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Coastal Erosion and Shoreline Classification in Stratford, Prince Edward Island

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This report is also available for download from the ACASA website at: www.atlanticadaptation.ca

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Introduction*

In the midst of updating its sustainable development plan, the Town of Stratford determined that information was needed to assess the vulnerability of its coastal areas to the impact of a rising sea level and climate change. In order to move towards this goal, Town officials contracted *Géo Littoral Consultants* to:

(a) compile and summarize historical erosion data for Stratford, its associated watershed (the Hillsborough River estuary), and other regions of the Province with similar geology and coastal features, and

(b) recommend a shoreline classification system for Stratford (including the Hillsborough River estuary) which could then be utilized to classify the entire shoreline of Prince Edward Island.

This report contains the findings of this study. It first provides an overview of the major processes involved in coastal erosion and coastal evolution, and discusses the impacts of climate change in the coastal setting of the Maritime Provinces. The following section deals with the erosion data compiled: the different data acquisition methodologies and their associated accuracy, the available sources of information, and the synthesis of the findings. This section is followed by a review of several shoreline classification systems that have been used in Eastern Canada and includes the description of a model suited for the study area. Finally, the report includes a section on the Town of Stratford: the coastal types present along the shores and the available erosion data compiled for the study area. This section is concluded with a list of recommended actions to be considered by the Town of Stratford in order to fulfil their goals of assessing the vulnerability of their coastal zone to erosion and climate change.

* **Important notice**
While the terms *shoreline* and *coastline* generally correspond to the high water mark and the higher high water mark, respectively, coastal geomorphologists use specific features to map them. The shoreline is usually located seaward of the coastline and coincides with the physical interface of land and water – the wet/dry beach boundary. The coastline is a more robust marker to monitor coastal erosion and accretion. It usually corresponds to the landward extent of the sea's action (to the exception of large storm events). Factors related to its reliable mapping when localizing it on aerial photographs or satellite images are also taken into account in the choice of the coastal feature that approximate the higher high water mark: the top of cliffs and bluffs, the top of dune scarps, the edge of the perennial vegetation on regular dune fronts, vegetation types indicative of tide frequency and duration in salt marshes, etc. In this report, *shoreline* is used as a generic term to identify the coast and *Géo Littoral Consultants* did not modify the terminology used by the different authors consulted.

Coastal processes, Coastal evolution, and Climate change[1]

Several land-forming processes are present at the coast, some of them being specific to that environment and related to the presence of the sea (***littoral processes*** *stricto sensu*), others being present over all emerged land (continental processes). In a given area, the shape of the shoreline will depend on the balance between these two categories of processes.

Coastal processes

In the Gulf of St. Lawrence and the Northumberland Strait, the main LITTORAL PROCESSES are related to waves, tides, sea-ice and wind.

Wave action can obviously cause erosion at the base of cliffs and bluffs and along beaches, dunes, and marshes. On cliffs and bluffs, their effect has to do with the force of impact of water and of the rock and other debris (ice, wood, etc.) that it carries. Waves will undercut steep slopes and destabilize their upper section. They will also carry away any debris fronting the base of cliffs and bluffs so that direct action on the scarp can resume. Waves also moisten rocks, deposits, and soils at the coast, raising their water content, which can be critical to some coastal processes (see below).

From a geomorphological point of view, the depth at which waves (the movement of water through the water column) are *felt* by the sea bed marks the seaward limit of the littoral zone: most transfers of coastal sediments occur in the zone between this depth and the coast. They take the form of currents such as:

(a) undertow and rips, which are directed offshore and return water piled-up onshore by the waves;

(b) the longshore current, which is present when waves reach the coast at an angle, results in an exchange of sediments along the shore.

Tides play an important role in coastal processes. On *wave-dominated coasts* (cliffs, bluffs, and sandy coasts) their level modulates the zone of direct action of waves at the shoreline. On *tide-dominated coasts* (salt marshes, on low energy-open coasts, and in estuaries), the duration and

[1] This section provides an overview of concepts in coastal geomorphology that are required for the understanding of coastal evolution. For further reading, we refer you to general textbooks such as DAVIDSON-ARNOTT (2010), MASSELINK and HUGHES (2003), WOODROFFE (2002), BIRD (2000), PASKOFF (2000) or TRENHAILE (1997).

frequencies of water levels determine the location of maximum sedimentation (and development) of tidal flats and salt marshes. Finally, in the presence of inlets or narrows, tidal currents can develop.

In cold climates of the middle or high latitudes, the presence of ***sea ice*** and ***ice foots*** can be a decisive factor in the evolution of the coast. During the sea-ice cover, waves will be dampened at the coast and this has a buffering effect on erosion of coastal features. The ice-foot will generally protect sandy coasts and salt marshes during winter but can cause erosion at the spring thaw, either by removal of ice-frozen sediments or through mechanical action of ice rafting. On cliffs and bluffs, the presence of an ice foot at the high tide level can promote weathering processes and undercutting of the slope.

Finally, ***wind action*** is especially important on sandy coasts as it is a requirement to the development of coastal dunes. Wind has a double effect of erosion (deflation), on beaches and in dunes (on dune scarps and deflation hollows for example), and sedimentation (like the creation of coastal dunes through its interplay with vegetation).

CONTINENTAL PROCESSES will be active on coastal lands as everywhere else on the Province. Here are a few of these processes active along the coast:

- ***frost action*** will cause rock outcrops to weather and release rock fragments of different sizes. This happens when water present within fissures or pores changes to ice. The occurrence of this process is seasonal but will favour the action of other processes such as rock fall and contribute to the retreat of cliffs.

- ***rock fall***, ***debris*** or ***land slides***, and ***soil slumping*** are mass wasting processes that can take place on coastal slopes and may occur at all time. However, because water content of rock/deposits/soils often plays a triggering role, these processes may show a seasonal pattern and/or come as a result of particular meteorological events.

- ***running water*** will cause erosion of bluffs and other coastal slopes, sometimes resulting in the development of gullies.

It is important to note that while processes described above are associated to erosion at a given location, they result in an input of sediment into the coastal system and might be linked to the balanced sedimentary budget of some other stretch of coast, which leads us to some concepts of coastal evolution.

Coastal evolution

Coastal geologists and geomorphologists differentiate between two main ***categories of coasts***: constructional and retrograded. CONSTRUCTIONAL COASTS are due to the accretion of sediments at the shoreline, either sand, gravel, cobbles and boulders (beaches) or fines[2] (salt marshes). They always form low-lying coasts. Cliffs and bluffs form RETROGRADED COASTS, which develop through the retreat of coastal land and the formation of a scarp of varying height.

It is important not to confuse these two modes of genesis (original development) of coasts with their ulterior evolution. As an example, once developed, constructional coasts can experience retreat, either through marine submersion and/or coastal erosion[3]. In the same way, a cliff can become isolated from the sea if accretion builds a beach and/or coastal dunes in front of it.

When discussing coastal evolution, it is practical to view the coast on a series of segment that are interconnected to each other. The concepts of *littoral cell* and *sedimentary budget* help doing so.

A ***littoral cell*** is a coastal segment which is individualized relative to the adjacent coast, from a sedimentary point of view. Typically, a littoral cell is bounded by coastal features that hinder longshore currents such as major headlands or deep fluvial channels at estuary mouths. By definition, sediment fluxes between sub-units of a littoral cell should then be more important than sediment fluxes through the boundaries of the littoral cell. For example, a river mouth bordering a cape can convey sediments to the coast, where it is carried by a longshore current and deposited on a beach/dune complex bordering another cape.

The concept of littoral cell emphasizes the dynamic link that often exists between the different parts of a coastal segment, which is highly relevant from management and land use planning perspectives. It also leads to the understanding of the coast as a system, with its sediment sources and sinks that are related to each other by fluxes.

The ***sedimentary budget*** is the sum of all inputs and outputs of sediments in the coastal system. It may be calculated at different scales but as it has been stated before, it must at least be approximated in order to establish the boundaries of a littoral cell. Sediment sources and sinks in the coastal system can be located underwater (the nearshore), at the land and sea interface

[2] Clay and silt particles (although salt marshes can also develop over fine sand).

[3] In that case, their recognition as constructional coasts emphasizes the fact that coastal evolution conditions have changed over time.

(the intertidal zone), and on land (the backshore, such as foredunes, or a river mouth). They include:

- inputs of sediments by rivers, wind, or longshore currents (coming from an adjacent cell); cliff or bluff erosion; artificially through beach nourishment; etc.
- outputs of sediments through coastal currents (directed offshore - rip currents - or a longshore current flowing towards an adjacent cell), winds; artificially as a result of sand extraction (sand mining); etc.

Once established (most of the time approximated), the sedimentary budget provides an assessment of the context within which coastal evolution is taking place. This information is useful in understanding the various responses of the coast to what seems at first to be similar forcings. For example, while a general context of crustal submergence might usually lead to coastal retreat and erosion, local sediment inputs by a river can be sufficient to offset this trend or mitigate it.

In ***recent geological times***, i.e. in the last few thousand years, the coasts of the Maritime Provinces have been submitted to a submergence by the sea. For the western part of Prince Edward Island, QUINLAN and BEAUMONT (1981) and SCOTT *et al.* (1981) calculated mean rates of relative sea-level rise of 10 cm/100 yrs (over the last 4000 years) and 8 cm/100 yrs (over the last 3000 years), respectively. These rates are comparable to an observed value of 25 to 30 cm on the New Brunswick coast of the Northumberland Strait in the 20th century (DAIGLE *et al*., 2006). It should be noted that in our region, these rates include an eustatic component (rise of the global sea level) and a tectonic component (crustal subsidence due to lithospheric unloading following the last ice age), hence the term *relative sea-level rise*.

Evidence of the response of the coast to the recent (geological) and present (historical) relative sea level rise can be found throughout Eastern Canada and the Gulf of St. Lawrence. Marsh vegetation outcrops in the intertidal zone attest to the landward migration of sand spits and tombolos. Historical retreat of cliffs and bluffs are well documented from maps and aerial photographs. Submergence of salt marshes has been highlighted in southeastern New Brunswick based on the 1944 to 2001 aerial photograph series. On the other hand, sandy coasts also showed sectors of accretion and growth of spits, as should be expected from such highly dynamic systems. Nevertheless, the general picture in the Maritimes suggests that retreat is a common response of most of the coasts to the present submergence.

Climate change

Predictions of climate change that are directly relevant to coastal environments include:

- ***an acceleration of the sea level rise***

  According to the International Panel on Climate Change (IPCC), global sea-level rise has been 17 cm in the 20th century and it is expected to reach 18 to 59 cm in the 2090-2099 decade relative to 1980-1999 (IPCC, 2007). These projections have been considered to underestimate the probable sea-level rise by several authors. RAHMSTORF (2007) proposed a range of 50 to 140 cm (instead of 18 to 59 cm). On the New Brunswick coast of the Northumberland Strait[4], DAIGLE *et al.* (2006) projected a relative sea-level rise of 50 to 59 ± 35 cm from 2000 to 2100. In a recent study, DAIGLE (2009) revised this range to 72 to 80 ± 28 cm.

- ***a shortening of the duration of the sea ice cover season***

  DAIGLE *et al.* (2006) concluded that it was not possible to recognize a significant trend relative to sea ice cover in the Gulf of St. Lawrence since 1969 with the current available data. Weak trends towards a shorter duration of the seasonal sea ice cover have been identified but could not be used to model future conditions. It was expected that the decrease of seasonal sea ice in the Gulf would happen at a slower pace than what is observed and modelled in the Arctic basin.

- ***an increase of the number and/or intensity of storms at middle latitudes***

  This prediction is generally listed with the two previous ones but it is also much less robust. However, given the expected sea-level rise, a storm event should reach higher water levels in the future. This means that the extreme conditions of today would have shorter return periods.

All of these changes would result in an intensification of coastal dynamics. On a regional scale, this should translate into higher rates of retreat of cliffs and bluffs, landward migration and/or submersion of salt marshes, and landward migration of sandy coasts. Of course, the landward migration of low-lying coastal habitats is only possible in the absence of obstacles preventing its migration, such as higher grounds or human infrastructure (roads, protection structures, etc.). The latter situation would lead to what has been called ***coastal squeeze*** (FRENCH, 2001), i.e. the loss of coastal habitats and the protection they afford as retreat and in-situ submersion proceeds. Whatever scenario is considered, the expected impacts of climate change warrant a sound coastal zone planning which takes into account the dynamic nature of the coast.

[4] Again, these regional rates include both the rise of the global sea level AND the crustal subsidence observed in the Maritimes (while the IPCC figures only reflect the former).

Shoreline Erosion Data

The current study was able to identify and compile a total of 1128 erosion values (calculated or measured), scattered around Prince Edward Island: 828 erosion values along the Gulf of St. Lawrence (73%), and 300 erosion values along the Northumberland Strait (27%). This total number would be significantly larger if all the data had been available (the majority of the data contained in the Provincial database – LRIS 1988 - as well as the majority of the monitoring data carried out by the Provincial government during the early 1990s, were not integrated in this project). As a result, no data was compiled for the following areas (Figure 1):

1. Along the Gulf coast, from North Cape to Kildare Cape
2. Along the entire barrier island system off the Gulf coast, from Alberton to Cape Tryon, including the Cascumpeque and Malpeque bays and their accompanying estuaries and tidal river systems
3. Along the Gulf coast, from Greenwich National Park to East Point
4. Along the Strait coast, from Campbellton to West Point

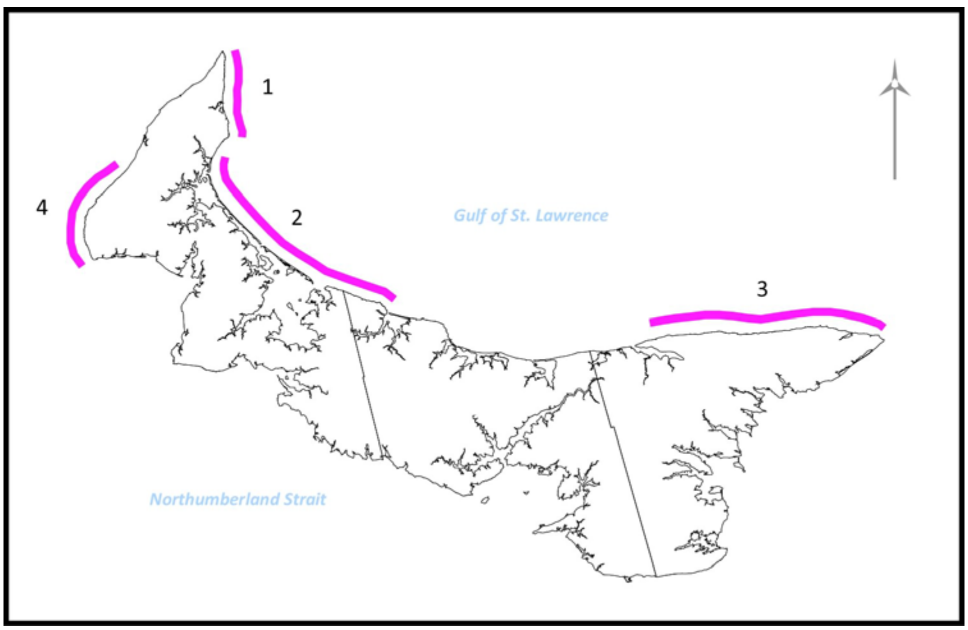

Figure 1. Areas of Prince Edward Island where no erosion data was compiled.

The list of figures showing the general location of the measurement sites used to collect erosion data is in Appendix 1 (Figures 1a to 1m). These figures are based on the federal 1:50 000 NTS sheets.

Erosion data acquisition – description of the different methodologies

The review of the literature permitted to identify a number of publications presenting erosion data for Prince Edward Island (see section *Available erosion data compiled in this study* for the complete list of documents consulted). Within these publications, 11 studies and reports contained sufficient information describing the methodology used, the location of measurements and the erosion data itself to be included in this report. The studies, reports and research projects that produced the erosion data presented here were completed anywhere between 1959 and 2010.

The erosion data compiled and summarized in the sections below were acquired through 6 different methods, which can be grouped into two broad categories: the methodologies using **direct** (field) measurements and the methodologies using **indirect** (laboratory) measurements. Each methodology within these two categories was assessed based on their relative degree of accuracy, i.e. how reliable is the data extracted from each method? The methods were then ranked by a qualitative score ranging from 1 (most accurate) to 6 (least accurate). Table 1 presents a brief overview of each methodology, their usual or common accuracy, and their relative rank or score and links each study or report used here to the appropriate methodology.

Table 1. Relative accuracy and ranking of the different methodologies used for the production of the erosion data compiled in this study.

	Method Overview	Usual/Common Accuracy	Score/Rank	Studies
Direct (field) Measurements	Digital field measurements – GPS-RTK	mms-cms	1 to 2	c
	Analog field measurements - total station	mms-cms	1 to 2	e
	Analog field measurements - tape measure	< 2 m	3	b, d, h
Indirect Measurements	Digital photogrammetry - GIS	3 to 7 m	4	i, j
	Analog photogrammetry - zoom transfer scope	> 7 m	5 to 6	f, g, k
	Analog map measurements - cadastral maps	>> 7 m	5 to 6	a

a: GENEST & JOSEPH (1989) - Jacques Cartier Provincial Park area
b: HAWKINS (2009) - PEI National Park area
c: GSC(1989-2008) - 7 monitoring sites along Gulf coast; 4 monitoring sites along Strait coast
d: SGSLC (2009) - Little Harbour beach and East Point cliff monitoring sites
e: MACPHAIL (2010) - Jacques Cartier Provincial Park and Kildare Cape areas
f: LRIS (1988) - only data located in the proximity of the Town of Stratford was used here
g: FORWARD *et al.* (1959) - the entire coast along the Northumberland Strait
h: PEI Dept. Community & Cultural Affairs (1984) - only data located in the proximity of the Town of Stratford was used here
i: MCCULLOCH *et al.* (2002) - the coast between Blooming Point and St Peters Bay
j: Coldwater Consultants (2009) - sandstone/till bluff along the Town of Souris
k: NUTT (1990) - the coast between Rustico Island and Greenwich National Park

Direct Measurements

The methodologies which use direct measurements for erosion data acquisition are based on change analysis and are carried out on site, in the field. This procedure involves the measure of displacement (or positional change over time) of specific features, such as coastlines, shorelines, coastal type boundaries, such as dunes, marshes, beaches, cliffs and bluffs, etc. relative to a known and fixed position. The methods can involve the use of a common *measuring tape*, a graduated metal chain, or more sophisticated equipment such as a *Total Station* or a high-precision GPS (*GPS-RTK*). Usually carried out in conjunction with survey monuments, corners of buildings or erosion pins, a measure is taken that represents the distance of a coastal feature to the known position (or baseline). Given the small time period over which the data is collected (usually less that 20 years), the direct methodologies generate erosion data that can be characterized as monitoring data, i.e. reflective of short term conditions at the coast during the data collection.

Digital field measurements – GPS-RTK

A high-precision Global Positioning System-Real Time Kinematic (*GPS-RTK*) is a sophisticated GPS technique which uses a fixed base station and mobile rovers to provide corrected coordinates in real time. The accuracy of a *GPS-RTK* unit can be in the sub-centimetre magnitude, but this precision is applicable mostly when the unit is set in the static mode, i.e. when the measure is made on one point during many consecutive minutes or even hours. When the unit is set in the roaming or kinematic mode (RTK) – many readings registered in a short time along a path or transect, as is typically the case – the accuracy tends to fall, but generally remains under 5 cm. In fact, many *GPS-RTK* units are set to accept readings that are no greater than a maximum of 5 cm horizontally (x,y) and no greater than 10 cm vertically (z).

Once the base station is set upon a known monument, the researcher or surveyor can measure the distance of a coastal feature (cliff, shoreline, etc.) to a baseline (erosion pin, building, etc.), at a sub-centimetre accuracy. For the purposes of this study, erosion data acquired by *Digital field measurements using a GPS-RTK* is considered the most accurate technique reviewed and received the rank of 1 to 2 (most accurate).

Analog field measurements - Total Station

A *Total Station* is an electronic/optical instrument mostly used in surveying. It is based on a direct line of sight of a prism by the unit to measure positions and distances; it is equipped with an electronic system that automatically calculates, by trigonometry and triangulation, the position of points relative to the *Total Station*. *Total Stations* are generally very accurate on short distances, within the order of a few millimetres. However, along the coast, where humidity is omnipresent and the atmospheric distortions are common, measurement quality deteriorates quickly. Distance of the unit relative to the prism is also a limiting factor that causes measurement quality to decrease. During a coastal study in northern New Brunswick, it was found that distances between the unit and the prism that were greater than 500 m resulted in an error exceeding 5 cm (horizontal and vertical) (D. Bérubé, New Brunswick DNR, pers. communication). Unless the *Total Station* is coupled to a GPS the data retrieved is considered relative, if no survey monument is located nearby.


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Once the *Total Station* is set, the researcher or surveyor, with the help of a second person, can measure the distance of a coastal feature (cliff, shoreline, etc.) to a known monument, at sub-centimetre accuracy. If all the conditions are optimal, the *Total Station* remains a very accurate means to acquire erosion data, and for the purposes of this study, it received the rank of 1 to 2 (very accurate).

Analog field measurements - Measuring Tape

The *measuring tape* method is probably the oldest way to monitor coastal erosion. It is quite straightforward: to measure the distance between a fixed object, such as an erosion pin - metal or wooden survey stake driven in the ground - and a coastal feature. The accuracy level of the *measuring tape* method will obviously first be related to the tape scaling (decimetres, centimetres, millimetres – one cannot provide a centimetre level of accuracy using a decimetre scale tape). Other factors that affect the level of accuracy are environmental: trees, branches and shrubs along the transect can lift or displace the tape measure; winds can cause the tape to curve. How much these environmental factors negatively affect the accuracy can be somewhat difficult to quantify. A comparative study undertaken in the Acadian Peninsula, which aimed at comparing dune monitoring results using a *GPS-RTK* and a *measuring tape*, revealed that there


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was an average of 1.8 m difference between the two data sets. As is the case with the *Total Station*, unless there is a survey monument located nearby, the data acquired through tape measurement is considered relative.

Albeit the apparent large inaccuracies related to the *measuring tape* method (< 2 m), it is still considered to be more accurate than the indirect methods. For the purposes of this study, it received the rank of 3 (accurate).

No matter which direct method is used for acquiring erosion data (GPS, Total Station, Measuring tape), part of the accuracy will depend on the ability of the user to correctly identify the type of feature in the field. As an example, not all sandstone cliffs or till bluffs have a sharp edge or scarp, as if they were cut with a knife: when the edge of a feature is rounded or smoothed, it is not always easy to come to an agreement as to how its edge or limit will be determined.

Indirect Measurements

The methodologies which use indirect measurements for erosion data acquisition are usually based on change analysis and are carried out in a laboratory. This procedure involves the measure of displacement (or positional change over time) of specific features: coastlines; shorelines; property boundaries; coastal feature boundaries, such as dunes, marshes, beaches, cliffs and bluffs, etc. The methods can be based on the use of maps (topographic, bathymetric, cadastral, etc.), but indirect methodologies most often use images (sequential vertical aerial photographs or satellite images). Most often, it is through the use of indirect methodologies that historical erosion data can be generated, i.e. long time periods (up to more than 80 years depending on the date of the earliest aerial photograph series available) that is reflective of the overall trend of the coast.

Digital photogrammetry - GIS

Digital photogrammetry using a Geographical Information System (GIS) is now a common photogrammetric method. Contrary to the *Analog photogrammetry using a Zoom Transfer Scope* (see below), which is essentially a manual mapping technique, *Digital photogrammetry using a GIS* is, to a very large extent, a computer assisted mapping technique. It is based on the registering (or georeferencing) of raster files (digital images – sequential vertical aerial photographs or satellite images), through the use of an orthophotograph - an already registered image - or through the use of ground coordinates obtained by GPS, in order to position the image appropriately in space. This registering process automatically assigns to the raster file a series of attributes required for geopositioning: x,y,z coordinates, projection, scale, ellipsoid, and datum.

The registering of aerial photographs using a GIS requires the identification of ground control points: natural or human landscape features that are recognizable from one image to another, and that have not changed position, such as corners of buildings, road intersections, drainage ditches, corners of fields, small ponds, isolated trees. These control points must be found on the aerial photographs as well as the orthophotograph, and must also be scattered evenly over the study area. To correctly register an image, a minimum of 10 control points is required, and the margin of error associated to their relative position (as mapped on the aerial photograph and on the orthophotograph) should not exceed a maximum horizontal distance determined by the user, usually no greater than 5 m.

Once aerial photographs of different time periods have been georeferenced and their coastal features mapped, the files can be merged together in order to measure shoreline (or coastline) displacement. The margin of error (or accuracy) associated to *Digital photogrammetry using GIS* is variable, and can range anywhere between 3 and 7 m. This margin of error can be calculated quite precisely and includes the integration of the following inaccuracies inherent to the process: the ground pixel value of the raster image, the accuracy of the orthophotograph used to register the image, the photograph and cartography quality, and the mean error of the ground control points.

For the purposes of this study, erosion data acquired by *Digital photogrammetry using GIS* is considered an accurate technique and received the rank of 4 (accurate). If all the necessary precautions are taken while using *Digital photogrammetry*, this technique is the most accurate of all the indirect measurement methods to acquire historical erosion data.

Analog photogrammetry - Zoom Transfer Scope

The *Zoom Transfer Scope* is an optical device that allows for simultaneous viewing and scale matching of a variety of sources (such as aerial photos, plates, and surveys) to a base map (such as a topographic map or a bathymetric map): it displays two images superimposed on a single display at nearly the same scale and orientation. Once the zoom lens is adjusted for scale differences, data can be transferred (or traced) manually to a base overlay, such as a mylar or acetate. The procedure requires that the base document (for example a topographic map) be

visible at the same time as the other source material (for example an aerial photograph). Through the use of a zoom lens, the user adjusts the scale (apparent size) of identifiable points (roads, lakes, houses) of the aerial photograph to the same scale (apparent size) of the same ones found on the base map (topographic map). When all the identifiable points have been matched, the user then manually drafts the features onto the transparent film, using a black film lead pencil. BOLSTAD and SMITH (1994) conclude their study on errors in GIS by stating that the accuracy of the *Zoom Transfer Scope* is variable in large part because the end result can only be as accurate as the base map used for the study. As an example, the authors state that some digitized maps can carry an error ranging anywhere from 3 to 10 metres. HAMILTON (2003) acknowledges that the accuracy of the *Zoom Transfer Scope* is highly variable, often unknown and potentially large.

For the purposes of this study, erosion data acquired by *Zoom Transfer Scope* is considered one of the two least accurate techniques reviewed and received the rank of 5 to 6 (least accurate).

Analog map measurements - Cadastral Maps

The use of cadastral maps (or survey maps) to acquire erosion data can be done in a number of ways, usually through *Digital photogrammetry using GIS* and *Analog photogrammetry using a Zoom Transfer Scope*, depending on the time period the study took place. In the case that concerns us here, *Map measurements using cadastral maps* will be associated to the *Analog photogrammetry using a Zoom Transfer Scope* described above (the erosion rates compiled for PEI through the use of cadastral maps were obtained in the late 1980s, before the full development of *Digital photogrammetry using GIS* in the 1990s).

Above and beyond the general error range associated to the *Zoom Transfer Scope* technique (3-10 m), the use of cadastral maps to acquire erosion data introduces another range of inaccuracy: the surveyor's ability to identify correctly the shoreline (or coastline). As we have seen in the **Direct** measurement methods presented above, not all coastal features are defined by a clear-cut boundary. For example, if the surveyor is required to map out the coastal boundary of a property using the Ordinary High Water Mark (OHWM), this «line» might be easier to interpret if the coast is characterized by a vertical sandstone cliff than if the coast is characterized by a very gently sloping beach/dune complex. Positioning the OHWM on the latter coastal type could induce an error ranging anywhere from a few metres to a dozen metres. A final element adding to the inaccuracies of this particular measurement method is the distortion of the maps caused by humidity (ambient humidity of the air).

For the purposes of this study, erosion data acquired by *Analog map measurements using Cadastral maps* is considered one of the two least accurate technique reviewed and received the rank of 5 to 6 (least accurate).

Available erosion data compiled in this study

All erosion data compiled in this study was extracted from 11 sources (see Table 2 for summary). They are listed here in the form of an annotated bibliography, outlining the location, discussing the methodology, presenting the number of erosion values they contain, and highlighting the major findings of the authors. An effort has been made to sort these 11 publications in order of priority for the Town of Stratford and the Hillsborough River area (similarity of coastal types, substrate, exposure, proximity to study site, etc.). The first of these erosion studies to be presented is the FORWARD *et al.* (1959), in great part because this study characterizes the entire coast along the Northumberland Strait (description based on field work), as much the outer (exposed) coast as the inner parts, such as the bays, harbours and upper reaches of estuaries. The FORWARD *et al.* (1959) study provides the most complete picture of the Strait's coastal zone and its evolutionary trend over the period 1935-1958.

Table 2. Number of erosion values compiled for the Gulf and Strait coasts, organized by methodology and coast types.

		Indirect Methods			Direct Methods			
		Survey Maps	Transfer Scope	Digital GIS	Tape Measure	GPS-RTK	Total Station	
Gulf Coast	Sandstone Cliff		1		59		8	68
	Till Bluff	2		105	20		42	169
	Marsh							0
	Dune		44	234	82	231		591
Total # for Gulf coast:		2	45	339	161	231	50	**828**
Strait Coast	Sandstone Cliff		77	34		9		120
	Till Bluff		87		10			97
	Marsh		21					21
	Dune		25		9	28		62
Total # for Strait coast:		0	210	34	19	37	0	**300**

Other sources of information contained erosion data but was considered too generalized (on average, the coastline of PEI is retreating at -0.5 m/yr since the last 6 000 years) or too imprecise in terms of location (the barrier islands of the north shore are retreating inland at a rate of -1 m/yr) to be included in the databases. However, a short annotated bibliography of publications relevant to this study is presented in Appendix 3 – it contains papers, studies or reports consulted or made available to *Géo Littoral Consultants*.

Annotated bibliography of the 11 data sources

1. Forward, C.N., Rayburn, J.A. and Raymond, C.W. 1959. Shoreline types, sequential changes and land use along the Northumberland Strait. Geographical Branch, Department of Mines and Technical Surveys, Ottawa, Ontario, 28 maps (1:50 000 scale).

The report that discusses FORWARD's methodology was not accessed; only the map sheets were available through the Geological Survey of Canada, Bedford (Robert B. TAYLOR, coastal geomorphologist). A brief overview of the methodology was provided by telephone on 7 April 2010 by Mr. TAYLOR, as well as by Dominique BÉRUBÉ (coastal geomorphologist, New Brunswick DNR) on 12 April 2010. One of the objectives of the FORWARD *et al.* (1959) study was to collect historical erosion rates along the shores of the Northumberland Strait in order to assess the impacts of a proposed causeway (land line) linking PEI and NB. Most of the rates derived from aerial photograph measurements are presumed to have been collected through the use of a *Zoom Transfer Scope*; the remaining rates presented in the study were collected by survey methods and private landowner feedback. A total of **208 erosion rates** are provided in the study (91 of these rates are derived from direct measurements, either by survey or provided by landowners – not specified on the maps). In many stretches of coast along the Northumberland Strait, no erosion data is indicated, but there is a qualitative appreciation of shoreline evolution: «Moderate erosion», «Rapid erosion», «Very rapid erosion», «Severe gullying». In addition to the erosion component, FORWARD and his colleagues classified the entire coastline of the Northumberland Strait based on the substrate and elevation at the coast. The «Erosion Face Types» recognized were:

1. Steep rock face
2. Undercut rock face
3. Jagged rock face
4. Rock shelf
5. Masked rock face
6. Unconsolidated face, rock based
7. Unconsolidated face (usually over 5 ft)
8. Unconsolidated face (up to 5 ft)
9. Esturarine
10. Depositional beach

The FORWARD *et al.* (1959) study provides mean erosion rates for the following coastal types along the Strait:

- dunes (24 values, ranging from -0.15 to **-6.16** m/yr)
- marshes (21 values, ranging from -0.37 to **-1.52** m/yr)
- till bluffs (86 values, ranging from -0.15 to **-4.88** m/yr)
- sandstone cliffs (76 values, ranging from -0.10 to **-1.98** m/yr)

No precise location of the measurement sites for the erosion data presented is given.

The approximate location of the measurement sites can be viewed in Appendix 1 (Figures 1a to 1k, and 1m) and the complete data set can be found in Appendix 2 (Table 2e), or accessed in the electronic spreadsheet: *PEI_AnalogPhotogrammetry_TransferScope.xls*.

2. Coldwater Consulting Ltd. 2009. Souris – Shoreline Erosion Study. Prepared by Davis, M.H. and MacDonald, N.J., submitted to the Town of Souris, 54 p.

