PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

BEACH DATA COLLECTION PROGRAMME IN CANADA

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INTRODUCTION AND HISTORICAL SKETCH

A beach study programme was initiated in May 1970 by the Ontario Department of Lands and Forests. The primary purpose of the study is to determine the extent and causes of the obvious process of erosion in the area of Point Pelee located on Lake Erie.

Also in May 1970 construction was begun on a low-cost scheme to protect a portion of the point known as Marentette Beach. A second purpose of the study is to evaluate the effects and effectiveness of these structures.

It is obvious that a field study such as this can also contribute considerably to the amount of field data available on such basic topics as longshore current velocities and distributions, onshore-offshore and littoral movement of sand, relationships between wind and wave fields, etc., with very little additional expenditure. The third and more scientific purpose of the study is therefore to gather field data in support of basic research.

The study is set up with limited funds available, however, a great deal of co-operation has been received from other agencies of both the Provincial and Federal governments. Much of the equipment used is rather crude in nature and many of the results hinge on innovation by the field crew. This crew consists of four university students. Because they are only available during the summer months, the study is carried out between the beginning of May and the middle of September of several successive years.

Point Pelee is located near the western end of the Canadian North Shore of Lake Erie. It forms with Pelee Island and a number of smaller Islands, the division between the Western and Central basins of the Lake (Fig. 1).

Geologically, the history of the area is complex, involving a number of glacial advances and retreats and the formation of several glacial lakes. In all, at least 26 lake levels existed long enough to form recognizable beaches.

