Coastal Geomorphology and Assessment of Proposed Dyke Construction at Lighthouse Point Provincial Nature Reserve, Pelee Island

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Abstract

In winter 1972 - 73 the barrier and dyke on the west shore of Lighthouse Point, Pelee Island, were breached due to high lake levels and severe storms, resulting in the flooding of a drained marsh area and creating what is known locally as Lake Henry. Marsh and sub-aquatic vegetation has been slow to re-establish in most of the area exposed to the action of waves propagating through the breach. As a result, it has been proposed that some form of artificial barrier be put in place to reduce this wave activity and hasten the re-establishment of a natural pond and wetland. An assessment of the coastal geomorphology of Lighthouse Point was made using historical air photographs, and field observations including profile surveying, sediment sample collection and diver observation. The Lighthouse Point barrier system appears to be an erosional feature, reflecting diminished sediment supply over the past 5,000 years and gradual loss of sediment through longshore sediment transport to the south. It is likely that the long-term natural loss of sediment has been exacerbated in recent years by a reduction in sediment supply from the area to the west as a result of armouring of the shoreline and trapping of sediment behind docks. However, reworking of the existing barrier sediments should result in natural closure of the breach and thus permit re-establishment of a natural barrier and lagoon marsh, which would be able to adjust dynamically to the net negative sediment budget. Closure of the breach through building of an armourstone dyke would likely result in severe alteration to the remainder of the system.

Introduction

This paper is a summary of a report prepared under a contract with Ontario Parks which required the assessment of coastal processes in the vicinity of Lighthouse Point Provincial Nature Reserve. More specifically, the report considers the coastal processes and structures that have controlled the evolution of the landform as well as the influence of human activities in these processes. The probable future evolution of the landform over the next 20 years is assessed, assuming that present conditions, including the presence of artificial structures, remain constant. The probable impact of a new "dividing" structure or dyke is also assessed and suggestions are given for alternative approaches and future management of the coastline of the Nature Reserve.

Pelee Island is the largest of the Erie Islands and is located in western Lake Erie approximately 15 km southwest of Point Pelee, Ontario and 30 km north of Sandusky, Ohio (Figure 1). The island is about 4300 ha in area and has a permanent population of just over 200. The highest point on the island is only about 12 m above lake level and much of it is at or below mean lake level and is protected by an extensive dyke system. The Erie Islands are formed primarily by outcrops of Devonian dolomitic limestones which have been upwarped through the Findlay Arch (Sly, 1976). The bedrock outcrops have been modified by glacial erosion and during the last glaciation – the Wisconsinan – thick layers of till were deposited between and over the bedrock outcrops (Holcombe et al., 1997).

Lighthouse Point is located at the northeast corner of Pelee Island and is 1.6 km long and 1.6 km wide at the base (Figure 2). It takes its name from a stone and wood lighthouse built at the tip of the point in the 19th Century, the base of which is still standing at the present shoreline. Most of the interior of Lighthouse Point, as well as other portions of Pelee Island, are below mean lake levels and were dyked and drained for agricultural use between 1888 and 1889 (Smith, 1899). In or just prior to 1972 the sand barrier on the west side of Lighthouse Point was breached and in November 1973 the western dyke was breached. This resulted in the flooding of the farmland on Lighthouse Point and the creation of what is known locally as Lake Henry. Armourstone was placed on the west side of the eastern dyke to protect it and cottages along the east shore of Lighthouse Point from flooding and erosion from the newly created Lake Henry.

Figure 1: Location of Pelee Island in Lake Erie

Figure 2: Lighthouse Point, Pelee Island (1966)

Post Glacial Lake Levels

The post-glacial lake level history (Figure 3), particularly of the past 3000 years, is important to the evolution of Pelee Island. As water levels rose in the lake, the glacial tills that composed most of the lakebed and surrounding area were eroded and bluffs were formed. The fine material in the eroding till was transported offshore to be deposited in the deeper waters while the coarser sand and gravel were transported along shore to create the various beaches and spits present today (Sly, 1976). Since Pelee Island is composed of the same till that forms much of the shoreline of Lake Erie, the processes of erosion, bluff formation and deposition of spits which formed the present shoreline were similar to those active along the north shore today.

