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BURLINGTON BAR AND BEACH

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by

LYNN DEANNE FRAZER

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AUTHOR: Lynn Deanne Frazer

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This thesis examines a bayhead bar in the western end of the Lake Ontario Basin with the purpose of determining the dominant factors in the process - response model. From former field examination of the bar, and through the collection of deep drill cores, an attempt has been made to establish former processes which acted in the area of the present bar. Presently, field study, especially through the collecting of drill cores, sediment samples, and wind data, and by the logging of wave data and longshore movement, has led to an attempt to establish the effect of present processes acting on the bar.

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BURLINGTON BAR AND BEACH

Lynn Deanne Frazer

ABSTRACT

This study deals with a four mile long bayhead bar and enclosed beach system which extends from Burlington on the north to Hamilton on the south. Over the period described as the Lake Ontario stage in history, this Bar was formed from two consecutively growing spits on either shore, and it continued to grow until it reached the dimensions it has today. Both nature and man have influenced bar growth substantially.

This bar is influenced by processes -- the dominant process being winds which generate waves and a longshore component. The percentage of significant winds speeds which affect the bar is minor, therefore, the generated waves have small periods and heights, and generally lead to the gradual build up of the bar. Storm conditions were rare during the summer and only slightly greater during the fall months. These generated systems promote changes in bar morphology which showed no particular sequence of change, and changes in sediment size distribution, which showed a general southerly increase in sediment size during the three month study period.

CHAPTER 1

INTRODUCTION

The Burlington Bar (Fig. 1.1), a four mile long, 7,500' - 24,000' wide, relatively flat bayhead bar is located at the western end of Lake Ontario. It extends from Hamilton on the south to Burlington on the north. Along the entire length of the eastern or Lake Ontario side of this Bar is a sand and pebble beach which varies in width from 13 feet to 130 feet. Burlington Bar, and the associated lakeside beach is also located in a closed tideless Great Lakes environmentary system. As such, the Bar is affected by waves which are generated by winds blowing over a limited fetch, and by an enclosed body generated swell component. Thus, the Burlington Bar is an area which offers itself to the study and understanding, at least in part, of the complicated process - response interactions which exist in a beach system. Although it is impossible to totally separate the various elements of a beach system with respect to the process - response model, an attempt will be made to determine how and to what extent the operative factors (processes) influence the response factors.

The earliest paper which deals with the

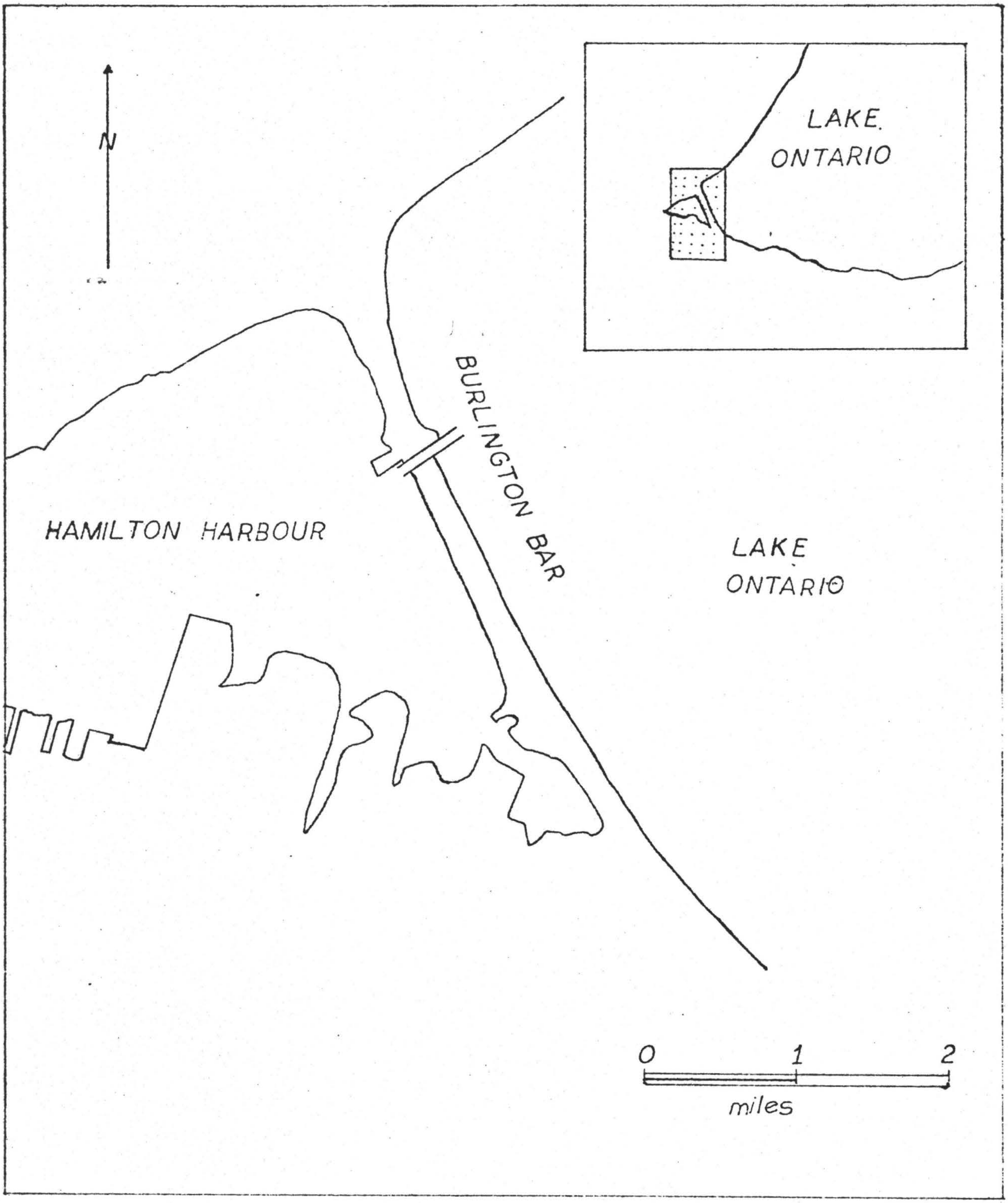


Fig 1:1 General Map of Burlington Bar

description of this Bar, with special reference to its formation, was written by Van Wagner (1884), but this paper is very brief and contains little detail. Later literature (Karrow, 1963) does not deal specifically with the Burlington Bar, but briefly mentions the similarity in formation and appearance of this Bar with the glacial Lake Iroquois Bar a few miles to the west. To date, most of the literature on Lake Ontario sediments deals with nearshore (Rukavina, 1969) and surficial (Thomas, Kemp, Lewis, 1972) sediments, and the Burlington Bar and beach sediments have not been considered. Due to the scarcity of information dealing with the genesis of the Burlington Bar, data collected from drill cores which were recently taken on this Bar by Ontario Hydro and for the Department of Transportation and Communications was used. Thus, in chapter two, the geological and geomorphological history of the area in which the Bar was later situated, and the evolutionary history of the Burlington Bar itself will be presented. Man greatly influences nature; and, present plan view changes of the Bar -- mainly created by man, and only slightly created by physical processes, will be examined with the aid of aerial photographs taken through the 1940 - 1972 period.

The theme of this thesis is carried through into chapter 3, which considers the main beach processes -- winds and waves. Wind data for the Burlington Bar was collected during the period May to December 1972. After specific analysis, hindcasting was attempted and compared with the periodically measured wave data for this area. Again, no constant hour to hour wave measurements have been taken in the vicinity of Burlington Bar. However, measured wave data from March 11 to November 6, 1972 taken from an Environment Canada waverider buoy installed on the co-ordinates 43°31' North, 79°19' West will be analyzed. From this analysis an attempt to apply the results and established generation conditions to the Burlington Bar will be made. Also, in order to test the influence of winds on the generation of longshore drift, a short term drift study was undertaken at various time intervals between September 16 and October 10, 1972, at two specified locations on either side of the canal.

The process factors always act such that various elements of the Bar system must respond. In chapter 4, the response of the beach foreshore and nearshore zones to these processes is studied by means of profiles taken during the period July to December 1972. Sedimentary character is also influenced to a great extent by these process factors. Therefore, chapter 5 deals with variations in grain sizes across and along the Bar during specified time intervals.

Up until now, the various aspects of the process - response model have been studied in a two dimensional system. In order to determine the consistency of these process and responses, a three dimensional study which will be discussed in chapter 6 was undertaken. This three dimensional study was made possible from drill cores taken by the Canada Centre for Inland Waters during the period August to December 1972.

Thus, the first objective of this thesis will be to study past process and response relationships which led to the initial formation of the Burlington Bar. Secondly, present process - response relationships will be considered in this little studied beach system.

CHAPTER 2

HISTORY OF BURLINGTON BAR

2.1 Pre-glacial Geology

Paleozoic sedimentary rocks, lying unconformably on one billion year old igneous and metamorphic pre-Cambrian rocks, are the bedrocks in which the Lake Ontario basin is cut. These marine Paleozoic sedimentary rocks, consisting of various thicknesses of limestone, dolomite, shales and sandstones, were deposited in a former marginal sea on the south side of the pre-Cambrian shield approximately 520 - 185 million years ago (Hurst, 1962). Due to the great thickness of these deposits, a long period of submergence was indicated, when sand, marl and clay accumulated on the sea floor. Geological evidence has suggested that during this period of submergence, the sea floor was depressed as fast as these deposits accumulated, and relatively shallow water conditions existed throughout most of the Paleozoic period. Near the end of this period, the sea floor ceased to be depressed, and the deposits which were being cemented due to the pressure of the overlying sediments, were uplifted above the sea. These uplifted sediments, which were originally horizontal, were slightly folded due to the intensity of the Appalachian Orogeny, which lead to the forming

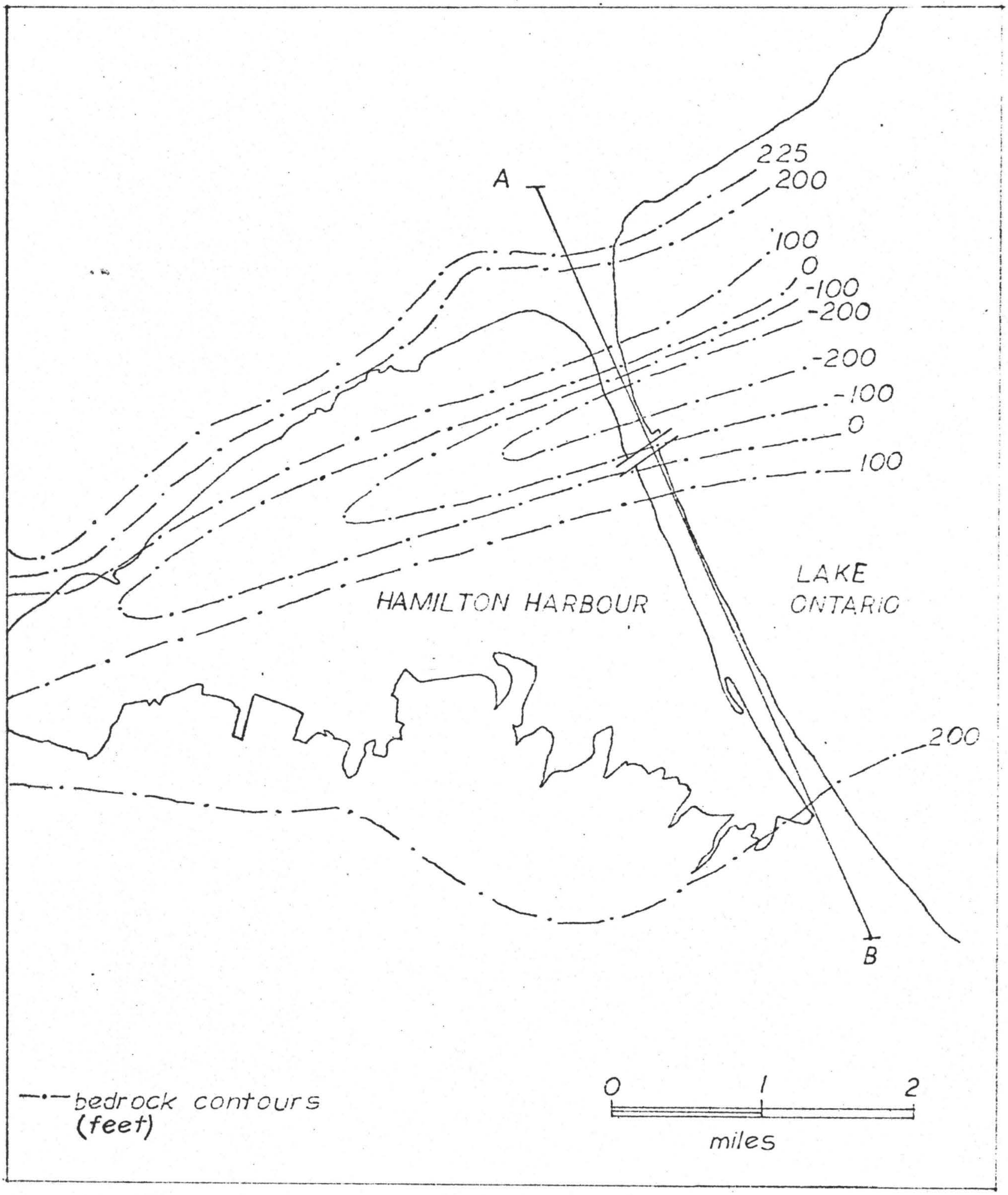


Fig 2:1 Bedrock Topography of The Hamilton Area, Southern Ontario.

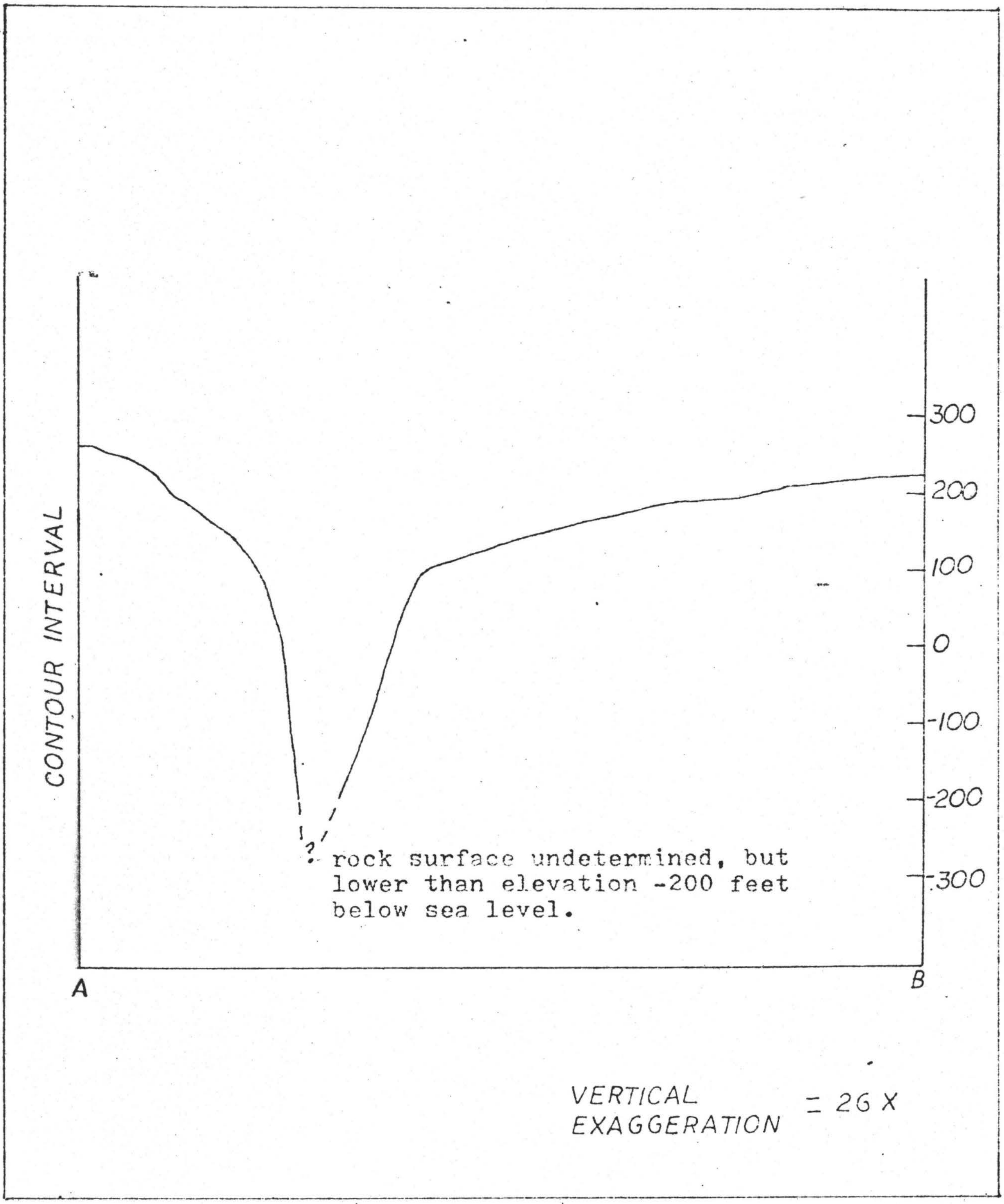


Fig 2:2 Bedrock Contour Cross Section Across
The Burlington Bar

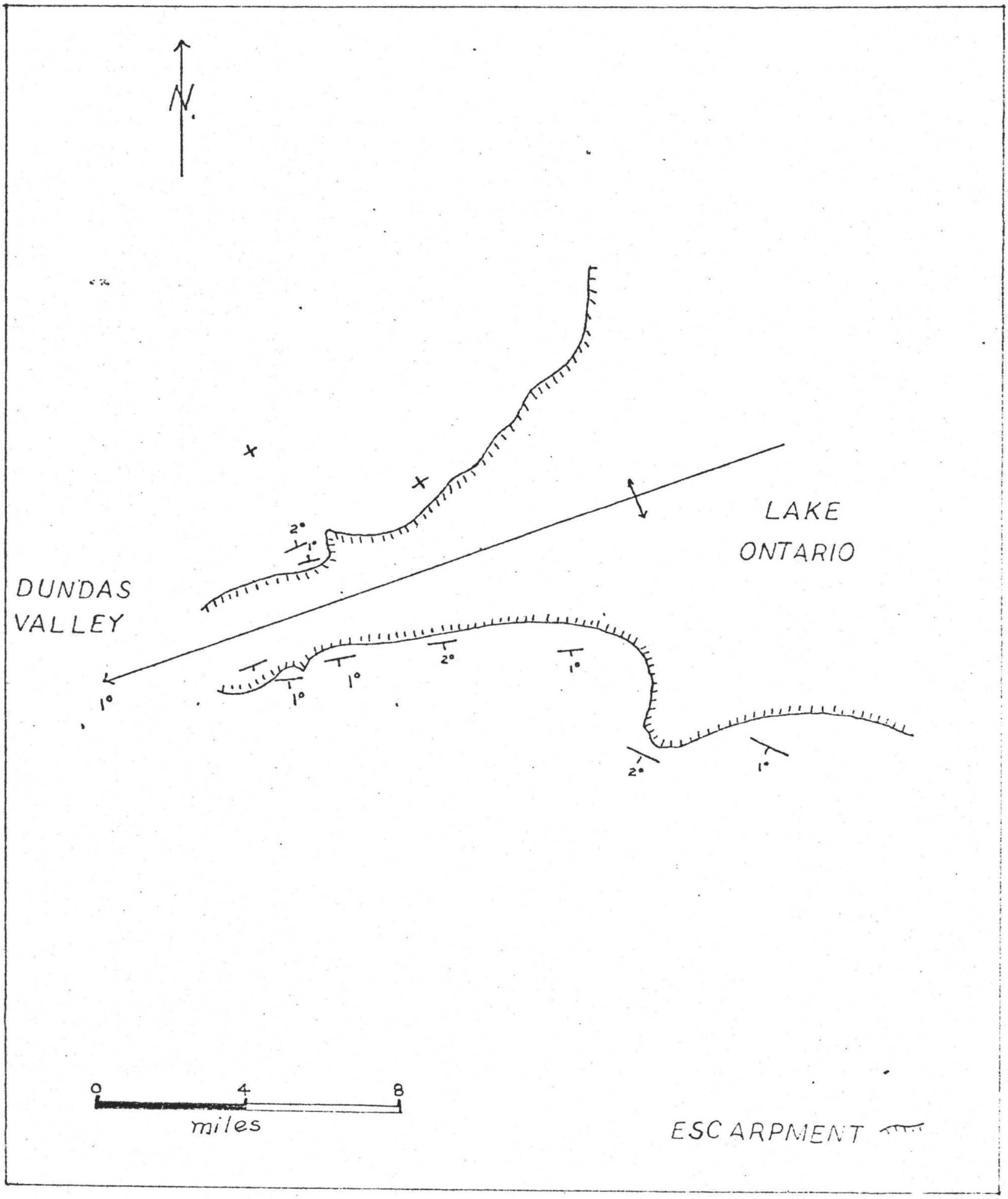


Fig. 2.2a Map of some attitudes and proposed anticlinal axis (after Hurst).

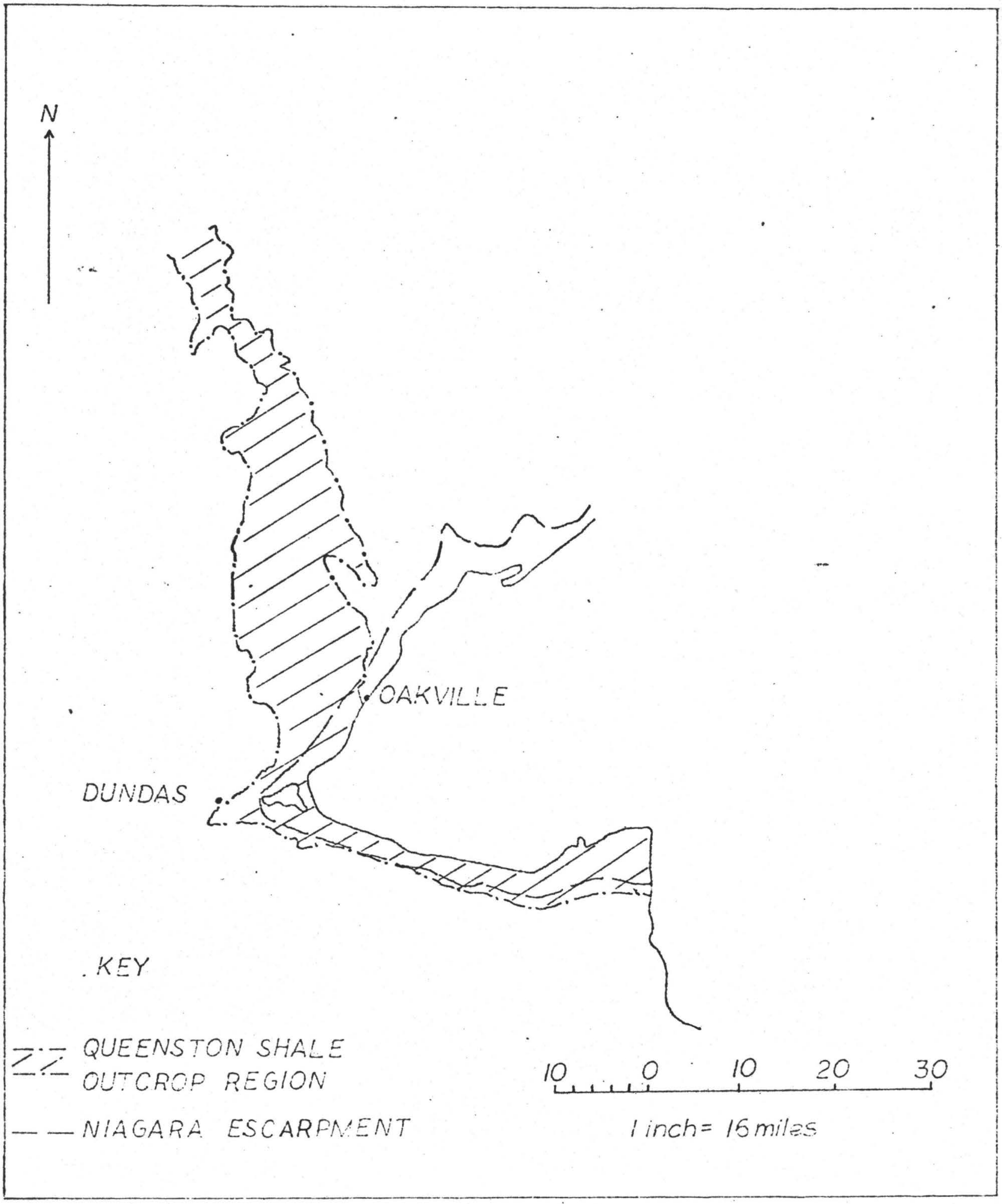


Fig 2:3 Queenston Shale Outcrop Region,
Southern Ontario.

of basin and arch structures. Structural measurements in this western end of the Lake Ontario basin have shown a dominant regional dip to the southwest. Also, during the process of uplift of these Paleozoic rocks and over a period of 250,000,000 years (Chapman and Putman, 1951), erosion, which was controlled by the varying degrees of resistance of the existing sedimentary structures, molded the bedrock contour surface (Fig. 2.1 and Fig. 2.2).

Ordovician rocks, which are significant in the Burlington Bar area (Fig 2.3), consist of a basal formation of limestone and dolomite which was overlain by three shale formations. These shales, specifically the uppermost Queenston shale, were later partially removed by glaciation. Only in a few places has Ordovician bedrock been reached beneath the Burlington Bar. From drill core data obtained from the Department of Transportation and Communications and the Hydro Electric Power Commission of Ontario, Queenston shale (bedrock) was reached between 127 and 109.5 feet above sea level. These levels are approximately 135 and 120 feet below the Bar's surface. Bedrock has only been encountered from bore hole methods for 10 feet in three locations. It, however, has not been located elsewhere, and this is probably due to the bedrock contour noted in Fig. 2.1. The located bedrock surface slopes north from it's first location at 109.5 feet above sea level to 127 feet above sea level respectively. From the drill cores, the bedrock was described as sound, medium hard, horizontally laminated reddish - brown shale containing grey bands and soft layers several inches thick at various elevations. The upper two feet of the shale appeared to be weathered.

Recent drillings have revealed in the centre of the Lake Ontario basin, the presence of a buried gorge which once contained a river of an extremely steep gradient eastward. According to Coleman, the suggesting of an old river valley following its deeper southern side from the shape of the Lake Ontario basin is not feasible. He feels that under present conditions of land and sea, no river could have carved out such a deep and wide valley, since the broad barrier of Laurentian granite and gneiss at the Thousand Islands cuts the basin off from the St. Lawrence beyond. Thus, instead of his acceptance of this proposed river valley, Coleman sees the Ontario basin as a rock rimmed basin whose depth is accounted for by the great changes in relative levels in the enclosed formation. This steep walled gorge was noted approximately 200 feet below sea level at the Burlington Bar (Fig. 2.2) compared to near sea level in the west. Bedrock profiles show that this gorge is itself contained in a larger valley which probably owes its existence to glacial or erosional modifications.

2.2 Glacial History

One or more ice sheets covered the area of the present Burlington Bar, and with special reference to the Pleistocene Stage, four main glacial periods were known to exist (Chart 2.1). Evidence of prior ice advances was usually destroyed by the following glacial advance which reworked, removed, or buried and concealed previous deposits. These buried deposits can only be discovered through drill cores, and from drill cores taken on the Burlington Bar, much evidence suggestive of pre-Wisconsin glacial environments existed. This evidence, which was located between 108 feet and 204 feet below sea level, where most of the particular drill cores in examination ended, can be divided into two clearly defined populations. Between 177 feet and 204 feet below sea level, a till complex consisting of a dense grey clayey silt, or silty clay sand, subangular and rounded gravel and boulders (up to 1 foot in diameter) was located. Directly above this layer, and extending up to 107 feet below sea level is a lacustrine deposit which contains a definite layer of silty sand between 163 and 167 feet below sea level. The total lacustrine deposit exhibited a layered clayey silt, or silty clay pattern which contained some sand, and in the upper part of this deposit, these varve-like layers varied in colour from red to gray. It must be remembered that part of this last lacustrine deposit consisted

INTERGLACIAL	GLACIAL.
Recent *+	
	Wisconsin *+
Sangamonian +*(?)	
	Illinoian +
Yarmouthian	
	Kansan
Aftonian	
	Nebraskan

* (?) found in area of Burlington Bar

+ found in Canada

Chart 2.1 Subdivisions of the Pleistocene Epoch also of undifferentiated early and mid Wisconsin lacustrine material.

Due to much depositional destruction by following glacial periods, and due to the fact that more information is present concerning the last glacial phase, the Wisconsin glacial period will only be studied.

The earliest advance in this glacial period moved into the Lake Ontario basin, blocking the St. Lawrence outlet. With this blockage, a lake named Lake Scarborough of approximately the same height as later Lake Iroquois was formed, and drained to the south through the Mohawk River Valley. Later, during the same period -- approximately 67,000 years B.P. (Dreimanis, 1969) as determined by radiocarbon methods, the ice lobe retreated freeing the St. Lawrence outlet, and simultaneously lowering the existing lake level. Glacial downwarping in the eastern Lake Ontario basin also led to the dropping of the lake level in the basin below the present Lake Ontario level. The lacustrine material deposited in the western end of what is now known as the Lake Ontario basin during this period, as indicated before, can not be separated from pre-Wisconsin lacustrine deposits. Thus, these deposits probably exist at elevations lower than 107 feet below sea level in the area of the Burlington Bar.

In the mid-Wisconsin glacial period, another ice lobe advanced and oscillated in the region now

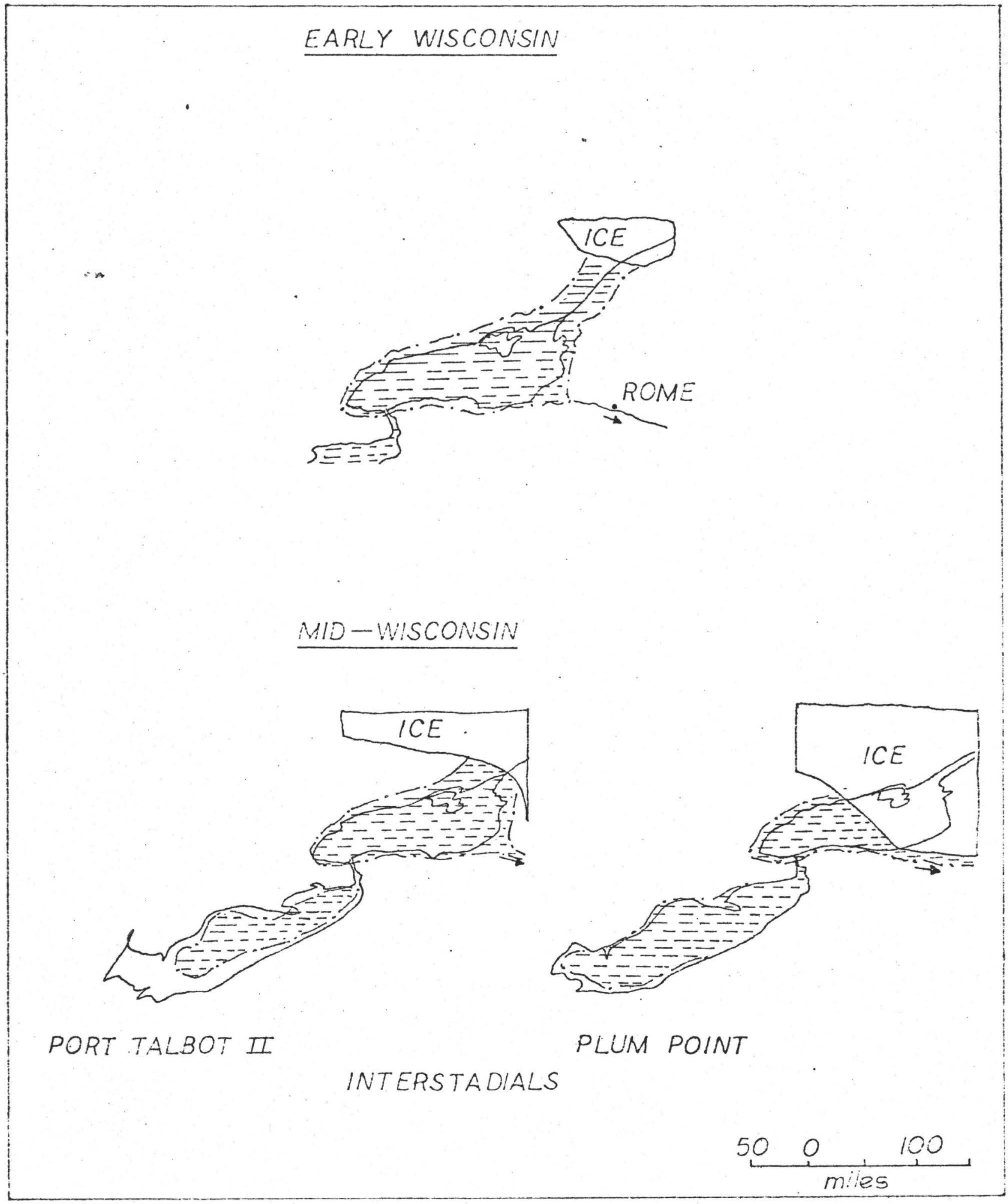


Fig. 2.4 Locations of Glacial Lakes in Southern Ontario.

known as Toronto. Thus, in the period between 34,000 and 49,000 years B. P. (Dreimanis, 1969), the lake level in this basin area was again forced to rise. Glacial evidence noted in the western end of the present Lake Ontario basin has suggested that this lake level reached 100 feet higher than the following Lake Iroquois height. The cause of the extreme height of this glacial lake, which existed during both Port Talbot interstadials, was probably due to the isostatic uplift of the Mohawk Valley outlet during the second Port Talbot interstadial. Again, it is difficult to differentiate these lacustrine deposits in the drill cores from the pre-Wisconsin lacustrine deposits.

Finally, during the late Wisconsin glacial period (20,000 years B. P.), the Ontario lobe re-advanced beyond the south-western end of the present Lake Ontario basin, and covered all of Southern Ontario. From drill core analysis, the tills, located between 107 and 93 feet below sea level on the Burlington Bar, and associated with this probable advance of the Wisconsin ice sheet, are described as being composed of sand, gravel, boulders, and a dense grey to brown clayey silt. Since this material represents the advance of the Wisconsin ice sheet, it can be dated as one million years old. The ice sheet remained in the Southern Ontario region until about 14,000 years B. P. (Hewitt and Karrow, 1963), when it began to retreat.

ELEVATION	DESCRIPTION
93-75 feet below sea level	This is a glacio-lacustrine deposit, representing a slight recessional period of the Wisconsin glacier. It is characterized by a predominance of silty clay, and a minor amount of sand.
75-45 feet below sea level	Red and grey silty clays with some minor sand, gravel and boulders are the predominantly defined textural parameters of this till complex. Glacial advancement is suggestive of this complex.
45-32 feet below sea level	The sediment of this glacio-lacustrine deposit is clayey silt with some sand. As compared to the prior glacio-lacustrine deposit included in this main depositional block, this sediment is not as fine grained.
32-25 feet below sea level	This very thin glacial till band is characterized by dense grey silt with some clay, and fine to coarse grained sand and gravel. There is a paucity of boulders which were present at lower levels.

Chart 2.2 Depositional Subdivisions of the late Wisconsin period.

ELEVATION	DESCRIPTION
25-10 feet below sea level	This is a glacio-lacustrine deposit which contains mainly silty clay and minor amounts of sand. This deposit can be correlated with similar described deposits located at 93-75 feet below sea level, and can be described as finer grained than those at 45-32 feet below sea level.
10-2 feet below sea level	This is a very thin bed of till material, which is characterized by silty clay and fine to coarse grained sand and gravel. Again, there is a paucity of boulders which were present at lower levels. This till complex is similar in thickness to that of 32-25 feet below sea level.
NOTE: Due to the decreasing thickness of till complexes with height in the depositional column, it can be postulated that the glacier did not retreat too far to the north. Thus, it did not have a large area over which to accumulate and to deposit a large till complex in the area of the present Bar.	
2 feet below sea level - 16 feet above sea level	This lacustrine deposit varied in thickness in the Western end of the Lake Ontario basin -- from 16'-35'. It is composed of mainly a grey silty clay. The upper part of this stratum consists of varved clays, and at various elevations, thin layers of clayey and sandy clay are present.

Chart 2.2 continued.

During this period of retreat, there were alternating recessional and advancement periods during which glacio-lacustrine and till complexes were deposited. These deposits, noted in drill cores taken on the Burlington Bar, represent 109 feet (16 feet above sea level to 93 feet below sea level) in the stratigraphic column. Noted in chart 2.2 are brief descriptions of the subdivisions of this depositional complex.

