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# THE RELATIONSHIP BETWEEN
# THE FORESHORE SLOPE,
# GRAIN SIZE AND WAVE HEIGHT

By

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**ABSTRACT**

This study reports on the relationship between the foreshore slopes, grain size characteristics and the wave height on the Hamilton-Burlington Beach. This beach is a non-tidal, low-enery beach. At five stations along the beach, profiles were taken, sediment samples were collected and the average wave heights determined. The slopes were plotted against the mean grain size, the median grain size and the wave heights. There was no clear relationship between the variables tested. It was determined, however, that there existed three areas along this beach. The first area was the one affected only by the wave energy, the second are was affected by both the wave energy and the grain size characteristics, and the third region was affected by the grain size characteristics.

## ACKNOWLEDGEMENTS

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# CHAPTER ONE

# INTRODUCTION

## 1.10 INTRODUCTION

The characteristics of the shore zone are the result of an extremely dynamic environment. The influences of climate, location and energy level can be seen in the changes which occur on the beach itself. One of the most variable aspects of the shore zone is the foreshore slope.

## 1.20 THE FORESHORE SLOPE

The foreshore slope is the sloping portion of the beach profile below the berm which is exposed to the action of the wave swash. Therefore, the attributes of the foreshore slope are the outcome of the varying intensities of the swash and the varying onshore-offshore sediment transport. As the swash runs up the foreshore slope, the water percolates into the sand. This, and frictional drag, will decrease the intensity of the backwash. The result is onshore movement of sediment which builds up the foreshore slope until the slope angle supports the backwash, resulting in a movement of sediment offshore. If the slope reaches a state where there is an equal amount of sediment being moved offshore and onshore, the foreshore is said to be in dynamic equilibrium.

Since the percolation of the swash into the sand is a governing factor in the deposition of the sediment in the foreshore zone, the grain size of the sediment being deposited becomes important as it governs the rate of percolation. Secondly, the intensity of the swash is another way of looking at the energy available to do work on the foreshore slope. However, the amount of energy available can also be represented by the height of the wave.

**1.30 PURPOSE OF THE PAPER**

This paper will examine the nature and interrelationships of the foreshore slope on the of the Hamilton-Burlington beach at the western end of Lake Ontario, which is a tideless coast. It will look at the changes of the profile of the foreshore slope in relation to the grain size characteristics of the sediment and the wave height. The characteristics of the foreshore at five stations will be compared to determine if any variations along the shore exist. As well, variations at a particular station throughout the study period, will be investigated.

# CHAPTER TWO

# PRIOR RESEARCH

## 2.10 INTRODUCTION

The relationship between the foreshore slope, grain size and wave height has been studied several times in the past. The most important papers are reviewed briefly below.

## 2.20 GRAIN SIZE CHARACTERISTICS

The slope of the foreshore depends mainly on the amount of water which percolates into the beach. King (1972) and Komar (1976) point out that the rate of percolation is partially a function of the grain size and sorting. The coarser the sediment, the greater the rate of percolation, the weaker the backwash. Therefore, the slope of the foreshore will be steeper because the intensity of the backwash has been weakened. The weakening of the backwash results in a decrease in erosion and an increase in deposition, which allows the beach to build up. Komar (1976) also stresses that if the sediment is well sorted the foreshore will have a steeper slope than if the sediment is poorly sorted. The beach of Lake Ontario is a mixed sand and gravel beach. McLean and Kirk (1968) examined the sorting of a mixed sand-shingle beach and found that the better sorted beach had a steeper slope, and the distribution of the sediment was bimodal.

The arrangement and sorting of the sediment on the foreshore was also discussed by Miller and Zeigler (1958). They pointed out that as an incoming breaker deposits its sediment, it is met with the backwash which is also carrying the sediment it had eroded from the beach. If the slope of the foreshore is relatively steep, the meeting of the incoming wave and the backwash will result in the development of a step. This step will be well sorted and consist of coarse materials. They also pointed out that the finer material does not settle out as quickly as the coarser particles. Therefore, the step would consist of the coarsest particles while the finer particles would be deposited seaward and landward from this. Krumbein (1963) also found that the to-and-fro motion of the swash and backwash sorted out and arranged the foreshore sediment according to its size, shape and density.

Dubois (1972) suggested that the relationship between the foreshore slope and mean grain size is a function of the heavy mineral content. Since he had a steepening foreshore with a decreasing particle size, he concluded that the resulting slope is not critically affected by the rate of percolation. It was determined that the high percentage of heavy minerals increased the weight per volume, which increased the resistance of the material to be removed by the backwash, resulting in the steep slope.

## 2.30 WAVE ENERGY

A second important factor which determines the slope of the foreshore is the degree to which the beach is exposed to wave action. McLean and Kirk (1968) state that a protected beach will have a steeper slope. Bascom (1951) and Wiegel (1964) studied the relationship between the foreshore zone and the median grain size for high-energy, exposed beaches and lower-energy, protected beaches, respectively. The protected east coast beaches of the United States have a steeper slope than the exposed west coast beaches. Bascom, (1951) studied the beach at Halfmoon Bay, California which is protected at one end and exposed at the other. The northern beaches were high-energy level profiles, which were similar to those of the west coast, and the southern profiles were low-energy profiles like those of the east coast. There was a gradational relationship of the beaches between the high-energy and low-enery beaches.

The height of the wave approaching the beach also affects the slope of the foreshore. Dolan and Ferm (1966) state that an increased wave height and swash velocity is associated with flatter beach slopes. Therefore, it is also associated with finer material and simple concave beach profiles. The wave height itself depends on the velocity of the wind, the fetch and the duration of the wind (Bajorunas, 1971).

## 2.40 ACTIVITIES AND FORMATIONS CHARACTERISTIC OF THE BEACHFACE

Several erosional and depositional patterns and major beachforms are usually present on beaches of all types. Weishar and Wood (1983) emphasized that the summer period is one for accretion resulting in a widening of the beach and a lakeward movement of the berm crest. It is in the late fall and early winter that erosion of the beach occurs, moving the berm crest shoreward. Their study was conducted on Lake Michigan, which is a tideless coast.

Kemp (1961) stated that there are two profile types. The first is a step profile and the second is a bar profile. The step profile forms on coast with low waves. The step itself is created by a vortex produced by the backwash, as it meets an incoming wave. As the wave height increases the step will move seaward because the coarsest material is trapped at the seaward face of the step. The step eventually disappears and the profile changes to a bar profile.

Another series of formations present on most beaches are beach cusps. According to Kemp (1961), cusps develops when an instability of the flow pattern arises. Local lateral circulations are set up which interfere with the completion of the backwash before the next plunge. Grelcher (1958) stated that the cusps are longer and more regular in sand than shingle. This is because the sand is easier to move than the shingle. Yet, he also pointed out that cusps are rarer in sand, probably because they need a steep slope to form, which is provided by gravel deposits. Chafetz and Kocurek (1981) studied the coarsening upward sequence of beach cusps. They stated that this sequence could be due to lateral migration of the cusps or the vertical growth of the forms.

A final feature that can be found on a beach is a ridge and runnel feature. Davis, et. al. (1972) stated that these features are formed as post-storm features. As the ridge begins to move shoreward, it is modified and becomes asymetrical. The leading (landward) edge is quite steep; that is, it is at the angle of repose of the migrating sand. The ridge migrates landward and will eventually weld itself to the beach.

# CHAPTER THREE

# STUDY SITE AND METHODOLOGY

## 3.10 INTRODUCTION

The shoreline between Van Wagner's Beach and the Burlington Canal, was selected for this study, because of the variations of exposure to the waves, the direction of the longshore drift and also because it is the least used area for recreation, so that there little human interference with the beach characteristics. The beach was studied in July, August and November, 1986. Five stations were selected for detailed observations. Station 1 was located at Van Wagner's beach and Station 5 was located approximately 200 m south of the Burlington Canal, Stations 2, 3, and 4 were located between these two. Each station was approximately one kilometer apart. (Figure 1.0)

## 3.20 STUDY SITE

Figures A1.0 to A15.0 illustrate the physical characteristics of each station (the letter "A" indicates that the figures are located in Appendix A). Figures A1.0 and A2.0 show that Station 1 was located between two groins. The area closest to the water was composed of sediment that was coarser than the sediment further onshore. Back of this area there once again occurred a coarse deposit. Station 2 (Figures A3.0 to A5.0) had a coarser deposit than that which