Figure 3: History of Post-Glacial Lake Levels

The presence of the resistant residual buttes of Devonian dolomitic limestone near the four corners determined the present morphology of the island. The bedrock outcrops resisted erosion and protected the less resistant glacial till from erosive waves and currents. Sand and gravel eroded from till bluffs around the island and in the nearshore were transported alongshore to form barrier beaches which connect the higher areas of the resistant rock outcrops (McCutcheon, 1967). As lake levels rose they flooded the low lying areas between the bedrock outcrops and surrounding till leading to the formation of marshes in the zones protected from wave action by the barrier beaches.

Sand and gravel supply to the beaches of Pelee Island would have been quite high during the main period of transgression under rising lake levels. However, as the lake level has stabilized over the past 1,000 to 2,000 years, the supply of sand and gravel from erosion has decreased and there are no other substantial sources, for example from river inputs. As a result, redistribution of beach sediments has occurred through longshore sediment transport, leading to shoreline recession in many parts of the north and east of the island and deposition in areas such as Fish Point at the southwest corner.

Modern Lake Level Fluctuations

As is the case with the entire Great Lakes shoreline, the barrier system of Lighthouse Point is influenced by seasonal and yearly lake level fluctuations.

Annual lake levels fluctuate about 0.6 m. Over a period of a decade the mean monthly lake level can vary by as much as 1.5 m. During lower lake levels a wide beach is exposed providing a greater buffer to wave action on the shoreline. Sometimes lake levels are low enough to expose offshore sandbars such as the exposed sandbar at the tip of Lighthouse Point during 1933 - 34 (Kindle, 1936). During high lake levels and storm set-up, the beach is more narrow allowing waves to reach back beach areas more easily leading to erosion of dunes and overwash of barriers (Davidson-Arnott and Fisher, 1992).

Wind and Wave Climate

The prevailing winds are from the southwest with fetch lengths being restricted because of the numerous islands and shoals at this end of Lake Erie. While Lighthouse Point is sheltered from waves from the west and southwest (Figure 2) waves from these directions refract around Sheridan Point, generating west-to-east longshore sediment transport in North Bay. This then provides a source of sediment for the northern barrier of Lighthouse Point. Winds from the northwest blow over fetch lengths of only 25-50 km, limiting the size of waves produced. The longest fetch is to the northeast (>300 km). While winds from this direction are less frequent than those from the western quadrant, they generate the highest waves. Waves from this direction lead to a southerly transport of sediment along the eastern shoreline and are the primary control on ongoing erosion (Alexander and Knowles, 1985).

Methodology

Field work was conducted during July 23-26, 1996 to assess the current geomorphology of Lighthouse Point. The field work included a survey of 18 profiles around the Lighthouse Point barrier complex and along the eastern shoreline. Sediment samples were collected along each line for subsequent size analysis, and diver observation of bottom sediments was carried out beyond the offshore limits of the surveyed profiles. Survey lines around the barrier breach were tied in to prominent local control points to enable them to be used in producing a map of the area in 1996.

A 1:10,000 scale 1985 Ontario Base Map was digitized using the Atlas GIS software package. A number of the established control points were then used to digitize shoreline changes from vertical aerial photographs. Vertical aerial photographs of Lighthouse Point were obtained for the years 1955, 1972, 1978 and 1985. The shorelines for each of these years were then digitized using the same software and referenced to the 1985 OBM map using the common control points. Because of the focus on shoreline change, there is no distortion due to relief displacement. Radial distortion was minimized by using photographs with the shoreline near the centre of the photographs and the effects of this and tilt are largely compensated for by the software using the common control points.

Finally, a map of the 1996 shoreline was produced by combining the ground surveys with information derived from oblique aerial photographs taken on July 17, 1996. This then permitted examination of shoreline change over the period 1955 - 1996.

Results

Shoreline Evolution: 1955 to 1996

In 1955 the dykes surrounding Lighthouse Point were completely intact and the interior of the Point was almost entirely farmland (Figure 4a). High lake levels and severe storms over the winter of 1972 - 73 caused a breach in the dyke at the southwest corner of the lagoon (Alexander and Knowles, 1985). The beginning of this breach can be seen in Figure 4b where only the outer sand barrier has been breached. The total breach of the sand barrier and dyke and the resulting flooding and formation of Lake Henry, which occurred in 1973 is clearly evident in 1978 (Figure 4c). By 1985 the breach had widened significantly, exposing much of the west side of the lagoon to Lake Erie (Figure 4d). A sandy spit had extended the southwest shoreline northeast along the line of the old dyke. In the summer of 1996 two new spits were observed that began at the edges of the breach and projected into the lagoon (Figure 4e). The northern spit extended from the western barrier to within 100 m of the eastern shore of Lake Henry nearly enclosing the northern portion of Lake Henry.