Thus, the Wisconsin period can best be described as consisting of many alternating glacial and inter-glacial periods during which Paleozoic bedrock was removed in large quantities from the Lake Ontario basin. This modification was accomplished on a macro-scale, but present existing resistant structures controlled to some degree the modification and thus the paths of the advancing glaciers.

2.3 Post Glacial History

Lake Iroquois Stage

Glacial Lake Iroquois was formed 12,500 years B. P. (Bird, 1972) as the ice retreated from the south-western area of Ontario setting the Lake Ontario basin free, and draining Lake Warren. This retreat was due to a temporary climatic warming, which was such that the ice retreated to the Oak Ridges moraine -- forming an ice front from Georgian Bay to the Thousand Islands. Since the St. Lawrence Valley was still blocked by ice, the overflow from Lake Algonquin, which occupied the basins of the upper three lakes, was caught by Lake Iroquois, whose outlet was near Rome, New York.

The water level in the south-western end at the beginning of Lake Iroquois was much lower than the now existing Lake Ontario level, due to the supression of the north-eastern area of the continent. However, during the existence of Lake Iroquois, the fluctuating ice front lead to the continual variation in the water level. In order for water level lowering, the basinal volume being exposed by the retreating ice probably continually exceeded the amount of meltwater that entered this basin. Evidence -- organic matter, located in old soils 30 feet below the level of the Lake Iroquois Bar, or 241 feet above sea level in the Hunter Street tunnel, Hamilton, supports the fact that Lake Iroquois was once lower than the final main water level of 362 feet above sea level (Coleman, 1936). This final level in the western end of Lake Iroquois was attributed to the isostatic rebound of 500 feet in the Hudson Valley outlet of the lake. Thus, in the south-western region of this lake, the shores were being continually tilted, and were sinking continually beneath the lake. Evidence also from old shore cliffs, beaches, gravel bars, and other lacustrine deposits which have been found high above the present level of Lake Ontario, and usually further inland, suggest that the highest water level of Lake Iroquois was 451 feet above sea level.

Lake Iroquois paleogeography again can be interpreted from the drill cores taken on the Burlington Bar. The evidence representative of the Lake Iroquois stage of the post glacial period is separated from the glacio-lacustrine and till complexes of the glacial period by a layer in which sand and gravel are incorporated into the surface of the underlying glacio-lacustrine silty clay. This change in particle size to a certain extent marks the lowering or shallowing of the existing water in the particular area encountered by the drill cores. Between 16 feet and 30 feet above sea level, the material shows an increase in grain size, with sand, gravel and residual boulders -- and, still shallowing water. This concentration of gravel and residual boulders suggests that there has been a change in the source of material supplied to the area of the later Burlington Bar. A possible source may have been the waters which were being received by Lake Iroquois -- those waters from Lake Erie through the Niagara River, or from the spillways from Georgian Bay. Radio-carbon dating of this material has determined sediment age as 10,150 $\pm$ 450 years. Between 30 feet and 115 feet above sea level, a reddish brown sandy silt, located at the top of the stratum, gradually changes to a clayey silt with depth. It is also horizontally stratified, and colour variations are extensive in the upper section of the strata. The layers of sand, silt, clayey silt, and very silty clay alternate in bands of 1/8 inch to several inches thick in this section. Some pockets of dense gravel, approximately two feet in thickness and other material such as spherical cavities, calcareous matter and organic matter also exist. In these cores, there is no loading evidence other than that imposed by the sediments.

Lake Iroquois finally terminated with the retreat of the ice lobe from the St. Lawrence Valley. With this retreat, the enclosed water could escape past the ice front against the northern section of the Adirondacks, and the level of Lake Iroquois rapidly lowered.

Gilbert Gulf Stage

After the recession of Lake Iroquois, during the Gilbert Gulf stage, the shore line in Lake Iroquois basin was approximately 40 miles east of Hamilton. Observations in the Burlington Bar drill cores between 200 - 210 feet above sea level, such as dessication cracks, erosional signs and peat deposits all indicate this lowering of water elevation before the existence of Lake Ontario. It has also been suggested that the exposure of clay and silt, causing dessication cracks to form, may have been accompanied by thin aeolian deposit development.

Lake Ontario Stage

With the withdrawal of the ice sheet from the mouth of the St. Lawrence Valley, Lake Ontario first began to form. During this formational period, isostatic rebound was a continuing process such that the eastern end of the basin was uplifted faster than the western end. Thus, the Lake Ontario water level continued to be raised approximately 200 feet, until it reached the western basinal area 3000 years B. P. (Karrow, 1963). As this water level continued to rise, a baymouth bar, presently named the Burlington Bar, was formed by easterly storms which had a fetch of 180 miles, and by the induced north-westerly moving shore current. This current carried and deposited sands and clays -- which had been eroded from the southern shores of Lake Ontario, such that the mouth of the lagoon behind the shore projection which existed to the east of Stoney Creek was filled. This material continued to be deposited along the southern shore of Lake Ontario, forcing the mouth of the old Grand River towards the west and forming the base of a growing spit, at the south side of the mouth of the Bay (Van Wagner, 1884). Upon the slopes of this spit, strong easterly winds drove cobbles, which were forced to remain since existing processes could not reach these deposits.

At the same time, a similar spit, growing from material eroded from the northern shores of Lake

Ontario, began to form at the north side of the mouth of the Bay.

These spits began to grow slowly under predominantly easterly wave conditions in the deeper water. As the spits reached the surface, material was rapidly added on to the sides and the extreme points of these spits, such that the two spits eventually were connected, forming the Burlington Bar.

Reviewing the Lake Ontario stage stratigraphic record obtained from drill cores, the specific formational material of the uppermost section of the bar can be noted (chart 2.3)

Throughout history, the Burlington Bar has only been naturally breached a total of two times. Firstly, it was broken at the southern end by discharge from the Albion re-entrant. The Redhill Creek forced passage through the Bar from Lottridge Pond, a marshy area created by the flooding back of water into the lower parts of valleys which had been cut by a former low water period. Secondly, the Bar was breached by an outlet on the present north side of the canal. Presently, both these breached areas have been completely filled in.

2.4 Modern Changes in Bar Morphology

Aerial photographs, the most modern and up to date method of mapping, were used to note the changes

ELEVATION	DESCRIPTION
115-220 feet above sea level	This section is composed of compact reddish brown silty sand. Within this section, the compact and dense grey sand located in the upper layers changes through a depth of approximately 5 feet to a stratum of compact red brown silty fine to medium sand which in turn becomes siltier with depth. These variations in sediment size reflect to some extent the varying water levels of Lake Ontario during its existence. Slight horizontal stratifications noted by small colour changes also exist, as does randomly distributed fine grained gravel. Below 180 feet above sea level, minute spherical cavities, and calcareous material in the form of dispersed shells, or thin concentrated layers, as well as organic matter are present.
220-240 feet above sea level	This unit is composed of compact and dense grey sand which is horizontally stratified in colour and composition. The upper 10 feet of this stratum contains lenses of very sandy gravel with shell fragments. The middle section contains gravels 3 inches in diameter dispersed throughout. The amount and size of these gravels decreases with depth. At the base of this stratum, thin layers of reddish brown fine silty sand exists.

Chart 2.3 Depositional Subdivisions of the Lake Ontario Stage

ELEVATION	DESCRIPTION
NOTE: At the contact between the above two units, there is a layer of very dark grey silty sand which has a high organic content.	
240 feet above sea level to the surface	The upper and most recent sedimentation layers of Lake Ontario are essentially loose grey sand. This stratum contains gravel of all sizes, organic matter -- tree fragments, shells and cross bedding structures. Above the water table, there is a drop in organic and calcareous matter. This unit is horizontally stratified in some locations due to gravel concentrations and organic concentrations.

Chart 2.3 continued

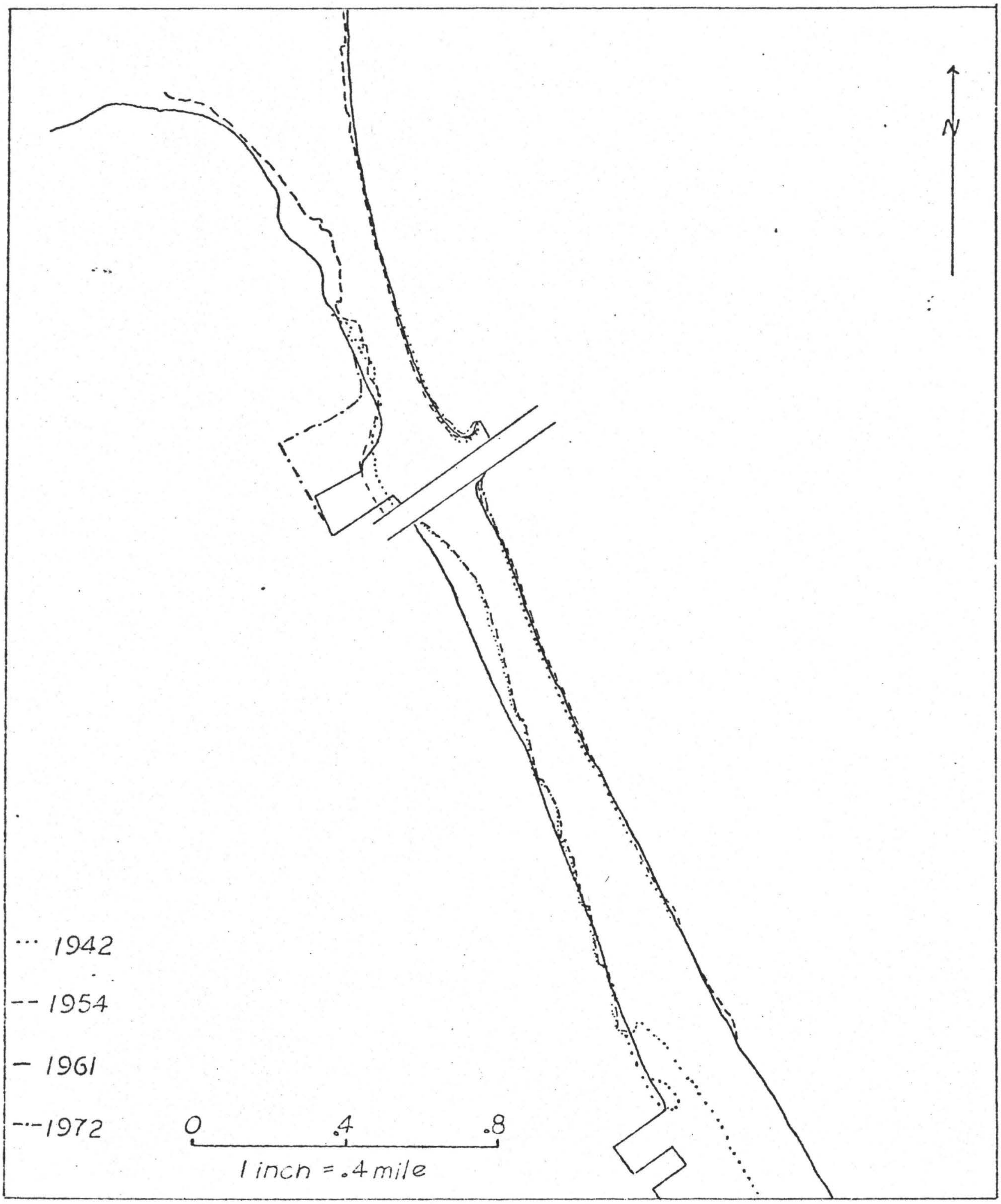


Fig. 2.5 Modern Changes in Bar Morphology

in Bar morphology over the past thirty years (1942-1972). Using the zoomtransferscope, the aerial photographs were either reduced or enlarged in scale, such that one single scale for photo comparison over time was available.

The variability in Bar morphology over this thirty year period is illustrated in Fig. 2.5. Man has resolved to greatly change the physical dimensions of the Bar, on the Hamilton Harbour side, by filling in the hollows and depressions until the present outline of the Bar has been attained. On the Lake Ontario side of the Bar, unmodified by man, nature has only acted to slightly modify the almost equilibrium beach environment.

CHAPTER 3

WINDS AND WAVES AFFECTING THE BURLINGTON BAR

3.1 Purpose of Wind and Wave Analysis

The purpose of this chapter is to examine the winds which affected the Burlington Bar over the period May 1 to December 31, 1972, and to see how often and to what extent significant winds affected the beach environment. It is also the intention of this chapter to determine the expected wave characteristics using the Bretschneider method of hindcasting; to compare these results with actual wave characteristics measured at Burlington Bar; and to examine the general longshore component over a short period of time.

3.2 Winds

Wind data, which was read hourly over the period May 1 to December 31, 1972, was collected from the Royal Botanical Gardens weather station in Aldershot. This data was assumed to be representative of winds which influenced the Burlington Bar over the same time period.

The data to be analysed was grouped according to wind direction and wind speed after the classification scheme set up by Richards (1967). Each value for each wind direction in a specific class interval represented the number of times the wind blew from that specific direction at the suggested wind speed over the month of observation.

Significant Wind Directions

The dominant wind directions over the eight month period were north-east, north-west, west and south-west, however, only one of these directions, north-east is significant for the influence of responses on the Burlington Beach. Less dominant wind directions -- north, east and south-east are also significant in influencing process-response factors. Generally, with the exception of May, the winds blew from the four significant directions less than 50% of the time during any month. During the months of May, November, June and December, the winds blew from 54.3% to 38.9% of the time from the significant directions, while during the remaining four months, a range of 33.5% to 27.4% of the time represented the percentage of winds blowing from significant directions.

Significant Wind Speeds

Significant wind speeds in this chapter were considered as those wind speeds which were greater than or equal to 11 mph. This value was chosen, for

MAY

DIRECTION	TOTAL HOURS	%
N	30	4.0
NE	220	29.6
E	131	17.6
SE	23	3.1
S	20	2.7
SW	140	18.8
W	99	13.3
NW	79	10.6
CALM	2	.3
TOTAL	744	100.0

DIRECTION	1-3 mph	4-6 mph	7-10 mph	11-16 mph	17-21 mph	22-27 mph
N	16	10	3	1		
NE	34	60	71	44	10	1
E	33	48	45	5		
SE	16	6	1			
S	10	9	1	1		
SW	19	41	43	33	2	2
W	40	47	9	2	1	
NW	10	21	22	21	3	2
CALM	2					

Significant Wind Direction -- 54.3% of the time

Significant Wind Speed -- 8.2% of the time

Chart 3.1 Classification of Wind Data.

JUNE

DIRECTION	TOTAL HOURS	%
N	43	5.97
NE	158	21.94
E	77	10.69
SE	9	1.25
S	7	.97
SW	169	23.47
W	140	19.45
NW	114	15.82
CALM	3	.42
TOTAL	720	100.00

DIRECTION	1-3 mph	4-6 mph	7-10 mph	11-16 mph	17-21 mph	22-27 mph	28-33 mph
N.	19	7	12	4		1	
NE	16	49	67	16	6	4	--
E	19	21	34	3			
SE	5	2	2				
S	6	1					
SW	14	61	44	47	3		
W	34	69	26	9	2		
NW	7	22	39	37	2	6	1
CALM	3						

Significant Wind Direction -- 39.85% of the time

Significant Wind Speed -- 4.72% of the time

Chart 3.1 continued

JULY

DIRECTION	TOTAL HOURS	%
N	35	4.7
NE	101	13.6
NW	61	8.2
E	45	6.0
SE	23	3.1
S	9	1.2
SW	292	39.3
W	177	23.8
CALM	1	.1
TOTAL	744	100.0

DIRECTION	1-3 mph	4-6 mph	7-10 mph	11-16 mph	17-21 mph	22-27 mph
N	25	9	1			
NE	21	42	37	1		
NW	25	12	13	11		
E	13	24	8			
SE	6	9	8			
S	2	6		1		
SW	27	89	113	58	5	
W	81	72	18	6		
CALM	1					

Significant Wind Direction -- 27.4% of the time

Significant Wind Speed -- .1% of the time

Chart 3.1 continued

AUGUST

DURATION DIRECTION	TOTAL HOURS	%
N	14	1.9
NE	202	27.2
NW	104	14.0
E	12	1.6
SE	17	2.3
S	3	.4
SW	297	39.0
W	94	12.6
CALM	1	.1
TOTAL	744	100.0

DIRECTION	1-3	4-6	7-10	11-16	17-21	22-27
N	10	4				
NE	26	98	72	6		
NW	19	30	36	18	1	
E	3	5	4			
SE	7	9	1			
S	2	1				
SW	48	125	97	26	1	
W	58	34	1	1		
CALM	1					

Significant Wind Direction -- 33.0% of the time

Significant Wind Speed -- .8%

Chart 3.1 continued

SEPTEMBER

DURATION DIRECTION	TOTAL HOURS	%
N	78	10.8
NE	123	17.1
E	28	3.9
SE	12	1.7
S	5	.7
SW	233	32.4
W	153	21.2
NW	86	11.9
CALM	2	.3
TOTAL	720	100.0

DIRECTION	1-3 mph	4-6 mph	7-10 mph	11-16 mph	17-21 mph	22-27 mph
N	21	31	23	3		
NE	24	39	42	18		
E	3	13	7	5		
SE	8	2		2		
S	2		3			
SW	26	62	87	55	3	
W	63	75	8	7		
NW	9	24	38	15		
CALM	2					

SIGNIFICANT WIND DIRECTION -- 33.5% of the tire

SIGNIFICANT WIND SPEED -- 3.6% of the time

Chart 3.1 continued

OCTOBER

DURATION DIRECTION	TOTAL HOURS	%
N	61	8.2
NE	119	16.0
E	29	3.9
SE	8	1.1
S	15	2.0
SW	216	29.0
W	172	23.1
NW	122	16.4
CALM	2	.3
TOTAL	744	100.0

DIRECTION	1-3 mph	4-6 mph	7-10 mph	11-16 mph	17-21 mph	22-27 mph
N	28	24	9			
NE	37	45	25	11	1	
E	9	14	6			
SE	2	6				
S	5	7	3			
SW	27	66	77	35	11	
W	65	61	23	17	4	2
NW	20	25	40	28	7	2
CALM	2					

Significant Wind Directions -- 29.2% of the time

Significant Wind Speeds -- 1.6% of the time

Chart 3.1 continued

NOVEMBER

DURATION DIRECTION	TOTAL HOURS	%
N	59	8.2
NE	186	25.8
E	20	2.8
SE	29	4.0
S	5	.7
SW	191	26.5
W	137	19.1
NW	93	12.9
TOTAL	720	100.0

DIRECTION	1-3 mph	4-6 mph	7-10 mph	11-16 mph	17-21 mph	22-27 mph
N	17	25	12	5		
NE	19	52	58	41	14	2
E	4	3	6	7		
SE	7	9	11	2		
S	2	2	1			
SW	28	34	42	64	22	1
W	65	61	9	2		
NW	23	26	24	16	4	

Significant Wind Directions -- 40.8% of the time

Significant Wind Speeds -- 9.9% of the time

Chart 3.1 continued

DECEMBER

DURATION DIRECTION	TOTAL HOURS	%
N	72	9.6
NE	175	23.5
E	36	5.0
SE	6	.8
S	3	.4
SW	214	28.8
W	148	19.9
NW	89	11.9
CALM	1	.1
TOTAL	744	100.0

DIRECTION	1-3 mph	4-6 mph	7-10 mph	11-16 mph	17-21 mph	22-27 mph
N	24	27	20	1		
NE	17	44	45	45	15	9
E	3	10	7	11	4	1
SE	2	3	1			
S	3					
SW	26	55	61	52	15	5
W	40	55	22	18	13	
CALM	1					

Significant Wind Directions -- 38.9% of the time

Significant Wind Speeds -- 11.6% of the time

Chart 3.1 Continued

	CALM	1-3 mph	4-6 mph	7-10 mph	11-16 mph	17-21 mph	22-27 mph	28-33 mph
C	.20							
N		2.72	2.33	1.36	.24		.02	
NE		3.30	7.30	7.09	3.10	.78	.27	
E		1.48	2.35	1.99	.53	.07	.02	
SE		.90	.78	.41	.07			
S		.54	.44	.14	.03			
SW		3.66	9.07	9.59	6.29	1.04	.14	
W		7.59	8.06	1.97	1.05	.34	.03	
NW		2.13	2.94	4.03	2.91	.49	.20	.05

Chart 3.2 Wind Classification in Percentages.

high wind speeds generate destructive waves which contain enough energy to greatly modify the response elements, by quickly downcombing the beach. Generally, wind speeds less than 11 mph. generate constructive waves which gently build up the beach over a long period of time.

Significant wind speeds which affected the Burlington Beach, varied from 11.6% of the total winds that blew during the month of December, to less than 1% of the time in July (.1%) and August (.8%). The duration of winds of these speeds was variable from one hour to 23 hours throughout the eight month study period, and generally each period of significant winds was separated by non-significant wind periods.

3.3 Wave Characteristics

No hour to hour wave parameters -- wave height and period have been measured in the area near the Burlington Beach; therefore, reliance on wave characteristics was placed on the observations of the author and on the characteristics produced by hindcasting.

Observations and Hindcasting

The wave parameters measured in Lake Ontario off the Burlington Bar appeared to fall within four main classes. Over many of the observation periods, a swell from the east was a dominant feature which was

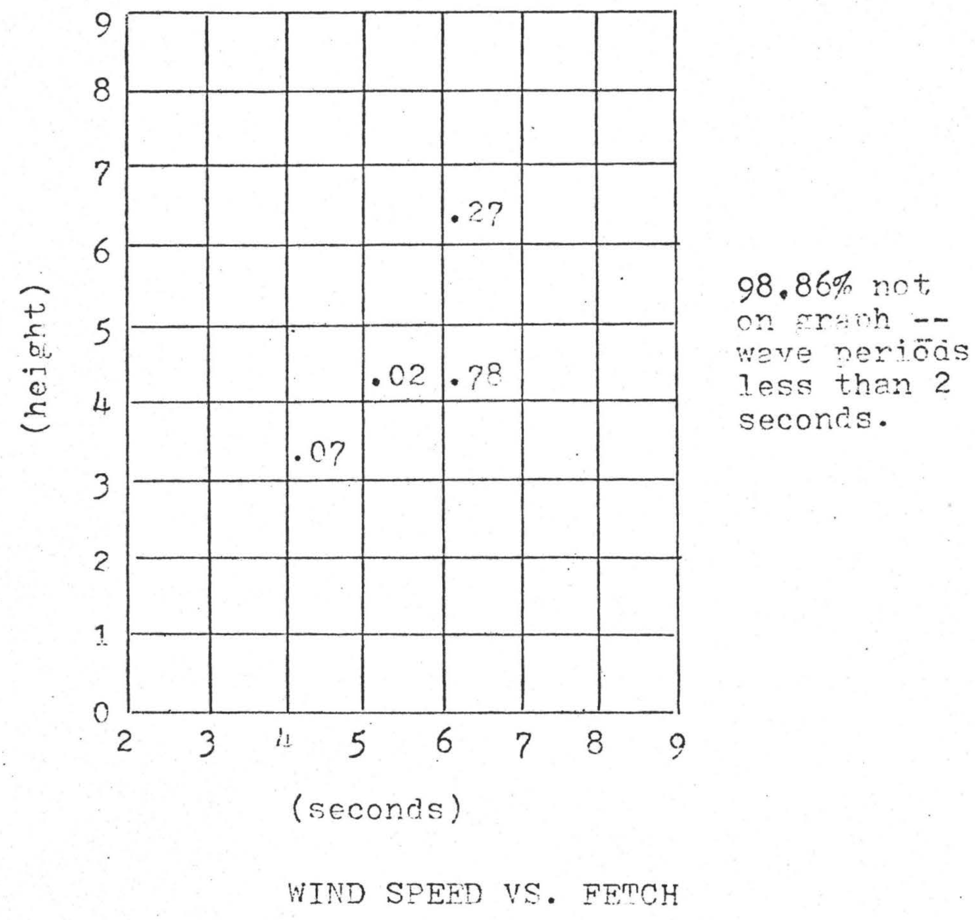
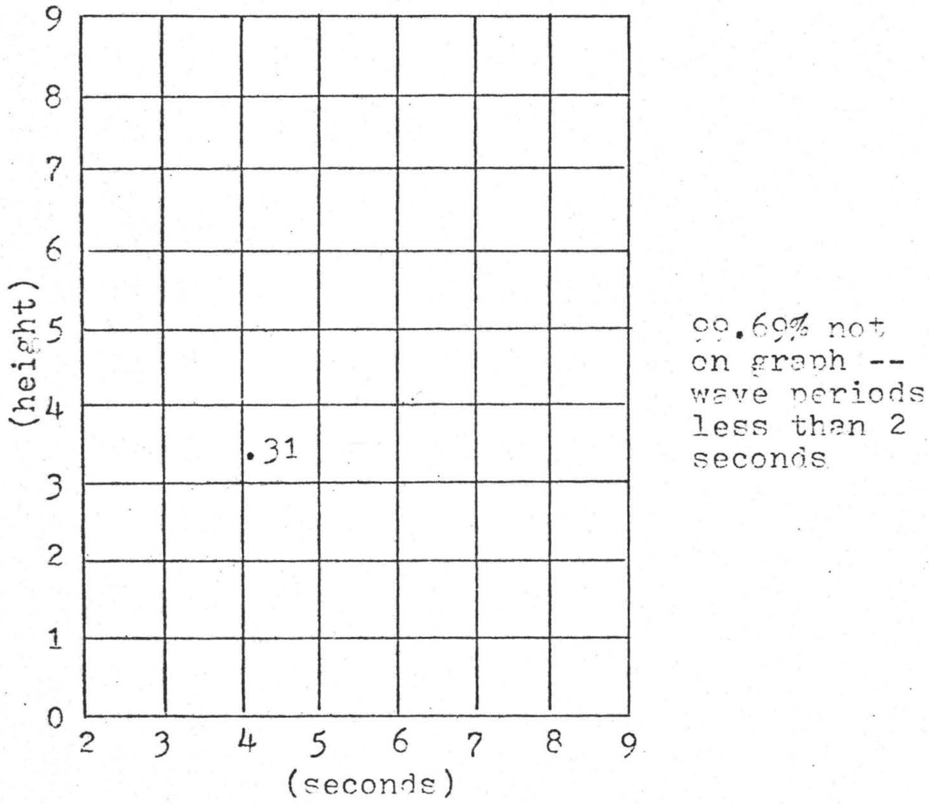
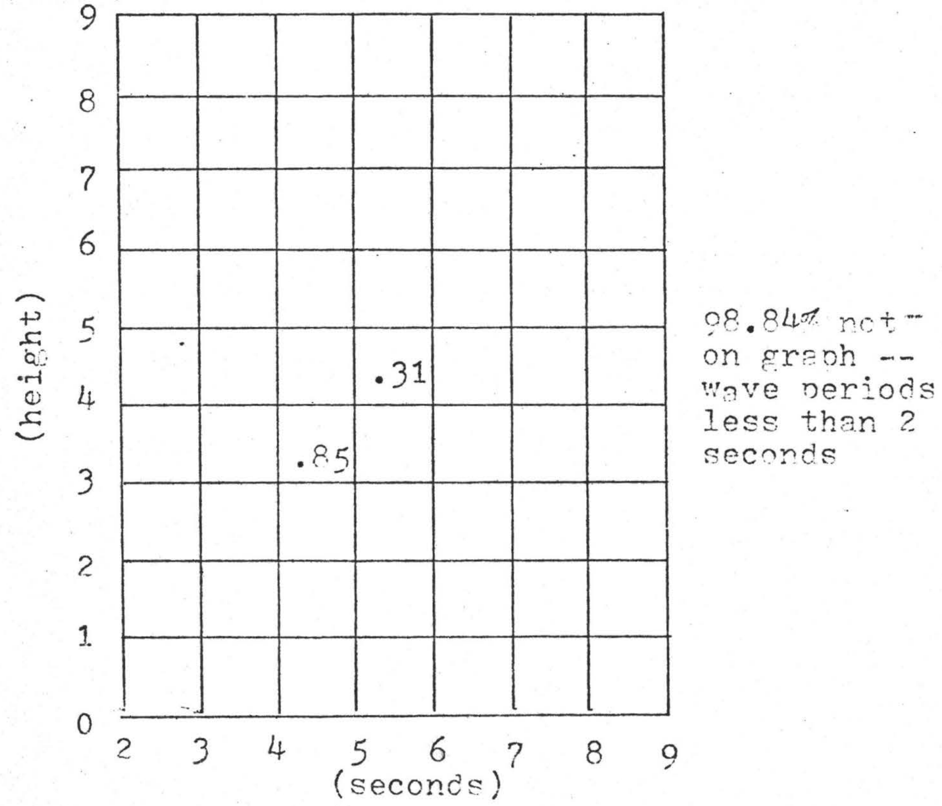


Chart 3.3 Hindcasted values in Percent



WIND SPEED VS. 2 HOUR WIND DURATION

Chart 3.3 continued



WIND SPEED VS. 5 HOUR WIND DURATION

Chart 3.3 continued.

usually superimposed on the wave pattern of that day. This daily pattern varied considerably with respect to wave height and period, however, the waves which were observed a greater percentage of the time were those defined as chop. These waves produced an interference pattern, therefore, the actual wave height and wave period could not be measured with any degree of accuracy. These waves also were noted to aid in the gradual build up of the beach. When actual wave height and period could be measured, the greatest majority of these waves had periods of less than 2.0 seconds and heights of less than 8 inches. Only on a few occasions did destructive waves, which downcombed the beach, affect the beach system. These waves had periods up to 5.2 seconds and heights of 3' 6" and were relatively rare during the summer and most of the fall months.

Since a complete set of daily measurements was not obtained, a method of hindcasting proposed by Bretschneider was used. This method plots wind speed against either fetch in miles or wind duration, and the convergence of these parameters shows the expected wave height in feet and wind speed in seconds. Since the duration of certain wind speeds is variable throughout each day and each month, hindcasting was undertaken for wind durations of two hours, the lowest time interval which was thought to be significant for the production of waves and for wind durations of five hours, which was a slightly longer but reasonable durational period for winds which affected the Burlington Bar. Since the hindcasting method is thought to present slightly higher wave height and period values than those actually produced in the beach system, the values calculated for duration and wind speed were compared to the values hindcasted for fetch and wind speed. In all three cases of hindcasting the results were noted to be similar. From the graphs, 98.86% of the values could not be placed on the fetch vs. wind speed graph -- most wave periods were less than 2 seconds, while 99.69% and 98.84% of the values had periods of less than 2 seconds when hindcasting was undertaken for durations of 2 hours and 5 hours respectively. The main wave characteristics which were generated by all the hindcasting parameters, and which did appear on these graphs were those of 4 seconds 3 feet height, 5 seconds 4 feet height, 6 seconds 4 feet height and 6 seconds 6 feet height. These last recorded values corresponded to the waves which were occasionally generated in the area of the Burlington Bar, as did the former hindcasted wave values with wave periods of less than 2 seconds.

3.4 Longshore -- Beach Drifting Study

The main objective of this study was to test whether shingle of different dimensions moved at

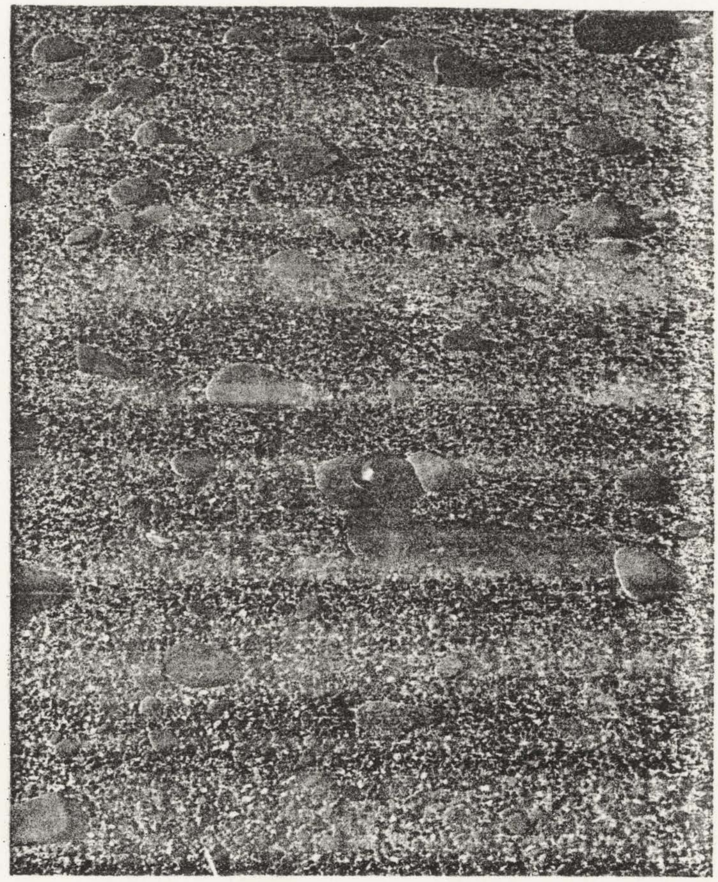


Plate 3.1 Sizes of pebbles collected from the beach

different rates and in different directions on opposite sides of the canal. In order to undertake this short-term half-month tracing study, pebbles of varying sizes were collected from various foreshore and nearshore zones and painted a bright red in order to contrast with the normal pebbles of the beach. Actual beach material was used for this study, for it was important that the material used for the tracing experiment had the same properties as the normal beach material.

The first tracing experiment was carried out at profile 7, on the south side of the canal. Painted pebbles were placed among similar sized material at certain distances from a marked reference point on the beach. Two 6" long pebbles, placed a distance of 50 feet from the reference point, showed no appreciable movement over the period of one day, and, the recovery rate was 100%. Four 3 -4" equidimensional pebbles placed among similar sized material at 48' 10" from the reference point, moved a lateral distance of 1' 9" to the north and a vertical distance of 2" toward the reference point over the one day period. Again, the recovery rate was 100%. Finally, fourteen 1 -2" pebbles, placed 46' 4" from the reference point -- at the step top, moved a lateral distance of 1' 11" to the south, and a vertical distance of 1' toward the reference point during one day. Only a 59.1% recovery rate was noted.

Unfortunately, this study could only be carried out between two consecutive days, since the pebbles were totally buried during the remainder of the study period. Even though this study was terminated early, a few factors were noted. For example, shingle of different dimensions moved at different rates. The smaller pebbles were moved easier and carried a greater distance than the medium or large pebbles. Also, there was a variation in the direction of movement of the medium and small pebbles, even though the pebbles only travelled a short distance.

The second tracing experiment was carried out at profile 1, on the extreme north side of the canal. Again, pebbles were played among normal beach material of similar size dimensions. Three 6" pebbles, placed 50' 6" from the marked reference point, showed no movement over the period of one day, and the recovery rate was 100%. On the third study day, again no movement was noted, and only a 33.3% recovery rate was noted, while on the fourth study date, the one remaining pebble had moved 1' laterally to the north, and 7" vertically toward the reference point. Six pebbles of 3 - 4" diameters, placed 47' 9" from the reference point, showed no lateral movement, but a movement vertically toward the reference point of 11" over the one day study period. At this time, the recovery rate was 83.3%. On the third study date, the recovery rate had decreased to 66.6%, and the pebbles had moved laterally 1' 7" to 4' 2" to the north and vertically from 16' 5" to 1' 5" toward the reference point. On the fourth study date, the recovery rate was 0%. Finally, nine 1 -2" pebbles, placed 45' 9" -- near the waterline, showed a lateral movement of 1' 6" to the north and a vertical movement of 4" toward the reference mark during a one day period. The recovery rate was 44.4%. On the third study date, the recovery rate was 22.2%, and the pebbles had moved laterally 5' 6.5" to 31' 4" to the north and vertically 15' 3" to 15' 8" toward the reference point, while on the fourth study date, a recovery rate of 11.1% was noted, and the pebble had moved laterally 67' 2" to the north and vertically 17' 7" toward the reference point. According to this study, there was a decrease in the recovery rate over the study period with respect to all the pebble sizes. Also, there was no variability in lateral transport of the pebbles, but, the large variability of movement within certain pebble sizes made it impossible to determine if the movement of the various sizes was significantly different.

During the period of this study in the near-shore zone of the Burlington Beach, waves were generally gentle, so that sand was moving onshore, and much of the transport, as shown above, was occurring in the near - nearshore zone.

3.5 Conclusions

The significant wind directions which influence the process-response model on the Burlington Beach are north, north-east, east, and south-east. Winds blew from these directions less than 50% of the time during any of the months from May to December 1972, and those winds of greater than 11 mph, which were considered as significant in producing distinct responses on the beach, varied from 11.6% in December to less than 1% in July and August. The greater percentage of non-significant winds which affected the Burlington Beach led to the generation of waves which generally had periods of less than two seconds. Greater wind speeds only led to the generation of waves which had periods of less than 5.2 seconds and heights of less than 3' 6". Thus, over most of the study period, wave energy was not great. This energy did lead to the generation of longshore transport or beach drifting -- a process which produced a variation in lateral shingle movement on the south side and no variation in movement on the north side of the canal. During the beach drifting study, different sized pebbles were moved at different rates, and there was a decrease in the pebble recovery rate.

