OBSERVATIONS MADE ON A 300 YEAR OLD ACADIAN DYKE

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ABSTRACT:

The Acadians inhabited the Bay of Fundy area of Nova Scotia from the early 1600s to 1755 when they were expelled by the British. The Acadians are best known for their construction of dykes in salt marsh areas to hold back the high tides that the Bay of Fundy is famous for. The dyked areas were used as farmland, taking advantage of fertility of the salt marsh soils. Presently, there is evidence that ongoing sediment deposition and rising sea level has either buried the original pre-1755 Acadian Dykes in some locations or required subsequent dyke raises since 1755. However, in other locations along the Cobequid Basin, it appears that some of the original Acadian dykes are still largely exposed and generally consistent with their 1755 configurations.

One Acadian dyke is located in Economy, NS and is known locally as the Great Dyke. As with many Acadian dykes, it was used by the post expulsion influx of English settlers who took over the dyked areas and farmed them as their own. The dyke is currently owned by Ducks Unlimited. The dyke has been breached in three locations where the aboiteau (low level drains) were presumably located. The timing of the breaches is unknown. The maximum height of dyke still standing is about 1.5 m, although remnants of the dykes in the breached areas suggest a former maximum height in the order of 3 m.

A review of the dyke was conducted in the late summer of 2010 to assess the condition of the dyke, the construction methods used by the Acadians and any subsequent modifications by English farmers. The information was reviewed to gain insight on the rate of sea level rise in the Minas Basin area. Information on the nature of the Bay of Fundy tides and dyke construction methods used by the Acadians will be provided as background for the discussions presented in the paper.

RÉSUMÉ :

Les Acadiens ont habité la partie néo-écossaise de la baie de Fundy du début des années 1600 jusqu'à leur déportation par les Britanniques, en 1755. Ce peuple est réputé pour la construction de digues dans les marais salés en vue de retenir les marées hautes exceptionnelles de la baie de Fundy. Les régions endiguées étaient utilisées comme terres agricoles, en raison de la fertilité du sol des marais salés. Aujourd’hui, il semble que l’accumulation continue de sédiments et la hausse du niveau de la mer aient enterré, à certains endroits, les digues acadiennes d’avant 1755, ou imposé, depuis, leur rehaussement. Dans certains endroits du bassin Cobequid, il semble, cependant, que certaines digues originales soient encore largement à découvert et qu’elles aient essentiellement la même configuration qu’en 1755.

Une de ces digues, située à Economy (N.-É.), est connue localement comme la Great Dyke. Comme plusieurs autres digues acadiennes, elle a été utilisée, après la déportation, par les immigrants anglais qui ont pris possession des terres endiguées et les ont cultivées. Aujourd’hui, cette digue appartient à Canards Illimités. Elle compte trois brèches où se situaient probablement les aboiteaux (drains peu élevés). La date de formation de ces brèches n’est pas connue. La hauteur maximale de la digue est d’environ 1,5 m, bien que des vestiges, dans les secteurs des brèches, semblent indiquer qu’elle ait pu atteindre 3 m en tout.

La digue a été examinée à la fin de l’été 2010 pour évaluer son état et en savoir plus sur les méthodes de construction des Acadiens et les modifications apportées ensuite par les fermiers anglais. Les résultats ont été analysés en vue de mieux connaître l’élévation du niveau de la mer dans la région du bassin Minas. Des renseignements sur la nature des marées de la baie de Fundy et les méthodes de construction des Acadiens seront fournis à titre d’information pour l’exposé présenté dans l’article.

1.0 INTRODUCTION

The Bay of Fundy region of Nova Scotia is known for its high tides and its early history of French settlement. The French settlers were known as the Acadians. They inhabited the Minas Basin and Cobequid Bay portions of the Bay of Fundy region in what is now known as Nova Scotia from about 1680 to 1755. In 1755 they were expelled by the British.

The Acadians were farmers who constructed dykes to hold back the Bay of Fundy tides to develop the rich soils found in the salt marshes located around the fringes of the upper portions of the Bay of Fundy. The salt marsh soils were generally free of coarse soil particles and were very fertile. Upon expulsion, the farmland formerly occupied by the Acadians was given to settlers loyal to Britain. In many locations, the land formerly farmed by Acadians is still farmed to this day.

Rising sea levels have resulted in the need to raise many of the old Acadian dykes to allow farming to continue. This has resulted in the original dykes being buried as dykes were raised. There is also evidence that natural sediment deposition is also causing the burial of some the original Acadian dykes, albeit in a much slower process (Bleakney, 2004). The Minas Basin and Cobequid Bay regions are known for having a high sediment load due to the relatively soft and erodible sedimentary bedrock that underlies the Bay of Fundy and its shoreline in this area.

Based on the preceding paragraph, one might be led to believe that the original Acadian dykes are buried out of site. However, not all former Acadian salt marsh fields are farmed to this day and not all regions of the Minas Basin and Cobequid Bay are experiencing rates of sediment deposition that cause burial of the original dykes. One such location is in Economy, Nova Scotia, a location familiar to one of the authors since 1979. There are a series of Acadian dykes at this location but one dyke, known locally at the Great Dyke, will be discussed in this paper. The location of Economy is shown in Figure 1. A plan showing Google Earth satellite imagery in the vicinity of the Great Dyke is shown in Figure 2.

