climate-change projections suggest an increase in the intensity of mid-latitude storms, heavy precipitation events and a greater number of freeze–thaw cycles, which would further increase the potential risk of flooding and/or erosion. Hence, there is a need to assess the stability of coastal areas and the vulnerability to change, so that this information would be available to towns for developing long-term planning and policy decisions.

To meet the objectives indicated above, the Geological Survey of Newfoundland and Labrador initiated a multi-year coastal monitoring program in 2011. This program aims to assess rates of the shoreline migration, changes in beach profiles, delineate areas of high vulnerability to coastal flooding and/or erosion, and to assess the connectivity between coastal stability and anthropogenic, climatic, oceanographic and geographical factors.

During the first field season, forty-five monitoring sites were established on the Island of Newfoundland and surveyed using Real Time Kinematics (RTK). Future work will involve yearly monitoring, additional sites being established, and the expansion of the program into Labrador. Discussions will be held with interested stakeholders including municipality officers, community groups, Memorial University and other government departments to identify new areas of concern, or of cultural, social or environmental importance, and these sites may be included into the program. A database will be created for the project, which will be maintained by the Geological Survey of Newfoundland and Labrador and available through the on-line Resources Atlas.

INTRODUCTION

Sea-level rise, wave action, storm surge and human activities represent factors impacting coastal areas in Newfoundland and Labrador, where 90% of the population live. The stability of the coastal environment is impacted by climatic, geographic, oceanographic and anthropogenic factors. Past incidents of coastal flooding, and cliff and beach erosion resulting in economic damage and loss of life show that these coastal areas are at risk; there have been at least thirty recorded deaths from coastal flooding in the Province since 1863 (Liverman *et al.,* 2003). One of the most severe coastal events, which hit the Burin Peninsula on November 18^{th}, 1929, was a tsunami; this tsunami killed twenty-eight people and caused property damage estimated at $1 million (1929 value) (Liverman *et al.,* 1994). Other incidences of flooding and erosion have been reported in Batterson *et al.* (1995, 1999, 2006) and Liverman *et al.* (2001, 2003). These risks are likely to increase with possibly greater severity due to the increased infrastructure development in coastal zones and changing environmental conditions (Westley *et al.,* 2011).

This report describes a multi-year coastal monitoring program, the objective of which is to collect and interpret data to quantify rates of coastal migration, understand beach dynamics and assess areas at risk to coastal flooding. The 2011 field season focused on installing and surveying forty-five monitoring sites on the Island. Site selection was based on incorporating a diversity of coastal environments with variations in sediment texture, site orientation, fetch, topography, vegetation, and bedrock; to incorporate areas of importance or concern to communities; and to re-survey areas previously studied by the Geological Survey of Canada and the Geological Survey of Newfoundland and Labrador. Sites included bluff, beach, barrier bar, and lagoon locations. Cliff-edges, transects of beaches, and measurable coastal features such as turflines, beach ridge crests and beach cusps, and the seaward edge of vegetation were surveyed using Real Time Kinematics methods. Ongoing work will involve yearly re-surveying of established sites, additional sites installed as required on the Island, and the expansion of the project into Labrador.

FACTORS AFFECTING COASTAL STABILITY

Storms and waves, changes in sea level, slope movement, human actions and changes in climate are all factors impacting the stability of coastal areas. Waves and storms may cause erosion, or beach and cliff retreat (Liverman *et al.,* 1994; Forbes *et al*., 2004). The impact of the storm is influenced by the angle at which waves reach the shoreline; the timing, track, and meteorological characteristics of the storm; and local characteristics of the areas including the shape, orientation and slope of the shoreline and surrounding area, sediment texture, geotechnical properties and nearshore circulation (Catto *et al*., 2003; Liverman *et al.,* 1994; Forbes *et al*., 2004; Plates 1, 2). Storms commonly flood low-lying areas and most severe flooding results when there is a high tide coinciding with a storm surge (defined as an increase in the level of the water caused by pressure and wind changes associated with storms; Shaw *et al.,* 1998; Plate 3)