This study is an assessment of coastal cliff and bluff retreat along the Town of Souris, between the harbour infrastructure and Souris Beach Provincial Park (the study site is a little over 1 km long). The study also examined engineering alternatives to counter the erosion problem (bulkhead, revetment, sand beach accretion using groynes or detached breakwaters). The bluffs are characterized by horizontally bedded sandstone at the base overlain by several metres of glacial till. The cliffs are generally low (around 2 m) in the area adjacent to Souris Beach and get higher along the rest of the study site (7 to 10 m). In order to assess coastal change, aerial photographs (1935, 1958, 1974, 1990 and 2000) were orthorectified. The study does not specify how the erosion data was collected; it can only be presumed here that *Digital photogrammetry using GIS* was employed. The methodology lacks clear indications concerning the identification of ground control points: what was used, how many were identified, what was the final margin of error. A best estimate is that **34 shoreline measurements** were measured at the study site, along 9-100 metre-long segments of the coast, for the years studied. It is not clear if each measurement represents an average value for each of these segments, or if only one measure was taken along each segment. The study does not include a table presenting the data; the data extracted for the present report was estimated based on a figure showing the approximate location of the shoreline of each year relative to the 1935 position (very generalized). All data extracted from this study is therefore considered approximate.

The study states that the bulk of the erosion observed in the past 65 years occurred during the period 1935-1958 and that relatively small changes have been observed during the 1990-2000 period. The greatest shoreline retreat is near the eastern-most section of the study site (segments 700-800, 800-900 and 900-1000), where the mean rate is **-0.1** m/yr (a retreat of 6 m over 65 years).

No precise location of the measurement sites for the erosion data presented is given.

The approximate location of the measurement sites can be viewed in Appendix 1 (Figure 1k) and the complete data set can be found in Appendix 2 (Table 2d), or accessed in the electronic spreadsheet: *PEI_DigitalPhotogrammetry_GIS.xls*.

3. Land Registry and Information System 1988. Air photo interpretation of coastal erosion on Prince Edward Island. Study prepared for the Prince Edward Island Department of Community & Cultural Affairs, August 1988, 1 p. + 12 maps (NTS sheets 1:50 000 scale)

In the late 1980s, the Land Registry and Information System-Amherst (LRIS) carried out a photo interpretation of coastal erosion for the entire coastline of Prince Edward Island in order to collect historical rates of coastline displacement. Information was carried out at 1 kilometre intervals and was recorded on 1:50 000 scale NTS maps. The study used in large part the 1935-1936 and 1980-1987 sets of aerial photographs. The *Bausch and Lomb Zoom Transfer Scope* was used to scale and position the 1935 air photographs in accordance to the 1980 air photos and then to map out the coastal feature (shoreline) on mylar bases. No margin of error is specified in the report, but control points were identified: «...all possible control was exercised: i.e., field boundaries, rivers, brooks, driveways, houses, sheds, barns, etc. ». A large inaccuracy may be associated to these rates as no apparent correction was made for distortion, and no clear evidence is provided detailing the exact type of coastal features mapped (shoreline VS coastline). The total number of erosion rates calculated is not mentioned in the report, but could be significant (somewhere close to 1000) since a measure was taken every kilometre, whenever possible. Also, the report does not mention if the inner part of the coastal zone was also assessed (the bays, harbours and estuaries).

For the present work contract, the Provincial government provided the 8 LRIS erosion rates available along the Town of Stratford boundaries (from Battery Point to Alexandra Point). The first 7 rates are in a sandstone cliff (overlain by glacial till) and range from -0.15 to **-0.30** m/yr, and the other rate, for a till bluff at Alexandra Point, shows a mean yearly retreat of **-0.06** m.

No precise location of the measurement sites for the erosion data presented is given.

The approximate location of the measurement sites can be viewed in Appendix 1 (Figure 1g) and the complete data set can be found in Appendix 2 (Table 2e), or accessed in the electronic spreadsheet: *PEI_AnalogPhotogrammetry_TransferScope.xls*.

4. PEI Dept. of Community & Cultural Affairs 2003. Q-4: Tea Hill monitoring site & Q-5: Hazard Point lighthouse monitoring site. Data entry sheets for both monitoring sites (1984-2003), 6 p.

The data obtained for the Tea Hill and Hazard Point monitoring sites (two separate .pdf fact sheets) was provided to *Géo Littoral Consultants* by Don JARDINE (Regional Adaptation Collaborative - PEI Project Coordinator) - no written report accompanied these documents. The short summary that follows is based on e-mail exchanges and verbal discussions with Mr. JARDINE.

In 1984, the PEI Department of Community & Cultural Affairs set up a coastal monitoring programme across the Province. This programme was volunteer-based, generally required minimal expenditure (erosion pins and tape measurements), and was intended to monitor coastal erosion on a yearly basis. No further information was gathered on the methodology nor on the definition of the «shoreline», i.e., what coastal feature was used for the measurements. The number and exact location of these sites can be obtained from DC&CA.

The Tea Hill monitoring site (Q-4) is located within the Tea Hill Provincial Park, along the fence line near the change house. It was intended to monitor a low till bluff. Five (5) measurements were taken at this location since its establishment: 8 June 1984 (establishment date), 11 June 1985, 13 May 1986, 30 June 1999, and 13 May 2003. Two erosion pins, 25 feet (7.62 m) apart, were installed at the site and the measurements were taken from the first erosion pin (the pin closest to the shoreline). During a monitoring visit in 1999, it was observed that the first erosion pin had been swept away by coastal retreat; a replacement erosion pin was positioned 25 feet (7.62 m) further away from the original second pin – the measurements were now being taken from the erosion pin closest to the shoreline. Based on the data gathered for this monitoring site, the shoreline till bluff at Tea Hill Park retreated **-13.31 m** from 1984 to 2003, representing a mean rate of **-0.70** m/yr.

The Hazard Point monitoring site (Q-4) is located at the Hazard Point lighthouse. It was intended to monitor a low till bluff situated in front of the lighthouse. Seven (7) measurements were taken at this location since its establishment: 28 June 1984 (establishment date), 11 June 1985, 13 May 1986, 15 June 1987, 30 December 1998, 30 June 1999, and 13 May 2003. All measurements were taken from the southeast corner of the lighthouse. Based on the data gathered for this monitoring site, the shoreline till bluff at Hazard Point retreated **-3.70 m** from 1984 to 2003, representing a mean rate of **-0.20** m/yr. It should be noted that based on the data entered on the fact sheet, the last three (3) measurements taken in 1998, 1999, and 2003 are relatively the same (ranging from 30' to 30'4'' – 9.14 to 9.24 m), which seems logical given the fact that a revetment wall (a mixture of hard rock and cement) was installed in front of the lighthouse a number of years ago (Don JARDINE, pers. communication). Based on these numbers, it could be argued that the revetment wall was installed somewhere between June 1987 and December 1998.

No precise location of the measurement sites for the erosion data presented is given.

The approximate location of the measurement sites can be viewed in Appendix 1 (Figure 1g) and the complete data set can be found in Appendix 2 (Table 2c), or accessed in the electronic spreadsheet: *PEI_AnalogFieldMeasurements_Tape.xls*.

5. DE Jardine Consulting 2009. Report on coastal erosion monitoring project: Little Harbour Beach and East Point, Prince Edward Island. Report prepared for the Southern Gulf of St. Lawrence Coalition on Sustainability, 6 November 2009, 3 p.

During the summer of 2009, the Southern Gulf of St. Lawrence Coalition on Sustainability and the Souris Wildlife Federation collaborated on setting up two coastal erosion monitoring sites in the eastern part of Prince Edward Island: Little Harbour Beach and East Point. Funds for this initiative were provided by Environment Canada. Both sites were surveyed using the *Analog field measurements using a measuring tape* method in conjunction with erosion pins. The Little Harbour Beach site (Northumberland Strait coast) is owned by the Province of PEI and corresponds to a beach/dune complex, while the East Point site (Gulf coast), located 500 m west of the East Point lighthouse, is privately owned and is characterized by moderately high sandstone cliffs (> 5 m). Three measurement lines (transects) have been established at both sites, and were monitored three times in 2009: August, October, and November. Monitoring values exist for these sites, but given the very short time frame since the start of the operations, no data was provided.

No precise location of the measurement sites for the erosion data presented is given.

The approximate location of the measurement sites can be viewed in Appendix 1 (Figure 1k) and some general site information data can be found in Appendix 2 (Table 2c), or accessed in the electronic spreadsheet: *PEI_AnalogFieldMeasurements_Tape.xls*.

6a. MacPhail, R. 2010. Shoreline survey: Jacques Cartier Park. Prince Edward Island Department of Transportation and Public Works, 4 sheets (1:500 scale).

6b. MacPhail, R. 2010. Shoreline survey: Kildare. Prince Edward Island Department of Transportation and Public Works, 1 sheet (1:500 scale).

No written report accompanied these maps – they were provided electronically (.pdf) to *Géo Littoral Consultants* by Don JARDINE (Regional Adaptation Collaborative - PEI Project Coordinator). According to Mr. JARDINE (pers. communication), the PEI DOT&PW regularly collects shoreline erosion data along sites where infrastructure is located near the coast. In the case of the Jacques Cartier Park and the Kildare Cape area, shoreline erosion data was collected three times, using a *Total Station*: December 2004, November 2009, and January 2010. No further information was provided on the methodology or on the precision of the data contained on these maps, other than that the shoreline is interpreted as the «top of the bank». The maps all show three lines corresponding to the shoreline at the three different monitoring dates. The erosion data however, is a selection of **51 measurement sites** along these two sectors: 43 sites along the 1 km-long Jacques Cartier Park sector and 8 sites along the 360 m-long Kildare Cape sector. No explanation is provided concerning the choice of the measurement sites (random? strongest shoreline retreat? important infrastructure near the coast?); the approximate locations of these sites do not indicate a regular interval (or spacing) of the measurement sites.

The Jacques Cartier Park coastline corresponds to a low sandy till bluff, while the Kildare Cape coastline is a moderately high sandstone cliff (> 5 m). The extreme values of shoreline retreat at Jacques Cartier Park sector range from -2.10 m, between 2004 and 2009 (or a mean value of -0.42 m/yr) to -11.20 m, between 2004 and 2010 (**-1.87** m/yr). In 2009 and 2010, the most important shoreline retreat value recorded was -3.70 m. The extreme values of shoreline retreat at Kildare Cape sector between 2004 and 2010 range from -2.20 m (or a mean value of -0.37 m/yr) to -9.30 m (**-1.55** m/yr).

No precise location of the measurement sites for the erosion data presented is given.

The approximate location of the measurement sites can be viewed in Appendix 1 (Figure 1b) and the complete data set can be found in Appendix 2 (Table 2b), or accessed in the electronic spreadsheet: *PEI_AnalogFieldMeasurements_TotalStation.xls*.

7. Genest, C. and Joseph, M.-C. 1989. 88 centimetres of coastal erosion per year: the case of Kildare (Alberton), Prince Edward Island, Canada. GeoJournal, vol. 18 (3): 297-303.

The study is centered on Kildare Cape and Jacques Cartier Provincial Park, just north of Alberton. The objective was to explain the conditions affecting erosion on PEI and to calculate the speed at which erosion is taking place. The data acquired in this study is based on private landowners' observations, on map measurements of land survey maps (1960 and 1986) – presumed via the use of a *Zoom Transfer Scope* -, and a year of field observations (July 1985 to July 1986). The comparison of the two land surveys (a 26 year period - 1960 to 1986) shows a -22 m erosion in the western part of the Park, and a -24 m erosion along the eastern part of the Park, which equal a mean rate of **-0.84** m/yr and **-0.92** m/yr, respectively. The authors were also able to witness the effects and impacts of the late July / early August storm of 1986. They document that the coast retreated 97.7 cm, on average during this event. At some places along the Park boundary, the cliffs retreated up to 50 cm. The undercut made by storm waves along the cliff base were in some places 90 cm to 1.6 m deep; this resulted in the crumbling of the top part of the cliff face (erosion from below).

No precise location of the measurement sites for the erosion data presented is given.

The approximate location of the measurement sites can be viewed in Appendix 1 (Figure 1b) and the complete data set can be found in Appendix 2 (Table 2f), or accessed in the electronic spreadsheet: *PEI_AnalogMapMeasurements_SurveyMaps.xls*.

8. Hawkins, R. 2009. Coastal erosion monitoring protocol. PEI National Park Environmental Integrity Monitoring and Reporting Program, Parks Canada, November 2009 Draft Version, 14 p.

This internal report presents the results of the coastal erosion monitoring operations that took place in Prince Edward Island National Park since 1985. The sites, which are located in the Cavendish section of PEI NP, were originally identified based on the threat of coastal retreat to park infrastructure. Up until 1996, seven (7) sites were being monitored on a yearly basis by park staff and an additional ten (10) sites were monitored by the Provincial government, although inconsistently. In 2002, the Park acquired the data from the Province and resumed sampling; two (2) new sites were added to the existing 17 sites. The yearly collection of data performed by the Park concerned 10 dune sites, 3 till bluffs, and 6 sandstone cliffs. The methodology employed until 2007 was through *Analog field measurements using a measuring tape* coupled to erosion pins. The distance of the cliff, bluff or dune edge (or scarp) to the erosion pin was measured and total loss was recorded as the accumulated loss from the time when sampling began.

During the 2002-2005 period of systematic monitoring, the dune erosion data shows that on average, the monitored dune sections of the Park retreated at a mean rate of **-0.78** m/yr; the till bluffs at **-0.74** m/yr; and the sandstone cliffs at **-0.20** m/yr.

Park personnel are currently working with the Geological Survey of Canada to assess the feasibility (financial and technical) of modifying its sampling protocol to include *Digital field measurements using GPS-RTK*.

The site location coordinate data was provided by Park personnel, and are considered exact locations.

The location of the measurement sites can be viewed in Appendix 1 (Figure 1m) and the complete data set can be found in Appendix 2 (Table 2c), or accessed in the electronic spreadsheet: *PEI_AnalogFieldMeasurements_Tape.xls*.

9. McCulloch, M.M., Forbes, D.L., Shaw, R.W. and the CCAF A041 Scientific Team 2002. Coastal impacts of climate change and sea-level rise on Prince Edward Island. Geological Survey of Canada, Open File 4261, 62 p. and 11 supporting documents.

The section of this report that relates to erosion data collection *is Chapter 9: Coastal geology and shore-zone processes* (FORBES, D.L. and MANSON, G.K.). This project, known as the «Charlottetown Project», was indeed centered on the Charlottetown coastal zone. For reasons of intense human infrastructure at the coast in the Charlottetown area, the erosion data acquisition component of the study was relocated on the north coast of the Island, a 12 km stretch of coast between eastern Tracadie Bay and Savage Harbour (near Pigots Point). The project team used vertical aerial photographs (1935, 1958, 1968, 1980, 1981 and 1990) to determine historical coastline change, using the *Digital photogrammetry using GIS* method. The cliff edge or dune scarp was used in order to acquire erosion data. All photographs were first scanned with a ground pixel value of 0.75 m. The rectification of the air photos was carried out either 1) in conjunction with a basemap, 2) with the use of GPS coordinates of identifiable control points, or 3) using a digital map. In all cases, sufficient ground control points were identified (7 to 14 gcp per photograph) and their margin of error (RMS – Root Mean Square) ranged from 1.5 m or less, up to 5 m. The study also details the calculations leading to the production of a margin of error associated to a measured distance or a calculated rate of displacement (erosion or accretion). The margin of error associated to measured distances was usually less than 2.0 m, and the margin of error associated to a calculated rate of displacement was usually less than 0.2 m/yr. This study produced **339 rates** (234 for dunes and 105 for bluffs).

The results of this study show that the sand dune environment is highly variable in space and time, showing erosion and accretion over short periods of time. For example, the Tracadie Bay dune sector is characterized by erosion during the period 1935-1958 (-0.5 to -1.5 m/yr), and by recovery or accretion during the following period 1958-1968 (up to **+2.0** m/yr). Since 1968, this sector is dominantly erosional, with mean rates around **-1.0** m/yr. In the till bluff section of Point Deroche, erosion was measured for all periods, and have not exceeded **-1.5** m/yr; the Pigots Point area was also erosional at around **-1.0** m/yr. Beyond Pigots Point, at the very easternmost edge of the study site, the sand dune environment fluctuated between erosion and accretion, but the most recent time period (1980-1990) shows an acceleration of erosion ranging from -2.0 to **-2.4** m/yr.

No precise location of the measurement sites for the erosion data presented is given.

The approximate location of the measurement sites can be viewed in Appendix 1 (Figure 1l) and the complete data set can be found in Appendix 2 (Table 2d), or accessed in the electronic spreadsheet: *PEI_DigitalPhotogrammetry_GIS.xls*.

10. Geological Survey of Canada, CoastWeb – National Coastal Monitoring Network (http//gsc.nrcan.gc.ca/coast/coastmon_e.php)

The GSC maintains coastal monitoring sites in Atlantic Canada (and in other coastal regions), where «...repetitive field observations, photographs and surveys provide baseline information about short-term, long-term, and cyclic shoreline changes. The information collected at the sites is archived as part of a national coastal database and is used to assess shoreline response to changing natural conditions, to human activities, and for establishing management guidelines within the coastal zone. » By accessing the NRCan website, it is possible to locate all the monitoring sites in Prince Edward Island and extract some metadata (site name, location, and coordinates; number of surveys and lines; date of first and last survey; resource person or contact name; etc.).

Even though all the sites on Prince Edward Island are now abandoned (monitoring terminated) except one (Point Deroche Beach), the GSC had established and operated a total of 12 monitoring sites from 1984 to 2006: eight (8) on the Gulf coast and four (4) on the Strait coast.

Not all monitoring sites were surveyed on a yearly basis – GSC Atlantic also has monitoring sites in NB, NS and NFL – but the sites were monitored as often as possible and usually following a major environmental event (Robert B. TAYLOR, GSC Atlantic, pers. communication). For each site and each survey line, the GSC collected data at very tightly spaced readings along the transect, through *Digital field measurements using a GPS-RTK*, on the distance, elevation, coordinates, morphology, and also on the GPS unit's performance (signal height, satellite angles, etc.).

The entire data set for these monitoring sites was not accessed by *Géo Littoral Consultants*. However, as the coastal features marking the coastline are identified along the transects, it is possible to say that there lies a potential of **259 erosion values** to be extracted within this data set. 231 of these potential erosion values concern the Gulf coast (all dune environments) and the remaining 28 potential erosion values are for the Strait coast: nine (9) along till bluffs and 19 along dune environments.

The site location coordinate data was provided by Robert B. TAYLOR (GSC Atlantic), and are considered exact locations.

The location of the measurement sites can be viewed in Appendix 1 (Figures 1e, 1i, 1j, 1k, 1l, and 1m) and some general site information data can be found in Appendix 2 (Table 2a), or accessed in the electronic spreadsheet: *PEI_DigitalFieldMeasurements_GPS.xls*.

11. Nutt, L.A. 1990. Foredune evolution on the north shore of Prince Edward Island. M.Sc. Thesis, McMaster University, Hamilton, ON, 174 p.

Historical air photograph analysis and field surveys were conducted to assess shoreline changes and also to assess the condition and evolution of foredunes along the north coast (from Brackley Beach to Greenwich National Park). Shoreline evolution was studied for the period 1938-1982 using air photos (1938, 1958, 1968, 1980 and 1982). The technical equipment used for the erosion measurements was the *Bausch and Lomb Zoom Transfer Scope*. Ortho maps (1:5 000) obtained from the PEI government were used to average the elevation above the datum over reference points, in order to lessen the error in the measurements. A divider and steel ruler were used to measure the distances to within 1/64 of an inch (1.63 cm). A total of **44 erosion rates** were calculated for the study site, and the general trend of each sector is as follows:

- Brackley Beach – general state of erosion (**-0.65** m/yr)
- Stanhope – shoreline retreat is significant and greatest near Covehead inlet (**-0.86** m/yr)
- Dalvay Beach – general erosion except at the distal (eastern) end of the spit (**-0.68** m/yr)
- Point Deroche – overall progradation of the dunes (**1.13** m/yr)
- Crowbush – general erosion except at the distal end of the spit (**-0.34** m/yr)
- St. Peters Lake – generally high erosion (**-1.67** m/yr)
- Greenwich – general state of erosion (**-0.96** m/yr)

Over the period 1959-1982, the rate of erosion or advance varied alongshore. The overall accrection along the Point Deroche sector, which stands out from the rest, is explained by the author as a situation of general overwash in 1938, which resulted in dune growth over the next few decades (shoreline advance at rates varying between +0.7 and +2.3 m/yr). Shoreline retreat did occur in the Point Deroche sector, at a mean rate of at least -0.3 m/yr, but only along that part of the coast where the older dunes had prevailed and were not overwashed in 1938.

The numerous illustrations contained in the document provide some information on the approximate location of the erosion measurements. No exact locations.

The approximate location of the measurement sites can be viewed in Appendix 1 (Figures 1l and 1m) and the complete data set can be found in Appendix 2 (Table 2e), or accessed in the electronic spreadsheet: *PEI_AnalogPhotogrammetry_TransferScope.xls*.

Synthesis of the erosion values compiled

1. Geographical coverage of the available data

The shoreline erosion studies that were compiled in this report present a relatively complete geographical coverage of PEI coasts (see Appendix 1 – Figures 1a to 1m). However, the density of shoreline erosion data is uneven along the coast. As an example, Gulf coast data account for 73.4% of all compiled values (table 2). This figure would not be changed significantly by including shoreline erosion data not compiled in this report, namely the LRIS (1988) values and the other Provincial monitoring sites.

2. Coastal types covered by the compiled data

The coverage of the different types of coasts by the compiled data is highly uneven, ranging from 1.9% (21) of the total number of values that were calculated from salt marshes areas, to 57.9% (653) that were measured and calculated in coastal dunes. These figures could have changed by including the entire shoreline erosion data not compiled in this report, namely the LRIS (1988) values and the other Provincial monitoring sites.

3. Time periods covered by the available data

With regard to long-term data that can be deemed representative of historical trends, 70% of the available data collected for the Northumberland Strait (210) covers the period 1935-1958 (FORWARD *et al.*, 1959), whereas the data collected for the Gulf coast (339) covers the period 1935-1990 (MCCULLOCH *et al.*, 2002). However, more than two thirds of these latter values concern dunes. There is a clear need for long-term data acquired by state-of-the-art methods for the Northumberland Strait coasts. These figures would not have changed significantly by including shoreline erosion data not compiled in this report, namely the LRIS (1988) values and the other Provincial monitoring sites.

Short-term erosion measurements cover the period from 1984 to the present (all studies considered) but have been acquired through various monitoring protocols.

4. Precision/accuracy/reliability of the available data

The different methods used in erosion studies have different margins of error associated to their data collection. Of all the erosion data compiled in this report, 77% (871) of the total number of values were collected via methods ranked from 1 to 4 according to our relative accuracy qualitative assessment (see Table 1, above). These include all field measurements (short-term erosion data) and the digital photogrammetry studies of MCCULLOCH *et al.* (2002) and Coldwater Consultants (2010). 210 out of 300 values compiled for Strait coast sites were acquired using now obsolete technology. Of the other 90 values, only 34 are long-term erosion rates (the sandstone/till bluffs in the Souris area).

5. Synthesis of observed erosion rates and general comments

Tables 3 presents the range of highest and lowest values compiled, by coast type and by method. Some comments can be made from these numbers.

Table 3. Range of highest and lowest erosion rate (m/yr) calculated by indirect (laboratory) methods for various coast types (A); Range of highest and lowest retreat measured over one year (m) and erosion rate (m/yr) calculated by direct (field measurement) methods for various coast types (B).

A — Indirect Methods

Coast Type	Value	Survey Maps	Analog Photogram.	Digital Photogram.
Sandstone Cliff	Highest	-	**-1.98 (g)**	-0.10 (j)
	Lowest	-	-0.10 (g)	**-0.03 (j)**
Till Bluff	Highest	-0.92 (a)	**-4.88 (g)**	-2.24 (i)
	Lowest	-0.85 (a)	-0.06 (f)	**-0.04 (i)**
Marsh	Highest	-	-1.52 (g)	-
	Lowest	-	-0.31 (g)	-
Dune	Highest	-	**-6.16 (g)**	-5.25 (i)
	Lowest	-	-0.10 (k)	**-0.06 (i)**

B — Direct Methods

Coast Type	Value	Tape m	Measure m/yr	GPS-RTK	Total m	Station m/yr
Sandstone Cliff	Highest	-0.55 (b)	-0.41 (b)	-	-	**-1.55 (e)**
	Lowest	0.00 (b)	**-0.06 (b)**	-	-	-0.22 (e)
Till Bluff	Highest	-2.33 (b)	-1.19 (b)	-	**-3.70 (e)**	**-1.87 (e)**
	Lowest	**0.00 (h)**	**-0.20 (h)**	-	-1.10 (e)	-0.42 (e)
Marsh	Highest	-		-	-	
	Lowest	-		-	-	
Dune	Highest	-3.30 (b)	-1.63 (b)	-	-	
	Lowest	-0.03 (b)	-0.11 (b)	-	-	

- Unsurprisingly, the highest erosion rates are observed in coastal dunes and/or till bluffs (depending on the use of indirect or direct methods), followed by sandstone cliffs. It is hard to draw conclusions from the few values coming from salt marshes.

- For a given coast type, values obtained through different methods can differ significantly. For example, maximum values observed in sandstone cliffs with indirect methods are -1.98 m/yr (analog photogrammetry) and -0.10 m/yr (digital photogrammetry). This can be related to several factors besides the accuracy of each method, such as location of sites, period considered, presence of protection structures, etc. Unless datasets coming from similar sectors and covering similar time periods are available, the precise assessment of the accuracy of available erosion data is hard to do and Table 3 should not be used to do so.

- It is important to keep in mind that retreat distances monitored for individual years can be much higher than mean yearly rates calculated over a given period of time. For example, in sandstone cliffs, the highest measured annual retreat by tape measurements is -0.55 m, but the mean yearly rate for the 1985-2009 period is -0.41 m/yr. The same pattern is seen in till bluffs (-2.33 m VS -1.19 m/yr) and dunes (-3.30 m VS -1.63 m/yr). The same reasoning applies to long-term mean yearly rates calculated from indirect methods over shorter and longer periods respectively.

- The highest and lowest retreat distance measured in dunes highlight the spatial variability in the response of the coast. These values were measured in 2005 by Parks Canada. For example, the most significant yearly loss (-3.30 m) was recorded near the Covehead lighthouse, and the lowest dune retreat (-0.09 m) was recorded only 2.7 km to the west.

Shoreline classification system

Any shoreline classification system (SCS) is scale dependent, meaning that the intended purpose of the classification system should guide the criteria of the mapping (FINKL, 2004; FAIRBRIDGE, 2004): it is easy to over-simplify a classification system as much as it is easy to make it too detailed. By their very nature, coastal zones are dynamic over short-term periods (crashing waves moving sediments alongshore) as well as long-term geological periods (the slow emergence of a rock coast due to lithospheric unloading). All shoreline classification attempts are based on an interpretation of the environment at one particular moment in time (field observations, historical charts, aerial photographs, satellite images) and may fail to describe seasonal or longer-term fluctuations. Furthermore, SCSs can require field observations, and in such become labour-intensive and time-consuming, while others can be used in conjunction with aerial photographs or remote sensing. In fact, Geographical Information Systems (GIS) are useful on study sites or areas of local and regional scales (coastlines of a few kilometres to hundreds of kilometres in length) in large part because their capacity to store and process data is great (DAVIDSON-ARNOTT, 2010).

The principles of scale and time as well as the work schedule and available budget should therefore be the basis for designing or choosing a shoreline classification system adapted to the user's needs.

Shoreline classification systems in Atlantic Canada

This section provides an overview of some classification systems applied to the shorelines of Atlantic Canada, and tries to describe their methodology as completely and briefly as possible.

Conception Bay, Newfoundland (CATTO *et al.*, 1999)

In 1999, the shorelines surrounding Conception Bay (well over 300 km in length) were classified based on similar classification systems used by the Department of Fisheries and Oceans Canada. Although it was shown that the application of this particular SCS presented difficulties to the Conception Bay region, it was retained on the grounds of regional consistency and to facilitate comparisons with other, similarly mapped shores of Newfoundland (CATTO *et al*., 1999).

The data integrated in the SCS is based on a videotape survey of the coastline, flown in July 1981, and some on-site ground-truthing investigations (CATTO *et al.*, 1999). The classification system used by CATTO (1999) is based on geomorphological and sedimentological criteria. It is based on substrate type and sediment composition to classify shore types. Three (3) substrate groups were determined: Rock, Rock & Sediment, and Sediments. Within the Rock group, three

(3) shore types were recognized: Wide Rock Platform, Narrow Rock Platform, and Rock Cliff. The Rock & Sediment group was subdivided into three (3) typologies: Gravel, Gravel & Sand, and Sand. The shore types recognized are associated to the group and typology (a total of 9 distinct shore types). For example the shore types within the Gravel typology are: Gravel Beach on Wide Rock Platform, Gravel Beach on Narrow Rock Platform, and Gravel Beach with Rock Cliff. Finally, the Sediment group contains six (6) typologies: Gravel, Gravel & Sand, Sand, Mud, Organics & Mixed Clastics, and Mixed. Twelve (12) shore types were recognized within this group: Wide and Narrow Gravel Flats, Steep Gravel Beach, Wide and Narrow Gravel & Sand Flat, Steep Gravel & Sand Beach, Wide and Narrow Sand Flat, Steep Sand Beach, Mudflat, Estuary & Fringing Lagoon, and finally Tidal Flat. This SCS has identified a total of 24 shore types.

2	Rock	None	Narrow	Low	Narrow Rock Platform	Bay de Verde; Island Point; Kingston
3	Rock	None	Narrow	Steep	Rock Cliff	Brigus; Bauline; Flambro Head; Recliff Head; Red Head
4	Rock & Sediments	Gravel	Wide	Low	Gravel Beach on Wide Rock Platform	Perry's Cove
5	Rock & Sediments	Gravel	Narrow	Low	Gravel Beach on Narrow Rock Platform	Kingston; Long Beach; Colliers Pt.; Grates Cove
6	Rock & Sediments	Gravel	Narrow	Steep	Gravel Beach with Rock Cliff	Gallows Cove; Healy's Cove; Hibb's Cove & numerous others
7	Rock & Sediment	Gravel & Sand	Wide	Low	G & S Beach on Wide Rock Platform	Perry's Cove; Spout Cove

Figure 2. Example of shoreline classification criteria used by CATTO *et al.* (1999) in the SCS of Conception Bay, Newfoundland.

For the shore types characterized by sediments (Rock & Sediments and Sediments groups), a further classification is applied based on sedimentary structures. It describes the sediment texture, the slope of the beach, the dimensions of the feature and its ability to withstand the environmental conditions (stability – Stable, Moderately Stable, Moderately Unstable, Unstable).

Southeastern New Brunswick

The New Brunswick coastline, especially the southeastern coast along the Northumberland Strait, has been the object of at least two (2) classifications in the recent years.

BÉRUBÉ and THIBAULT (1996)

In the 1990s, the coast was classified by BÉRUBÉ and THIBAULT (1996). Their classification system was based on geomorphological and sedimentological criteria. The data was collected from field observations, aerial photography, and various cartographic documents and reported on 1:10 000 scale maps. The classified coast spans from Cap Lumière (north) to Port Elgin (south), a 580 km-long study area. This 5-year project aimed at providing a detailed description of the foreshore (which includes the intertidal zone), the backshore, and the coast.

The observations and data were collected to describe three (3) coastal features: the Coastline, the Backshore, and the Foreshore. Three (3) coastal types were recognized for the Coastline feature: Rocky, Unconsolidated, and Anthropogenic. Two (2) coastal types were recognized for the Backshore: Beach and Tidal Salt Marsh. Two (2) coastal types were recognized for the Foreshore: Tidal Flat and Tidal Stream. For these 7 coastal types, a further identification was performed and : 1- a visual determination of sediment size and distribution (relative percentage of clay, silt, sand, gravel, pebbles, cobbles, boulders); 2- measurements on the width and elevation of the foreshore, backshore, and the coast; and 3- an approximation of susceptibility to erosion (low, medium, high). A total of 23 maps were produced.

O'CARROLL *et al.* (2006)

In the mid-2000, Environment Canada headed a multi-disciplinary research project aimed at quantifying the impacts of climate change and accelerated sea-level rise on the southeastern coast of New Brunswick (DAIGLE *et al.*, 2006). One component of the project was to gather historical coastal evolution data, while describing the coastal evolution of the past 65 years. This part of the project used a classification system based on aerial photograph interpretation. The coast along the study area (from Pointe Sapin in the north to Cape Jourimain in the south – approximately 800 km of shoreline) was classified using historical aerial photographs and GIS. This classification was an evolution-style classification: long-term coastline displacement rates (erosion or accretion) were calculated and coastal evolution models were generated using all coastline positions (based on the available aerial photography).

The development of the SCS was based on the coastal types present along the shore: beaches, dunes, salt marshes, sandstone cliffs and till bluffs, and human infrastructure. For each coastal type a detailed mapping of the coastline (and shoreline) was carried out for all available air photo series (from 1945 through to 2001). In this study, the coastline was distinguished from the shoreline and both were associated to a specific tidal water level: the high water mark (HWM) for the shoreline and the higher high water mark (HHWM) for the coastline. A set of attributes (a legend) was developed and each coastal type mapped was coded according to the attribute table (a list of feature codes). For example, the top of the scarp was used to map the coastline along a dune system where the foredune was cliffed, and the vector (or line) associated to this particular coastline was given the feature code «TCDUNEF». When the foredune wasn't scarped or cliffed, the edge of the vegetation (marram grass) was used as the coastline, and the vector associated to this feature was given the feature code «TCDUNE». The table below presents an overview of the main coastal types and their associated feature codes used in the SCS.

