CHAPTER 69

BEACH CHANGES AND WAVE CONDITIONS, NEW BRUNSWICK

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ABSTRACT

The coast line of Kouchibouguac Bay, New Brunswick, within the southern Gulf of St. Lawrence coastal province, consists of a barrier island system of sand beaches and low dunes. It is a relatively low energy system in a protected location with the important waves entering the bay through a narrow fetch window from the northeast. The behaviour of these wave trains and their refraction patterns within the S. Gulf of St. Lawrence and Kouchibouguac Bay were simulated by the construction of a series of refraction diagrams, from which it is possible to obtain a realistic appraisal of wave conditions at the shore. Waves entering the bay from N and NE directions are concentrated on the southern part of the barrier island system, and those entering from the ENE and E are concentrated on the northern part. In greater detail, a series of wave refraction diagrams, based on former conditions of nearshore bathymetry at Richiboucto Inlet, help to explain the changes which have occurred there in the past 80 years. The simulation of wave behaviour in Kouchibouguac Bay has provided useful additional information which helps to explain the recent evolution of the barrier island system.

INTRODUCTION

Barrier island systems constitute an important part of the coastline of the southern Gulf of St. Lawrence and the Kouchibouguac Bay, New Brunswick system with its limited fetch window to the northeast provides a simplified case study with implications for other more complex systems in the southern Gulf (Fig.1). This paper concerns one aspect of a case study-- the use of wave refraction diagrams in defining the important wave regimes and the resultant areas of wave energy concentration at the shore, which have modified in the past and continue to modify today this barrier island-sandspit system. It is also concerned with a retrospective view of wave conditions over nearshore bathymetry near Richibucto Inlet since 1894 and the effect of such conditions on documented changes along the shoreline.

The Kouchibouguac barrier system consists of 29 km of sand beaches and dunes running in a gentle arc from SSE to NNW across the head of the bay. The continuity of the system is broken by three inlets of which the southerly one, Richibucto Inlet, is the largest and most stable.

Structurally the system is simple with only local developments of dune ridges. With a mean tidal range of 0.67m, the intertidal oceanside beach varies in width from 15 to 50m and is succeeded seawards by a series of offshore bars. The smooth offshore countours parallel the curve of the coastline except that in the northern and southern parts of the bay broad submarine ridges extend outwards to the shallow trough which is succeeded eastwards by the northward submarine extension of Prince Edward Island (Fig. 1).

There has been little research on the barrier islands of the Maritime provinces but it is clear that the general conditions of the barrier systems of the eastern U.S.A., with continual changes in configuration and overall shoreward retreat, are present here. For Kouchibouguac Bay long term changes have been documented from earlier air photo cover and hydrographic charts, and short term changes have been measured in the field using conventional ground survey and mapping. There has been frequent and significant breaching and infilling of the barrier in the area of the central inlet, Blacklands Gully, and similar though less frequent occurrences at the northern end and at Richiboucto Inlet over the last 150 years. Within the last thirty years at least 5 important breaches have occurred and been subsequently infilled. In the short term, beach profiles for 1970-72 show active erosion of the main dune ridge in the southern part of the bay.

METHODS

It is considered that waves generated within Kouchibouguac Bay (less than 6 seconds) are relatively insignificant in terms of changes in the gross configuration of the islands. The important waves are generated in the southern Gulf of St. Lawrence and enter the bay through the narrow window between the northern end of Prince Edward Island and Point Sapin. These wave trains, from north to east directions, and the subsequent refraction patterns within the southern Gulf and across Kouchibouguac Bay were simulated using a computer program developed by R.S. Dobson (1967).

In the absence of any suitable real wave data for the southern Gulf of St. Lawrence the selection of appropriate wave trains was based upon data contained in a comprehensive hindcast study by Quon, Keyte and Pearson (1963), which used the Pierson, Neuman and James method to compile characteristic hourly wave lengths and heights for the months March to December, 1956-60. Five wave directions were selected--north, north-northeast, northeast, east-northeast and east, and refraction diagrams constructed for each of four periods--6.25, 7.65, 8.84 and 9.88 seconds--for each direction. The procedure for the construction of the diagrams involved the use of base maps at three scales. Wave rays from the five directions, for each of four periods in turn, were first generated in deep water in the Gulf of St. Lawrence using bathymetry and a grid based on the small scale hydrographic chart. Once wave rays entered Kouchibouguac Bay they were transferred to a second larger scale grid with more detailed bathymetry and the refraction procedure continued until they reached the shore. Those rays entering the southern part of the bay and affecting the Richibucto Inlet area were transferred again onto a still larger scale grid and the refraction procedure continued using four different bathymetries taken from detailed charts dated 1894, 1930, 1955, and 1964. For the Richibucto maps high tide depths, plus an additional value for storm surge effects were used in the construction of the wave refraction diagrams. Increased water levels due to surge conditions could reasonably be expected to occur in the Richibucto Inlet for the wave conditions, and causative weather conditions, which were modelled in the refraction diagram procedure.