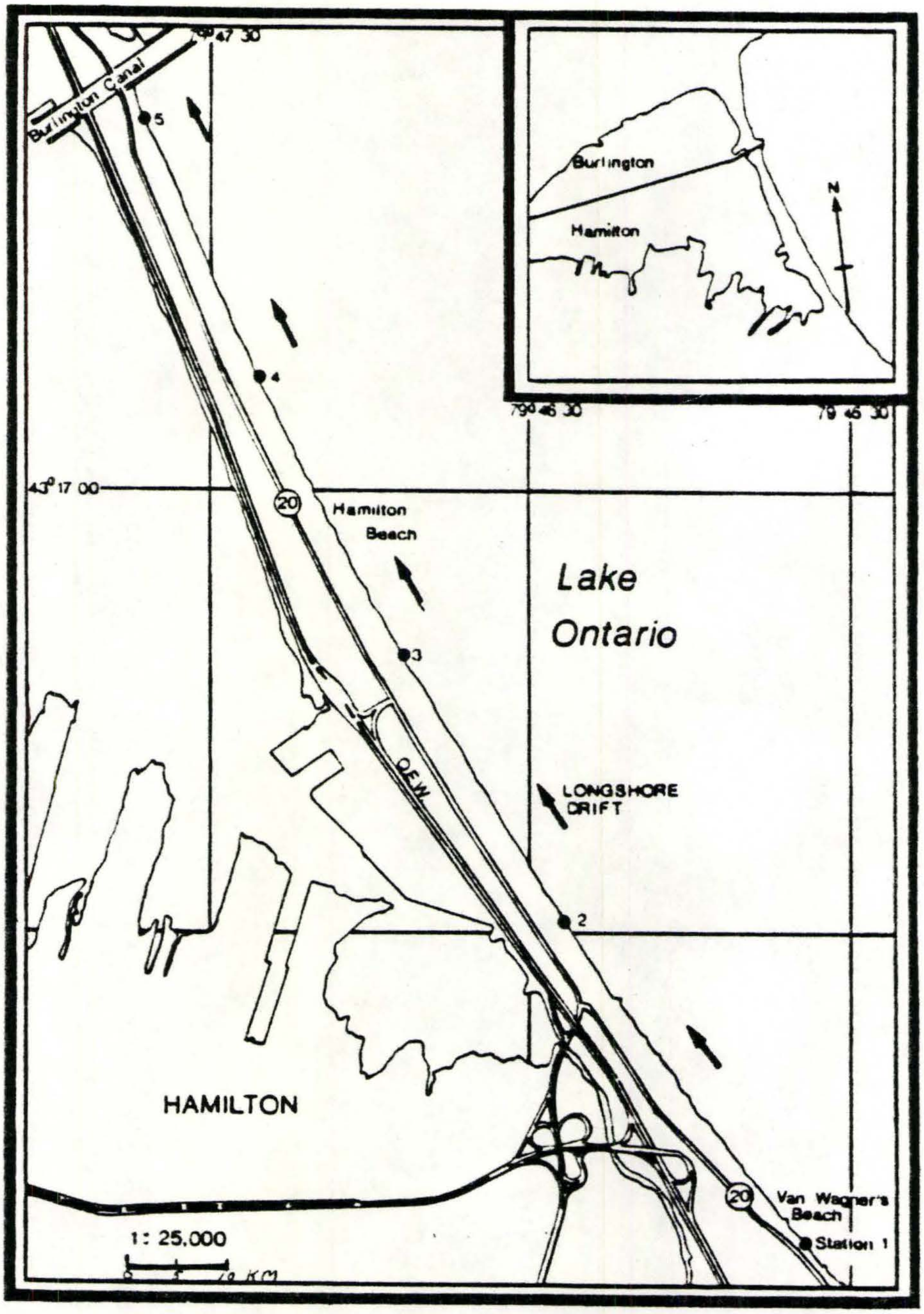



Figure 1.0 THE AREA OF STUDY ALONG THE HAMILTON-BURLINGTON BEACH

was found at Station 1. Also, it is evident that this station had a greater exposure to wave energy. Station 3 (Figure A6.0 to A8.0) is located where there is a bend in the shoreline. Therefore, this station should have less exposure to wave action that Station 2. The deposit closest to the water was coarser than the deposit further onshore, and the sediment at Station 3 is finer than the sediment found at Station 2. Figures A9.0 to A11.0 show the location of Station 4. The beach was much narrower here but the same sediment pattern occurs, with the coarser material located near the water's edge. Overall, the sediment was finer than that of the three previous stations. At Station 5 (Figures A12.0 to A15.0) the beach once again widened. The deposit closest to the water's edge was the coarsest, but there was a greater amount of fine material than at the other four stations. The figures illustrate that Station 5 is exposed to less wave energy than the other four stations. Particulars and changes which occured in the beach formations at each station are discussed in section 4.5.

As mentioned earler, this beach is a non-tidal beach. As well, Figures A1.0 to A15.0 emphasize that this beach is a low-energy beach. The waves which worked the sediment on the beach were, for the most part, small. The only time when these beaches were exposed to high waves was then there was a storm event or a series of days during which storms occurred. The waves obliquely approached the shore from the north, and sometines from the south, but this was rare. The longshore drift travelled from the south to the north. Therefore, it is expected that the heaviest (largest) material would be deposited at Station 1 and the finest material at Station 5.

The weather varied throughout the study period. The sutdy was done during the months of July, August and November. During July the weather was fair, with sunny conditions and warm temperatures. At the time of the study in August there were a number of thunderstorms, and there was a greater number of rainy days. In November the weather was cooler, however it was clear with little cloud cover. During the study period the winds were from the west and the south.

### 3.30 METHODOLOGY

Field measurements were made daily between July 16 to 24, August 20 to 29, and on November 2 and November 9. On each observation day the profile of the foreshore slope was surveyed, at each station, using a precise level. A permanent object was used as a backsite to ensure that repeated profiles had the same datum. Also, stakes were driven in and left in the beach so that the profile was taken on exactly the same line each time. The foreshore slope was considered to be that area of the beach located between the base of the back berm and the base of the first step (or bar) beneath the still water line. (Figure B1.0A)

The profiles were graphed, and their slopes determined. Two slope were determined for each profile: a) from the average limit of the swash (slope S); and b) from the maximum limit of swash during that day (Figure B1.0A). All the profiles were graphed together, for each station, for the total sampling period, to determine of their enveloping curves.

Sediment samples were obtained on the first sampling day and the last sampling day of each month. All sediment samples were taken from the swash zone. The swash zone is the portion of the beach face which is alternately covered by the wave swash and exposed by the backwash. On the first day of each month five samples (A-E) were taken, A and B were above the swash line, C was at the swash line, and D and E were below. On the last day of sampling, only sample C was collected (Figures B1.0B and B1.0C). A hundred grams of each sample was placed in a stack of sieves, ranging from -5.0 to 4.0 phi. The stack was shaken for 15 minutes on a mechanical shaker.

The results were graphed as a grain size distribution curve, and the Folk and Ward statistical method was applied. Once the statistics for each of the five monthly samples from the first sampling day of the month, were determined, an average for was calculated. This was averaged with data from the last sampling day of the month for every station for every month. Following this, an overall average was obtained for each station for the total sampling period.

The results obtained from the above analysis were used to investigate the relationships which exist between the foreshore slope and the grain size characteristics within and between stations. First, the average mean of the five samples was plotted against the mean of the middle sample (C) to determine if the mean of (C) was representative. Secondly, the means of the samples were plotted against the standard deviations (sorting) to determine if any patterns exist. Thirdly, the mean of the grain size was plotted against both slopes, to see if a relationship existed.

Finally, the wave height for each day at each station was determined. It was measured in an area where there was minimal interference from the bed, using a measuring rod ruled off in centimeters. With this placed in the water, the average heights for the crests and the troughs of the wave were measured and the wave height was calculated. Frequency histograms were drawn for each station, in order to determine the most common wave height and to determine any patterns or relationships which may exist as one move downshore from Station 1 to Station 5. The wave heights were plotted against the slopes to determine any possible relationships. The wave heights were then regressed against the slopes, using the Minitab program, for which no significant result was determined. Therefore, the results obtained will not be used in the paper, because it is felt that the graphs provide a better interpretation of any relationships that do exist.

The Minitab program was also used to regress the slopes against the wind direction and wind speeds, which were obtained from the Hamilton Weather Office. However, no significant relationship exists, and the results will not be used in this paper. This is because most of the winds came out of the western or the southern directions. All of the plots were done on the VP-Planner software package.

# CHAPTER FOUR

# RESULTS

## 4.10 INTRODUCTION

The profiles obtained at the study site show the build up of the beach during the month of July and August, and provide evidence of a period of erosion during the latter part of November. The movement of the sand from below the still water line onto the foreshore is a process which occurs throughout the study period. Also, there were changes in the grain size distributions throughout the study period. Distributions ranged from being linear to extremely bimodal. The grain sizes varied from station to station, becoming finer as one moved from Station 1 to Station 5. The wave heights showed a bimodal distribution overall. However, when the area of mode was investigated in greater detail some interesting results occured. The following is a detailed comment on the results obtained.

## 4.20 PROFILES

The profiles obtained at Station 1 show the characteristics mentioned above. During July the profiles show that sediment was moved onshore as a series of steps and bars moving inshore. The sand bars will eventually join to the backshore of the beach to develop a 'welded' bar. As mentioned earlier, two slopes were calculated; slope A, which was from the maximum limit of the swash, and slope S, which was from the average limit of the swash, for that time. The average slope for July from (A) was 1:7.1 and the average slope from (S) was 1:5.8.

In August the welded bars were larger than they were in July. Also, the sand was still moving on shore by steps, and there was no evidence of any ridge and runnel systems. The average slope from (A) was 1:7.3, and from (S) it was 1:6.6.

During November several changes occured. On November 2 the sand was moved onshore through a series of ridge and runnels. On November 9 there were no welded bars, the sand was moved onto the beach by steps only. The average slope from (A) was 1:15.4, and from (S) was 1:6.2.

Generally, at Station 1, the slope from (S) was steeper than the slope from (A). This characteristic is maintained throughout the three months. Secondly, the slopes became increasingly gradual during the study period.

During July, at Station 2, a large amount of sediment was moved onto the beach. As a result, the profile developed steps, and ridge and runnel features. Yet, it did not develop any welded bars. The average slope for July from (A) was 1:7.4, and from (S) was 1:5.3. Therefore, the slope from the average limit of the swash was steeper than the slope from the maximum limit of the swash.

In August, the profiles of the beach at Station 2 became increasingly gradual. As sediment moved onto the beach it created, steps as it did in July, but there were no ridge and runnel features. In addition to the development of a step feature, the profiles in August showed the development of welded bars. From August 26 to August 29, the profile began to lower. This could have been and indication of the beginning of the erosional period. The average slope from (A) was 1:8.2, and from (S) was 1:7.8.

Therefore, as in July, the slope from the average limit of the swash was steeper than slope from the maximum limit of the swash. Secondly, the slope measurements indicate that the foreshore had become increasingly gentle.

The profile of the beach on November 2, shows a dominant ridge, which was approximately 10.5 cm high. The profile has now risen which seems to indicate that the erosional period did not actually begin, or that there was a period of build up on the beach. On November 9, the profile had developed a welded bar, which was approximately 12.0 cm high. Secondly, the beach below the still water line had extended seaward. This is an indication that the sand was moving off the beach in a seaward direction, and that erosion of the beachface was occurring. The average slope calculated from (A) was 1:9.7, and from (S) was 1:10.0. Therefore, the profile in November was gentler than it was in July and August. Secondly the slope calculated from the average limit of the swash was gentler than the slope calculated from the maximum limit of the swash. This relationship occured only in November.

As in the case of the previous stations, the profiles obtained in July for Station 3 showed the sediment moving onshore by welded bars and steps. Following the deposition of the sediment, there was a tendency for the profile to level out. The average slope from (A) was 1:8.7, and from (S) was 1:7.8.

In August the sediment was still being moved onshore by sand bars and steps. The profile, also during this, had a tendency to level out following a period of deposition. However, the profile for August 22, was not typical of the rest of the profiles for this month. The profile had risen by .5 m. It dropped 1.15 m, to the still water line, in a distance of 4.00 m. During this drop in height there were no steps, welded bars or ridge and runnel features present. Beneath the still water line, the profile continued for another 8.0 m, dropping a total of .58 m prior to reaching the formation of a step. Therefore, the profile dropped 1.73 m in a total 12.0 m distance without any depositional features. Its slope, therefore, was steeper than usual during this month for this station, and this will have an influence on the average slope results. The average slope from (A) was 1:8.7 and from (S) was 1:9.1. Here, it is noted that the slope from (S) was gentler than the slope from (A).

On November 2, there was an increase in profile height. This is an indication that deposition was still occurring at this time. The sediment was moved onto the beach by a series of bars. On November 9, the profile had lowered. This was probably a sign that the erosion of the beachface had begun. There were no bars present in the profile, but instead the sand was moved onshore by step features. The average slope from (A) was 1:7.3 and the average slope from (S) was 1:6.8.

The average slopes for Station 3 suggest that the profile became increasingly gentle in August. However, in November the profile once again bacame steep.

At <u>Station 4</u>, the profiles for July show the sediment being moved onshore by sand bars and steps. There was a lesser tendency for the profiles to level out following a depositional period. The average slope from (A) was 1:7.1 and from (S) was 1:6.1.