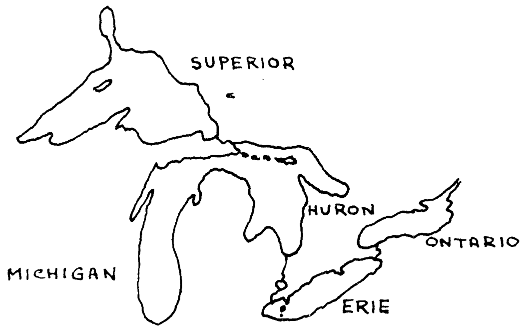


Fig 1a: GREAT LAKES

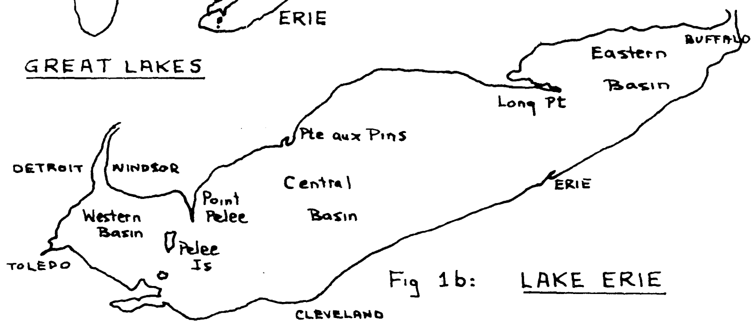


Fig 1b: LAKE ERIE

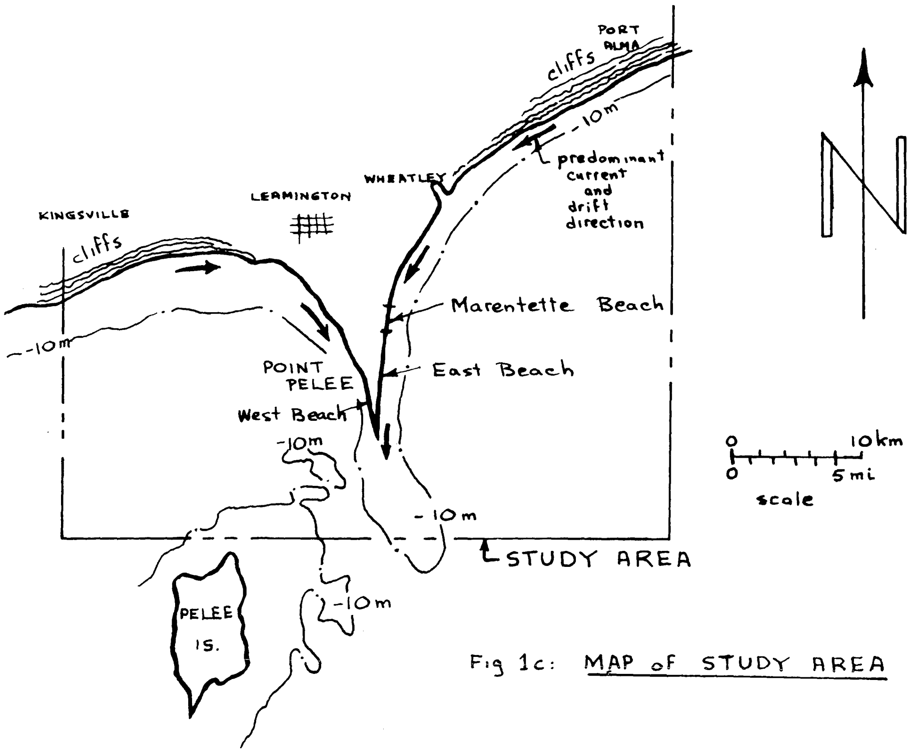


Fig 1c: MAP of STUDY AREA

The present rate of riseof the water level in the area of Pelee has been about 60 cm per century for the past four centuries. This is caused by isostatic rebound resulting in a progressive tilting of the basin toward the West.

The probable history of the point is as follows. About 10 to 12000 years ago, Lake Erie rose suddenly about 50 m. to approximately its present level. This rise in water level formed a shore consisting of a number of bluffs which proceeded to erode. In the Point Pelee area the surface currents carried the eroded material from both directions, forming the peninsula with an entrapped lagoon possibly around an existing protrusion (Fig. 2).

From aerial photographs (Fig. 3) it would appear that in recent times the point has accreted toward the West. This is a conclusion reached by several previous investigations, i.e. the East beach of the point erodes and the West beach accretes. This is a rather simplified picture and at present it would appear that both sides are subject to erosion. Since Point Pelee is a National Park and the Pelee marsh one of North America's most famous bird sanctuaries, it is understandable that considerable concern is expressed about its preservation, and further understanding of the coastal processes in the area is very desirable.

DESCRIPTION OF THE STUDY

Beach Profiles

Since from the beach profiles wave conditions, wave erosion and ice erosion can be deduced, as well as such overall transport patterns as sand waves and longshore bars, the measurement of beach profiles at regular intervals is an absolute necessity. Beach profile measurement is also the method used to determine the effectiveness of the protection structures at Marentette Beach.

A base line was surveyed for reference and the locations of the profiles to be measured were staked out on the base line. For the land portion of the profile, a level is set up and sights are taken on a level rod at intervals from the base line to approximately 1.5 m. depth of water.

The total measured profile extends to a water depth of 8 m . The portion of the profile between -1.5 m. and -8 m . is measured from a pontoon boat. For this operation two range poles are set up on the line of the profile to be measured; one near the shore line, the other near the base line, or further back if necessary. Other range poles are set up on the base line at various distances from the profile line. The boat is steered so that it is on the profile line and as the boat sails into shore, or away from shore, depth readings are taken as well as sextant sightings on the range poles to determine distance from the base line.

An alternate arrangement is also used. Two theodolites are set up on the base line and the distance of the boat from the base line is determined by

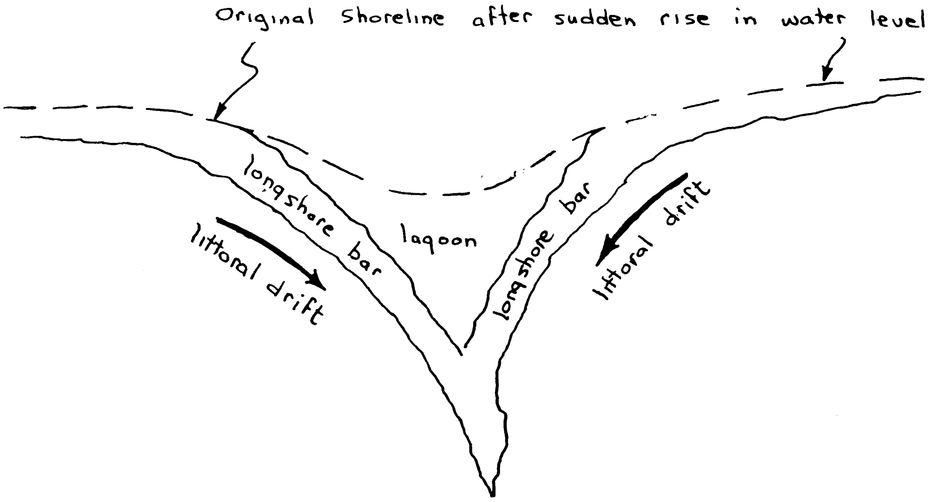


Fig 2 : PROBABLE ORIGIN OF POINT PELEE
± 10,000 B.C.