RESULTS AND DISCUSSION

The series of diagrams of wave orthogonals accompanying this paper have been selected, from the more than 100 diagrams constructed for the analysis, to illustrate the refraction patterns for what appear to be the most significant waves to affect the coastline. Each stage of the analysis is represented by a separate series of diagrams--Figure 2, Gulf of St. Lawrence; Figure 3, Kouchibouguac Bay; Figure 6, Richibucto Inlet. In Figures 2 and 3, the first group of diagrams shows 7.65 second period waves from each of the 5 directions within the northeast quadrant; the second and third group of diagrams illustrate the behaviour of waves from the NNE and NE, respectively, at different periods. In Figure 6, only waves from the NNE at four different periods are illustrated for four different bottom configurations.

Wave refraction within the S. Gulf of St. Lawrence filters all large waves substantially before they enter Kouchibouguac Bay. This refraction depends on the angle of wave approach to a large submarine ridge, which is the northward extension of Prince Edward Island, and the parallel trough to the west which is directed southwards into Northumberland Strait. The ridge affects waves from ENE and E, the trough waves from the N to NE, and the tendency is to create a divergence of wave rays into Kouchibouguac Bay and a concentration on the northwest coast of Prince Edward Island for all wave directions (Fig. 2.1). The bathymetry of the S. Gulf acts most effectively on the longer period waves so that as wave period increases orthogonals diverge more into Kouchibouguac Bay and concentrate to a greater extent on the west coast of Prince Edward Island (Fig. 2.2). With NE waves (Fig. 2.3) as against NNE waves there is a somewhat greater concentration of orthogonals around Point Sapin at the northern end of Kouchibouguac Bay with the divergence within the bay increasing. Therefore, of the waves entering from the S. Gulf those of shorter period (less than 8 seconds) will be most effective at the shoreline in Kouchibouguac Bay; for longer wave periods those from the NNE and NE will be most effective.

Within Kouchibouguac Bay further wave refraction is caused by two broad submarine ridges extending northeastwards from shore. As wave period increases there is a pronounced concentration of orthogonals on the northern barrier island (Fig. 3.2, 3.3) while the southern part of the system becomes more protected. The greatest effects of this bathymetry is observed not with a change in wave period but with change in direction of wave approach. North and northeast waves are concentrated along the southern part of the barrier island system while the northern part remains sheltered. As wave direction becomes more easterly, the southern part of the bay becomes sheltered and it is in the northern part that wave orthogonals are concentrated (Fig. 3.1). The bay is thus under the influence of two wave regimes and it is possible for long sections of the barrier islands to be unscathed during storms while other sections are being eroded. Such a situation occurred between 1970-71 when the southern dune ridges underwent marked shoreward retreat due to storms with N-NE waves while the northern end of the bay remained unchanged.

In order to obtain some idea of which part of the shoreline of Kouchibouguac Bay is receiving the most vigorous wave action, the position at shore of all the orthogonals in each of the refraction diagrams constructed for Kouchibouguac Bay was marked on a single map. An arbitrary classification of the grouping of the points into light, moderate and heavy was used to define areas of wave energy concentration (Fig.4). Those areas of heavy and moderate concentration correspond very closely with those areas which have undergone frequent change over the past 150 years, as defined from a series of accurate charts and, more recently, air photographs.

A very much more convincing demonstration of the fact that the wave refraction diagrams constructed for Kouchibouguac Bay provide a realistic simulation of sets of real world conditions is provided by the sequential retrospective construction of refraction diagrams for a series of past bathymetries at Richibucto Inlet in the southern part of the bay. The area has been accurately mapped since 1894 and there are four good hydrographic charts--1894, 1930, 1955, and 1964 (Fig.5), as well as other maps and air photography covering the last 35 years. Both the shoreline and nearshore bottom topography have undergone considerable changes in this period. The four shoal areas of 1894 have given way to a consolidated linear shoal, or bank, extending from the northern side of the inlet and defining a deep and regular river-tidal channel to the south. The 1894 shoreline position remains basically the same, though the southern side of the inlet was breached in 1930 and has undergone some erosion and the northern side shows the effect of a breakwater first noticeable on the 1894 chart.