Table 4. Example of some coastal types and feature codes used in the SCS by O'CARROLL *et al*. (2006).

Feature Code	Coastal Type
LRPLAGE	Shoreline - Beach (wet/dry sand boundary)
TCDUNE	Coastline - Foredune (edge of vegetation) uncliffed
TCDUNEF	Coastline - Foredune top of scarp or cliff
LRMARAIS	Shoreline - Salt marsh (seaward extent of vegetation) edge of vegetation
LRMARAISF	Shoreline - Salt marsh (seaward extent of vegetation) top of cliff
TCMARAIS	Coastline - Salt marsh (landward boundary) salt to fresh vegetation transition
TCTERRE	Coastline - Upland (sandstone or till) top of gentle slope
TCTERREF	Coastline - Upland (sandstone or till) edge of cliff
TCARTIFICIEL	Coastline - Seaward edge of human infrastructure (wharf, riprap, road, etc.)

By mapping out the coastal zone using this classification system, the project team was able to extract, tally and compare a significant amount of data concerning the recent evolution of the coast. For example, yearly statistics were gathered for: the total length of cliffed and non-cliffed foredunes, of sandy and cobble beaches, of shore protection structures along the coast, of salt marshes, of sandstone cliffs and till bluffs, etc. Also, data on surface area variability over time was calculated for targeted habitats: salt marshes, brackish transition marshes, sandy beaches, dunes, etc. Using all the available years mapped, coastline position change was measured in all coastal types in order to gather and assess rates of displacement (erosion or accretion rates). Finally, by combining all the yearly maps produced, models of coastal evolution were generated, showing how the coastline and shorelines of various coastal types responded to coastal forcing over time.

Bras d'Or Lakes, Nova Scotia (SHAW *et al*., 2006)

In 2006, the Bras d'Or Lakes coasts were assessed on the basis of their sensitivity to sea-level rise (SHAW *et al.,* 2006). The objectives of this project were to map the coastal environments, to assess future impacts of sea-level rise on the coastal environments and determine their vulnerability, and to transfer this scientific knowledge to the stakeholders. This study was funded by Natural Resources Canada's Geoscience for Ocean Management Program and the Climate Change Impacts and Adaptation Program. In order to classify the 1200 km-long coastal zone, the scientific team adopted a shoreline classification system based on geomorphic grouping. The description of the coastal environments was mostly carried out using an aerial video flown in 1996 and further complemented with brief field surveys at representative sites in 2004. The SCS, as well as all the data acquired, was carried out using a GIS.

Three geomorphic groups were used in the classification (Rock, Unconsolidated, and Artificial) and were further subdivided into 12 shore types (or taxons) (see complete list in Figure 3).

Shore Type & Coverage (%)			Description
Rock (10 %)	1	**Low Rock Outcrop (0.6)**	Outcrops and ramps, no continuous beaches; low elevation; plan form controlled by bedrock orientation.
Rock (10 %)	2	**Rock Cliff (6.7)**	Outcrops with cliffs or steep slopes, blow holes and caves; no beaches. Cliffs may have overburden. Moderate to high elevation.
Rock (10 %)	3	**Rock with Fringing Beach (2.8)**	Cliffed or non-cliffed shores with beaches wider than 10 m. Backshores reached by wave action during high water or storm events. Moderate to high backshore elevation
Unconsolidated (74 %)	4	**Unconsolidated Cliff (3.8)**	Eroding cliffs composed of glacial sediment, moderate elevation, exposed to higher energy waves
Unconsolidated (74 %)	5	**Unconsolidated Cliff with Beach (13.6)**	Cliffs composed of glacial sediment fronted by wide beaches; cliff face only impacted by storm wave action; low to moderate elevation, backshore slope may be vegetated.
Unconsolidated (74 %)	6	**Fringing Beach (13.7)**	Continuous wide beach backed by non-cliffed backshore rising to higher elevation; includes forelands with no backshore water.
Unconsolidated (74 %)	7	**Coastal Barrier (12.3)**	Low sand & gravel or gravel beach backed by water or wetland; can be a barrier beach, spit or tombolo.
Unconsolidated (74 %)	8	**Vegetated - Exposed (11.9)**	Winnowed boulder shore, some scarped backshore, limited wave exposure along narrow channel or limited beach reworked infrequently by waves from restricted fetch direction; little organic accumulation.
Unconsolidated (74 %)	9	**Vegetated - Protected (12.6)**	Emergent and submergent vegetation, restricted fetch and waves; more organic accumulation, no beach development
	10	**Riverine (6.0)**	Delta or drowned river mouth, levees, channels and wetlands
Artificial (3 %)	11	**Artificial (2.7)**	Man-made material including armour rock, vertical walls, fill, bridge structures, causeways, wharves, boat launches
		Undifferentiated (13.3)	No information available - most unconsolidated and vegetated.

Figure 3. The shoreline classification criteria used by SHAW *et al.* (2006) in the SCS of the Bras d'Or Lakes, Nova Scotia.

St. Lawrence River estuary (LOSLRS)

STEWART (2003) presents the shore protection and nearshore classification system adopted by the Lake Ontario-St. Lawrence River Water Level Regulation Study (LOSLRS). This latter is part of an International Joint Commission (USA and Canada) study of the impacts of high lake levels and storm events on coastal properties. This system is based on a kilometre-by-kilometre reach representation, a series of equal 1000 metre segments of the shore. This spatial resolution was selected because it was consistent with the resolution at which other data collection activities were being conducted. This classification scheme was developed using lithology data, geological reports, bathymetry charts, land-use maps, recent aerial photography, video, topographic maps, etc. All the data for this 4000 km coastline was compiled using a GIS.

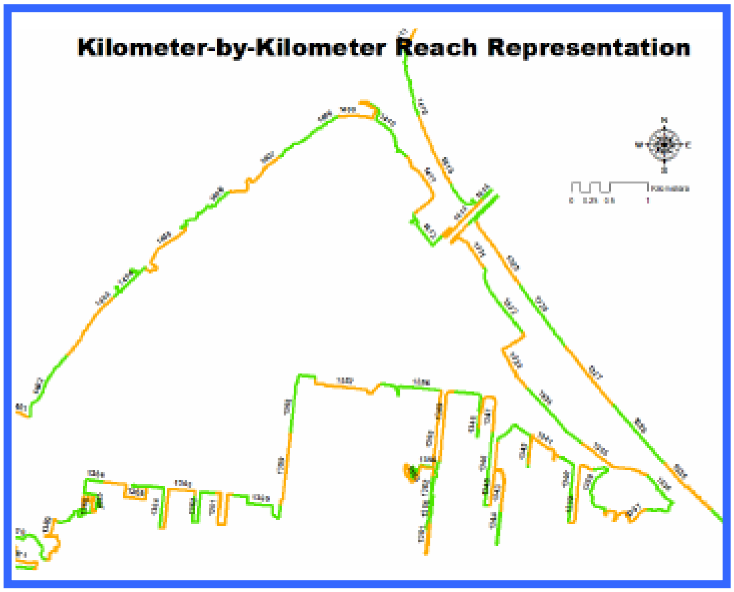

Figure 4. Example of the shoreline segmentation used for the LOSLRS study (STEWART, 2003).

The LOSLRS SCS is divided into three main groups: Geomorphic, Shore Protection, and Nearshore Subaqueous. The Geomorphic group is made up of 10 typologies (categories) and numerous taxons which further details the shore types. Examples of these typologies and taxons are: Sand or Cohesive Bluffs (8 taxons, based on the % of sand content); Marine Clay Bluffs (2 taxons); Low Bank (5 taxons based on elevation); Sandy Beach/Dune Complex (5 taxons); Coarse Beaches (3 taxons); Bedrock (resistant) (3 taxons); Bedrock (erosive) (3 taxons); etc. The Shore Protection group contains the most typologies (16 – all having 3 taxons) and include such shore types as: Revetment; Seawall/Bulkhead; Groynes; Jetties; Offshore Marina Breakwaters; Beach Nourishment; Vegetation Planting/Bioengineering; Ad Hoc Concrete Rubble/Rip-rap; Protected Wetlands; Boat Launches; etc. The Nearshore and Subaqueous group contains 8 typologies and a maximum of 3 taxons (detailing the thickness of the overlying material – Thick, Moderate, Thin). Examples of shore types in this category are: Cohesive (till); Cohesive (clay); Sandy Lake Bed; Bedrock (resistant); Bedrock (erosive); etc.

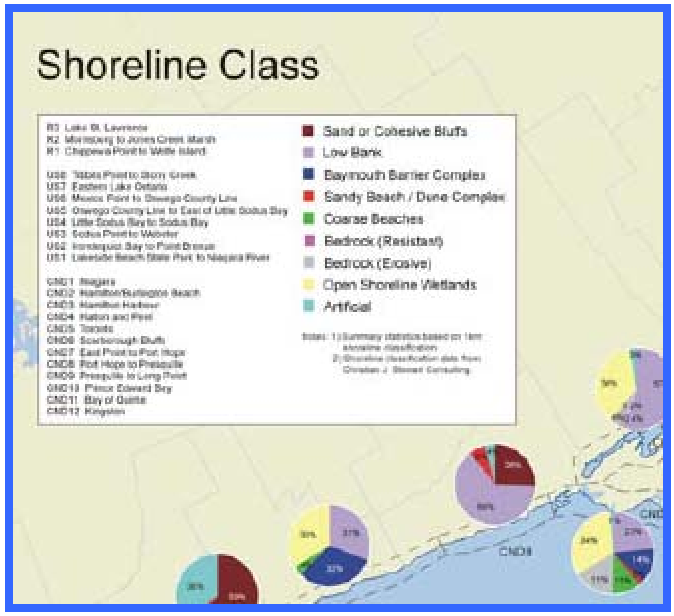

Figure 5. Example of the shoreline classification system used for the LOSLRS study (STEWART, 2003).

Îles-de-la-Madeleine, Québec (BERNATCHEZ *et al*., 2008)

The BERNATCHEZ *et al.* (2008) study, funded in part by and produced for OURANOS - a consortium of scientists and professionals that carry out research on Climate sciences and Impacts & Adaptation - proposes a shoreline mapping system based on coastal evolution scenarios. It provides a classification system but also includes evolution trend information and is land use-oriented, which rather makes it an integral part of a coastal planning system. This system takes into consideration the historical coastline evolution of the coastal types, based on long-term erosion rates, and proposes an evaluation of coastal sensitivity to climate change impacts. The study focused on three (3) sites along and within the Gulf of St. Lawrence: Sept-Îles, Percé, and the Îles-de-la-Madeleine.

The SCS is a geomorphic-based system and recognized 13 coastal types: Salt Marshes; Sand Spits; Sand Spits with Salt Marshes; Sand or Gravel Berms (mainland beach); Berms (mainland beach) with adjacent Salt Marshes; Tombolos; Low Unconsolidated Cliffs; Unconsolidated Cliffs of Medium Height; High Unconsolidated Cliffs; Low Rock Cliffs; Rock Cliffs of Medium Height; High Rock Cliffs; Artificial Shoreline. Using digital photogrammetry (GIS), all available aerial photograph series from 1936 to 2001 were scanned and georeferenced in order to map the costal types and also to position other coastal features such as the coastline and shoreline. Field work was carried out in order to ground-truth some representative sites. Three (3) mapping products were generated, showing: 1- the current state of the coast (based on most recent available imagery, 2001); 2- the long-term trend of the coastline (based on historical erosion rates calculated for the period 1936-2001); and 3- shoreline evolution forecast scenarios (for the period 2001-2050). Figure 7 below is an example of shoreline evolution forecast scenarios for the area of Pointe-aux-Loups, Îles-de-la-Madeleine. It shows the coastal types and the zones associated to the different probable positions of the shoreline, under specific evolution scenarios related to climate change.

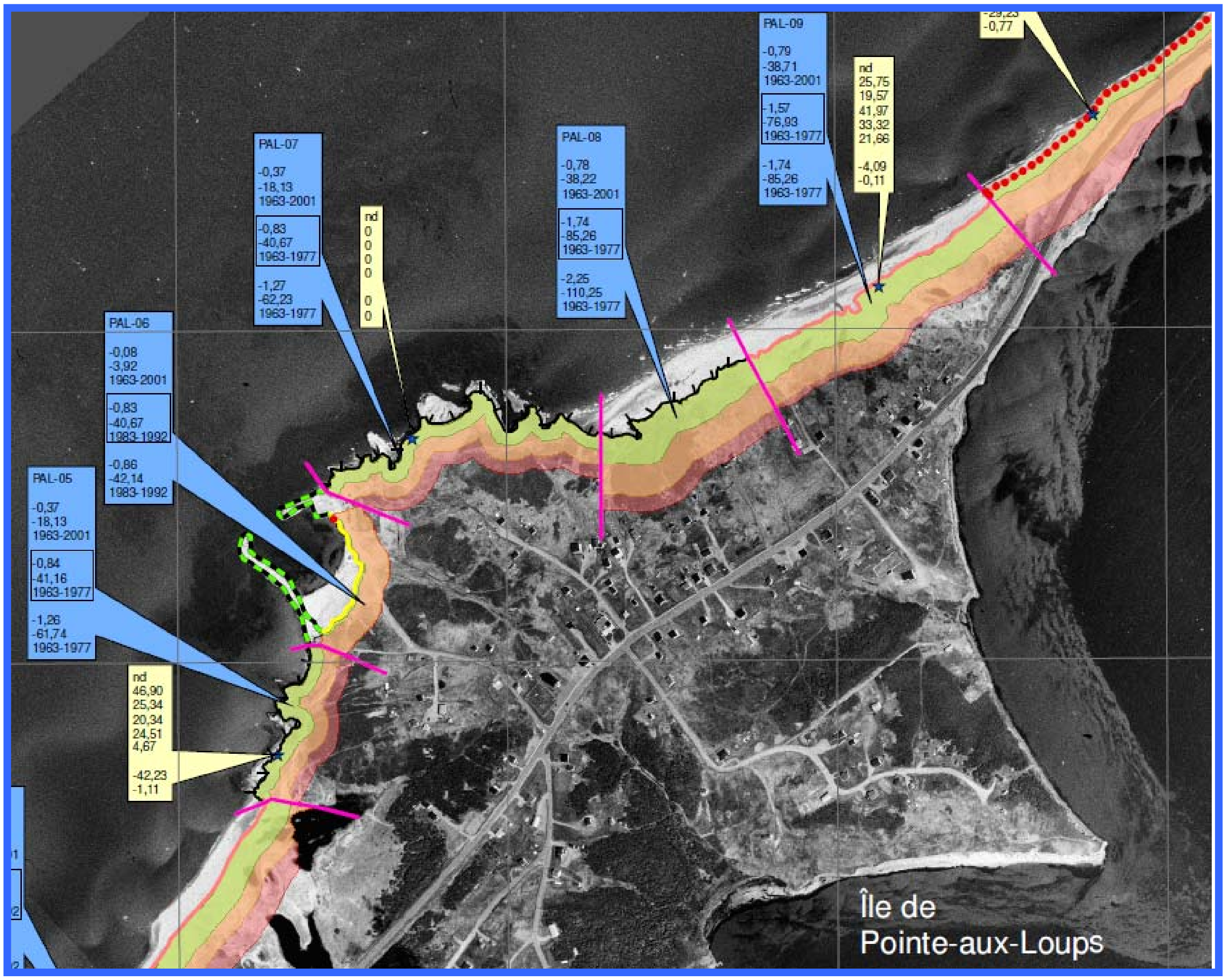

Figure 6. Example of a shoreline evolution forecast scenario for Pointe-aux-Loups Island, Îles-de-la-Madeleine (BERNATCHEZ *et al*., 2008).

A SCS suited for the Town of Stratford and the Hillsborough River estuary

Within the scope of work required by *Géo Littoral Consultants* is the mandate of recommending a shoreline classification system for the Town of Stratford and the Hillsborough River estuary (the study area), which could then be utilized to classify the entire shoreline of Prince Edward Island.

After reviewing a variety of SCSs developed for various coasts along the Gulf of St. Lawrence (Eastern Canada), it is clear that some of them are better suited to classify the study area's shorelines, while remaining applicable to the Province's shorelines as a whole. The field-type classification systems (CATTO *et al.*, 1999; LOSLRS, 2003; BÉRUBÉ and THIBAULT, 1996) are fitted to local scale studies, to large areas for the development of coastal databases, and when money and time constraints are not an issue. Some of these systems also have been developed for specific uses such as emergency preparedness in the advent of oil spills or from a habitat distribution perspective. However, based on the requirements of the Town of Stratford and its concerns, specifically related to adaptation to climate change from a land use perspective, it is of *Géo Littoral Consultants*' opinion that the model from which to develop a suitable SCS that meets the Town requirements should resemble the system described in BERNATCHEZ *et al*. (2008).

The BERNATCHEZ system goes beyond the simple identification and characterization of selected coastal types: it also includes information on evolutionary trends of the shoreline and proposes scenarios of coastal evolution based on climate change predictions (it offers a look at past trends, present conditions, and probable future evolution). Such a SCS would also offer an advantage from the perspective of regional consistency and the ability to facilitate comparisons with similar work on coastal zones along the Gulf of St. Lawrence.

A closer look at the components and methodology of the BERNATCHEZ *et al*. (2008) SCS is warranted. All available aerial photographs between 1931 and 2001 were scanned at a common 600 dpi resolution and georeferenced using a GIS. Only the central portion of each photograph was digitized, to avoid the edge distortions associated to camera lens curvature. The shoreline was used to map the coastal features (habitats) such as beaches, dunes, cliffs and salt marshes (including a category for human infrastructure) as well as to collect shoreline displacement measures. Theses measurements were in turn used to calculate erosion or accretion rates (see Figures 7 and 8). To determine shoreline positional change over time, transects were drawn at 50 metre-intervals along the coast. Besides the 1931-2001 mean annual value, and to generate additional scenarios of future coastal evolution, long-term trends of the shoreline position were reported for intermediate periods no smaller than 10 years (between available aerial photograph series).

In order to generate shoreline evolution forecasts (see Figure 6, above), BERNATCHEZ *et al*. (2008) developed three (3) evolution scenarios leading up to the year 2050. These scenarios are based on coastal retreat (erosion) or advance (accretion) data measured for the longest time period available.

- The first scenario projects that the historical trend will continue unchanged, i.e., that the predicted climate change effects will not modify the shoreline displacement rate leading up to 2050. The average measurement is used to determine the mean yearly rate.

- The second scenario considers plausible that the intensity of shoreline erosion, for a given coast type, will be comparable to the mean retreat rate measured during the 10 to 15 year period showing the highest retreat between 1931 and 2001. This scenario thus implies that climate change would cause an acceleration of coastal erosion relative to the average historical trend for the whole 1931-2001 period.

- The third scenario is a projection based on the average of the erosion rates that are above the mean retreat rate measured during the 10 to 15 year period showing the highest retreat recorded between 1931 and 2001. This scenario thus supposes a major acceleration of coastal erosion for the year 2050, caused by climate change (see Figure 9, below).

Obviously, the scenarios to consider in the development of mapping products for Prince Edward Island can be different from those proposed by BERNATCHEZ *et al.* (2008) and can also be set on a different time horizon than the year 2050 (in New Brunswick for example, other types of scenarios have been considered - see DAIGLE, 2009). As well, the maps can be scaled differently and the information they contain relative to coastal evolution can be integrated to existing documents (such as local zoning/planning maps). This type of process or methodology is considered more thorough than what can be accomplished with other SCS, and seems better suited to meet the objectives of the Town of Stratford.

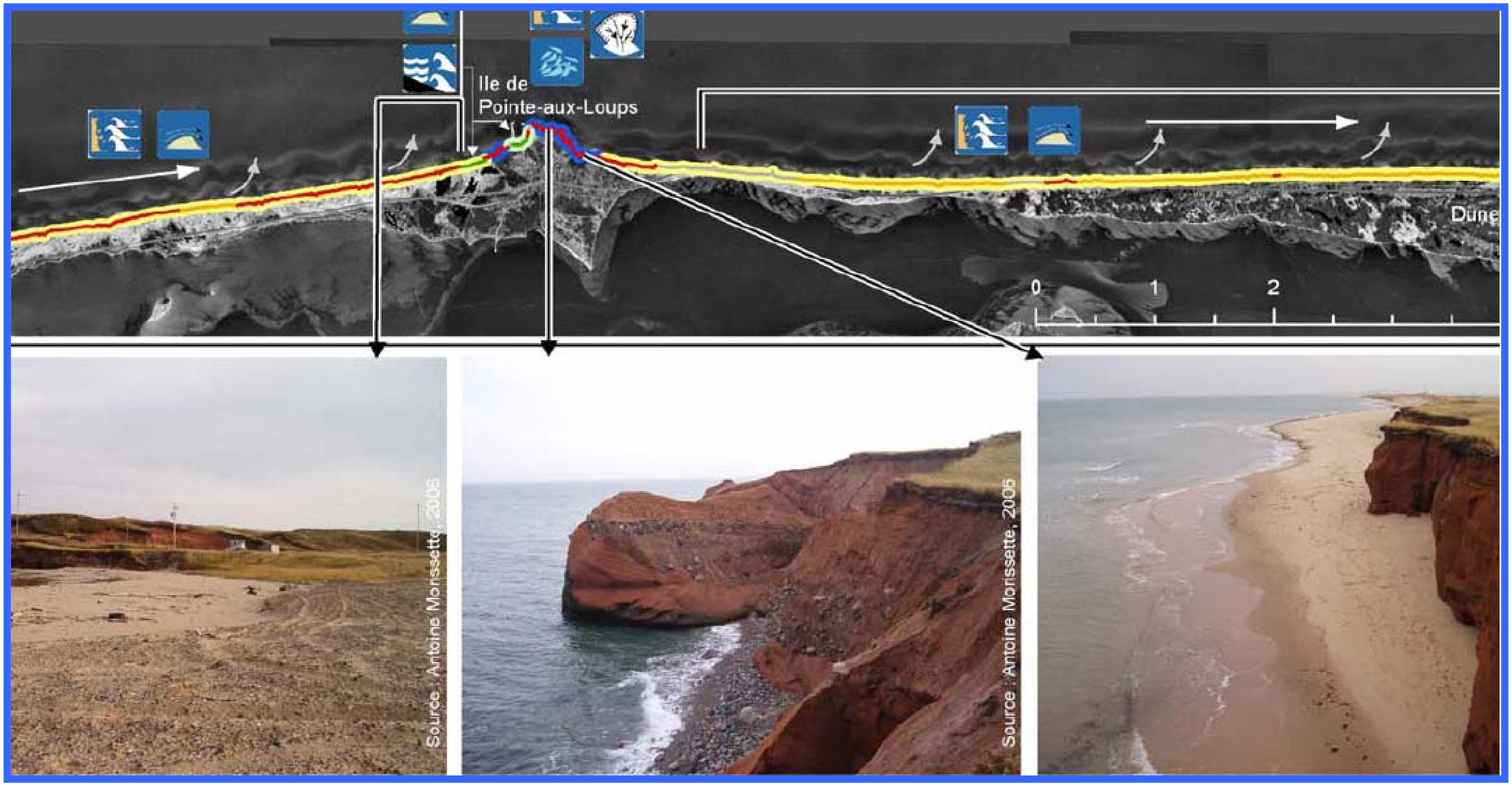

Figure 7. Extract of the current state of the coast (2001 coastal types) at the Pointe-aux-Loups island, Îles-de-la-Madeleine (BERNATCHEZ *et al.*, 2008).

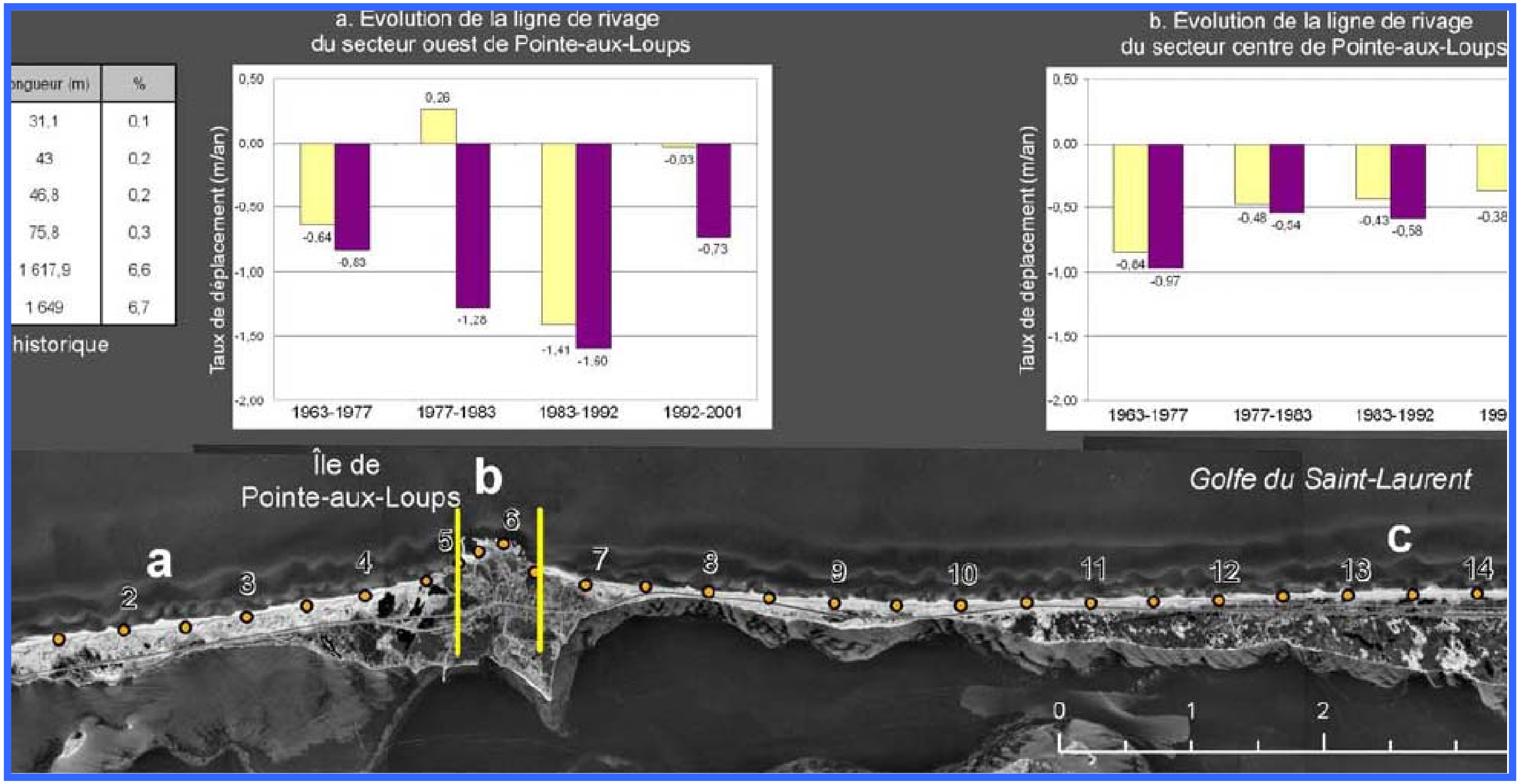

Figure 8. Extract of the historical evolution of the coast at the Pointe-aux-Loups island, Îles-de-la-Madeleine (BERNATCHEZ *et al*., 2008). The yellow column on the histogram represents the mean shoreline displacement rate (m/yr), calculated with all measured values (accretion, no change, erosion) and the purple column represents the mean shoreline erosion rate (m/yr), calculated for values indicating erosion only. Note that for this sector, the longest study period is 1963-2001 (based on the available aerial photograph coverage).

Scenario 1: no change in historical trend (see Figure 6 for mapping example).

Scenario 2: accelerated erosion equal to the average of the most intense period (see Figure 6 for mapping example).

Scenario 3: accelerated erosion equal to the average of the highest rates of the most intense period (see Figure 6 for mapping example).

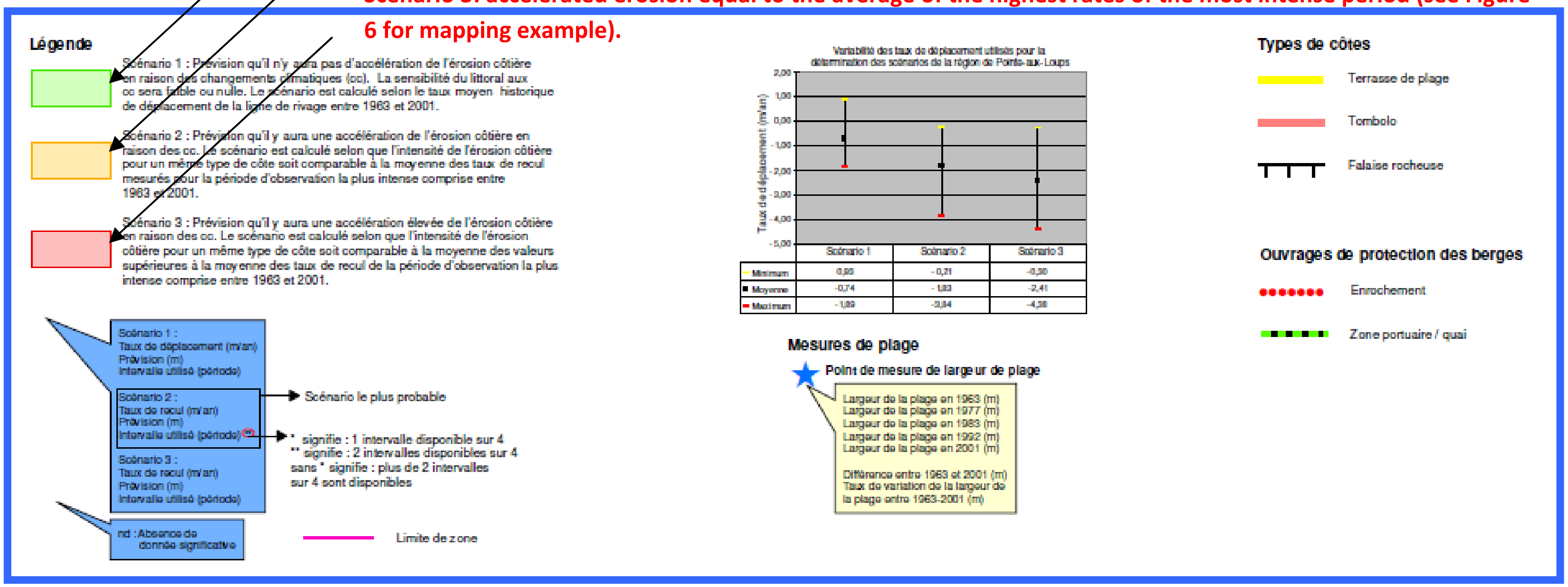

Figure 9. Extract of the legend accompanying the shoreline evolution forecast scenarios maps (BERNATCHEZ *et al.*, 2008).

Coastal types and available erosion data for the Town of Stratford and Recommendations

The coastal zone along the Town of Stratford and the Hillsborough River estuary is diverse, characterized by sandstone cliffs and till bluffs along the Northumberland Strait, and till bluffs and salt marshes, with scattered small outcrops of sandstone, along the Hillsborough River estuary (Figure 2). Based on FORWARD et al. (1959), the height at the coast along the sandstone cliffs facing the Northumberland Strait varies between 1.5 and 9 m, while the till bluffs along the Hillsborough River estuary are from 1 to 7 m in height.