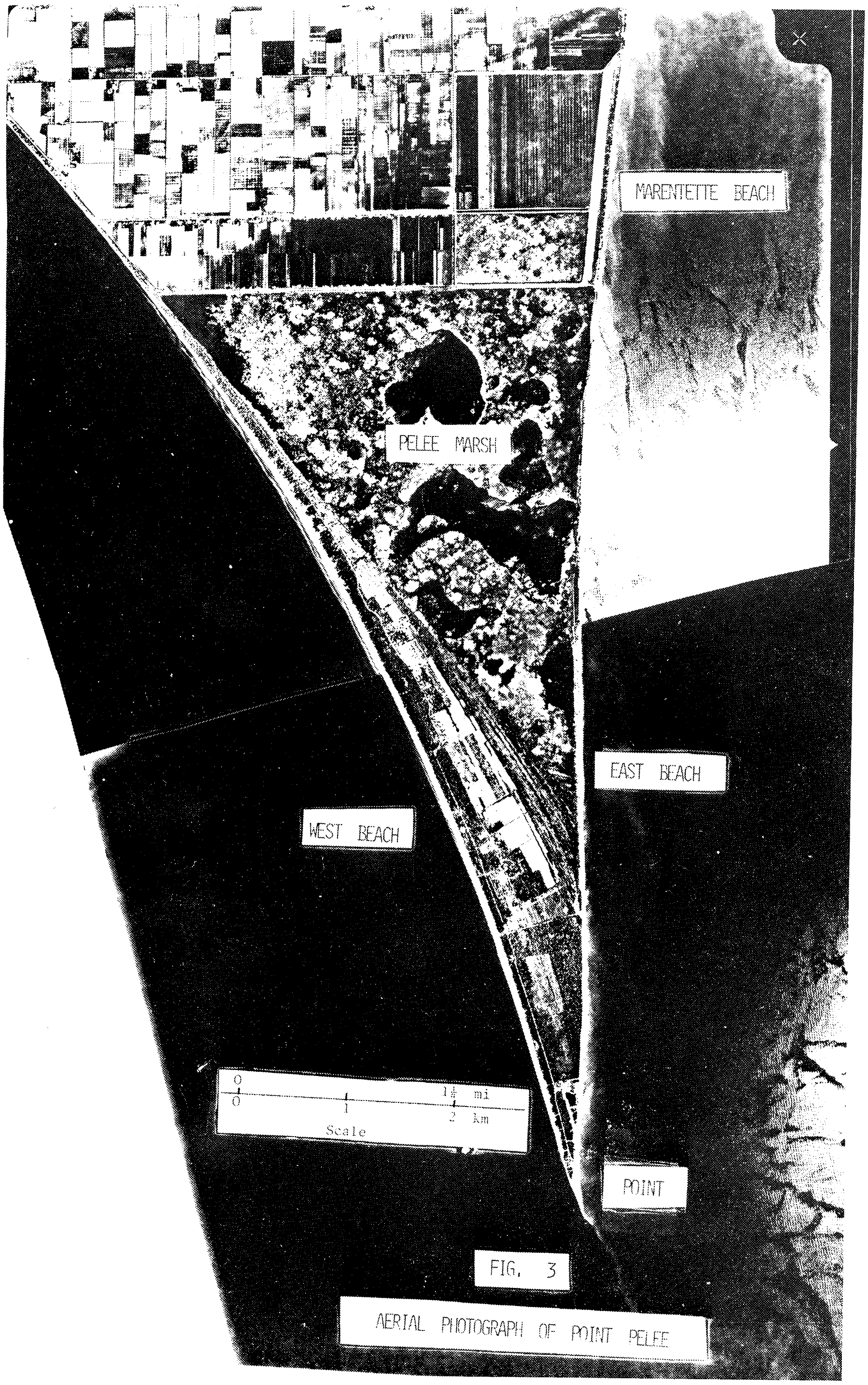


FIG. 3

AERIAL PHOTOGRAPH OF POINT PELEE

triangulation. The sextant when used properly is superior to instruments on shore. The whole survey party is together, avoiding slip-ups in communication, and the sextant allows the instrument man to pick one of several targets, thus keeping the measured angles between 30 and 60 degrees for maximum accuracy. The instruments on shore need to be continually moved in order to obtain comparable accuracy.

In addition to the depth measurement, the bottom material composition is also examined by divers, in order to determine the width of the margin of moveable material.

The beach profiles are plotted up as soon as they are taken and differences with previous profiles are planimetered to assess erosion or accretion (Fig. 4). Also detailed contour maps are drawn to investigate the existence of sand waves and their movement. With the extent of available time between the beginning of May and the middle of September it is just possible for the Pelee area to determine winter or early spring beach profiles taken as soon as the crew arrives and late summer profiles taken immediately before they leave.