When wave refraction diagrams are constructed using the 1894 bathymetry of Richibucto Inlet there are no marked areas of concentration or divergence of wave orthogonals. Figure 6.1 shows the situation for waves from the NNE at different periods, and the situation for all wave directions from the NE quadrant is similar. The wave refraction patterns reflect the four offshore shoal areas which have the effect of distributing wave energy evenly along the shoreline for a variety of wave periods and directions. The pattern for 1930 is substantially different. Figure 6.2, again for NNE waves, shows definite areas of wave orthogonal concentration--at the breach on the southern beach and to either side of it. This pattern holds for all wave periods and directions out of the NE quadrant, and is a direct result of the consolidation of the offshore shoals (see Fig. 5). Whereas the nearshore bathymetry of 1894 caused wave energy to be more or less equal all along the shore, the 1930 bathymetry resulted in a concentration of wave energy at particular points onshore. By 1955 the shoals offshore from the southern side of the inlet had disappeared and the shoal extending from the northern beach had become regular in shape and depth and extended southeastwards. The 1955 wave refraction patterns are a response to these forms and there was again a fairly even distribution of wave energy along the southern beach (Fig. 6.3). The only consistent area of orthogonal concentration is to the east of the breach. Thus the extension and consolidation of the bar on the northern side, partly as a result of the construction of breakwalls, had caused wave energy to be concentrated to the east of the breach. This breach, or small inlet, was not receiving the same degree of wave attack as it did in 1930, and thus, instead of maintaining itself, was being infilled by 1955. By 1964, the offshore bar on the northern side of the inlet had grown further to the southeast and the depth of water over it had shallowed. The wave refraction pattern is very similar to that for 1955, but the waves show a response to the increased shoaling of the bar (Fig. 6.4). The old breached inlet is an area of orthogonal divergence and waves are concentrated to either side of it, particularly to the east. This is the area undergoing coastal erosion and retreat at the present time (field survey evidence 1970-72) and if the recent trends of bathymetric change continue then this erosion is likely to continue.

CONCLUSIONS

1. Wave refraction in S. Gulf of St. Lawrence affects waves from between N and E before they enter Kouchibouguac Bay, causing a divergence of wave rays within the bay and a concentration on the west coast of Prince Edward Island. Thus only the shorter waves and those from the NNE and NE for longer wave periods affect Kouchibouguac Bay to any degree.

2. Within Kouchibouguac Bay waves of less than 6.5 second periods undergo little refraction. Longer period waves from N and NE are concentrated on the southern barrier islands and waves from E and ENE are concentrated on northern barrier islands so that the bay is divided into two waves regimes.

3. Wave refraction patterns, in detail, in the area of Richibucto Inlet have changed since 1894, in response to changing bathymetry, which to some extent is due to the construction of breakwaters. The varying refraction patterns over time have produced changes in the beaches south of the inlet and will continue to erode the frontal dune ridge to the east of the 1930 breach.

REFERENCES

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Quon, C., F.K. Keyte, and A. Pearson, 1963. Comparison of 5 years hindcast wave statistics in the Gulf of St. Lawrence and Lake Superior. Bedford Institute of Oceanography Report 63-2, 59pp.