Plate 1. *View southwest along the beach at Great Barasway. This site, along with other coastal areas of Placentia Bay such as Ship Cove, are vulnerable to storms from the south and southwest as the surrounding landmasses (Burin Peninsula, Avalon Peninsula and central Newfoundland) restrict the fetch from other directions.*

Plate 2. *Eroding coastal cliffs in Kippens. The unconsolidated cliffs between Port au Port and Stephenville are eroding at rates of up to 1.25 m/a, with the gully development and slumping associated with the characteristics of the sediment, notably marine diamicton and marine muds overlain by sands and gravels (Forbes* et al.*, 1995).*

Plate 3. *In 2006, a storm surge flooded Coley's Point and low-lying parts of the community were inundated with water.*

Relative sea-level rise (the change in the sea level relative to the land) can lead to coastal retreat and cause areas affected by flooding and erosion to migrate landward (Shaw and Forbes, 1990; Liverman *et al.,* 1994; Nicholls *et al.,* 2007). Relative sea-level change is controlled by both the vertical movement of the land (isostatic adjustment) and changes in global sea level (eustatic adjustment), and the sea level is currently rising across most of the Island, is stable or falling along the northern part of the Northern Peninsula and southern Labrador, and is falling along the rest of the Labrador coast (Batterson and Liverman, 2010).

Mass movement of sediment or bedrock (landslides, rockfalls and slumps) produce coastal erosion. The type and rate of movement is influenced by slope angle and sediment type, and the trigger for slope movement can be heavy precipitation, frost action or waves undercutting the base of slopes (Plates 4, 5).

Plate 4. *Landslide in Daniels Harbour, 2007. This slope movement damaged houses and outbuildings, forced residents to be relocated from their homes and the Northern Peninsula highway was moved farther inland. Landslides such as this one may become more frequent due to rising sea levels, increased storm activity and heavy precipitation events.*

Climate-change projections for North America/North Atlantic show a potential warming climate and associated warming of the ocean adjacent to the Province. This may increase the severity of hurricanes and other mid-latitude storms, with the consequent increase in storm surge and large waves; these could exacerbate the risk of coastal erosion and flooding (Field *et al.,* 2007). Sea levels are projected to rise across the entire Province, with increases of between 30 to 40 cm by 2049 and between 70 to 100+ cm by 2099 (Batterson and Liverman, 2010). Similarly, a predicted increase in the number of freeze–thaw cycles and extreme precipitation events, and higher sea levels may increase the risk of slope movement (Field *et al.,* 2007). There is currently a decrease in the cover and duration of sea ice, and this trend will likely continue in the future (Field *et al.,* 2007), which will further increase the risk of coastal erosion, as sea ice provides protection to the shore from waves and winter storms.

Anthropogenic activities decrease or enhance risks associated with coastal hazards. Removal of beach sediment, quarrying in coastal areas and vehicle access to beaches can increase the risk of flooding or erosion. Initiatives in the Province to identify coastal issues include geological hazard mapping (Batterson and Stapleton, 2011), desk-top modelling of coastal vulnerability (Westley *et al.,* 2011), and flood-risk mapping. Information from these studies can provide guidance to planning and policies for coastal development. Infrastructure remediation or preventative efforts in the Province include the establishment of breakwaters, gabions and sea-walls (Plate 6).

Plate 5: *Debris torrent that resulted from heavy rainfall in Harbour Breton in 1973, killing four children and destroying four houses (Batterson* et al.*, 1995).*

Plate 6: *A sea-wall was built along Placentia to provide flood protection. The community of Placentia is built close to sea level on a beach-ridge system, and parts of the community are at risk of flooding due to waves, high tides and storm surges.*

PREVIOUS STUDIES

Shaw *et al*. (1998) provided a national assessment of the sensitivity of coastal areas in Canada, where sensitivity is defined as the degree to which sea-level rise and other factors would impact coastal areas. The sensitivity index comprises seven variables and most areas in this Province have a low to moderate sensitivity ranking; however, the methods used oversimplify the coastline, likely causing smaller sensitive areas to be overlooked (Shaw *et al*., 1998). The inclusion of these smaller areas will require more detailed mapping. Catto *et al*. (2003) provided a regional assessment on the coastline of eastern Newfoundland, classifying areas based on substrate, texture, width of foreshore zone and slope.