Wind and Waves

The forces moving beach material in the Pelee area are a result of the motion of wind generated waves. Since it is impossible to understand the movement of beach material without knowing the wind and wave conditions and since also the presently known relationships between wind, waves and sediment transport are far from solved a concentrated measuring programme was initiated in this area. All measurements are made morning, noon and evening, but during periods of storm, heavy wave action or rapidly changing conditions, the measurements are made more often, if possible hourly.

Although ideally wind velocity, velocity distribution, and direction should be measured continuously, wind velocities are measured at 10 meters above the lake surface using a hand anemometer. Wind direction is measured using a weather vane.

Wave conditions can be measured using anything from very rudimentary observation techniques to highly sophisticated instrumentation.

For this study waves are mostly measured using a graduated pole outside the surf zone. During a portion of the study a recording accelerometer is available to give inshore wave spectra and wave height distributions, as well as a more meaningful interpretation of the staff readings. Also during a part of the study an accelerometer station will be set up in deep water to give deep water wave conditions.

The breakers are carefully noted with respect to height, depth and angle at breaking, width of the breaker zone and type of breaker. The maximum uprush distance and maximum time of uprush are also recorded.

Longshore current velocities and velocity distributions with distance from

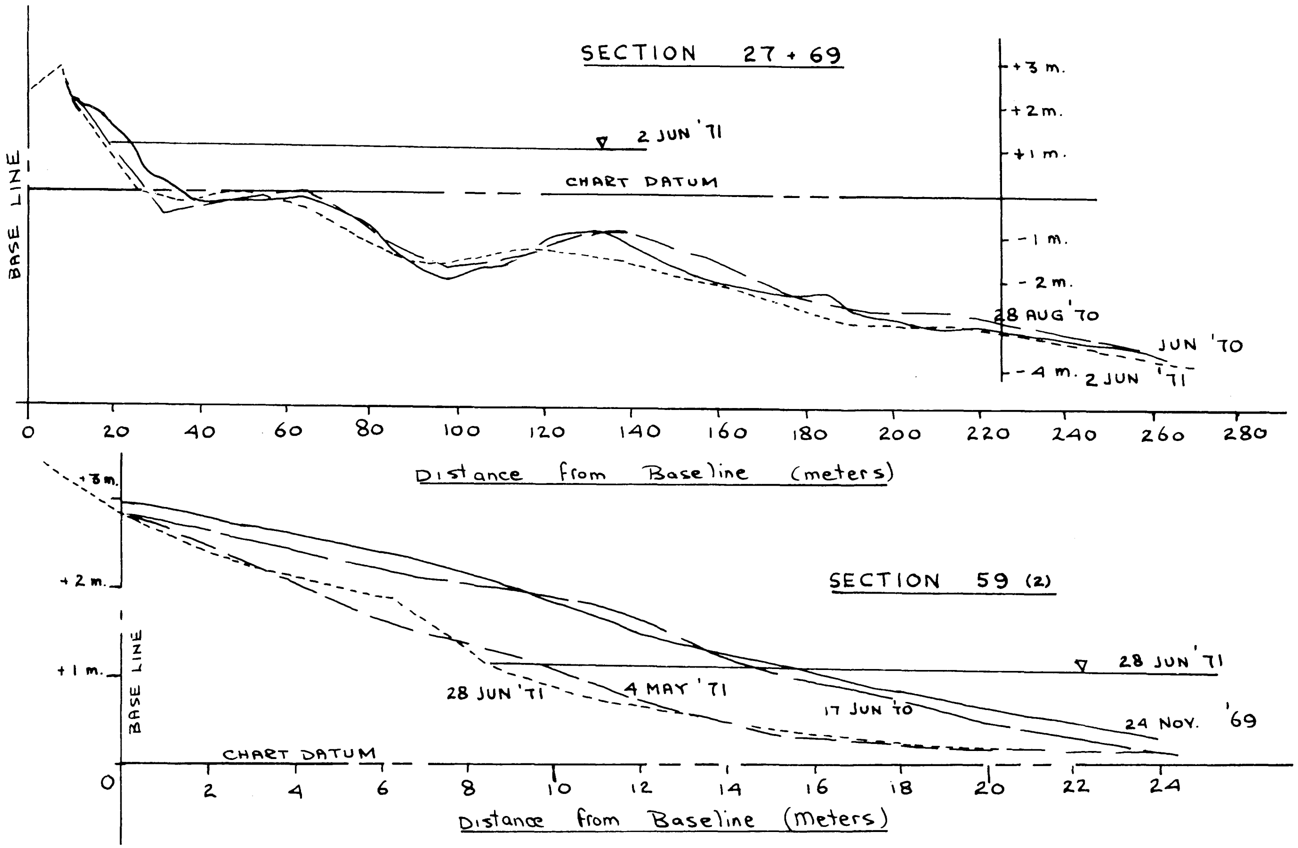


Fig. 4 PARTIAL BEACH PROFILES

shore are also measured. Water filled balloons are used in the breaker zone and shoreward for this purpose. Outside the breaker zone, current crosses are used as well as balloons.