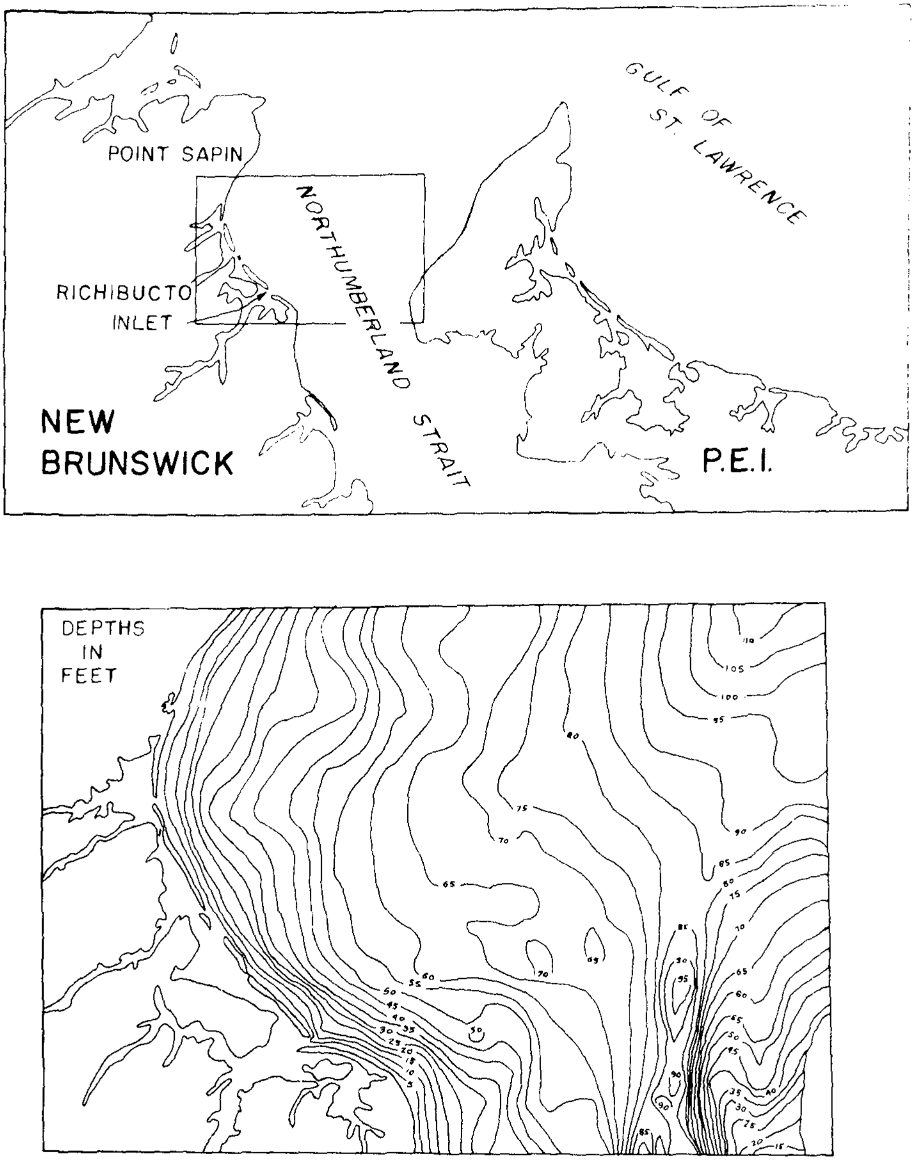
POINT SAPIN
RICHIBUCTO
INLET
NORTHUMBERLAND STRAIT
GULF OF ST. LAWRENCE
NEW
BRUNSWICK
P.E.I.
DEPTHS
IN
FEET