CHAPTER 4

FORESHORE AND NEARSHORE MORPHOLOGY

4.1 Purpose of Morphogenetic Study

The purpose of this chapter is to examine the three main morphogenetic units of the Burlington Bar, and investigate the changing form of specific locations within two of these units, Canal North and Canal South, over the study period. This chapter also considers the effect of water level height on beach form, the results of a search for bars in the nearshore zone of the Burlington Beach, and minor beach forms which were located in the beach system.

4.2 Descriptive Morphology

The Burlington Beach, a long linear beach, attached at each end to the headland, can be divided into three distinct areas. These areas, as one progresses northward along the Bar from Van Wagner's Beach, are described as the groyne area, canal south, and canal north.

Groyne Area

The groynes, constructed normal to the shore, for the purpose of reducing the amount of beach material

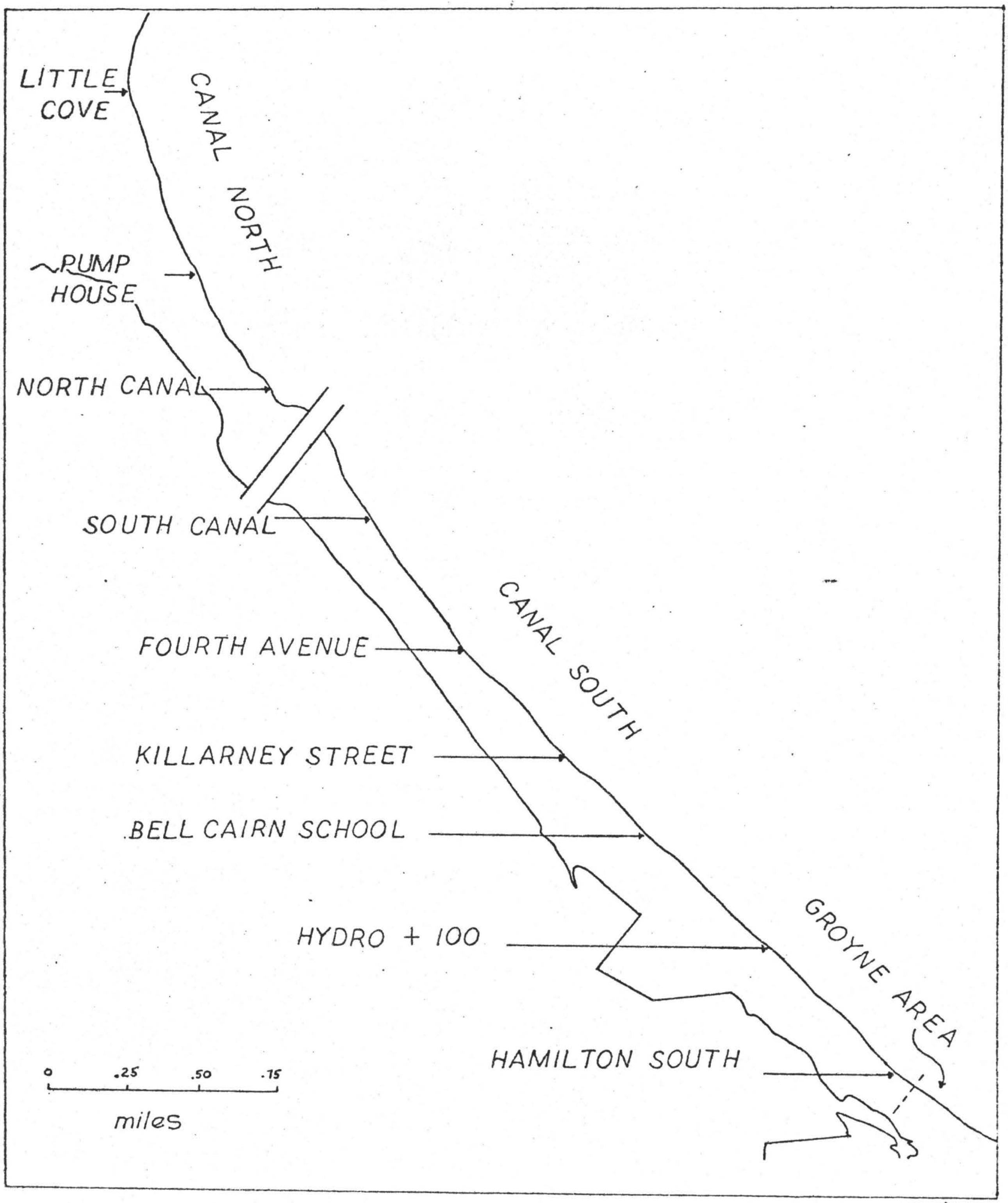


Fig. 4.1 Morphological Units of Burlington Bar.

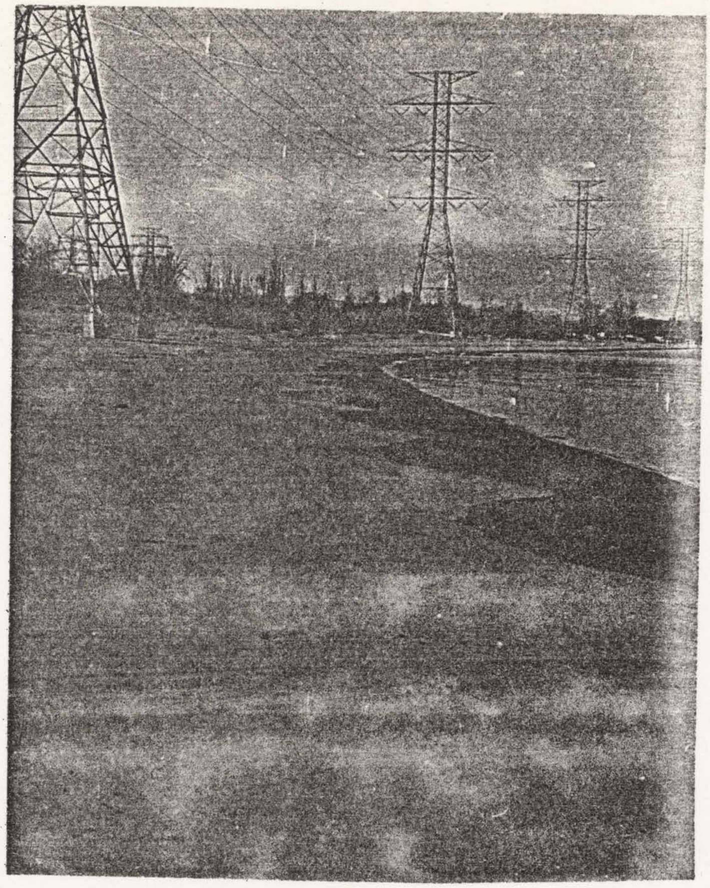


Plate 4.1 Canal North

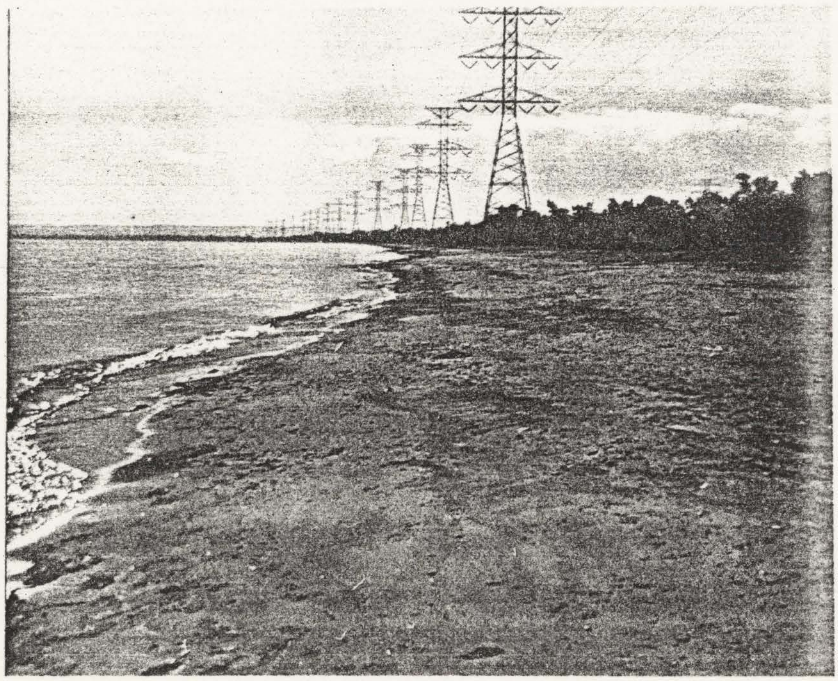


Plate 4.2 Canal South

lost by erosion, have only been in existence for the past twenty years. They extend 2,600 feet along the beach, and each of the ten groynes is placed 250 feet apart. These groynes are built of boulder material, approximately four feet high and extending thirty feet seaward, through which the water and sand can not move. Due to this, on the updrift side of the groyne, sand has built up, and the beach has been widened, while on the downdrift side, only very slight erosion of the original beach zone has occurred. Overall, the beach area between each groyne has a concave shape lakeward, and a steeper slope on the updrift side of the groyne, as compared to that on the downdrift side.

To study this beach area would require a micro-scale study, and since this thesis deals mainly with regional changes, this area was not dealt with.

Canal South

This beach area extends 13,100 feet along the Burlington Bar from the last groyne to the canal. Due to the length of this section, and the variability of factors along the beach, various sub-sections as shown on Fig. 4.1, will be described from a study made on June 4, 1972.

At Hamilton South, there is an eroded sand and soil bank at the extreme back of the beach. This bank increases in elevation towards Hydro + 100, and in one

Plate 4.3 Fourth Avenue

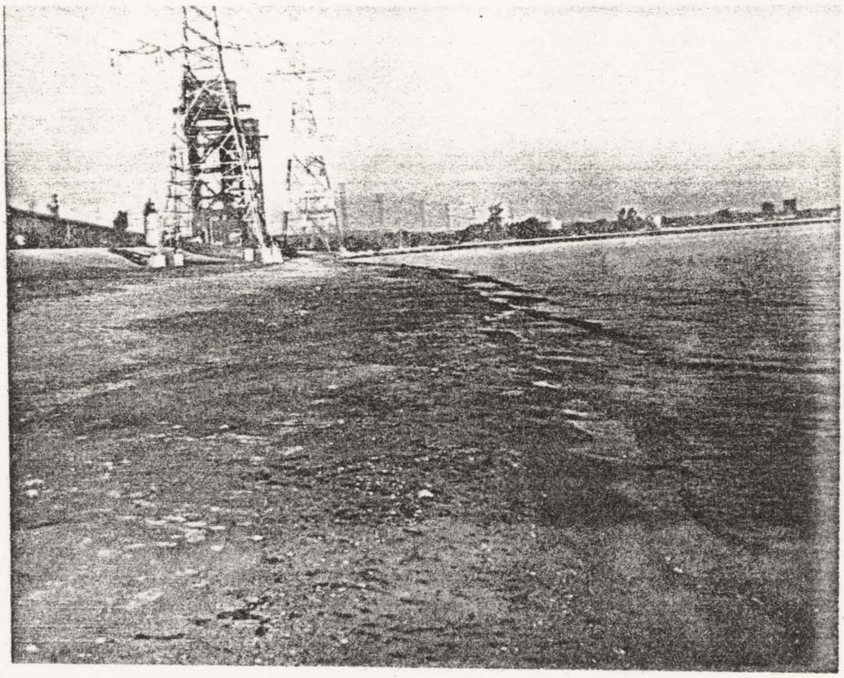


Plate 4.4 South Canal

Plate 4.5 Bell Cairn School

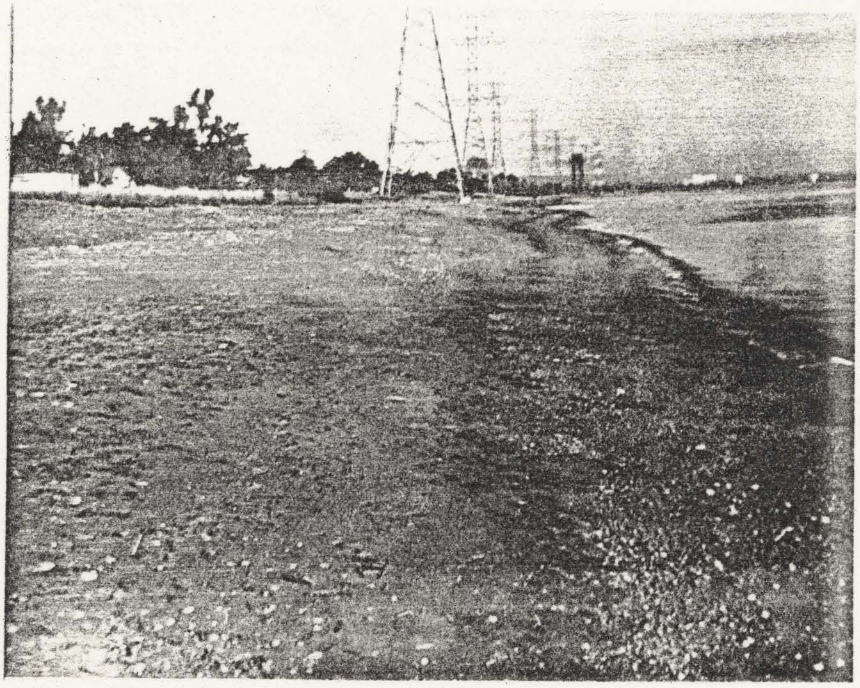


Plate 4.6 Killarney Street

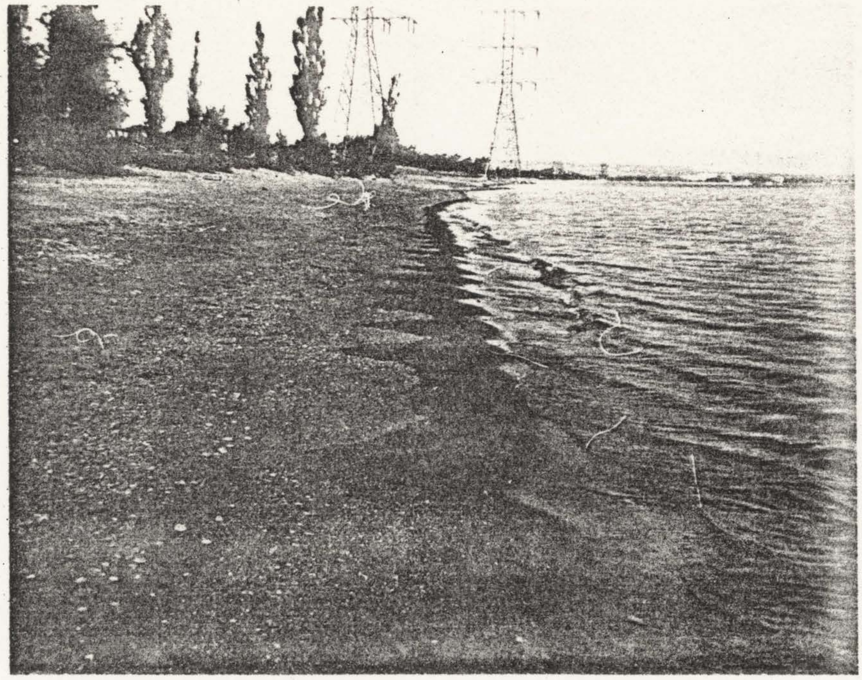


Plate 4.7 Hamilton South

Plate 4.8 Hydro + 100

particular location, railway ties have been used in an attempt to protect this exposed bank from erosion. Also, in this area, a few of the concrete tower foundations project out into the water and act as mini-groynes.. To the south of these foundations, there is slight deposition, while the area immediately to the north of the foundations shows slight erosion.

The beach zone gradually widens between Hydro + 100 and Bell Cairn School, leaving a wider area which is susceptible to beach drifting. This condition however is somewhat reduced in the area at the back of the beach, for thin, long grasses and a few shrubs are beginning to stabilize the area, and minimize beach drifting. Along this relatively straight beach area, definite small beach cusps, similar in width -- five feet but varying in length -- six feet to ten feet, had developed. At Bell Cairn School, a rock breakwall constructed of large limestone boulders protects the back of the beach from erosion. This, however, is not the only method of beach protection used. In the area from Bell Cairn School to Killarney Street, there are small grasses, and some bushes and trees, which are growing and stabilizing the very sandy area at the back of the beach. Beach cusps, of similar dimensions to those formerly noted were present, and distinct variations in beach material over a very small area was noted.

This stabilization of the back of the beach zone by long grasses, shrubs and trees is still noted in the sub-section of beach defined by Killarney Street and Fourth Avenue. In this area, the general linear trend of the beach is broken by the presence of many beach cusps, which are well defined by cobble material. To the north of this area -- that zone between Fourth Avenue and South Canal, the vegetation cover at the back of the beach is left unprotected and is highly suscep- tibile to beach drifting. This beach area exhibits a gentle sloping foreshore and backshore zone from the railway tracks lakeward, and there is a slight concave curvature in the linear trend of the beach. This curvature may be due to the fact that the canal acts as a maxi-groyne.

Finally, between South Canal and the canal itself, there is ninety yards of limestone boulder fill. This protects the back of the beach from the extreme erosion which takes place in this area due to wave concentration caused by the presence of the pier. Behind the rock fill zone, long grasses and a few shrubs exist on the compact brown sandy fill which was emplaced during the construction of the canal.

Canal North

This section of the beach extends for 6,850 feet from the pier to the concrete foundation at Little

Cove, and is composed of various beach sections. Due to this variation within the beach, each sub-section will be discussed separately.

Between the canal and North Canal, there is a ninety yard limestone boulder fill area, which protects the tall grass and small shrub vegetated area at the back of the beach. The material under this vegetation is composed of compact sandy brown fill which replaced the original sediment when the canal was constructed. Also, in this area, the general linear trend of the beach gives way to a concave sandy beach, with a radius of curvature of twenty yards. This depositional area appears to be representative of an area in the updrift region of a groyne system. Thus, it is possible and feasible that the pier acts as a maxi-groyne and affects the depositional system in the proximate area.

From North Canal to Power House, the beach returns to its linear trend, and deposition in a few areas is controlled by a series of rock rubble areas, formerly pylons for Hydro towers, which exist in the nearshore zone. The width of the beach diminishes to the north, as does the vegetative cover at the back of the beach.

From Power House to Little Cove, the beach narrows, and becomes a series of coves defined by present and former Hydro tower foundations. In a few of these coves, the railway bank at the back of the

PLACE NAME	PROFILE NUMBER
Little Cove	1
Pump House	2
North Canal	3
South Canal	4
Fourth Avenue	5
Killarney Street	6
Bell Cairn School	7
Hydro + 100	8
Hamilton South	9

NOTE: Places will be referred to by profile numbers in the remaining chapters.

Chart 4.1 Place names and associated profile numbers.

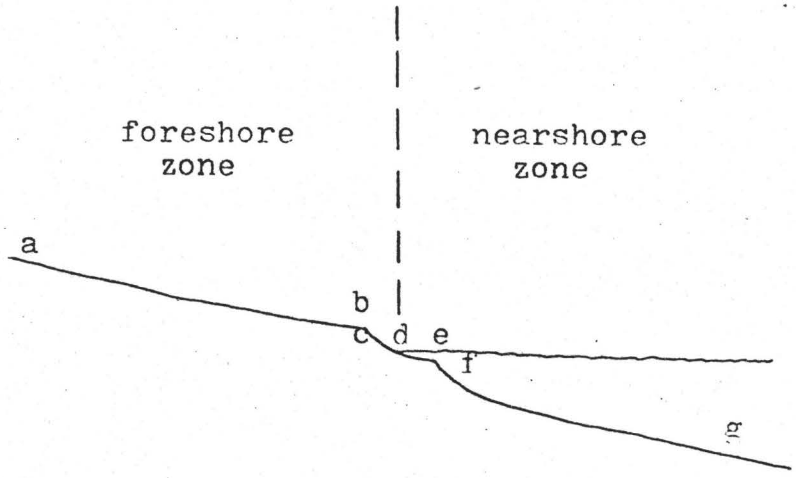
beach has been deeply eroded and is presently a local source of pebbles, cobbles and coarse sand material.

4.3 Beach Profiles

Beach profiles are representative of active beach changes within the process-response model. For example, there is a continual adjustment in the foreshore slope with changes in energy and material factors. Low energy waves with spilling breakers produce a constructive swash which leads to the building up of the foreshore and the construction of a distinct berm. The higher energy, steeper waves however produce a destructive backwash from the plunging breakers, and the sediment on the beach is combed down. There are also modifications of this beach profile due to changes in land and sea - emergence leads to progradation, due to cuspate movement, and due to backshore sand drifting.

Survey Procedure

Surveying of the Burlington Beach from established bench marks at the nine profile locations (Fig. 4.1) was carried out over a four month period. Representative profiles of this period were taken on July 2, August 5, September 23, and October 14, 1972. In order to determine short term changes within any one profile location, readings were taken at the back



a -- back of the beach

b -- berm

c -- swashlimit

d -- waterline

e -- top of the step

f -- bottom of the step

g -- lakeward of the bottom of the step

Fig. 4.2 A general beach profile

of the beach, berm, swashlimit, top of step, bottom of step, and lakeward of the bottom of the step, but within survey means. Modifications of these positional readings were only made when no berm was in existence, and at profile 4 during July and August. During the summer months, swimmers disturbed the natural profile of the beach at this location.

Interpretation of Profiles

The tendency for the profile patterns over the four month period was to show many variable trends which increased in variability towards the end of the profiling period. Much of this variability can be attributed to sand drifting in the backshore zone, the movement of cusp forms along the beach, and normal beach processes generated by low energy and high energy waves. This general variability with respect to profile changes will be considered throughout the periods between the profile dates in order to portray similar patterns.

July 2 - August 5, 1972.

Over this period, only profiles 8, 7, 6 and 1 showed total deposition, while all the remaining profiles showed the variable depositional and erosional patterns. Deposition occurred in the backshore zone at profiles 9 and 2, from the waterline to the step top

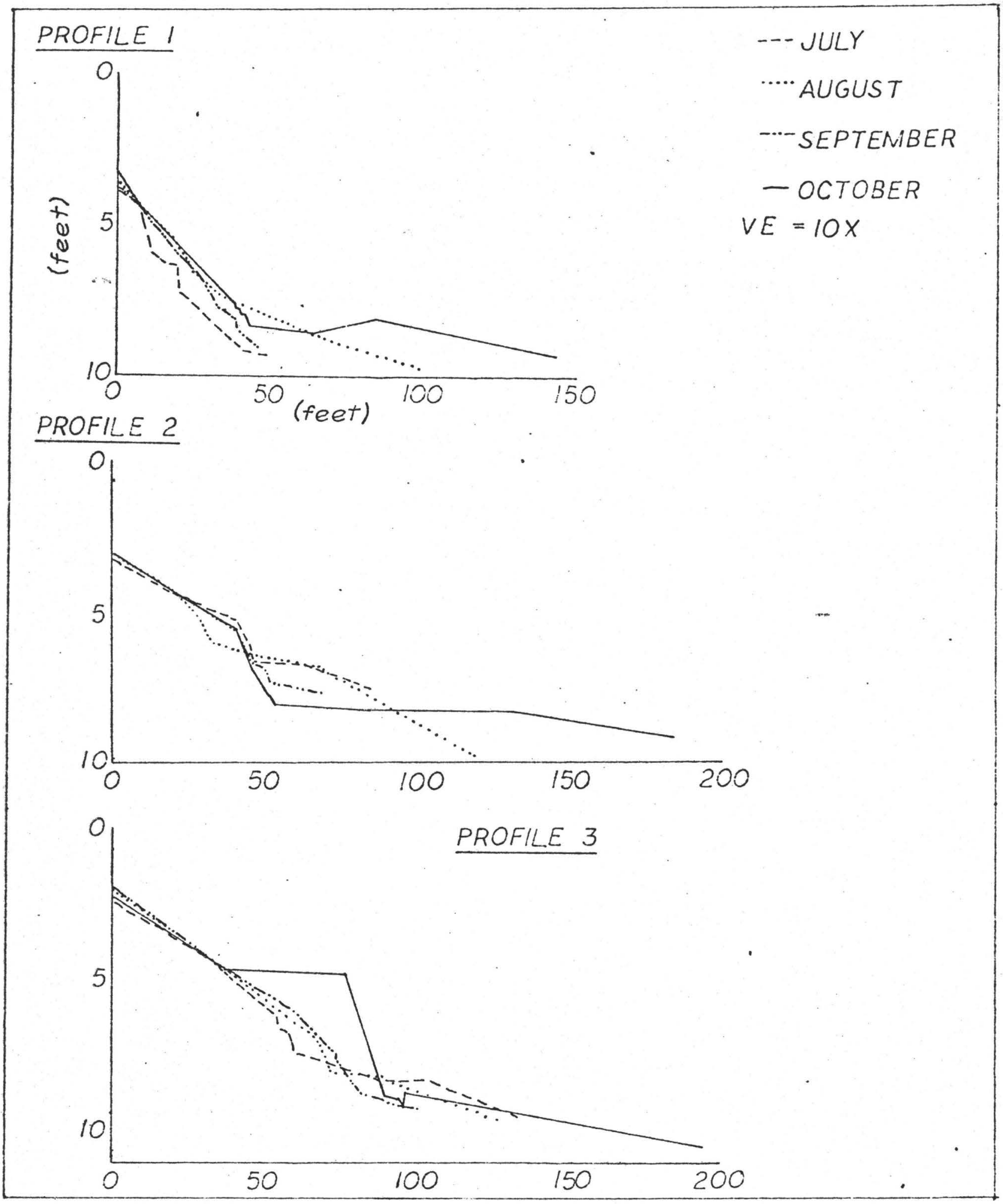


Fig. 4.3 Profiles of Burlington Beach.

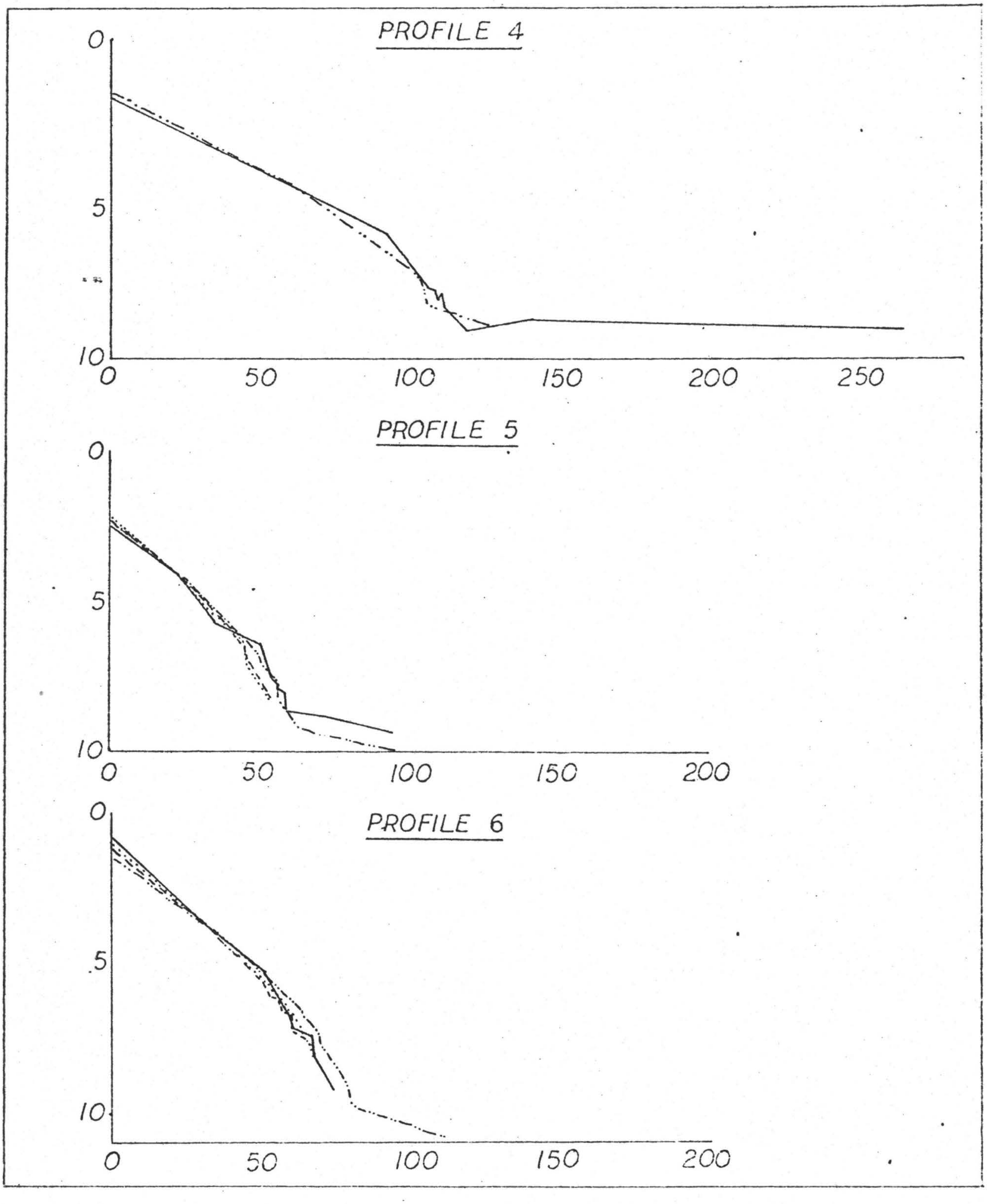


Fig. 4.3 continued

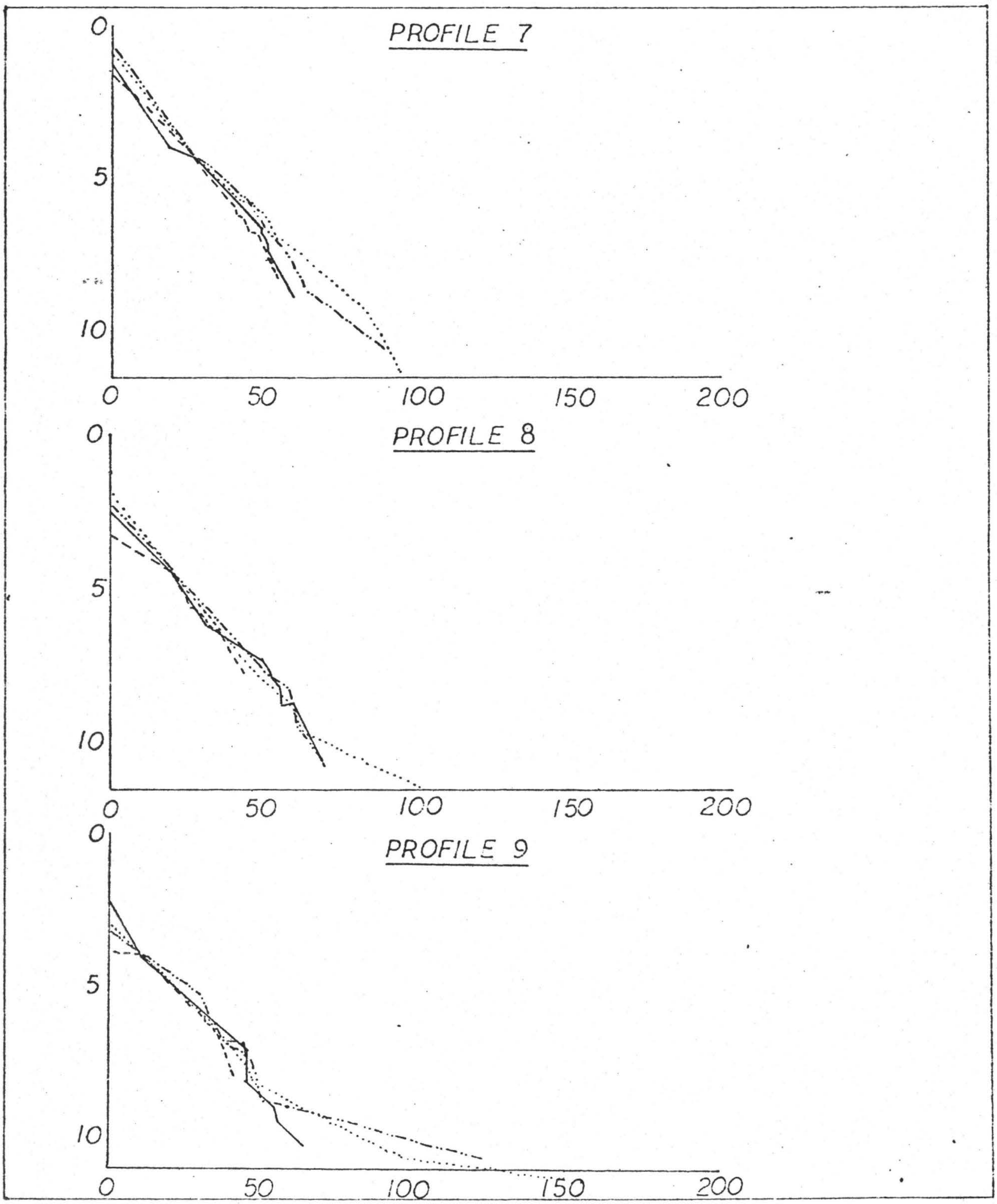


Fig. 4.3 continued

at profile 5, and lakeward from the waterline and step top at profiles 9 and 2 respectively. Only at profile 3 was there any evidence of deposition in the near - nearshore zone. At five profile locations, erosion was noted, and at two of these five locations -- profiles 7 and 6, erosion was noted due to a slight shift in cusp location. The remaining three profile locations, profiles 5, 3, and 2 showed variable erosional patterns. Profile 5 was eroded from the benchmark to the swash-limit and from the step lakeward, while profile 3 was eroded in the backshore and far - nearshore zone. Most of profile 2, from the benchmark to the step top also showed erosion. These profiles have generally moved lakeward, with the exception of profiles 5 and 1 which showed no movement, and profile 2 which moved landward.

August 5 - September 23, 1972.

A greater variability with respect to the change in erosional and depositional areas within the beach profile occurred at all nine profiles. One similarity however existed which showed a general profile extension lakeward. Deposition was noted from the benchmark lakeward at profiles 9, 8, 3 and 6. Profile 7 showed deposition occurred in the zone between the backshore and the swashlimit, while deposition occurred from the step lakeward at profiles 5 and 2.

Unfortunately, profile 1 was disturbed by a bull-dozer which removed the benchmark and the beach! Erosion occurred at the backshore zone, and from the step lakeward at profiles 9, 8, and 2, only at the back of the beach at profile 6, and from the bottom of the step lakeward at profile 2. At profile 7, the entire profile from the swashlimit lakeward was eroded.

September 23 - October 14, 1972.

The greatest variability in the erosional and depositional areas of the profiles is noted during this period. At profiles 9 and 6, deposition occurred in the backshore zone, while erosion of this zone occurred at profiles 8, 5 and 4. Erosion of the total profile occurred at profile 7, while total deposition was noted at profiles 1 and 3. Slight erosion and deposition occurred at profile 6 between the benchmark and the swashlimit, while greater depositional patterns were noted between the berm and step at profiles 9 and 8, the swashlimit lakeward at profile 5, and the bench-mark to the step at profile 4. At profiles 9 and 8, erosion was noted between the benchmark and the berm and the top of the step lakeward, while at profiles 5 and 2, erosion was noted from the benchmark to the swashlimit and from the waterline lakeward respectively. During this period, most of these profiles have moved lakeward, with the exception of profiles 8 and 6

Sweep zone dimensions	Deposition in feet at the back of the beach over the four month study period	Final deposition in feet at the back of the beach	Profile number
narrow	1.66'	1.66'	9
narrow	1.61'	1.03'	8
narrow	.77'	.24'	7
narrow	.68'	.34'	6
narrow	.10'	.10'	5
narrow	-.15'	-.15'	4
narrow	.15'	.15'	3
narrow	.21'	.21'	2
narrow	.71'	.71'	1

Chart 4.2 Burlington Beach profile information.

which moved landward, and profile 7 which remained in the same location.

Throughout the total four month period, all profiles, with the exception of profile 4 showed an overall total positive depositional profile in the backshore zone (chart 4.2). Also, all the profiles showed narrow sweep zones which suggested that this beach was in a stable or equilibrium state. Supporting this idea of equilibrium is the fact that the Burlington Beach is oriented normal to the dominant easterly wave and swell direction. In order to determine whether the Burlington Beach exists as an equilibrium system, a longer study period would have to be undertaken to determine if the variations in the profiles were cyclical and restored over a period of time by natural processes.