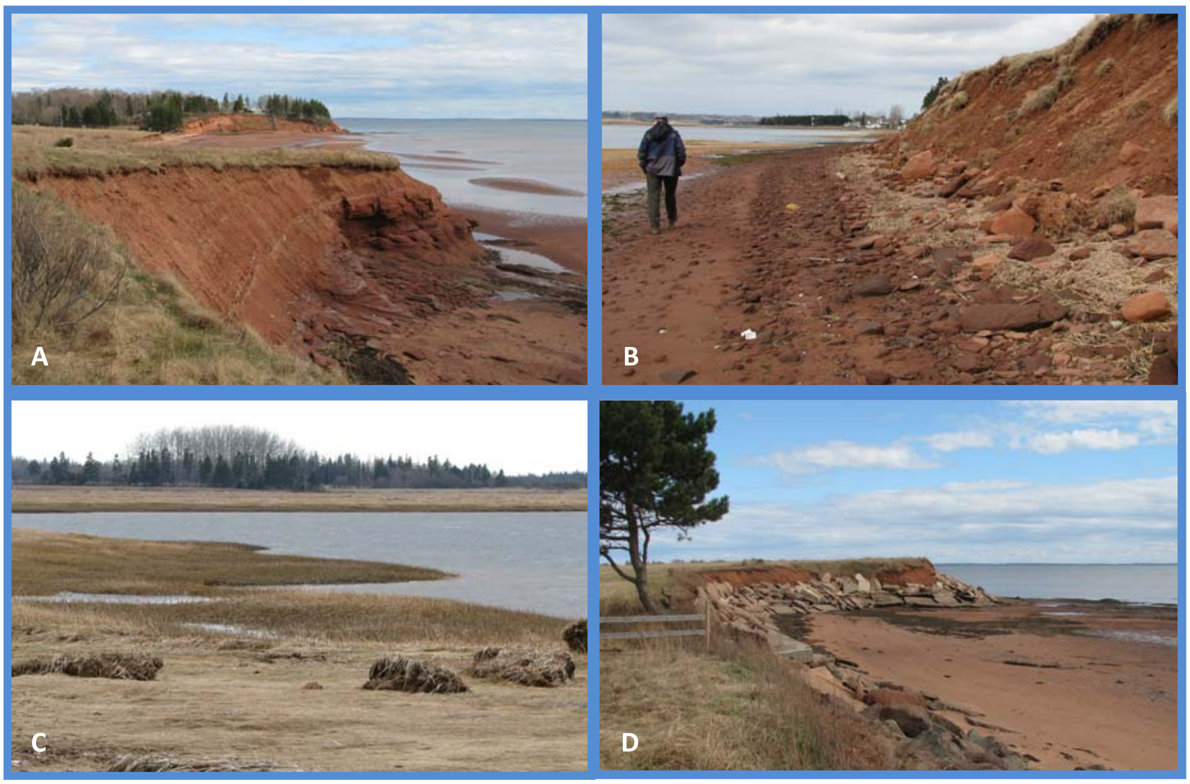

Figure 10. Most common coastal feature types present along the Town of Stratford and Hillsborough River coastal zone. A- sandstone cliffs (overlain or not by glacial till deposits); B- till bluffs (unconsolidated and heterogeneous material); C- salt marshes (mainly found in the upper reaches of the Hillsborough River and its tributaries or in low energy environments); and D- artificially protected shoreline (riprap, revetment, cement or wood walls, gabions).

The erosion data available for the Town of Stratford and the Hillsborough River estuary was extracted from three (3) sources: FORWARD *et al.* (1959), LRIS (1988), and the Provincial monitoring sites of Hazard Point (Q-5) and Tea Hill (Q-4) (see Appendix 1, Figure 1g for approximate location of the measurement sites). In total, 15 erosion rate values were compiled: seven (7) in till bluffs and eight (8) in sandstone cliffs (Table 5). Thirteen (13) rates are located on the Northumberland Strait and two (2) along the Hillsborough River estuary. No erosion data was compiled for the salt marshes, but FORWARD *et al.* (1959) do calculate salt marsh erosion rates for other sites along the Northumberland Strait, and the values range from -0.31 to -1.52 m/yr (see Appendix 2, Table 2e).

Table 5. Available erosion data (mean rate m/yr) for the Town of Stratford and the Hillsborough River estuary area.

Coast Type	Site ID	FORWARD (1959)	Site ID	LRIS (1988)	Site ID	Provincial Monitoring
Till Bluffs (5 sites)	F108*	-0,15 @ -0,20	**LRIS07**	**-0,21**	**Q-5**	**-0.20**
	F109*	-0,15 @ -0,20	LRIS08	-0,06	Q-4	-0.70
	F110	**-0,31**				
Sandstone Cliffs (8 sites)	F111	-0,31 @ -0,46	LRIS01	-0,30		
	F112	-0,31	LRIS02	-0,15		
			LRIS03	-0,24		
			LRIS04	-0,21		
			LRIS05	-0,24		
			LRIS06	-0,18		

* Values are for till bluffs along the eastern shore of the Hillsborough River estuary.
F110, LRIS07, and Q-5 (**in bold**) correspond to approximately the same measurement site location.

The data from FORWARD *et al.* (1959) concerns the oldest period, namely 1935 to 1958 (23 years); the LRIS (1988) data spans over the longest period, namely 1935 to 1980 (45 years); and the Provincial Monitoring data concerns the most recent period, from 1984 to 2003 (19 years).

Till bluffs

Seven (7) erosion rates were compiled for the till bluffs exposed to the **Northumberland Strait** and range from -0.06 to -0.70 m/yr. An interesting result stemming from this compilation is that one measuring site was common to all three studies, i.e., the till bluff situated in front of the Hazard Point lighthouse, which enables a comparison of the methods. At this location, FORWARD et al. (1959) measured the highest erosion rate at -0.31 m/yr, while the Provincial Monitoring Programme measured the lowest rate at -0.20 m/yr, just slightly lower that the LRIS (1988) rate at -0.21 m/yr.


Hazard Point Lighthouse
April, 2010

The apparent discrepancies between the FORWARD and LRIS rates could be explained in the same manner as the sandstone cliffs (see below). Based on the methodology assessment detailed in the section *Erosion data acquisition – description of the different methodologies*, the Provincial Monitoring Programme rate of -0.20 m/yr, acquired through Analog field measurements using a measuring tape, should be considered the most accurate data of the three presented here. This low retreat rate is probably due to the presence of a shoreline protection structure during the monitoring programme (1984-2003). However, while the fact sheet detailing the measurements taken at the Q-5 monitoring site show slight to nil erosion between 1984 and 1987 (a total retreat of -0.03 m, which could actually stem from a measurement inaccuracy), and again slight to nil erosion from 1998 to 2003 (a total retreat of -0.10 m, which is also within the margin of error of the method), there is still a total retreat of -3.70 m to account for, which logically should have happened between 1987 and 1998. We do not have the necessary information to assess this value.

FORWARD *et al.* (1959) reported two (2) sites (F108 and F109), having identical erosion rates, along the **Hillsborough River till bluffs**, both ranging from -0.15 to -0.20 m/yr, which is within the range of values observed along the Northumberland Strait.

Sandstone cliffs

The sandstone cliff erosion rates calculated by FORWARD *et al.* (1959) are higher than those calculated by LRIS (1988). This could in part be explained by their location: FORWARD's measurement sites are along the coast of Belleview Point, where the height at the coast is under 5 m and exposure is to the SW. The LRIS measurement sites are located in the Lobster Point area, where the height at the coast can reach a little over 7 m and the coast is facing the S. Another possible explanation for FORWARD's higher rates could be related to the time period considered: 1935-1958 (vs 1935-1980 for LRIS). Using historical aerial photographs and digital photogrammetry (GIS), Coldwater Consultants Ltd (2009b) established that the erosion of the sandstone/till cliffs along the Town of Souris was greater during the period 1935-1958 (up to -0.08 m/yr) compared to the more recent time periods. Therefore, the 45 year period considered in the LRIS (1988) study could tamper the erosion rate, if in fact the years between 1958 and 1980 were characterized by a lesser energy arriving at the coast (fewer storms). Part of the difference in the calculated erosion rates could also be related to technological improvements of the Zoom Transfer Scope equipment in the more recent years. Given these reasons and the fact that no measurement site is common to the two studies, there is no reason not to consider that both set of values are accurate.

Recommendations

The following recommendations are for the Town of Stratford and the Hillsborough River estuary (the study area). They have been developed by *Géo Littoral Consultants* while keeping the original mandate in mind: whatever work on shoreline erosion data and shoreline classification is done in Stratford must also be applicable to the rest of the Province.

In order to assess the vulnerability of its coastal areas to the impacts of rising sea-levels and climate change, it is recommended that the Town of Stratford (the study area) consider the following actions (structured by priority and sequence of events):

- Acquire ***accurate historical erosion rates*** for the longest time-period, through Digital Photogrammetry using GIS.

  Based on the results shown in the previous sections, it is recommended that long-term mean erosion rates be calculated from shoreline mapping via Digital photogrammetry using a GIS. These mean values are the best estimate of historical trends in the evolution of the coast and future retreat scenarios, over a similar time span, can be based upon them. The oldest (and highest quality) aerial photographs series, as well as the most recent set of aerial photographs, should be acquired, scanned, and georeferenced. This mapping exercise should be accomplished using the available LiDAR data (acquired by the PEI Provincial Government in 2007), mainly to enable a quality georeferencing process (the elevation at the coast can be greater than 7 m in places, and this must be taken into account by the GIS system in order to accurately georeference the aerial photographs).

- Adopt a ***Shoreline Classification System*** based on a model similar to the one developed by BERNATCHEZ *et al*. (2008).

  The BERNATCHEZ classification system uses simple identification and characterization of coastal types; it can readily be used in combination with information on evolutionary trends of the shoreline and proposed scenarios of coastal evolution, based on climate change predictions. This system, or a variant of it, will be useful in land-use planning and management of the Town of Stratford's coastal zone.

- Resume ***shoreline monitoring activities*** at existing sites and along new targeted sites.

  Gathering yearly erosion data through the establishment of shoreline monitoring sites will help to better understand and nuance the changes operating at the coast. Yearly monitoring of shoreline change provides an opportunity to measure the effects of individual or groups of storm events, which cannot readily be deciphered through the study of historical erosion rates. Both the short-term variability and recent/future acceleration of erosion rates can not provide this information. As monitoring programs demand a continuing commitment in order to keep databases accurate and complete, they generally require optimal use of human and material resources to succeed.

  If a monitoring program is developed it should probably be based on a limited number of study sites that are representative of the main coastal types and conditions (i.e., Gulf VS Strait coasts, coast exposure, etc.) present in the Province that are relevant to adaptation to climate change. Some of these sites already exist, such as the monitoring carried out by the PEI National Park. Provincial and Town authorities as well as local community groups should be involved in this undertaking in order to increase its chances to become a successful coastal data acquisition program.

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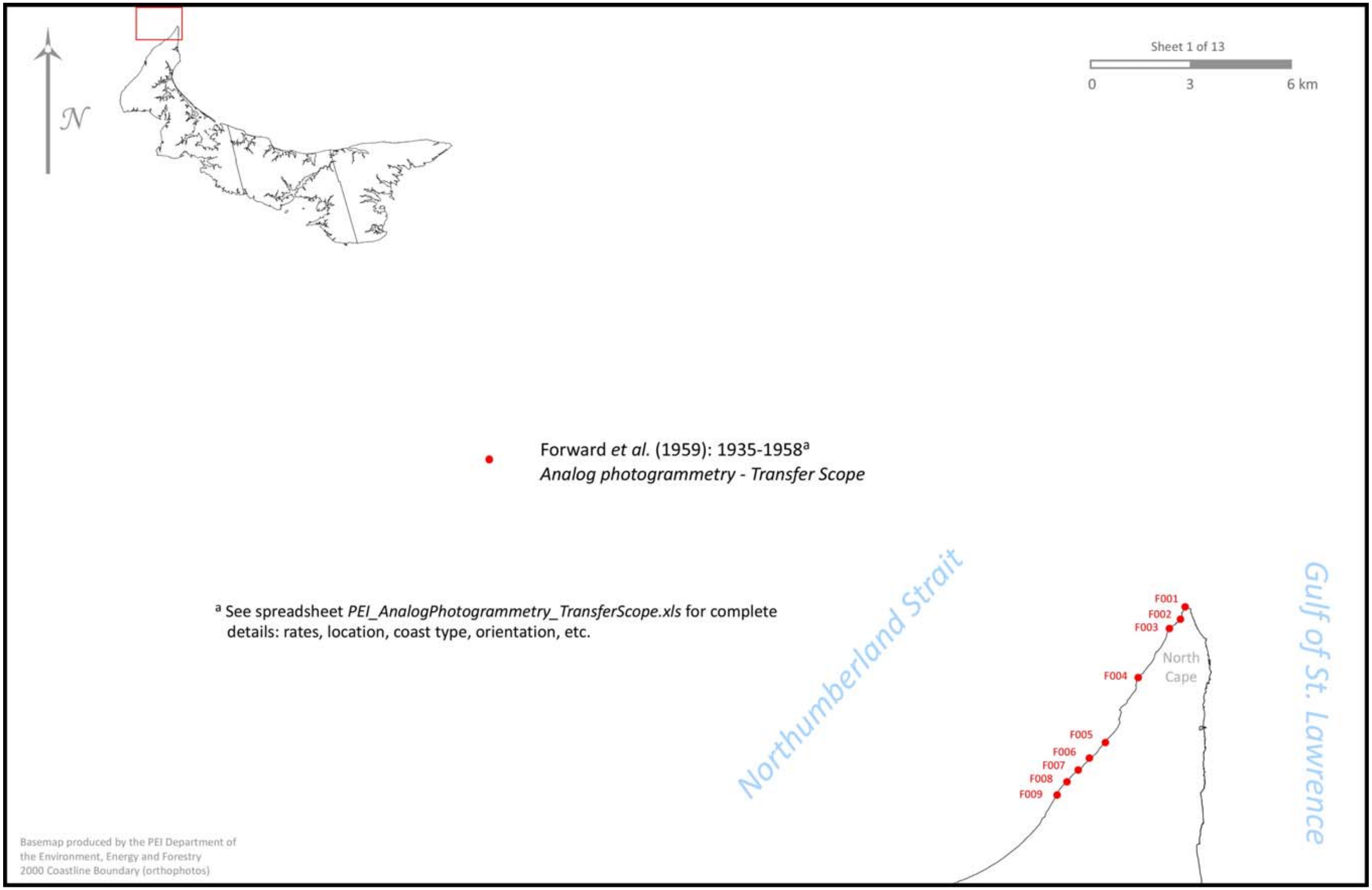
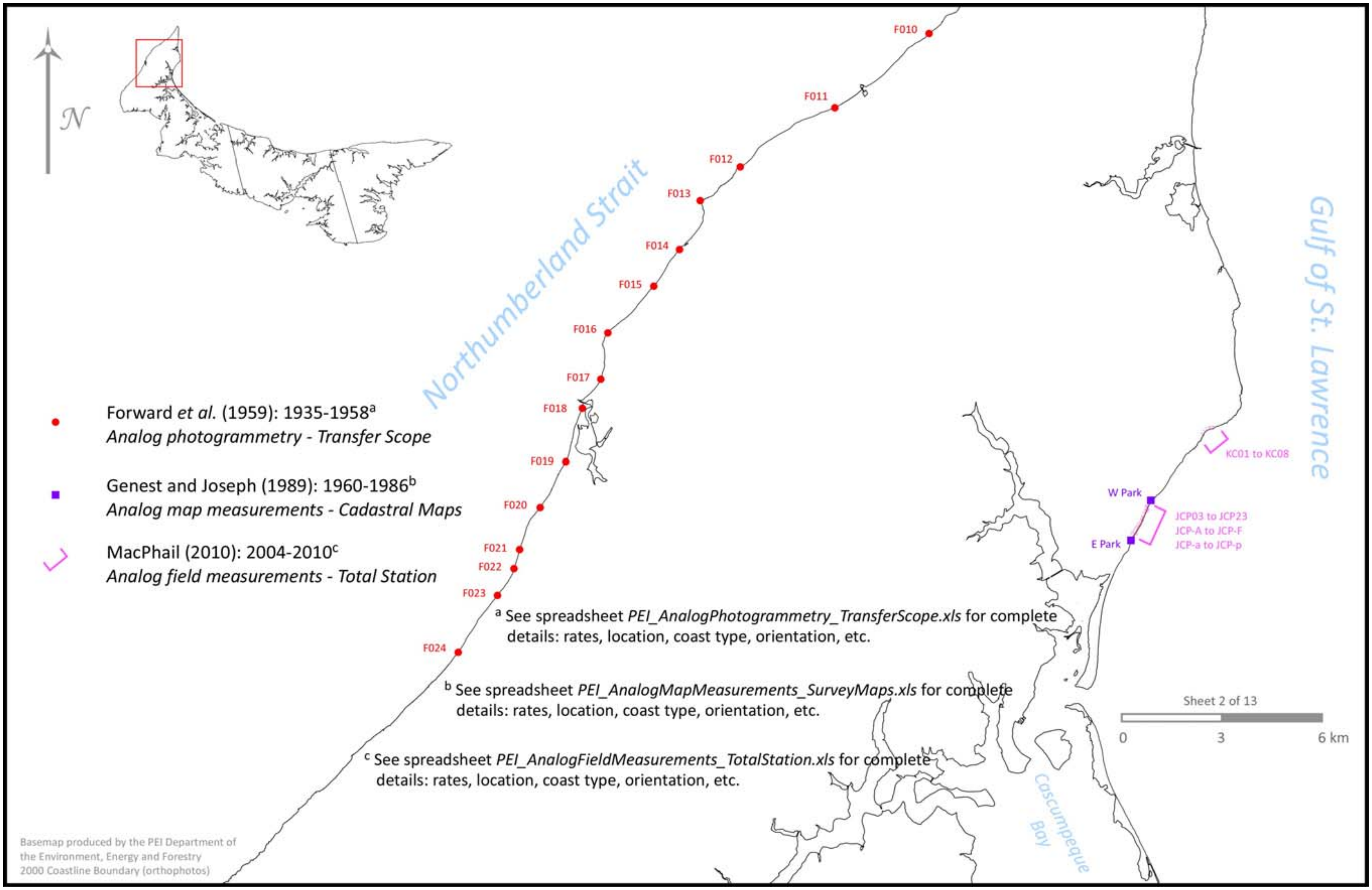
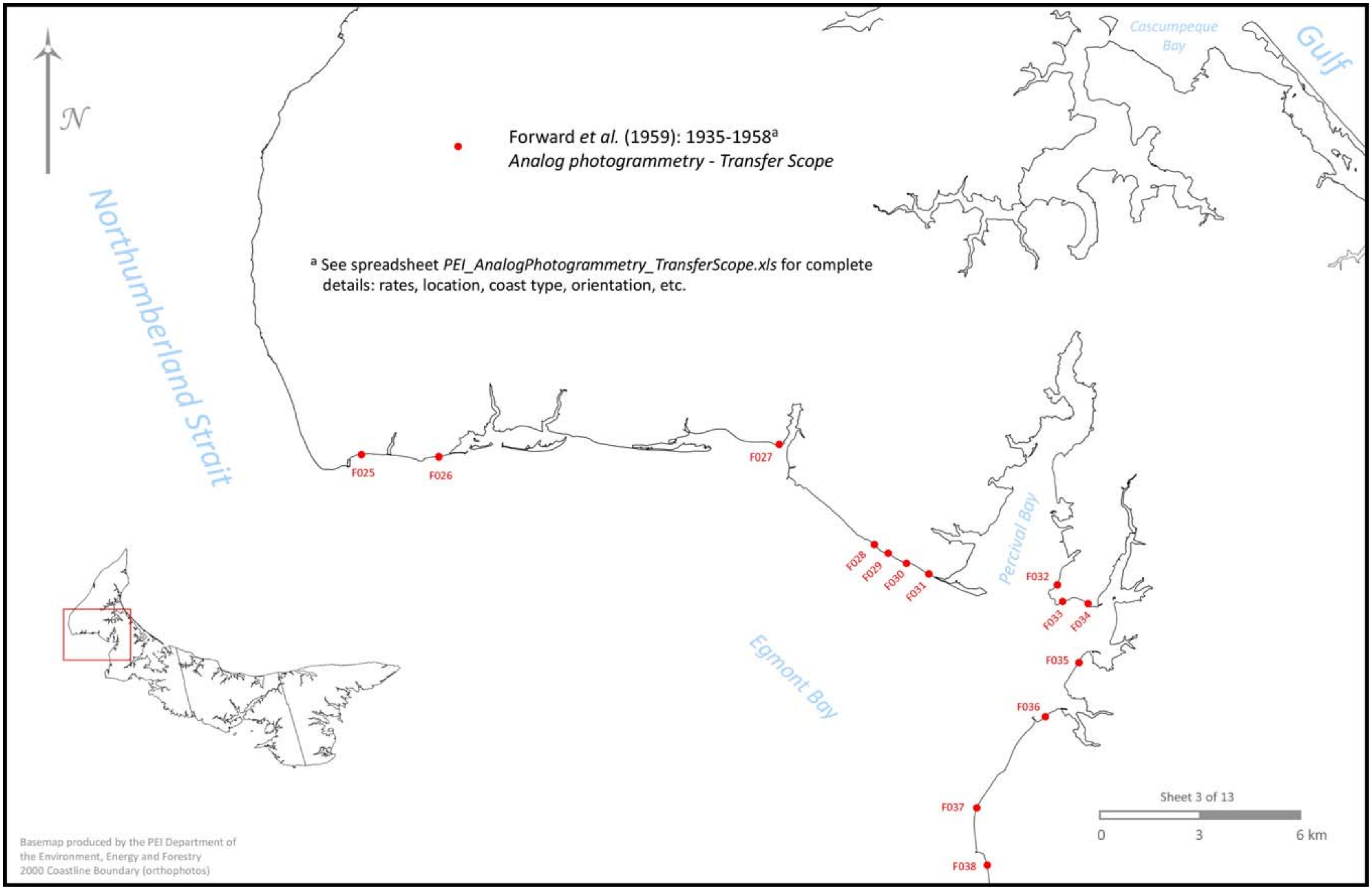
Appendix 1 - General location of the shoreline erosion data compiled



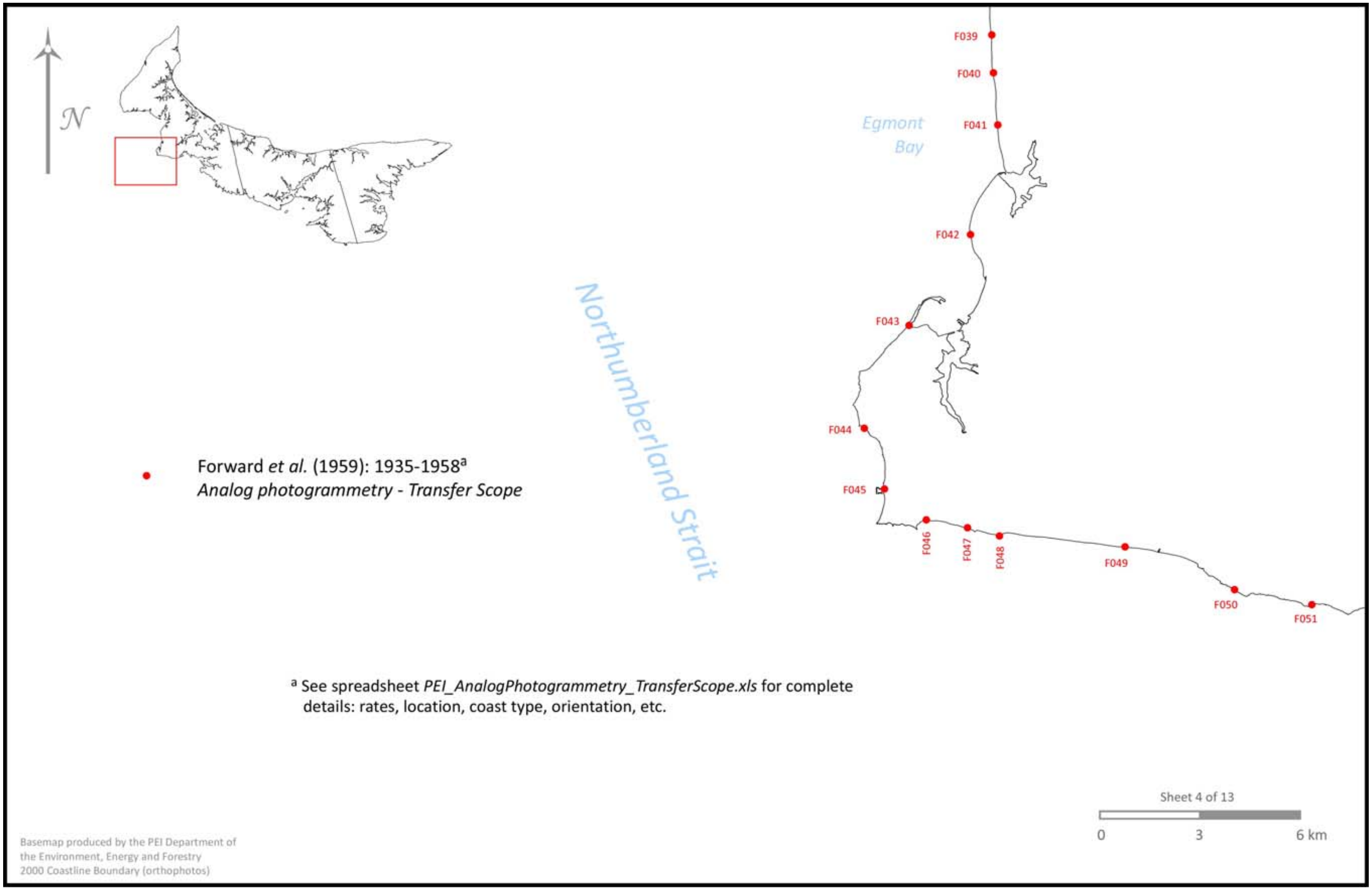
Appendix 1, Figure 1a. General location of erosion data: North Cape - NTS sheet 21P/01.



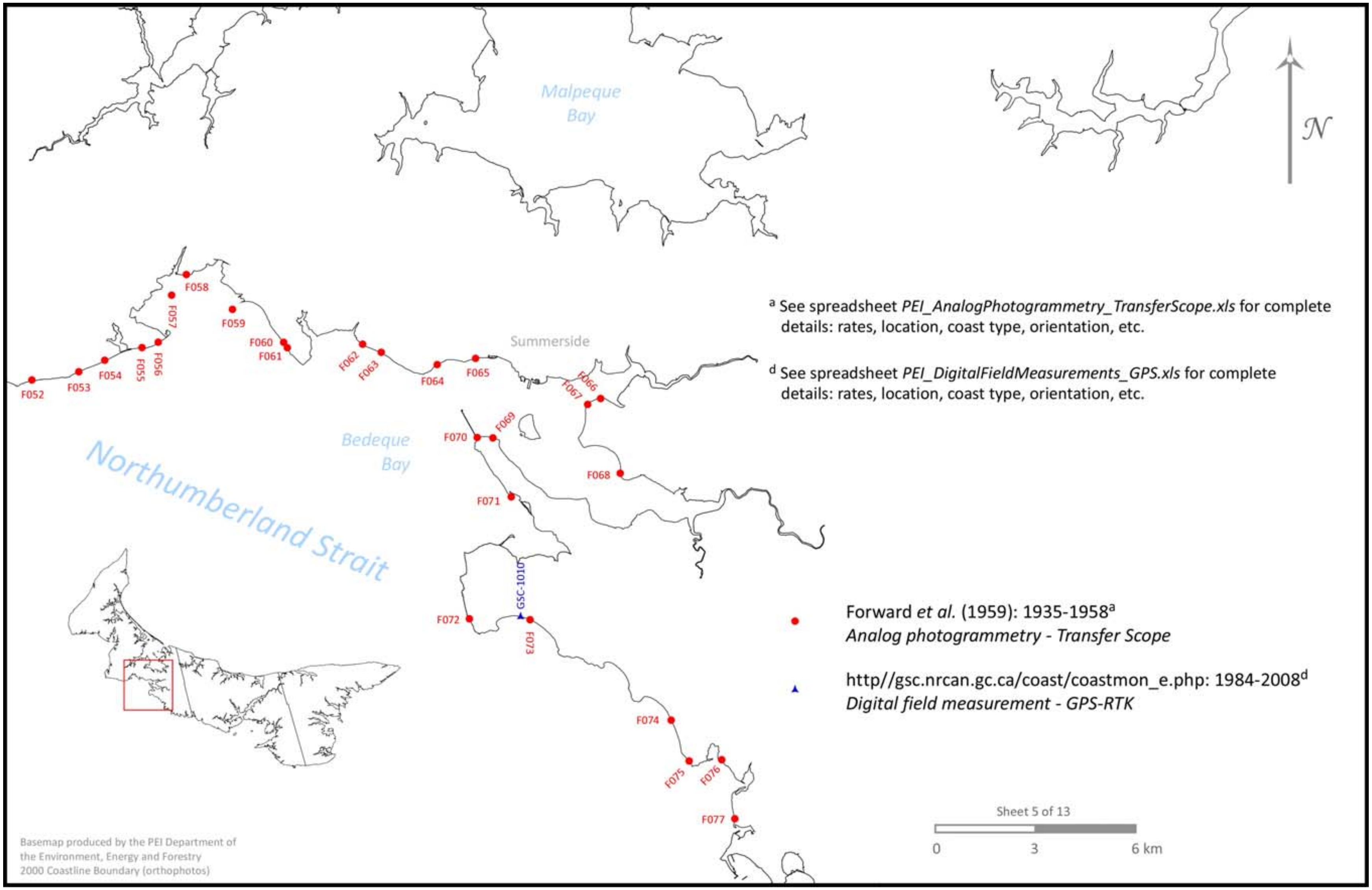
Appendix 1, Figure 1b. General location of erosion data: Tignish - NTS sheet 21I/16.



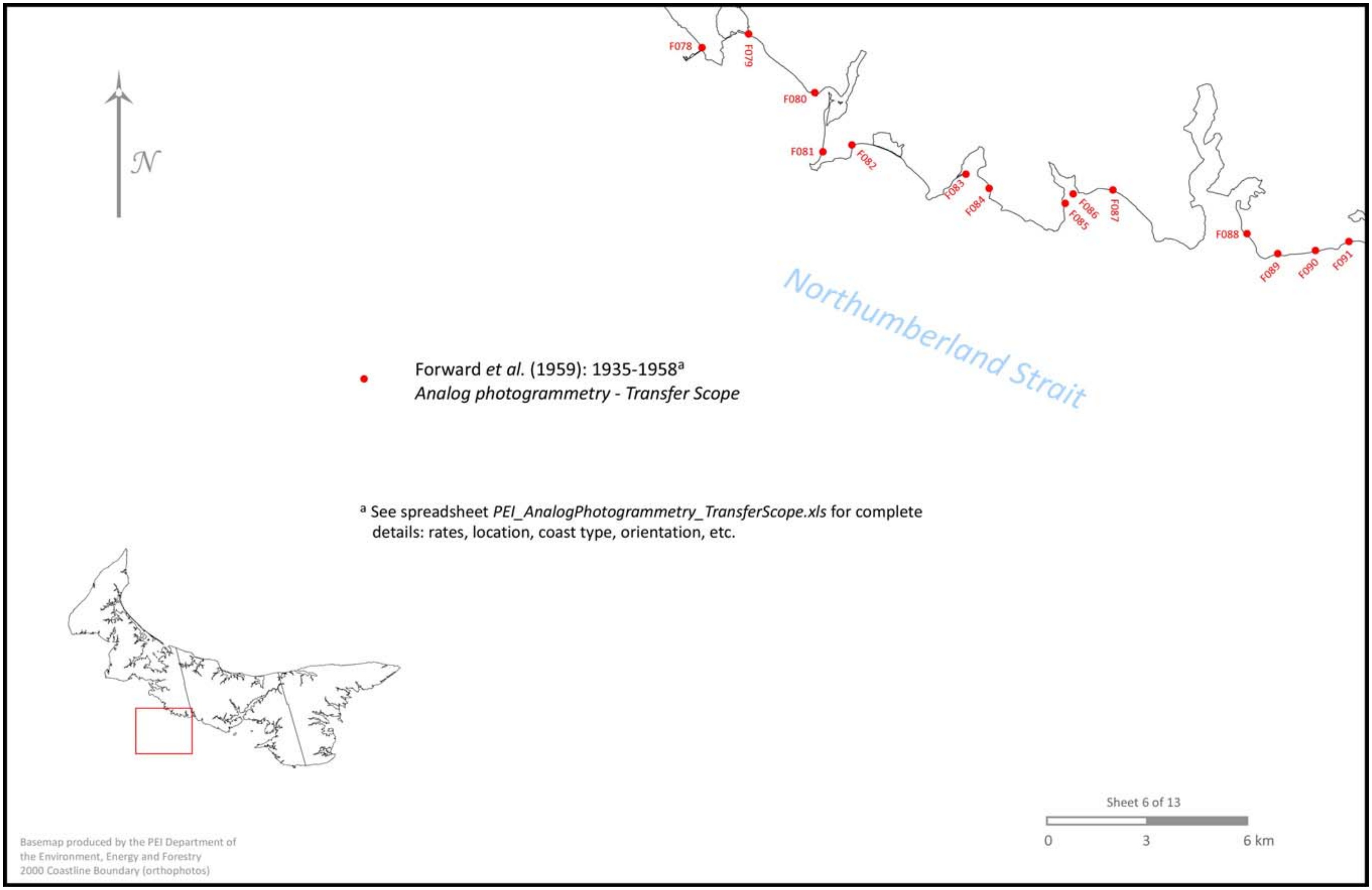
Appendix 1, Figure 1c. General location of erosion data: O'Leary - NTS sheet 21I/09.