FIG. 1

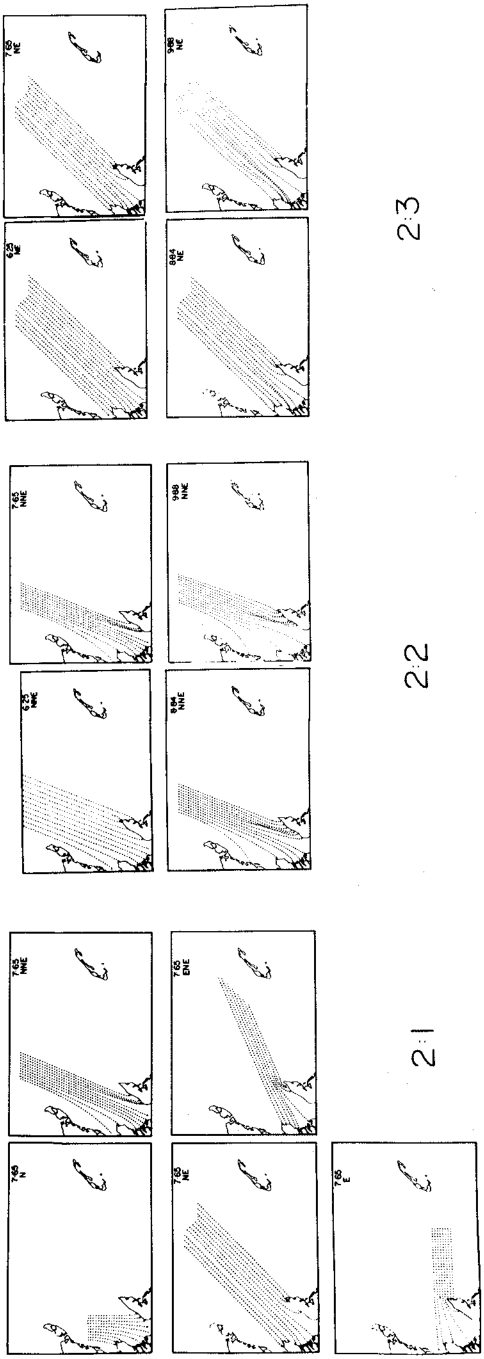

FIGURE 2

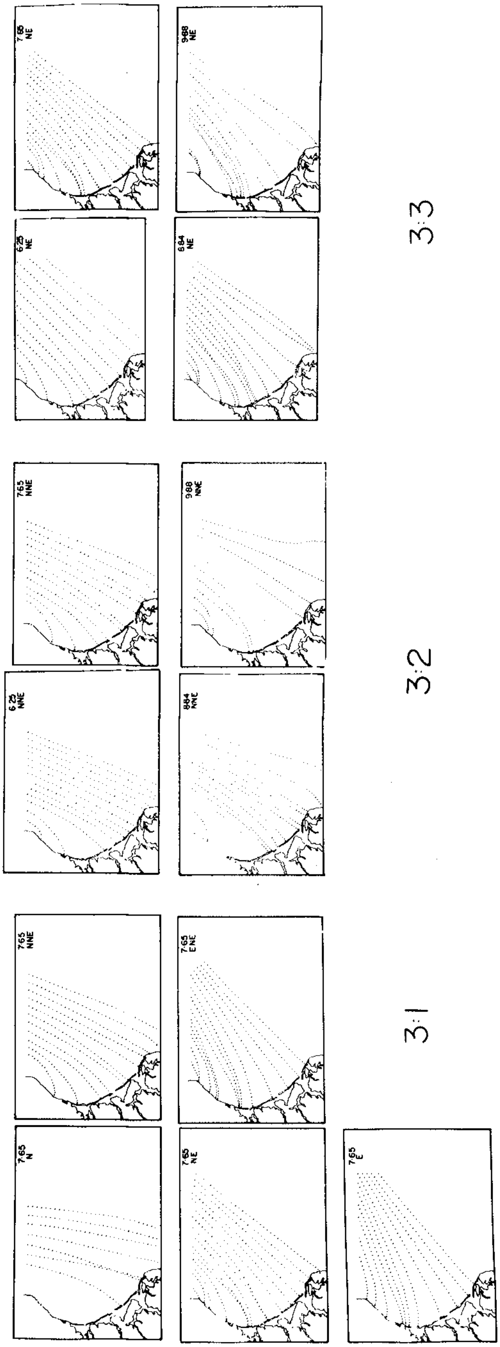

FIGURE 3