Finally, using underwater photography of particles slightly heavier than water the orbital motion at the bottom, mass transport velocities and movement of the bottom material are recorded at various depths. This work is directly complimentary to theoretical and laboratory work in progress at Queen's University.

An example of the summary sheets produced is given in Fig. 5.

Water Levels

Because Lake Erie is a shallow lake, subject to large water level fluctuations, as a result of various modes of oscillation, water levels are measured morning, noon and evening daily and during periods of rapid variation, they are often monitored continuously. The equipment consists of a simple standpipe in the beach or on a structure, penetrated some distance into the beach or subsoil of the structure to dampen the rapid variations in level caused by waves. The water levels measured are tied in at regular intervals to a government gauge in the vicinity.

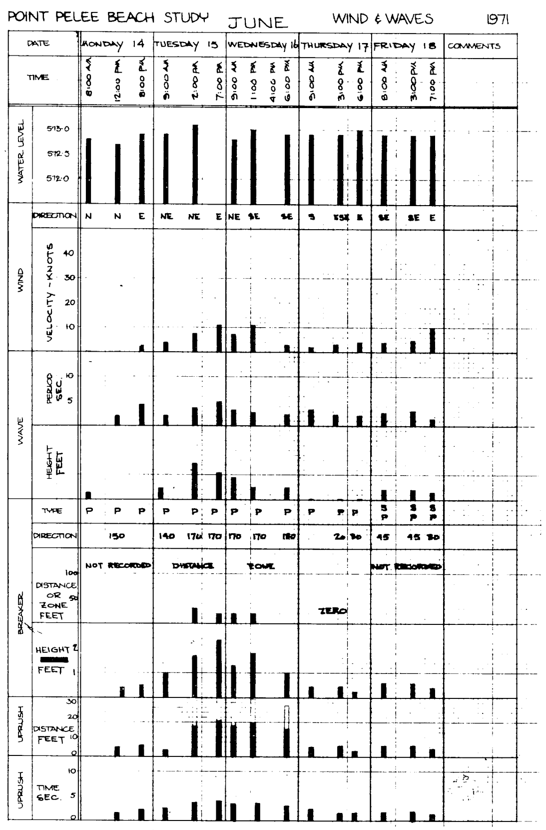
Near Shore Current Patterns

In addition to the current measurements performed at the test site an overall picture of longshore current patterns is obtained. For this purpose water filled balloons are used. The longshore currents are observed for several storms at regular distance intervals throughout the study area. This whole survey is repeated throughout the duration of each storm, as often as possible and positions of rip currents, and rip current velocities are noted.

Sediment Motion

The motion of sediment is related to the wave action and the longshore current pattern, but although many relationships have been proposed in the literature, exact relationships that have a universal applicability are not at all clear. Thus to make a realistic estimate of sediment transport for a particular storm for which wave and current conditions are known is already difficult but to estimate long term sediment transport, using unknown average annual wind fields and wave conditions is virtually impossible at this time.

At Point Pelee the difficulties are aggravated by a beach material that is extremely mobile and by apparently radically different current patterns for normal wave conditions and for storm conditions. As is the case on many beaches, during normal weather conditions, substantial sediment movement takes place, but during storm periods tremendous amounts of material are set into motion. For instance, along the East side of the point, it is found that the longshore current (and littoral transport) is usually from South to North, but during periods of major wave action, when waves come from a north-easterly to