During August, the sediment was not only moved onshore by welded bars and steps, it was also moved onshore by ridge and runnel features. As at Station 3, the profile determined for August 22 was not typical of the other profiles for the month and station. This profile had risen by half a meter. It dropped 1.2 m, to the still water line over a distance of 3.4 m. Below the still water line, it dropped 0.2 m over a distance of 2.6 m, prior to forming a step. Its profile is very similar to the profile from Station 3 for this same date. The only real difference in in the distance covered by the profile. The profile has an effect upon the averages obtained for this month. The average slope from (A) was 1:8.1, and from (S) the average slope is 1:7.8.

On November 2, the profile for Station 4 was very different from what one would expect, judging from the profiles obtained at other stations. The slope from (A) for this profile is 1:1.8. This relates to a drop in elevation of 2.3 m in a distance of 3.0 m. In addition, the profile had risen 1.6 m since August. This compared to November 9, where the profile had lowered 1.5 m, and the average slope from (A) was 1:10.7, almost ten times more gentle. It can be seen, therefore, that the slope for (A) on November 2 greatly influenced the average slope. The sediment during November was moved on shore by a series of steps. These were larger than those generally found to have occurred in previous months. The average slope from (A) was 1:8.2 and from (S) was 1:13.6. The profiles of Station 4 generally became increasingly gentle thoughout the study period.

At <u>Station 5</u>, the July profiles indicate that the greatest amount of deposition occurred during this month. The movement of the sand onto the beach resulted in step, ridge and runnel features, and a few welded bar features. The slope calculated from (A) was 1:7.3, and from (S) 1:6.0. Therefore, the slope calculated from the average limit of the swash was steeper than the calculated slope from the maximum limit of the swash.

In August, the profiles were generally gentler and increasingly gradual, but August 20 and 22 were the exceptions to this relationship. The profiles of this month have fewer ridge and runnel features and more welded bar features. Also, with the exception of August 22 and 23, the water was shallower than it was in July. The average slope from (A) was 1:9.4 and from (S) was 1:10.5. Therefore, the slopes became increasingly gentle, and the slope from (S) was gentler than the slope from (A).

The profiles of the beach in November show welded bar and step features. The profile had lowered, indicating that the sediment was being removed from the beach face. The average slope from (A) was 1:1.9 and from (S) was 1:8.2. Therefore, slope (S) had remained gentler than the slope from (A).

### 4.21 THE ENVELOPING CURVES

The enveloping curves show the variations of the profiles over the study period time (Figures B2.0A to B2.0E). The amount of variation was relatively constant at Station 1 (Figure B2.0A). It varied approximately 1.0 m in height, and 6.5 m in length. At Station 2 (Figure B2.0B) the amount of variation increased in the region below the height of 0.0 m. Here it varied by about 1.0 m in height, but only 6.0 m in length. At Station 3 (Figure B2.0C) the top of the profile had the greatest amount of variability, and the least amount was in the region of 0.0 m. There is a variation of approximately 1.0 m in height, and a general variation of 2.0 m in length, however there was a maximum variation of 6.5 m in length. Station 4 (Figure B2.0D) had the least amount of variability. The general variation was in the order of approximately 20 to 25 cm in height, and 5 m in length. The variability of the profiles seemed to have decreased from Station 1 to Station 4. However, Station 5 (Figure B2.0E) showed the greatest amount of variability. At the top of the profile, the variability was in the order of 1.3 m, and by the time one reached 0.0 m it was of the order of 65 m. Finally, at the bottom the variability was as large as 90 cm. Stations 4 and 5 emphasize the effects of the storm waves. As the sediment got finer, the effects became more noticable in the profiles.

### 4.30 GRAIN SIZE CHARACTERISTICS

The statistics of the grain sizes for each station and sampling day are summarized in Tables C1.0 to C7.0. Refer to Tables C1.0 to C5.0 for the statistics for each sample, Table C6.0 for the average statistics for each month, and Table C7.0 for the final average statistics for each station.

Station 1 was composed of sediment which was similar in size to the sediment at Station 3. On July 16, the grain size distributions indicated that at least 43% of the sediment was coarser than very coarse sand (0.00 $\phi$). The coarse tail of the distribution was widely dispersed, wheras the fine tail had less dispersion. The distribution for July 24, showed an increase in linearity and a decrease in the dispersion of the coarse tail. At least 57% of the sediment was coarser than very coarse sand. The average median and mean grain size for July was coarse sand. The distribution was moderately sorted and negatively skewed.

The linearity of the distribution remained on August 20. Also, only 27% of the sediment was coarser than very coarse sand. Therefore, it had become finer than it was in July. On August 29, the sediment began to exhibit bimodal characteristics. At this time 47% was coarser than very coarse sand. The average median size was coarse sand, and the average mean size was very coarse sand. The sediment was moderately sorted, and negatively skewed.

On November 2, the sediment became increasingly bimodal, and at the same time had become increasingly dispersed. At least 49% of the sediment was coarser than very coarse sand. An increase in the bimodality occurred on November 9. At this time at least 57% of the sediment was coarser than very coarse sand. It had become coarser on November than it was in July and August. The average median and mean grain size was very coarse sand. The sediment was moderately sorted and positively skewed.

Station 2 was composed of coarser sediment than Station 1. The curves from July 16, indicated that at least 99% of the sediment sampled was coarser than very coarse sand. The distribution had little or no fine tail. Grain sizes coarser than pebble size composed the coarse tail of the distribution. The sediment sampled on July 24, was such that 95% it was coarser than very coarse sand. The sediment had became fairly linear. It had also developed a longer and less varying coarse tail. The average median and mean grain size for July was granuale size. The sediment was well sorted and negatively skewed.

On August 20, the sediment size distribution curves were related in a closer manner to one another than in July. At least 40% of the sediment was coarser than very coarse sand. Also, 60% of the sediment composed the coarse tail, and a small fine tail was present was well. The curve representing August 29, had shifted to the coarser sediment sizes. At least 92.5% of the sediment was coarser than very coarse sand. Therefore, the sediment was coarser at the end of the sampling period in August than it was at the beginning. The average median and mean grain size for August was very coarse sand. The sediment was well sorted and positively skewed.

The distribution of the sediment sampled on November 2, was very linear. The curves were quite close to one another, with a longer fine tail than in July and August. At least 87% of the sediment was coarser than very coarse sand. On November 9, the linearity had decreased, and at least 89% of the sediment was coarser than very coarse sand. The average median and mean grain size for November was granule size, as well. The sediment was well sorted and positively skewed.

Although Station 3 and Station 1 were composed of similar grain sizes, the distributions obtained for Station 3 on July 16 showed a concave pattern. Also, these graphs showed a uniform and close distribution. However, there was an increase in dispersion in the coarse and fine tails. At this time at least 46% of the sediment was coarser than very coarse sand. On July 24, there was an increase in bimodality. As well, only 41% of the sediment was coarser than very coarse sand. The average median grain size for

July was coarse sand, and the average mean was very coarse sand. The sediment was moderately sorted, and positively skewed.

The bimodality seemed to disappear on August 20. Also, as the bimodality decreased, the distribution became increasingly linear. The sediment was composed of finer material, at this time. This was shown by the distribution having only 27% of its sediment coarser than very coarse sand. On August 29, the sediment was once again composed of coarser material. At least 57% of the sediment is coarser than very coarse sand. As the sediment became increasingly coarse, it also became increasingly bimodal. The average median for August was coarse sand, and the average mean was also coarse sand. The sediment was moderately sorted and negatively skewed.

On November 2, the sediment had become finer once again. Only 38% of it was coarser than very coarse sand. As the sediment became finer, the concave pattern returns. This pattern was accompanied by small indications of bimodal characteristics. On November 9, there was an increase in the bimodality of the sediment. At this time 41% of it was coarser than very coarse sand. The average median and mean grain size for the month of November was coarse sand. The sediment was moderately sorted and positively skewed.

The sediment at Station 4, on July 16, also showed slight bimodal characteristics. On July 24, the bimodality bacame increasingly less. At least 51% of the sediment on July 16 was coarser than very coarse, whereas, only 41% of it on July 24 was coarser than very coarse sand. The average median and mean grain size for July was very coarse sand. The sediment was moderately sorted and positively skewed.

On August 20, there was an increase in the linearity of the distribution. This relationship holds true, except for two cases which showed bimodal characteristics. At least 40% of the sediment was coarser than very coarse sand. On August 29, at least 60% of it was coarser than very coarse sand. As the sediment became coarser, it developed bimodal characteristics. The average median and the aveage mean for August was very coarse sand. The sediment was moderately sorted, and negatively skewed.

The bimodal characteristic remained on November 2. At the same time there was a decrease in the dispersion of the sediment. Only 25% of it was coarser than very -coarse sand. On November 9, the sediment remained very bimodal, but had became much coarser. At this time at least 64% of it was coarser than very coarse sand. The average median and mean grain size for November was very coarse sand. The sediment had remained moderately sorted and had become positively skewed.

On July 16, the sediment samples from Station 5 had a grain size distribution which was slightly bimodal. At least 82% of the sediment was coarser than very coarse sand. The curves contain little dispersion. The curves representing July 24, showed that at least 19.5% of the sediment was coarser than very coarse sand. It had become very much finer than at the beginning of the sample period for July. This distribution also showed an increase in linearity. The average median and mean grain size for July was coarse sand. The sediment was moderately sorted and negatively skewed.

The distribution curves for August 20, had such a small dispersion that the curves almost formed one line. At least 10% of the sediment was coarser than very coarse sand. On August 29, the bimodal nature of the sediment became more apparent. At least 38% of the it was coarser than very coarse sand. The average medium and mean grain size for the sediment was medium sand. It was moderately sorted, and was negatively skewed.

On November 2, the sediment had become extremely bimodal. At least 54% was coarser than very coarse sand. Therefore, it looked as if the finer portion of the distribution was getting finer, while the coarser portion of the distribution was getting coarser. On November 9, the sediment maintained a bimodal characteristic. At least 45% was coarser than very coarse sand. The average median and mean grain size for November was coarse sand. The sediment was moderately sorted and negatively skewed.

**4.31 GRAPHS RELATED TO THE GRAIN SIZE CHARACTERISTICS**

As mentioned earlier, the average mean for the five sediment samples was graphed against the middle sample of the five (C), in order to see if taking only one was justifiable (Figure B3.0). The plot indicated that in most cases there was a deviation from the 1:1 line. There are only 4-5 plots which fell within a significent distance of this line. It could therefore be determined that using the average of several samples is better than using just one sample. If only one sample was used there would be a decrease in the accuracy of one's results and interpratations. As a result, there was a possibility of a decrease in the accuracy of the interpretation of the samples collected on the last day of each study period of each month. However, it was expected that the errors which developed would not affect the results to any great extent, for the plots did surround the 1:1 line even though they did not fall on it.