The Geological Survey of Canada in conjunction with the Geological Survey of Newfoundland and Labrador established 79 coastal monitoring sites across the Island in the 1980s, 23 of which include multiple transects and were re-surveyed at least once (Forbes, 1984). Site monitoring included Real Time Kinematics (RTK), levelling and/or or a tape system, and estimations of coastal erosion rates were determined for a few locations that were surveyed over many years.

COASTAL MONITORING FIELD WORK – 2011

In 2011, a multi-year coastal monitoring program was initiated by the Geological Survey of Newfoundland and Labrador, in conjunction with the Geological Survey of Canada. Monitoring will focus on collecting data to estimate cliff erosion rates, and changes in beach profiles.

LOCATION

Forty-five coastal monitoring sites were established on the Island in 2011; these included a combination of cliff-top erosion monitoring sites and beach profiles (Figure 1, Plates 7, 8). Sites were selected to a) ensure representation of different environments and geographic areas, b) to provide an assessment of areas of current concern, c) to include areas of social, cultural, historic and environmental importance, and d) to build on previous studies.

METHODS

Sites were accessed by truck and foot, and each survey took between a half-day and two days to complete. Sites were surveyed using Lecia GSO9 Global Navigation Satellite System (GNSS) Real Time Kinematics (RTK) equipment. The RTK is able to collect accurate (sub-cm) position data in real time (O'Carroll, 2010) and involves a reference receiver (base station) and one or more roving receivers that communicate with a radio link (Dail *et al*., 2000). If possible, the reference receiver is set up over a known position, such as a survey monument. In order to collect accurate location data, the reference receiver takes measurements

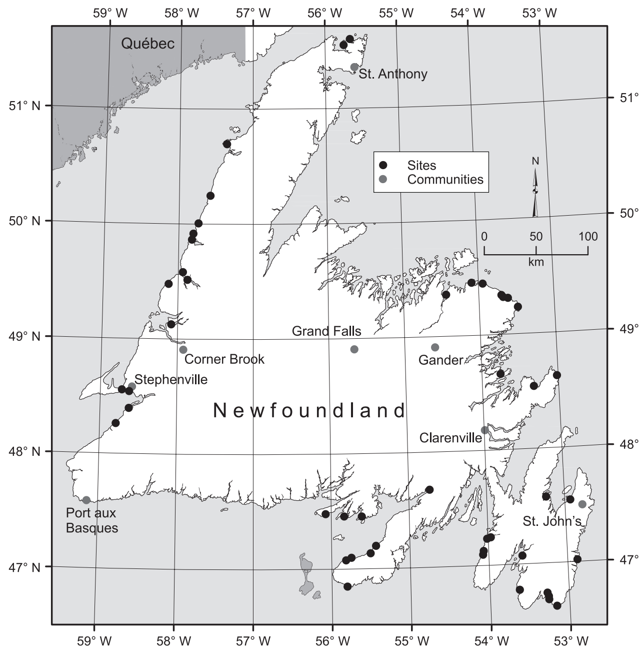

Figure 1. *Location of coastal monitoring sites established in 2011.*

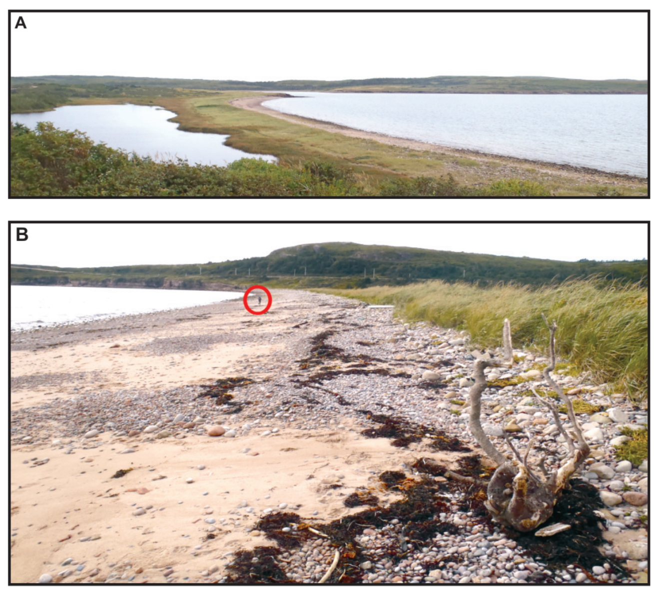

Plate 7. *St. John's Bay site, near the community of Coomb's Cove. A) View of St. John's Bay beach site, looking east; landward of the primary sandy gravel cobble beach is a lagoon and marsh. B) Cobble, boulder, sand beach near profile line two, looking west. Researcher circled for scale.*