Present Shoreline of Lighthouse Point

The eastern side of Lighthouse Point consists of beaches up to 20 m wide north of Lizard Point and armourstone shore with narrow beaches immediately south of Lizard Point. Armourstone revetments protect most of the cottages and the abandoned lighthouse at the northeast edge of the point. On this shoreline sand is found up to 100-125 m offshore. At this point, sand is replaced by a 30-40 m wide band of cobble-covered glacial till. Beyond the band of till is exposed bedrock in water depths of 3-4 m. South of Lighthouse Point the sand cover extends further offshore.

Sand dunes in the vicinity of the lighthouse rise to a height of 4-5 m above the lake level and are covered by large trees and undergrowth. The old dunes are preserved along the western shoreline in the vicinity of the lighthouse, but erosion here has resulted in narrow beaches developed in fine to medium sand. The sand is derived from the dunes as well as recent extensive deposits of zebra mussel shells. Further west the old barrier and western dyke are eroded. A narrow sandy barrier has developed some 30-40 m east (onshore) of the location of the old barrier apparently fed by sediments eroded from the old dunes near the point. There is a very gentle gradient offshore and dead trees are visible where the breached dyke was located. In 1996 the new barrier was rapidly being colonized by a variety of grasses and shrubs. The spit at the north end of the breach, which is building into Lake Henry, is fed by sediments moving westward into the breach and by the summer of 1996 this had extended almost to the eastern dyke.

At the south end of the breach a new barrier has also developed landward of the original barrier and dyke. Presently erosion of this barrier is supplying sediments to the southern spit which is also building into Lake Henry and enclosing a sheltered area at the southwest corner. The southern spit has a similar composition to the northern one, but is shorter and supports less vegetation than the northern spit. A 0.75 m high bluff has developed on the shoreline immediately to the southwest of the spit and trees are being undermined. Conditions offshore on the southern side of the breach are the same as the northern side and water depths across the breach are fairly constant and remain under 2 m.

Figure 4: Evolution of Light House Point, Pelee Island (a) 1955, (b) 1972, (c) 1978, (d) 1985, and (e) 1996 with location of profiles 3-15.

Post Glacial Evolution of Lighthouse Point

Based on background information on the geology and geomorphology of Pelee Island, the history of lake levels in the Erie Basin, and information gathered for this study, it is possible to put forward a general picture of the evolution of the present coastal features at Lighthouse Point. Because of limitations in the amount of information available from previous work and of measurements carried out particularly for this study, such a picture is somewhat speculative and lacking in details, and thus should be treated with some caution. Nevertheless, the broad conclusions seem reasonable in light of the evidence available and they may be helpful in assessing what is likely to happen in the next few decades.

The most significant feature of the evolution of the Lighthouse Point region is that it appears to be an erosional feature. The Point has probably undergone erosion and a reduction in size over the past 2,000 - 3,000 years as lake levels have risen slowly and as the sediment supply from erosion of the nearshore and beach has decreased. This is in contrast to Fish Point at the south end of the island, which has a similar shape. At Fish Point there was an abundant sediment supply leading to progradation of the shoreline, as is evident from the extensive beach ridge deposits in coarse sand and gravel. Fish Point thus appears to have formed as a cuspate foreland similar to Point Pelee on the north shore of Lake Erie with continuous extension of the point and progradation of the sides.

Lighthouse Point, while superficially similar in shape to Point Pelee, has a number of features that indicate a relatively small sediment supply and a shoreline that is transgressive rather than progradational. These features include:

1. the absence of any extensive sand deposits forming a depositional platform lakeward of the tip of the point;
2. the low height of dunes on the east and west barrier systems and their narrow width even prior to the high lake levels in 1972 – the only area of significant dunes is near the tip where wave convergence creates somewhat wider beaches;
3. the absence of extensive sand deposits or dune ridge sequences in the area surrounded by the barriers – instead there was an extensive marsh which was at or below the mean lake level and thus was dyked; and,
4. the presence of bedrock and remnants of till deposits offshore along many of the profile lines on the point.