It has been suggested earlier that a change in land and sea relations has lead to modifications in the general profile. A review of lake level data over the four month period which encompassed this study showed that there was a continual decrease in lake level (Fig 4.4 and chart 4.3). This then accounted partially for the increasing growth of the beach lakeward from the benchmark.

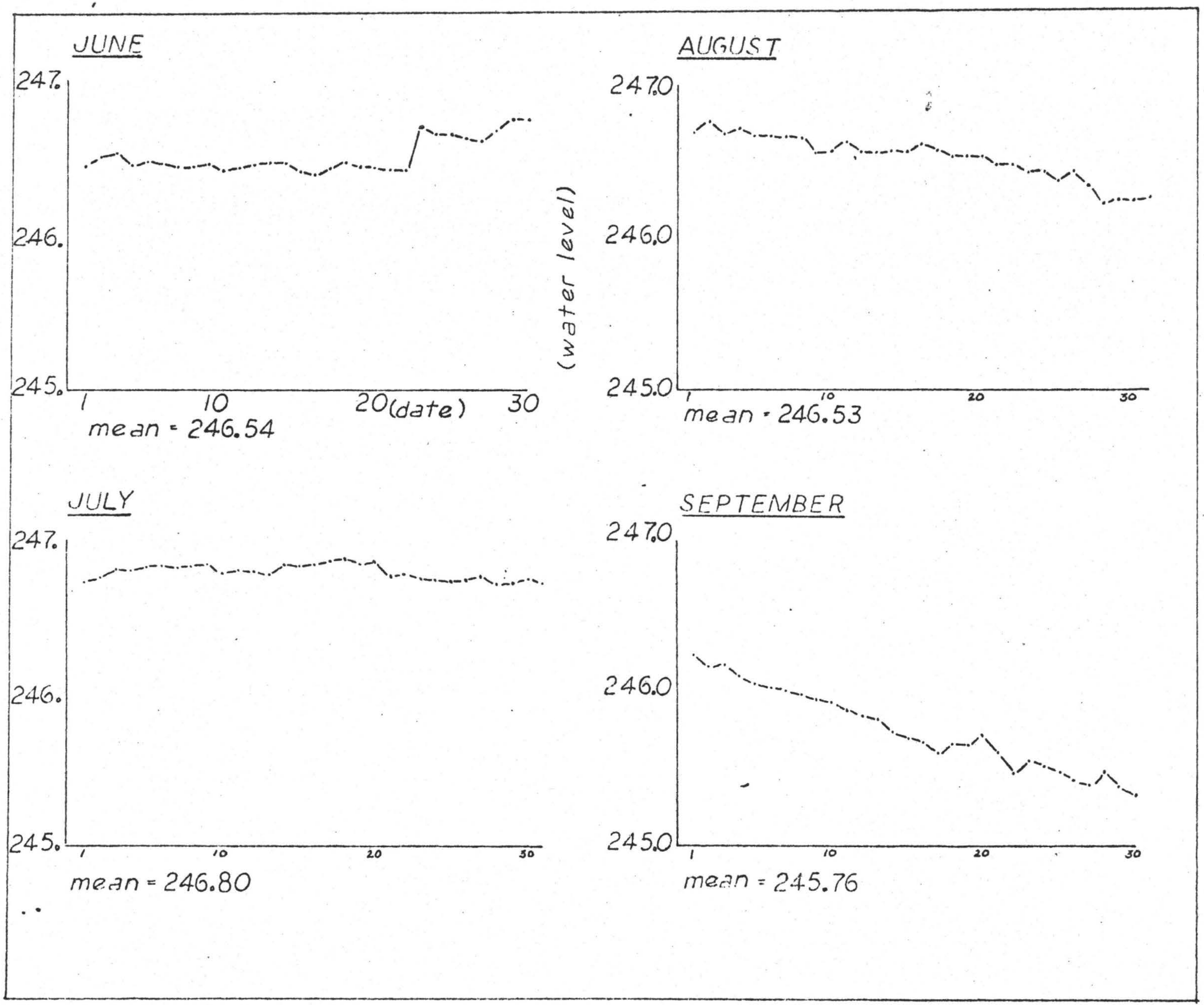
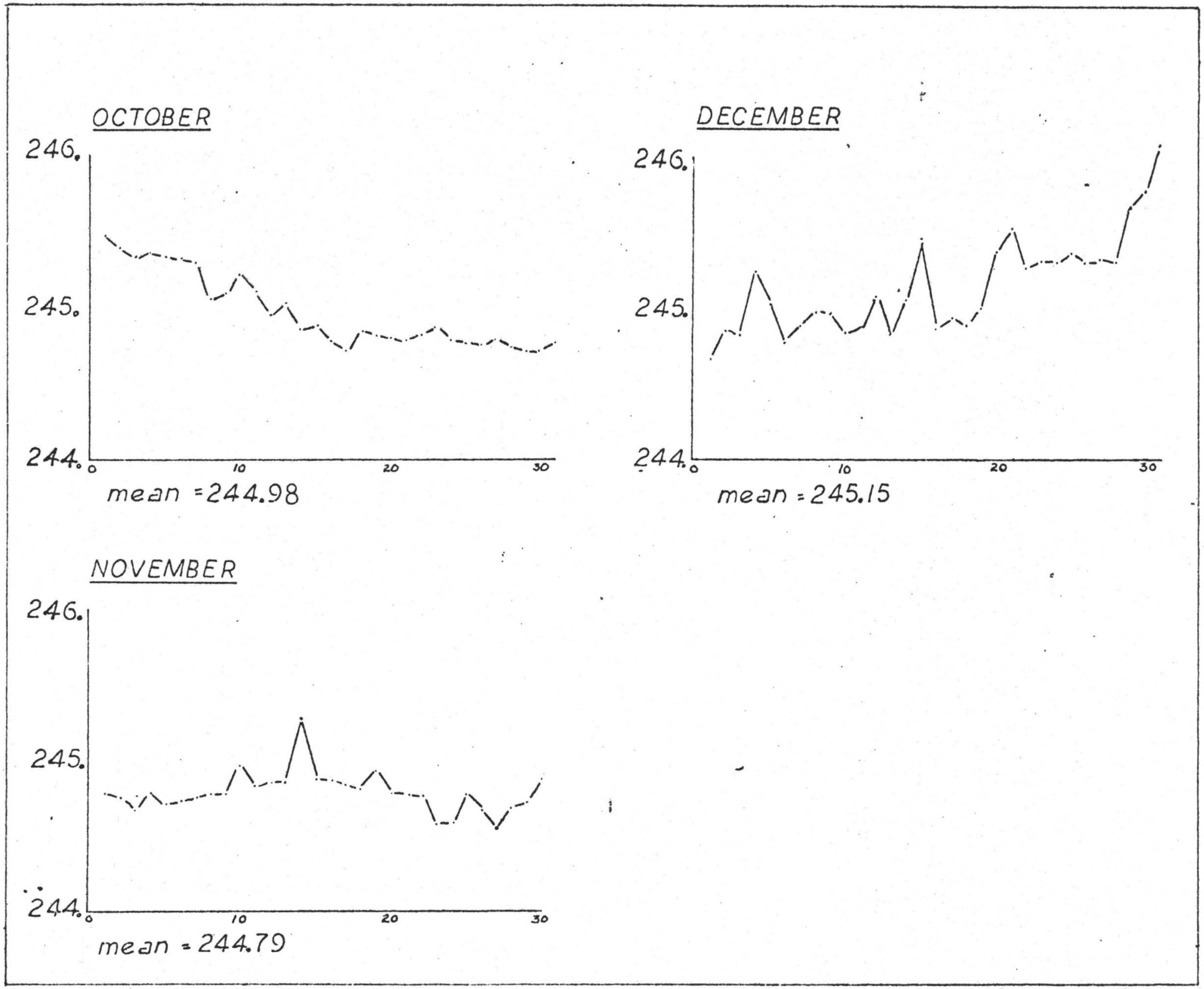


Fig. 4.4 Lake Ontario water level heights. (1972)

Fig. 4.4 continued



DATE	LAKE LEVEL
July 2, 1972	246.78
August 5	246.68
September 24	245.51
October 14	244.88

Chart 4.3 Lake Ontario water levels on survey dates.

4.4 Offshore Bars

To accompany the profile study, another study was undertaken to determine if any offshore bars were in existence at Burlington Beach, and to note the extent and dimensions of these bars. Only one study, on July 8, 1972, was undertaken for only the existence of bars was important. Since bars change daily with respect to normal processes, a detailed study to determine bar movement could not be undertaken in the allotted study period.

To determine the nearshore profiles of the Burlington Beach, proper survey methods had to be abandoned since the rod was not long enough for readings to be obtained, and a crude survey method had to be designed. A lead weight, which was attached to a string marked at six inch intervals with a distinct pattern, was lowered from a canoe until the lead weight reached the lake bottom. The string was then read in approximate values from the water level line. This technique was then repeated at varying positions lakeward from the benchmark.

At most of the profiles, only one bar was encountered within 350 feet of the benchmark, with the exception of profiles 5 and 8, where a small runnel system had also developed in the near - nearshore zone. All the bars varied widely with respect to height, the smallest bar being only .2 feet and the largest bar

Position (profile)	Distance from benchmark	Height of bar	Extent of bar
1	93'	1.3'	48'
1A (cove south of 1)	153'	.2'	67'
2	183'	.4'	26'
3	200'	.2'	9'
5	140'	.2'	9'
	290'	.2'	-
6	150'	.5'	105'
7	345'	2.5'	-
8	135'	.2'	45'
	9'	.5'	7'
9	126'	.3'	25'

Chart 4.4 Offshore bar measurements.

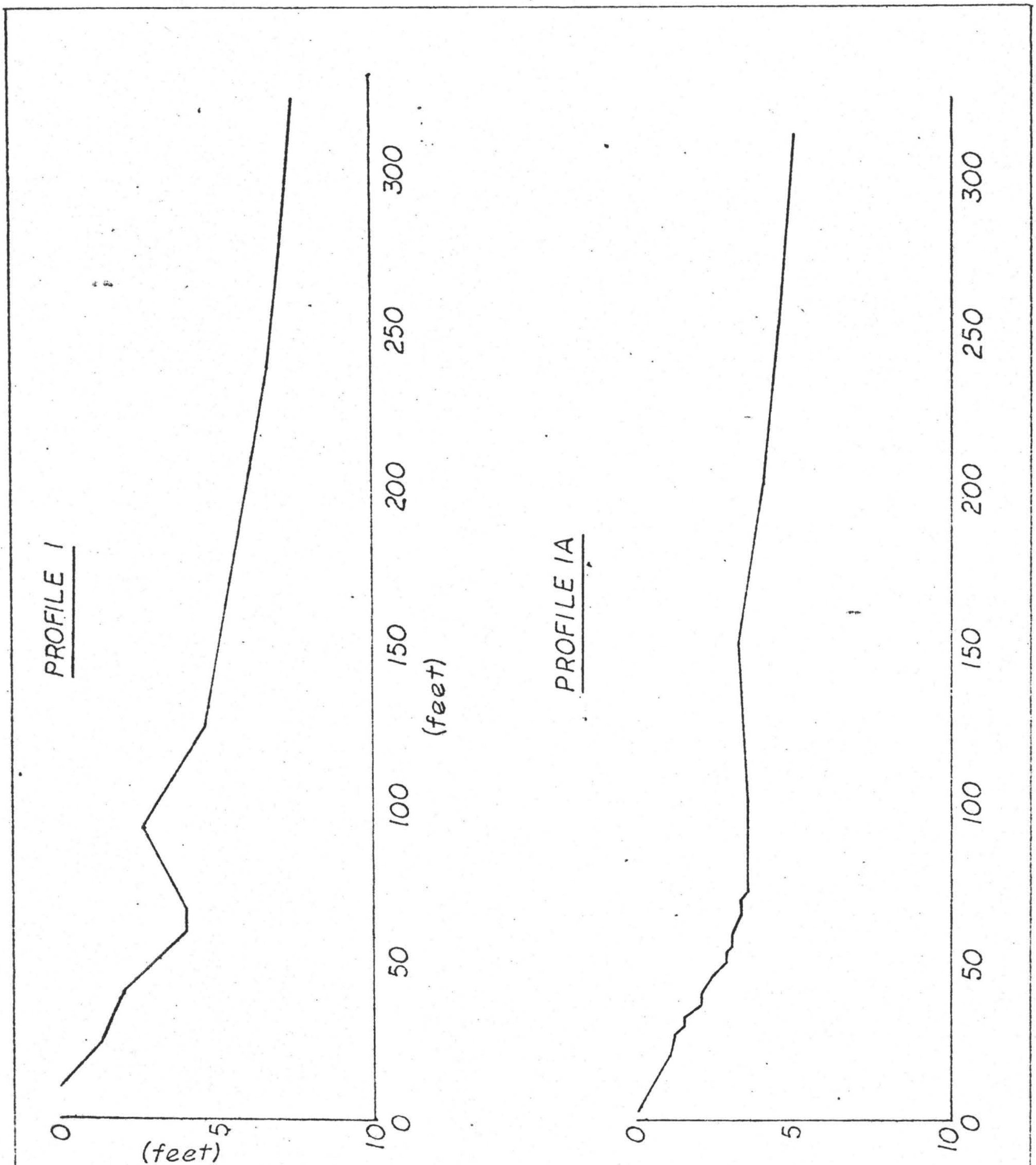
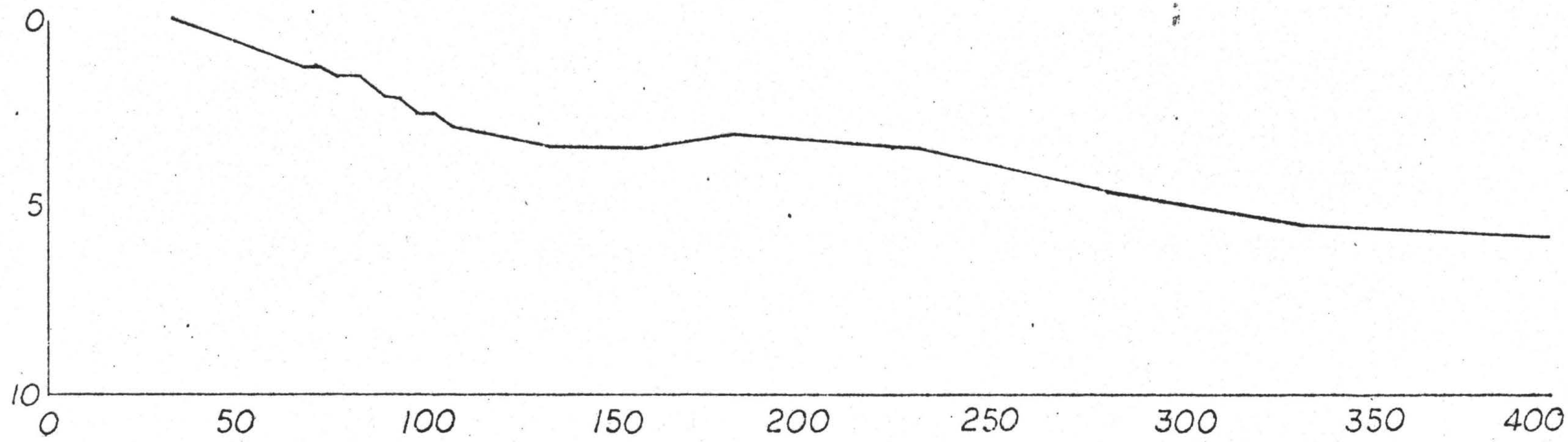
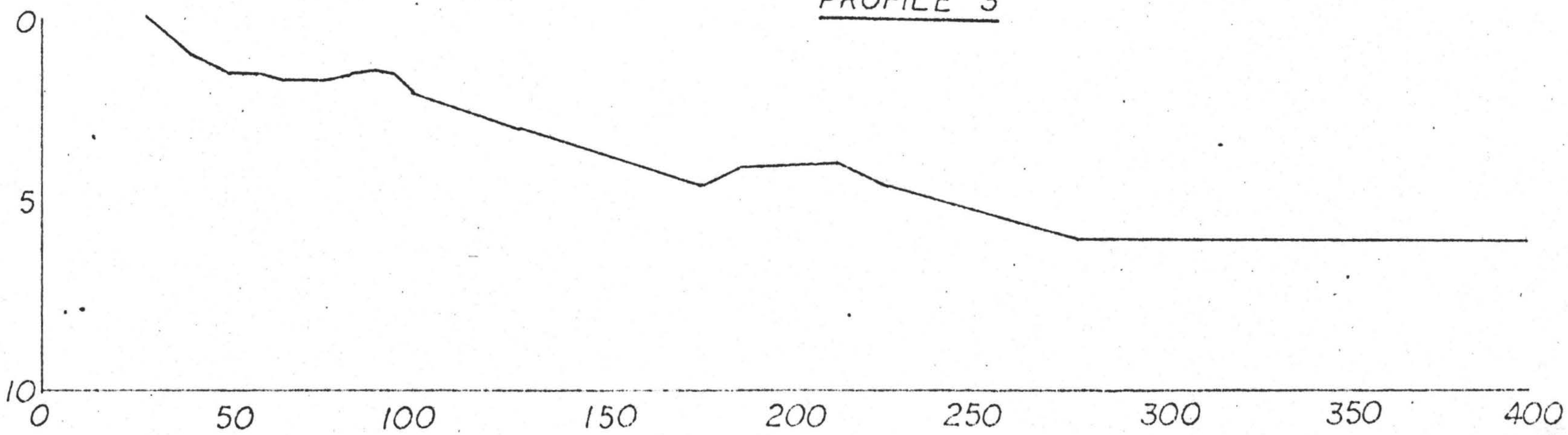


Fig. 4.5 Offshore Bar Profiles

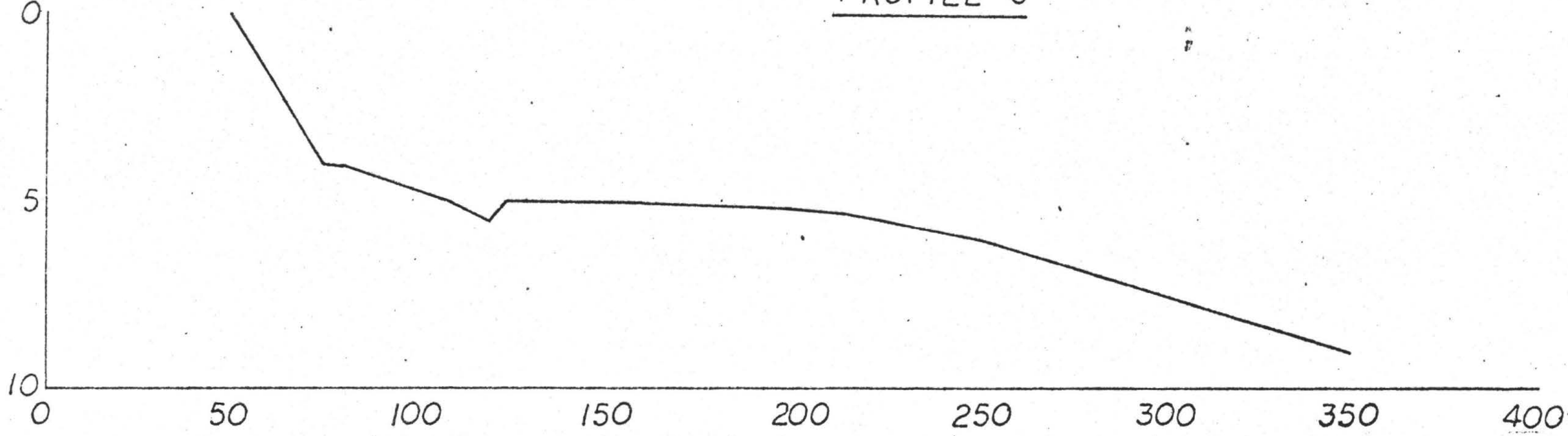
PROFILE 2



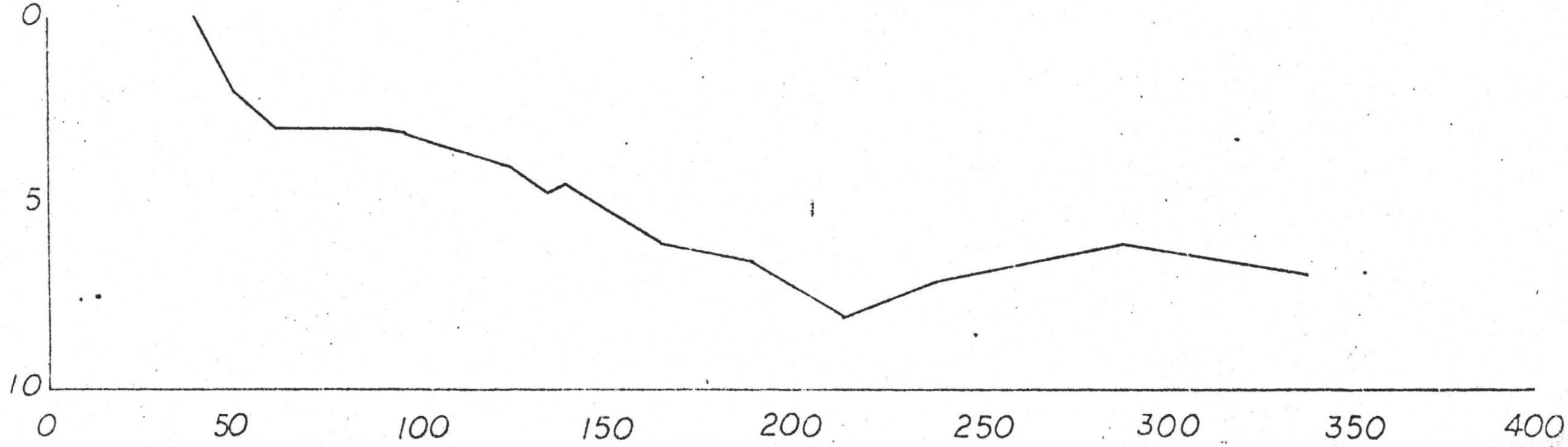
PROFILE 3

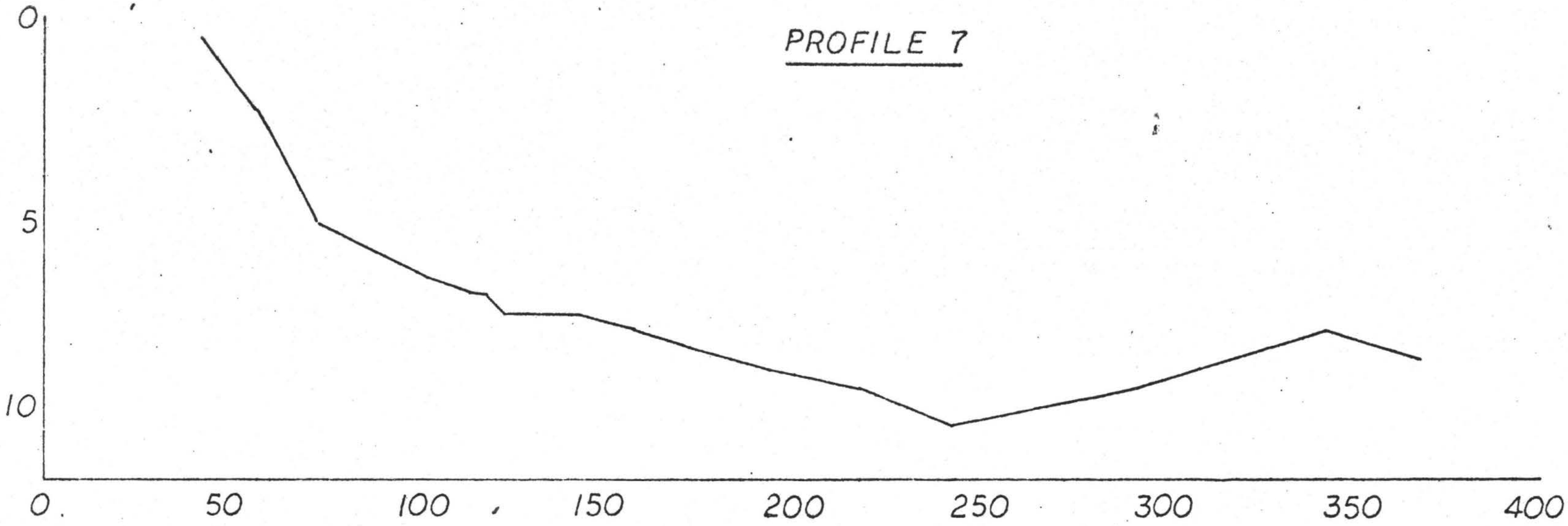


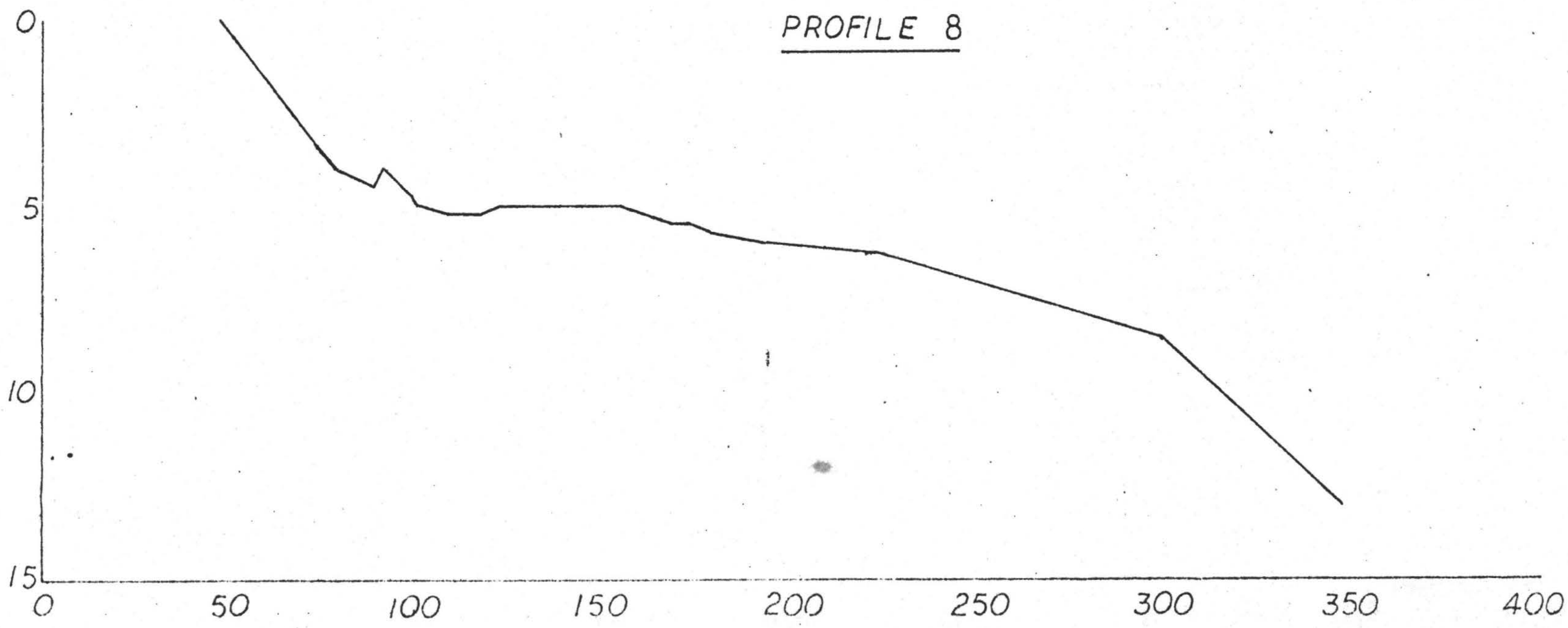
PROFILE 6

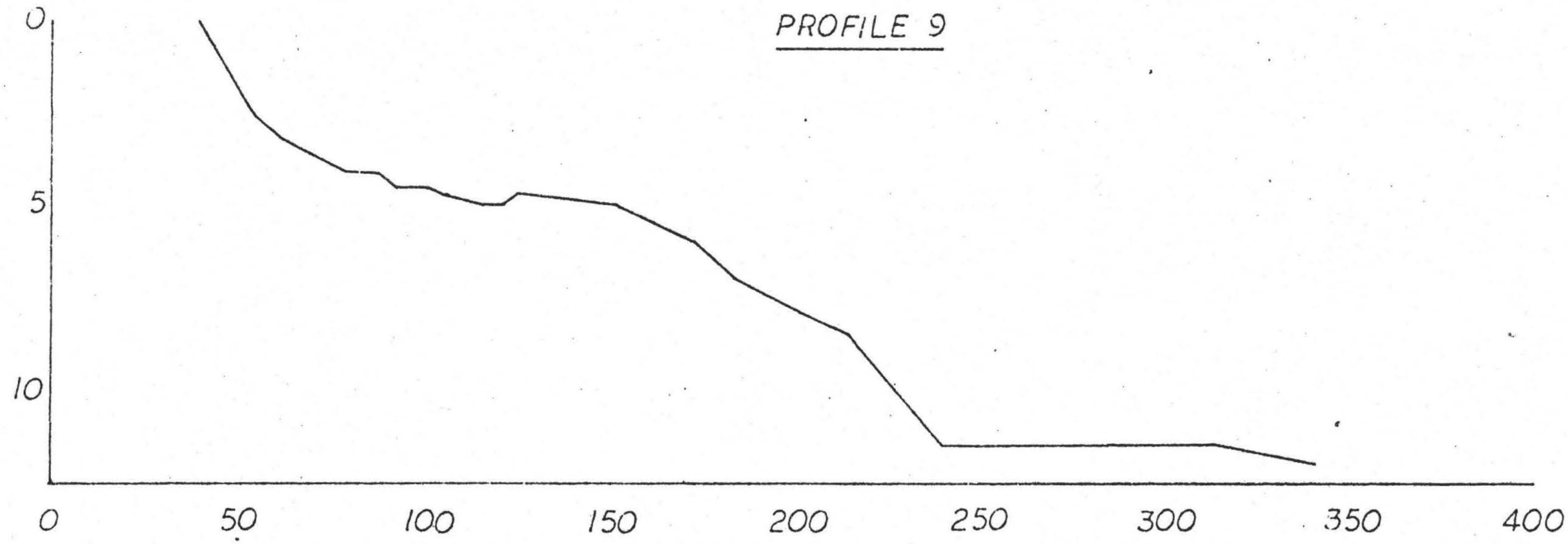


PROFILE 5




PROFILE 7
0
5
10
0
50
100
150
200
250
300
350
400


PROFILE 8
0
5
10
15
0
50
100
150
200
250
300
350
400


PROFILE 9
0
5
10
0
50
100
150
200
250
300
350
400

being 2.5 feet, and with respect to form. Form can be divided into those bars which had relatively flat crests and those which had sharp crests. No correlation between the type of crest of a bar and the extent of the bar, which varied from 9 feet at profile 5 to 105 feet at profile 6 was noted.

4.5 Minor Beach Features

Every beach, no matter how large or small has developed minor beach features, whether they be swash-marks, backwash marks, ripples or cusps. Of particular interest to this author were the ripple systems, shingle beach, beach cusps, ridge and runnel system, and the changing foreshore characteristics which were found in the Burlington Beach system.

Ripples

Ripples are always present on sandy lake beds where sand is subjected to moving water which has a velocity between .33 and 2.50 feet per second. Since wave fronts usually parallel the shore, ripple crests and troughs also parallel the shore, thus, it can be stated that ripples generally develop parallel with the wave front. At Burlington Beach, two distinct ripple types, solitary and trachoidal, characterized by the shape of the troughs were present. Solitary ripples had flat troughs, and developed where shallow water,

Plate 4.9 Ripples

a suitable amount of sediment in suspension and fine sand conditions existed, and when the orbital amplitude and the bottom velocity of the waves was great. Since the troughs were flat, there was no vortex movement. Hovever, in the similarly developed trachoidal ripples, rounded troughs had led to the development of vorticies.

Sand at the crest of the ripple is an important factor in the development of ripple measurements. The size of the sand determines ripple height which in turn determines the width of the flow-shadow, and the repetition distance of the ripples. At Burlington Beach, the crests of the symmetrical ripples were composed of fine sand (chart 4.5) which led to the the development of two to three inch ripple heights and repetition distances of five to seven inches.

Shingle Beach

A shingle beach, like that found along Canal South, is formed by destructive waves which throw pebbles onto the beach beyond the reach of the normal waves. King has suggested that this pebble material is more mobile than finer grained beach material. Thus, accretion on the beach profile during a given period will be greater under similar conditions if the beach is composed of shingle material. This development leads to the formation of shingle beach ridges. At Burlington Beach, shingle material was emplaced by storm

Chart 4.5 Ripple and Changing Foreshore Measurements.

RIPPLE MEASUREMENTS

location	mode	median	mean	standard deviation	skewness	kurtosis	sorting coefficient
crest	2.50	2.02	2.01	.39	-.31	.55	44.66
trough	2.50	1.99	1.97	.41	-.76	3.70	50.72

CHANGING FORESHORE MEASUREMENTS -- June 3

location	mode	median	mean	standard deviation	skewness	kurtosis	sorting coefficient
berm	1.00	.70	.57	.88	-1.01	1.52	26.25
swashlimit	-2.00	-.07	-.26	1.17	-.02	-.83	14.80
waterline	-2.00	.25	-.13	1.27	-.26	-1.04	16.98
step top	-2.00	-1.06	-1.13	.80	.66	.42	24.96
step bottom	-1.50	-.49	-.52	1.0	.40	.08	18.59

-- June 4

location	mode	median	mean	standard deviation	skewness	kurtosis	sorting coefficient
swashlimit	-2.00	-.84	-.78	1.06	.39	.40	19.07
waterline			----------------				
step top	-4.00	-2.21	-2.90	1.19	.48	.02	48.71
" bottom	-4.50	-3.35	-3.68	1.06	.76	-.61	43.21

waves, and was generally well sorted, and varied in pebble sizes from one inch at one location to three inches in maximum diameter at a second location. The foreshore was steeper where shingle material was present, and a general association with beach cusps, rather than nearshore ripples was noted.

Beach Cusps

On Burlington Beach, these temporary spaced cresent shaped depressions are situated normal to the lake front and face concave lakeward. The cusps are composed of sands, cobbles and gravels along Canal South, and appear to vary in size and shape under varying wave conditions. Most of the cusps composed of gravel material are separated from each other by stretches of smooth sand areas, while those cusps composed of sand are elongate and join each other at an acute point. In the intervals between the cusps, shoreface terraces with scalloped faces formed by the backwash winnowing out the finer grained material, and depositing it in these intervals is found.

Although many studies have been done concerning the formation of cusps, no exact method of cuspate formation has been established. It is understood though that general features must exist. For example, there must be irregularities along the beach face, waves must strike the beach directly, and the swash patterns

RIDGE AND RUNNEL SYSTEM ON BURLINGTON BEACH

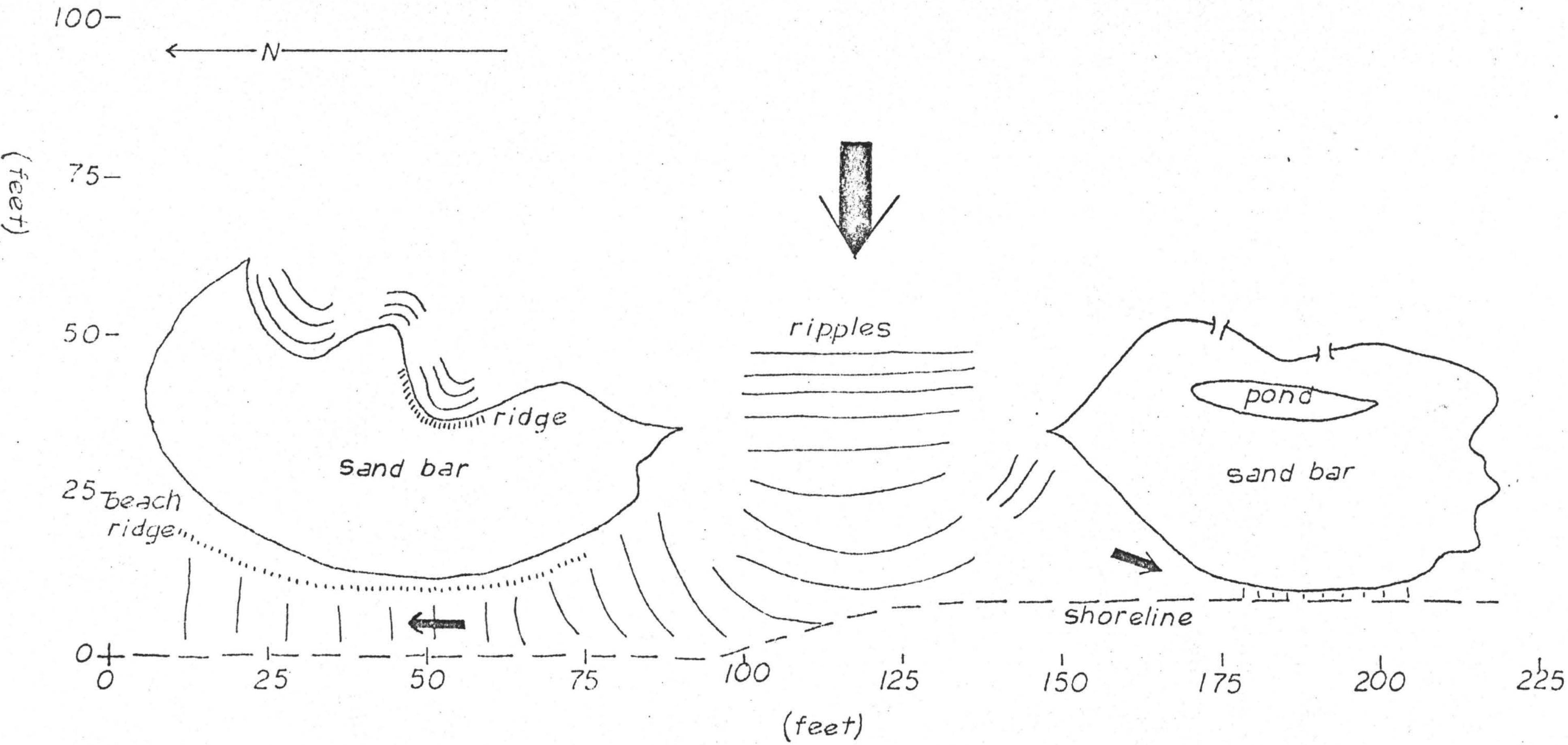


Fig. 4.6

must intersect each other.