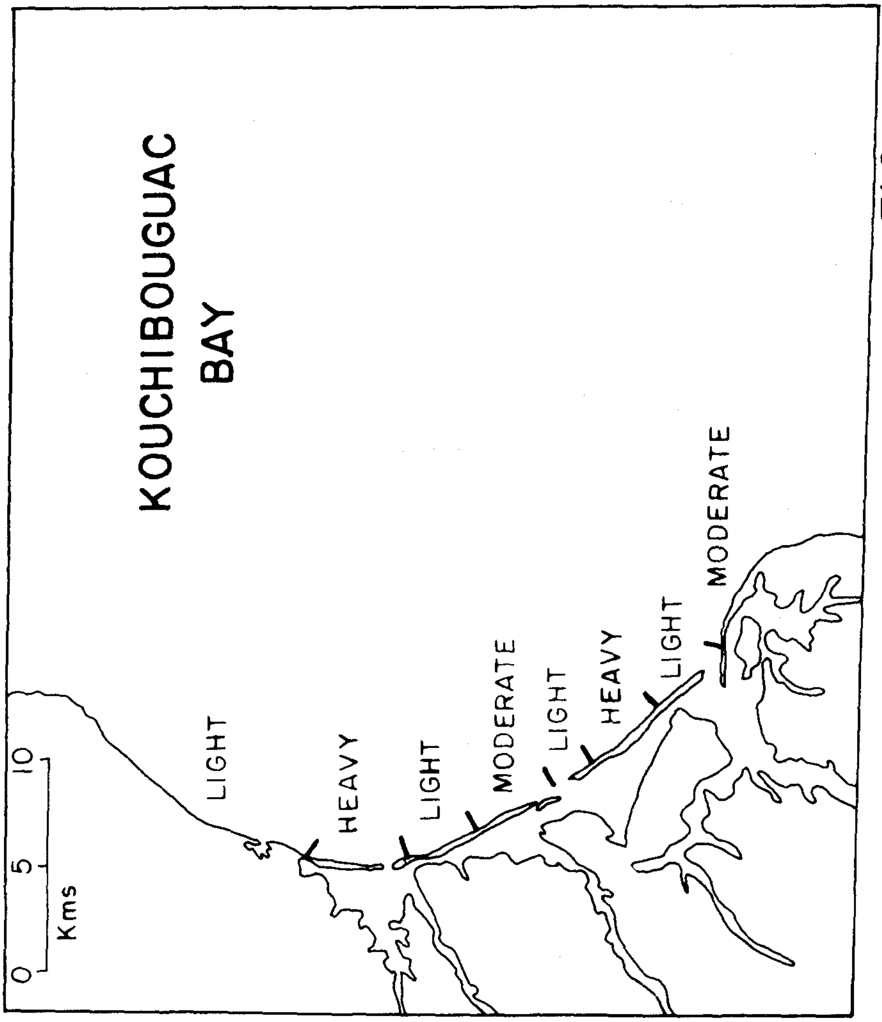
KOUCHIBOUGUAC
BAY
LIGHT
HEAVY
LIGHT
MODERATE
LIGHT
HEAVY
LIGHT
MODERATE
0
5
10
Kms