Over the past 3,000 - 4,000 years, the lake level at the western end of the basin has risen slowly due to isostatic adjustments. This rise in lake level has affected the whole of Pelee Island, resulting in the landward migration of barriers and the flooding of lowlying land between outcrops of the Devonian dolomite. This flooding created the extensive marshes that occupied so much of the island before they were dyked and drained about 100 years ago. At the beginning of the period the shoreline in the vicinity of Lighthouse Point probably extended further north and may well have been connected to a bedrock high point that now forms an extensive shoal northeast of the present point (Figure 2). It is likely that rising lake level and erosion of the till deposits covering the bedrock would have led to flooding of the low lying area, creating first an island and then, with further erosion of the till cover, a shoal. Meanwhile, flooding of the area behind the beach and dune system would have led to the development of the east and west barriers. Erosion of till deposits on the lake bed as water levels rose would supply sand and gravel to the beaches but this supply does not appear to have been particularly extensive, because of the absence of any large accumulations of gravel deposits. Instead, the sediments making up the barrier systems at Lighthouse Point and forming the beach and dune systems along the east coast are generally well sorted sands suggesting that there has been extensive reworking of sediments as the shoreline retreated, rather than the generation of a continuous new supply. This again is in contrast to Fish Point, where there has been continuous sediment supply from erosion of the nearshore and from low bluffs.

Controls on Breaching of the Western Barrier

The landward migration of the western barrier and breaching of the dyke in 1972 suggest a relatively limited sediment supply. In part, this is a reflection of the continued evolution of the Lighthouse Point barrier system by natural processes. As the surficial till cover in the nearshore has been eroded, exposing the underlying bedrock, supplies of sediment from this source have decreased over time. However, the extent of overwash and retreat of the Lighthouse Point barrier system during the recent high water periods may have been increased as a result of human activities over the past century. Offshore dredging, armouring of the shoreline and pier construction to the west of Lighthouse Point all reduce sediment supply.

At present there is a limited supply of sediment to Lighthouse Point from the west –perhaps in the order of a few hundred m^3 /yr – which appears to be the direction of net sediment movement in North Bay. The volume of sediment in the south spit is on the order of 3,000-4,000 m^3, and it has been built over a period of at least 4 - 5 years, giving an annual sediment supply of less than 1,000 m^3. However, most of the sediment appears to have been derived from erosion of the barrier so that the net input from the west will be a small portion of this.

Both field observations and an analysis of historical aerial photographs indicate that sediment does move in both directions around the point, but net sediment transport is probably to the south along the east shore. Beaches become wider and quantities of offshore sand increase from Lighthouse Point towards Middle Point, suggesting that net sediment transport is to the south. This loss of sediment is small over the short-term, but over the long-term leads to a gradual reduction in the volume of sediment stored in the Lighthouse Point barriers and thus a gradual decrease in the size of the feature.

It is probable that under natural conditions – i.e., without the dyke and the cultivated land behind it – the western barrier would have responded to the high lake levels of 1972 and 1985 in a different manner. Instead of breaching completely and developing a wide inlet, the barrier might have migrated eastward through dune cliffing and overwash. The presence of cultivated land behind the dyke rather than marsh meant that when a breach occurred the flooding of the agricultural areas produced a large body of open water – Lake Henry. This lake lacked the dense stands of rushes and aquatic vegetation that would have been present in a more natural setting and which would have absorbed wave energy and promoted sand deposition. During periods of easterly winds, current outflows from Lake Henry probably led to scouring of a channel and there was insufficient sediment supply along the barrier to repair the breach.

Another factor that may have promoted the formation of the inlet is oxidation of organic matter during cultivation due to the lowered water table. This may have led to compaction of the largely organic sediments in the drained area, thus promoting a larger deeper water body. Once the area behind the barrier became flooded, it was expected that submergent and emergent vegetation typical of a protected pond and wetland area would soon establish. However, while this has begun to occur in the areas protected by the new spits growing into Lake Henry, there is little evidence to date of successful colonization in the main body of water. The primary cause of this is thought to be the effect of wave action propagating through the wide inlet entrance and the resultant high turbidity of water within Lake Henry. High turbidity results from wave and current action and may be exacerbated at times by carp, which can get into the ponds through the breach. Closure of the breach and the reduction of wave and current action would likely reduce turbidity. The protection from wave activity would also promote the establishment of sheltered aquatic and emergent vegetation. Consequently consideration has been given to the possibility of closing the breach artificially.