Review of readily available historical information (Creighton, 1979, Anita McLellan, personal communication) indicates that the Acadians were settled in Economy (formerly Ville Conomie, Colchester Historical Society Museum, 2003) around 1700. Further discussions with long standing community members indicate that the dyked area was farmed by English farmers to a date that varies between “well before 1929” to a time around the late 1940s. There is a paucity of information on any repairs that were made to the dyke prior to breaching aside from knowledge that the dyke was repaired at least once some time before it was breached.

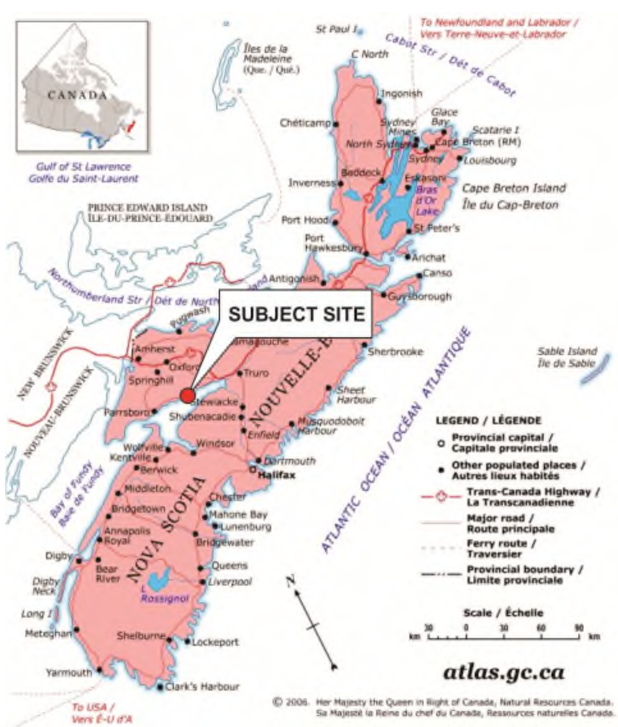

Figure 1: Site location plan

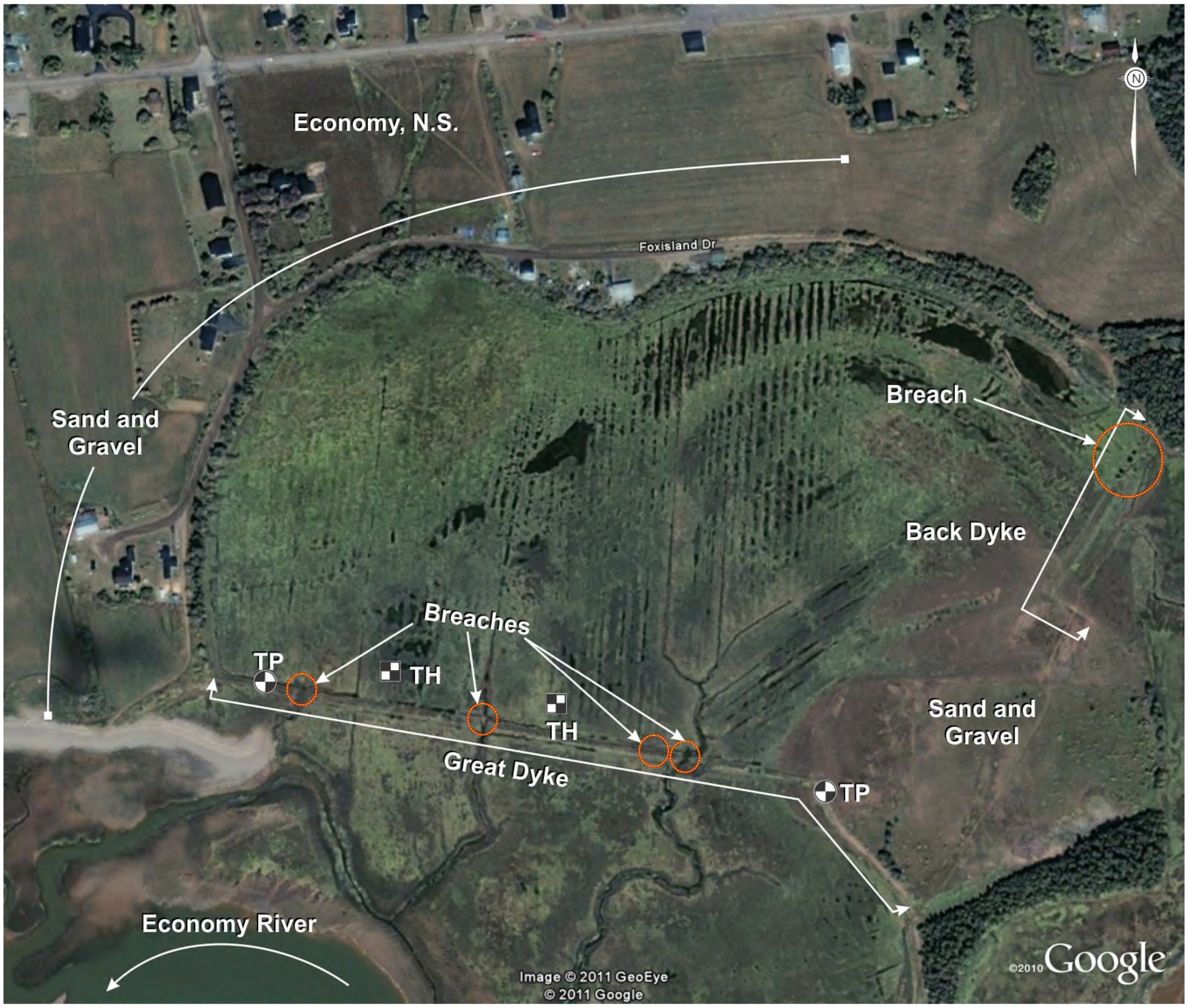

Figure 2: Satellite imagery of Great Dyke area

A review of the Great Dyke was conducted in the late summer of 2010 to assess its condition, the construction methods used by the Acadians and any subsequent modifications by English farmers. A level survey was conducted of the dyke crest in conjunction with monitoring high tide levels to assess the influence of rising sea levels. Finally, a simple subsurface investigation and laboratory testing program was conducted to assess the geotechnical properties of the salt marsh soils and the soils used in the construction of the dyke. Information on the nature of the Bay of Fundy tides and dyke construction methods used by the Acadians will be provided as background for the discussions presented in the paper.

2.0 SUMMARY OF ACADIAN DYKE BUILDING

The history of Acadian dykeland construction at Grand Pré is presented in Bleakney (2004). Based on his research, it appears that teams of five or six men with an ox or horse-drawn cart or drag and special sod cutting spades were used to construct dykes out of 0.1 m thick sods cut from the marsh surface. The summary of construction methodology presented in the following paragraphs is from Bleakney's publication.

Construction began by marking out the centre-line of a new dyke with a rope and stripping the sod to six feet of either side of the line. A key trench was then dug along the same line and posts were driven at six to ten foot intervals. This addressed the risk of dyke instability along the fill – foundation interface.

Sod "borrow" pits were established close to the walls to minimize the haul length of the drags or even allow sod cutters to pitch their own sods into place. The Acadians appear to have used specific types of salt marsh grass sods for different purposes during dyke construction. Experienced sod cutters would typically cut the wall facing sods since they were required to fit together tightly, like bricks. Dyke construction started by placing the hard packed centre-fill sods in and around the key trench and posts, creating a relatively rigid backfilled key trench. The grassed side of the sod would be placed on the upstream and downstream sides of the dyke to create a relatively erosion proof surface to protect the dyke from waves or overtopping during periods of high tide.