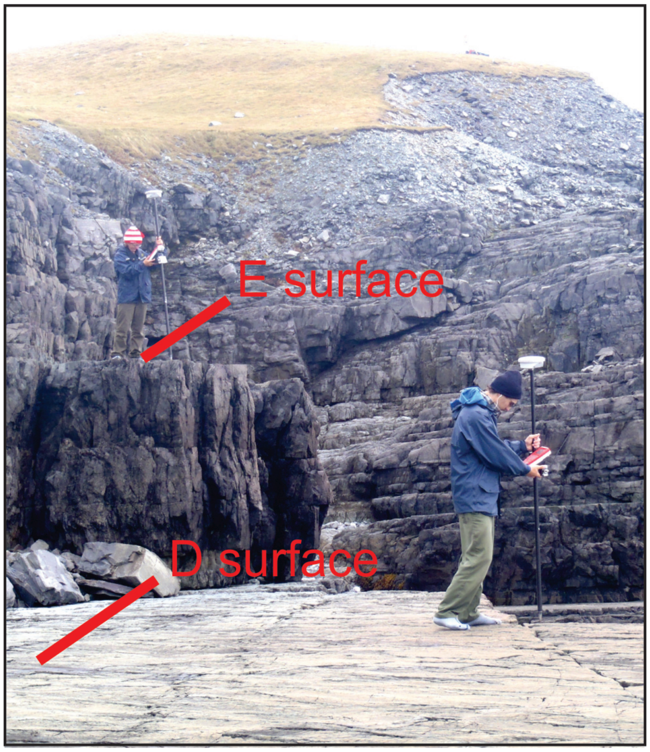

Plate 8. *Coastal monitoring of D (foreground) and E fossil surfaces at Mistaken Point Ecological Reserve. Note eroding turfline with RTK base station setup in background. Coastal erosion is threatening to damage the 575 to 560 Ma Ediacaran fossils preserved in the mudstone and sandstone. Coastal monitoring will provide data onto the current rate of coastal erosion and the sensitivity of the area to change.*

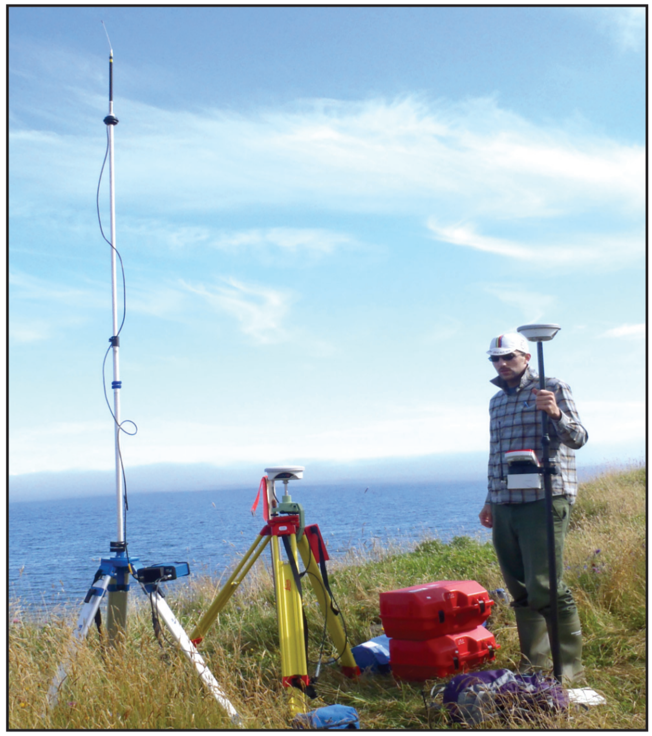

Plate 9. *Radio and antenna (blue and grey tripod) and reference receiver (yellow tripod) set up over a permanent survey monument in Fortune. Hand-held roving receiver used during surveying held by researcher.*

from the satellites and transmits the measurements to the roving receivers. The roving receiver takes measurements from the satellites, and processes them in real time with the offset values received from the reference receiver. This allows the roving receiver to correct their relative and absolute position.