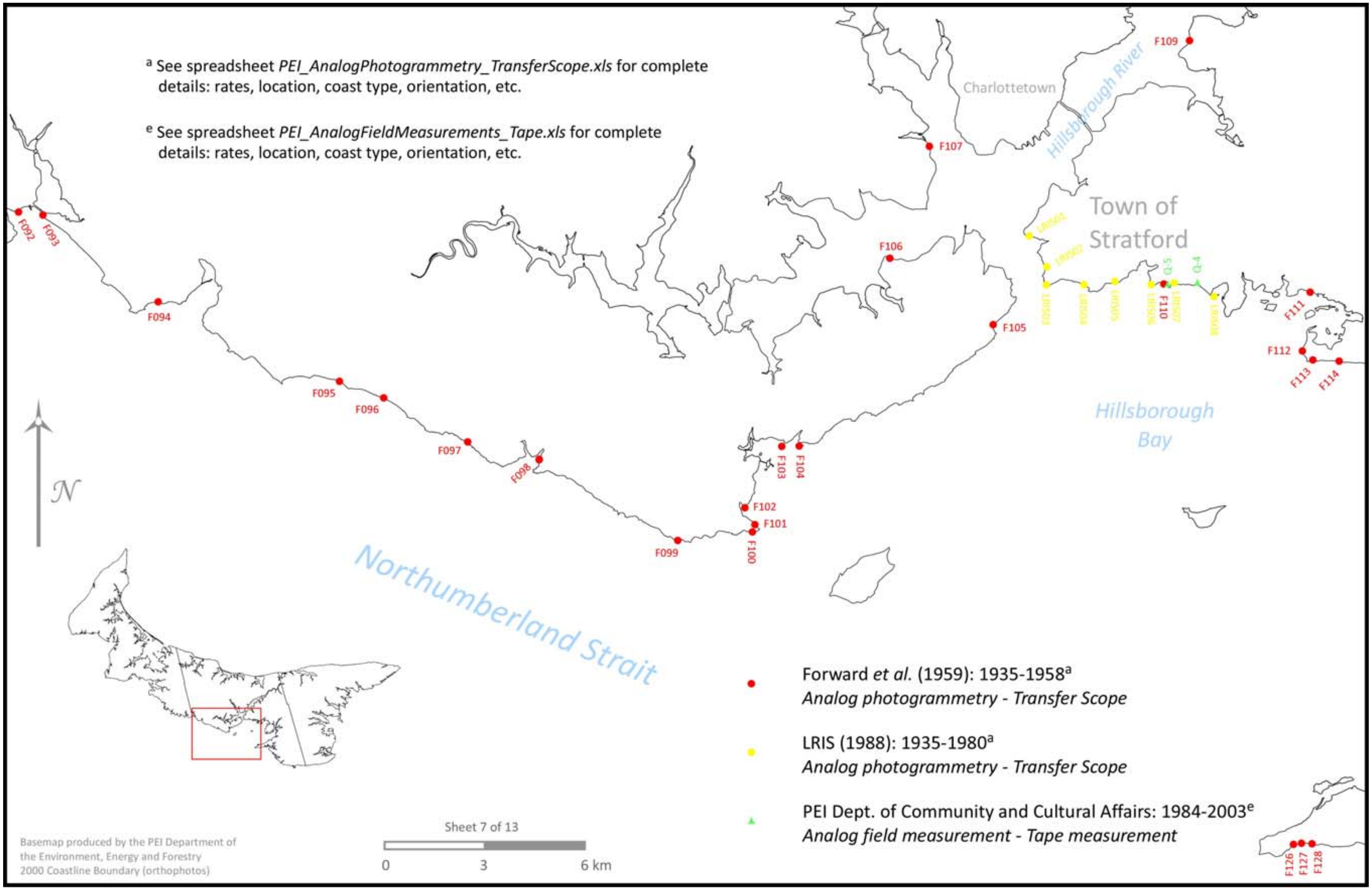
Appendix 1, Figure 1d. General location of erosion data: Cape Egmont - NTS sheet 21I/08.



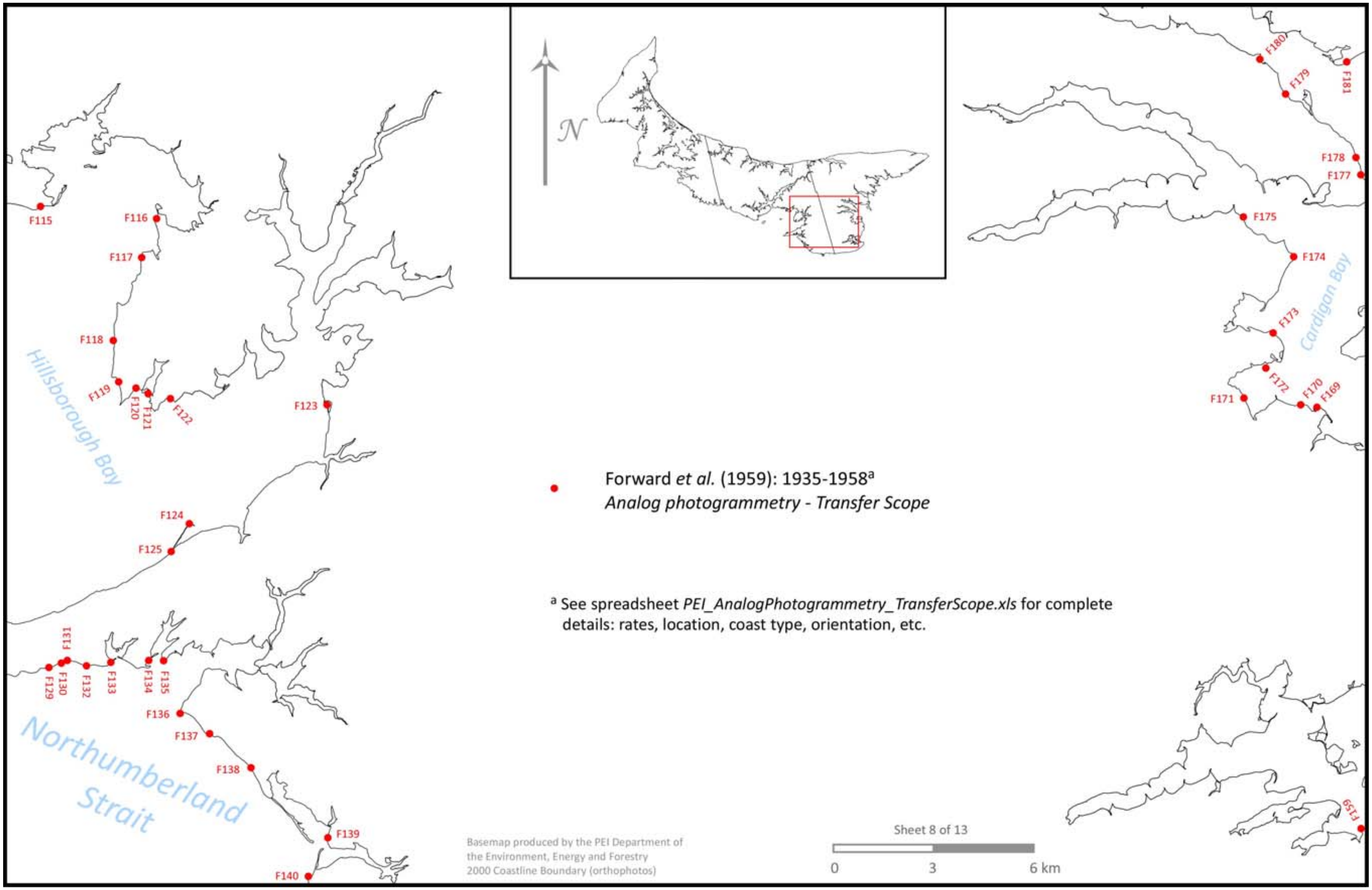
Appendix 1, Figure 1e. General location of erosion data: Summerside - NTS sheet 11L/05.



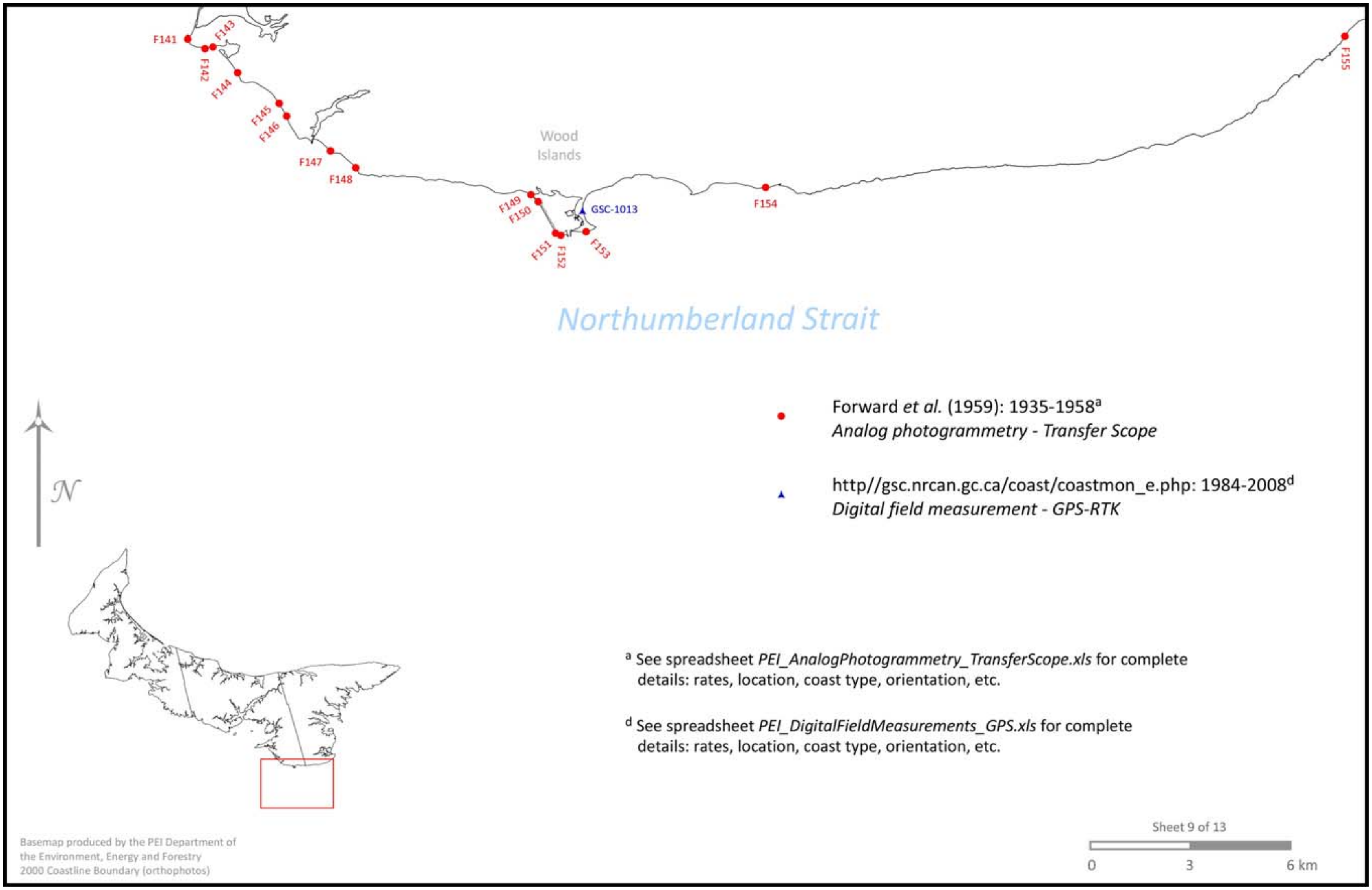
Appendix 1, Figure 1f. General location of erosion data: Cape Tourmentine - NTS sheet 11L/04.



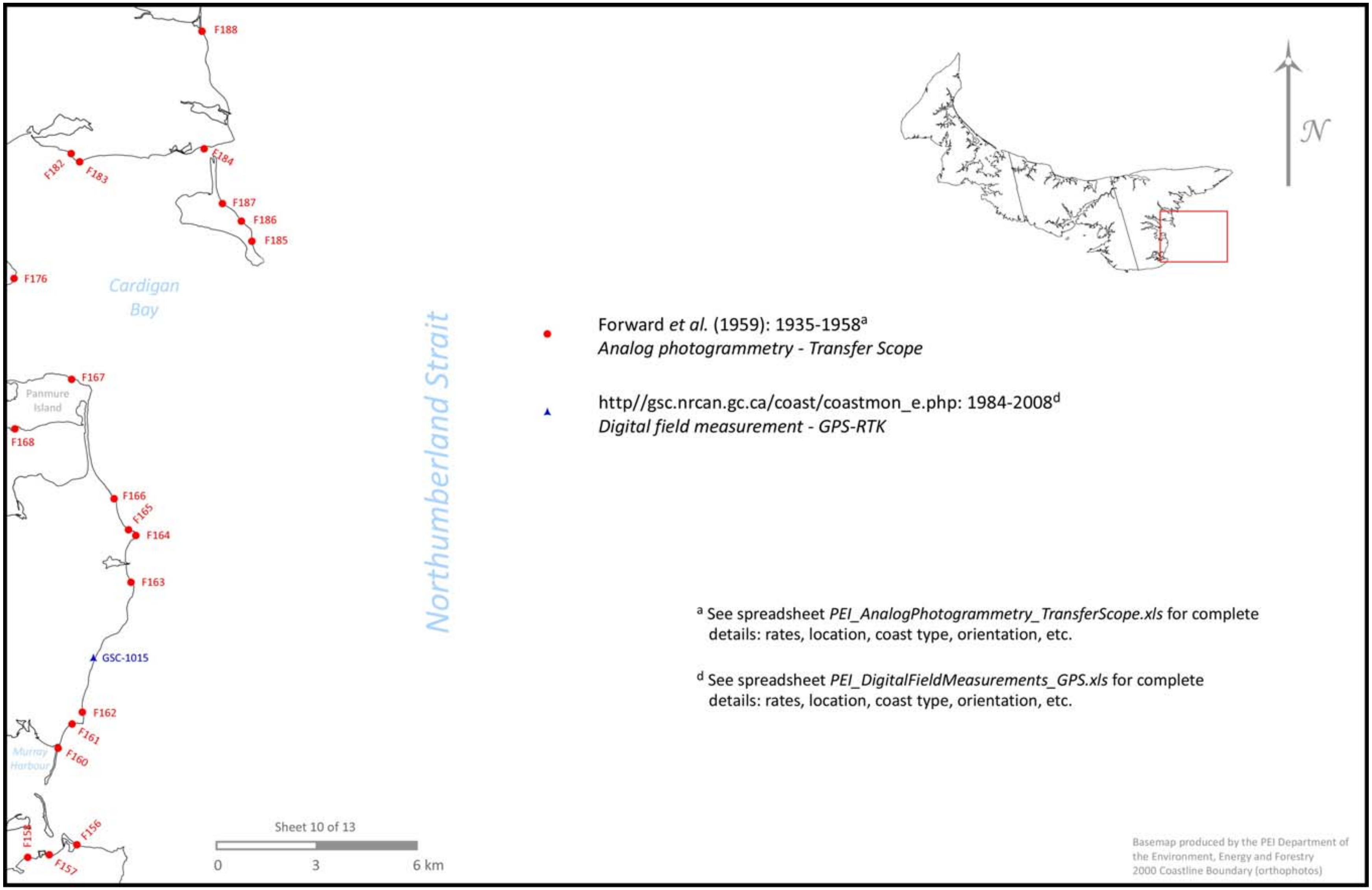
Appendix 1, Figure 1g. General location of erosion data: Charlottetown - NTS sheet 11L/03.



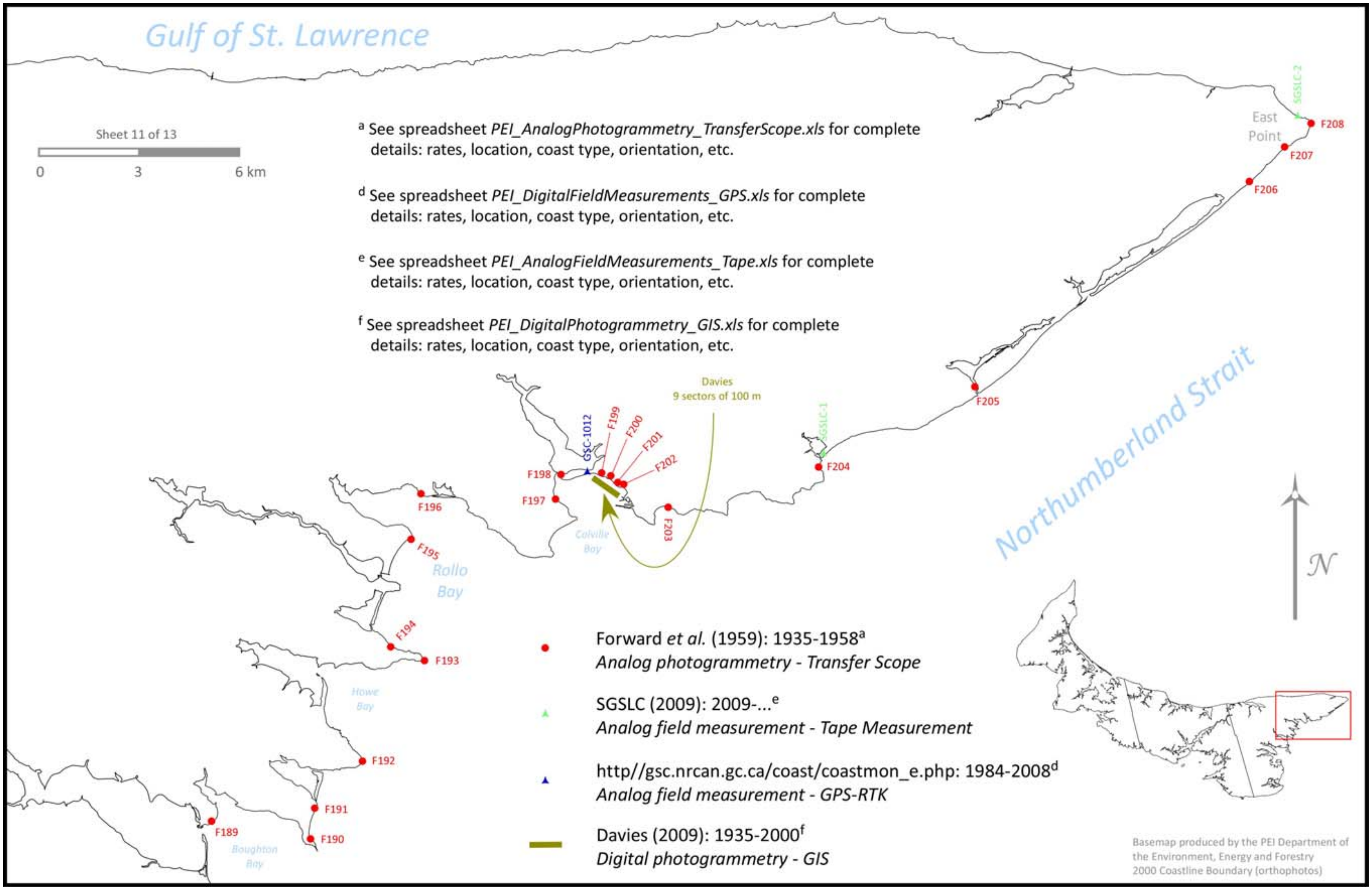
Appendix 1, Figure 1h. General location of erosion data: Montague - NTS sheet 11L/02.



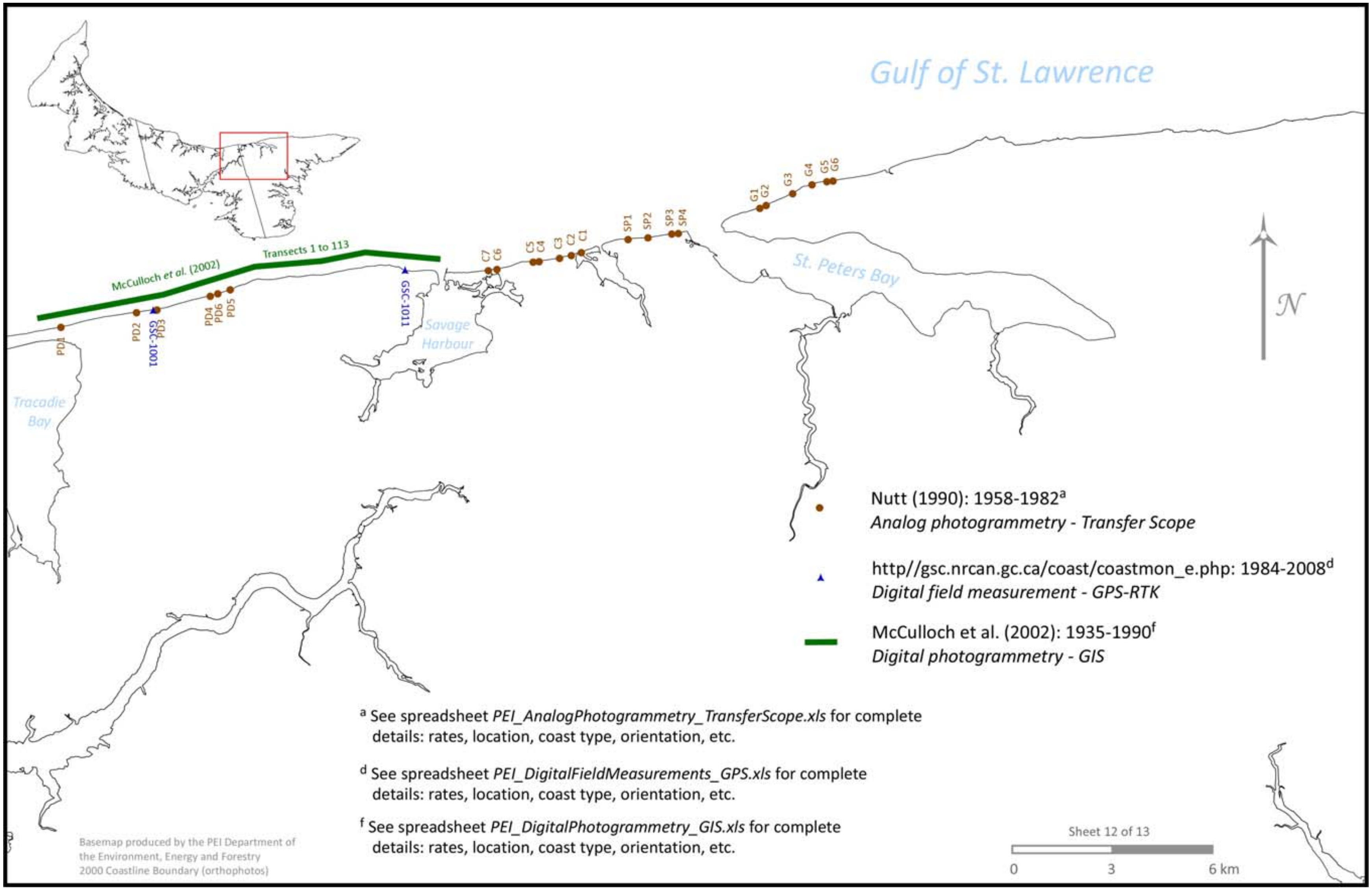
Appendix 1, Figure 1i. General location of erosion data: Pictou Island - NTS sheet 11E/15.



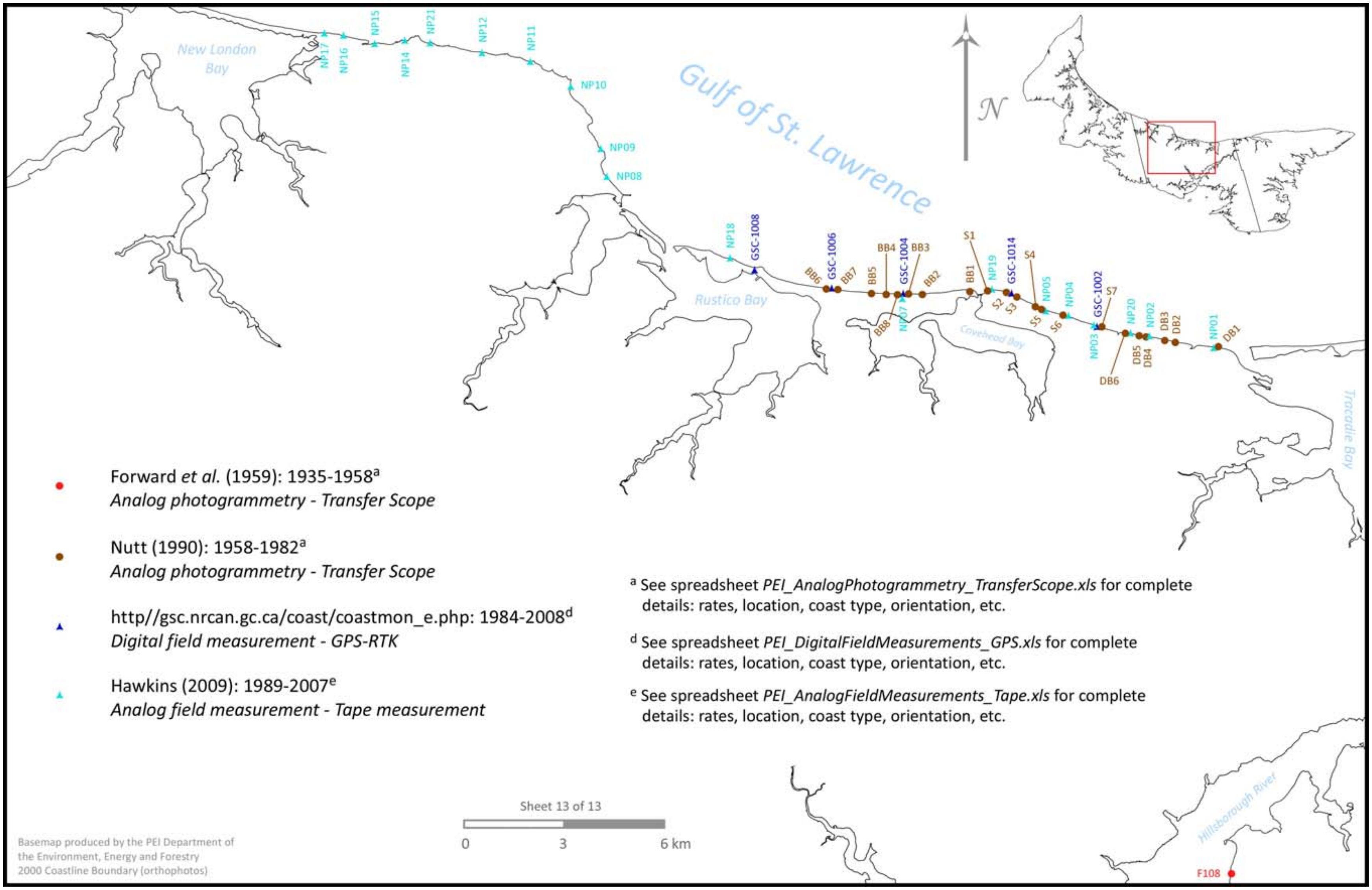
Appendix 1, Figure 1j. General location of erosion data: Boughton Island - NTS sheet 11L/01.



Appendix 1, Figure 1k. General location of erosion data: Souris - NTS sheet 11L/08.



Appendix 1, Figure 1l. General location of erosion data: Mount Stewart - NTS sheet 11L/07.



Appendix 1, Figure 1m. General location of erosion data: North Rustico - NTS sheet 11L/06.

Appendix 2 – Tables presenting the erosion data compiled

Direct (field) measurements

Indirect (laboratory) measurements

Appendix 2, Table 2a. Available raw data collected using Digital Field Measurements (GPS-RTK)

Site ID	General Location	Exposure	Coast Type	Survey Method	Site coor.* Latitude	Site coor.* Longitude	NTS Map	# of surveys	# of lines	First Survey	Last Survey	ID on Map**
GSC_1001	Point Deroche Beach	Gulf	dune	C.S.P.	46,4224646	-62,9424634	11L/7			1985	2008	C
GSC_1002	Stanhope Lane	Gulf	dune	C.S.P.	46,4203304	-63,0987014	11L/6	20	3	1984	2005	C
GSC_1003	Stanhope	Gulf	dune	C.S.P.	46,4233351	-63,1105031	11L/6	3	0	1999	2005	C
GSC_1004	Brackley Beach East	Gulf	dune	C.S.P.	46,4293225	-63,1775404	11L/6	13	3	1989	2005	C
GSC_1006	Brackley Beach West	Gulf	dune	C.S.P.	46,4307755	-63,2064160	11L/6	17	3	1989	2001	C
GSC_1008	Robinsons Island Beach	Gulf	dune	C.S.P.	46,4359200	-63,2377231	11L/6	6	1	1989	2000	C
GSC_1010	Gardiner Shore	Strait	till	C.S.P.	46,3201016	-63,7915518	11L/5	3	2	1994	2006	C
GSC_1011	Pigots Point	Gulf	dune	C.S.P.	46,4329325	-62,8478645	11L/7	5	3	1999	2004	C
GSC_1012	Souris Beach	Strait	dune	C.S.P.	46,3568030	-62,2664865	11L/8	3	5	1999	2000	C
GSC_1013	Wood Islands	Strait	dune	C.S.P.	45,9546502	-62,7466742	11E/15	2	2	2000	2005	C
GSC_1014	Cape Stanhope	Gulf	dune	C.S.P.	46,4295275	-63,1335656	11L/6	6	3	2000	2001	C
GSC_1015	Condons Pond cliff	Strait	till	C.S.P.	46,0700000	-62,4660000	11L/1	3	1	1991	2001	C

.+ values in *italics* are approximate.
* no value is entered when data is absent or when the site is unknown or too generalized.
** for cross-reference purposes, this letter also appears next to the same plotted sites on the GIS map: ***PEI_ErosionData_Sites***
** the ID letter in this column also refers to the bibliography listed below

C.M. = measurements using cadastral maps
P.GIS = photogrammetry using GIS
P.T. = photogrammetry using transfer scope
T.S. = total station
E.P. = erosion pins using tape measurement
C.S.P. = cross-shore profiles using GPS

C: See website: http//gsc.nrcan.gc.ca/coast/coastmon_e.php

Appendix 2, Table 2b. Available raw data collected using Analog Field Measurements (Total Station)

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Distance 2004-2009	Rate (m/yr) 2004-2009	Distance (m) 2004-2010	Rate (m/yr) 2004-2010	Distance (m) 2009-2010	NTS Map	Orientation	ID on Map**
JPC-A	Jacques Cartier Provincial Park	Gulf	sandy till	*322524.72*	*75578.14*	T.S.	-7,90	-1,58				21I/16	SW-NE	E
JCP-a	Jacques Cartier Provincial Park	Gulf	sandy till	*322527.02*	*755581.78*	T.S.					-3,10	21I/16	SW-NE	E
JCP-b	Jacques Cartier Provincial Park	Gulf	sandy till	*322546.28*	*755616.04*	T.S.					-2,50	21I/16	SW-NE	E
JCP-B	Jacques Cartier Provincial Park	Gulf	sandy till	*322549.16*	*755620.80*	T.S.	-6,20	-1,24				21I/16	SW-NE	E
JCP03	Jacques Cartier Provincial Park	Gulf	sandy till	*322579.24*	*755641.76*	T.S.			-6,30	-1,05		21I/16	SW-NE	E
JCP04	Jacques Cartier Provincial Park	Gulf	sandy till	*322597.32*	*755665.56*	T.S.			-9,10	-1,52		21I/16	SW-NE	E
JCP-C	Jacques Cartier Provincial Park	Gulf	sandy till	*322584.64*	*755677.48*	T.S.	-8,20	-1,64				21I/16	SW-NE	E
JCP05	Jacques Cartier Provincial Park	Gulf	sandy till	*322601.72*	*755672.16*	T.S.			-7,10	-1,18		21I/16	SW-NE	E
JCP-D	Jacques Cartier Provincial Park	Gulf	sandy till	*322641.60*	*755784.74*	T.S.	-4,30	-0,86				21I/16	SW-NE	E
JCP06	Jacques Cartier Provincial Park	Gulf	sandy till	*322621.54*	*755712.70*	T.S.			-6,20	-1,03		21I/16	SW-NE	E
JCP-c	Jacques Cartier Provincial Park	Gulf	sandy till	*322655.28*	*755812.16*	T.S.					-2,20	21I/16	SW-NE	E
JCP07	Jacques Cartier Provincial Park	Gulf	sandy till	*322660.36*	*755782.36*	T.S.			-11,20	-1,87		21I/16	SW-NE	E
JCP-E	Jacques Cartier Provincial Park	Gulf	sandy till	*322682.86*	*755837.74*	T.S.	-7,80	-1,56				21I/16	SW-NE	E
JCP-d	Jacques Cartier Provincial Park	Gulf	sandy till	*322685.88*	*755841.04*	T.S.					-2,60	21I/16	SW-NE	E
JCP-e	Jacques Cartier Provincial Park	Gulf	sandy till	*322693.24*	*755855.20*	T.S.					-2,90	21I/16	SW-NE	E
JCP08	Jacques Cartier Provincial Park	Gulf	sandy till	*322670.94*	*755807.38*	T.S.			-5,70	-0,95		21I/16	SW-NE	E
JCP-f	Jacques Cartier Provincial Park	Gulf	sandy till	*322715.32*	*755888.46*	T.S.					-3,00	21I/16	SW-NE	E
JCP09	Jacques Cartier Provincial Park	Gulf	sandy till	*322706.62*	*755852.32*	T.S.			-6,70	-1,12		21I/16	SW-NE	E
JCP10	Jacques Cartier Provincial Park	Gulf	sandy till	*322767.44*	*755967.80*	T.S.			-4,50	-0,75		21I/16	SW-NE	E
JCP-g	Jacques Cartier Provincial Park	Gulf	sandy till	*322764.56*	*755983.30*	T.S.					-2,80	21I/16	SW-NE	E
JCP11	Jacques Cartier Provincial Park	Gulf	sandy till	*322789.96*	*756020.50*	T.S.			-2,80	-0,47		21I/16	SW-NE	E
JCP12	Jacques Cartier Provincial Park	Gulf	sandy till	*322800.40*	*756047.44*	T.S.			-4,50	-0,75		21I/16	SW-NE	E
JCP-h	Jacques Cartier Provincial Park	Gulf	sandy till	*322794.30*	*756059.50*	T.S.					-3,70	21I/16	SW-NE	E
JCP-i	Jacques Cartier Provincial Park	Gulf	sandy till	*322812.44*	*756097.16*	T.S.					-1,10	21I/16	SW-NE	E
JCP13	Jacques Cartier Provincial Park	Gulf	sandy till	*322825.18*	*756109.50*	T.S.			-2,60	-0,43		21I/16	SW-NE	E
JCP-j	Jacques Cartier Provincial Park	Gulf	sandy till	*322821.50*	*756128.90*	T.S.					-1,80	21I/16	SW-NE	E
JCP14	Jacques Cartier Provincial Park	Gulf	sandy till	*322835.40*	*756138.54*	T.S.			-3,10	-0,52		21I/16	SW-NE	E
JCP15	Jacques Cartier Provincial Park	Gulf	sandy till	*322870.68*	*756219.10*	T.S.			-4,00	-0,67		21I/16	SW-NE	E
JCP16	Jacques Cartier Provincial Park	Gulf	sandy till	*322890.34*	*756264.78*	T.S.			-3,50	-0,58		21I/16	SW-NE	E
JCP-k	Jacques Cartier Provincial Park	Gulf	sandy till	*322897.32*	*756302.72*	T.S.					-1,70	21I/16	SW-NE	E
JCP-l	Jacques Cartier Provincial Park	Gulf	sandy till	*322901.58*	*756318.02*	T.S.					-2,40	21I/16	SW-NE	E
JCP17	Jacques Cartier Provincial Park	Gulf	sandy till	*322918.66*	*756318.42*	T.S.			-4,30	-0,72		21I/16	SW-NE	E
JCP18	Jacques Cartier Provincial Park	Gulf	sandy till	*322922.38*	*756333.50*	T.S.			-6,20	-1,03		21I/16	SW-NE	E
JCP19	Jacques Cartier Provincial Park	Gulf	sandy till	*322922.84*	*756337.44*	T.S.			-8,00	-1,33		21I/16	SW-NE	E
JCP20	Jacques Cartier Provincial Park	Gulf	sandy till	*322928.40*	*756356.26*	T.S.			-5,60	-0,93		21I/16	SW-NE	E
JCP-m	Jacques Cartier Provincial Park	Gulf	sandy till	*322916.58*	*756358.80*	T.S.					-3,00	21I/16	SW-NE	E
JCP21	Jacques Cartier Provincial Park	Gulf	sandy till	*322942.98*	*756396.86*	T.S.			-3,90	-0,65		21I/16	SW-NE	E
JCP-n	Jacques Cartier Provincial Park	Gulf	sandy till	*322929.30*	*756395.88*	T.S.					-3,50	21I/16	SW-NE	E
JCP22	Jacques Cartier Provincial Park	Gulf	sandy till	*322950.64*	*756418.46*	T.S.			-3,20	-0,53		21I/16	SW-NE	E
JCP-o	Jacques Cartier Provincial Park	Gulf	sandy till	*322934.96*	*756411.74*	T.S.					-2,50	21I/16	SW-NE	E
JCP23	Jacques Cartier Provincial Park	Gulf	sandy till	*322956.28*	*756456.76*	T.S.			-3,50	-0,58		21I/16	SW-NE	E
JCP-p	Jacques Cartier Provincial Park	Gulf	sandy till	*322975.56*	*756472.06*	T.S.					-1,80	21I/16	SW-NE	E

Appendix 2, Table 2b. Available raw data collected using Analog Field Measurements (Total Station) ...continued...