The hand-built dykes were constructed with a narrow crest, one to two feet in width, just large enough to walk on. This is one of the major distinctions from the dykes constructed or repaired by heavy equipment, with crests wide enough to permit driving of the machines. The amount of freeboard above the maximum normal tide level is unknown but the known practicality of farmers through the centuries and the labour intensive nature of dyke building would have resulted in it being as little as possible, and likely measured in inches. It is expected that the assessment of required dyke height would be adjusted as observations permitted a greater understanding of variability in maximum tide height. The side slope angles of the Acadian dykes were reported to vary between 1.5H:1V to 2H:1V.

Fresh water build up behind the dykes in the farmed areas was an operational issue that was addressed with a buried drainage mechanism called an aboiteau. An aboiteau is a wooden sluice with a clapper valve installed in the dyke wall in the creek bed. The clapper valve would permit water to flow freely in one directly by swinging open and into a prefabricated slot on the roof of the aboiteau to allow full flow. When water attempted to flow in reverse, the clapper would close tightly and restrict the water like a back flow valve. The use of aboiteau permitted the freshwater to drain from behind the dyke at low tide while restricting the salt water from flooding the dyked farmland at high tide.

The portions of the dykes constructed in natural drainage channels such as creeks where aboiteaux were located were the highest sections of the dykes. With increased height came additional concerns regarding dyke embankment stability which were addressed with placement of brush layering at the base of the fill, much like the use of non-woven geotextile and geogrid in current construction practices, to reduce the risk of localised bearing capacity failure and also to provide additional shearing resistance at the fill – foundation interface. Additional log reinforcement of slopes and the fill were also reported to have been used at the aboiteau sections of the dykes.

3.0 TIDAL RANGE AND SEA LEVEL RISE CONSIDERATIONS

The Minas Basin is famous for high tides that occur twice a day. The tide consists of two waves, one on each side of the earth, that circle the earth due to the gravitational force of the moon (Bascom, 1980). The tide travels from east to west, from Europe across the Atlantic Ocean to the east coast of North America. A detailed description on the tide from an oceanographic sense can be found in the Canadian Tidal Manual (Forrester, 1983).

The tides in the Cobequid Bay region have a tidal amplitude that varies from approximately 8 to 15 m which indicates the difference in water level from low tide to high tide. It is said the Minas Basin and Cobequid Bay regions of the Bay of Fundy have the highest tides on earth. This is due to a harmonic oscillation effect caused by the period of the tide and the natural period of the shape of the Bay of Fundy and part of the adjoining Gulf of Maine. The tide in the Bay of Fundy is said to be semi-diurnal which means it has two generally equal high tides and two generally equal low tides each day. The high tides in the Bay of Fundy occur approximately a little less than every 12.5 hours which is due to the influence of the moon.