Secondly, the mean grain size was plotted against the standard deviation (sorting) (Figures B4.0A to B4.0F). The plot indicated that as the mean grain size increased from -2.00$\phi$ to 1.00$\phi$ the sample became less sorted (0.30$\phi$ to 1.80$\phi$). However, once the mean grain size was greater than 1.00$\phi$, the sorting once again improved. Stations 1 and 4 showed the least variability in the mean grain sizes and the sorting (Figures B4.0B to B4.0E). However, Station 5 (Figure B4.0F) showed the greatest variability in the mean grain sizes and the sorting of the sediment.

**4.40 WAVE HEIGHT OBSERVATIONS**

After the wave heights were obtained, they were plotted on a bar graph which showed the frequency of occurance for wave heights ranging from 0.0 cm to 100 cm (Figure B5.0 A). The general plot indicated a bimodal distribution, with one mode at 5 cm and the other mode at 75 cm. Since the mode of 5 cm is the greatest mode, another plot was drawn up ranging from 0.0 cm to 20 cm (Figure B5.0B). Once again, the distribution appeared to be bimodal, with one mode occurring at 3 cm and the second at 10 cm. Therefore, the study area was mainly affected by wave heights which were less than 20 cm. Also, of these waves the ones which occurred most often were only 3 cm high, thereby emphasizing that this beach is a low-energy beach.

When Stations 1 to 5 were graphed individually, some interesting results occurred. The distribution of the plots ranging from 0.0 cm to 100.0 cm, for all of the stations, was positively skewed. Stations 1, 2 and 5 had a mode of 5 cm, and Stations 3 and 4 had a mode of 10 cm. The plots ranging from 0.0 cm to 20.0 cm showed a bimodal distribution for Stations 1, 4 and 5. Station 1 attained a mode at the wave heights of 4 cm and 8 cm. The modes which were attained for Station 4 were approximately 3 cm and 10 cm, and for Station 5 the modes were 5 cm and 10 cm. However, at Stations 2 and 3 (Figures B6.0A and B6.0B) there was such a regularity to the distributions that a determination of the mode and type of distribution could not be done. At Station 2 the wave heights of 1, 3, 5, 6, and 9 cm occurred approximately 11.8% of the time. The wave heights of 2, 10 to 13, 15, and 20 cm all occurred approximately 5.9% of the time. The other wave heights did not occur at all during the sampling time. At Station 3 the wave heights of 2, 3, 6, 8, and 12 cm all occurred approximately 11.8% of the time. Also, the wave heights of 7, 9, 11, 13, 15, 16 and 20 all occurred 5.9% of the time. It is interesting to note the regularity of the distribution, and the fact that at both stations the percentage of time for their occurance happens to be the same, although the wave heights occurring may not be the same.

## 4.5 FORMATIONS CHARACTERISTIC OF THE STUDY AREA

As noted above, the profiles obtained in July and August indicated a period of accretion. Sediment appeared to be moving onshore and the berm grew lakeward. November was the beginning of the erosion period. This was indicated by an increase of sediment offshore beneath the still water line. These findings agree with those found by Weishar and Wood (1983) in a study of a beach on Lake Michigan.

Cusps appeared at every station at least once during the sampling period. In July and August the forms were generally quite small and were usually created and destroyed in the same day. (Figures A1.0, A3.0, A4.0, A6.0, A9.0, A12.0 and A13.0) However, in November, these features appeared at a much larger scale and were susually found much further landward than those which formed during the summer, indicating that they existed for longer than a 24 hour period. This is further emphasized at Stations 4 and 5 where relict cusps were found landward and at the same time new cusps were being formed (Figures A10.0, A14.0 and A15.0). The coarsening upward sequence mentioned by Chafetz and Kocurek (1981) was also noted to occur. It was especially noticable in November at Stations 4 and 5. It is felt that this coarsening upward sequence was due to the vertical growth of the forms since no lateral migration was noted. Also, when these formations occurred, it was apparent that the completion of the backwash could not occur, prior to the next swash motion, because it was interferred with (Figures A3.0, A4.0, and A6.0). These observations agree with those of Kemp (1961).

Finally, ridge and runnel features were also found on the study site. As in the case of the cuspate features, these formations were generally small in the summer. However, at Stations 1 and 2 during November, the formations were large and dominated the beach (Figures A2.0 and A5.0). At the time which they were being observed, they had no welded themselves onto the beach. Also, the landward edge did not have the steeper slope as was indicated by Davis et. al., (1972). These features were symetrical, as shown in the figures.

**4.60 SUMMARY**

Table C8.0 is a summary table of the overall average slopes and the overall grain size characteristics, for each station. The significance of the information contained in the table will be discussed in the Chapter Five.

The first comparison was made by graphing the median grain size against the two slopes (Figure 2.0). Two points of interest were noted about this relationship. First of all, Station 2 and Station 5 were the maximum and minimum limits of this result respectively. The foreshore zone which had the greatest amount of exposure was station 2, and the foreshore zone with greatest amount protection was

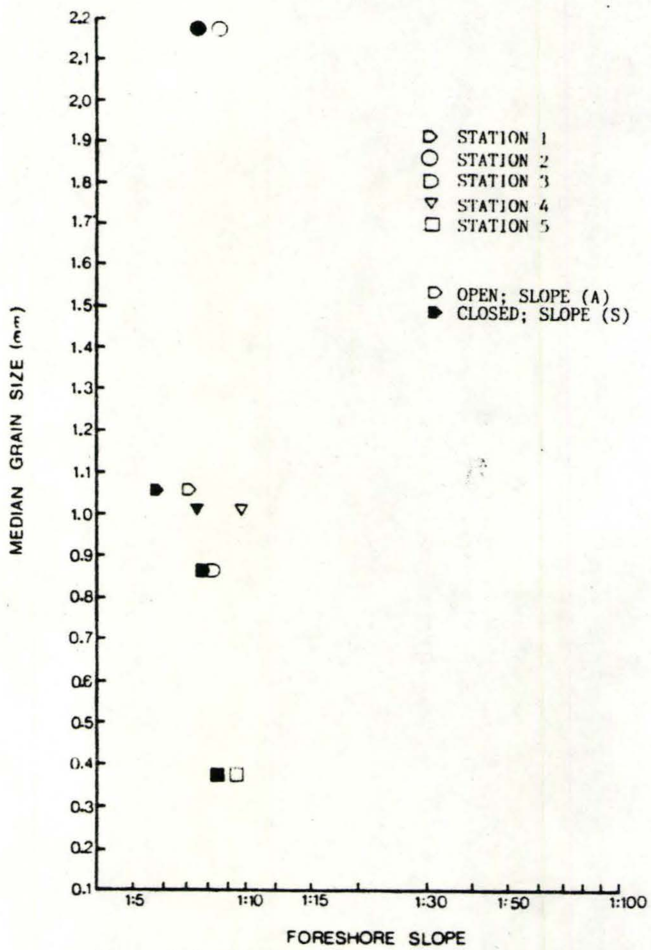



Figure 2.0: The foreshore slope plotted against the median grain size.

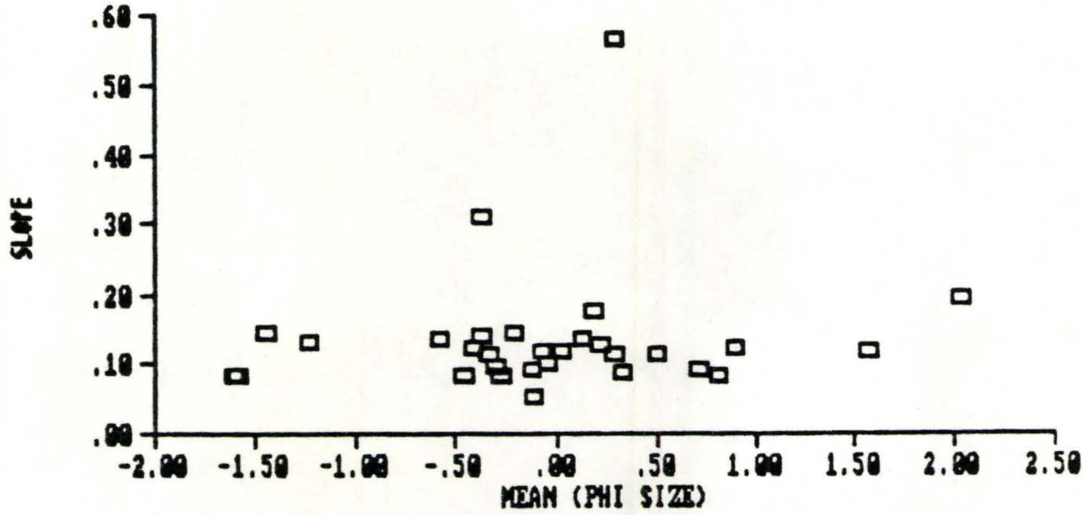
→ Bad x axis 1:5 to 1:15.

Station 5. Secondly, Stations 1, 3, and 4 all plotted in the same area of the graph. However, Station 1 plotted higher on the graph than Station 4, and Station 4 higher than Station 3.

The mean grain size was plotted against both slopes. In the case of slope (A) (Figure 3.0A), the slope rarely got above .20 no matter what the mean grain size was. Also, the slope (S) (Figure 3.0B) was rarely steeper than .30, no matter what the mean grain size was. Therefore, there appeared to be no relationship between the mean grain size and the slope. However, the plot for slope (S) seemed to have a greater amount of variability, thereby indicating that what ever the effect the mean grain size had on the slope, it affected slope (S) more so than slope (A).