For this study, the RTK base station was set up over the nearest accessible, undamaged permanent survey monument (Plate 9). Survey data were collected using two roving receivers with a GS09 GNSS antenna, modem and GS09 field controller attached to a hand-held telescopic pole. Depending on site characteristics, data were collected in one of two modes, survey or automatic by distance. In survey mode, point data are collected when specified by the user, whereas in automatic by distance mode, data are collected when the rover is moved a specified (10 cm) distance. Data were collected in NAD 83 or NAD 27 and included location information (X, Y, and Z), date, time and a description of site characteristics. Sites included beach profiles and cliff-erosion monitoring sites.

Beach Surveys

At a beach site, three to six profile lines were established. Plastic pins, on two-foot long pieces of 5/8th inch rebar, were hammered into the ground at the landward end of the profile line to decrease the risk of pins becoming lost or destroyed by coastal processes. Each pin location was described and photographed and, where possible, the location of the pin relative to other prominent features was noted. At sites where pins could not be installed into the ground due to surface conditions, other markers, such as distinctive bedrock features, were used. Using the Lecia GSO9 rover, 100 RTK readings were averaged and recorded for each pin location. Using a compass, profile lines were walked with the rover on survey or automatic by distance-mode from the pin to the water. Surveys also included measurable site characteristics including beach crests and cusps, sediment changes, backshore and the seaward edge of vegetation.

Cliff Surveys

Profile lines were also established at cliff-erosion monitoring sites (Plate 10). Similar to beach sites, plastic pins on

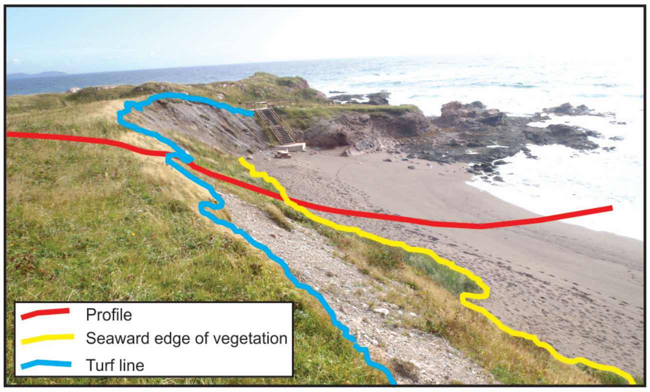

Plate 10. *Coastal monitoring of a cliff-erosion site at Harbour Breton. Coloured lines represent RTK surveys.*

Plate 11. *Coastal monitoring pin established at the landward end of a profile line at Port au Port.*

two-foot long pieces of 5/8th inch rebar were hammered into the ground several metres away from the cliff edge (Plate 11). Each pin location was described and measured using the same method as the beach surveys. Using a compass, profile lines were walked from the pin to the cliff edge, down the cliff face if possible, and from the cliff base to the water, using either survey- or automatic by distance-mode. Other site characteristics, such as the turfline, backshore and seaward edge of vegetation, and beach characteristics including beach cusps, crests and sediment changes, were surveyed.

FUTURE WORK

This is a multi-year program involving annual surveying of sites established in 2011. To increase the geographic coverage across the Island, additional sites will be added; also, the program will be expanded into Labrador. Where possible, the coastal monitoring sites of the Geological Survey of Canada and Geological Survey of Newfoundland and Labrador in the 1980s will be re-surveyed, and the data collected will be analyzed to determine erosion rates and changes in beach profiles. Discussions with local municipalities, community groups and other interested stakeholders will identify new areas of geographic concern or areas of cultural, social or environmental importance, and these sites will be considered for inclusion in the program. A database of relevant information will be created for the project, and will be maintained by the Geological Survey of Newfoundland and Labrador, and publically available through the online Resources Atlas.

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