The variation in the tidal range is due to the interaction of the gravitation forces associated with the sun and moon. When the sun and the moon are on the same side of the earth (i.e., a “new” moon period), the gravitational pull causing the tide wave is the sum of the moon’s and the sun’s gravitational forces. New moon periods are when the highest tides in any given month will occur. When the sun is on the opposite side of the earth from the moon (i.e., a “full” moon period), the gravitation force of the moon on the tide is reduced by a portion of the sun’s opposing gravitational force. Full moon periods are generally when the second highest tides in any given month will occur. It is important to note that, due to the closer proximity of the moon, the influence of the moon on the tides is much greater than that of the sun. The various phases of the moon where the sun is out of plane from the moon (e.g., a “quarter” moon) will be generally periods where the sun’s influence on the tides is more muted, resulting in lower tides. A plot of tidal range in the area the Five Islands (near Economy) showing the various phases of the moon is shown in Figure 3. The period of new moons is every 29.5 days as reported by Bleakney, 2004.

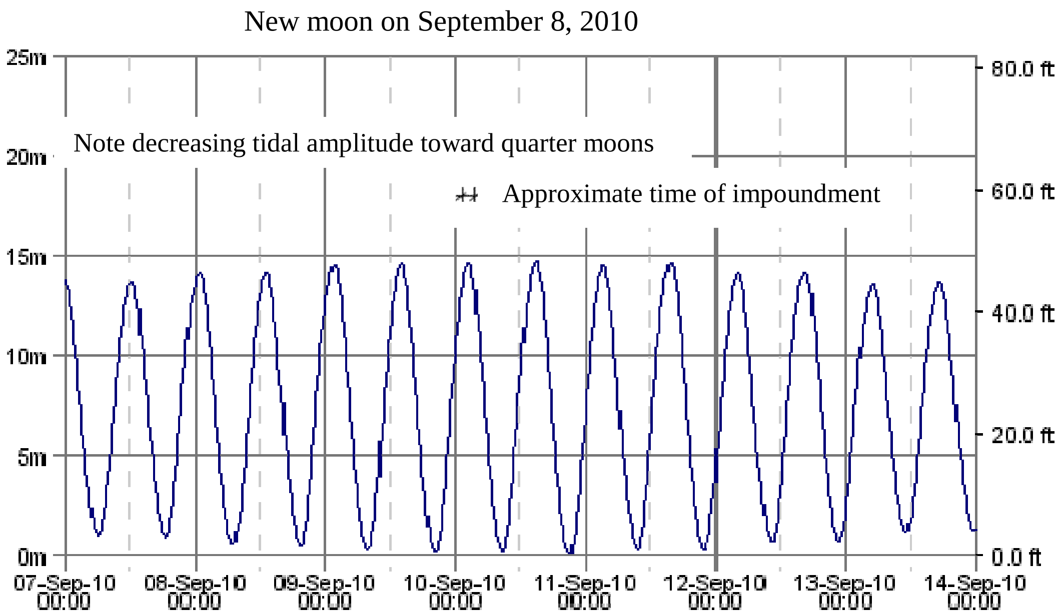

Figure 3: Times and heights for high and low tides for Five Islands, NS in early September 2010 from Canadian Hydrographic Service

The salt marshes farmed by the Acadians at Economy were located at relatively high elevations. Therefore the dykes constructed by the Acadians in Economy did not continuously hold back or "impound" the ocean. The period of impoundment could be two or three hours or less as shown in Figure 3.

There are other important influences on the amplitude of tidal range and they relate to the orbit of the moon around Earth, the interaction of the moon and the sun and weather. The moon's orbit is not circular and, as such, has periods where it is closest and furthest away from the earth. Due to the increase in the proximity of the moon to the earth, the gravitational force of the moon causing the tide wave is increased with a corresponding increase in tidal variation. The moon is said to be in Perigee when it is closest to the earth and this condition occurs approximately every 27.55 days (Bleakney, 2004). A weak lunar effect is due to the variation of the declination of the moon (how high it rises in the sky). A much stronger, but longer term effect is due to the interaction of the moon's position with that of the sun which is known as the Seros cycle which creates a year over year gradual increase or decrease in high tide levels. The Seros cycle peaks every 18.03 years with lesser peaks every 4.52 years (Bleakney, 2004). The next Seros peak will be in 2013. The Acadians at Ville Conomie would have understood the implications of the Seros cycle as Seros peaks would have occurred in 1687 (Acadians in Grand Pré would have experienced this one), 1705, 1723 and 1741, not mentioning the lesser peaks in between. This appreciation would have likely lead to episodes of dyke raising to accommodate the fluctuations in the height of the highest tides.

The influence of weather is an important consideration as wind set up during periods of high tide can produce tidal ranges much higher (i.e., a storm surge) than predicted using mathematics for any given lunar cycle. One storm event of note was the Saxby Gale of 1869 which generally travelled up the Bay of Fundy during one of the "mini peak" years. This storm caused extensive flooding and damage to low lying coastal areas due to its coincidence with a high tide.

A final consideration which does not affect tidal range but is an important consideration in this paper is rising sea levels. Sea levels are rising due to the subsidence of the land mass of Nova Scotia in the vicinity of the Minas Basin and Cobequid bay but also to an increase in ocean levels worldwide which are reported to vary between 3 to 6 cm per century worldwide (Bleakney, 2004). The rate sea level in the Minas Basin rise is not clearly established and varies as follows:

- 0.2 m per century (Dalrymple, Amos, and Yeo 1992, as reported in Bleakney, 2004);
- Up to 0.9 m per century (Bleakney, 2004); and
- 0.8 m over the next century (Webster and Stiff, 2008).