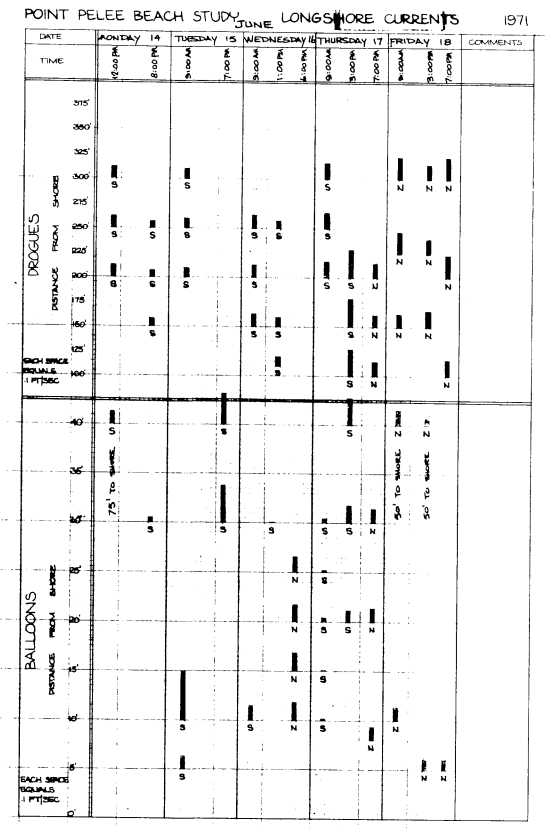


Fig 5: EXAMPLE of DATA SHEETS

easterly direction the transport is from North to South and in a few hours more material is transported to the South than was brought from the South in months. The total process in the Pelee area is therefore complex and to determine the sediment transport rates and directions in the Pelee area is rather difficult.

Two methods are available to ascertain transport rates and directions with some degree of success. It is possible to evaluate sediment transport by constructing a total littoral barrier such as a long groin. If the littoral transport is predominantly in one direction with little onshore-offshore motion, this method gives an accurate estimate of the quantity and direction of sediment transport in the region. The success of this method in the complicated pattern at Point Pelee remains to be seen and basically depends on how well the various components of transport can be separated.

A study groin was constructed for this purpose (Fig. 6) and the results of accretion and erosion near this structure have been plotted. Subsequent construction of protection structures in the vicinity has interfered with this part of the study, however, with some careful evaluation of the accretion and erosion patterns it is still possible to assess the total transport with some degree of accuracy.

The detail sediment motion can be assessed using tracer techniques. Some of the indigenous material has been excavated and labelled with a fluorescent dye (Rhodamine B). The material is replaced where excavated and a number of sampling programmes have been set up to determine the movement of the tracer. A grid is laid out as shown in Fig. 7 and samples weighing approximately 100 grams are retrieved at the node points of the grid at certain time intervals. The number of tracer particles in these samples is counted under ultraviolet light and some samples are sieved to give the granulometric composition.

The tracer study will be carried out on regular stretches of beach, as well as in the vicinity of the point. Near the point some of the work will involve relatively deep water and it may be necessary to use radioactive tracers which are less labour intensive.

Material Sources

From preliminary observation it appears that the material feeding the beaches in the Pelee area is indeed supplied by cliff erosion. The quantity and quality of the supply material must therefore be assessed. Cliff elevations are determined by simple measurements at intervals of 1000 m. along a stadia survey. The rates of recession are determined from aerial photographs and resident interviews. The composition is obtained by cutting 25 kg samples from the top, middle and bottom of the cliffs at several locations. Smaller samples of 3 to 5 kg are taken out of the beach below the cliffs as well as at Wheatley, East Beach and the point (Fig. 1). Further, water samples are taken in 1 1/2 m. of water and several distances further out from