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Distance 2004-2009	Rate (m/yr) 2004-2009	Distance (m) 2004-2010	Rate (m/yr) 2004-2010	Distance (m) 2009-2010	NTS Map	Orientation	ID on Map**
JCP-F	Jacques Cartier Provincial Park	Gulf	sandy till	*322968.02*	*756478.18*	T.S.	-2,10	-0,42				21I/16	SW-NE	E
KC01	Kildare Cape	Gulf	sandstone	*324623.00*	*758597.48*	T.S.			-2,80	-0,47		21I/16	N-S	E
KC02	Kildare Cape	Gulf	sandstone	*324628.42*	*758620.08*	T.S.			-1,30	-0,22		21I/16	N-S	E
KC03	Kildare Cape	Gulf	sandstone	*324669.36*	*758678.22*	T.S.			-2,20	-0,37		21I/16	SW-NE	E
KC04	Kildare Cape	Gulf	sandstone	*324731.94*	*758724.34*	T.S.			-3,70	-0,62		21I/16	SW-NE	E
KC05	Kildare Cape	Gulf	sandstone	*324807.96*	*758758.70*	T.S.			-9,20	-1,53		21I/16	SW-NE	E
KC06	Kildare Cape	Gulf	sandstone	*324829.36*	*758764.82*	T.S.			-9,30	-1,55		21I/16	SW-NE	E
KC07	Kildare Cape	Gulf	sandstone	*324887.70*	*758773.54*	T.S.			-2,20	-0,37		21I/16	E-W	E
KC08	Kildare Cape	Gulf	sandstone	*324930.76*	*758786.24*	T.S.			-2,60	-0,43		21I/16	SW-NE	E

.+ values in *italics* are approximate.

* no value is entered when data is absent or when the site is unknown or too generalized.

** for cross-reference purposes, this letter also appears next to the same plotted sites on the GIS map: ***PEI_ErosionData_Sites***

** the ID letter in this column also refers to the bibliography listed below

C.M. = measurements using cadastral maps
P.GIS = photogrammetry using GIS
P.T. = photogrammetry using transfer scope
T.S. = total station
E.P. = erosion pins using tape measurement
C.S.P. = cross-shore profiles using GPS

E: MacPhail, R. 2010. Shoreline survey, Jacques Cartier Park. PEI Dept. Of Transportation and Public Works. 4 Sheets at 1:500 scale.
MacPhail, R. 2010. Shoreline survey, Kildare Cape. PEI Dept. Of Transportation and Public Works. 1 Sheet at 1:500 scale.

Appendix 2, Table 2c. Available raw data collected using Analog Field Measurements (Measuring Tape)

Site ID	General Location	Exposure	Coast Type	Survey Method	Site coor.* Easting	Site coor.* Northing	NTS Map	1989	1991	1992	1995	1996	2002	2003	2004	2005	2006	2007	ID on Map**
NP01	E of Campbell's Pond; W of Watt's Rd. park footpath	Gulf	dune	E.P.	396020.82	707085.92	11L/6						-0,48	-0,51	-0,41	-0,39	-0,34		B
NP02	Across Dalvay National Park compound	Gulf	dune	E.P.	394008.72	707453.08	11L/6						-0,91	-0,89	-0,85	-1,09	-1,04	-0,83	B
NP03	Across and W of Stanhope Lane	Gulf	dune	E.P.	392351.92	707773.82	11L/6	-1,91	-1,32	-1,22	-0,85	-0,78	-0,64	-0,64	-0,59	-0,71	-0,61	-0,66	B
NP04	Across from Stanhope Beach Campground	Gulf	dune	E.P.	391503.74	708107.40	11L/6	-0,91	-0,78	-0,80	-1,42	-1,38	-1,08	-1,14	-1,10	-1,17	-1,19	-1,13	B
NP05	E of Ross Lane day-use beach parking lot	Gulf	dune	E.P.	390781.46	708250.08	11L/6						-0,94	-1,06	-0,98	-1,04	-0,97	-0,95	B
NP07	Between Covehead bridge and Brackley Beach	Gulf	dune	E.P.	386335.60	708621.90	11L/6		0,00	-0,17	-0,10	-0,12	-0,10	-0,10	-0,10	-0,09	-0,13	-0,13	B
NP08	E of North Rustico access gate;West of kitchen shelter	Gulf	till	E.P.	377124.92	712429.58	11L/6		0,00	-0,13	-0,31	-0,26	-0,21	-0,22	-0,21	-0,20	-0,23	-0,22	B
NP09	Across access road to cottages; N of Rolling's Pond	Gulf	sandstone	E.P.	376936.98	713318.20	11L/6		-0,34	-0,20	-0,17	-0,14	-0,13	-0,13	-0,13	-0,13	-0,14	-0,13	B
NP10	E end of Cape Turner picnic area	Gulf	sandstone	E.P.	376004.48	715244.40	11L/6		0,00	-0,18	-0,09	-0,11	-0,12	-0,13	-0,14	-0,15	-0,14	-0,15	B
NP11	Near Orby Head	Gulf	sandstone	E.P.	374758.56	716022.08	11L/6		0,00	0,00	-0,19	-0,23	-0,20	-0,20	-0,18	-0,21	-0,26	-0,26	B
NP12	W of Orby Head, near PEI monument #2070	Gulf	sandstone	E.P.	373250.70	716287.66	11L/6		0,00	-0,31	-0,24	-0,25	-0,25						B
NP14	NE corner of Cavendish East parking lot	Gulf	sandstone	E.P.	370853.10	716682.12	11L/6		-0,09	-0,04	-0,08	-0,07	-0,06	-0,06	-0,07	-0,09	-0,05	-0,01	B
NP15	W of Cavendish Main Beach boardwalk beach access	Gulf	dune	E.P.	369912.60	716573.94	11L/6		-0,21	-0,35	-0,51	-0,52	-0,33	-0,34	-0,32	-0,32			B
NP16	E of Cavendish Campground Beach	Gulf	dune	E.P.	368941.76	716830.32	11L/6		-0,52	-0,34	-0,43	-0,36	-0,75	-0,67	-0,65	-0,90	-0,65	-0,63	B
NP17	W of Cavendish Campground Beach	Gulf	dune	E.P.	368351.84	716906.74	11L/6		-0,03	-0,09	-0,38	-0,32	-0,92	-0,87	-0,81	-1,11	-1,05	-0,48	B
NP18	NW corner of old day-use area parking lot on Rustico I.	Gulf	till	E.P.	380974.00	709908.92	11L/6							-0,21	-0,63	-2,33	-1,18	-1,59	B
NP19	65 m E of Covehead Lighthouse	Gulf	dune	E.P.	389051.74	708900.04	11L/6							-0,20	-0,20	-3,30	-2,46	-2,00	B
NP20	Old Red Hill parking lot area; W of Reeds and Rushes trail	Gulf	till	E.P.	393432.88	707566.06	11L/6							-0,46	-0,94	-1,13	-0,80	-0,70	B
NP21	E of Cawnpore Lane National Park access; E of site NP13	Gulf	sandstone	E.P.	371633.08	716602.06	11L/6							-0,55	-0,37	-0,44	-0,35	-0,34	B

Site ID	General Location	Exposure	Coast Type	Survey Method	Site coor.* Easting	Site coor.* Northing	NTS Map	1984	1985	1986	1987	1998	1999	2003	Total 84-'03	Rate m/yr			ID on Map**
Q-4	Tea Hill Park, along western fence near change house	Strait	till	E.P.	*395162.14*	*682681.82*	11L/3	-	-0,66	-0,05	-	-	-10,95	-1,71	-13,31	-0,70			H
Q-5	Hazard Point Front Range (SE corner of Lighthouse)	Strait	till	E.P.	*394317.52*	*682656.60*	11L/3	-	0,00	-0,02	0,00	-3,58	-0,10	0,00	-3,70	-0,20			H

Appendix 2, Table 2c. Available raw data collected using Analog Field Measurements (Measuring Tape) ...continued...

Site ID	General Location	Exposure	Coast Type	Survey Method	Site coor.* Latitude	Site coor.* Longitude	NTS Map	# of surveys	# of lines	First Survey	Last Survey	ID on Map**
SGSLC-1	Little Harbour Beach	Strait	dune	C.S.P.	*46.361303*	*-62.170475*	11L/8	3	3	2009	...	D
SGSLC-2	East Point Cliff	Gulf	sandstone	C.S.P.	*46.454411*	*-61.976678*	11L/8	3	3	2009	...	D

.+ values in *italics* are approximate.
* no value is entered when data is absent or when the site is unknown or too generalized.
** for cross-reference purposes, this letter also appears next to the same plotted sites on the GIS map: ***PEI_ErosionData_Sites***
** the ID letter in this column also refers to the bibliography listed below

C.M. = measurements using cadastral maps
P.GIS = photogrammetry using GIS
P.T. = photogrammetry using transfer scope
T.S. = total station
E.P. = erosion pins using tape measurement
C.S.P. = cross-shore profiles using GPS

B: Hawkins, R. 2009. Coastal erosion monitoring protocol, PEI National Park Ecological Integrity monitoring and reporting program. Parks Canada, Draft Version 2.1, 19 p.
H: Shoreline erosion survey (PEI Dept. Community & C. Affairs)
D: SGSLC, 2009. Report on coastal erosion monitoring project: Little Harbour and East Point, PEI. 3 p. http://www.coalition-sgsl.ca/atlas.php

Appendix 2, Table 2d. Available raw data collected using Digital Photogrammetry (GIS)

General Location	Exposure	Site ID	Survey Method	Coast Type	Site* Easting	Site* Northing	NTS Map	Rate (m/yr) 1935-1958 [a]	Error (m) 1935-1958	Rate (m/yr) 1958-1968 [a]	Error (m) 1958-1968	Rate (m/yr) 1968-1980 [a]	Error (m) 1968-1980	Rate (m/yr) 1968-1981 [a]	Error (m) 1968-1981	Rate (m/yr) 1980-1990 [a]	Error (m) 1980-1990	ID on Map**
PEI	Gulf	**Tr. 1**	P. GIS	dune			11L/7			0,79	0,19	-2,52	0,17			-1,78	0,20	I
National	Gulf	**Tr. 2**	P. GIS	dune			11L/7									-6,25	0,20	I
Park	Gulf	**Tr. 3**	P. GIS	dune			11L/7			3,27	0,19	-0,60	0,17			-6,20	0,20	I
	Gulf	**Tr. 4**	P. GIS	dune			11L/7			0,46	0,19	-2,02	0,17			-2,24	0,20	I
	Gulf	**Tr. 5**	P. GIS	dune			11L/7			-0,99	0,19	-3,14	0,17			-2,15	0,20	I
	Gulf	**Tr. 6**	P. GIS	dune			11L/7			-0,74	0,19	-4,67	0,17			-1,67	0,20	I
	Gulf	**Tr. 7**	P. GIS	dune			11L/7	-9,41	0,10	-0,34	0,19	-1,98	0,17			-0,60	0,20	I
	Gulf	**Tr. 8**	P. GIS	dune			11L/7			-4,05	0,19	-1,42	0,17			0,10	0,20	I
	Gulf	**Tr. 9**	P. GIS	dune			11L/7			-2,97	0,19	0,44	0,17			0,14	0,20	I
Point	Gulf	**Tr. 10**	P. GIS	dune			11L/7	-0,07	0,10	-1,17	0,19	1,26	0,17			0,22	0,20	I
Deroche	Gulf	**Tr. 11**	P. GIS	dune			11L/7	0,62	0,10	0,61	0,19	1,02	0,17			0,34	0,20	I
Pond	Gulf	**Tr. 12**	P. GIS	dune			11L/7	0,49	0,10	0,96	0,19	0,80	0,17			0,83	0,20	I
	Gulf	**Tr. 13**	P. GIS	dune			11L/7	0,59	0,10	1,06	0,19	0,76	0,17			0,46	0,20	I
	Gulf	**Tr. 14**	P. GIS	dune			11L/7	1,47	0,10	-1,54	0,19	0,76	0,17			0,25	0,20	I
	Gulf	**Tr. 15**	P. GIS	dune			11L/7	1,36	0,09	-1,06	0,19	0,36	0,17			0,46	0,20	I
	Gulf	**Tr. 16**	P. GIS	dune			11L/7	0,66	0,09	-1,73	0,19	-0,19	0,17			0,34	0,20	I
	Gulf	**Tr.17**	P. GIS	dune			11L/7	1,84	0,09	-3,66	0,19	-0,61	0,17			0,55	0,20	I
	Gulf	**Tr. 18**	P. GIS	dune			11L/7	-0,22	0,09	-5,80	0,19	-1,64	0,17			-0,62	0,20	I
	Gulf	**Tr. 19**	P. GIS	dune			11L/7	2,66	0,09	-2,21	0,16	-2,60	0,14			-0,72	0,20	I
	Gulf	**Tr. 20**	P. GIS	dune			11L/7	1,22	0,09	-1,13	0,16	-1,24	0,14			-0,15	0,20	I
	Gulf	**Tr. 21**	P. GIS	dune			11L/7	0,51	0,09	-0,45	0,16	0,28	0,14			0,54	0,20	I
	Gulf	**Tr. 22**	P. GIS	dune			11L/7	0,91	0,09	-1,96	0,16	0,45	0,14			0,65	0,20	I
	Gulf	**Tr. 23**	P. GIS	dune			11L/7	1,00	0,09	-2,32	0,16	0,52	0,14			0,56	0,20	I
	Gulf	**Tr. 24**	P. GIS	dune			11L/7	1,22	0,08	-1,95	0,13	0,93	0,14			1,00	0,16	I
	Gulf	**Tr. 25**	P. GIS	dune			11L/7	0,81	0,08	-0,53	0,13	1,10	0,11			0,72	0,12	I
	Gulf	**Tr. 26**	P. GIS	dune			11L/7	1,18	0,08	0,11	0,13	0,85	0,11			0,53	0,12	I
	Gulf	**Tr. 27**	P. GIS	dune			11L/7	0,84	0,08	-0,32	0,13	0,75	0,11			0,24	0,12	I
	Gulf	**Tr.28**	P. GIS	dune			11L/7	0,62	0,08	0,03	0,13	-0,13	0,11			0,11	0,12	I
	Gulf	**Tr. 29**	P. GIS	dune			11L/7	-1,02	0,08	-1,03	0,13	0,11	0,11			-0,55	0,12	I
	Gulf	**Tr. 30**	P. GIS	dune			11L/7	-1,10	0,08	-1,69	0,13	-0,13	0,11			-1,20	0,12	I
	Gulf	**Tr. 31**	P. GIS	dune			11L/7	0,84	0,08	-3,45	0,13	-1,25	0,11			-1,01	0,12	I
	Gulf	**Tr. 32**	P. GIS	dune			11L/7	0,14	0,08	-2,74	0,13	-0,53	0,11			-1,31	0,17	I
	Gulf	**Tr. 33**	P. GIS	dune			11L/7	0,81	0,09	-3,19	0,16	-0,43	0,15			-1,22	0,20	I
	Gulf	**Tr. 34**	P. GIS	dune			11L/7	0,18	0,09	-2,61	0,16	-0,53	0,15			-1,22	0,20	I
	Gulf	**Tr. 35**	P. GIS	dune			11L/7	2,22	0,09	-1,08	0,16	-1,42	0,15			-1,01	0,20	I
	Gulf	**Tr. 36**	P. GIS	dune			11L/7	2,73	0,09	-2,46	0,16	-0,91	0,15			-0,81	0,20	I
	Gulf	**Tr. 37**	P. GIS	dune			11L/7	2,11	0,09	-1,52	0,16	-0,42	0,15			-1,34	0,20	I
	Gulf	**Tr. 38**	P. GIS	dune			11L/7	1,81	0,09	0,35	0,16	-1,41	0,15			-0,83	0,20	I

Appendix 2, Table 2d. Available raw data collected using Digital Photogrammetry (GIS) ...continued...

General Location	Exposure	Site ID	Survey Method	Coast Type	Site* Easting	Site* Northing	NTS Map	Rate (m/yr) 1935-1958 [a]	Error (m) 1935-1958	Rate (m/yr) 1958-1968 [a]	Error (m) 1958-1968	Rate (m/yr) 1968-1980 [a]	Error (m) 1968-1980	Rate (m/yr) 1968-1981 [a]	Error (m) 1968-1981	Rate (m/yr) 1980-1990 [a]	Error (m) 1980-1990	ID on Map**
	Gulf	**Tr. 39**	P. GIS	dune			11L/7	1,58	0,09	-0,03	0,17	-1,02	0,16			-0,09	0,20	I
	Gulf	**Tr. 40**	P. GIS	dune			11L/7	1,72	0,09	-1,71	0,18	-1,81	0,16			-0,39	0,20	I
	Gulf	**Tr. 41**	P. GIS	dune			11L/7	2,05	0,09	-1,33	0,18	-1,73	0,16			-0,19	0,20	I
	Gulf	**Tr. 42**	P. GIS	dune			11L/7	0,93	0,09	-1,27	0,18	-2,58	0,16			0,31	0,20	I
	Gulf	**Tr. 43**	P. GIS	dune			11L/7	1,95	0,09	-2,27	0,18	-1,31	0,16			0,00	0,20	I
	Gulf	**Tr. 44**	P. GIS	dune			11L/7	1,65	0,09	-2,58	0,18	-1,07	0,16			-0,09	0,20	I
	Gulf	**Tr. 45**	P. GIS	dune			11L/7	0,86	0,09	-2,01	0,18	-0,84	0,16			0,79	0,20	I
	Gulf	**Tr. 46**	P. GIS	dune			11L/7	1,17	0,09	-4,55	0,18	-0,19	0,16			0,58	0,20	I
	Gulf	**Tr. 47**	P. GIS	dune			11L/7	0,06	0,09	-2,50	0,20	1,11	0,18			0,61	0,20	I
	Gulf	**Tr. 48**	P. GIS	dune			11L/7	-0,09	0,09	-0,38	0,20	0,70	0,18			0,57	0,20	I
	Gulf	**Tr. 49**	P. GIS	dune			11L/7	0,17	0,09	-0,16	0,20	0,35	0,18			0,36	0,20	I
	Gulf	**Tr. 50**	P. GIS	dune			11L/7	-0,88	0,09	-0,23	0,20	0,91	0,18			0,54	0,20	I
	Gulf	**Tr. 51**	P. GIS	dune			11L/7	-0,19	0,09	-3,77	0,20	0,75	0,18			0,54	0,20	I
	Gulf	**Tr. 52**	P. GIS	dune			11L/7	-1,25	0,09	-0,99	0,20	1,08	0,18			0,64	0,20	I
	Gulf	**Tr. 53**	P. GIS	dune			11L/7	-0,22	0,09	1,79	0,20	0,20	0,18			0,09	0,20	I
	Gulf	**Tr. 54**	P. GIS	dune			11L/7	0,23	0,09	1,24	0,20	0,70	0,18			1,18	0,20	I
	Gulf	**Tr. 55**	P. GIS	till			11L/7	0,68	0,09	-0,05	0,20	0,54	0,18			0,80	0,20	I
	Gulf	**Tr. 56**	P. GIS	till			11L/7	0,74	0,09	0,09	0,20	0,75	0,18			0,53	0,20	I
	Gulf	**Tr. 57**	P. GIS	till			11L/7	0,17	0,09	0,67	0,20	0,61	0,18			0,40	0,20	I
	Gulf	**Tr. 58**	P. GIS	till			11L/7	-0,17	0,09	1,33	0,20	0,87	0,18			0,56	0,20	I
Point	Gulf	**Tr. 59**	P. GIS	till			11L/7	-0,39	0,09	1,07	0,20	0,73	0,18			0,77	0,20	I
Deroche	Gulf	**Tr. 60**	P. GIS	till			11L/7	0,56	0,09	0,44	0,20	1,19	0,18			0,73	0,20	I
	Gulf	**Tr. 61**	P. GIS	till			11L/7	0,10	0,09	0,74	0,20	0,54	0,18			0,30	0,20	I
	Gulf	**Tr. 62**	P. GIS	till			11L/7	0,05	0,09	0,94	0,20	0,46	0,18			0,14	0,20	I
	Gulf	**Tr. 63**	P. GIS	till			11L/7	0,10	0,09	1,38	0,20	0,38	0,18			0,28	0,20	I
	Gulf	**Tr. 64**	P. GIS	till			11L/7	0,28	0,08	0,99	0,17	0,43	0,16			0,48	0,20	I
Doyles	Gulf	**Tr. 65**	P. GIS	till			11L/7	0,14	0,08	-0,13	0,17	0,83	0,15			0,30	0,18	I
Point	Gulf	**Tr. 66**	P. GIS	till			11L/7	-0,88	0,08	0,32	0,17	0,91	0,15			0,21	0,18	I
	Gulf	**Tr. 67**	P. GIS	till			11L/7	-0,26	0,08	0,31	0,17	0,61	0,15			0,58	0,18	I
	Gulf	**Tr. 68**	P. GIS	till			11L/7	0,11	0,08	0,73	0,17	0,84	0,15			0,28	0,18	I
	Gulf	**Tr. 69**	P. GIS	till			11L/7	0,54	0,08	0,16	0,17	0,66	0,15			0,51	0,18	I
Feehans	Gulf	**Tr. 70**	P. GIS	till			11L/7	0,26	0,09	0,63	0,17	0,65	0,15			0,54	0,18	I
Point	Gulf	**Tr. 71**	P. GIS	till			11L/7	0,46	0,09	0,51	0,17	0,96	0,15			0,53	0,18	I
	Gulf	**Tr. 72**	P. GIS	till			11L/7	0,59	0,09	0,14	0,17	0,67	0,15			0,53	0,18	I
	Gulf	**Tr. 73**	P. GIS	till			11L/7	0,43	0,09	0,15	0,17	1,35	0,15			-0,06	0,18	I
	Gulf	**Tr. 74**	P. GIS	till			11L/7	0,68	0,09	-0,83	0,17	1,51	0,15			0,62	0,18	I
	Gulf	**Tr. 75**	P. GIS	till			11L/7	0,78	0,09	-0,41	0,17	1,04	0,15			0,36	0,18	I
	Gulf	**Tr. 76**	P. GIS	till			11L/7	0,51	0,09	0,19	0,17	1,47	0,15			0,27	0,18	I

Appendix 2, Table 2d. Available raw data collected using Digital Photogrammetry (GIS) ...continued...

General Location	Exposure	Site ID	Survey Method	Coast Type	Site* Easting	Site* Northing	NTS Map	Rate (m/yr) 1935-1958 [a]	Error (m) 1935-1958	Rate (m/yr) 1958-1968 [a]	Error (m) 1958-1968	Rate (m/yr) 1968-1980 [a]	Error (m) 1968-1980	Rate (m/yr) 1968-1981 [a]	Error (m) 1968-1981	Rate (m/yr) 1980-1990 [a]	Error (m) 1980-1990	ID on Map**
	Gulf	**Tr. 77**	P. GIS	till			11L/7	0,41	0,09	0,69	0,17	2,24	0,15			0,34	0,18	I
	Gulf	**Tr. 78**	P. GIS	till			11L/7	0,89	0,09	0,28	0,17	1,00	0,15			0,30	0,18	I
	Gulf	**Tr. 79**	P. GIS	till			11L/7	0,67	0,09	-0,16	0,17	0,61	0,15			-0,14	0,18	I
	Gulf	**Tr. 80**	P. GIS	till			11L/7	0,05	0,09	0,36	0,17	0,68	0,15			-0,33	0,18	I
	Gulf	**Tr. 81**	P. GIS	till			11L/7	0,50	0,09	0,37	0,17	0,31	0,15			0,24	0,18	I
	Gulf	**Tr. 82**	P. GIS	till			11L/7	0,10	0,09	-0,06	0,17	0,29	0,15			0,34	0,18	I
	Gulf	**Tr. 83**	P. GIS	till			11L/7	0,15	0,09	0,13	0,17	0,77	0,15			0,15	0,18	I
	Gulf	**Tr. 84**	P. GIS	till			11L/7	0,42	0,09	0,17	0,17	0,59	0,15			0,15	0,18	I
	Gulf	**Tr. 85**	P. GIS	till			11L/7	0,46	0,09	0,25	0,17	0,70	0,15			0,15	0,18	I
	Gulf	**Tr. 86**	P. GIS	till			11L/7	0,43	0,09	0,29	0,17	0,55	0,15			0,26	0,18	I
	Gulf	**Tr. 87**	P. GIS	till			11L/7	0,27	0,09	0,44	0,17	0,56	0,15			0,26	0,18	I
	Gulf	**Tr. 88**	P. GIS	till			11L/7	0,17	0,09	0,19	0,15	0,24	0,13			0,44	0,18	I
	Gulf	**Tr. 89**	P. GIS	till			11L/7	0,22	0,09	0,10	0,15	0,41	0,13			0,32	0,18	I
	Gulf	**Tr. 90**	P. GIS	till			11L/7	0,04	0,09	0,14	0,15	0,51	0,13			0,25	0,18	I
	Gulf	**Tr. 91**	P. GIS	till			11L/7	0,11	0,09	0,34	0,15	0,49	0,13			0,05	0,18	I
	Gulf	**Tr. 92**	P. GIS	till			11L/7	0,06	0,09	0,42	0,15	0,57	0,13			0,18	0,18	I
	Gulf	**Tr. 93**	P. GIS	till			11L/7	0,40	0,09	0,82	0,15	0,32	0,13			0,44	0,18	I
	Gulf	**Tr. 94**	P. GIS	till			11L/7	0,06	0,09	1,06	0,15	0,47	0,13			0,35	0,18	I
	Gulf	**Tr. 95**	P. GIS	till			11L/7	0,29	0,09	0,93	0,15	0,40	0,13			0,15	0,16	I
	Gulf	**Tr. 96**	P. GIS	till			11L/7	0,34	0,09	0,31	0,15			-0,10	0,10			I
	Gulf	**Tr. 97**	P. GIS	till			11L/7	0,30	0,09	0,31	0,15			0,14	0,10			I
	Gulf	**Tr. 98**	P. GIS	till			11L/7	0,42	0,09	0,34	0,15			0,14	0,10			I
Pigots	Gulf	**Tr. 99**	P. GIS	till			11L/7	0,43	0,09	0,41	0,15			0,07	0,10			I
Point	Gulf	**Tr. 100**	P. GIS	till			11L/7	0,61	0,09	0,19	0,15			0,30	0,10			I
	Gulf	**Tr. 101**	P. GIS	till			11L/7	0,64	0,09	0,54	0,15			0,22	0,10			I
	Gulf	**Tr. 102**	P. GIS	till			11L/7	0,60	0,09	0,47	0,15			0,35	0,10			I
	Gulf	**Tr. 103**	P. GIS	dune			11L/7	1,07	0,09	-0,05	0,15			0,86	0,10			I
	Gulf	**Tr. 104**	P. GIS	dune			11L/7	0,51	0,09	0,21	0,15			1,21	0,10			I
	Gulf	**Tr. 105**	P. GIS	dune			11L/7	0,12	0,09	0,25	0,15			1,05	0,10			I
	Gulf	**Tr. 106**	P. GIS	dune			11L/7	0,11	0,09	-0,88	0,18			1,47	0,12			I
	Gulf	**Tr. 107**	P. GIS	dune			11L/7	0,08	0,10	0,29	0,19			1,24	0,12			I
	Gulf	**Tr. 108**	P. GIS	dune			11L/7	0,46	0,10	0,50	0,19			0,81	0,12			I
	Gulf	**Tr. 109**	P. GIS	dune			11L/7			-0,06	0,19			0,95	0,12			I
	Gulf	**Tr. 110**	P. GIS	dune			11L/7			0,27	0,19			1,32	0,12			I
	Gulf	**Tr. 111**	P. GIS	dune			11L/7			0,29	0,19			0,66	0,12			I
	Gulf	**Tr. 112**	P. GIS	dune			11L/7			0,52	0,19			1,02	0,12			I
	Gulf	**Tr. 113**	P. GIS	dune			11L/7			5,25	0,19			1,65	0,12			I

Appendix 2, Table 2d. Available raw data collected using Digital Photogrammetry (GIS) ...continued...