Thirdly, the slopes were graphed against the wave heights (Figures 4.0A and 4.0B). In the case of slope (A), the majority of the slopes were clustered below 0.2, and were affected by wave heights which were less than 50 cm. However, if the wave height was greater than 50 cm, the slope seemed to steepen slightly. The plot for slope (S) showed an increase in scatter. If the wave heights were less than 50 cm the slopes generally remained below 0.3. However, it is noted that if the wave heights were greater than 50 cm, the same scatter pattern will occur here as it did for slope (A). Therefore, the greater wave height

A




B

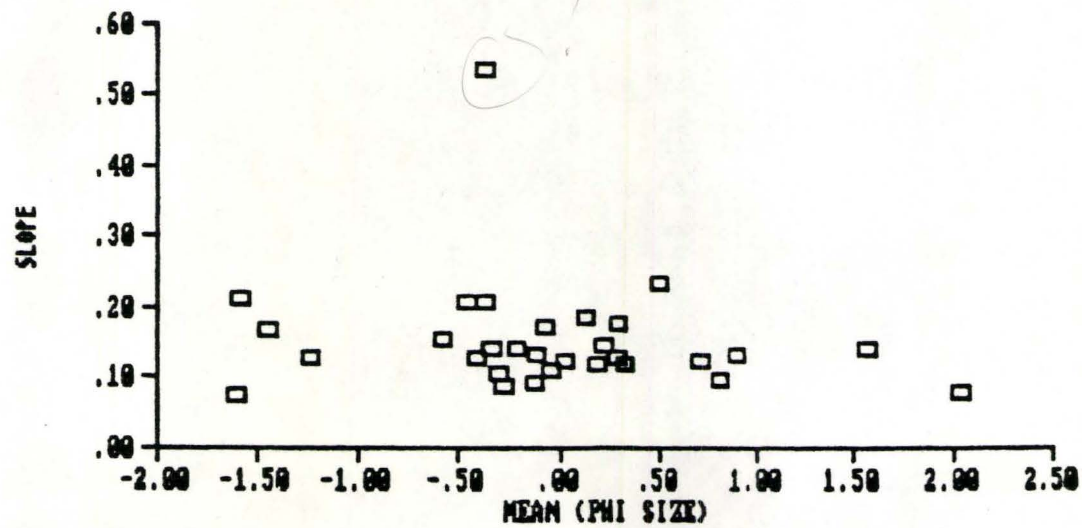
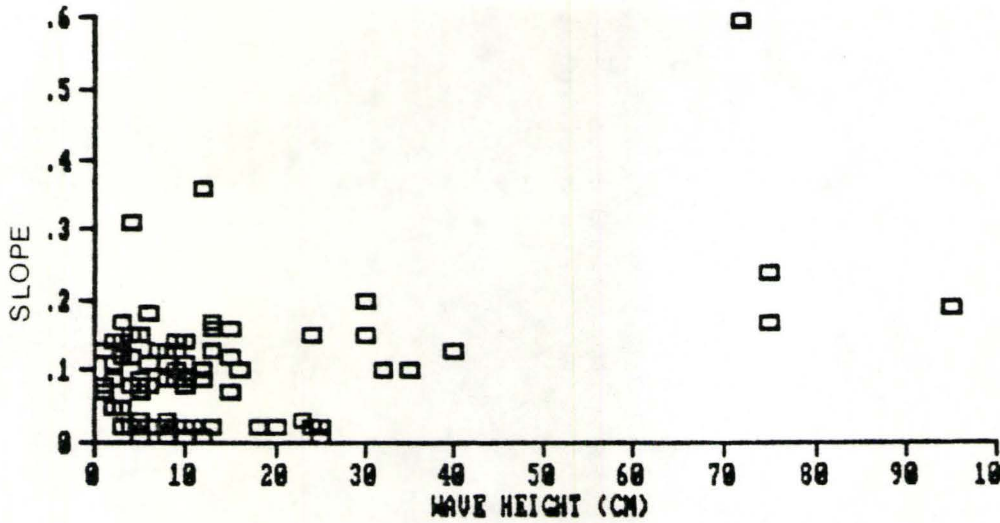



Figure 3.0: The relationship between the mean grain size and the slope for: A) Slope (A); and B) Slope (S).

Cut y axis

A




B

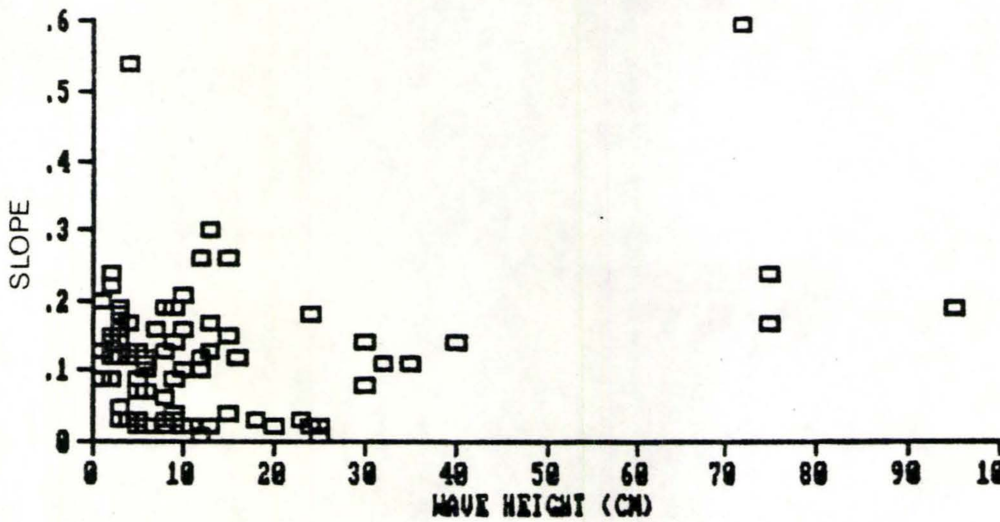



Figure 4.0: The relationship between the wave height and the slope for: A) Slope (A); and B) Slope (S).

affected both slopes in the same manner, but the smaller waves seemed to affect slope (S) to a greater extent.

# CHAPTER FIVE

# CONCLUSIONS

## 5.10 CONCLUSIONS

The above results led to interesting and unexpected relationships between the variables tested. the changes which occur throughout the study site are on a small scale. However, these are reflected in the slopes of the beach.

First, the variations in the slopes and grain size characteristics occurred at each station (Table C8.0). Station 1 was located between two groins, and as a result had a greater amount of protection from wave energy than Station 2. The (S) and (A) slopes at Station 1 became gentler during the summer months. This was due to a build up of the beach. Further evidence of this comes from the mean and median grain sizes, which remained the same throughout July and August. If erosion had occurred the finer sediment would have been removed, resulting in a coarser mean and median grain size. This is what happened in November. As well, slope (A) became quite gentle (1:15.4) which shows a widening of the beach seaward as sediment is removed. The coarse sediment which remained was reworked into a series of ridge and runnel formations (Figure A2.0). This same relationship occurred at Stations 2, 4 and 5. The lag sediment was reworked as a ridge and runnel formation, at Station 2, and as a cusp formation at

Stations 4 and 5 (Figures A5.0, A10.0, A14.0 and A15.0).

The figure illustrating Station 5 in November shows clearly that the finer sediment has been eroded from the shore. However, slope (A) was steeper due to an extension of the beach seaward, rather than the presence of a coarser sediment size.

In November at Station 3, instead of a gentle slope, there was a steepening of both the (S) and (A) slopes. As well, the mean and medium grain sizes became finer in August but remained the same in November. On November 2 the profile had risen in height, which suggests that the sediment is still being deposited, whereas on November 9 the profile was lowered and extended further into the water suggesting the beginning of an erosion period. Therefore, although the pattern which occurred at the other four stations had not developed at Station 3 at this time, the results for November 9 indicate that such a pattern was starting to develop. The delay in the occurance of the pattern is due to the location of the station; it is protected to a greater extent than Stations 1, 2, and 4, and not affected by extra currents as in the case of Station 5.

Secondly, there was no apparent relation between the slopes and the grain size characteristics (Table C8.0). Station 1 had the steepest slope, but did not have the coarsest grain size, or the best sorting. Its steeper slope is due to its location between the groins. Here Station 1 is more protected from the amount of wave energy affecting the foreshore, thereby resulting in a steeper slope. Station 2 had the coarsest deposit and the best sorting, however it did not have the steepest slope. The station with the steepest (S) slope was Station 4, and the station with the steepest (A) slope was Station 3. The gentlest slopes occurred at Station 5, which had the same mean grain size (coarse sand) as Station 3.

Both slopes were graphed against the mean grain size (Figures 3.0A and 3.0B). This illustrates that no clear relationship between the two variables exists. Although the mean grain size affected slope (S) more so than slope (A), the slopes remained below 0.20 or 0.30 no matter what the mean grain size was. When the slopes were graphed against the median grain size (Figure 2.0), it was determined that no relationship could be found. Therefore, there is no relationship between the size of the sediment which was deposited on the beach, and the slope which formed.

Figures B4.0A to B4.0F illustrate that there is a relationship between the mean grain size and the sorting. The close relationship between the mean grain size and the sorting of the sediment suggests that a relationship which exists between the slopes and the mean grain size reflects a relationship between the slopes and the sorting of the sediment. Since, there was no relationship between the mean grain size and the slopes, there is no clear relationship between the sorting of the sediment and the slopes. This is also suggested at Station 2 which had the best sorted sediment of all five stations, but did not have the steepest slope. Therefore, it can be concluded that no clear relationship exists between the resulting slopes and the grain size characteristics.

Thirdly, the slopes could be affected by the amount of wave energy to which they are exposed. The enveloping curves for each station (Figures B2.0A to B2.0E)indicate the different rates of variability of the slopes. The variability decreased from Station 2 to Station 4, it was similar between Stations 1 and 3, but increased at Station 5. These curves indicate that the beach became increasingly protected from wave energy, except for Station 5 which suggests that it is affected by something other than wave energy.

The shape of the coast line indicates that the protection from the wave energy affecting the foreshore should increase from Station 1 to Station 5. The steeper slopes should be those with the most protection. However, Station 5 had the gentlest slopes but it should have attained steeper slopes (Table C8.0). The protection of a slope and its effects is best shown at Station 1. The sediment was moderately sorted, very coarse sand, yet it attained the steepest slopes. Its location between the two groins increased the protection from wave energy. If Stations 3 and 4 are more protected than Station 2, the slopes of Stations 3 and 4 should be steeper. This is in fact what did occur. However, when Station 4 attained the steepest (S) slope, it did not attain the steepest (A) slope, Station 3 did.

The effect of wave energy on the foreshore slope is also reflected by the relationship between the wave heights and the slopes shown in Figures 4.0A and 4.0B. There is a clustering of points below the 20 cm wave height. However, once the waves got larger than 30 cm a small relationship did begin to develop. The clustering at the bottom of the figures illustrates a weak relationship. The weakness of the relationship would also explain why Station 5 did not follow the pattern and become steeper than Stations 3 and 4.

There are, therefore, three regions to this beach. The first is Station 1, which is controlled by the protection it receives from the wave energy by the groins. Secondly, there is the region containing Stations 2, 3, and 4 which is not only affected by the amount of exposure to the wave energy, but is also affected to some extent by the grain size characteristics. Thirdly, there is Station 5, which was dominantly affected by the grain size characteristics of the deposited sediment.

The above conclusions are quite different from what has been found by most researchers in the past. The weakness of the relationships found in this study indicates that improvements could be made on the conclusions through further research. First, it would be advantageous to determine the period of the waves which affect the foreshore. This will enable the calculation of the energy available to affect the beach. In this paper it was assumed that the wave height represented the amount of wave energy. This assumption could have resulted in the indication of a weak relationship between the foreshore slope and the amount of energy affecting it.

Secondly, Figure B3.0 indicated that taking only one sediment sample is not representative of the sediment which has been deposited on the beach. In this study only one sample was taken on the last sampling day of each month, and this could have led to errors in the interpretation of the effect of the grain size on the foreshore slope. It would therefore be appropriate to take several samples and average them. Also, it would be advantageous to take samples several times throughout the study period, enabling a better interpretation of the changes in the foreshore. In this study there were no samples collected between the first and last day of each sampling period of each month. This could have led to a misinterpretation of the grain sizes for each month, resulting in the weak relationship found to exist between the grain size characteristics and the foreshore slope.