Ridge and Runnel System

Only during the months of August and part of September did this ridge and runnel system (fig. 4.5) develop at North Canal (profile 3). Two sand bars 60 feet apart have progressively moved inshore until they were within twelve feet and one foot of the shore. During high wave conditions, waters spilled over these features, and slight dissected ripple pattern developed on these bars. Generally though, these bars were exposed, and the main region for incoming waves was between the two bars. Here, ripples developed parallel with the wave front and parallel with the shore. As the wave approached nearer to shore, it was refracted by the bars and produced a concave lakeward ripple pattern. At the shore, the water was diverted either north, or south along the existing runnel systems. In these systems, especially the northerly runnel system, asymmetrical ripples were formed normal to the shore, but parallel to the direction of water movement. Due to the closeness to shore of the most southerly sand bar, only small ripple forms were formed.

Changing Foreshore Characteristics

On June 4, 1972, two beach positional systems were noted to exist in the area of profile 8, and extend down the beach to profile 7. The highest positional system on the beach was representative of a storm system produced on June 3, while the lower system was being produced under low energy conditions on June 4. Samples were taken from the five main positional locations in order to determine the variability in sediment over a two day period at similar positions at the same sample location. On both days, the material coarsened from the berm, and was accompanied by an increasing poorer degree of sorting lakeward. On June 4, the swashlimit was located at the same location as the bottom of the step on June 3, and both swashlimit material on the consecutive days, as well as the step bottom material showed similar grain sizes and sorting patterns. On June 4, the remaining positions lakeward from the swashlimit had coarsened in sediment size from that found on June 3, and the degree of sorting had become poorer. This increase in grain size can only be accounted for on June 4 by the transporting in of coarser material to the area by means of the longshore current.

4.6 Conclusions

Burlington Beach was divided into three distinct morphological regions which were defined by their location with respect to the canal and by internal characteristics. The groyne area was defined by the presence of groynes which were built in an attempt to protect the beach from erosion. Canal South, a linear segment of the beach, whose linearity was only broken by cusp formation, tower foundation influence, and canal influence, was defined by its location with respect to the canal. Also defined by its location with respect to the canal was Canal North which could be compared, especially in the area near the canal, to an area in the updrift region of a groyne. Its linearity was broken by tower foundations, and to a great extent by the canal which acted as a maxi-groyne.

The Burlington Beach profiles showed variable patterns of deposition and erosion over the four month study, with greater variability noted towards the end of this period. Most of the causes of this variability were noted as changing energy conditions, land and sea variations, cuspate movement and backshore sand drifting. Many of the profiles showed a general lakeward movement and narrow sweep zones. The orientation of the beach normal to the dominant swell and wave directions, and the narrow sweep zones suggested that an equilibrium beach system, possibly brought about by the building of the canal, existed at Burlington Beach.

Along the beach, at least one bar was found at each profile location, while varying minor beach features such as ripples, shingle, cusps and a ridge and runnel system existed at varying locations.

CHAPTER 5

THE BEACH SEDIMENTS OF BURLINGTON BAR

5.1 Purpose of Sedimentary Analysis

The purpose of this chapter is to investigate the nature of the material at specific locations on the Burlington Beach, and to see if this material varied in composition at any one place throughout the summer. It is also the intention in this chapter to examine cross beach variations, to find out if they are regular at one location or at all locations; to determine if regular variations exist along the beach; and to see if variations exist between the areas located north and south of the canal.

The Hamilton Harbour side of the Bar was not studied, for it could not be compared with the Lake Ontario (Burlington Beach) side due to

1) the great influence man has recently had on this beach environment, and
2) the fact that the sediment on the Hamilton Harbour side of the Bar comes from a different source area.

5.2 Sampling Procedure

For the purpose of this short term study, sediment was sampled at nine locations, beginning at the south (Hamilton) extent of the Bar, 25 feet from the first groyne, and then approximately every half mile to the northern extremity of the Bar. This system set up six sampling locations on the beach south of the canal and three locations north of the canal, which were also used for survey positions. This spacing was considered to be adequate for the determination of a regional trend along the four mile Bar, and only picked up local effects at profile 1. Samples were taken at each profile at five locations across the beach -- the berm, swashlimit, waterline and the top and bottom of the step, since these positions were usually evident on the beach, and only changed in relative position throughout the season. This sampling scheme was repeated on three occasions -- June 4, August 5 and September 16, 1972 such that a total of 135 samples were taken.

The sediment obtained was intended to be representative of a constant depositional process, and to be representative of the whole unit under investigation. Thus, the sample was taken at random within each subgroup - depositional lamina, but systematically within the whole population (Blatt, Middleton, Murray, 1972). The top one centimeter of sediment was removed from the sampling location to prevent contamination of the depositional lamina by wind blown material, and this lamina was sampled within an eight centimeter square area.

Outside factors affected the established sampling procedure at various times. On August 5, at profile 2, a large accumulation of weed hid the location of the step, and made sampling impossible without great disturbance of sediment near the step. Also on this date, samples were not taken at profile 4 due to the presence of many swimmers which disturbed the natural distribution of beach and nearshore sediment.

A detailed sampling procedure immediately north and south of the canal was undertaken in November 1972 for a comparison with a study done in November 1971 by Bryce, Egginton and Wilkins. Samples were taken starting at a distance of 90 yards from the pier at ten twenty yard intervals, in order to allow a sufficient lateral extent of sampling which was not too widely spaced to lose the pattern of continuity. On the north side of the canal, ten samples were taken at the back of the beach since the remaining portion of the beach was frozen, while on the southern side of the canal, ten samples were taken at the middle of the swash zone.

5.3 Laboratory Procedure

Prior to the analysis of sediments collected from the Burlington Beach, a study to test the methods used in analysing and measuring sediments was undertaken. By noting the advantages and disadvantages of the two methods chosen -- sieving and visual accumulation tube, the most accurate method of analysis could be determined and employed in the ensuing study.

Samples for this study were obtained from different beach levels -- berm, waterline and the back of the beach, on the Lake Ontario side of the Burlington Bar on November 19, 1971.

The first method tested was the sieving method. Sieves at ½ phi intervals were used in order to introduce an accurate overall picture of the sediment size distribution, and in order to compare the results with the visual accumulation tube results. It was decided that one phi intervals would be useless in determining sediment distribution and that ¼ phi intervals would be too time consuming and the results obtained could not be used for comparison with the visual accumulation results. Each sample was dried and samples 1, 2, 3, 5, 6, and 8 were divided by using the divider and weighed as split sand samples. Samples 4 and 7 were treated differently because of their visible coarse grained content. They were sieved through a -1.0 phi sieve in order to separate the granular material from the sand fraction. The total sand fraction was then weighed, then split and weighed again. The granule fraction was resieved through -3.5 phi to -1.0 phi sieves and the contents of each pan weighed in a beaker. Then, all the split sand samples were sieved for fifteen minutes by machine in sieves from -0.5 phi to +4.0 phi. Upon completion of sieving, the contents of eash sieve was placed in a beaker and weighed to four decimal places. Material in the pan was treated as material finer than +4.0 phi.

There are however certain disadvantages with this method. For example:--

1) some of the sand particles stick in the mesh of the particular sieves and a measuring error is introduced, since the original total sediment weight is depleted by a small fraction.
2) there is sometimes difficulty in separating the sieves and care must be taken in order to keep the contents in the sieve.
3) material, particularly fines, may easily rise and be lost, when the material is being transferred from the sieve to the beaker. Thus, again, a measuring error is introduced, and
4) the sieve falling off the machine causes a disturbance in the distribution of the sample.

The error factor involved in each of the samples is shown in chart 5.1. These results are accurate to ± 1.5%.

The second method tested was the visual accumulation tube. This method is intended primarily for the size analysis of sediment samples consisting of

Sample number	Error (%)
1	-1.3264
2	-0.2919
3	-0.3734
4	-0.0963
5	-0.1810
6	-0.3566
7	-0.3489
8	0.0054

Chart 5.1 Error in percentage by the sieving method.

mainly sand or samples from which the finer material has been removed. This fine material (silts and clays) should be removed to improve the accuracy of the analysis. This size frequency analysis is based on the fall diameter of particles in the sample, since the sample particles settle in the visual accumulation tube with higher velocities than those for the same particles falling separately. This fall diameter can be explained as the diameter of a sphere having a specific gravity of 2.65, and having the same terminal uniform fall velocity as the particle in unagitated distilled water, with the fall velocity independent of any effect from the tube walls or adjacent particles (Krumbein and Pettijohn, 1938).

Only five grams of the sediment sample was used in this tube, for it was the maximum amount of material which could be used to produce acceptable results. A plug was placed in the bottom of the tube, the tube was filled with distilled water above the valve, and the temperature was taken. The chart and pen were oriented and the telescope set with the cross hair at the top of the plug. The valve was closed, the chamber was filled to the reference mark with distilled water and the sample was placed in the mixing chamber and agitated for five seconds. The plunger was removed, the valve was opened immediately and the accumulation of sediment at the base of the tube was followed by the cross hair on the telescope. It is important to note at this point that the settling of material in the visual accumulation tube is water temperature dependent. With a low water temperature, the water is more viscous and settling is slower, while the reverse is true with a high water temperature.

There however tend to be many disadvantages with this method. For example:--

1) material settles at the top of the collecting section and then the material settles again as it procedes down this section. Thus, the settling distribution of the material is disturbed; there is a time lag in settling due to this double settling, and the correct result of settling is not obtained. This double settling indicates that the tube is too small for the sample and the sample should be run again, with less material. This last result caused in many cases a reversal in the sediment percentage trend between +2.5 ∅ and +3.0 ∅.
2) air bubbles in the column cause the material to be carried up the tube and settling is again disturbed.
3) if the valve is not opened wide enough, the drum will not begin to move and the settling of the sample can not be recorded.
4) there is a major problem in keeping the cross

hair on the telescope even with the top of the settling sediment, and this affects the results plotted on the chart. It is virtually impossible to keep up with well sorted material since it settles quickly at one interval.

5) sediment coarser than 0.0 phi can not be measured by this method.

6) with the throwing of the valve, an eddy may be caused by the falling water, and the settling of sediment is disturbed, since the material is again put into suspension.

7) some of the original material is very fine grained, thus taking longer to settle, and it can not be recorded, since the drum records material settling for just over three minutes.

It should be noted here that both results obtained by sieving and the visual accumulation tube are dependent on the splitting method. By using the splitter properly, a sediment sample should be equally divided. However, the sediment may not be divided equally and this unequal division will influence the results obtained by both methods. In my analysis, this possible error is taken into account.

With the data obtained from sieving and the visual accumulation tube, individual percents, and cumulative percents were calculated and plotted as histograms and cumulative curves. Graphic measures presented on chart 5.2. These results were obtained from sediments which were analyzed only once by each method. For better accuracy, sediments should be analyzed twice to see if the same result is obtained by the same method. Also, an improvement could be made with respect to the chart on the settling column drum. If the intervals on this chart were $\frac{1}{4}$ phi intervals, a more specific distribution of the sediment could be obtained and sieving at $\frac{1}{4}$ phi intervals could be used as a comparison.

In conclusion, the results obtained by the settling column (visual accumulation) method and the sieving method approximated each other.

Because of the large amount of sediment to be analyzed from the Burlington Beach, a wide distribution of size classes and an analysis of the total sediment needed, the sieving method was chosen. Sieves were generally nested in $\frac{1}{2}$ phi intervals from -2.0 Ø to +4.0 Ø, but at various times, the nesting of the sieves was modified to range from -5.0 Ø to +4.5 Ø.

The samples were dried in the oven at 120° C for approximately twenty - four hours, split into fractions weighing fifty to seventy grams using the dividers, and sieved for ten minutes on the mechanical shaker. This time interval was thought to be suitable for the differentiation of sediment into various sizes. The contents of each sieve was weighed to one one-hundredth

SAMPLE	METHOD	HISTOGRAM	CUMULATIVE (%)	
		mode	mean	standard deviation
1	sieve	2.5 ø	2.43 ø	.36
	tube	3.0 ø	2.52 ø	.60
2	sieve	2.5 ø	2.33 ø	.30
	tube	3.0 ø	2.52 ø	.26
3	sieve	2.5 ø	2.34 ø	.31
	tube	2.5 ø	2.43 ø	.51
4	sieve	2.5 ø	1.39 ø	1.18
	tube	2.5 ø	1.42 ø	.81
5	sieve	2.5 ø	1.46 ø	.74
	tube	1.0 ø	1.37 ø	.57
6	sieve	2.0 ø	1.53 ø	.77
	tube	2.5 ø	1.07 ø	.72
7	sieve	-1.0 ø	.19 ø	.74
	tube	.5 ø	.43 ø	.26
8	sieve	1.5 ø	1.49 ø	.43
	tube	2.0 ø	1.33 ø	.43

Chart 5.2 Sieve and Visual Accumulation Comparisons.

of a gram, and the content of the pan, which usually represented less than one percent of the total sample, was considered as insignificant in the determination of the overall sediment size distribution pattern.

5.4 Statistical Analysis

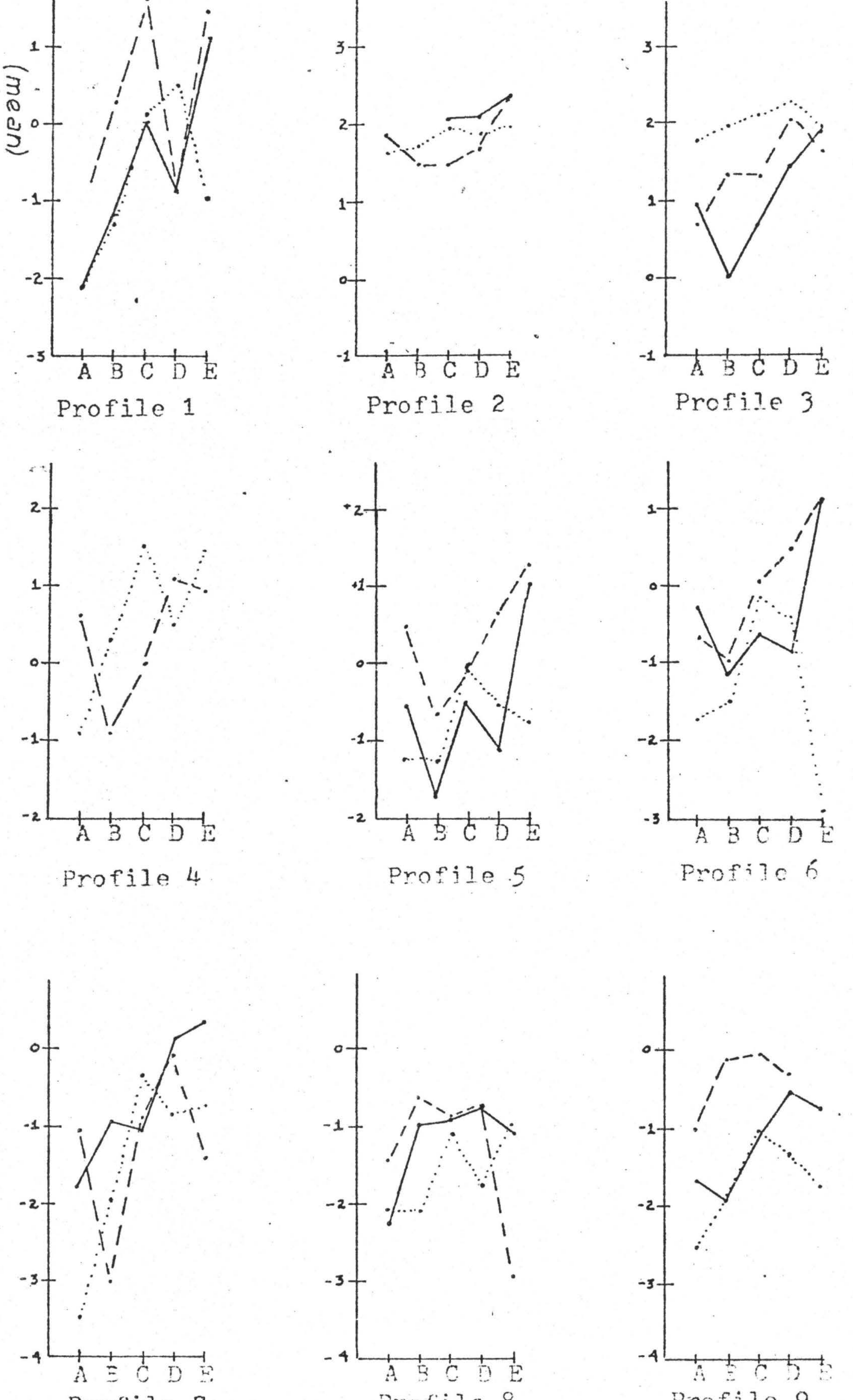
Statistical analysis of the sieved samples was carried out with the use of a computer program modified from a Woods Hole Oceanographic Institute program written by D. R. Ingram in April 1968. This program, using the weight percent of each size fraction of the sample, plotted a histogram and cumulative percentage curve, and calculated the main central tendency measures -- mode, mean, median, standard deviation, skewness, kurtosis and the coefficient of sorting. This data has in part been portrayed as graphic displays of sediment across and along the beach, and in bivariate plots. Only the mean, from which size determination can be made using the Udden-Wentworth grade scale, the standard deviation, from which the degree of sorting can be obtained using the Folk and Ward (1957) sorting scale and skewness, which is environmentally significant (Friedman, 1967) were useful for sediment interpretation. Kurtosis, the measure of peakedness was ignored, since it is not geologically significant.

Appendix 1 contains all the output data for the sediments analyzed during the three sampling periods.

5.5 Interpretation of Results

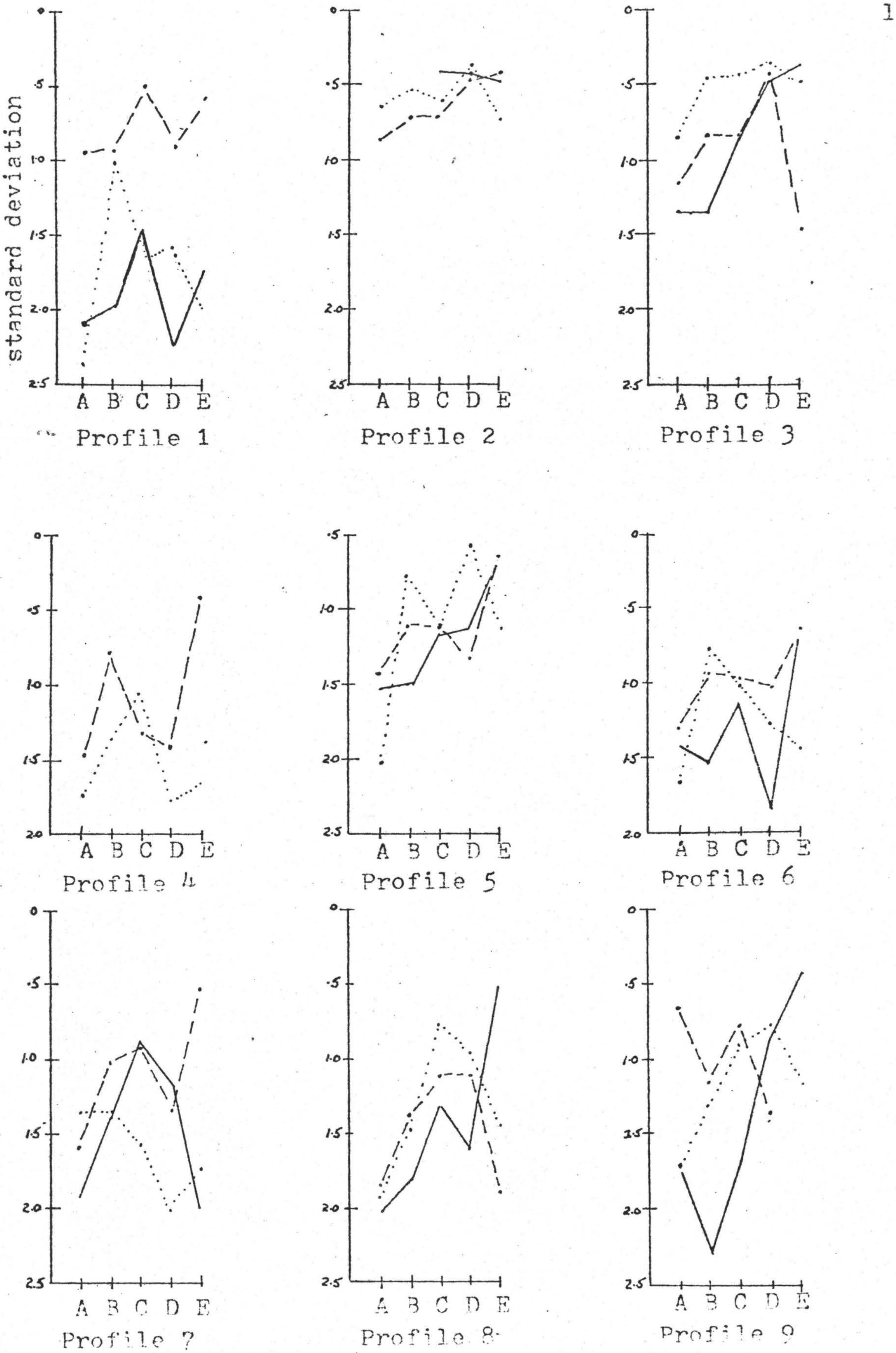
The sediment size distribution studied on the Burlington Beach showed a large range of variability over the three month study period. In June, August and September, sediment sizes were noted to vary from -3.1 ∅ to +2.2 ∅. -2.2 ∅ to +2.3 ∅ and -3.5 ∅ to +2.2 ∅ respectively, and encompass large sediment ranges of 5.4 ∅. 4.5 ∅ and 5.7 ∅. In all cases, the finest sized material was located on the northern side of the canal in the foreshore zone at profiles 2 or 3, while the coarsest material was located on the southern side of the canal in the near-nearshore zone at either profile 7 or 8. Generally, sediment size appeared to coarsen with distance from the canal.

The degree of sorting also varied considerably on the Burlington Beach during the three month study period. In June, August and September, the degree of sorting was noted to vary from 1.9 ∅ to .4 ∅, 2.3 ∅ to .4 ∅ and 2.3 ∅ to .4 ∅ respectively while the range of the degree of sorting varied from 1.5 ∅ to 1.9 ∅ over this period. In all cases, the best sorted material was located on the northern side of the canal in the foreshore zone at profile 2 or 3, while the poorest degree of sorting was noted at the profiles farthest from the canal at the extremities of the positions -- the berm and the bottom of the step.



A -- bottom of step
B -- top of step
C -- waterline
D -- swash limit
E -- berm

-- June
— August
···· September



A -- bottom of step
B -- top of step
C -- waterline
D -- swashlimit
E -- berm

-- June
— August
... September

Site and Profile Variation

Profile 1

The samples taken from the five sampling positions over the four month period varied in grain size from medium sand (+1.6 ∅) to pebbles (+2.1 ∅). The coarsest material at all three sampling times was located in the nearshore zone at the step bottom, while the finest material was found at various positions in the foreshore zone. Site trends show that the sediment sampled at the berm and the swashlimit had coarsened noticeably over the second half of the study period, while the material located at the three remaining sites -- the waterline and the step top and bottom had coarsened during the first half of this period. With this increase in sediment size, there was a distinct decrease in the degree of sorting, except at the berm, where no definite sorting trend existed.

The sediment and sorting patterns across the beach during the June and August sampling periods showed a general lakeward increase in sediment size and a corresponding decrease in the degree of sorting. This trend was divided into two specific lakeward decreasing trends -- one from the berm to the swashlimit, and the second from the waterline to the step bottom. During the September sampling period, only the second specific trend remained constant, while the first trend showed a complete reversal to that formerly established.

Profile 2

Over the study period, a very small range of sediment, medium (+1.5 Ø) to fine (+2.3 Ø) sand, existed at this profile. At all three sampling times, the coarsest material was found at various sites in the nearshore zone, while the finest material was constantly found in the foreshore zone at the berm. Site trends showed that over the study period there was a general cyclical pattern with respect to sediment size. The sediment became finer grained by the end of the first half of the study period, and then coarsened to a similar pattern displayed by the June samples. This pattern appeared to be established due to the presence of a sediment transport eddy system in the area north of the canal (Fig. 5.3). The accompanying sorting trend does not show this cyclical pattern, except at the waterline. Only at the berm does this pattern show the expected decrease in the degree of sorting with an increase in grain size.

A similar coarsening in sediment size lakeward is noted across the beach during the three sampling periods. This trend is accompanied in June by the expected decrease in the degree of sorting lakeward; however, a reversal of this trend was noted during the August and September sampling period.

Profile 3

A small variation within the sand fraction,

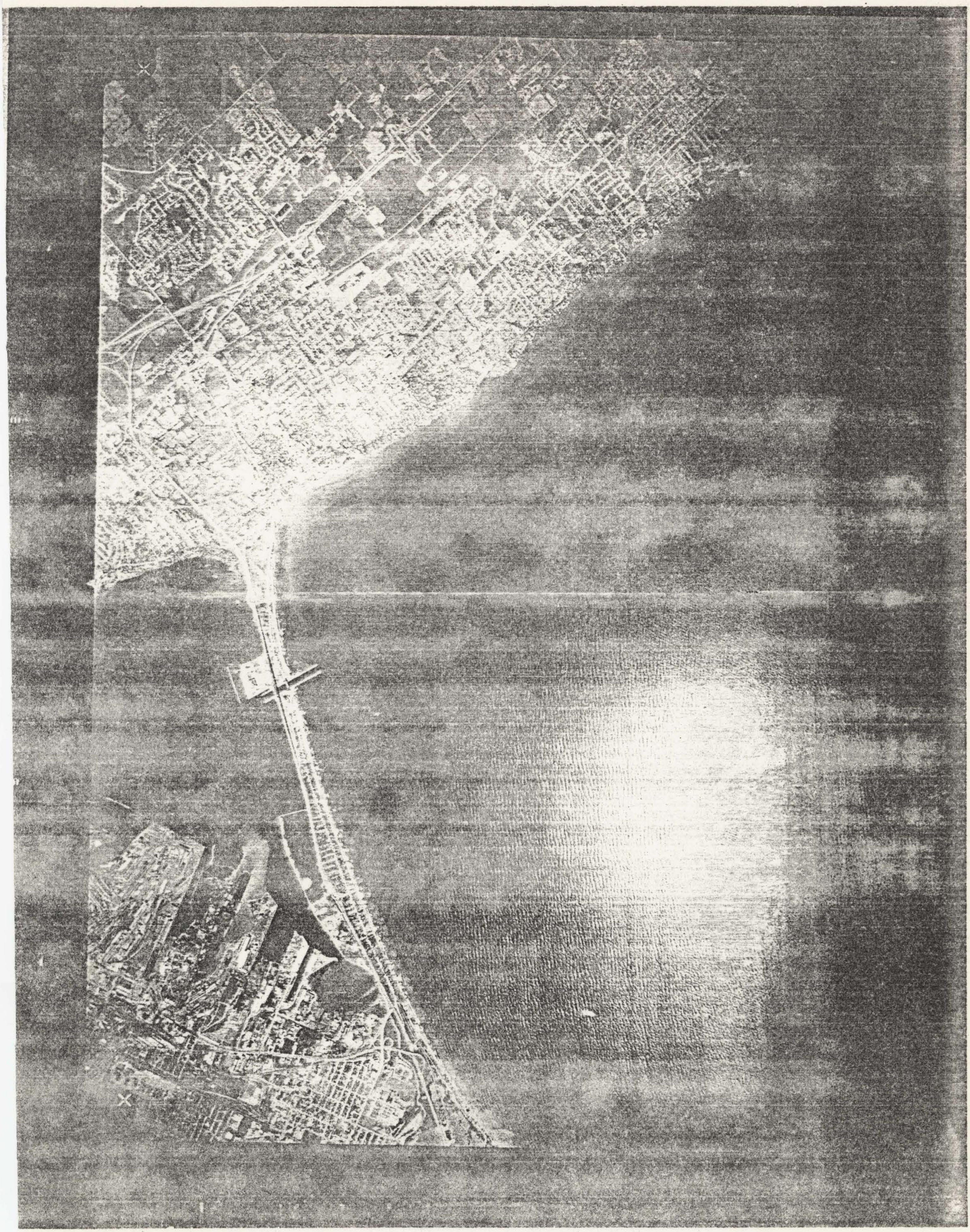


Fig. 5.3

fine (+2.2 ø) to coarse (+.01 ø) grained, is characteristic of the sediment size distribution found at this profile over the study period. The coarsest sand fractions were generally found in the nearshore zone at various sites, while the fine grain fractions were confined to either the swashlimit or the berm. Site analysis showed that a cyclical pattern, influenced by the eddy system in the area north of the canal, existed at the swashlimit, waterline and step top. The sediment taken from the extremities of the site locations -- the berm and the step bottom, did not conform to this cyclical pattern, but became finer grained over the study period. The sorting trends at all five sites showed the expected decrease in the degree of sorting with the coarsening of sediment, and, over the four month study period, all the sites gradually showed a higher degree of sorting.

The sediment and sorting patterns across the beach during the four month study period showed considerable variation. Generally, a coarsening of sediment size lakeward, accompanied by a similar decreasing degree of sorting was noted during June and August. During the month of September, only the sediment trend is reversed, such that now the sediment coarsens lakeward. The sorting degree was anomalous with respect to the expected trend during September.

Profile 4

The sediment sampled at profile 4, over the period of four months, varied in size from very coarse (-.9 Ø) to medium (+1.5 Ø) sand. The coarsest sand was found during the study period in the nearshore zone at various sites, while the finest material was located at various sites in the foreshore zone. Site trends showed that the sediment located at the berm and swash-limit coarsened noticeably throughout the analysis period, while the material at the remaining three sites -- the waterline and step top and bottom became finer grained. The site sorting trends showed no correlation with sediment size, but became progressively poorer sorted.

The sediment trends across the beach during the June and September sampling periods showed a general lakeward increase in sediment size. This trend can be divided into two zones -- the foreshore zone and the nearshore zone in which minor varying specific trends could be noted. The expected sorting trend, with respect to sediment size, only existed in the foreshore zone during June, and the nearshore zone during September, while the remaining zones were anomalous to the expected pattern. The anomalous trend may be due to the influence that the sediment discharged from the canal had on this profile.

Profile 5

Over the four month study period, sediment size at this profile varied from medium sand (+1.3 ∅) to granular (-1.7 ∅) material. At all three sampling periods, the coarsest material was located at the step top in the nearshore zone, while the finest material was noted to exist at varying sites throughout the foreshore zone. According to site analysis; the material located at the berm, swashlimit and step bottom coarsened; the material at the waterline became finer; and, the material at the step top showed a cyclical pattern over the four month study period. Accompanying these various trends was a variable sorting pattern which existed irrespective of sediment size.

The sediment and sorting patterns across the beach during the four month study period showed a general lakeward increase in sediment size and a corresponding decrease in the degree of sorting. These patterns were only modified by variations of the established specific trends within the general trend.

Profile 6

A wide variation of grain sizes, medium sand (+1.1 ∅) to pebble material (-3.0 ∅) was found over a four month study period at this profile. Site analysis showed that the coarsest material was found at various sites in the nearshore zone, with the exception of the

September study, when the coarsest material was located at the berm. The finest material was found at various sites in the foreshore zone. The sediment located at the step top remained constant over the study period, while the material at the four remaining sites coarsened. Accompanying this increase in sediment size, except at the berm and swashlimit, was a decrease in the degree of sorting.

A general coarsening in sediment size lakeward, accompanied by the expected lakeward decrease in the degree of sorting was noted across the beach during the four month study period. Only slight modifications of these general trends were noted to exist within the encompassed specific trends.

Profile 7

The variation between medium sand (+0.4 Ø) and pebble material (-3.5 Ø) is characteristic of the sediment found at this location over the study period. The coarsest material was found at all three sampling times at various locations in the nearshore zone, while the finest material was located at various sites within the foreshore zone. Site analysis showed that trends varied considerably from site to site. For example, the material located at the berm and step bottom coarsened, the sediment at the swashlimit and waterline remained constant, and the material at the step top showed a cyclical trend over the study period. These trends were accompanied by varying sorting trends which showed that the coarser grained material had a poorer degree of sorting than the finer grained material.

The sediment and sorting patterns across the beach during the June and August sampling periods showed a general increase in sediment size and a corresponding decrease in the degree of sorting lakeward. During the September sampling period, a complete reversal of both the sorting and sediment trends was noted. Again, slight modifications of these general trends existed in one of the two specific trends.

Profile 8

Medium sand (-0.6 Ø) to pebble material (-2.9 Ø) characterized this portion of the beach over the four month study period. Site analysis showed that the coarsest material was found in the nearshore zone at the bottom of the step, except during the September study period, when the coarsest material was found at the berm. Generally, the finest grained material was found at various sites in the foreshore zone, with the exception of June when the finest material was found in the near-shore zone at the step top. No consistent trends existed at any of the five sites. Instead, the sediment at the waterline and step top coarsened, while the material at the step bottom became finer grained. The berm exhibited a cyclical pattern, while the swashlimit showed no distinct trend. As expected, there existed a wide variation in sorting trends which existed irrespective of sediment size.

During the June and September sampling periods, similar general sorting and sediment trends existed across the beach. The degree of sorting decreased landward, and the sediment size coarsened in the same direction. The August sampling period, however, showed a complete reversal of both these trends.

Profile 9

This profile, over the four month study period consisted of sediment varying in size from coarse sand (-1.0 ∅) to pebble material (-2.6 ∅). The coarsest material was found at various sites within the nearshore zone, while the finest material was found at either the swashlimit, or the waterline over the study period. Site analysis showed that two distinct trends, with regard to the sediment size and the degree of sorting existed. The sediment found at the swashlimit, waterline and step top had coarsened over the period, while that located at the berm and step bottom had a cyclical pattern. Accompanying these sediment trends were different but distinct sorting trends. For example, sorting showed a cyclical pattern at the berm, swashlimit and waterline, while no patterns were noted in the nearshore zone.

Variable trends across the beach were noted between the three sampling periods. During the June and August sampling period, there was a general increase in sediment size lakeward which was accompanied only in August by the expected decrease in the degree of sorting lakeward. The degree in sorting during June decreased landward. Both sediment and sorting patterns established in August had been completely reversed by September.

Several similar and different sediment and sorting trends were evident throughout the four month period at various profiles. In June, a general coarsening trend existed at most locations and was only modified by one of the two specific trends at profiles 3, 4, 8 and 9. During the August sampling period, this general lakeward trend remained constant, and only during the final sampling period was this trend reversed. Modifications of this September trend by one of the specific trends existed at profiles 1, 2, 4, 5 and 6. Accompanying these general sediment trends were sorting trends which showed a similar variation at each sampling period. In June, all the profiles showed a general lakeward decrease in the degree of sorting, except for one of the specific trends at profiles 3 and 9. This same trend is in existence in August, except for one of the specific trends at profiles 2 and 7. A complete reversal of the general trend, except at profiles 3 and 7, and at one of the specific trends at profiles 4, 6 and 7 existed during the final sampling period.

These trends showed a distinct correlation between sorting and sediment size -- the coarser the sediment, the poorer the degree of sorting. This correlation was dependent on the competence of the transporting medium. As the competence decreased, the coarser fraction of the material in transport was deposited, and the remaining suspended material became better sorted.