General Location	Exposure	Site ID	Survey Method	Coast Type	Site* Easting	Site* Northing	NTS Map	Dist. (m) 1935-1958	Rate (m/yr) 1935-1958	Dist. (m) 1935-1974	Rate (m/yr) 1935-1974	Dist. (m) 1935-1990	Rate (m/yr) 1935-1990	Dist. (m) 1935-2000	Rate (m/yr) 1935-2000	ID on Map**
	Strait	100-200	P. GIS	sandstone			11L/8	*2,00*	*0,09*			*5,00*	*0,09*	*5,50*	*0,09*	J
	Strait	200-300	P. GIS	sandstone			11L/8	*-1,10*	*-0,05*	*-1,00*	*-0,03*	*-1,55*	*-0,03*	*-2,10*	*-0,03*	J
	Strait	300-400	P. GIS	sandstone			11L/8	*-0,80*	*-0,03*	*-1,70*	*-0,04*	*-2,20*	*-0,04*	*-3,10*	*-0,05*	J
Souris	Strait	400-500	P. GIS	sandstone			11L/8	*-0,70*	*-0,03*	*-1,70*	*-0,04*	*-1,60*	*-0,03*	*-1,90*	*-0,03*	J
Bluffs	Strait	500-600	P. GIS	sandstone			11L/8	*-1,00*	*-0,04*			*-1,80*	*-0,03*	*-1,70*	*-0,03*	J
	Strait	600-700	P. GIS	sandstone			11L/8	*-1,95*	*-0,08*	*-2,30*	*-0,06*	*-3,30*	*-0,06*	*-3,00*	*-0,05*	J
	Strait	700-800	P. GIS	sandstone			11L/8	*-0,90*	*-0,04*	*-2,10*	*-0,05*	*-2,45*	*-0,05*	*-5,70*	*-0,09*	J
	Strait	800-900	P. GIS	sandstone			11L/8	*-0,70*	*-0,03*	*-1,90*	*-0,05*	*-5,00*	*-0,09*	*-6,20*	*-0,10*	J
	Strait	900-1000	P. GIS	sandstone			11L/8	*-1,70*	*-0,07*	*-2,00*	*-0,05*	*-2,30*	*-0,04*	*-3,20*	*-0,05*	J
							Average Change	*-0,76*	*-0,03*	*-1,81*	*-0,05*	*-1,69*	*-0,03*	*-2,38*	*-0,04*	
							Mean Erosion (-)	*-1,11*	*-0,05*	*-1,81*	*-0,05*	*-2,53*	*-0,05*	*-3,36*	*-0,05*	
							Mean Accretion (+)	*2,00*	*0,09*	*0,00*	*0,00*	*5,00*	*0,09*	*5,50*	*0,09*	

.+ values in *italics* are approximate.

* no value is entered when data is absent or when the site is unknown or too generalized.

[a] rates preceeded by a hyphen (-) correspond to accretion; those not preceeded by a hyphen correspond to erosion.

** for cross-reference purposes, this letter also appears next to the same plotted sites on the GIS map: ***PEI_ErosionData_Sites***

** the ID letter in this column also refers to the bibliography listed below

C.M. = measurements using cadastral maps

P.GIS = photogrammetry using GIS

P.T. = photogrammetry using transfer scope

T.S. = total station

E.P. = erosion pins using tape measurement

C.S.P. = cross-shore profiles using GPS

I: McCulloch, M.M., Forbes, D.L. and Shaw, R.W. and the CCAF A041 Scientific Team. 2002. Coastal impacts of climate change and sea-level rise on Prince Edward Island. Geological Survey of Canada Open File 4261, 62 p.

J: Coldwater Consulting Ltd. 2009. Souris - Shoreline Erosion Study. Prepared by Davies, M.H. and MacDonald, N.J. for the Town of Souris, PEI. 54 p.

Appendix 2, Table 2e. Available raw data collected using Analog Photogrammetry (Zoom Transfer Scope)

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period 1935-1980	Distance (m) 1935-1980	Rate (m/yr) 1935-1980	NTS Map	Orientation	ID on Map**
LRIS01	Battery Point, Keppoch, Town of Stratford	Strait	sandstone	*390431.78*	*684015.66*	P.T.	1935-1980		-0,30	11L/3	E-W	F
LRIS02	Keppoch, Town of Stratford	Strait	sandstone	*390895.42*	*683168.20*	P.T.	1935-1980		-0,15	11L/3	N-S	F
LRIS03	Seatrout Point, Keppoch, Town of Stratford	Strait	sandstone	*390895.42*	*682643.82*	P.T.	1935-1980		-0,24	11L/3	E-W	F
LRIS04	Keppoch Beach, Town of Stratford	Strait	sandstone	*391976.36*	*682646.48*	P.T.	1935-1980		-0,21	11L/3	NW-SE	F
LRIS05	E of Lobster Point, Keppoch, Town of Stratford	Strait	sandstone/till	*392840.04*	*682733.86*	P.T.	1935-1980		-0,24	11L/3	SW-NE	F
LRIS06	Belleview Point, Town of Stratford	Strait	sandstone	*393838.48*	*682647.80*	P.T.	1935-1980		-0,18	11L/3	NW-SE	F
LRIS07	E of Hazard Point, Town of Stratford	Strait	sandstone/till	*394503.46*	*682700.76*	P.T.	1935-1980		-0,21	11L/3	SW-NE	F
LRIS08	Alexandra Point, Town of Stratford	Strait	till	*395640.04*	*682314.10*	P.T.	1935-1980		-0,06	11L/3	SW-NE	F

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period 1935-1958	Distance (m) 1935-1958	Rate (m/yr) 1935-1958	NTS Map	Orientation	ID on Map**
F001	North Point, near Tignish Lighthouse	Gulf	sandstone	*324226.54*	*779232.64*	P.T./S.M.	1935-1958		-0,23	21P/1	E-W	G
F002	North Point, SW Tignish Lighthouse	Strait	sandstone	*324098.00*	*778890.32*	P.T./S.M.	1935-1958		-0,46	21P/1	SW-NE	G
F003	North Point, SW Tignish Lighthouse	Strait	sandstone	*323805.32*	*778636.04*	P.T./S.M.	1935-1958		-0,46	21P/1	SW-NE	G
F004	2.3 km SW of North Cape	Strait	sandstone	*322954.64*	*777305.78*	P.T./S.M.	1935-1958		-0,46	21I/16	SW-NE	G
F005	4.2 km SW of North Cape	Strait	sandstone	*322062.16*	*775549.74*	P.T./S.M.	1935-1958		-0,46	21I/16	SW-NE	G
F006	2.8 km NE of Nail Pond	Strait	sandstone	*321636.20*	*775115.52*	P.T./S.M.	1935-1958	-19,20	-0,82	21I/16	SW-NE	G
F007	2.4 km NE of Nail Pond	Strait	sandstone	*321329.92*	*774793.64*	P.T./S.M.	1935-1958		-0,61	21I/16	SW-NE	G
F008	1.8 km NE of Nail Pond	Strait	till	*321022.00*	*774475.96*	P.T./S.M.	1935-1958		-0,61	21I/16	SW-NE	G
F009	Achorage point of Nail Pond spit	Strait	dune	*320752.68*	*774117.50*	P.T./S.M.	1935-1958		-0,46	21I/16	SW-NE	G
F010	Nail Head	Strait	sandstone	*316383.00*	*770641.48*	P.T./S.M.	1935-1958	-11,58	-0,52	21I/16	SW-NE	G
F011	Skinners Pond	Strait	dune	313555.24	*768417.44*	P.T./S.M.	1935-1958		-0,61	21I/16	SW-NE	G
F012	Waterford	Strait	sandstone	*310722.12*	*766641.42*	P.T./S.M.	1935-1958		-0,61	21I/16	SW-NE	G
F013	Horse Head	Strait	sandstone	*309526.98*	*765612.08*	P.T./S.M.	1935-1958		-0,30	21I/16	E-W	G
F014	Pleasant View	Strait	till	*308892.08*	*764150.72*	P.T./S.M.	1935-1958		-0,76	21I/16	SW-NE	G
F015	SW of Pleasant View	Strait	till	*308113.10*	*763041.36*	P.T./S.M.	1935-1958	-22,86	-1,00	21I/16	SW-NE	G
F016	Cape Gage	Strait	sandstone	*306741.90*	*761649.34*	P.T./S.M.	1935-1958		-0,30	21I/16	SW-NE	G
F017	1.4 km S of Cape Gage	Strait	sandstone	*306533.80*	*760254.64*	P.T./S.M.	1935-1958		-0,70	21I/16	SW-NE	G
F018	Miminegash Run	Strait	dune	*305968.24*	*759382.60*	P.T./S.M.	1935-1958	-12,19	-0,49	21I/16	SW-NE	G
F019	Miminegash Pond	Strait	till	*305482.70*	*757790.60*	P.T./S.M.	1935-1958	-13,72	-0,61	21I/16	SW-NE	G
F020	2 km SW of Miminegash Pond	Strait	sandstone	*304714.40*	*756411.92*	P.T./S.M.	1935-1958	-18,29	-0,79	21I/16	SW-NE	G
F021	3.2 km SW of Miminegash Pond	Strait	sandstone	*304106.16*	*755158.58*	P.T./S.M.	1935-1958		-0,37	21I/16	SW-NE	G
F022	700 meters NE of Little Miminegash Pond	Strait	dune	*303930.10*	*754777.24*	P.T./S.M.	1935-1958	-21,64	-0,94	21I/16	SW-NE	G
F023	Little Miminegash Pond	Strait	sandstone	*303444.58*	*753782.59*	P.T./S.M.	1935-1958		-0,46	21I/16	SW-NE	G
F024	2.2 km SW of Little Miminegash Pond	Strait	sandstone	*302249.46*	*752075.88*	P.T./S.M.	1935-1958	-6,71	-0,30	21I/16	SW-NE	G

Appendix 2, Table 2e. Available raw data collected using Analog Photogrammetry (Zoom Transfer Scope) ...continued...

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period 1935-1958	Distance (m) 1935-1958	Rate (m/yr) 1935-1958	NTS Map	Orientation	ID on Map**
F025	West Point	Strait	dune	*295306.18*	*731022.98*	P.T./S.M.	1935-1958	-33,53	-1,52	21I/9	E-W	G
F026	West of Indian Point Sand Hills	Strait	till	*297749.94*	*730966.40*	P.T./S.M.	1935-1958	-60,96	-2,74	21I/9	E-W	G
F027	West Shore of Brae Harbour	Strait	dune	*308499.92*	*731343.96*	P.T./S.M.	1935-1958	-10,67	-0,52	21I/9	E-W	G
F028	Grande Digue Shore	Strait	till	*311488.96*	*728195.86*	P.T./S.M.	1935-1958	-30,48	-1,37	21I/9	SE-NW	G
F029	Grande Digue Shore	Strait	till	*311920.92*	*727929.90*	P.T./S.M.	1935-1958	-14,94	-0,61	21I/9	SE-NW	G
F030	Grande Digue Shore	Strait	sandstone	*312503.12*	*727607.62*	P.T./S.M.	1935-1958	-10,97	-0,49	21I/9	SE-NW	G
F031	Grande Digue Shore	Strait	dune	*313213.28*	*727283.76*	P.T./S.M.	1935-1958	-24,08	-1,07	21I/9	SE-NW	G
F032	Mossy Point North	Estuary	marsh	*317264.10*	*726930.16*	P.T./S.M.	1935-1958		-0,91 @ -1,52	21I/9	SW-NE	G
F033	Mossy Point South	Strait	marsh	*317426.92*	*726395.78*	P.T./S.M.	1935-1958		-0,91 @ -1,52	21I/9	SW-NE	G
F034	Enman Shore	Strait	sandstone	*318226.98*	*726336.14*	P.T./S.M.	1935-1958	-14,63	-0,61	21I/9	SE-NW	G
F035	Yoes Shore	Estuary	sandstone	*317947.08*	*724465.04*	P.T./S.M.	1935-1958	-4,57	-0,20	21I/9	SW-NE	G
F036	Higgins Wharf	Estuary	till	*316890.40*	*722764.60*	P.T./S.M.	1935-1958		-0,61	21I/9	SW-NE	G
F037	Rocky Point	Strait	till	*314733.12*	*719886.22*	P.T./S.M.	1935-1958	-34,44	-1,52	21I/9	SW-NE	G
F038	Saint Chrysostome	Strait	till	*315057.40*	*718071.64*	P.T./S.M.	1935-1958	-60,05	-2,59	21I/9	N-S	G
F039	1.8 km S of Saint Chrysostome	Strait	till	*315166.52*	*716720.32*	P.T./S.M.	1935-1958	-46,63	-2,01	21I/8	N-S	G
F040	2.6 km S of Saint Chrysostome	Strait	till	*315198.92*	*715906.52*	P.T./S.M.	1935-1958	-32,00	-1,37	21I/8	N-S	G
F041	Egmont Bay	Strait	till	*315300.18*	*714801.14*	P.T./S.M.	1935-1958	-11,58	-0,49	21I/8	N-S	G
F042	Abrams Village	Strait	till	*314721.00*	*712464.96*	P.T./S.M.	1935-1958	-59,74	-2,49	21I/8	N-S	G
F043	Maximeville Sandspit	Strait	dune	*313408.70*	*710513.38*	P.T./S.M.	1935-1958		-0,15 @ -0,20	21I/8	SW-NE	G
F044	Red Head	Strait	sandstone	*312464.98*	*708333.08*	P.T./S.M.	1935-1958	-6,10	-0,25	21I/8	E-W	G
F045	Fishing Cove	Strait	sandstone	*312882.14*	*707045.52*	P.T./S.M.	1935-1958		-0,30 @ -0,61	21I/8	N-S	G
F046	1 km E of Cape Egmont	Strait	sandstone	*313777.24*	*706389.62*	P.T./S.M.	1935-1958		-0,91	21I/8	E-W	G
F047	1.9 km E of Cape Egmont	Strait	sandstone	*314652.08*	*706215.52*	P.T./S.M.	1935-1958		-1,22	21I/8	SW-NE	G
F048	Cape Egmont (Village)	Strait	sandstone	*315340.62*	*706049.52*	P.T./S.M.	1935-1958	-27,43	-1,22	21I/8	SW-NE	G
F049	Mount Carmel W	Strait	till	*318009.68*	*705818.70*	P.T./S.M.	1935-1958		-0,46	21I/8	E-W	G
F050	Fifteen Point	Strait	sandstone	*320339.08*	*704902.62*	P.T./S.M.	1935-1958	-9,14	-0,40	21I/8	SE-NW	G
F051	1.4 km E of Fifteen Point	Strait	till	*321979.26*	*704586.70*	P.T./S.M.	1935-1958	-26,52	-1,16	21I/8	SW-NE	G
F052	Union Corner Provin. Park	Strait	till	*323234.40*	*704576.86*	P.T./S.M.	1935-1958		-1,22	11L/5	SW-NE	G
F053	1.3 km E of Union Corner	Strait	sandstone	*324752.96*	*704837.28*	P.T./S.M.	1935-1958	-15,24	-0,61	11L/5	SW-NE	G
F054	2.2 km E of Union Corner	Strait	till	*325591.08*	*705210.52*	P.T./S.M.	1935-1958		-1,13	11L/5	SW-NE	G
F055	Sunbury Point	Strait	till	*326794.54*	*705631.94*	P.T./S.M.	1935-1958	-114,00	-4,88	11L/5	E-W	G
F056	Sunbury Point	Strait	sandstone	*327313.20*	*705802.82*	P.T./S.M.	1935-1958	-45,72	-1,98	11L/5	SW-NE	G
F057	Muddy Creek Marsh Point	Estuary	marsh	*327754.16*	*707324.12*	P.T./S.M.	1935-1958		-1,46	11L/5	SW-NE	G
F058	Perrys Pond	Estuary	marsh	*328226.52*	*707996.18*	P.T./S.M.	1935-1958	-28,65	-1,22	11L/5	E-W	G
F059	Saltgrass Point	Strait	marsh	*329715.96*	*706865.72*	P.T./S.M.	1935-1958		-1,22	11L/5	SE-NW	G
F060	Ives point	Strait	till	*331383.16*	*705784.26*	P.T./S.M.	1935-1958	-89,00	-3,87	11L/5	SE-NW	G
F061	Ives point	Strait	till	*331499.72*	*705618.42*	P.T./S.M.	1935-1958		-3,66	11L/5	SE-NW	G
F062	Linkletter Shore	Strait	till	*333927.54*	*705732.88*	P.T./S.M.	1935-1958	-30,48	-1,31	11L/5	SE-NW	G
F063	Linkletter Provin. Park	Strait	till	*334526.46*	*705468.00*	P.T./S.M.	1935-1958		-0,91	11L/5	SE-NW	G

Appendix 2, Table 2e. Available raw data collected using Analog Photogrammetry (Zoom Transfer Scope) ...continued...

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period 1935-1958	Distance (m) 1935-1958	Rate (m/yr) 1935-1958	NTS Map	Orientation	ID on Map**
F064	Shooting Gallery Shore	Strait	sandstone	*336348.56*	*705087.10*	P.T./S.M.	1935-1958	-29,26	-1,25	11L/5	SW-NE	G
F065	Summerside	Strait	till	*337582.24*	*705278.12*	P.T./S.M.	1935-1958	-7,62	-0,30	11L/5	SW-NE	G
F066	Schumans Point	Estuary	till	*341626.68*	*703996.56*	P.T./S.M.	1935-1958		-0,23	11L/5	E-W	G
F067	Schumans Point	Estuary	sandstone	*341207.90*	*703798.00*	P.T./S.M.	1935-1958		-0,30	11L/5	SW-NE	G
F068	Oyster Point	Estuary	till	*342270.32*	*711578.00*	P.T./S.M.	1935-1958		-0,61	11L/5	N-S	G
F069	500 meters E of MacCallums Point	Estuary	till	*338142.98*	*702713.80*	P.T./S.M.	1935-1958		-0,46 @ -0,61	11L/5	SE-NW	G
F070	MacCallums Point	Estuary	sandstone	*337636.22*	*702726.60*	P.T./S.M.	1935-1958		-0,30	11L/5	E-W	G
F071	2.2 km SE of MacCallums Point	Strait	dune	*338723.60*	*700793.70*	P.T./S.M.	1935-1958		-1,71	11L/5	SE-NW	G
F072	Seacow Head	Strait	sandstone	*337377.88*	*696861.44*	P.T./S.M.	1935-1958		-0,23 @ -0,30	11L/5	SE-NW	G
F073	Gardiner Shore	Strait	till	*339340.32*	*696842.68*	P.T./S.M.	1935-1958		-0,61	11L/5	SE-NW	G
F074	Gordon Cove	Strait	marsh	*343919.44*	*693585.24*	P.T./S.M.	1935-1958		-0,46	11L/5	SE-NW	G
F075	Gordon Point	Strait	till	*344495.92*	*692266.06*	P.T./S.M.	1935-1958		-0,79	11L/5	SE-NW	G
F076	Carleton Cove	Strait	till	*345539.80*	*692294.08*	P.T./S.M.	1935-1958	-15,24	-0,64	11L/5	SE-NW	G
F077	Noonans Marsh	Strait	till	*345964.24*	*690388.46*	P.T./S.M.	1935-1958		-0,40	11L/5	N-S	G
F078	Amherst Point	Strait	sandstone	*347176.50*	*688364.46*	P.T./S.M.	1935-1958		-0,15 @ -0,20	11L/4	SE-NW	G
F079	Amherst Cove	Strait	till	*348191.74*	*688658.16*	P.T./S.M.	1935-1958		-0,43	11L/4	SE-NW	G
F080	Cape Traverse Landing	Strait	dune	*349618.04*	*687384.08*	P.T./S.M.	1935-1958	-30,48	-1,22	11L/4	SE-NW	G
F081	Bells Point	Strait	till	*349796.06*	*686103.18*	P.T./S.M.	1935-1958		-0,15 @ -0,20	11L/4	N-S	G
F082	Prevost Cove	Strait	till	*350436.58*	*686246.72*	P.T./S.M.	1935-1958		-0,40	11L/4	N-S	G
F083	Augustine Cove W	Strait	till	*352913.94*	*685620.62*	P.T./S.M.	1935-1958	-21,64	-0,94	11L/4	SW-NE	G
F084	Augustine Cove E	Strait	sandstone	*353408.12*	*685305.16*	P.T./S.M.	1935-1958		-0,30	11L/4	N-S	G
F085	Cumberland Cove W	Strait	marsh	*355065.18*	*684980.86*	P.T./S.M.	1935-1958	-19,51	-0,82	11L/4	SW-NE	G
F086	Cumberland Cove Center	Strait	marsh	*355231.70*	*685187.60*	P.T./S.M.	1935-1958	-35,66	-1,52	11L/4	SW-NE	G
F087	Cumberland Cove E	Strait	till	*356093.86*	*685273.50*	P.T./S.M.	1935-1958	-36,88	-1,62	11L/4	SE-NW	G
F088	600 meters NW of Birch Point	Estuary	till	*359011.04*	*684315.20*	P.T./S.M.	1935-1958	-60,05	-2,59	11L/4	SE-NW	G
F089	350 meters E of Birch Point	Strait	till	*359683.42*	*683883.54*	P.T./S.M.	1935-1958	-79,25	-3,44	11L/4	E-W	G
F090	Victoria Harbour	Strait	sandstone	*360497.74*	*683954.50*	P.T./S.M.	1935-1958		-0,30	11L/4	E-W	G
F091	500 meters W of Wrights Point	Strait	marsh	*361221.38*	*684149.62*	P.T./S.M.	1935-1958		-0,91	11L/4	E-W	G
F092	Victoria	Strait	sandstone	*361894.60*	*684705.08*	P.T./S.M.	1935-1958		-0,61	11L/3	E-W	G
F093	Victoria Provin. Park	Strait	dune	*362578.84*	*684623.84*	P.T./S.M.	1935-1958		-0,30 @ -0,61	11L/3	SE-NW	G
F094	750 metres E of MacIvors Point	Strait	sandstone	*365837.36*	*682169.46*	P.T./S.M.	1935-1958	-7,62	-0,30	11L/3	E-W	G
F095	800 meters E of Argyle Provin. Park	Strait	marsh	*370955.24*	*679935.68*	P.T./S.M.	1935-1958		-0,76 @ -0,91	11L/3	SE-NW	G
F096	Argyle Shore	Strait	till	*372206.52*	*679454.66*	P.T./S.M.	1935-1958		-0,30	11L/3	SE-NW	G
F097	2 km SE of Argyle Shore	Strait	sandstone	*374567.52*	*678213.88*	P.T./S.M.	1935-1958		-0,30	11L/3	SE-NW	G
F098	Canoe Cove	Strait	till	*376590.40*	*677718.42*	P.T./S.M.	1935-1958		-0,61	11L/3	N-S	G
F099	2.3 km W of Rice Point	Strait	sandstone	*380503.22*	*675449.16*	P.T./S.M.	1935-1958		-0,46 @ -0,61	11L/3	SE-NW	G
F100	Rice Point South	Strait	till	*382613.58*	*675688.88*	P.T./S.M.	1935-1958	-49,99	-2,13	11L/3	SE-NW	G
F101	Rice Point North	Strait	till	*382681.50*	*675882.30*	P.T./S.M.	1935-1958		-0,46	11L/3	SE-NW	G
F102	730 meters N of Rice Point	Strait	marsh	*382393.32*	*676372.32*	P.T./S.M.	1935-1958		-0,46 @ -0,61	11L/3	SW-NE	G

Appendix 2, Table 2e. Available raw data collected using Analog Photogrammetry (Zoom Transfer Scope) ...continued...

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period 1935-1958	Distance (m) 1935-1958	Rate (m/yr) 1935-1958	NTS Map	Orientation	ID on Map**
F103	Bacon Cove W	Strait	marsh	*383439.02*	*678091.18*	P.T./S.M.	1935-1958	-29,87	-1,28	11L/3	E-W	G
F104	Bacon Cove E	Strait	marsh	*383922.78*	*678083.98*	P.T./S.M.	1935-1958	-19,81	-0,85	11L/3	E-W	G
F105	Holland Cove, Rocky Point	Strait	till	*389416.64*	*681529.46*	P.T./S.M.	1935-1958		-0,46	11L/3	SW-NE	G
F106	Ferguson Point, West River	Estuary	sandstone	*386490.16*	*683413.14*	P.T./S.M.	1935-1958		-0,31 @ -0,46	11L/3	E-W	G
F107	York Point, North River	Estuary	till	*387609.34*	*686546.84*	P.T./S.M.	1935-1958		-0,15 @ -0,20	11L/3	N-S	G
F108	S of MacLeods Island, Hillsborough R.	Estuary	till	*396552.32*	*690771.74*	P.T./S.M.	1935-1958		-0,15 @ -0,20	11L/6	N-S	G
F109	Between Doyles & Munns Point, Hillsborough R.	Estuary	till	*394923.16*	*689548.52*	P.T./S.M.	1935-1958		-0,15 @ -0,20	11L/6	N-S	G
F110	Hazard Point (W of Lighthouse)	Strait	till	*394287.44*	*682666.26*	P.T./S.M.	1935-1958		-0,31	11L/3	NW-SE	G
F111	Squaw Bay, Alexandria	Strait	marsh	*398344.72*	*682446.96*	P.T./S.M.	1935-1958		-0,31 @ -0,46	11L/3	NW-SE	G
F112	Jardine's Point near Crown Point	Strait	sandstone	*398115.80*	*680781.96*	P.T./S.M.	1935-1958		-0,31	11L/3	N-S	G
F113	Crown Point W	Strait	sandstone	*398429.98*	*680518.42*	P.T./S.M.	1935-1958		-0,31 @ -0,46	11L/3	E-W	G
F114	Crown Point E	Strait	sandstone	*399167.36*	*680492.68*	P.T./S.M.	1935-1958		-0,31	11L/3	E-W	G
F115	Pawnol Point	Strait	sandstone	*400639.38*	*680363.08*	P.T./S.M.	1935-1958	-17,98	-0,76	11L/2	SW-NE	G
F116	Irvings Bar	Strait	till	*403966.24*	*680016.80*	P.T./S.M.	1935-1958	-27,43	-1,22	11L/2	SW-NE	G
F117	Haydens Point	Strait	sandstone	*403547.82*	*678905.96*	P.T./S.M.	1935-1958		-0,82	11L/2	N-S	G
F118	Earnscliff	Strait	sandstone	*402741.80*	*676514.56*	P.T./S.M.	1935-1958		-0,10 @ -0,15	11L/2	N-S	G
F119	Gallas Point	Strait	marsh	*402891.74*	*675308.14*	P.T./S.M.	1935-1958		-0,85	11L/2	N-S	G
F120	Youngs Marsh W	Strait	till	*403395.58*	*675147.50*	P.T./S.M.	1935-1958	-9,75	-0,40	11L/2	E-W	G
F121	Youngs Marsh E	Strait	marsh	*403730.85*	*674978.72*	P.T./S.M.	1935-1958		-0,79	11L/2	N-S	G
F122	Mc Innis Point Marsh	Strait	marsh	*404376.04*	*674834.42*	P.T./S.M.	1935-1958		-0,85	11L/2	SE-NW	G
F123	Lower Newton	Strait	marsh	*408877.98*	*674656.04*	P.T./S.M.	1935-1958		-0,46 @ -0,61	11L/2	N-S	G
F124	Buchanans Island	Strait	dune	*404918.00*	*671245.98*	P.T./S.M.	1935-1958	-19,81	-0,85	11L/2	E-W	G
F125	Mount Buchanan	Strait	till	*404392.36*	*670448.30*	P.T./S.M.	1935-1958		-0,61	11L/2	SW-NE	G
F126	1 km E of Point Prim	Strait	sandstone	*397881.26*	*666864.28*	P.T./S.M.	1935-1958	-17,07	-0,70	11L/3	E-W	G
F127	1.2 km E of Point Prim	Strait	sandstone	*398102.98*	*666895.42*	P.T./S.M.	1935-1958	-25,91	-1,07	11L/3	E-W	G
F128	1.5 km E of Point Prim	Strait	sandstone	*398401.66*	*666878.94*	P.T./S.M.	1935-1958		-0,91	11L/3	E-W	G
F129	2.5 km W of Pond Point	Strait	sandstone	*400886.34*	*667117.96*	P.T./S.M.	1935-1958	-16,76	-0,70	11L/2	SW-NE	G
F130	2.2 km W of Pond Point	Strait	sandstone	*401249.14*	*667238.84*	P.T./S.M.	1935-1958		-0,61	11L/2	SW-NE	G
F131	2 km W of Pond Point	Strait	sandstone	*401414.06*	*667337.74*	P.T./S.M.	1935-1958	-27,43	-1,13	11L/2	SW-NE	G
F132	1.5 km W of Pond Point	Strait	sandstone	*401963.76*	*667169.24*	P.T./S.M.	1935-1958		-0,61	11L/2	E-W	G
F133	800 meters W of Pond Point	Strait	dune	*402661.08*	*667266.00*	P.T./S.M.	1935-1958	-36,58	-1,52	11L/2	SW-NE	G
F134	Pond Point	Strait	till	*403763.12*	*667334.62*	P.T./S.M.	1935-1958		-0,76	11L/2	SW-NE	G
F135	Long Creek Point	Strait	sandstone	*404185.64*	*667311.74*	P.T./S.M.	1935-1958	-26,82	-1,13	11L/2	SE-NW	G
F136	Pinette Point	Strait	sandstone	*404645.10*	*665788.60*	P.T./S.M.	1935-1958	-22,56	-0,94	11L/2	SE-NW	G
F137	1 km SE of Pinette Point	Strait	sandstone	*405498.90*	*665216.64*	P.T./S.M.	1935-1958		-0,46	11L/2	SE-NW	G
F138	2.5 km SE of Pinette Point	Strait	beach	*406687.42*	*664229.90*	P.T./S.M.	1935-1958		-4,60	11L/2	SE-NW	G
F139	Gascoigne Cove	Strait	till	*408905.04*	*662215.88*	P.T./S.M.	1935-1958	-19,81	-0,82	11L/2	N-S	G
F140	Big Point	Strait	till	*408334.70*	*661095.72*	P.T./S.M.	1935-1958	-46,67	-1,52	11L/2	N-S	G
F141	115 meters S of Big Point	Strait	till	*408344.76*	*660978.34*	P.T./S.M.	1935-1958		-0,79	21E/15	N-S	G

Appendix 2, Table 2e. Available raw data collected using Analog Photogrammetry (Zoom Transfer Scope) ...continued...

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period 1935-1958	Distance (m) 1935-1958	Rate (m/yr) 1935-1958	NTS Map	Orientation	ID on Map**
F142	Black Marsh W	Strait	till	408848.02	660711.70	P.T./S.M.	1935-1958		-0,52	21E/15	E-W	G
F143	Black Marsh E	Strait	till	409069.44	660751.94	P.T./S.M.	1935-1958	-10,97	-0,46	21E/15	E-W	G
F144	Nickolson point	Strait	marsh	409770.66	660010.76	P.T./S.M.	1935-1958		-0,52	21E/15	SE-NW	G
F145	1.1 km N of Stuart Point	Strait	till	410958.30	659138.74	P.T./S.M.	1935-1958		-0,52	21E/15	SE-NW	G
F146	725 meters N of Stuart Point	Strait	till	411169.68	658783.24	P.T./S.M.	1935-1958		-0,52	21E/15	SE-NW	G
F147	1 km N of Bell Pt	Strait	till	412427.78	657772.06	P.T./S.M.	1935-1958	-11,58	-0,49	21E/15	SE-NW	G
F148	Bell Pt	Strait	till	413145.74	657294.14	P.T./S.M.	1935-1958	-8,53	-0,37	21E/15	SE-NW	G
F149	Wood Islands Spit (begining)	Strait	dune	418154.44	656536.80	P.T./S.M.	1935-1958		-0,49	21E/15	SE-NW	G
F150	Wood Islands Spit	Strait	dune	418362.70	656319.86	P.T./S.M.	1935-1958		-0,49	21E/15	SE-NW	G
F151	Wood Islands Spit (point)	Strait	dune	418862.60	655424.38	P.T./S.M.	1935-1958	-29,87	-1,31	21E/15	SE-NW	G
F152	Wood Islands point	Strait	sandstone	419013.58	655364.02	P.T./S.M.	1935-1958		-0,15	21E/15	E-W	G
F153	Wood Islands Spit Provin. Park	Strait	till	419728.20	655471.34	P.T./S.M.	1935-1958		-0,15	21E/15	E-W	G
F154	Little Sands	Strait	till	424863.86	656734.22	P.T./S.M.	1935-1958		-0,30	21E/15	E-W	G
F155	770 meters SW of Cape Bear	Strait	sandstone	441419.52	661061.20	P.T./S.M.	1935-1958	-6,98	-0,30	21E/15	SW-NE	G
F156	Beach Point	Strait	dune	440804.98	663236.90	P.T./S.M.	1935-1958	-23,47	-1,00	11L/1	SE-NW	G
F157	100 meters E of Beach Point wharf	Estuary	till	439945.12	662929.64	P.T./S.M.	1935-1958		-0,52	11L/1	E-W	G
F158	Penny Point	Estuary	till	439298.20	662851.50	P.T./S.M.	1935-1958		-0,62	11L/1	E-W	G
F159	1 km E of Murray Harbour wharf	Estuary	till	438645.92	662466.20	P.T./S.M.	1935-1958		-0,61	11L/2	SW-NE	G
F160	Poverty Beach spit	Strait	dune	440228.12	666207.36	P.T./S.M.	1935-1958		-0,61	11L/1	SW-NE	G
F161	330 meters W of Irvings Cape	Strait	till	440656.68	666953.72	P.T./S.M.	1935-1958	-42,37	-1,83	11L/1	SW-NE	G
F162	340 meters N of Irvings Cape	Strait	dune	440982.84	667325.54	P.T./S.M.	1935-1958	-26,82	-1,16	11L/1	N-S	G
F163	Graham Point	Strait	till	442484.18	671315.90	P.T./S.M.	1935-1958	-8,23	-0,37	11L/1	SE-NW	G
F164	Cape Sharp	Strait	sandstone	442621.64	672753.32	P.T./S.M.	1935-1958	-10,67	-0,46	11L/1	SW-NE	G
F165	285 meters NW of Cape Sharp	Strait	sandstone	442397.92	672936.54	P.T./S.M.	1935-1958	-8,23	-0,37	11L/1	SE-NW	G
F166	Steeles Pond	Strait	sandstone	441947.78	673891.68	P.T./S.M.	1935-1958		-0,30	11L/1	SE-NW	G
F167	W of Panmure Head	Strait	sandstone	440640.46	677553.20	P.T./S.M.	1935-1958		-0,30	11L/1	SE-NW	G
F168	Panmure Island South	Estuary	marsh	438907.30	676021.40	P.T./S.M.	1935-1958	-8,23	-0,37	11L/1	SW-NE	G
F169	Wrights Point	Estuary	till	437332.34	674598.26	P.T./S.M.	1935-1958	-20,42	-0,88	11L/2	SE-NW	G
F170	715 meters E of Sturgeon pier	Estuary	till	436867.64	674661.76	P.T./S.M.	1935-1958		-0,61	11L/2	E-W	G
F171	Sturgeon Bay	Estuary	till	435230.52	674853.30	P.T./S.M.	1935-1958		-0,30	11L/2	SE-NW	G
F172	Albion	Estuary	marsh	435869.24	675716.90	P.T./S.M.	1935-1958		-0,61	11L/2	N-S	G
F173	Meadowfoot Point	Estuary	till	436067.58	676725.00	P.T./S.M.	1935-1958	-22,25	-0,98	11L/2	SE-NW	G
F174	St Andrews Point Park	Strait	till	436666.60	678925.08	P.T./S.M.	1935-1958	-9,75	-0,43	11L/2	N-S	G
F175	Aitken Point	Estuary	till	435210.20	680067.70	P.T./S.M.	1935-1958	-8,53	-0,37	11L/2	SE-NW	G
F176	Burnt Point	Strait	till	438876.80	680647.34	P.T./S.M.	1935-1958		-1,52	11L/1	SW-NE	G
F177	525 meters NW of Burnt Point	Strait	till	438624.82	681277.82	P.T./S.M.	1935-1958		-1,52	11L/2	SE-NW	G
F178	McPhee Beach	Strait	till	438454.36	681780.82	P.T./S.M.	1935-1958		-1,52	11L/2	SE-NW	G
F179	1.2 km SE of Morrison Beach	Estuary	till	436423.40	633606.72	P.T./S.M.	1935-1958		-0,30	11L/2	SE-NW	G
F180	Morrison Beach	Estuary	dune	435693.38	684601.28	P.T./S.M.	1935-1958	-15,24	-0,67	11L/2	SE-NW	G

Appendix 2, Table 2e. Available raw data collected using Analog Photogrammetry (Zoom Transfer Scope) ...continued...