Assessment and Recommendations

Dyke Construction

The proposed dyke structure would close the large breach and cut off Lake Henry from wave action generated in Lake Erie. On the positive side, the dyke would stabilize the shoreline and likely lead to the acceleration of marsh re-establishment in the central section of the water body. However, since the dyke will be exposed to direct wave action it will have to be lined with armourstone and tied in to the area of hardened shoreline near the private docking structure just to the west of the nature reserve. While there is still considerable debate as to whether dykes/seawalls lead to an acceleration of erosion of the whole profile (e.g., Wood, 1988; Kraus, 1988) there is general agreement that reflection does result in deeper water close to the structure and an absence of a beach. This can be seen along the armoured area of the west coast of Pelee Island where beaches are absent and waves break directly on the dyke.

The disadvantage of the proposed dyke is that it will eliminate sandy beaches and areas of pioneer plant species along the west shore with all the attendant implications for the associated animal, insect, and bird population. Moreover, sand moving along the proposed dyke from the west will be deflected offshore and not continue on to nourish the beach on the east shore. Ultimately, this will require the dyke to extend around the point to protect this area, thus further reducing the sandy beach and dune habitat and threatening the cottages on the east shore. Thus, the presence of the dyke would eliminate the unique habitats provided by the sandy beaches and spits and replace them with one type of environment in the area behind the dyke. The environment would be different from that which existed before dyking and drainage of the area, and probably less diverse in flora and fauna compared to the current environment.

Beach Nourishment

While closure of the breach in the barrier system is likely to eventually occur under natural conditions, the rate of this process could be increased by sand nourishment to the western barrier in the vicinity of the breach, which could fill in the existing inlet opening creating an artificial beach. Such a course of action would speed up development of a new barrier and thus also the development of a wetland in the area behind it. This course of action would, however, require careful analysis of the amounts of sediment required and identification of a source for the nourishment material.

If the costs for nourishment are reasonable, this course of action is preferred. It cuts off wave energy from Lake Henry, thus promoting the re-establishment of marshes in this area; it establishes a natural sandy barrier shoreline that provides habitat for a number of bird and animal species as well as the vegetation that is common to these areas; and it has very little potential to harm the environment, even if it fails.

Natural Evolution

There are a number of natural morphological changes that may occur in the next 20 to 40 years. It is possible that the continuous barrier may reform along the west shoreline if lake levels fall below the long-term mean for several years. With the absence of substantial supplies of sediment from the shoreline to the west, much of the sand for this rebuilding of the barrier must come from erosion of the shoreline and dunes in the vicinity of the lighthouse. If lake levels are low for a significant amount of time then colonization by vegetation and building of new dunes will occur. This may permit the new barrier to survive new periods of higher lake levels. The building of a relatively stable barrier could take ten or twenty years and it is possible that this may not occur in the foreseeable future.

In the meantime, the current northern spit will probably extend further eastward and attach to the eastern dyke by the end of 1997 and the southern spit may extend further to the southeast and attach to the southern shore of Lake Henry in the next few years. When this occurs, two naturally protected ponds will be formed within which submerged aquatics as well as emergent wetland species can be expected to colonize. The enclosed areas will also be protected from the activities of carp. The spits and the associated wetland areas behind them thus will form a diverse set of natural environments which can be expected to support a wide range of plants, aquatic life and habitat for waterfowl and shorebirds. The areas already protected by the spits show evidence of developing extensive marsh communities and some submerged aquatics while the spits themselves are being colonized by a variety of plant species.

Establishment of submergent and emergent vegetation in the remaining area of Lake Henry will be slow as long as it is exposed to wave action. Developments in this area will thus depend on when and if the breach in the barrier is infilled.

Lighthouse Consideration

If the barrier is left to evolve naturally over the next few decades then consideration will have to be given to the fate of the lighthouse at the end of the point. Increased armourstone protection of the lighthouse will be required over the next few years if it is to remain in its present location and condition. The addition of more armourstone would result in increased erosion of the surrounding beach and dunes due to wave reflection and eventually create a "lighthouse island" where the lighthouse and surrounding armourstone are separated from the receding shoreline. In these circumstances it would seem more cost-effective and environmentally responsible to preserve the lighthouse by relocating it to the base of Lighthouse Point. Here, restoration and incorporation of the structure into an interpretation facility would be possible. However, it is not clear that the value of the remaining structure can justify the cost of preserving it.