The increase in sea level discussed later in this paper will relate to the high tide level which would have been the concern of the farmers who operated the salt marsh dykes.

4.0 CURRENT CONDITION OF DYKE

The condition of the Great Dyke in the fall of 2010 is summarized in this section. The Great Dyke is located in a salt marsh that is surrounded by a sand and gravel glacial outwash plain. It is possible that the salt marsh has formed on a former terrace eroded into the sand and gravel deposits by the Economy River. Sand and gravel exposures are visible between the dyke and the bay.

Review of the Google Earth imagery presented in Figure 2 shows the location of Great Dyke as well as the Back Dyke. The former location of Ville Conomie was immediately to the west of the Great Dyke which supports the conclusion that the Great Dyke and Back Dyke were constructed first. The Great Dyke was used to stop water from entering the dyked area from the sea whereas the Back Dyke was used to stop flooding of the dyked area from the Economy River during very high tides before additional dykes were built to the east. This was consistent with Acadian Dyke building practices in the Grand Pré area described by Bleakney, 2004. Review of the satellite imagery presented in Figure 2 indicates that the ditch and dale farming patterns used by the English farmers and the preceding Acadian farmers to drain the salt marsh surface are still present. This observation, combined with the presence of surficial exposures of sand and gravel on the sea side of the Great Dyke indicate that ongoing sediment deposition during high tides is generally not occurring at a rapid rate.

The Great Dyke is approximately 460 m long and is on average about 1.5 m high. The crest width of the Great Dyke is between 0.5 m and 1.2 m (average 0.9 m) for the dyke section constructed over marsh soils and 0.5 to 0.7 m where it was constructed over gravel. Interestingly, it appears the section of dyke constructed over sand and gravel was constructed with sand and gravel, not salt marsh sods. The side slope angles on the upstream and downstream side are approximately 1.7H:1V and 2H:1V respectively. The current condition of the Great Dyke is presented in Photos 1 and 2. The portion of the Great Dyke constructed with gravel is presented in Photo 3. The Great Dyke is about 0.5 to 1.0 m high were it is constructed on top of sand and gravel. The Back Dyke is about approximately150 m long and averages 1.2 m high with similar slope angles to the Great Dyke. Similar to the Great Dyke, the Back Dyke has been constructed with sand and gravel where it overlies sand and gravel. The Back Dyke is depicted in Photo 4.

Photo 1: View of Great Dyke from west abutment, facing east

Photo 2: Breached sections in Great Dyke, facing south

Photo 3: Gravel portion of Great Dyke, facing west

Photo 4: Back Dyke, facing south towards the Great Dyke

The crest of the Great Dyke appears to be in relatively good condition. Grass is growing on either side of the dyke and on the crest. The only location where the dyke is not covered with grass is at the three breach locations. Foot traffic near the west abutment appears to have degraded the grass cover between the west abutment and the first breach. Closer inspection of the dyke indicates that there appears to be some steeper sections of the dyke near the crest which indicates that it was raised sometime in the past. Based on field observations, the apparent height of historic dyke raising, or at least the most recent dyke raise, has been estimated to be 0.3 m or less. Additionally, recent deposits of sand and gravel were observed to have been on top of the grass on the crest. This is likely due to ice floes with entrained sand and gravel being floated on the surface of the dyke, though no evidence of ice gouging or related erosion was noted. Uprooted trees can be floated by the tide onto the dyke crest which could contribute to crest erosion. There was only one location where localised crest erosion of the intact dyke was noted. In general, there was organic flotsam located over the entire length of the dyke which indicates that the entire dyke crest is inundated at one time or another. It is important to note that, due to the breaches through the dyke, the intact portions of the dyke are only overtopped when the water level in front of and behind the dyke rises to crest elevation. As such, there is currently limited crest erosion potential due to the overtopping of the dyke.

There are four sections where the Great Dyke has failed and been completely washed away by tidal action. In these locations, it appears that the dyke was formerly at least 3 m high based on the observed elevation of the base of the tidal creeks passing through each of these breaches. It is believed that these breaches sections were the location of aboiteau; however, no sign of aboiteau were observed during the site reconnaissances associated with this study. However, at one of these breach locations, the brush layer placed between the aboiteau fill and the underlying natural salt marsh is visible as shown in Photo 5. The current elevation difference between the base of the tidal creeks and the current crest of the dyke is greater than 3 m; however, review of Figure 2 showing the salt marsh and terrain between the Great Dyke and the Economy River shows that these tidal creeks have likely had their outlets eroded by the Economy River and due to wave action from the bay. This could cause increased down cutting erosion which could quickly extend back to the dyke location due to the relatively soft nature of the salt marsh soils.

Deep erosion gullies in the order of 1.0 to 1.5 m deep have formed behind the Great Dyke on the western portion of the dyke and to a lesser extent on the ocean side of the dyke. The western two breaches are the deepest and the gullies associated them are also the deepest. It is believed that the gullies have been eroded since the final breaches occurred in response to down cutting of the creeks at the breach locations.