This study, however, emphasizes that the relationships between the foreshore slope, grain size characteristics and wave heights are not fully understood. It is often considered acceptable to assume that the same relationship which occurs on tidal coasts also occur on non-tidal coasts. This study emphasizes that the relationships are not as clear on a non-tidal coast. Also, it is possible that there may be other factors which could affect the variables on a non-tidal coast, but which may be considered irrelevant on tidal coasts. It is felt, therefore, that further research is required on the characteristics of a non-tidal coast. The lack of literature on this emphasizes the need for further understanding of the interrelationships of aspects on non-tidal coasts.

Cusps? l.c.



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# APPENDIX A

Figure A1.0: Station 1, taken July 16. Note the cusp formations, and the distribution of the coarsest sediment.

Figure A2.0: Station 1, taken November 2. This figure shows the size of the ridge and runnel formations which occurred.

STA 1 (1).

Figures A3.0 and A4.0: Station 2, taken July 18. These figures show the cuspate formations and the incomplete backwash which causes them to form.

STAT 2

Figure A5.0: Station 2, taken November 2. This figure shows the ridge and runnel formation which was prominent at this station during this month.

Figure A6.0: Station 3, taken July 18. This figure shows the incomplete backwash which accompanies the cusps.

Figure A7.0: Station 3, taken November 2. This figure shows the distribution and the type of sediment.

STAT 3

Figure A8.0: Station 3, November 9. This figure shows the finer sediment on the upper part of the beach.

Figure A9.0: Station 4, taken July 16. This shows the distribution of the sediment at this station.

Figure A10.0: Station 4, taken November 2. This figure shows the large cusp formations.

STAT 4

Figure A11.0: Station 4, taken November 9. This figure shows the distribution of the sediment and the wave enegy level for this month.

Figure A12.0: Station 5, July 16. This figure shows the wave energy level which was typical for this station.

Figure A13.0: Station 5, July 18. This figure shows the distribution of the sediment.

STAT 5

Figure A14.0: Station 5, taken November 2. This figure shows the size of the cusps at this time, and the type of sediment of which they are formed.

Figure A15.0: Station 5, November 9. This figure shows the large cusp features.

# APPENDIX B

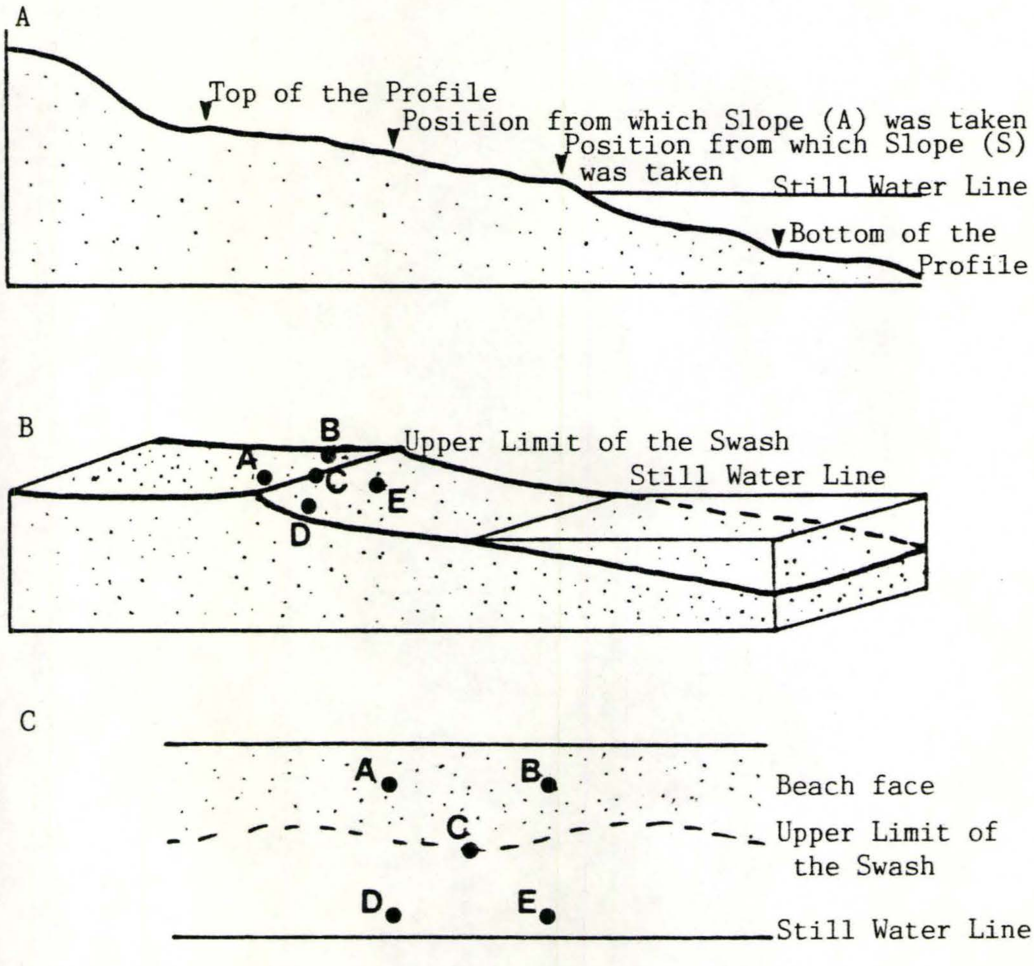



Figure B1.0: These figures demonstrate the method of sampling where: A) illustrates the maximum and minimum limits of the profiles, and from where the two slopes were calculated; B) shows a three-dimensional view of the location of the sediment samples collected in the feild; and, C) shows the plan view of the position of the sediment samples on the beach.

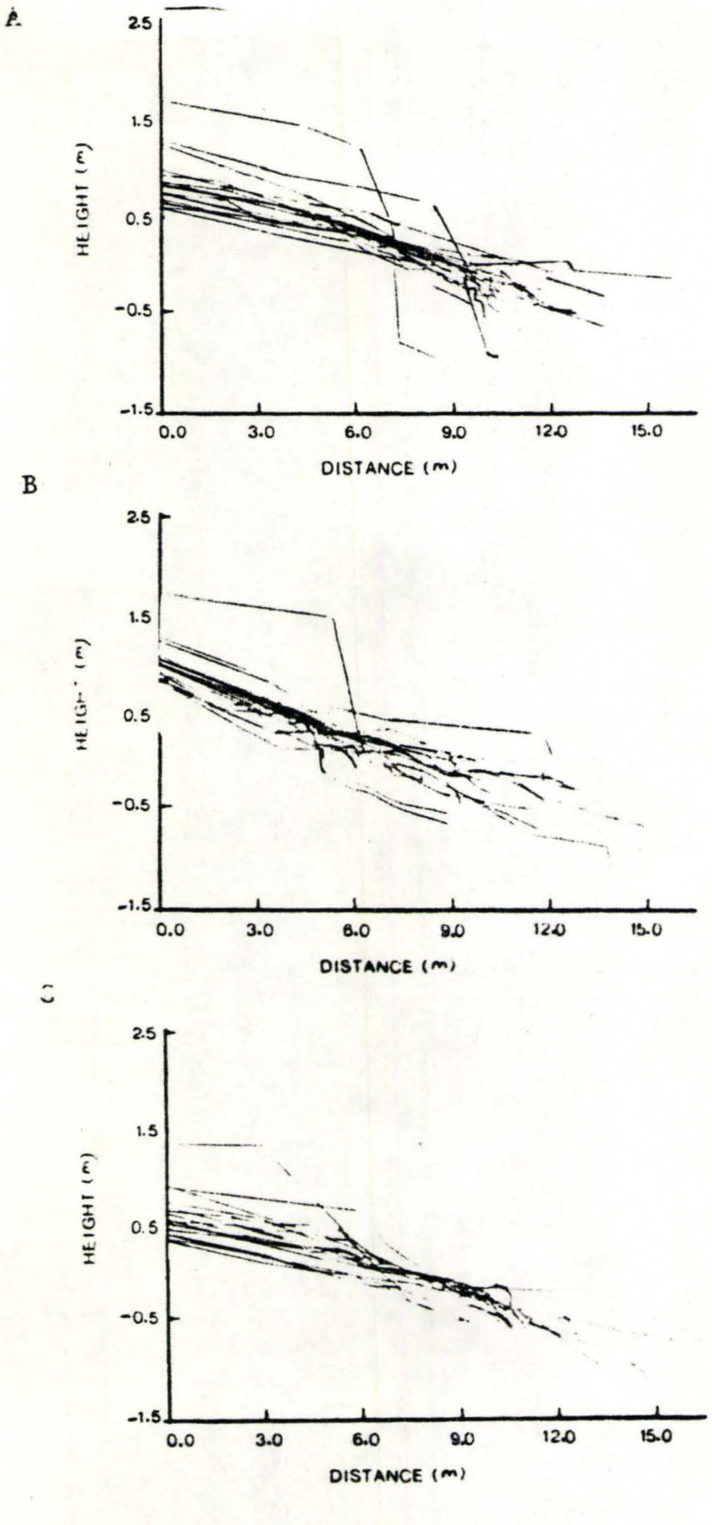
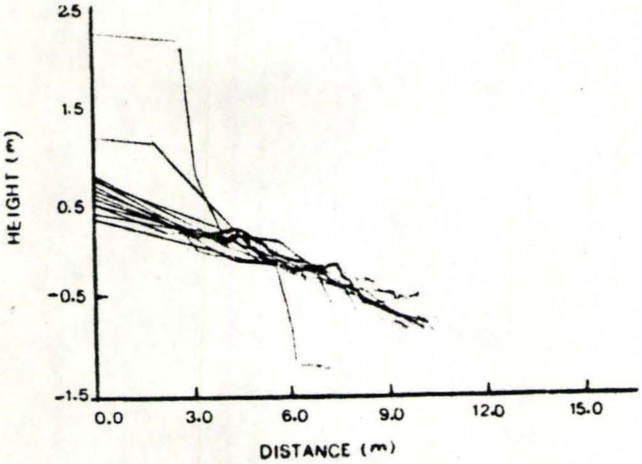



Figure 3.0: Enveloping for: A) Station 1;
B) Station 2; and C) Station 3.

D




E

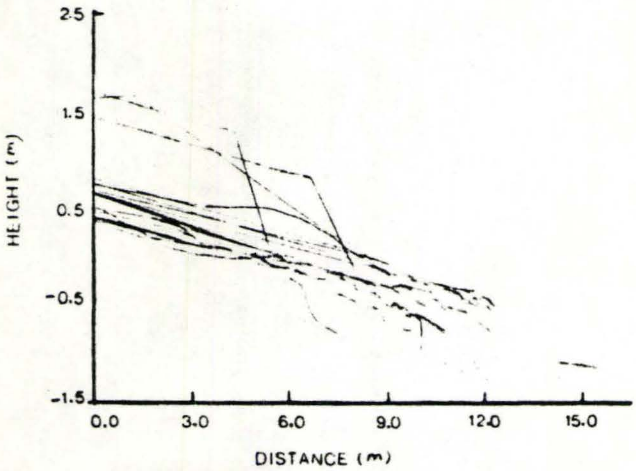



Figure 3.0 Con't: Enveloping for: D) Stat on 4; E) Station 5.