Fig. 6 Study Groin

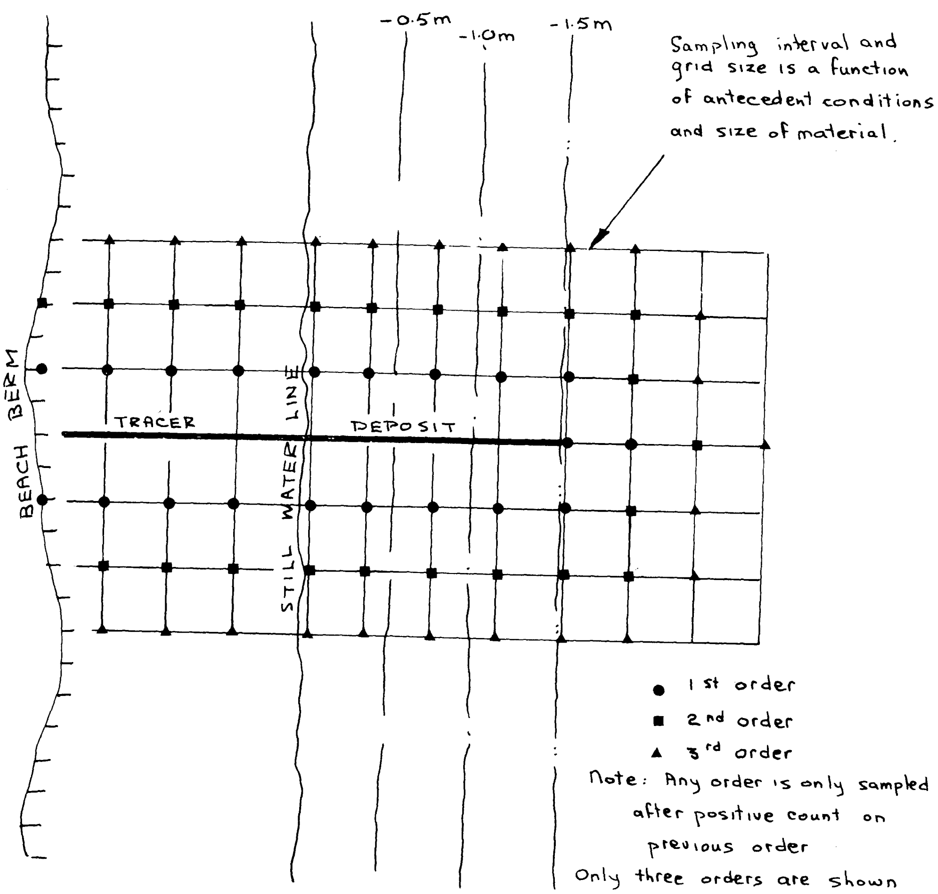


Fig 7 : FLUORESCENT TRACER SAMPLING GRID shore. All samples are analyzed as to mineralogical and granulometric properties.

Material Sinks

As may be seen from Fig. 1, the lake acts as a material sink. The sand forms a long shoal off the end of the point and eventually all the material eroded from the cliffs disappears into deep water at the end of the shoal. But during most of the year the littoral drift is North. Thus it may be expected that the shoal acts as a feeder beach during most of the year and only during violent storms from the East does the material move into deeper water. The tracer study will shed some light on this process. Eventually it may then also be possible to determine if sand mining operations, which take place near this shoal, have a deliterious effect on the stability of the Pelee beaches.

Ice

The ice conditions at Point Pelee vary. During severe winters the lake freezes over entirely, but during most winters ice is formed at the shore. This young ice is usually blown out to deeper water and returned to shore as small pieces. These small pieces of ice form a buildup on the shore and on structures (Fig. 8) which can become more than 10 m. high. Ice conditions are observed by volunteers and any damage to structures is noted.

Structures

At Marentette Beach (Fig. 1), a number of low-cost shore protection structures have been built consisting of various combinations of gabion mattresses, groins and seawalls, wooden pile groins, wooden sheetpile groins and headwalls, and timber crib groins. This experimental protection grouping is about 2 km. long and will give a good indication of cost benefit for medium exposed areas of shore.

RESULTS TO DATE

The beach profiles and attendant dives indicate that the beach extends into the water at a rather steep slope and that the sand ends at a depth of about 5 m. Beyond that depth, the bottom consists of a solid clayey glacial deposit. This would indicate that the actual amount of material in transit from source to sink is rather limited. Comparisons between profiles taken at the same location have not been made except in the area of Marentette Beach where the structures were built. From the detailed profile maps there appears to be a definite pattern of sand waves, migrating in a southerly direction.

The study of wind, waves, water levels and currents has not yet yielded firm results, but some preliminary results are available. As an example, the maximum longshore current velocity at the test site is plotted against the