Photo 5: Use of brush layering beneath dyke fill near former location of aboiteau

The Back Dyke also has a breached section which appears to have occurred in a low lying area to the north of the dyked area that was not farmed, likely due to poor drainage conditions. Similar to the Great Dyke breach locations, there is no trace of the failed dyke, as it has been eroded away by tidal action over the years since it failed. The aboiteau was located on the flanks of the failed area, indicating that it was not possible for the aboiteau to be installed in the lowest possible location, likely due to poor drainage in this area. Additionally, recreational use of all-terrain vehicles (i.e., quads) has eroded a path crossing the crest of the Back Dyke. This kind of erosion or degradation of the dykes was not present elsewhere in the study area.

5.0 2010 INVESTIGATION

A brief investigation of the Great Dyke and Back Dyke was undertaken by the authors in the fall of 2010. The investigation consisted of inspection of the dykes, level survey of the crest of the dykes and a limited subsurface investigation.

The 2010 investigation was timed to be in early September to correspond to a new moon period when tides were expected to be highest for 2010. The tidal predictions presented on the Canadian Hydrographic Service website (as presented in Figure 3) were used in scheduling the investigation. In addition to being the time of a new moon, the early September 2010 period was also a period of lunar perigee where the moon was closest to the earth for all of 2010 which resulted in the highest tides of the year being experienced at this time. The level survey of the dyke crests also included setting a benchmark near the west abutment to record the maximum tide height during the period of the 2010 investigation and during subsequent visits during periods of new moon high tide.

5.1 Subsurface Investigation

A subsurface investigation consisting of two small test pits excavated through the dyke fill and two shallow hand augered boreholes in the salt marsh behind the Great Dyke.

The location of the hand excavated test pits are presented on Figure 2. The test pits were excavated a maximum depth of 1.0 m through the downstream crest of the dyke and were backfilled and the surficial grass sod replaced. The two shallow test pits excavated into the Great Dyke near the west abutment and through the section constructed on sand and gravel confirmed the following:

- The portion of the Great Dyke constructed on the salt marsh was constructed with soils of similar nature to those encountered beneath the salt marsh surface, but denser and drier;
- There was a faint light coloured stripe pattern that repeated throughout the fill every 10 to 20 cm that could possibly be attributed to construction with sods;
- The original salt marsh grass was encountered at the base of the dyke;
- The portions of Great Dyke constructed on sand and gravel was completely constructed with sand and gravel.

Two hand augered test holes were drilled behind the Great Dyke in locations shown in Figure 2. The test hole depths varied between 1.0 and 1.2 m deep. Shelby tube samples were taken of the salt marsh soils encountered in the hand augered holes. Soil samples taken during the investigation were tested in geotechnical soils labs for index properties (moisture content, organic content, Atterberg Limits, salinity) and also for their compressibility properties (primary compression index and secondary compression ratio, Cc and $C\alpha, \varepsilon$ respectively) through consolidation testing. A summary of the test results are presented in Table 1.

Table 1: Summary of soil properties from lab testing

Soil Type	Moisture Content (%) ASTM D2216	Organic Content (%) ASTM D2974-87	Atterberg Limits ASTM D4318		Salinity (ppt)	Compressional Properties ASTM D2435			
			Plastic Limit (%)	Liquid Limit (%)		Cc	Unit Weight (kg/m³)	Preconsolidation Pressure (kPa)	$C\alpha, \varepsilon$
Sod from dyke	27.1 to 35.6 (increasing with depth)	1.5 and 7.5 (0.3 m and 0.8 m depth respectively)	N/A	N/A	28	N/A	N/A	N/A	N/A
Salt marsh from behind dyke	52.0 to 93.1, average 70.1	2.7 to 8.6, average 4.9	49 to 55	26 to 30	25 to 29	1.045	1450 to 1600	20 to 30	0.05 to 0.06

Review of the testing data indicated the following:

- The difference between moisture content of the dyke fill and the salt marsh soils shows the dyke fill has drained over time due to being elevated above the salt marsh surface;
- The similarity in the salinity content for the dyke fill and salt marsh soils shows they were both deposited in a marine environment, further supporting the concept that the salt marsh soils were used to construct the dyke. The timing of inundation during high tide would not be sufficient to set up steady state seepage through the dyke and introduce salinity into previously non-saline soils;

- The results of the Atterberg Limits test confirm that the organic content of the soils is such that these soils behave similar to low to high plastic organic soils (OL to OH) or medium to high plastic clays (CI-CH);
- The Cc and $C\alpha,\varepsilon$ values estimated from consolidation testing indicate the salt marsh soils would settle under dyke fill loading and would experience secondary consolidation (i.e. creep settlement) for some time after construction. The Cc values were reviewed against published values for other soils (Holtz and Kovacs, 1981) and were found to be consistent with Cc values associated with organic silt and certain marine clays. The $C\alpha$, ε values from the consolidation testing were found to be higher than what was suggested for organic silt ($C\alpha$, ε values up to 0.02 in Holtz and Kovacs, 1981). This will be reviewed further, but suggests that the salt marsh soils could experience relatively large creep settlements under loading.

The unit weight of the dyke fill constructed with sods was not tested but has been estimated based on experience and degree of difficulty during excavation to be in the order of 1700 to 1800 kg/m^3.