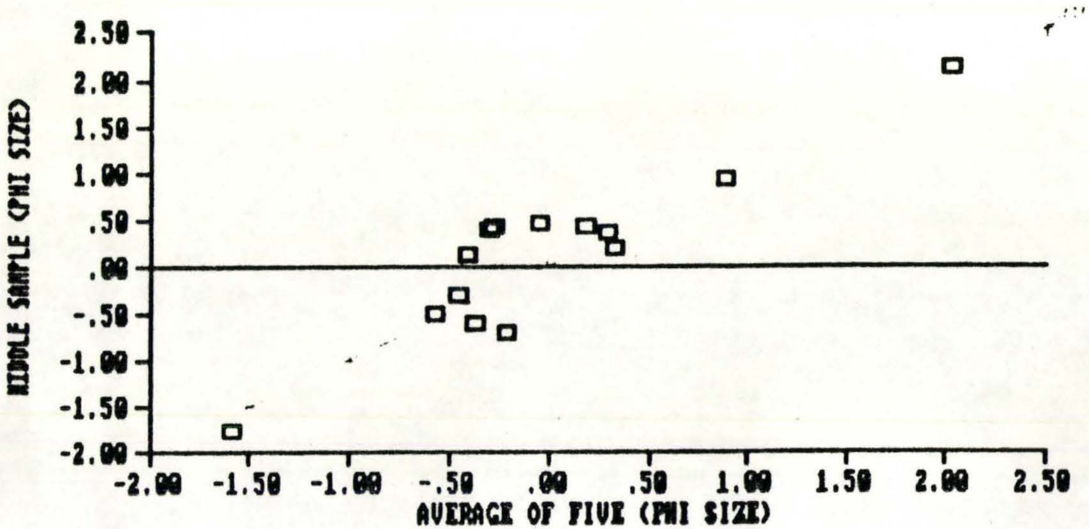



Figure B3 .0: The average of the five sediment samples from the first sampling day plotted against the middle sample (C) from the last sampling day. This graph illustrates that the middle sample is not representative of the sediment at that time.

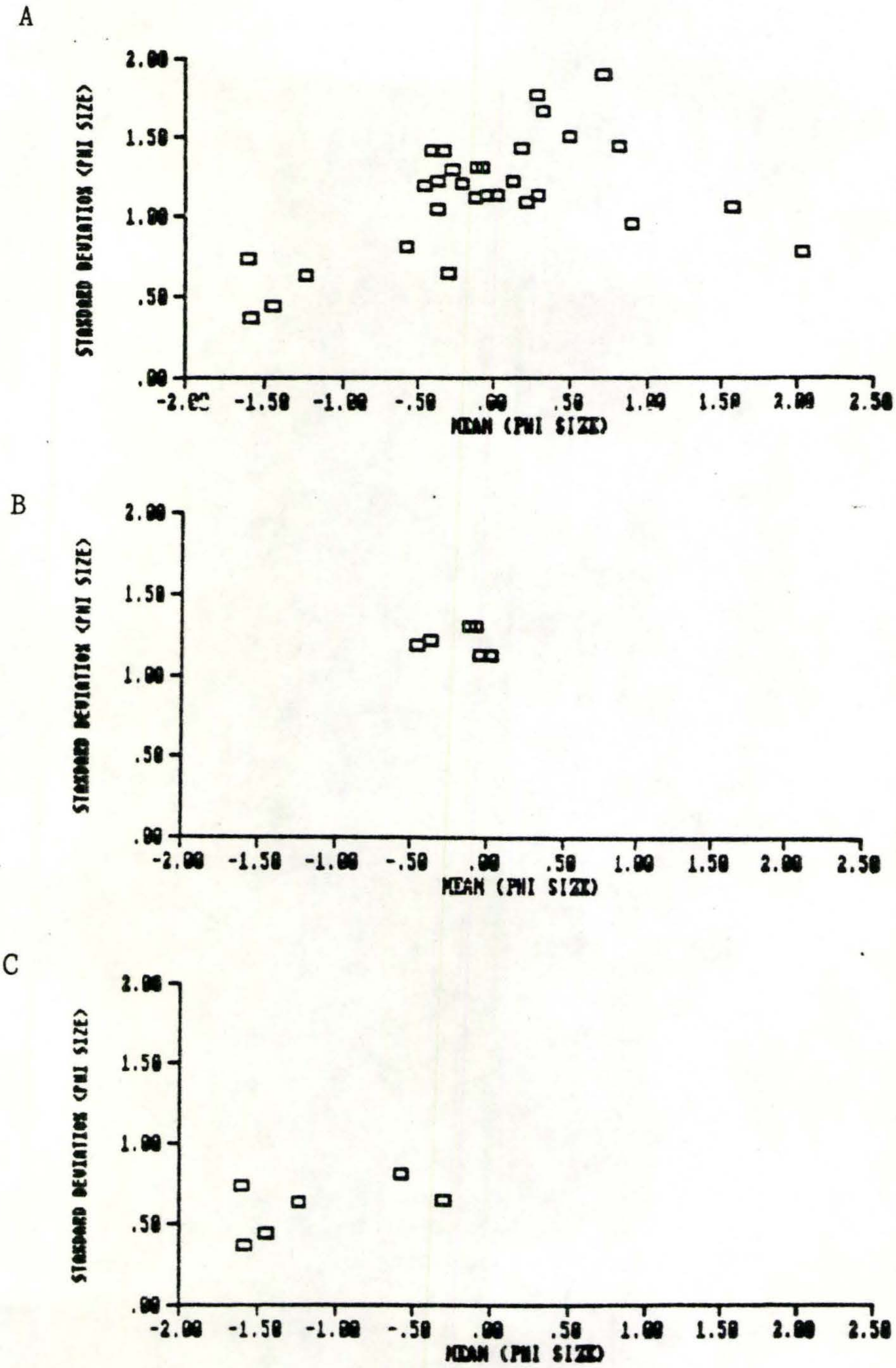



Figure B4.0: The mean grain size plotted against the sorting for: A) All stations; B) Station 1: and C) Station 2.

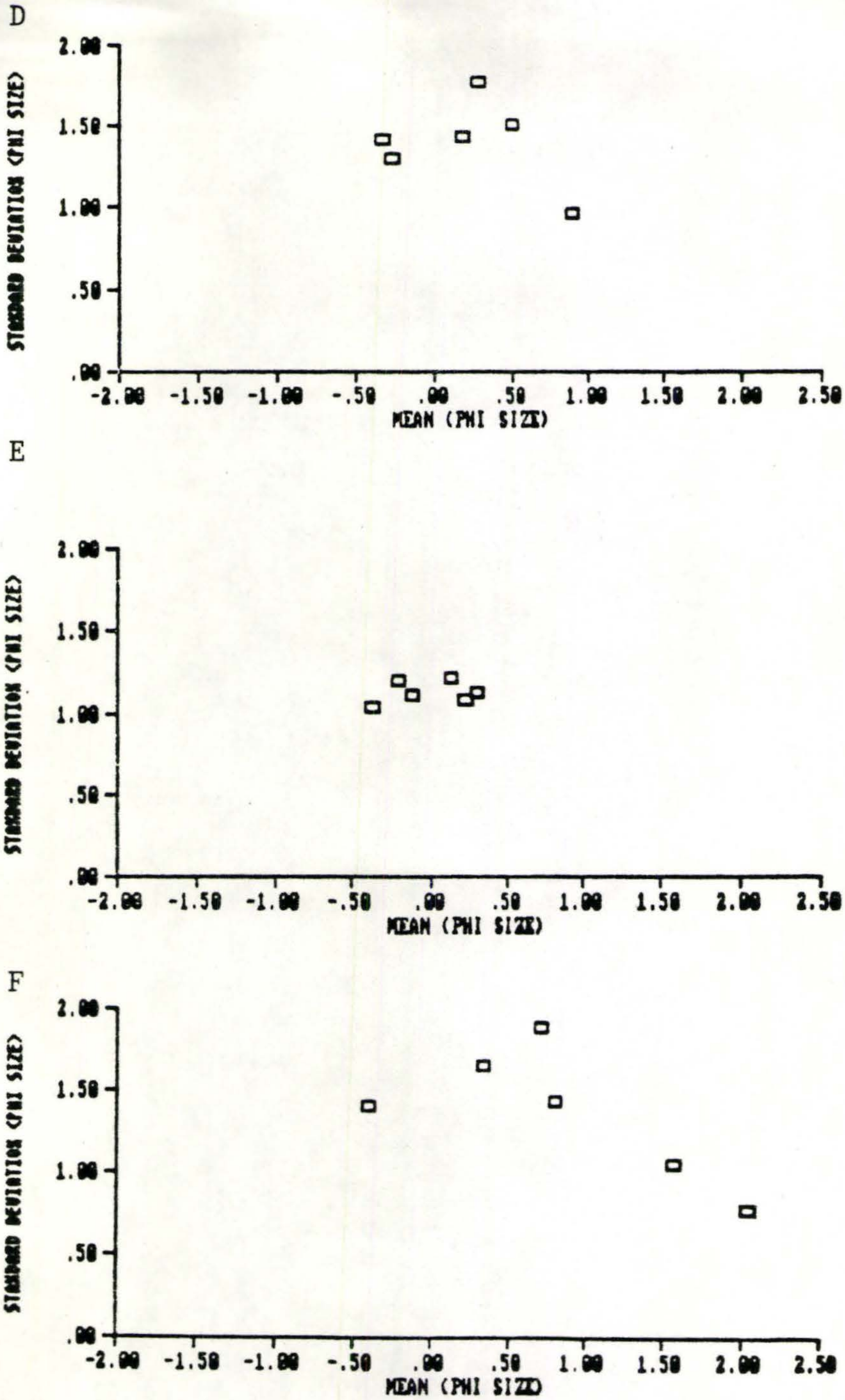
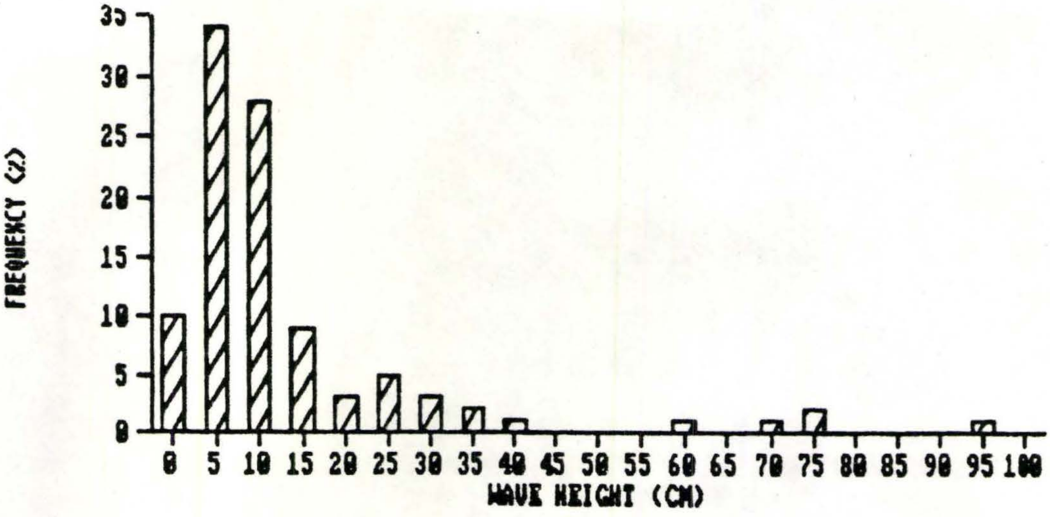



Figure B4.0 Con't: The mean grain size plotted against the sorting for : D) Station 3; E) Station 4; and F) Station 5.