Fig. 8 Ice Buildup on Shore

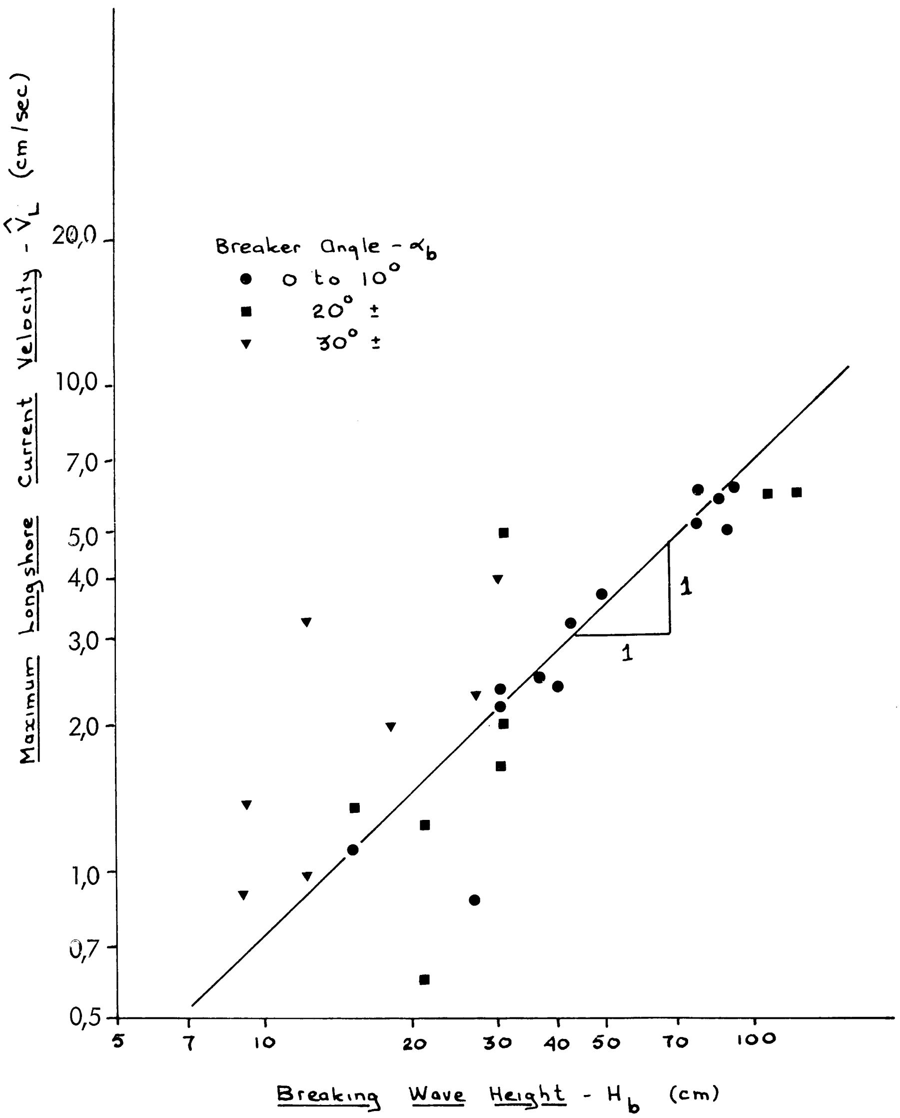


Fig 9 : LONGSHORE CURRENT VELOCITY

height of the breaking wave in Fig. 9 . It may be seen that this maximum velocity is a direct function of the wave height at breaking and that the angle of approach is not nearly as important as is normally stated. A great deal of additional data is necessary here, but it is interesting to find that the field data quoted by Galvin [1, pp.18 and 19] indicate the same trend, i.e. that longshore current velocities are rather insensitive to the angle of the breaking.

The results with respect to sediment motion have not yet been analyzed in detail and the same is true for the sources and sinks.

Although the winter was not severe, the following effects of ice have been noted. The ice pack when it recedes takes with it a substantial amount of surface beach sand from high up on the beach. Also, gabion structures that are constructed late in the season are very susceptible to ice damage. A gabion mat tends to work its tip into the sand in a relatively short time. If the time available is not sufficient, however, or if the sand supply is insufficient, the ice will be able to attack the seaward end of the gabion and damage it. The main body of a gabion structure appears to resist damage from ice effectively and only a very few broken wires were noted.

A number of rock filled cribs were constructed at Marentette Beach and piles were used to pin the structures into the beach for stability against sliding and overturning by ice. The spacing of the piles was varied from structure to structure and in the past mild winter, no damage was noted to any of these.

From the Marentette Beach protection it appears that a number of schemes could be used with reasonable success and visual observation indicates that the rapid beach erosion has at least temporarily been stabilized. The detailed calculations are not yet completed.

CONCLUDING REMARKS

From the experience gained in the process of this study it may be stated that for proper understanding of beach processes in an area, at least a pilot study must be made in which most parameters listed in the section 'Description of the Study' must be measured to some extent.

Although a great mass of field results of this type are undoubtedly available to individual organizations, it is at present still impossible to state beyond doubt what the sediment transport patterns are for an area of coast, when average and some continuously measured wind and wave conditions are known.

It appears from this study that "beach-protection-at-low-cost" is feasible and an extended study of this type of protection is overdue. The area of application of this kind of protection is in the private sector such as hotels, resorts and parks. These organizations are very likely to opt for economical beach protection "wonder works" advertised in many countries and no one has tested these 'structures' in a consistent and scientific manner to determine their actual value.

Finally, although a number of creditable attempts have been made to translate research into engineering expertise, this area needs more concentrated effort. The only vehicle to bring about this translation is parallel, theoretical, laboratory and field research. Field research has been lacking, basically because of its great cost. It is now possible, however, to perform reasonable field research using skeleton staff and good but inexpensive equipment. Perhaps the results do not achieve the last decimal place, but often the additional accuracy is unnecessary.

ACKNOWLEDGMENTS

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