Sediment composition (size-wise) is determined to a large extent by transport systems -- wave and longshore currents, which themselves are governed by wind conditions. These wind conditions, in the 24 hours prior to sampling, and during the sampling period were observed in an attempt to correlate winds with sorting and sediment size. Apparently, there was no correlation between these three factors, with respect to trend determination. If this were so, then similar trends, instead of the reverse, should have existed between September and June, when winds blew 83.4% and 100% of the time from similar directions -- west and south-west.

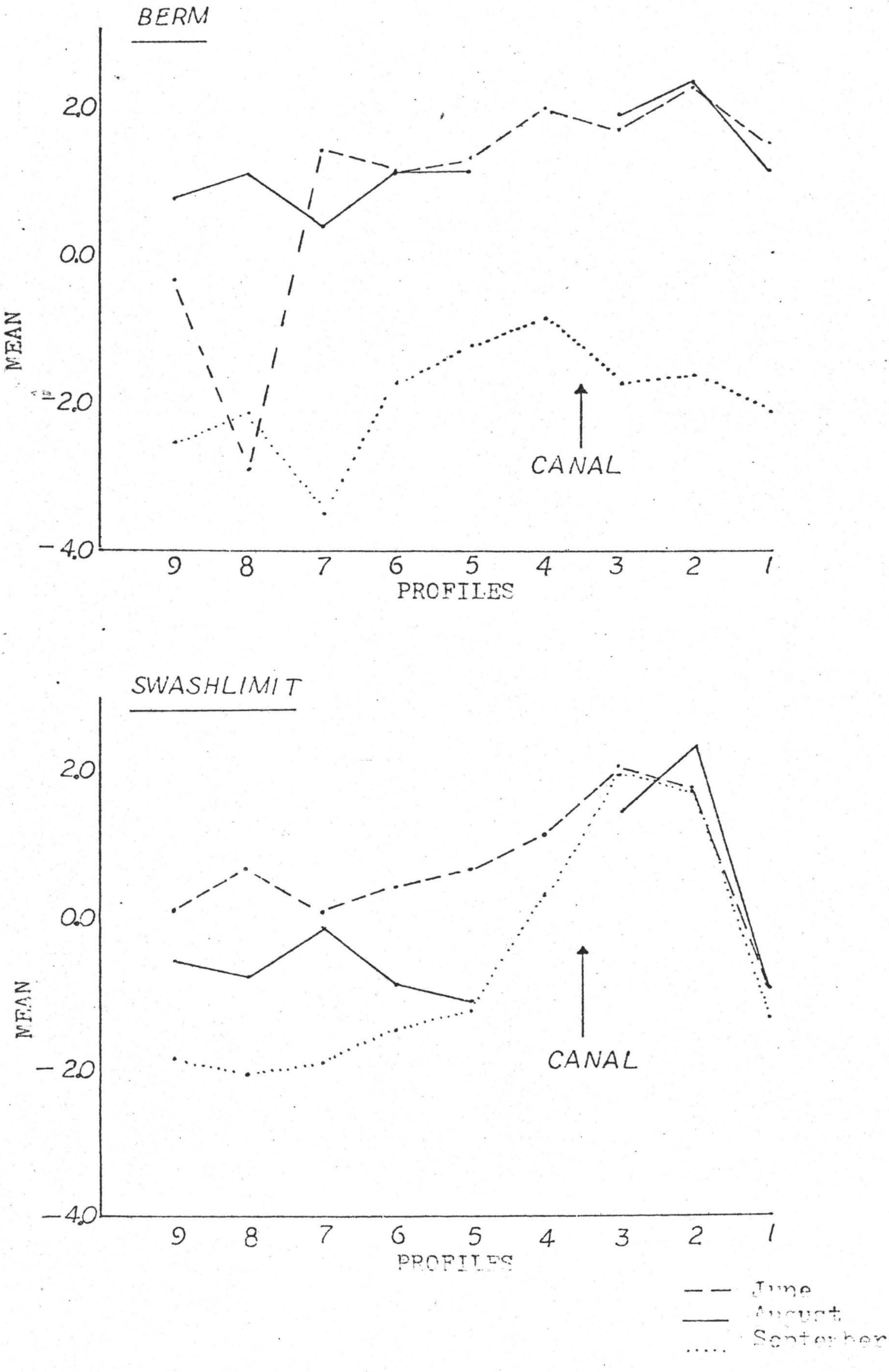
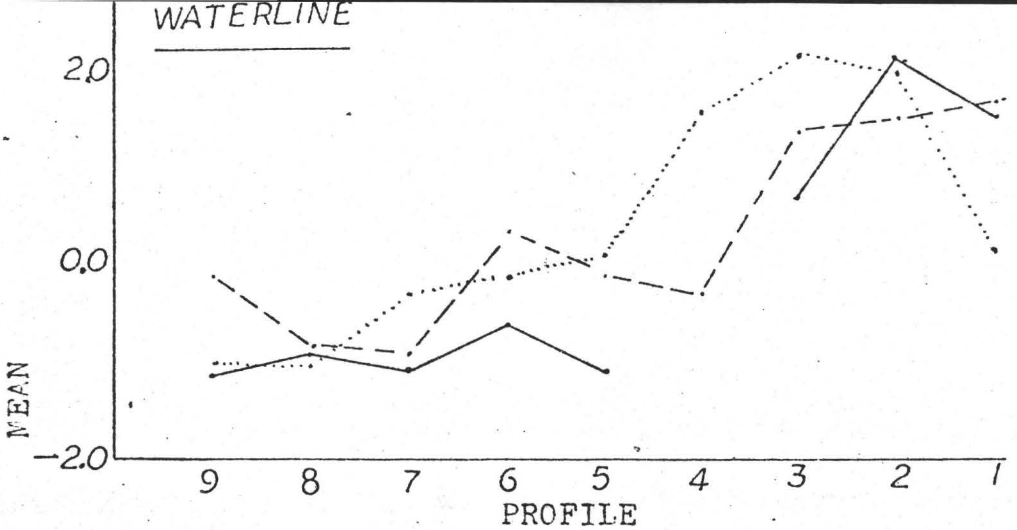
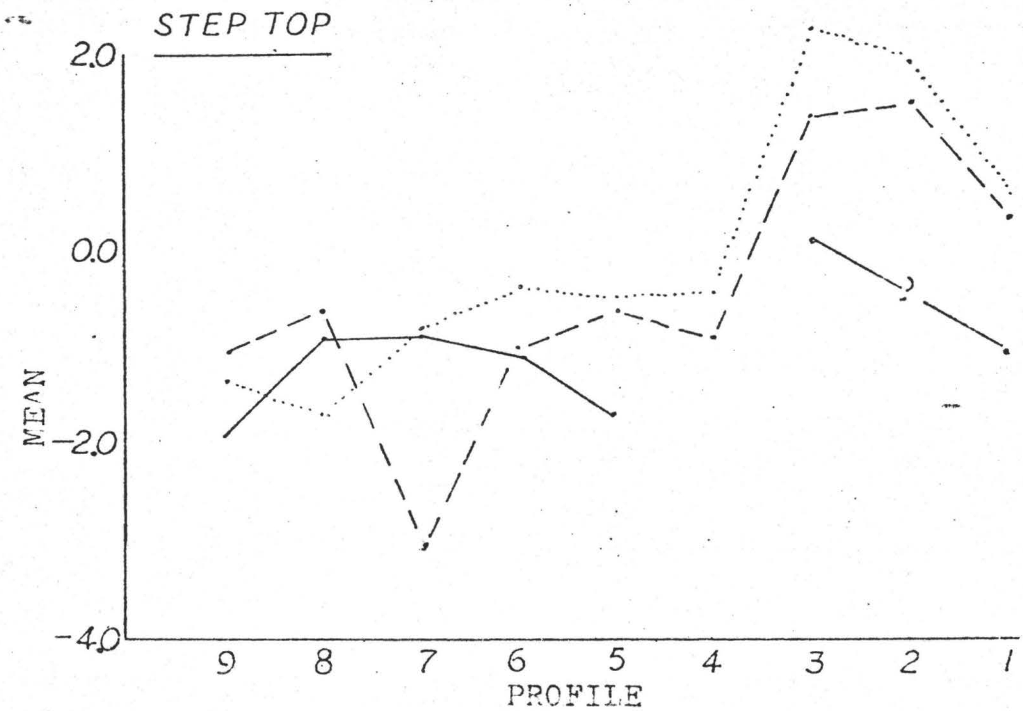
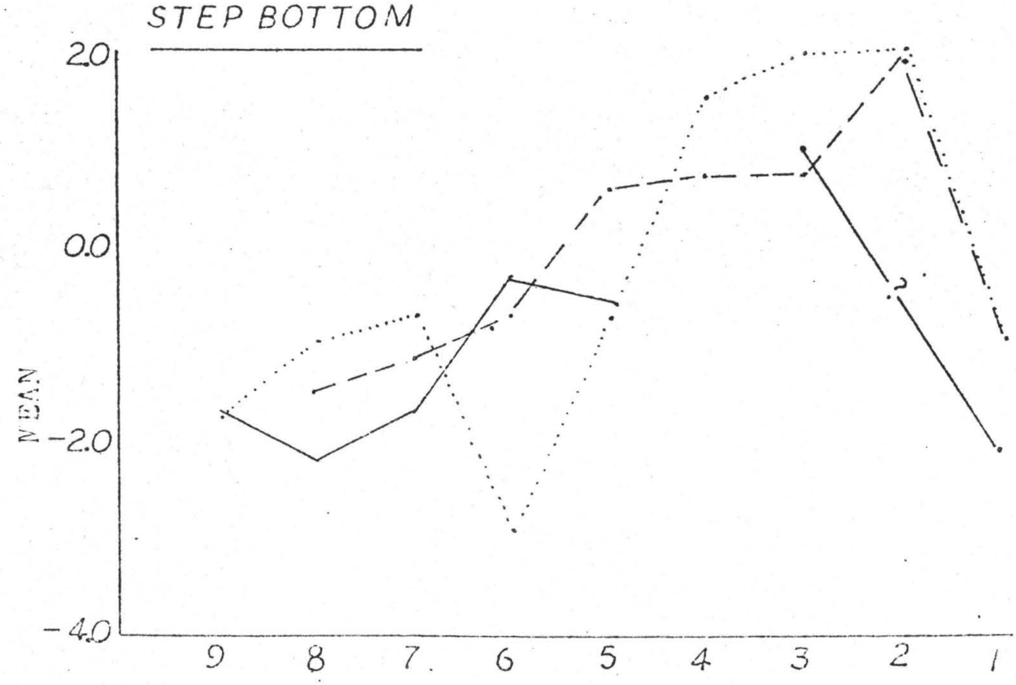


Fig. 5.4 Regional variation trends


WATERLINE
2.0
0.0
-2.0
MEAN
9
8
7
6
5
4
3
2
1
PROFILE


STEP TOP
2.0
0.0
-2.0
-4.0
MEAN
9
8
7
6
5
4
3
2
1
PROFILE


STEP BOTTOM
2.0
0.0
-2.0
-4.0
MEAN
9
8
7
6
5
4
3
2
1

Regional Variation

The statistics, mean and standard deviation calculated for each site at the nine profiles on the Burlington Beach were plotted positionally in order to determine trends which were otherwise obscurred in the mass of data. These trends may also aid in the determination of processes which were in existence along the beach. These plots are shown in Fig. 5.4, and it should be noted that the horizontal scale is proportional to the distance between profile stations.

The plots show that there was a general overall decrease in the size of sediment from profile 1 to profile 9 at the top and bottom of the step, and at the waterline. A few exceptions to this trend were noted only at the berm during the September study, and at the swashlimit during both June and August. This general trend when observed closely could be subdivided into a two component system -- that system defined by the stretch of beach from the canal to profile 9, and the reverse system from the canal to profile 1.

Three distinct trends have been noted to exist in this last reverse system -- that of a coarsening sediment trend to profile 1, that of no trend, and that of a coarsening trend to the canal. The first trend, of a coarsening of sediment toward profile 1, existed during the entire sampling period at the top of the step, during the second half of the sampling period at the step bottom, and during June and September at the swashlimit and waterline respectively. The second trend -- no trend, was present during the entire sampling period at the berm, and during June, August, and August and September, at the bottom of the step, the waterline and the swashlimit respectively. Only once, at the waterline during the month of June did the sediment coarsen towards the canal.

The first component system, between the canal and profile 9, showed a main trend of sediment coarsening southward. This was seen at all five sites, except at the swashlimit during August, when the sediment coarsened to the canal, and at the top of the step in June, when no trend existed.

This variation in trends in opposite directions from the canal has led to the suggestion that the sediment composing the two component systems has originated from different source areas. This is also substantiated by the fact that the sediment on the north side of the canal was finer grained, and showed less variabiligy in sediment size except in August, and in June at the step bottom, than the sediment located on the southern side of the canal. These trends are shown in Fig. 5.5.

The regional two component system which appeared to be influenced by different source areas was analyzed by a second way. The mean of the five sites was calculated and plotted for each of the nine profile

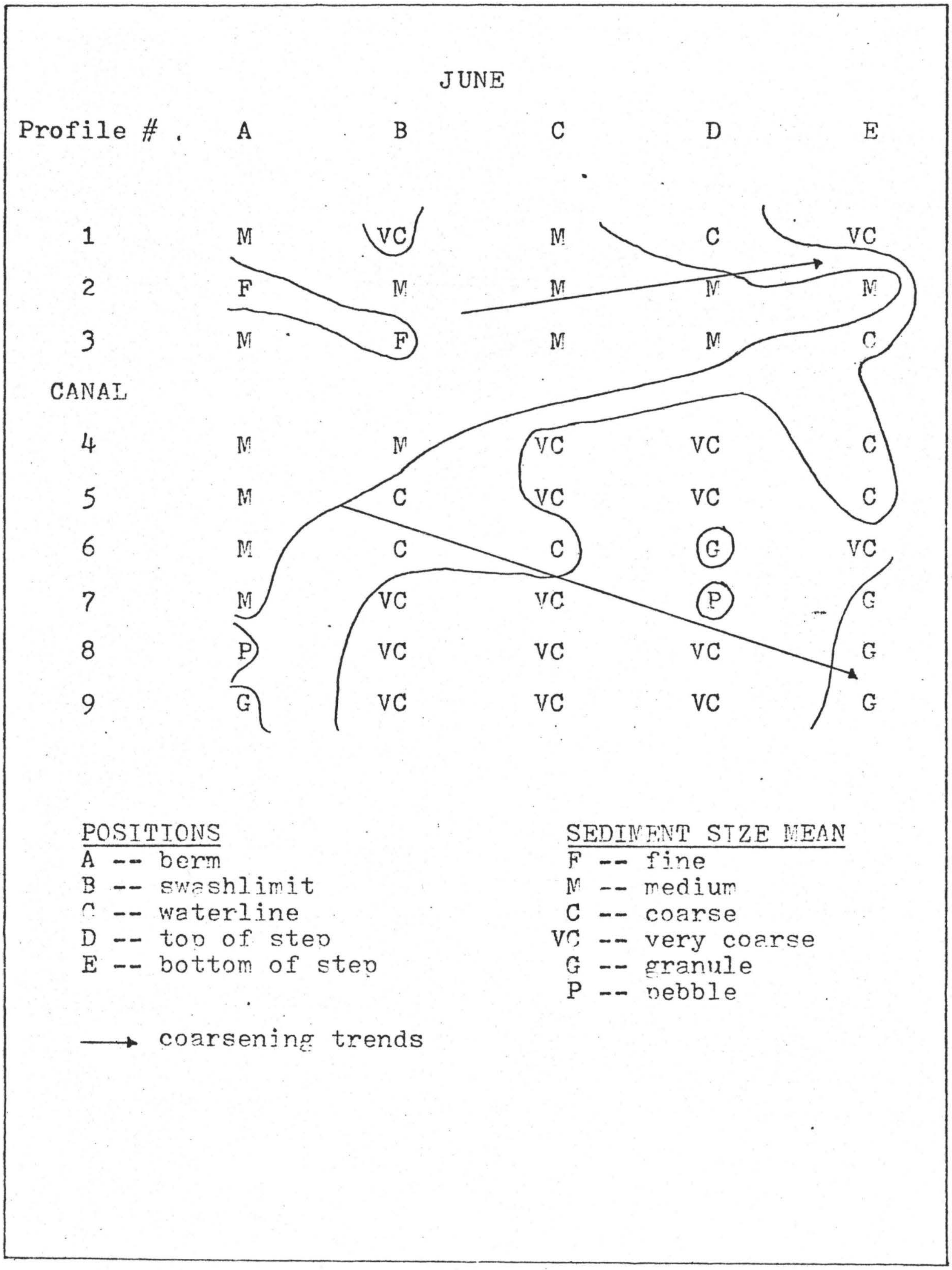
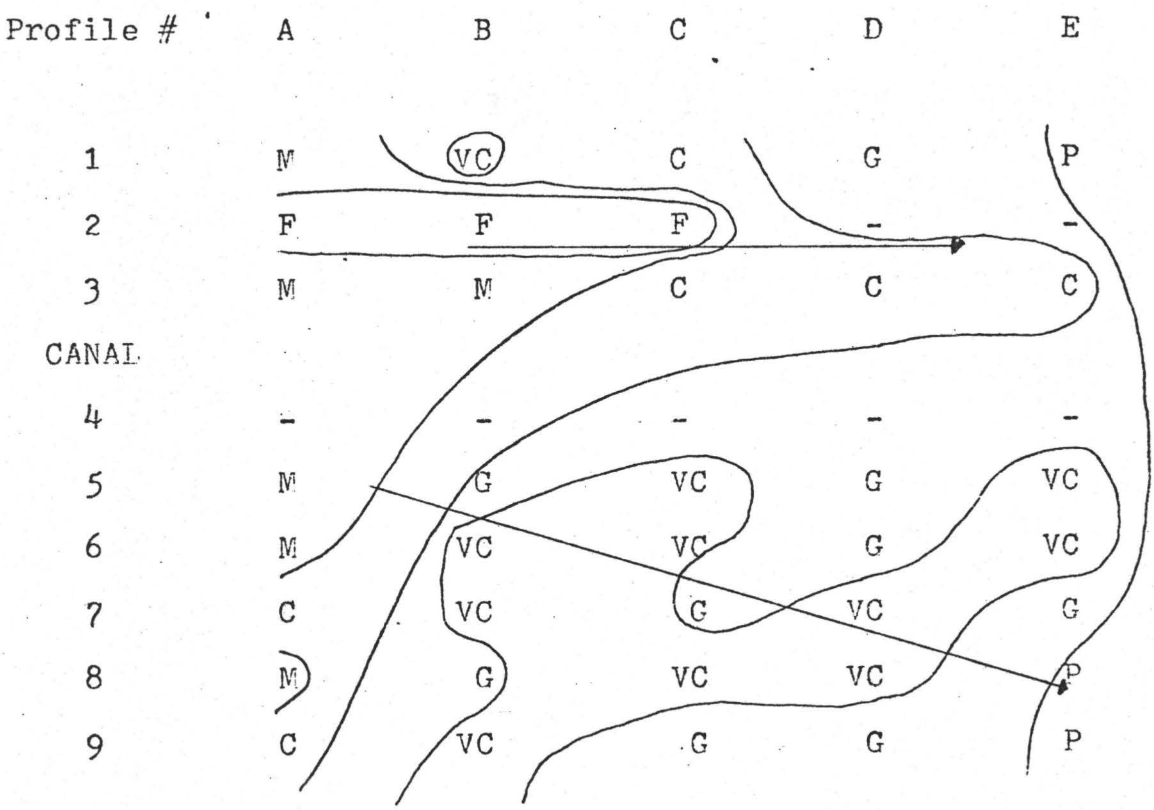


Fig. 5.5 Sediment Size Distribution Along and Across the Bar.

AUGUST

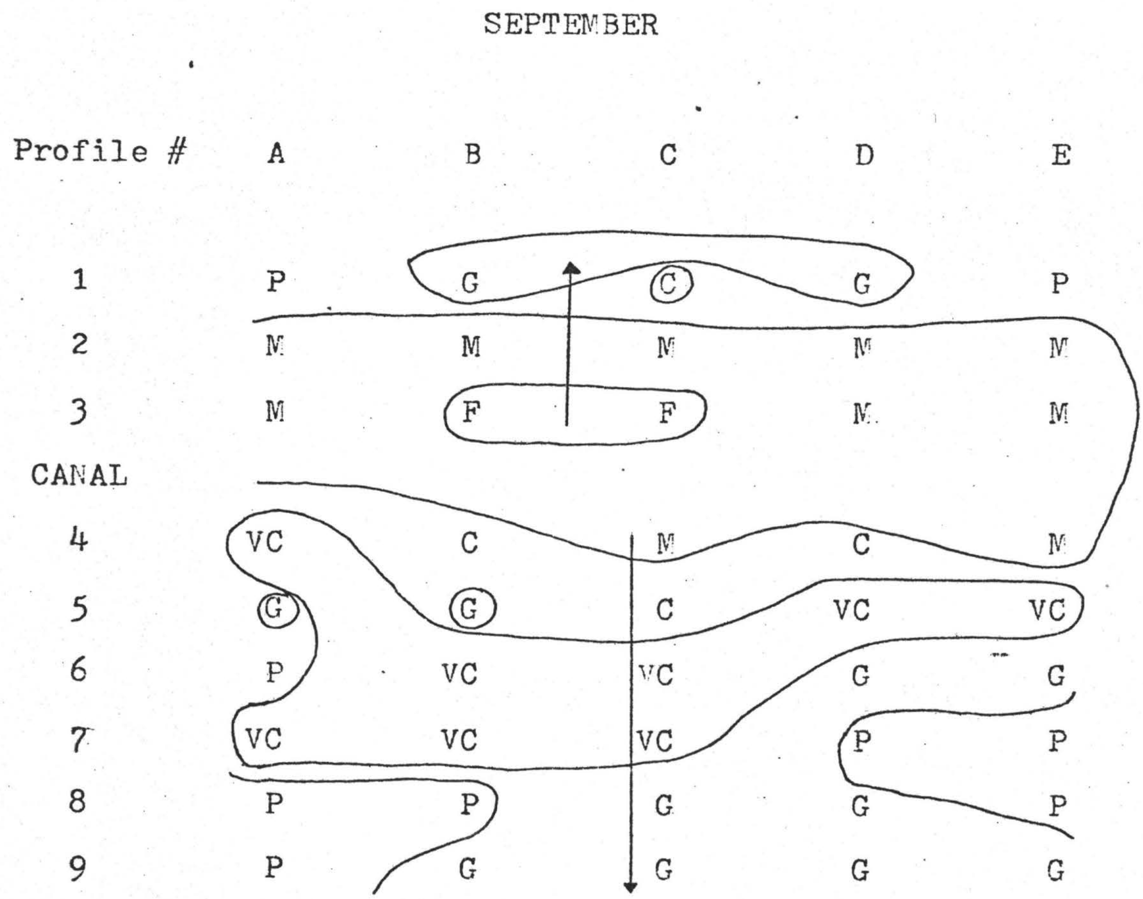


POSITIONS
A--berm
B--swashlimit
C--waterline
D--top of step
E--bottom of step

→ coarsening trends

SEDIMENT SIZE MEAN
F--fine
M--medium
C--coarse
VC--very coarse
G--granule
P--pebble

Fig. 5.5 continued



POSITIONS
A -- berm
B -- swashlimit
C -- waterline
D -- top of step
E -- bottom of step

SEDIMENT SIZE MEAN
F -- fine
M -- medium
C -- coarse
VC -- very coarse
G -- granule
P -- pebble

⟶ coarsening trends

Fig. 5.5 continued

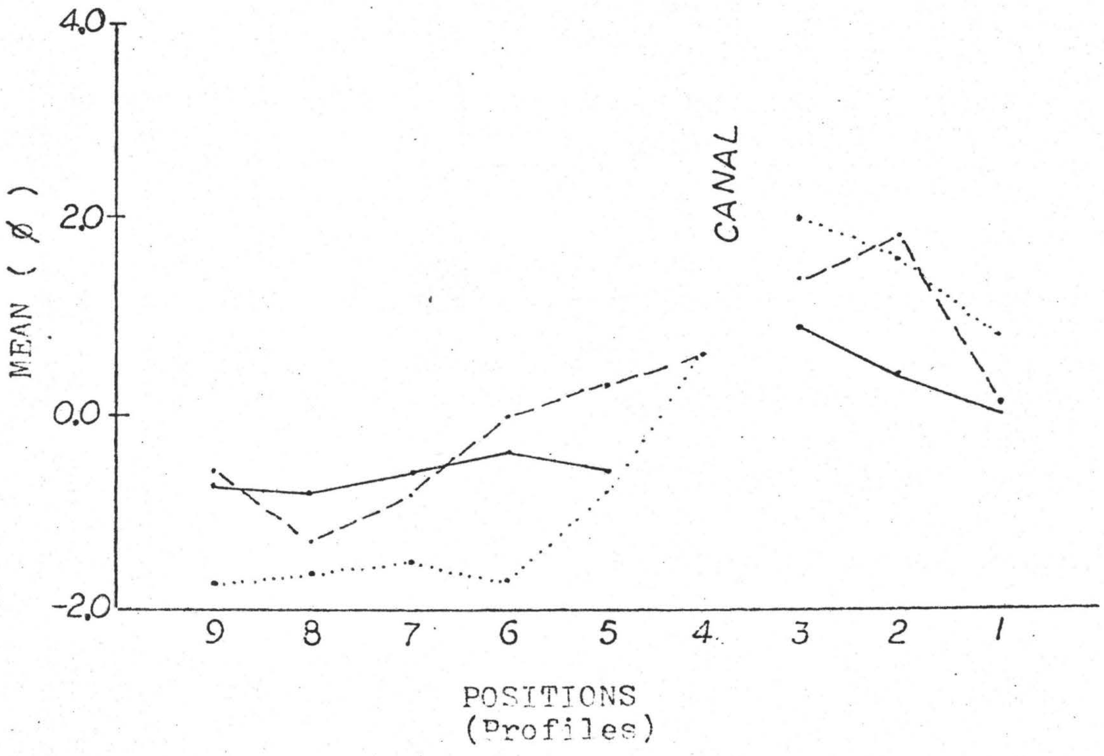


Fig. 5.6 Sediment variation along the Burlington Beach.

locations. From this plot (Fig. 4.6), the data for the August and September sampling periods shows a distinct increase in sediment size as distance from the canal was increased, while the June period showed this trend only on the south side of the canal. Again, two separate source areas appeared to be suggested.

The regional degree of sorting showed that there were a great many variable trends, but these trends generally reflected a decrease in sorting with a coarsening of sediment. Also, these trends reflected the influence that the differing sediment size distributions on either side of the canal had on the sorting system -- better sorting was present on the north side of the canal (Fig. 5.7).

Population Distinction

Environmentally significant moment measures, mean and standard deviation, when combined and plotted as bivariate plots may show distinct environments. These environments however may not be distinguished due to the type of source material and its influence within the system, or due to the influence of the varying processes over the beach system, or both. For example, in using this plot, the sampled area cannot be assumed to be influenced by just wave depositional processes, for sand distribution from a beach may also be due to other processes such as winds.

The values, when plotted for the Burlington

JUNE

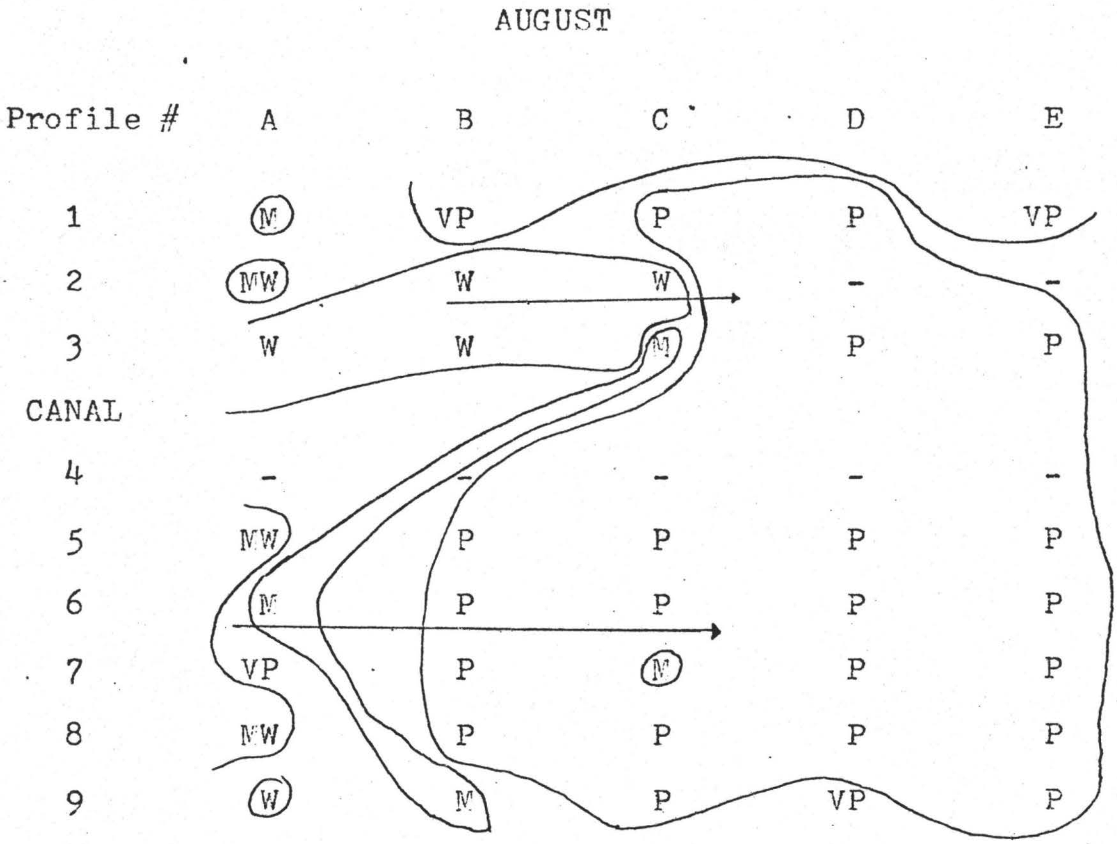
Profile #	A	B	C	D	E
1	MW	M	W	M	M
2	W	W	MW	MW	M
3	P	W	M	M	P
CANAL					
4	W	P	P	M	P
5	M	P	P	P	P
6	M	P	M	M	P
7	M	P	M	P	P
8	P	P	P	P	P
9	P	P	M	P	MW

POSITIONS
A -- berm
B -- swashlimit
C -- waterline
D -- top of step
E -- bottom of step

SORTING
W -- well
MW -- moderately well
M -- moderate
P -- poor

⟶ decreasing degree of sorting

Fig. 5.7 Sediment Sorting Along and Across the Beach.



POSITIONS
A -- berm
B -- swashlimit
C -- waterline
D -- top of step
E -- bottom of step

SORTING
W -- well
MW -- moderately well
M -- moderate
P -- poor
VP -- very poor

⟶ decreasing degree of sorting

Fig. 5.7 continued

SEPTEMBER

Profile #	A	B	C	D	E
1	P	P	P	M	VP
2	MW	MW	MW	W	M
3	M	W	W	W	M
CANAL					
4	P	P	P	P	P
5	P	MW	P	M	VP
6	P	P	P	M	P
7	P	P	P	P	P
8	P	P	M	M	P
9	P	P	M	M	P

POSITIONS
A -- berm
B -- swashlimit
C -- waterline
D -- top of step
E -- bottom of step