FIG. 4

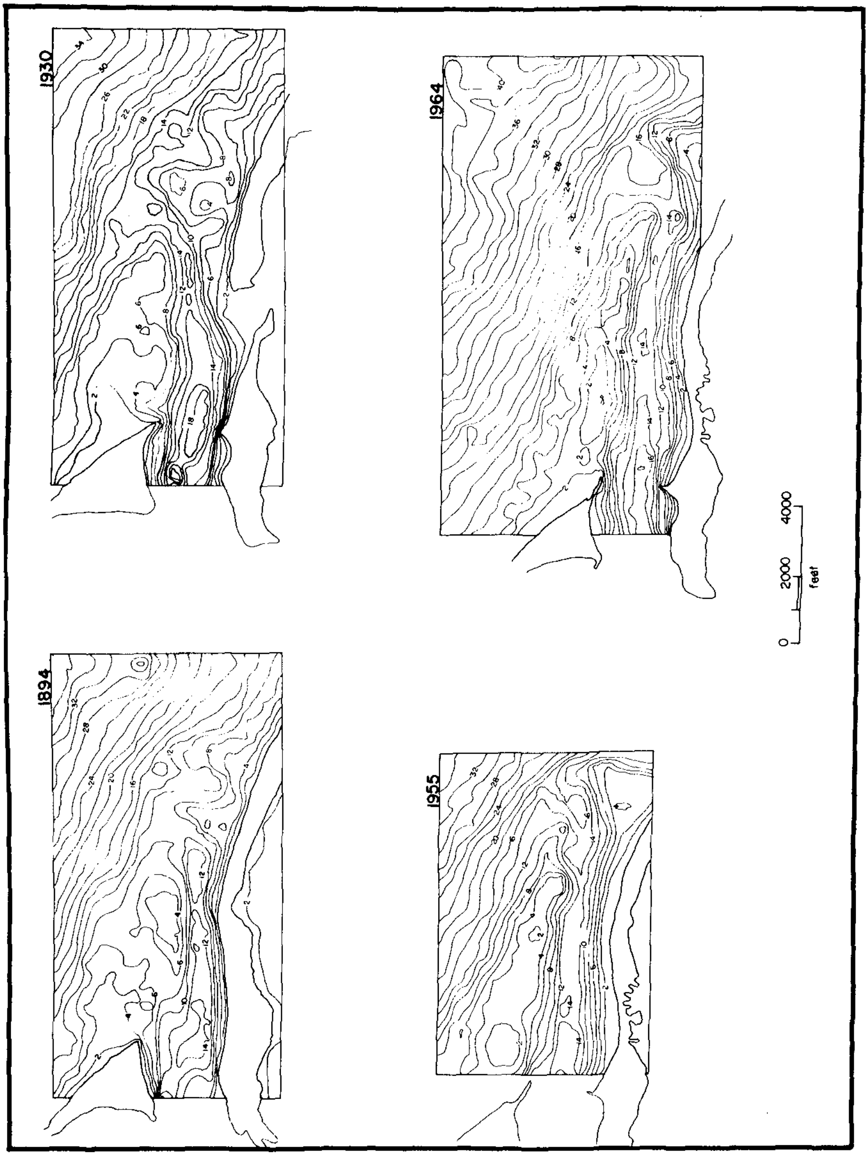

FIG. 5

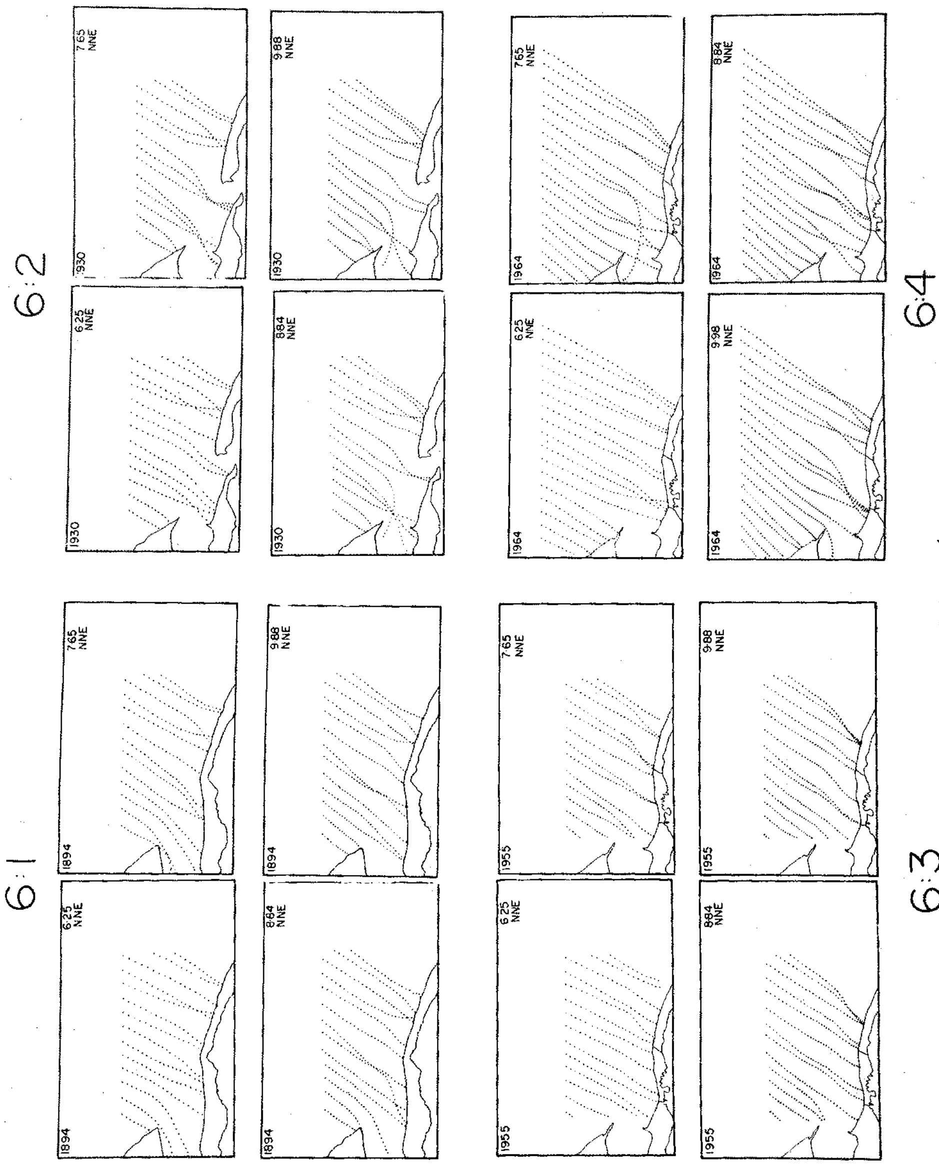
6:1
6:2
6:3
6:4
1894
1930
1955
1964
6·25 NNE
7·65 NNE
8·84 NNE
9·88 NNE
9·98 NNE

FIGURE 6