5.2 Level Survey

The results of the level survey are presented in Figures 4 and 5 for the Great Dyke and Back Dyke respectively along with the maximum tide height recorded. The elevations highest tide levels for September and October 2010 were recorded by measuring the elevation difference between water level and benchmark level (assumed to be 100.000 m). The dyke was completely covered with water with the exception of the west abutment on September 10, 2010 as shown in Photo 6. The maximum height of water recorded at the west abutment at this time was 5.5 cm above the top of the benchmark, or at an elevation of 100.055 m as shown on Figures 4 and 5. The weather during the high tide level measurements was clear to overcast with a gentle breeze to light wind.

Review of the survey data and maximum high tide elevation indicates the following:

- The crest of the Great Dyke appears to have settled a maximum of 0.74 m where it is founded on salt marsh soils;
- The portions of the Great Dyke that are founded on sand and gravel appear to have settled the least or not at all;
- The portions of the Great Dyke founded on salt marsh soils and sand and gravel were overtopped by the maximum high tide observed during this study by an average of 0.77 m and 0.23 m respectively; and
- The portion of the Back Dyke constructed with sand and gravel was overtopped by the maximum high tide observed during this study by an average of 0.47 m. The crest elevations of these two gravel dyke sections are sufficiently different to warrant further consideration.

Photo 6: Crest of Great Dyke inundated at high tide

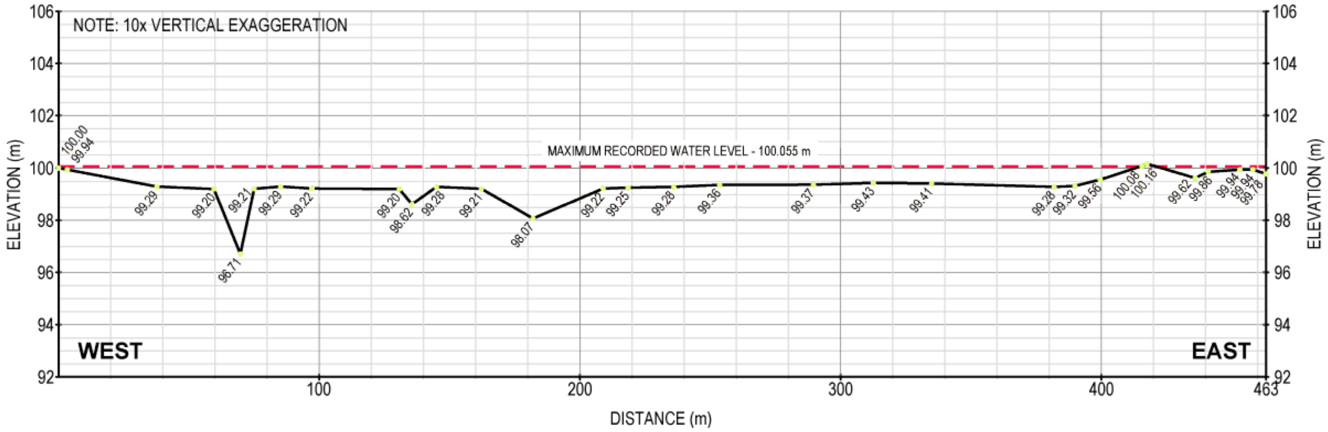

Figure 4: Profile of crest of Great Dyke with recorded high tide level at western abutment