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period 1935-1958	Distance (m) 1935-1958	Rate (m/yr) 1935-1958	NTS Map	Orientation	ID on Map**
F181	Campbell Point	Estuary	till	*438192.62*	*684534.10*	P.T./S.M.	1935-1958		-0,30	11L/2	SW-NE	G
F182	860 meters S of DeGros Marsh	Estuary	till	*440634.40*	*684490.94*	P.T./S.M.	1935-1958	-17,07	-0,73	11L/1	N-S	G
F183	Red Point	Estuary	till	*440885.04*	*684243.08*	P.T./S.M.	1935-1958		-0,46	11L/1	E-W	G
F184	950 meters W of Launching Point	Estuary	dune	*444712.12*	*684652.52*	P.T./S.M.	1935-1958	-29,26	-1,28	11L/1	E-W	G
F185	Boughton Island South	Strait	dune	*446189.04*	*681793.88*	P.T./S.M.	1935-1958	-12,50	-0,55	11L/1	N-S	G
F186	Boughton Island Centre	Strait	sandstone	*445854.84*	*682414.86*	P.T./S.M.	1935-1958	-10,67	-0,46	11L/1	SE-NW	G
F187	Boughton Island North	Strait	dune	*445288.86*	*682953.68*	P.T./S.M.	1935-1958	-29,87	-1,31	11L/1	SE-NW	G
F188	South of Launching Pond	Strait	till	*444652.84*	*688262.16*	P.T./S.M.	1935-1958	-17,07	-0,73	11L/1	SE-NW	G
F189	Annadale	Strait	till	*444766.30*	*690092.70*	P.T./S.M.	1935-1958		-0,76	11L/8	SW-NE	G
F190	Cape Spry	Strait	sandstone	*447858.08*	*689546.34*	P.T./S.M.	1935-1958		-0,30	11L/8	SE-NW	G
F191	250 meters S of Little Pond spit	Strait	sandstone	*447980.44*	*690492.28*	P.T./S.M.	1935-1958		-0,40	11L/8	SW-NE	G
F192	Durell Point	Strait	sandstone	*449473.92*	*691966.38*	P.T./S.M.	1935-1958	-11,28	-0,49	11L/8	SW-NE	G
F193	Howe Point	Strait	sandstone	*451407.80*	*695095.22*	P.T./S.M.	1935-1958	-22,86	-1,00	11L/8	N-S	G
F194	Eglington	Strait	till	*450351.42*	*695530.40*	P.T./S.M.	1935-1958		-0,69	11L/8	SE-NW	G
F195	Rollo Point	Strait	sandstone	*450984.90*	*698885.10*	P.T./S.M.	1935-1958	-13,11	-0,58	11L/8	SW-NE	G
F196	Rollo Bay	Strait	till	*451288.98*	*700304.64*	P.T./S.M.	1935-1958		-0,30	11L/8	SE-NW	G
F197	E of Leslies Pond	Strait	till	*455479.64*	*700137.62*	P.T./S.M.	1935-1958	-18,90	-0,82	11L/8	SE-NW	G
F198	Distal end of Souris Beach Park (before causeway)	Estuary	dune	*455646.90*	*700903.80*	P.T./S.M.	1935-1958	-141,73	-6,16	11L/8	N-S	G
F199	Souris	Strait	sandstone	*456876.06*	*700883.86*	P.T./S.M.	1935-1958		-0,30	11L/8	SE-NW	G
F200	Souris	Strait	sandstone	*457159.94*	*700788.76*	P.T./S.M.	1935-1958		-0,30	11L/8	SE-NW	G
F201	Souris	Strait	sandstone	*457387.04*	*700566.34*	P.T./S.M.	1935-1958		-0,30	11L/8	SE-NW	G
F202	Souris	Strait	sandstone	*457572.72*	*700520.32*	P.T./S.M.	1935-1958		-0,30	11L/8	SE-NW	G
F203	Norris Pond	Strait	sandstone	*458987.44*	*699892.30*	P.T./S.M.	1935-1958		-0,30	11L/8	E-W	G
F204	Little Harbour	Strait	sandstone	*463680.00*	*701142.32*	P.T./S.M.	1935-1958		-0,15	11L/8	N-S	G
F205	Basin Head Harbour	Strait	till	*468551.42*	*703640.66*	P.T./S.M.	1935-1958	-12,80	-0,55	11L/8	SE-NW	G
F206	1.7 km NE of South Lake	Strait	sandstone	*477105.80*	*710032.96*	P.T./S.M.	1935-1958	-11,28	-0,49	11L/8	SW-NE	G
F207	1.1 km SW of East Point radio station	Strait	sandstone	*478204.74*	*711109.74*	P.T./S.M.	1935-1958		-1,07	11L/8	SW-NE	G
F208	East Point (near radio station)	Strait	sandstone	*479030.12*	*711852.12*	P.T./S.M.	1935-1958	-9,75	-0,43	11L/8	SW-NE	G

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period 1958-1982	Distance (m) 1958-1982	Rate (m/yr) 1958-1982	NTS Map	Orientation	ID on Map**
BB6	650 meters W of Brackley Beach parking	Gulf	dune	*383967.26*	*708967.06*	P.T.	1958-1982	-6,10	-0,30	11L/6	E-W	K
BB7	350 meters W of Brackley Beach parking	Gulf	dune	*384278.56*	*708930.82*	P.T.	1958-1982	-33,70	-0,50	11L/6	E-W	K
BB5	Across Brackley Beach chalets	Gulf	dune	*385371.98*	*708829.70*	P.T.	1958-1982	-14,90	-0,60	11L/6	E-W	K
BB4		Gulf	dune	*385829.18*	*708801.44*	P.T.	1958-1982	-24,40	-1,00	11L/6	E-W	K
BB8		Gulf	dune	*386215.32*	*708794.78*	P.T.	1958-1982	-14,20	-0,50	11L/6	E-W	K

Appendix 2, Table 2e. Available raw data collected using Analog Photogrammetry (Zoom Transfer Scope) ...continued...

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period 1958-1982	Distance (m) 1958-1982	Rate (m/yr) 1958-1982	NTS Map	Orientation	ID on Map**
BB3	Just W of frontal blowout	Gulf	dune	*386435.58*	*708790.16*	P.T.	1958-1982	-7,90	-0,60	11L/6	E-W	K
BB2	E of frontal blowout	Gulf	dune	*386954.66*	*708794.02*	P.T.	1958-1982	-11,10	-1,40	11L/6	E-W	K
BB1	Near Covehead Bay inlet (west of)	Gulf	dune	*388433.38*	*708889.72*	P.T.	1958-1982	-12,70	-0,30	11L/6	E-W	K
S1	Next to Covehead Bay Lighthouse	Gulf	dune	*389025.84*	*708915.62*	P.T.	1958-1982	-66,80	-3,60	11L/6	SW-NE	K
S2	Across Stanhope Bayshore parking lot	Gulf	dune	*389560.76*	*708863.76*	P.T.	1958-1982	-18,70	-0,80	11L/6	SE-NW	K
S3	Across Stanhope Beach pond	Gulf	dune	*389892.10*	*708728.28*	P.T.	1958-1982	-21,80	-0,90	11L/6	SE-NW	K
S4	Stanhope Beach	Gulf	dune	*390476.28*	*708419.06*	P.T.	1958-1982	-8,20	-0,30	11L/6	SE-NW	K
S5	Stanhope Beach	Gulf	dune	*390684.18*	*708325.44*	P.T.	1958-1982	-15,40	-0,60	11L/6	SE-NW	K
S6	Stanhope Beach	Gulf	dune	*391321.94*	*708159.76*	P.T.	1958-1982	2,90	0,10	11L/6	SE-NW	K
S7	E of Stanhope Beach parking lot	Gulf	dune	*392447.76*	*707770.20*	P.T.	1958-1982	-11,30	-0,50	11L/6	SE-NW	K
DB6	N of Long Pond	Gulf	dune	*393297.62*	*707591.46*	P.T.	1958-1982	-17,40	-0,70	11L/6	SE-NW	K
DB5	NW of Dalvay Pond	Gulf	dune	*393694.86*	*707525.62*	P.T.	1958-1982	-21,70	-0,90	11L/6	SE-NW	K
DB4	Across service entrance to Park Administation	Gulf	dune	*393985.88*	*707472.54*	P.T.	1958-1982	-6,50	-0,30	11L/6	SE-NW	K
DB3	Across main entrance to Park Administration	Gulf	dune	*394506.32*	*707374.86*	P.T.	1958-1982	-16,60	-0,70	11L/6	SE-NW	K
DB2	Across Dalvay Lake	Gulf	dune	*394835.56*	*707319.64*	P.T.	1958-1982	-19,80	-0,80	11L/6	SE-NW	K
DB1	N of Campbells Pond	Gulf	dune	*396086.72*	*707141.24*	P.T.	1958-1982	102,00	4,30	11L/6	SE-NW	K
PD1	Eastern limit of PEI National Park	Gulf	dune	*401747.68*	*707561.36*	P.T.	1958-1980	14,55	0,70	11L/7	SW-NE	K
PD2	N of western edge of Point Deroche Pond	Gulf	dune	*403932.06*	*707979.34*	P.T.	1958-1980	-7,20	-0,30	11L/7	SW-NE	K
PD3	Between 2 ponds, along foredune	Gulf	dune	*404480.04*	*708051.66*	P.T.	1958-1980	42,54	1,90	11L/7	SW-NE	K
PD4	950 meters W of Point Deroche	Gulf	dune	*406067.40*	*708460.24*	P.T.	1958-1980	49,53	2,30	11L/7	SW-NE	K
PD6	Eastern edge of Point Deroche Pond	Gulf	dune	*406276.40*	*708526.34*	P.T.	1958-1980	28,11	1,30	11L/7	SW-NE	K
PD5	360 meters W of Point Deroche	Gulf	dune	*406638.84*	*708645.36*	P.T.	1958-1980	21,41	0,10	11L/7	SW-NE	K
C7	1.2 km E of the Savage inlet groyne	Gulf	dune	*414094.12*	*709196.02*	P.T.	1958-1980	-2,90	-0,10	11L/7	SW-NE	K
C6	1.4 km E of the Savage inlet groyne	Gulf	dune	*414341.10*	*709235.60*	P.T.	1958-1980	8,30	0,40	11L/7	SW-NE	K
C5	Across W pond of Crowbush Golf Course	Gulf	dune	*415385.56*	*709446.68*	P.T.	1958-1980	2,80	0,10	11L/7	E-W	K
C4	Between 2 ponds of Crowbush Golf Course	Gulf	dune	*415555.16*	*709464.56*	P.T.	1958-1980	-9,00	-0,40	11L/7	E-W	K
C3	W of Crowbush Beach	Gulf	dune	*416147.16*	*709550.32*	P.T.	1958-1980	-14,30	-0,60	11L/7	SW-NE	K
C2	E of Crowbush Beach	Gulf	dune	*416486.50*	*709637.02*	P.T.	1958-1980	-8,80	-0,40	11L/7	SW-NE	K
C1	W of St Peters Lake inlet	Gulf	dune	*416776.84*	*709715.22*	P.T.	1958-1980	-30,90	-1,30	11L/7	SW-NE	K
SP1	E of St Peters Lake inlet	Gulf	dune	*418120.60*	*710099.26*	P.T.	1958-1981	-116,40	-3,40	11L/7	E-W	K
SP2	E of large blowouts	Gulf	dune	*418705.52*	*710147.12*	P.T.	1958-1981	-92,50	-2,20	11L/7	E-W	K
SP3	E of foot path to beach area	Gulf	dune	*419438.26*	*710259.48*	P.T.	1958-1981	-65,60	-1,50	11L/7	E-W	K
SP4	W of St Peters inlet	Gulf	dune	*419515.28*	*710265.72*	P.T.	1958-1981	32,10	0,50	11L/7	E-W	K
G1	Across western parabolic dune	Gulf	dune	*421936.92*	*711003.30*	P.T.	1958-1981	-56,10	-1,60	11L/7	SW-NE	K
G2	Edge of large marsh next to parabolic dune	Gulf	dune	*422119.16*	*711078.30*	P.T.	1958-1981	13,20	0,03	11L/7	SW-NE	K
G3	Eastern edge of large marsh area	Gulf	dune	*422882.58*	*711426.16*	P.T.	1958-1981	-11,90	-0,70	11L/7	SW-NE	K
G4	Across Big Pond	Gulf	dune	*423435.60*	*711680.54*	P.T.	1958-1981	-38,70	-1,00	11L/7	SW-NE	K
G5	250 meters NW of parking lot	Gulf	dune	*423870.84*	*711774.84*	P.T.	1958-1981	-68,40	-1,70	11L/7	E-W	K
G6	350 meters NW of parking lot	Gulf	dune	*424027.36*	*711792.00*	P.T.	1958-1981	-25,50	-0,70	11L/7	E-W	K

Appendix 2, Table 2e. Available raw data collected using Analog Photogrammetry (Zoom Transfer Scope) ...continued...

.+ values in *italics* are approximate.	
* no value is entered when data is absent or when the site is unknown or too generalized.	
** for cross-reference purposes, this letter also appears next to the same plotted sites on the GIS map: ***PEI_ErosionData_Sites***	
** the ID letter in this column also refers to the bibliography listed below	
C.M. = measurements using cadastral maps	
P.GIS = photogrammetry using GIS	
P.T. = photogrammetry using transfer scope	
T.S. = total station	
E.P. = erosion pins using tape measurement	
C.S.P. = cross-shore profiles using GPS	
F:	LRIS 1988. Air photo interpretation of coastal erosion on Prince Edward Island. PEI Dept. Community & Cultural Affairs, 12p.
G:	Forward, C.N. et al. 1959. The physical character of the shorelines along the Northumberland Strait and the effects
	of tidal changes resulting from the construction of a causeway. Dept. of Mines & Surveys, non published report: 15p. 18 maps, 19 sketches.
K:	Nutt, L.A. 1990. Foredune evolution on the north shore of Prince Edward Island. M.Sc. Thesis, McMaster University, Hamilton, Ontario, 174 p.

Appendix 2, Table 2f. Available raw data collected using Analog Map Measurements (Cadastral Maps)

Site ID	General Location	Exposure	Coast Type	Site coor.* Easting	Site coor.* Northing	Survey Method	Period	Distance (m) 1960-1986	Rate (m/yr) 1960-1986	NTS Map	Orientation	ID on Map**
W Park	Western end of Jacques Cartier Provincial Park	Gulf	sandy till			C.M.	1960-1986	-22,00	-0,85	21I/16	SW-NE	A
E Park	Eastern end of Jacques Cartier Provincial Park	Gulf	sandy till			C.M.	1960-1986	-24,00	-0,92	21I/16	SW-NE	A

.+ values in *italics* are approximate.
* no value is entered when data is absent or when the site is unknown or too generalized.
** for cross-reference purposes, this letter also appears next to the same plotted sites on the GIS map: ***PEI_ErosionData_Sites***
** the ID letter in this column also refers to the bibliography listed below

C.M. = measurements using cadastral maps
P.GIS = photogrammetry using GIS
P.T. = photogrammetry using transfer scope
T.S. = total station
E.P. = erosion pins using tape measurement
C.S.P. = cross-shore profiles using GPS

A: Genest, C. & Joseph, M.-C. 1989. 88 centimetres of coastal erosion per year: the case of Kildare (Alberton), PEI. GeoJournal, vol. 18(3): 297-303.

Appendix 3 – Short annotated bibliographies of documents consulted

Sojan, M., Davidson-Arnott, R.G.D. And Ollerhead, J. 2010. Evolution of a beach-dune system following a catastrophic strom overwash event: Greenwich dunes, Prince Edward Island, 1936-2005. Canadian Journal of Earth Sciences, vol. 47: 273-290.

This study attempts to characterize the recent evolution of the Greenwich dunes, PEI National Park. Through the use of aerial photographs from the 1936, 1953, 1971, 1997 and 2005 series, orthophoto mosaics and Digital Elevation Models (DEM) have been generated from the 1953, 1971, and 1997 air photos. These digital files enabled the calculation of topographic and volumetric changes. A descriptive model of the stages of evolution of the dune system is proposed. The paper presents an extensive description of the methodology used to generate LiDAR-type DEMs, based on large-scale historical aerial photography. The paper does discuss briefly the evolution of the shoreline. Based on the cartography and superposition of all the shorelines (1936, 1953, 1971, 1997 and 2005), the authors come to the conclusion that despite the radical changes observed in the inland dune volume and morphology, the position of the shoreline did not vary significantly during the period 1936-2005 – relative stability over the majority of the study site and slight erosion (recession) in the extreme western part of the system. The only striking changes of the shoreline position over the study period concerns the distal end of the spit, where progradation at the entrance of the St. Peters Bay estuary resulted in the formation of a series of low dune ridges.

Coldwater Consulting Ltd. 2009. Coastal Processes Study – West Point, PEI. Prepared by Davis, M.H. and submitted to the PEI Department of Environment, Energy and Forestry, 55 p.

This study is an assessment of coastal processes along the shores of West Point (Northumberland Strait), more specifically in the wharf and lighthouse area. Its main focus is on the sediment budget and shoreline changes. The study discusses wave and wind regime and uses numerical models in conjunction with sand mining removal permits to estimate sand volumes transiting in the sediment cell. An aerial photograph analysis was also carried out to measure shoreline changes over time using the 1935, 1958, 1974, 1990, and 2000 series, as well as a 2006 Digital Globe Imagery dataset. The shoreline for each period was mapped using Digital photogrammetry (GIS) and superimposed in order to estimate sand volume changes (erosion or accretion) No measurements were taken to assess shoreline position change over time; photogrammetry aspect of the study was used mostly to assess qualitative shoreline evolution (overall growth or retreat, change in shape). This report also presents the evolution of the West Point shoreline through the use of historical maps (dating back to the early 1800s) and shows the absence of the West Point sand spit until the construction of the wharf, in the early 1900s. The study concludes that the volume of sand lost from the West Point spit (1980-today) corresponds to the volume of sand removed by mining operations (sand extraction).

Shaw, J., Duffy, G., Taylor, R.B., Chassé, J. and Frobel, D. 2008. Role of a submarine bank in the long-term evolution of the northeast coast of Prince Edward Island, Canada. Journal of Coastal Research, vol. 24(5): 1249-1259. (abstract by authors)

In order to understand regional variations in coastal behaviour on Prince Edward Island, Canada, we investigated the role of Milne Bank, as submarine bank at East Point, the eastern tip of the island. The objective was to determine how the bank might facilitate transfer sediment from the eroding north coast to the adjacent sediment-rich south coast. The study utilized grain-size and seismic data collected on Milne Bank in 1989 and multibeam sonar surveys in 1997 and 1999. The disturbing effect of East Point on the hydrodynamic regime controls sediment transport. The northern boundary of the bank is a steep sand wave located where southward tidal and wave-driven currents rounding East Point suddenly decelerate. Sand from the north coast enters Milne Bank and is carried south in a field of migrating sand waves that are shed from the northern bounding sand wave toward the prograding end of the bank. Milne Bank is a major sediment sink, rather than a link between the eroding north coast and the sediment-rich south-facing coast. Longshore transport in the nearshore bars is more likely to be responsible for continued sediment accumulation on the south coast. Embayments on the south coast have filled up in a cascading fashion, each one facilitating sediment bypassing when it has reached full capacity.

Forbes, D.L., Parkes, G.S., Manson, G.K. and Ketch, L.A. 2004. Storms and shoreline retreat in the southern Gulf of St Lawrence. Marine Geology, vol. 210: 169-204. (abstract by authors)

Storms play a major role in shoreline recession on transgressive coasts. In the southern Gulf of St. Lawrence, southeastern Canada, long-term relative sea-level rise off the North Shore of PEI has averaged 0.3 m/century over the past 6000 years (>0.2 m/century over 2000 years). This has driven long-term coastal retreat at mean rates >0.5 m/a, but the variance and details of coastal profile response remain poorly understood. Despite extensive sandy shores, sediment supply is limited and sand is transferred landward into multidecadal to century-scale storage in coastal dunes, barrier washover deposits, and flood-tidal delta sinks. Charlottetown tide-gauge records show mean relative sea-level rise of 3.2 mm/a (0.32 m/century) since 1911. A further rise of 0.7 +or- 0.4 m is projected over the next 100 years. When differenced from tidal predictions, the water-level data provide a 90-year record of storm surge occurrence. Combined with wind, wave hindcast, and sea-ice data, this provides a catalogue of potentially significant coastal storms. We also document coastal impacts from three recent storms of great severity in January and October 2000 and November 2001. Digital photogrammetry (1935-1990) and shore-zone surveys (1989-2001) show large spatial and temporal variance in coastal recession rates, weakly correlated with the storm record, in part because of wave suppression or coastal protection by sea ice. Large storms cause rapid erosion from which recovery depends in part on local sand supply, but barrier volume may be conserved by washover deposition. Barrier shores with dunes show high longshore and interdecadal variance, with extensive multidecadal healing of former inlet and overwash gaps. This reflects recovery from an episode of widespread overwash prior to 1935, possibly initiated by intense storms or groups of storms in the latter half of the 19th century. With evidence from the storms of 2000-2001, this points to the importance of storm clustering on scales of weeks to years in determining erosion vulnerability, as well as the need for a long-term, large-scale perspective in assessing coastal stability. The expected acceleration in relative sea-level rise, together with projections of increasing storm intensity and greatly diminished ice cover in the southern Gulf of St. Lawrence, implies a significant increase in coastal erosion hazards in the future.

Lajeunesse, D., Hawkins, R., Ayles, L.T.P.A. and McCabe, P. 2003. Coastal ecosystem management : a battle of conflicting elements. Parks Canada, Prince Edward Island National Park : 8 p. (summary by authors)

Coastal landscapes are dynamic systems continuously being altered by wind, high wave energy events and storm surges. These natural disturbances remodel the landscape by creating sand spits, re-directing freshwater outflows, and forming dune slacks and barachois ponds. The ecosystems in these unique landforms provide habitat for plants, animals and other organisms. The stability of coastal sand dunes, already vulnerable to natural process, is threatened further by damage resulting from human use and trampling. The natural features of the coastal landscape provide an appealing environment for recreational activities. Each year, over 1 million visitors visit PEI during the summer months. A large number of these visitors will visit PEI National Park of Canada. This high visitation rate in such a short season creates enormous pressure on the natural ecosystems. The peak of visitation coincides with the time natural systems are most productive and the most sensitive to human disturbance. The prime tourist activities as expressed in the latest survey of 2002 are beaches, soft outdoor adventures and sightseeing. In the past, we have managed protected natural areas by trying to control the natural disturbances while providing unrestricted and easy access to nature. The focus on our culture and priorities has changed and today we must restore and maintain the integrity of the natural systems. The challenge is to manage these dynamic landscapes while providing recreational opportunities that do not compromise the protection of ecosystem components and processes. Presented are various examples of the challenges of managing a dynamic coastal landscape, such as the cost of coastal erosion, restoring a watershed, and protection of species at risk.

Webster, T., Dickie, S., O'Reilly, C., Forbes, D.L., Parkes, G., Poole, D. and Quinn, R. 2003. Mapping storm surge flood risk using a LiDAR-derived DEM. Elevation, May 2003: 5 p.

Due to its vulnerability to coastal flooding due to storm surges, the city of Charlottetown was selected as a pilot-project for LiDAR mapping. The LiDAR survey was flown in 2000 and the data collected was used to generate a Digital Elevation Model (DEM), capable of simulating inundation scenarios from storm surge events. The reported accuracy of the system used is quoted at 30 cm (horizontal) and 20 cm (vertical). The different water levels used in the flooding scenarios were correlated to Chart Datum (lowest water level at low tide) and were: 4.23 m; 4.70 m, and 4.93 m. All the flood-risk maps produced were transferred to the City of Charlottetown Planning Division for land-use management.

Giles, P.T. 2002. Historical coastline adjustment at MacVanes Pond inlet, eastern Prince Edward Island. The Canadian Geographer, vol. 46 (1): 6-16. (abstract by author)

Sea levels are rising throughout the Atlantic Provinces at present and this is expected to continue throughout this century, forcing general coastline retreat and adjustment. In this study, a part of the coastline of eastern Prince Edward Island is examined for changes during historical time (1784-1994) using maps and aerial photography. MacVanes Pond is located between Basin Head Harbour and South Lake, all three of which were once lagoons connected to the same tidal circulation system. Sand barrier retreat has closed the connection to Basin Head Harbour and it is now a separate body of water. Meanwhile, the location of a tidal inlet at MacVanes Pond has been strongly influenced by longshore drift and the inlet has closed, re-opened to the north-east, and subsequently shifted to the south-west. Human activities in the area have previously been, and will continue to be, affected by sea level rise and transgression.

Shaw, J., Gareau, P. and Courtney, R.C. 2002. Palaeogeography of Atlantic Canada 13-0 kyr. Qutenary Science Reviews, vol. 21: 1861-1878. (abstract by authors)

We combine isobase maps with a digital terrain model of Atlantic Canada to map coastlines from 13 ^{14}C kyr BP to the present. At the 13 ^{14}C kyr BP there are ridges of high relative sea level (rsl) values over Newfoundland and the Maritime Provinces, and a re-entrant of low values in the Gulf of St. Lawrence. This pattern persist well into the Holocene, and reflects crustal response to the slow wasting of ice caps that persisted in Newfoundland and the Maritime Provinces for up to five millennia after the removal of ice from the Gulf of St. Lawrence by a migrating calving embayment. The palaeogeographic reconstructions reveal an archipelago on the outer shelf, from Grand Bank to the continent, that persisted from >13 ^{14}C kyr BP until ca. 8 ^{14}C kyr BP. Much of the Magdalen Shelf was exposed, but the Magdalen Islands were never connected to the mainland. Prince Edward Island was initially separated from the mainland, became connected after 11 ^{14}C kyr BP, and was separated again just before 6 ^{14}C kyr BP, when Northumberland Strait formed. The reconstructions are highly sensitive to relatively small changes in isobase values, especially on the shallow banks on the continental shelf.

Shaw, J. Taylor, R.B., Solomon, S., Christian, H.A. and Forbes, D.L. 1998. Potential impacts of global sea-level rise on Canadian coasts. The Canadian Geographer, vol. 42(4): 365-379. (abstract by authors)

The sea-level rise that may result from global climate change is placed within the context of past and present sea-level changes on Canadian coasts. To assess future impact, a dimensionless index of sensitivity is determined. Coasts with low, moderate, and high sensitivity constitute 67%, 30%, and 3% of the total coastline, respectively. The most sensitive regions are: (1) several parts of the Maritime Provinces; (2) two areas of the British Columbia coast; and (3) a large part of Beaufort Sea coast. Impacts in four regions – Bay of Fundy, Beaufort Sea, Fraser Delta, and Eastern Shore of Nova Scotia – are discussed in detail. It is argued that the societal response to changes in sea level should favour retreat and accommodation strategies.

Ollerhead, J. 1997. Quantifying shoreline geomorphology at Cape Jourimain. Proceedings Canadian Coastal Conference 1997, Guelph April 21-May 14:253-266.

This paper details the methodology used for monitoring cross-shore profiles along dunes, till bluffs, and sandstone cliffs in the Cape Jourimain area (Northumberland Strait). 19 shoreline profiles were established in 1995-1996 and measured using standard surveying techniques (not mentioned), and contain coordinate data for all of them. 10 transects (profiles) were established across a foredune; the remaining 9 transects were located along till bluffs and sandstone cliffs. Transects 0-12 were surveyed 3 times (June 1995, June 1996, and November 1996) and transects 13-18 were surveyed twice (June 1996 and November 1996). The short time period for the study makes it difficult to extract representative coastal displacement data. However, the study does discuss shoreline displacement rates calculated and presented in other studies. Eastern Designers & Co. Ltd (1987) estimate that for the period 1935-1980, the rate of shoreline recession for Jourimain Island is -0.4 m/yr, that the erosion rate for east of Jourimain Island is -0.3 m/yr and that the erosion rate for west of Jourimain Island is -0.6 m/yr. Jacques Whitford Consultants (1994) estimate that the west of Jourimain Island receeded -0.3 m/yr, for the period 1935-1993. ROBERGE (1994) calculated a bluff recession rate of -0.52 +/- 0.15 m/yr in this sector (period 1945-1982).

Forbes, D.L., Taylor, R.B. and Shaw, J. 1989. Shorelines and Rising Sea Levels in Eastern Canada. Episodes, vol. 2(1): 23-28. (abstract by authors)

One of the major impacts of a climate warming is likely to be a rise in sea level. Many studies are now concentrating on coastal regions in order to determine the effects, past and present, of changes in sea level on shorelines and on the people who live nearby. This article and the following on by John

CLAGUE summarize respectively recent work along Canada's low-lying eastern coast and its more rugged western one, which provides part of the scientific background required in order to understand and cope with changes in the coastal zone. The authors show here the importance of variations, not only in sea level, but also in conditions of sediment supply.

Armon, J.W. and McCann, S.B. 1979. Morphology and landward sediment transfer in a transgressive barrier island system, southern Gulf of St. Lawrence, Canada. Marine Geology, vol. 31: 333-344. (abstract by authors)

The main focus of this paper is the discussion of the sediment budget. The Malpeque barrier system (PEI) is a narrow, high dune shoreline retreating at an average rate of -0.26 m/yr. The main sources of sand for the longshore transport (net 40 000 to 200 000 m^3/yr) are the subtidal erosion of the shoreface and the erosion of the weakly indurated bedrock outcropping north of the barrier system (see ARMON and MCCANN, 1977: Longshore sediment transport and sediment budget for the Malpeque barrier system, southern Gulf of St. Lawrence. Canadian Journal of Earth Sciences, 14 (11): 2429-2439). Rates of duneline retreat, measured from air photographs taken in 1935 and 1968 are generally in the range of **0** to **-1** m/yr. The average rate for the whole shoreline during this period is **-0.26** m/yr.

Johnson, D.W. 1913. The shoreline of Cascumpeque Harbour, Prince Edward Island. The Geographical Journal, vol. XLII: 152-164.

The article discusses the geomorphology of Cascumpeque Harbour in relation to the theories of that period: can crustal subsidence also be responsible for the rise in sea-level and the type of features present at the coast? The author centers his argument against crustal subsidence as a possible reason for sea-level rise on the basis of the Black Bank - a cliff within sphagnum peat extending below the high tide on the eastern-most shore of Cascumpeque Harbour – and the presence of forested dune ridges and swales that were being eroded.