Recommendations

The present shoreline of Lighthouse Point is continuing to evolve following the breach of the natural barrier and west dyke in 1972. It is difficult to predict exactly how the area will evolve over the next two decades but it should continue to provide a rich ecological environment based on increasing wetland development and maintenance of some form of sandy barrier system. There does not appear to be any threat to the existing dyke along the east shore or to the cottages along it. Allowing the barrier to continue to evolve under natural conditions seems to be the simplest and least costly course of action and one that is perhaps most desirable in terms of the preservation of the sandy barrier environments that are unique to Pelee Island. We conclude the following recommendations:

Recommendation 1: Leave the west barrier of Lighthouse Point alone so that it may evolve naturally.

Recommendation 2: If a structure is built to close off the present inlet on the west side of Lighthouse Point, it should be designed by a professional coastal engineer and the design should be reviewed by a committee which includes a biologist, coastal geomorphologist and local interests.

Recommendation 3: Give consideration over the next five years to removal of the lighthouse from its present position in order to avoid the continued need to protect it and the possible impact of this protection on the adjacent beaches.

Recommendation 4: The Ontario Ministry of Natural Resources should develop a management plan for the Lighthouse Point Nature Reserve before any decision is made on the construction of a structure to close off the breach in the western barrier.

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References

Alexander, L.J. and W.L.C. Knowles. 1985. Pelee Island shoreline erosion study. Proceedings from the Canadian Coastal Conference. St John's, Nfld: 475-494.

Calkin, P.E. and B.H. Feenstra. 1985. Evolution of the Erie Basin, Great Lakes. In Karrow, P.F. and Calkin, P.E., eds. Quaternary Evolution of the Great Lakes; Geological Association of Canada Special Paper 30: 149-170. St John's, Newfoundland.

Chapman, L.J. and D.F. Putnam. 1984. The Physiography of Southern Ontario. Ontario Geological Survey Special Volume 2. Toronto: Ontario Ministry of Natural Resources.

Coakley, J.P. 1992. Holocene transgression and coastal-landform evolution in northeastern Erie, Canada. In Fletcher, C.H. III and Wehmiller, J.F., eds. Quaternary Coasts of the United States: Marine and Lacustrine Systems. SEPM Special Publication No. 48: 415-426. Tulsa, Oklahoma.

Coakley, J.P. and L.F.M. Lewis. 1985. Post glacial lake levels in the Erie Basin. In Karrow, P.F. and Calkin, P.E. eds. Quaternary Evolution of the Great

Lakes; Geological Association of Canada Special Paper 30: 196-212. St John's, Newfoundland.
Holcombe, T.L., Warren, J.S., Taylor, L.A., Reid, D.F. and Herdendorf, C.E. 1997. Lakefloor geomorphology of Western Lake Erie. Journal of Great Lakes Research, 23: 190-201.
Hough, J.L. 1958. Geology of the Great Lakes. Urbana: University of Illinois.
Kindle, E.M. 1936. Geology of Pelee and adjacent islands. 45th Annual Report of the Ontario Department of Mines, Toronto, pt. 7: 75-121.
Kraus, N.C. 1988. The effects of seawalls on the beach: an extended literature review. Journal of Coastal Research. Special Issue no. 4: 1-28.
McCutcheon, R. 1967. The evolution of Pelee Island. Ontario Geographer. 1: 12-27.
Rukavina, N.A. 1976. Nearshore sediments of Lakes Ontario and Erie. Geoscience Canada. 3(3): 185-190.
Sly, P.G. 1976. Lake Erie and its basin. J. Fish. Res. Board Can. 33: 355-370.
Smith, T. 1899. Point au Pelee Island; An historical sketch of and an account of the McCormick Family who were the first white owners of the Island. Amberstburg, The Echo Printing Company, Ltd.
Stone, W.G. 1949. Geographical Survey of Pelee Island. Unpublished M.Sc. Thesis, Department of Geography, University of Western Ontario, London.
Wood, W.L. 1988. Effects of seawalls on profile adjustment along Great Lakes coastlines. Journal of Coastal Research - Special Issue 4: 137-146