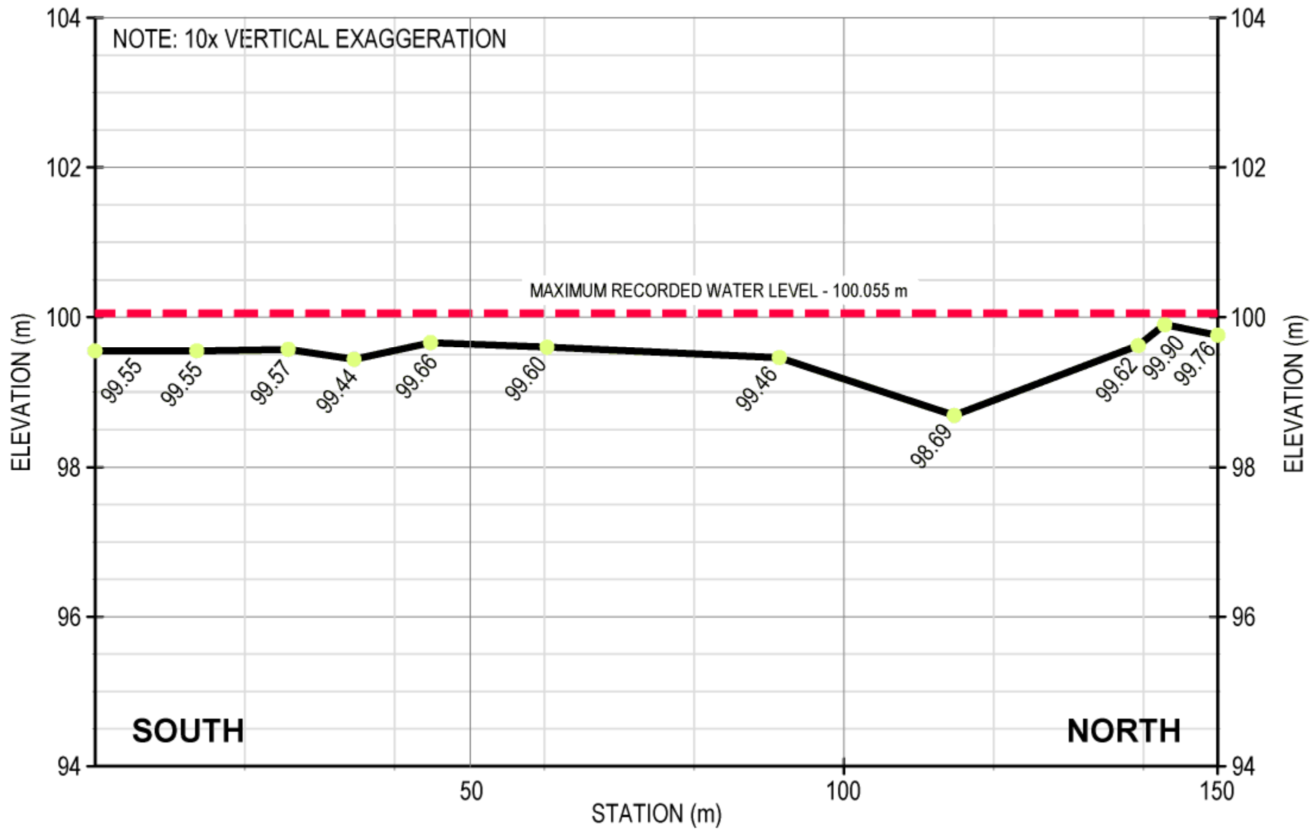

Figure 5: Profile of crest of Back Dyke with recorded high tide level at western abutment

6.0 DISCUSSION

Review of the information gathered during this study has indicated the following:

- The Acadians modified their dyke building techniques as required by the materials readily at hand as indicated by the presence of sand and gravel sections of dyke at the Great Dyke and Back Dyke;
- The breaches at the creek locations or low lying poorly drained areas where crest width appears to have been locally wider indicates that the mechanism of failure was related to the height of the dykes or presence of aboiteau and could be due to settlement and subsequent overtopping, slope failure or internal erosion or some combination of all three. The location of the Back Dyke aboiteau outside of the breach area indicates the Back Dyke breach was more due to settlement/overtopping, slope failure or some combination thereof;

- The observed greater settlement of the portions of the Great Dyke founded on salt marsh soils shows that these soils are compressible under loading and that short term and long term (i.e., creep) settlement would have occurred after initial construction or after dyke raises;
- There is one anomalous crest elevation data point where the height of the gravel section of the Great Dyke is above the maximum high tide level. It is believed this is either a collection of flotsam or some other construction feature that cannot be explained at this time. It has been excluded from consideration in this paper;
- The observed difference in the height of the gravel sections of the Great Dyke and Back Dyke could be attributed to the presence of dykes to the east of the Back Dyke. These dykes may have been constructed later and would have been outer perimeter dykes. Any emphasis on raising dyke crests in response to rising sea levels may have been focussed on the perimeter dykes, not the interior Back Dyke; and
- The elevations of the portion of the Great Dyke crest where it is founded on sand and gravel soils will provide a better indication of the rate of sea level rise as the influence of creep settlements would be removed from consideration. The settlement of the sand and gravel foundation would have occurred during dyke construction.

Based on the anecdotal information on when salt marsh farming ended behind the Great Dyke reported earlier, and assuming that the portion of the Great Dyke constructed on a sand and gravel foundation would have been able to impound the highest tides with zero freeboard, the rate of sea level rise, as determined by reviewing the maximum high tide observed during this study, appears to be about 0.23 m over 62 to 82 years which corresponds to 0.37 m to 0.28 m per century. This assessment is subject to the following uncertainties:

- The influence of any crest erosion on the portions of the Great Dyke constructed on gravel due to human or natural forces, while not apparent during this investigation, has not been accounted for in this calculation;
- The actual freeboard at the time of abandonment is unknown;
- An average degree of overtopping over the gravel section of the Great Dyke was used in the calculation of sea level increase. If what is believed to be the maximum intended dyke crest elevation in this area (i.e. excluding the anomalous crest elevation reading) is used instead of an average, the rate of sea level rise falls into the range of 0.19 to 0.14 m per century which is generally consistent with the rate reported by Dalrymple et al, 1992;
- The period of time over which the dykes have been left unattended and unmodified is also unknown due to lack of currently available historic information on when farming stopped and the nature and date of the last modifications to the Great Dyke. This will also affect the back calculation of sea level rise;
- Consideration of the maximum high tides recorded during the peak of the current Seros Cycle will need to be considered in 2013; and
- The rate of sea level rise assessed in this paper is retrospective and approximate at best over a relatively unclear period of time. The methods described herein do not permit a prediction of what sea levels or high tide levels may be in the future.

With regard to the lower elevation of the gravel portion of the Back Dyke crest with respect to the elevation of the crest of the gravel portion of the Great Dyke, it is interesting to note that the use of the 0.19 m/century sea level rise rate corresponds to an increase of sea level of about 0.5 m since around the time Acadians were expelled. As previously discussed, the gravel portion of the Back Dyke was observed to be overtopped by an average of 0.47 m during the maximum high tide observed during this study. It could be postulated that the Back Dyke was not raised since that time with any repairs or dyke raises post 1755 being focussed on the outer perimeter dykes to the east and at the Great Dyke. Additional surveying of the crest elevations of the dykes to the east of the Back Dyke would be required to further explore this uncertainty.

The authors will continue to visit the Great Dyke and the Economy area and, time and tide permitting, may further address some of the aforementioned uncertainties.

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