SORTING
W -- well
MW -- moderately well
M -- moderate
P -- poor
VP -- very poor

⟶ decreasing degree of sorting

Fig. 5.7 continued

BIVARIATE PLOTS

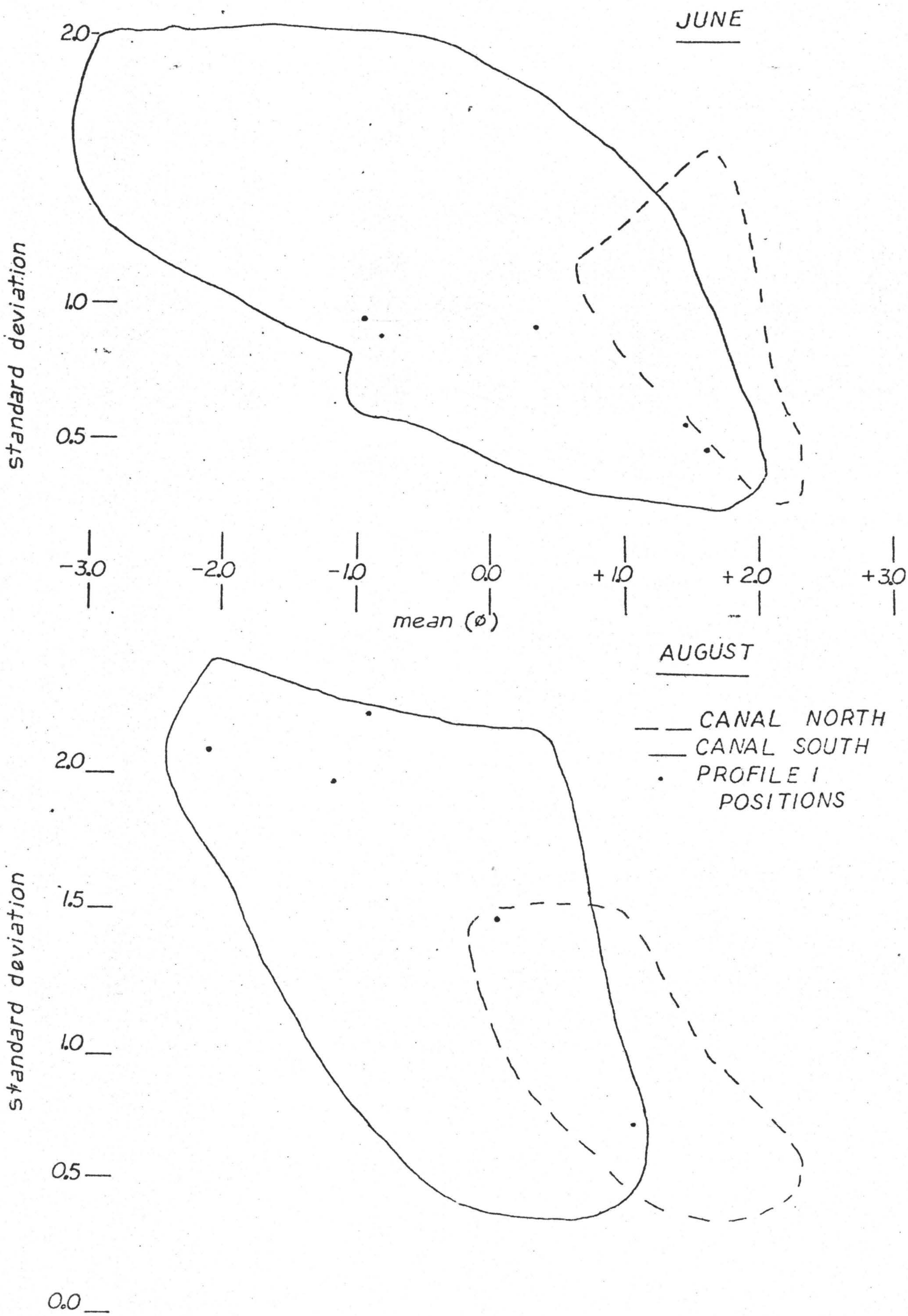


FIG. 5.8

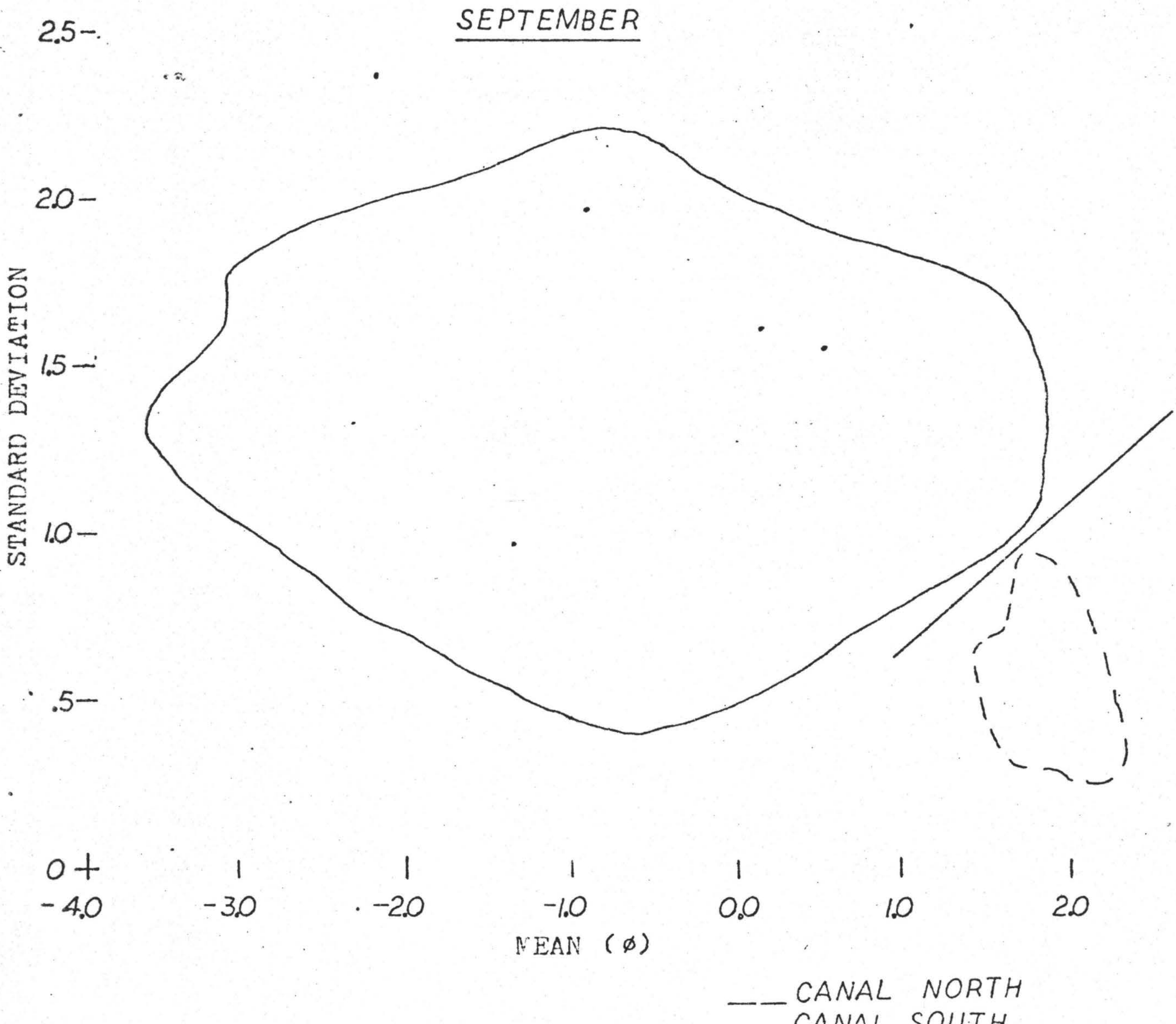
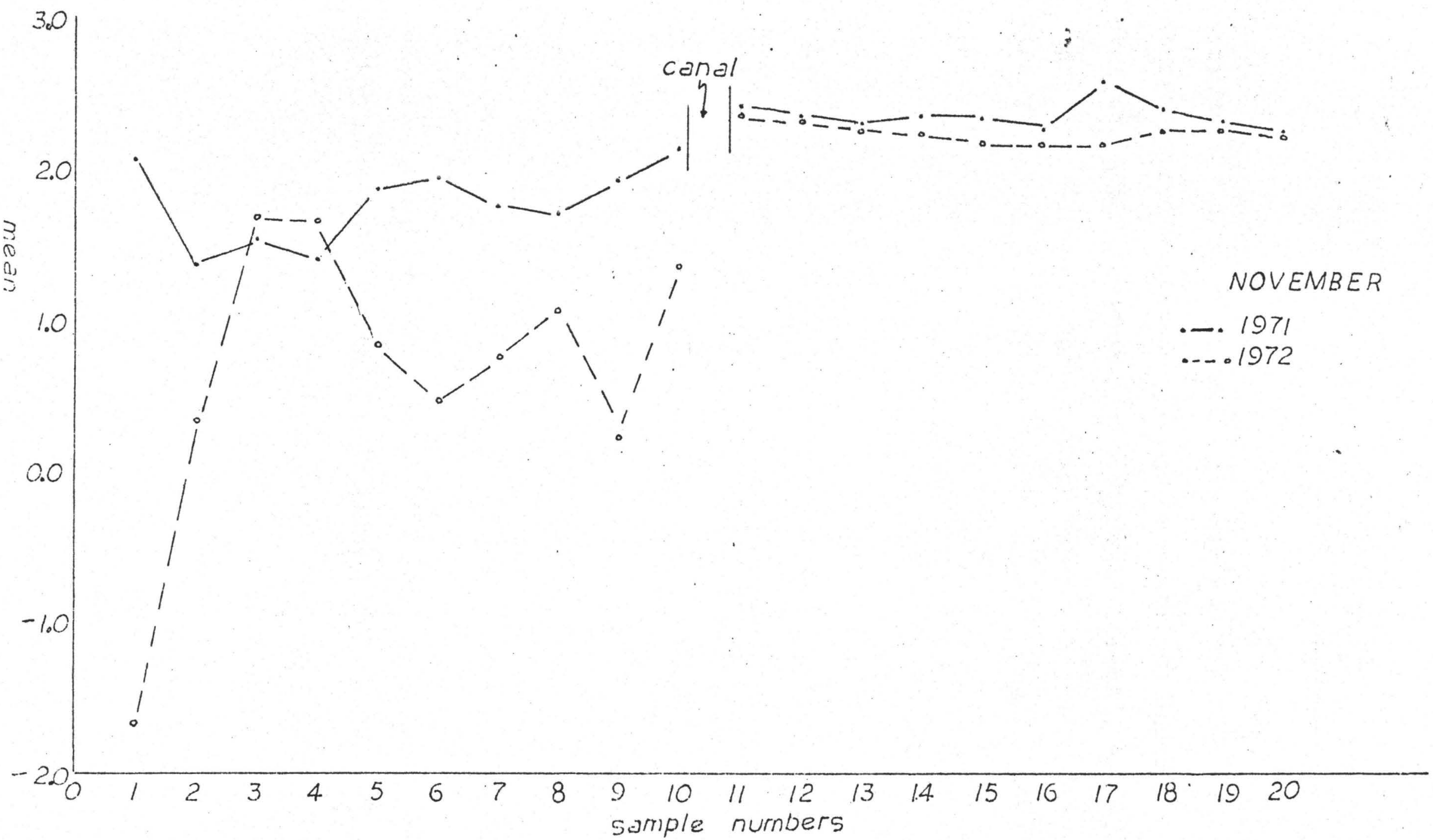


Fig. 5.8 Bivariate plots continued.

Beach, showed no distinct environments existed in June and August. These plots only showed that the north side of the canal sediments were finer grained and better sorted than the south canal sediments. The variability of wind conditions, and associated wave and longshore conditions within 24 hours of sediment sampling may be the cause of non-environmental distinction. The bivariate plot for September however does show two distinct environments, when the sediment sampled from profile 1 was considered as representative of a local source. The two environments distinguished over relatively constant 24 hour wind conditions were that of the south canal system and that of the north canal system. This substantiates the regional trends which suggested that two distinct environments caused by two distinct source areas existed.

Long Term Changes

It is impossible in the restricted period of this study to view the long term changes in the Burlington Beach system. A study done in 1971 (Bryce, Egginton, and Wilkins) concerning the variability of sediments on both sides of the canal and the suggestion concerning the effect of the canal breakwaters led to the investigation of a similar study by this author. The sampling scheme used by Bryce, Egginton and Wilkins was duplicated in the 1972 study.


3.0
2.0
1.0
0.0
-1.0
-2.0
mean
canal
NOVEMBER
1971
1972
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
sample numbers

Sediments analyzed for the north side of the canal showed a distinct, similar trend over the yearly period. All these samples were fine grained and very well to well sorted. The sediments found at the southern locations showed a wide variability in size over the one year period, except at positions 3 and 4, where the sediments were similar in composition. The 1971 study showed that all the samples consisted of medium grained sand. This was just one grain size coarser than the material found at the north side of the canal. The sediment in the 1972 study varied considerably, from granule (-1.6 ∅) to medium sand and thus varied greatly from the sediments on the north side of the canal.

Environmental determination by the plotting of environmentally significant parameters -- mean and standard deviation, is shown in Fig. 5.10 . As expected, two distinct environments on either side of the canal existed. This fact also can be seen with respect to the skewness values. The sediments located at the north side of the canal had positive skewness values indicative of an aeolian environment (Friedman, 1967), while most of the south canal sediments were negatively skewed, and were representative of a beach environment.

Over the period of a year, sediment character varied differently with respect to positional location

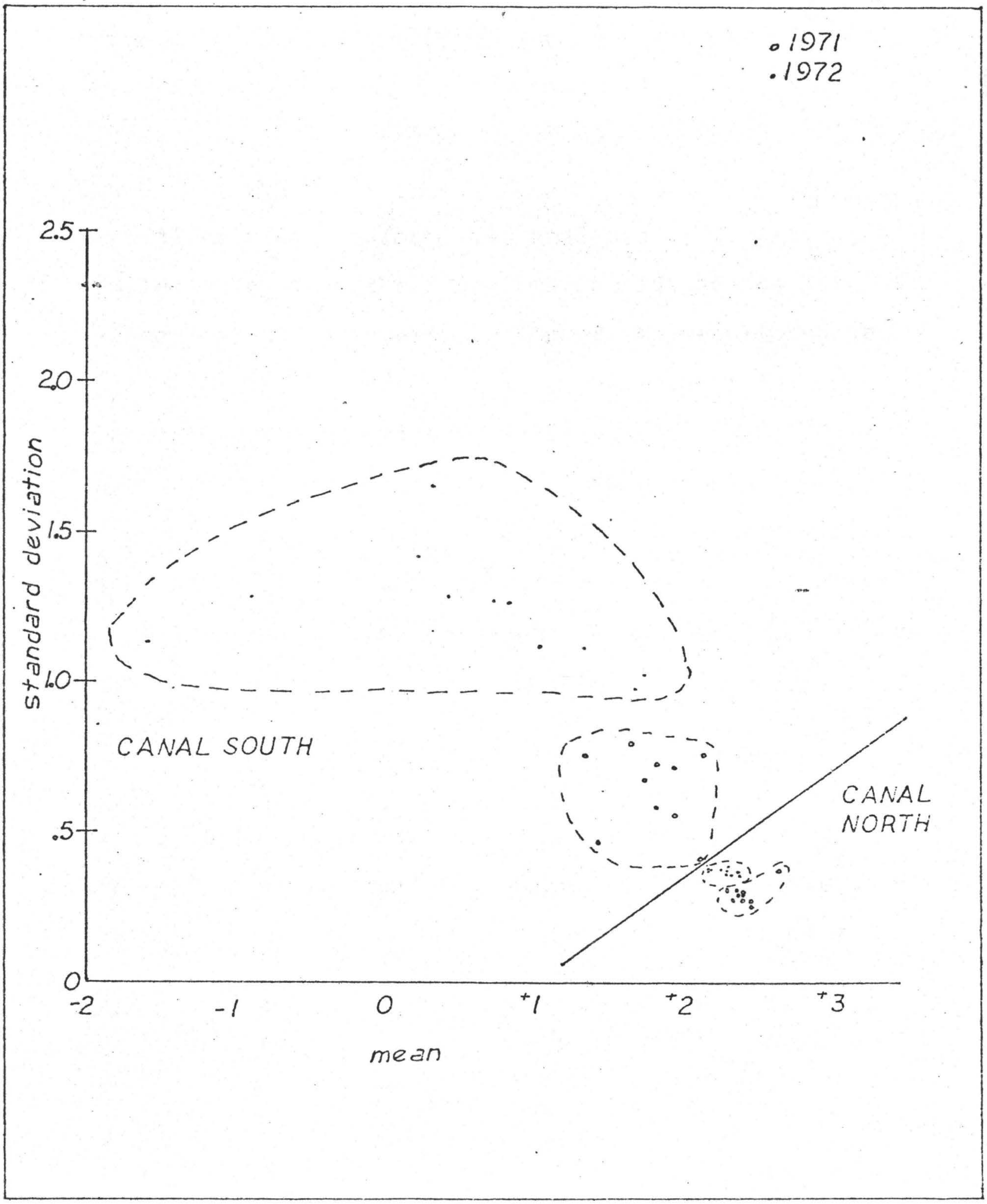


Fig. 5.10 Bivariate plot for the Long Term study

along the beach as did the characteristics of the environment, specifically with respect to the south side of the canal.

5.6 Conclusions

After sieve and computer analysis of the sediment samples taken from the Lake Ontario side of the Bar was completed, an interpretation of the results showed that a wide range of sediment size -- pebble to fine sand existed on this beach during the study period. Generally, the finest and best sorted material was located in the foreshore zone on the north side of the canal at profiles 2 and 3, while the coarsest material was found in the nearshore zone on the south side of the canal at profiles 7 and 8. The poorest degree of sorting was noted to exist at the profiles farthest from the canal -- profiles 1 and 9.

Profile analysis showed that one general sorting and sediment trend usually existed at each profile, and that this trend contained two similar specific trends. During June and August, similar lakeward coarsening sediment trends were present, while during the September study period, these trends were noted to have been completely reversed at most profile locations. Certain exceptions however did exist. Site analysis also showed variable sediment and sorting trends, and at three specific profiles, certain effects influenced the established patterns. At profiles 2 and 3, cyclical profile and site patterns existed due to the presence of a transport eddy system which had established itself on the north side of the canal during certain periods. The system was probably influenced by the presence of the canal. The canal also influenced to some extent the sediments at profile 4, for sediment output from the Harbour side of the Bar usually drifted towards the south. Both site and profile analysis showed that generally with a decrease of sediment in grain size, there was an increased degree of sorting.

A total view of the main sediment parameters along Burlington Beach showed that there was an overall increase in sediment size and an accompanying decrease in the degree of sorting from profile 1 to profile 9. Included in this overall pattern were two specific systems -- the system defined by Canal South, and that defined by Canal North. Both of these systems showed a coarsening of sediment accompanied by a decrease in the degree of sorting with a decreasing distance from the canal. These system trends both suggested the possibility that there were two distinct source areas for the material.

Statistical parameters -- mean and standard deviation when plotted on a bivariate plot only showed the presence of two distinct environmentally defined systems -- Canal North and Canal South, during the

September study period. This confirmed the possibility of two source areas. The plots for June and August both showed some mixing of the two defined systems.

Long term changes in the areas adjacent to the canal showed that the sediment at the back of the beach on the north side of the canal remained relatively constant over the one year study period, while the sediment taken from the middle of the swash zone on the south side of the canal varied considerably. It was expected that when the statistical parameters -- mean and standard deviation for both times and areas were plotted on a bivariate plot, two distinct beach environments would be outlined. These environments distinguished wind blown sediments from beach sediments.

CHAPTER 6

A THREE DIMENSIONAL STUDY OF THE BURLINGTON BEACH

6.1 Purpose of Core Analysis

Drill cores are taken as a means of obtaining the three dimensional aspect of a system which has only been considered as a two dimensional system. It is the purpose of this chapter to investigate the nature of beach sediments found in the three dimensional system at Burlington Bar, and to see if these sediments varied through time. Variation with respect to time may lead to inferences concerning the processes operative on the exposed beach sediments at any particular period. Also, this chapter examines the internal beach structures, the correlation and variation between sediments taken from two distinct environments -- the foreshore, and the nearshore, and the variation in geochemistry between the upper samples and bottom samples of the cores.

6.2 Sampling Procedure

On December 14, 1972, an attempt to obtain four cores -- two space equidistant across the exposed Bar surface and two in the nearshore zone on either side of the exposed Bar was undertaken. This sampling scheme however had to be modified since limitations of the Beachcor equipment restricted its use to the foreshore or nearshore zones of the beach. Of the many attempts to obtain cores in the respective zones, only one partial core was obtained in the nearshore zone at a water depth of two feet on the north side of the canal at Burlington Beach. The remaining cores which were analyzed, were obtained from the Canada Centre for Inland Waters (Burlington). These cores were collected on August 11, 1972 on the north side of the canal on Burlington Beach at an elevation of approximately one meter above lake level, and on October 24, 1972 off-shore of Burlington Beach in a water depth of approximately four meters on the north side of the canal.

Beachcor

Sediment cores were taken using the beachcor equipment (plates 6.1, 6.2, and 6.3) supplied by the Canada Centre for Inland Waters. The whole beachcor system was dependent on the presence of water for its operation, therefore, samples could only be taken in the foreshore and nearshore zones. The intake valve and attached hose, which was connected to a pump, was placed in the water about five to seven yards from shore. Also attached to the pump was a second hose which was connected to the shaft of the beachcor and

Plate 6.1 Beachcor

Plate 6.2 Beachcor

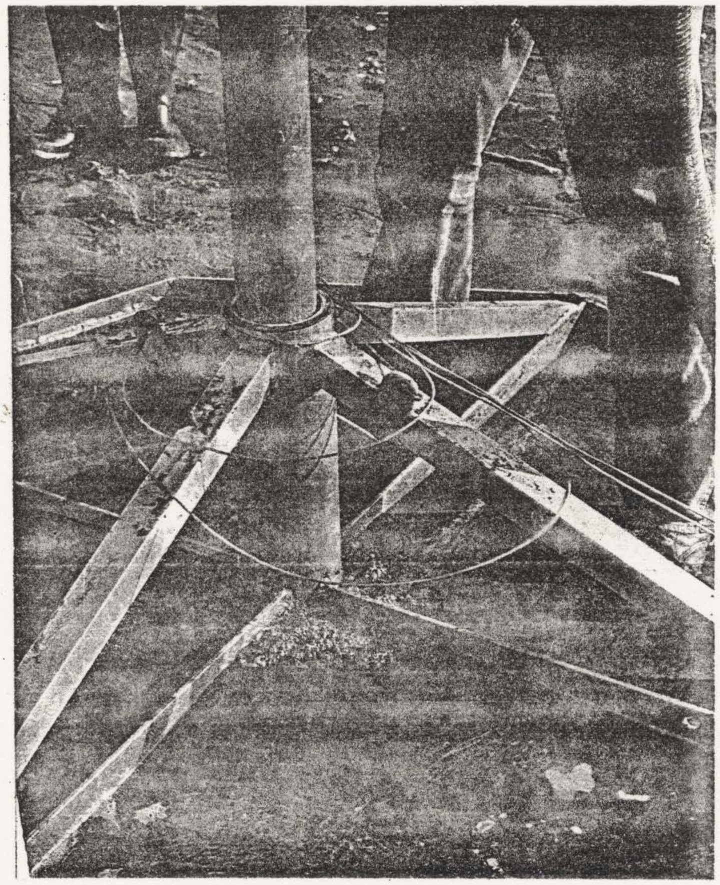


Plate 6.3 Beachcor

through which the water was channelled. The water then flowed between the inner and outer shafts, and the exerted pressure forced the beachcor into the sediment. Before the entire coring process was begun, a compressed plastic liner was inserted into the inner shaft of the beachcor. At the bottom of the inner collecting shaft, a safety catch was attached such that the sediment once it had been collected would be securely held in the then extended plastic liner. Once this system was in operation, another limitation soon became evident. The beachcor could not be used in uncompacted sediments which contained pebble material, for the pebbles clogged the opening at the base of the inner shaft, and this would not allow the collection of further sediment. Once the core had been collected successfully, it was sealed and placed in cold storage until it was ready to be analyzed.

6.3 Laboratory Procedure

Upon recover, the core was radiographed by an industrial x-ray unit (Rukavine, 1967) such that the internal structures of the core, which were otherwise obscured, could be revealed.

Each specific subsection of the core was described in terms of location within the cores, thickness, colour, structure, pebble and organic content, and presence or absence of sulphur or carbonate material. Size determination was undertaken using the same sieve method described in section 5.3, but the material finer than 4.0 Ø, which was present in percentages of .1% to 10.1%, was treated as combined silts and clays.

6.4 Statistical Analysis

Statistical analysis of the samples analyzed from the cores was carried out using the computer method described in section 5.4. This data obtained from this method -- particularly mean and standard deviation, had been displayed as a bivariate plot.

6.5 Interpretation of Results

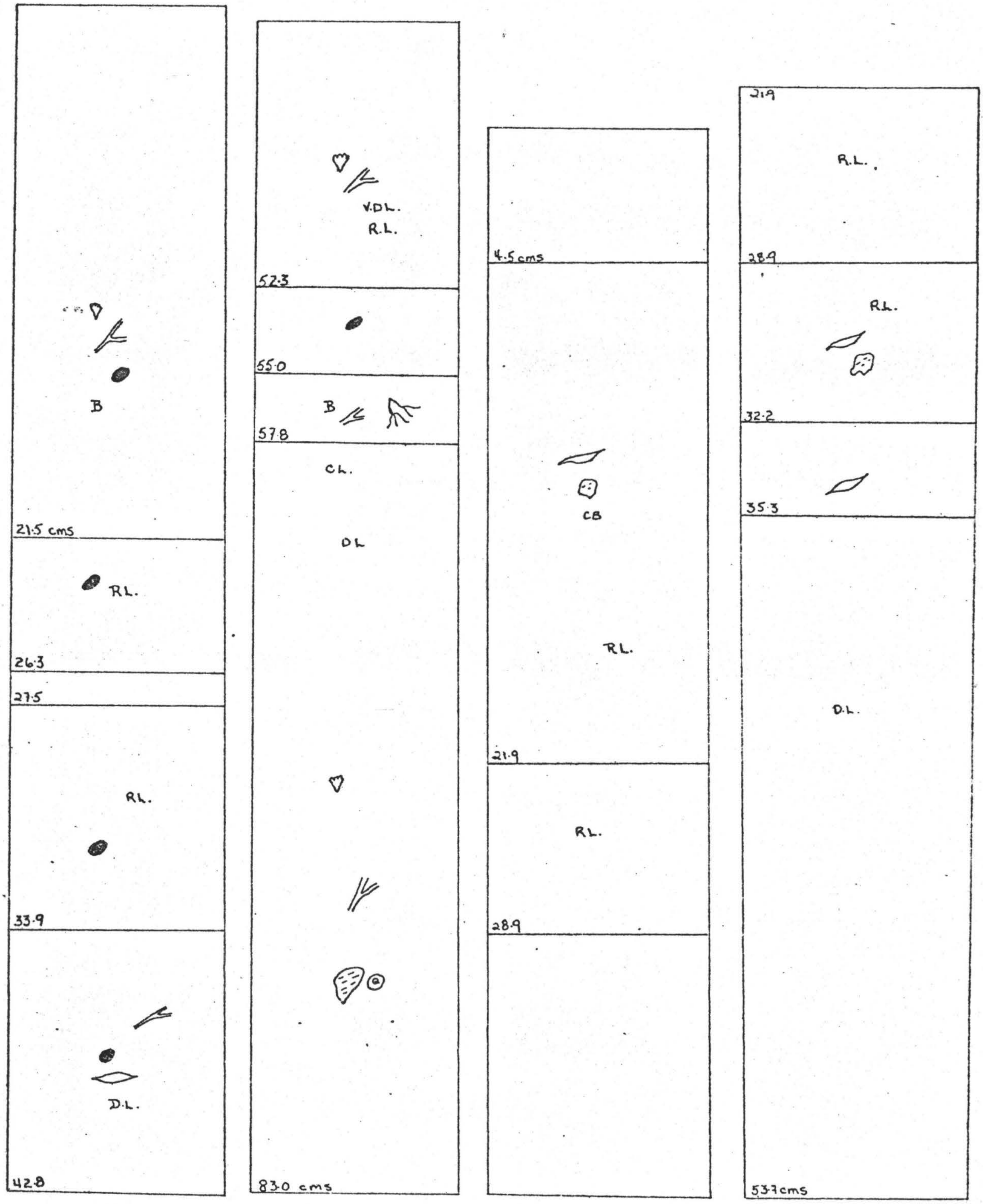
The characteristics of each core are general to that core, and therefore, each will be discussed separately.

Core 1

This core taken at Burlington Beach on the north side of the canal, one meter above sea level, consisted of sand size sediment which varied only slightly in size within the fine fraction and between the fine and medium sized fractions. This slight variation suggests that similar environments existed during the period of deposition of the material found in the core. A distinct decrease in the degree of sorting was noted between the top and the bottom of the core, and suggested that the sediment had been deposited

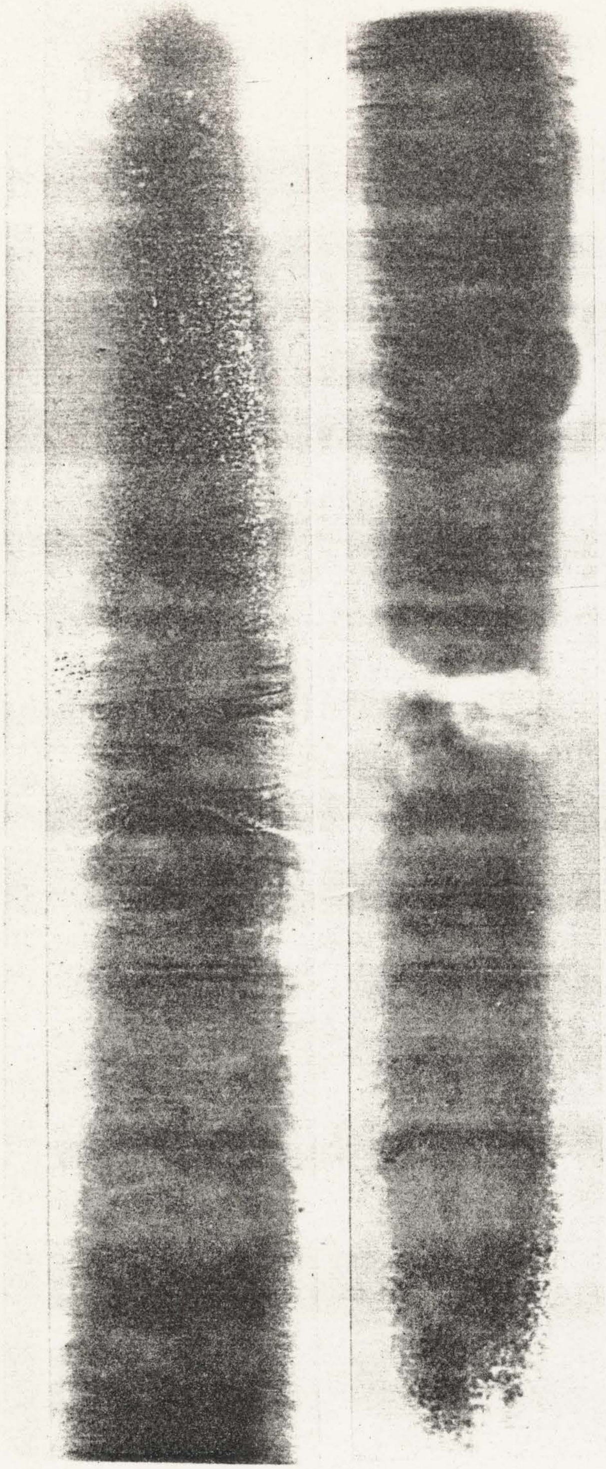
KEY TO CORE OVERLAYS

B	BARK
	CLAY POCKET
CB	COARSE BANDS
CL	CROSS LAMINATIONS
DL	DIFFUSE LAMINATIONS
	HEAVY MINERALS
O/OL	ORGANIC MATTER / LAYER
	PEBBLES
RL.	RIPPLE LAMINATIONS
	SHELLS
	TREE MATERIAL
V.D.L.	VERY DISTURBED LAMINA

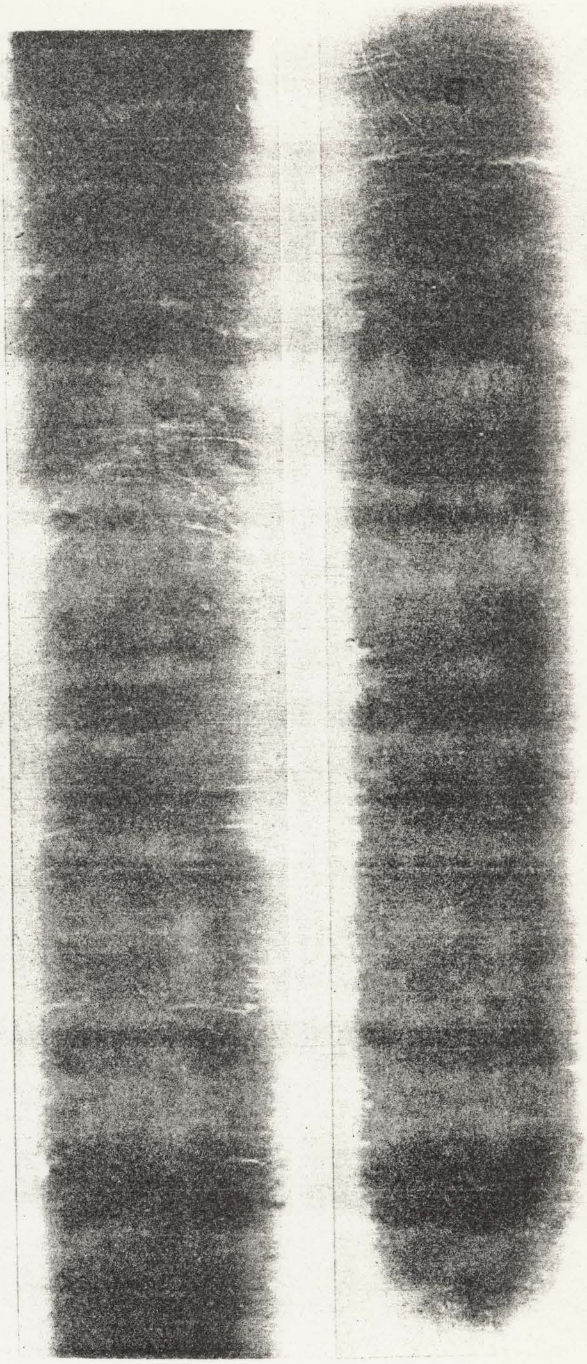

V.DL.
R.L.
52.3
55.0
B
57.8
CL.
DL
83.0 cms
B
21.5 cms
RL.
26.3
27.5
RL.
33.9
D.L.
42.8
4.5 cms
CB
RL.
21.9
RL.
28.9
21.9
R.L.
28.9
RL.
32.2
35.3
D.L.
53.7cms

CORE 1

CORE 2



CORE 1



CORE 2

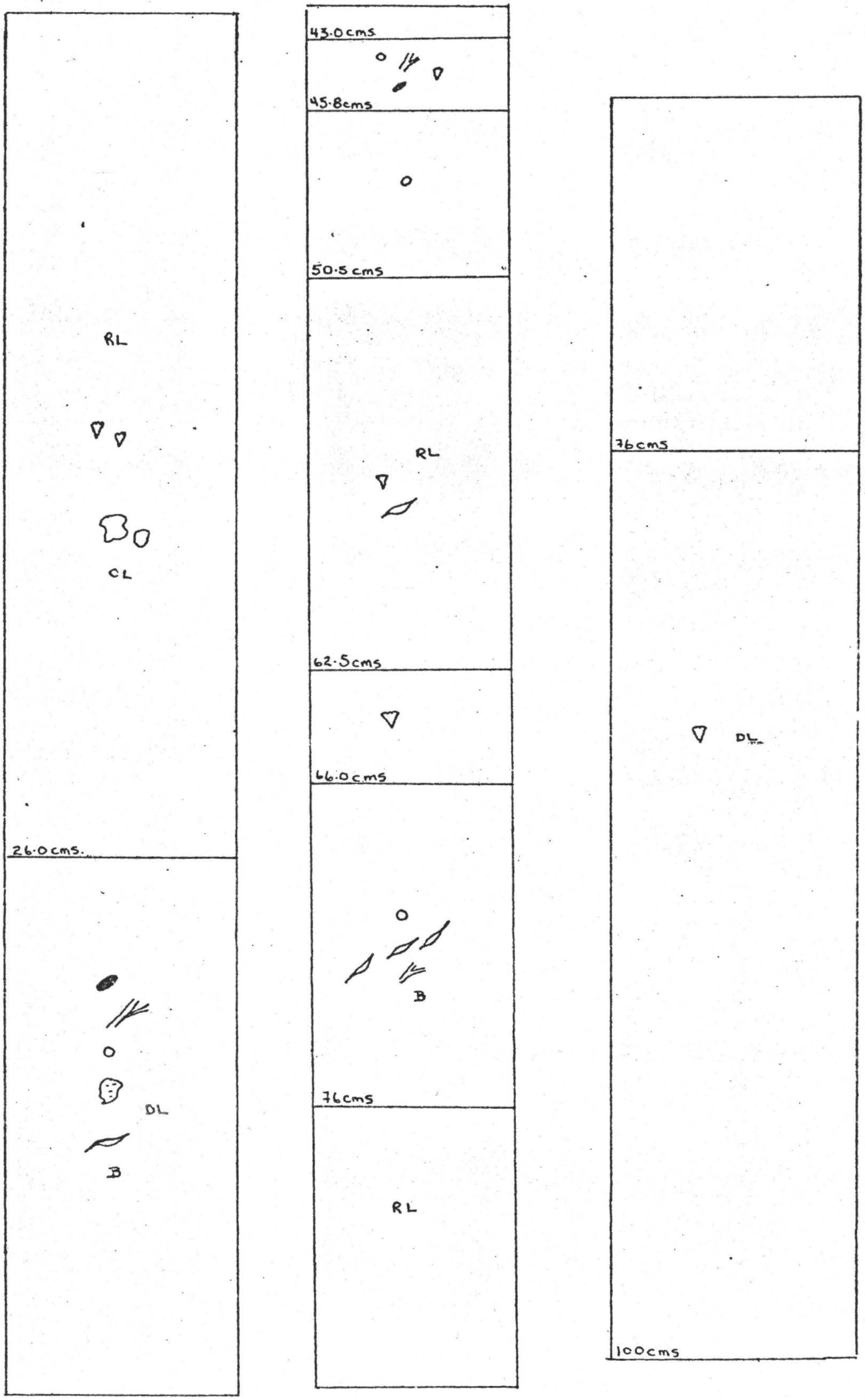
faster during the exposure period of the sediment at the base of the core than during later exposed accumulative periods, or, wind or water winnowing had not had a chance to sort the material. Only once, at depths between 27.4 and 33.9 cms. did skewness suggest the possible existence of wind blown sediments. All the remaining skewness values were negatively skewed and suggestive of a beach environment. The colour of the sediment became darker, and the abundance of pebbles became greater towards the base of the core. All the sampled sections of the core contained carbonate and sulphur material, while other features such as wood fragments, tree bark, shells, concentrations of dark material, clay pockets and plant roots were dispersed throughout various sections of the core. Three distinct types of laminations were observed from the radiograph of this core. Between 21.5 and 26.3 cms. ripple laminations were emphasized by concentrations of heavy minerals, diffuse laminations were present at depths between 33.9 and 42.5 cms., and finally, disturbed laminations were present between 42.8 and 49.1 cms. below the top of the core.

Core 2

This core, taken just north of the canal on the Burlington Beach in a depth of water of four meters, consisted of mainly very fine sand, with the exception of the sediment located at a depth between 28.1 and 32.2 cms., which was fine grained. This similarity in sediment throughout the core is suggestive of similar depositional environments. Towards the base of the core, the degree of sorting decreased, but at the base of the core, the sediment became better sorted. These degrees of sorting suggest that winnowing processes had been more active on the sediments deposited in the upper portion of the core. All the samples have negative skewness values which are indicative of a beach environment, and contain carbonate material. Most of the samples also were homogeneous in sediment composition, but a few clay pockets, pebbles, and bands of coarse material were distributed throughout the sediment. The colour of the sediment was noted to vary between the top and the bottom of the core, while sulphur material was only noted to exist in the topmost sample. Lenticular clay lamina and ripple and cross laminations were evident throughout the core from the radiographs and were generally outlined by coarser material.

Core 3

Core 3, taken in the same general location as core 1, consisted of sand sized material which was medium grained at the top of the core, and then alternated with depth in sections of very fine and fine sand. Organic material, in two distinct layers was also noted at depths between 45.8 to 50.5 cms. and 66.0 to 76.0


RL
CL
26.0cms.
DL
B
43.0cms
45.8cms
50.5cms
RL
62.5cms
66.0cms
B
76cms
RL
76cms
DL
100cms

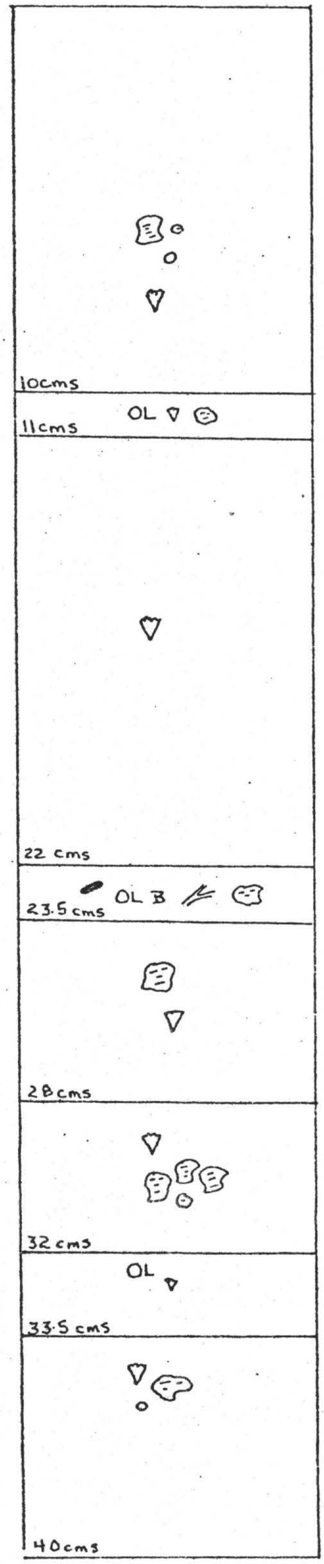
CORE 3

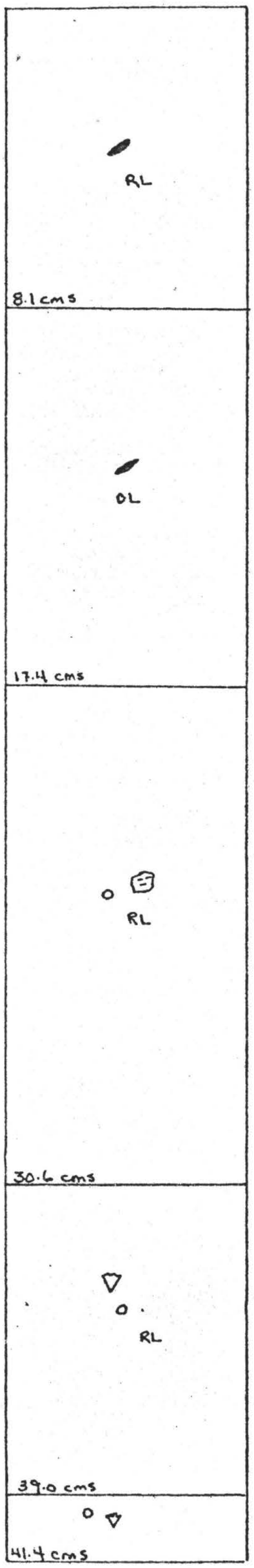
CORE 3

cms. This variation in material suggest a change had occurred in the depositional environments over time, such that during specific periods, a stagnant depositional area, indicated by the organic material, probably existed. Within the sand sections of this core, the degree of sorting -- well to moderately well, suggested that similar operative processes existed during the deposition of the sand material. All the skewness values, except that calculated at depths between 50.0 to 62.5 cms., were negatively skewed and suggestive of a beach environment. The colour of the sediment varied throughout the core from that of black to medium and light brown, and in places, bands of dark heavy minerals outlined the laminations . These laminations were of three types -- cross laminations (22.0 cms. depth), diffuse laminations (33.0 cms. depth), and parallel or slight ripple laminations (55.0 cms. depth). All the sections of the core contained some sulphur and carbonate material, while the content of clay pockets, shells, bark, twigs, pebbles and roots decreased in the sand fractions with depth.

Core 4

Taken at Burlington Beach, just north of the canal at a water depth of .6 meters, this core consisted of sediment which varied throughout the core from medium to coarse sand. Also, three distinct organic

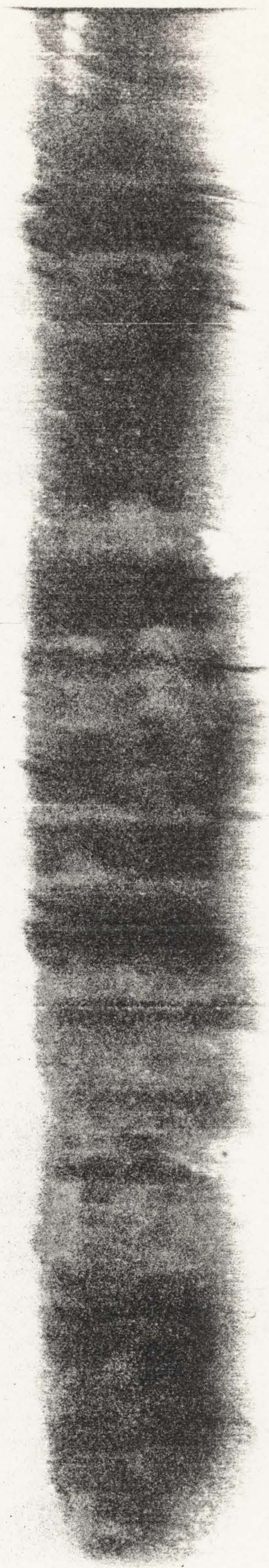

10cms
OL
11cms
22 cms
OL B
23.5 cms
28cms
32 cms
OL
33.5 cms
40cms


RL
8.1 cms
OL
17.4 cms
RL
30.6 cms
RL
39.0 cms
41.4 cms

CORE 4

CORE 5

CORE 4



CORE 5

layers located between 10.0 to 11.0 cms, 22.0 to 23.5 cms., and 32.0 to 33.5 cms. depth were present. The variation in the material found in this core suggests that distinctly different environments existed during depositional history. Again, the presence of organic material suggested that stagnant water or marshy conditions existed for three short periods. The degree of sorting of the sand fractions as expected varied throughout the core, and generally, the coarser grained sediments showed the poorest degree of sorting. At all depths except between 28.0 to 32.0 cms., skewness was indicative of a beach environment since all the values were negative. Throughout this core, sediment colour varied from black to dark and light brown, carbonate and sulphur material were present, and the concentrations of organic matter, pebbles and shells varied considerably. Only in the lower half of the core were diffuse laminations present.

Core 5

This core, taken in the same location as core 1, appeared to be part of a core taken at depth. It consisted of a small variability of sediment in the fine sand fraction which suggested that similar processes were effective during depositional history. The degree of sorting also substantiated this suggestion. The sediment is well to moderately well sorted, and only very slightly decreased in degree towards the core bottom. Within this core, all the skewness values were negative, indicative of a beach environment; all the medium brown sand sections contained carbonate and sulphur material; and in each of these sections, ripple laminations were emphasized by dark heavy minerals. Towards the bottom of the core, the material didn't appear as homogeneous as it was at the core top, and pebbles and layers of organic matter had been incorporated into the sediment.

Foreshore Sediments

The cores taken in the foreshore zone north of the canal on Burlington Beach showed a variability in sediment size from very fine to medium sand. No distinct layers could be correlated from core to core, but generally, it could be stated that operative beach processes have been similar over the past formational age, with the exception in places of conditions, most likely stagnant water, which led to the generation of organic layers. On the bivariate plot, most of the presently defined foreshore cores fell within the same environmentally defined range, with the exception of one point, from the base of core one, which fell within the area defined by the nearshore cores.

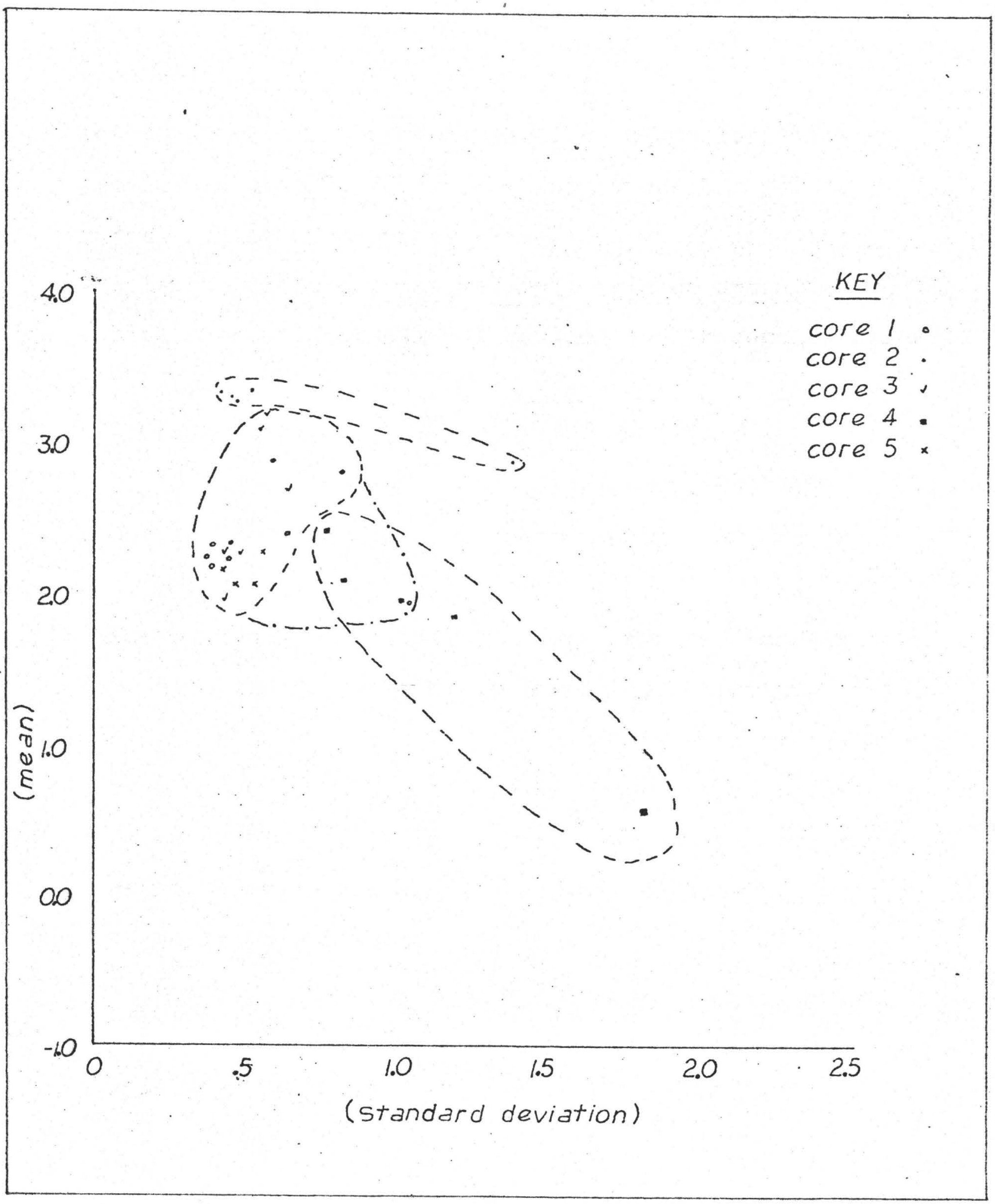


Fig. 6.1 Bivariate plot of drill core sediments.

Nearshore Sediments

According to the bivariate plot, the presently defined nearshore sediments are representative of totally distinct environments. The characteristics previously defined for core 4 and core 2 can not be correlated to any degree, thus it may be stated that completely different process factors were operative during the past formational period at both core locations.

6.6 Mineralogy

The sediments of the cores when observed under the binocular microscope showed similar mineralogical components. The main minerals noted were calcite, muscovite, biotite, chert, sphene, hornblende, potash feldspar, plagioclase, quartz and olivine. Also, granitic rock fragments, sedimentary rock fragments -- predominantly shales and carbonates, and some rock fragments which exhibited a schistose nature were present. Most of these minerals and rock fragments were present in the analyzed core sediments, and only varied in abundance from sample to sample.

6.7 Element Analysis

Laboratory Procedure

Samples collected from the top and the bottom of the cores were used for element analysis in an attempt to determine if these samples varied considerably in composition. However, before each sample could be analyzed, the fraction of the sediment finer than 2.5 ∅ had to be mixed with graphite (containing .025% Pd) in a 1:1 ratio in an agate mortar. The sample was then packed to the top of a graphite electrode and placed in the spectrograph. A four mm. arc gap existed between the pointed upper graphite electrode and the electrode containing the sample. The sample was then arced for 60 seconds, during which time the spectra, between 2200 Å and 4800 Å, was recorded on camera plates.

Interpretation of Results

The main elements which could be determined from the spectrograph method of analysis were silica, manganese, magnewium, iron, aluminum, sodium, titanium, vanadium, calcium, molybdenum, strontium, barium and carbon. These elements varied in amounts with respect to their location in the core and between cores. Since the variability of elements within each core was of interest, each core will be discussed separately.

Core 1

Only the sediment sample analyzed by the spectrograph for the core base could be used, for the sample run from the sediment taken from the core top

Core 1 -- Base				
1000	1000	1000-100	100	100
Si, Mn, Mg, Fe, Al, Na, Ti, V	Ca	Sr, Ba,		C
Core 2 -- Top				
1000	1000	1000-100	100	100
Si, Mg, Fe, Al, Mo, Na, Mn, V	Ca	Ti, Sr, Ba,		C
Core 2 -- Bottom				
1000	1000	1000-100	100	100
Si, Mg, Fe, Al, Mo, Na, Mn, V	Ca	Ti, Sr, Ba,		C
Core 3 -- Top				
1000	1000	1000-100	100	100
Si, Mn, Mg, Fe, Al, Na, Ti, V	Ca	Sr, Ba		C

Chart 6.1 Element analysis

Core 3 -- Bottom

1000	1000	1000-100	100	100
Si, Mg, Mn, Fe, Al, Na, Ti, Sr, V,	Ca	Ba		C

Core 4 -- Top

1000	1000	1000-100	100	100
Si, Mg, Fe, Al, Mo, Na, Ti, Mn, V	Ca Sr	Ba		C

Core 4 -- Bottom

1000	1000	1000-100	100	100
Si, Mg, Fe, Al, Mo, Na, V	Ca	Mn, Sr	Cu	C, Ti

Core 5 -- top

1000	1000	1000-100	100	100
Si, Mg, Fe, Al, Mo, Na, V	Ca	Mn, Sr, Ba		C

Chart 6.1 continued

Core 5 -- Bottom

>1000	1000	1000-100	100	<100
Si, Mn, Fe, Al, Mo, Na, Ti, V, Ba,	Ca, Mg, Sr,		Cu	C

Chart 6.1 continued

was destroyed. As shown on chart 6.1, most of the main elements were present in amounts of greater than 1000 ppm., while only calcium, magnesium and carbon were present in smaller amounts.

Core 2

Both samples analyzed from core two showed no element variation with respect to location within the core. Silica, magnesium, iron, aluminium, molybdenum, sodium, manganese and vanadium were present in amounts greater than 1000 ppm., while calcium was present in amounts of 1000 ppm. The remaining elements -- titanium, strontium, barium and carbon were present in amounts smaller than this.

Core 3

The element analysis for core 3 showed that similar elements in similar percentages were present in the samples taken from the core top and bottom. Only the amount of strontium varied between the two locations. In the core bottom sample, the amount of strontium had increased considerably. Those elements which were present in amounts of greater than 1000 ppm. were silica, magnesium, manganese, iron, aluminium, sodium, titanium and vanadium. Calcium, barium and carbon were present in smaller amounts.

Core 4

Between the top of core 4 and the base of this core, there was a substantial decrease in the amount of manganese, strontium and titanium, and the loss of the element barium. In the bottom sample, a small amount of copper was noted. Other than these changes, the remaining elements were present in similar amounts (chart 6.1).

Core 5

This core showed the greatest element variability with respect to location within the core. The sediment sample taken from the base of the core showed an increase in ppm. of manganese, titanium and barium. There was also the introduction of three new elements -- barium, titanium and copper, while there was a slight decrease in the amount of magnesium. Besides these locational variations, the remaining elements not mentioned remained in constant amounts.

6.8 Conclusions

The sediments found in the cores generally showed a small variation in size -- very coarse to very fine sand being the sediment range encompassed over all the cores. This small variation suggests that similar depositional environments existed over the historical period during which the sediment was deposited. The only exception to this statement was the layers of organic material which suggested that the depositional environment had changed at times during the historical period, and possibly stagnant water conditions or a transgression had occurred to facilitate the development of this organic layer. Most of the sediment was characteristic of a beach environment, being negatively skewed, while only one or two sections of the core showed positive skewness values which suggested wind deposited sediments. Each core showed minor features such as bark, tree fragments, pebbles, shells, carbonate and sulphur material interspersed throughout the core. Also, three main types of structural features -- ripple, diffuse and parallel laminations were evident in part of each core.

Statistical measures, especially mean and standard deviation when plotted on a bivariate plot, showed that the cores were representatives of three distinct environments. Cores 1, 3 and 5 were representative of a distinct environment which was assumed to be that of the foreshore, since all these cores were taken in that environment. The cores taken in the nearshore zone, cores 2,and 4, however showed two separate environments.

The main elements which were expected to be present in the minerals of the beach sand, silica, iron, manganese, magnesium, aluminium, sodium, vanadium, and calcium were generally present in amounts of 1000 ppm. and greater. Minor amounts of carbon, barium, strontium and titanium were also present in the Burlington Beach sediment. A comparison of the amounts of elements with respect to their location in the core showed that a great degree of variation generally did not occur between the top and the bottom of the core.

CHAPTER 7

CONCLUSIONS

This paper has pointed out that Burlington Bar was formed by the growth of two consecutive spits from the north and south headlands during the period of history described as the Lake Ontario Stage. The main processes which influenced bar growth were the dominant easterly winds and storms which generated waves and a longshore component. These processes transported material into the area, and aided in the building of the spits above sea level. Finally, the spits were joined, and the bayhead bar, as we now see the Burlington Bar, was formed.

Processes relatively similar to those which led to the building of the bar exist today. Material eroded from both the north and south shores of Lake Ontario is transported under complimentary wind, wave and longshore transport conditions towards the bar. Winds blowing from the north, north-east, east, and south-east generate the waves which affect the Lake Ontario beach side of the Burlington Bar. Since the percentage of significant wind speeds is minor, the majority of generated waves have periods which are less than two seconds, and heights which are less than two feet. These wave conditions lead to a gradual change in bar morphology -- a gradual build up of the beach. Only on a few occasions during the summer and fall months, did winds generate destructive waves which led to a rapid change in beach morphology by a downcombing of the beach. Observations of profiles showed that each profile varied with respect to specific areas of erosion and deposition, but most of the profiles were built up at the back of the beach and, with a few exceptions, extended lakeward. One possible cause of this lakeward growth was a definite decrease in lake level over the study period. Variability of wave conditions also led to a change in foreshore and nearshore sediment size over the study period. The sediment size across the beach generally showed a coarsening trend lakeward during June and August, with various exceptions caused by a reversal of one of the specific trends encompassed by the general trend. During September, the general trend showed a complete reversal -- there was a coarsening of sediment size landward. All three trends were usually accompanied by a sorting trend which became poorer with a coarsening of sediment. Viewing the sediment composition along the beach, there was a general decrease in sediment size from profile 1 to profile 9.

In order to understand at least in part, the processes which occurred in the past, drill cores were analyzed and from this analysis, three distinct environments were noted to exist. In a few of the cores, organic matter, characteristic of either transgressive or stagnant waters existed and disrupted the relatively stable conditions during which the material found in the cores was deposited.

It can be stated that the Burlington Bar and Beach were formed under varying processes and responses which appear to have been similar over the modern stage of development.

APPENDIX 1

The following recorded data is the moment measure output data from the computer program for the three short term sampling periods -- June 4, August 5, and September 16, 1972, and for the long term sampling period -- November 1971 and November 1972. Profile numbers refer to the profile stations shown on Fig. 4.1, while sites A, B, C, D, and E represent the bottom of the step, step top, waterline, swashlimit and berm sampling sites respectively.

JUNE

PROFILE	SITE	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS	SORTING COEFFICIENT
9	A	-	-	-	-	-
	B	-1.10	.68	.58	2.68	35.67
	C	-.18	1.13	.34	.02	14.97
	D	-.08	.79	.21	1.04	27.30
	E	-.33	1.36	.16	-1.23	16.71
8	A	-1.41	1.86	.24	-.65	15.52
	B	-.61	1.39	.72	-.55	17.51
	C	-.83	1.18	1.18	1.02	20.05
	D	-.73	1.11	1.17	.88	20.40
	E	-2.89	1.90	.59	-1.02	45.75
7	A	-1.15	1.58	.67	-.63	12.07
	B	-3.06	1.06	.61	-.71	32.44
	C	-.92	.93	.93	.85	23.30
	D	-.11	1.35	.10	-1.21	10.83
	E	1.40	.50	-.10	.16	35.17
6	A	-.73	1.31	.49	-.12	17.72
	B	-1.00	.95	1.52	2.67	26.37
	C	.03	.98	.34	.27	19.45
	D	.47	1.03	-.29	-.02	18.33
	E	1.14	.64	-.21	.25	30.96
5	A	.53	1.43	-.29	-1.18	9.80
	B	-.65	1.14	1.36	1.53	24.33
	C	-.11	1.14	.96	.09	23.04
	D	.66	1.33	-.18	-1.22	13.851
	E	1.27	.63	.07	-.59	25.26

JUNE

PROFILE	SITE	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS	SORTING COEFFIC-IENT
4	A	.64	1.47	-.25	-1.41	13.37
	B	-.91	.76	1.55	4.60	33.28
	C.	-.04	1.32	.24	-1.07	14.74
	D	1.12	1.42	-1.24	.29	21.88
	E	1.96	.42	-.26	.40	40.63
3	A	.70	1.16	-.26	-1.23	25.66
	B + C	1.36	.85	-1.16	1.48	27.81
	D	2.02	.41	-.27	.09	38.09
	E	1.61	1.49	-1.69	1.40	34.55
2	A	1.86	.88	-2.38	6.62	38.33
	B + C	1.46	.70	-.34	.03	23.72
	D	1.67	.48	.34	-.40	41.21
	E	2.27	.40	.23	.28	44.86
1	A	-.97	.95	1.36	2.68	24.81
	B	.30	.93	.31	.41	21.03
	C	1.61	.49	-2.74	9.90	69.11
	D	-.85	.89	.42	-.14	24.12
	E	1.46	.58	-.75	1.62	38.12

AUGUST

PROFILE	SITE	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS	SORTING COEFFIC-IENT
9	A	-1.70	1.73	.56	-.70	17.71
	B	-1.94	2.31	.16	-1.46	29.14
	C	-1.12	1.68	.11	-1.07	10.49
	D	-.57	.87	.57	.70	23.26
	E	.79	.42	.22	.37	39.43
8	A	-2.20	2.02	.50	-.85	25.95
	B	-.98	1.83	.14	-1.27	8.67
	C	-.94	1.33	.66	-.39	15.18
	D	-.79	1.60	.004	-.84	15.13
	E	1.09	.52	-1.16	7.33	45.59
7	A	-1.76	1.92	.46	-1.10	12.83
	B	-.94	1.39	.55	-.61	10.60
	C	-1.09	.88	.51	.98	21.06
	D	.16	1.18	-.42	-.51	17.13
	E	.40	2.08	-1.55	.79	28.46
6	A	-.34	1.43	-.15	-.99	9.14
	B	-1.19	1.54	.23	-.92	12.56
	C	-.62	1.16	-.07	-.40	14.32
	D	-.87	1.84	-.39	-1.23	12.28
	E	1.13	.72	-.91	2.82	32.36
5	A	-.54	1.52	.42	-.37	13.64
	B	-1.71	1.50	.09	-.68	14.30
	C	-.55	1.16	.21	.11	19.85
	D	-1.17	1.11	-.34	-.71	21.80
	E	1.09	.68	.33	-.68	27.32

AUGUST

PROFILE	SITE	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS	SORTING COEFFICIENT
3	A	.99	1.38	-1.04	.07	15.75
	B	.01	1.38	-.23	-.46	11.89
	C	.63	.84	-.30	-.19	22.69
	D	1.43	.48	-.51	2.69	44.26
	E	1.84	.38	-.07	-.01	44.85
2	A	----	---	----	----	----
	B	----	---	----	----	----
	C	2.08	.41	.11	.39	44.31
	D	2.27	.44	.23	.02	35.51
	E	2.31	.51	-2.68	19.18	50.48
1	A	-2.12	2.10	.91	-.51	17.18
	B	-1.18	1.97	.37	-1.08	9.44
	C	.08	1.47	-.08	1.22	10.60
	D	-.99	2.25	-.05	-1.34	19.27
	E	1.13	.72	-.91	2.82	32.36

SEPTEMBER

PROFILE	SITE	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS	SORTING COEFFICIENT
9	A	-2.55	1.71	.25	-1.30	20.38
	B	-1.84	1.31	.24	-1.07	22.51
	C	-1.04	.90	.26	.19	26.22
	D	-1.40	.78	-.31	.28	25.43
	E	-1.79	1.17	.35	-.28	25.10
8	A	-2.16	1.01	.27	-.72	16.96
	B	-2.10	1.47	.07	-.14	17.26
	C	-1.06	.77	.13	-.10	28.52
	D	-1.71	.97	.88	.70	31.61
	E	-1.00	1.47	.29	-.89	6.62
7	A	-3.52	1.39	1.31	2.94	28.18
	B	-1.97	1.39	.95	.68	21.26
	C	-.36	1.56	.10	-.87	9.69
	D	-.85	2.19	-.20	-1.26	7.81
	E	-.73	1.74	.37	-.77	8.18
6	A	-1.77	1.69	1.02	-.01	17.03
	B	-1.50	.77	.58	.52	31.11
	C	-.18	1.02	.76	.40	19.96
	D	-.40	1.30	.21	-.78	15.84
	E	-2.95	1.82	1.44	1.24	24.99
5	A	-1.23	2.03	.13	-.94	12.32
	B	-1.25	.78	-.27	2.50	37.49
	C	.01	1.12	1.03	.25	25.74
	D	-.52	.57	.85	3.68	40.25
	E	-.78	1.15	-.53	.07	21.14

SEPTEMBER

PROFILE	SITE	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS	SORTING COEFFIC-IENT
4	A	-.90	1.72	.67	-.65	11.54
	B	.32	1.37	.05	-1.19	10.59
	C	1.52	1.08	-1.37	.80	29.39
	D	.53	1.76	-.34	-1.52	22.99
	E	1.49	1.65	-2.07	2.86	40.59
3	A	1.78	.87	-1.36	2.46	24.90
	B	1.99	.48	-1.08	4.25	44.77
	C	2.09	.47	-1.28	5.82	47.31
	D	2.22	.37	-1.04	8.61	57.45
	E	1.91	.49	-1.56	8.44	46.27
2	A	1.61	.67	-1.41	2.64	35.28
	B	1.67	.53	-1.40	4.86	44.22
	C	1.92	.61	-.48	1.21	39.37
	D	1.84	.39	-1.46	10.09	57.76
	E	1.99	.75	-1.62	3.18	38.57
1	A	-2.14	2.38	.62	-.96	15.51
	B	-1.39	.98	.21	.24	23.25
	C	.11	1.64	-.57	-.57	10.14
	D	.50	1.56	-.57	-.36	8.37
	E	-.92	1.98	.11	-1.57	12.37

LONG TERM STUDY DATA

1971 STATION	MEAN	STANDARD DEVIATION	SKEWNESS	1972 STATION	MEAN	STANDARD DEVIATION	SKEWNESS
SOUTH CANAL							
1 (nearest canal)	2.09	.44	-.04	1	-1.68	1.14	1.01
2	1.38	.76	-.16	2	.30	1.65	.09
3	1.61	.80	-.34	3	1.77	1.04	-1.58
4	1.40	.48	-.09	4	1.67	.99	-1.46
5	1.89	.77	-.69	5	.84	1.27	-.09
6	1.95	.71	-.65	6	.48	1.29	-.09
7	1.79	.60	-.16	7	.76	1.27	-.15
8	1.71	.69	-.54	8	1.07	1.14	-.24
9	1.93	.56	-.67	9	.22	1.41	.20
10 (farthest from the canal)	2.13	.77	-.47	10	1.36	1.13	-1.05
NORTH CANAL							
11 (nearest canal)	2.42	.28	.08	11	2.36	.36	.02
12	2.31	.29	-07	12	2.34	.36	-.05
13	2.31	.30	.04	13	2.26	.36	.02
14	2.33	.29	-.01	14	2.23	.37	.01
15	2.33	.31	-.23	15	2.19	.37	.05
16	2.38	.29	.01	16	2.27	.40	.04
17	2.59	.37	.33	17	2.19	.39	-.51
18	2.40	.37	.19	18	2.28	.36	.02
19	2.32	.31	-.01	19	2.28	.36	.03
20 (farthest from the canal)	2.28	.31	.02	20	2.27	.40	-.05

APPENDIX 2

Each core was analyzed with respect to certain characteristics -- location in the core, colour, sediment size, the presence of carbonate, sulphur and organic matter, and the presence of shells, pebbles and tree bark. The following is the detailed analysis of each core.

DESCRIPTION OF CORE 1

Location	0.0-21.5 cms	21.5-26.3 cms	26.5-27.5 cms	27.5-33.9 cms	33.9-44.9 cms
Thickness	21.5 cms	4.8 cms	1.0 cms	6.5 cms	11.0 cms.
Colour	light to medium brown dark material emphasizing ripple laminations	medium brown dark minerals concentrated in pockets	dark brown	dark brown	medium brown concentrations of dark minerals
Sample	12.0-16.0 cms	23.5-25.5 cms	26.5-27.5 cms	30.0-31.8 cms	36.7-39.0 cms
Mode	2.5	2.5	2.5	2.5	2.5
Median	2.2	2.2	2.2	2.3	2.3
Mean	2.2	2.2	2.2	2.3	2.3
Standard deviation	.4	.4	.4	.4	.4
Skewness	-1.5	-.2	-1.5	.03	-.4
Kurtosis	10.7	2.8	9.3	3.6	7.0
Sorting coefficient	57.7	54.2	52.6	53.5	51.6
Carbonates	yes	yes	yes	yes	yes
Sulphur	yes	yes	yes	yes	yes
Other	wood, bark, shells,			concentration of dark matter along side of core	clay pockets, wood fragments

DESCRIPTION OF CORE 1 (continued)

Location	44.9-52.3 cms	52.3-55.0 cms	55.0-57.8 cms	57.8-83.0 cms
Thickness	7.4 cms	2.7 cms	2.8 cms	25.2 cms
Colour	very dark brown	medium brown pockets of dark matter	very dark matter, dark brown	brown -- medium to dark
Sample	47.8-49.8 cms	52.3-55.0 cms	56.0-57.0 cms	77.0-79.0 cms.
Mode	3.0	2.5	2.5	2.5
Median	2.9	2.3	2.9	2.1
Mean	2.9	2.4	2.8	1.9
Standard deviation	.6	.6	.8	1.0
Skewness	-.4	-.2	-.9	-1.5
Kurtosis	1.7	3.1	2.3	2.3
Sorting coefficient	33.9	36.9	23.4	28.9
Carbonates	yes	yes	yes	yes
Sulphur	yes	yes	yes	yes
Other	wood, shells		wood, bark, roots	shale pebbles, wood, shells, quartz pebbles, gradual sediment size change in the section of the core.

DESCRIPTION OF CORE 2

Location	0.0-4.5cms	4.5-21.9 cms	21.9-28.9 cms	28.9-32.2 cms	32.2-35.3 cms.	35.3-53.7 cms.
Thickness	4.5 cms.	17.4 cms.	6.2 cms.	4.2 cms.	3.1 cms.	18.4 cms.
Colour	medium brown	medium to dark brown	medium brown, dark laminations	medium brown	medium to dark brown	light to medium brown
Mode	3.5	3.5	3.5	3.5		3.5
Median	3.4	3.4	3.3	3.2		3.3
Mean	3.3	3.3	3.3	2.9		3.3
Standard deviation	.4	.5	.5	1.4		.5
Skewness	-.4	-1.2	-.9	-2.4		-.5
Kurtosis	.4	5.7	3.8	5.2		1.1
Sorting coefficient	38.4	36.9	38.9	30.9		36.7
Sample	3.5-4.5 cms.	19.5-21.5 cms.	23.0-24.5 cms.	29.0-31.0 cms.		42.0-45.0 cms.
Carbonates	yes	yes	yes	yes		yes
Sulphur	yes	---	---	---		---
Other	homogeneous	clay pockets, pebbles, bands of coarser material	homogeneous	pebbles, clay pockets	clay pockets	homogeneous

DESCRIPTION OF CORE 3

Location	0-26 cms.	26.0-43.0 cms	43.0-45.8 cms	45.8-50.5 cms	50.0-62.5 cms
Thickness	26.0 cms	17.0 cms	2.8 cms	4.7 cms	12.5 cms
Colour	medium brown	medium brown heavy dark material outlining ripples	dark brown organic layer, wood, shells,	medium to dark brown	medium brown
Sample	12.0-14.0 cms	29.0-32.0 cms		46.0-48.0 cms	57.0-59.0 cms
Mode	2.0	2.5		3.5	3.0
Median	1.9	2.3		3.2	2.5
Mean	1.9	2.2		3.2	2.6
Standard deviation	.4	.4		.6	.7
Skewness	-1.1	-.5		-.9	+.3
Kurtosis	7.2	5.9		1.5	-.6
Sorting coefficient	51.9	50.8		33.5	19.8
Carbonates	yes	yes		yes	yes
Sulphur	yes	yes		yes	yes
Other	shells, pebbles	organic matter, clay pockets, pebbles, wood,		organic matter	shells, clay pockets.

DESCRIPTION OF CORE 3 (continued)

Location	62.5-66.0 cms	66.0-67.0 cms	76.0-100.0 cms
Thickness	3.5 cms	1.0 cms	24.0 cms.
Colour	dark brown	black organic layer, high % of tree matter, bark, clays,	medium brown
Sample	64.0-65.5 cms		83.5-86.5 cms
Mode	3.0		2.5
Median	3.1		2.3
Mean	3.0		2.3
Standard deviation	.5		.5
Skewness	-.3		-.2
Kurtosis	.1		2.3
Sorting coefficient	26.4		40.6
Carbonates	yes		yes
Sulphur	yes		yes
Others	shells		shells

DESCRIPTION OF CORE 4

Location	0.0-10.0 cms.	10.0-11.0 cms	11.0-22.0 cms	22.0-23.5 cms	23.5-28.0 cms
Thickness	10.0 cms	1.0 cms	11.0 cms	1.5 cms	4.5 cms
Colour	light brown	black, organic matter, shells, pebbles	light brown	black, organic matter, wood, pebbles,	dark brown
Sample	5.0-6.0 cms		17.0-19.0 cms		26.0-27.0 cms
Mode	2.5		2.5		2.5
Median	2.2		2.2		2.2
Mean	1.8		2.1		2.0
Standard deviation	1.2		.8		1.0
Skewness	-1.9		-2.4		-2.1
Kurtosis	3.0		7.1		4.1
Sorting coefficient	31.2		43.5		37.6
Carbonates	yes		yes		yes
Sulphur	yes		yes		yes
Other	pebbles, bands of organic matter, shells		shells		pebbles, shells

DESCRIPTION OF CORE 4 (continued)

Location	28.0-32.0 cms	32.0-33.5 cms	33.5 to 40.0 cms
Thickness	4.0 cms	1.5 cms	6.5 cms.
Colour	dark brown	black organic matter, shells,	medium brown
Sample	29.0-31.0 cms		36.0-38.0 cms
Mode	2.5		2.5
Median	-.7		2.5
Mean	.1		
Standard deviation	1.8		.8
Skewness	.4		-3.2
Kurtosis	-1.5		13.8
Sorting coefficient	17.1		46.9
Carbonates	yes		yes
Sulphur	yes		yes
Other	shells, pebbles,		shells, pebbles, organic matter in a layer.

DESCRIPTION OF CORE 5

Location	0-8.1 cms.	8.1-17.4 cms	17.4-30.6 cms	30.6-39.0 cms	39.0-41.4 cms
Thickness	8.1 cms.	9.3 cms	13.2 cms	8.4 cms	2.4 cms
Colour	medium brown dark bands emphasizing ripples	medium brown dark bands emphasizing ripples	medium brown dark bands emphasizing ripples	medium brown dark bands emphasizing ripples	medium brown dark bands emphasizing ripples
Sample	5.0-6.5 cms	13-15 cms	24.0 - 26.0	35.0-36.5 cms	-------------
Mode	2.5	2.4	2.2	2.5	
Median	2.1	2.1	2.1	2.3	
Mean	2.2	2.1	2.1	2.3	
Standard deviation	.4	.5	.5	.6	
Skewness	-.8	-.8	-2.1	-1.7	
Kurtosis	6.6	4.8	10.9	8.3	
Sorting coefficient	51.2	46.8	49.8	45.6	
Carbonates	yes	yes	yes	yes	
Sulphur	yes	yes	yes	yes	
Other	homogeneous	homogeneous	pebbles, organic material	shells, small amount of organic material	small layers of organic material

APPENDIX 3

Source of Figures.

Fig. 2.1 Karrow, P. F., 1963.

Fig. 2.3 Hewitt, D. F. and Karrow, P. F., 1963.

Fig. 2.4 Dreimanis, A., 1969.

Source of Charts.

Chart 2.1 Hewitt, D. F. and Karrow, P. F., 1963.

Chart 2.2 Modified from drill core information obtained from the Hydro Electric Power Commission of Ontario.

Chart 2.3 (same as chart 2.2)

Chart 4.3 Water level data obtained from the Canada Centre for Inland Waters, Marine Sciences Branch, Burlington, 1972.

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