A




B

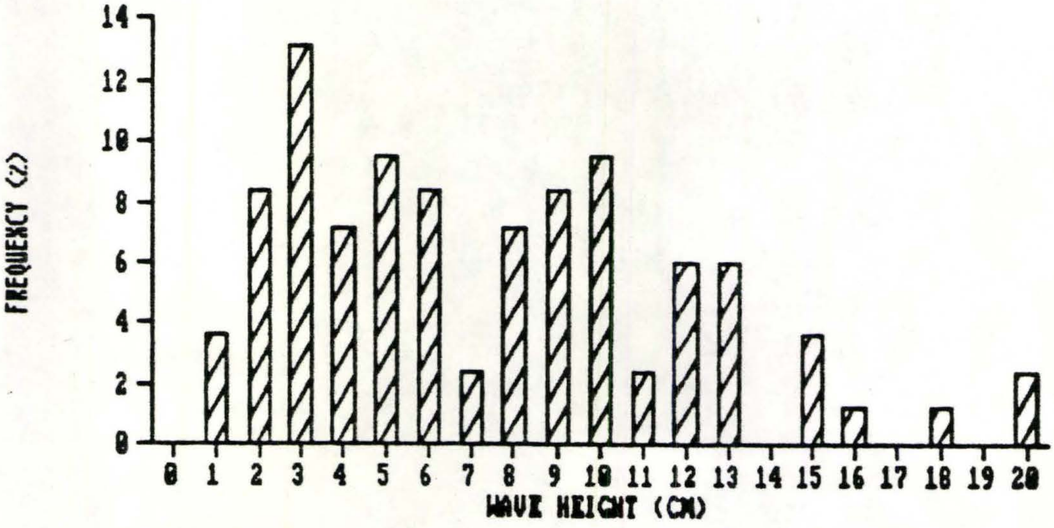
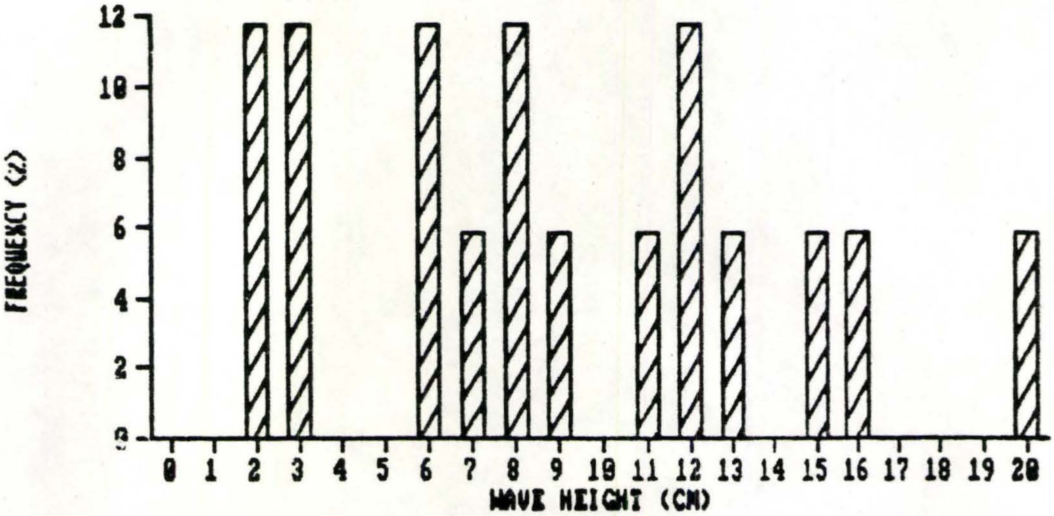



Figure B5.0: The frequency of wave height occurrence at the study site, where: A) is the total number of waves for the entire study period; and B) is a graph of the waves which appear to affect the area the most.

A




B

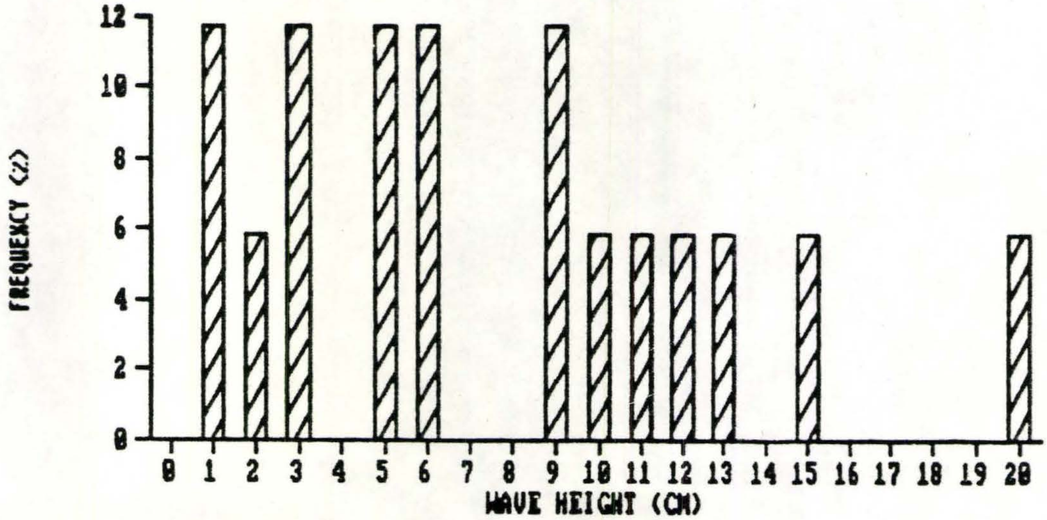



Figure B6.0: A graph of the wave height frequencies, showing the regularity surrounding the mode at: A) Station 2; and B) Station 3.

# APPENDIX C

Table C1.0

GRAIN SIZE CHARACTERISTICS
1986

STATION ONE

| | JULY 16 | | | | | | JULY 24 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | .438 | -.688 | -.413 | .313 | -.250 | -.120 | .250 |
| MEAN | -.004 | -.613 | -.596 | -.108 | -.533 | -.371 | -.074 |
| SORTING | 1.258 | 1.053 | 1.596 | 1.237 | .956 | 1.220 | 1.313 |
| SKEWNESS | -.421 | .929 | -.201 | .176 | .517 | .200 | -.336 |
| KURTOSIS | .830 | .308 | .830 | .305 | .308 | .516 | -4.780 |

| | AUGUST 20 | | | | | | AUGUST 29 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | .600 | .500 | .725 | -.938 | -.588 | .060 | .125 |
| MEAN | .253 | .296 | .442 | -.729 | -.496 | -.047 | .021 |
| SORTING | 1.041 | 1.204 | 1.317 | 1.054 | 1.066 | 1.136 | 1.142 |
| SKEWNESS | .032 | -.267 | -.345 | .249 | .142 | -.038 | -.137 |
| KURTOSIS | .442 | 1.039 | 1.172 | .967 | .875 | .899 | .767 |

| | NOVEMBER 02 | | | | | | NOVEMBER 09 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | -1.438 | -.938 | -.625 | -.250 | .025 | -.645 | -.225 |
| MEAN | -1.400 | -.879 | -.296 | -.067 | .358 | -.457 | -.117 |
| SORTING | .836 | 1.050 | 1.249 | 1.491 | 1.356 | 1.196 | 1.310 |
| SKEWNESS | .111 | .126 | .331 | .080 | .292 | .188 | .063 |
| KURTOSIS | 1.235 | 1.757 | 1.033 | 1.053 | 1.171 | 1.250 | 1.010 |

Table C2.0
Grain Size Characteristics
1986

STATION TWO

| | JULY 16 | | | | | | JULY 24 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | -2.478 | -2.363 | -1.375 | -1.750 | -1.250 | -1.843 | -1.525 |
| MEAN | -1.276 | -2.346 | -1.767 | -.750 | -1.792 | -1.586 | -1.446 |
| SORTING | -.451 | .648 | .704 | -.087 | 1.042 | .371 | .444 |
| SKEWNESS | -4.140 | 21.422 | -13.454 | 4.500 | 2.100 | 2.086 | -23.641 |
| KURTOSIS | -.120 | .032 | -.019 | .030 | .145 | .014 | -.028 |

| | AUGUST 20 | | | | | | AUGUST 29 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | .063 | -1.563 | .250 | -.288 | -.288 | -.365 | -.938 |
| MEAN | -.325 | -.333 | .379 | -.654 | -.596 | -.306 | -1.234 |
| SORTING | .767 | .283 | .421 | 1.050 | .717 | .648 | .631 |
| SKEWNESS | .201 | 5.443 | .528 | .573 | .660 | 1.481 | 9.700 |
| KURTOSIS | .328 | 1.462 | .193 | .257 | .222 | .492 | .034 |

| | NOVEMBER 02 | | | | | | NOVEMBER 09 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | -.875 | -1.000 | -.538 | -.313 | -.250 | -.595 | -1.475 |
| MEAN | -.825 | -.988 | -.509 | -.296 | -.275 | -.578 | -1.600 |
| SORTING | .998 | .796 | .840 | .761 | .675 | .814 | .741 |
| SKEWNESS | .002 | .073 | .002 | -.101 | -.102 | -.025 | 8.280 |
| KURTOSIS | .797 | 1.186 | .923 | 1.147 | .966 | 1.004 | .042 |

Table C3.0
Grain Size Characteristics
1986

STATION THREE

| | JULY 16 | | | | | | JULY 24 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | -.688 | .188 | -.250 | .000 | -.344 | -.219 | .375 |
| MEAN | -.817 | -.125 | .438 | -.325 | -.573 | -.280 | .283 |
| SORTING | 1.606 | 1.292 | .703 | 1.175 | 1.724 | 1.300 | 1.772 |
| SKEWNESS | .780 | .293 | 1.281 | .362 | -.152 | .513 | -.164 |
| KURTOSIS | .209 | .367 | .198 | .361 | .791 | .385 | .934 |

| | AUGUST 20 | | | | | | AUGUST 29 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | 1.625 | .563 | .888 | .888 | .500 | .893 | -.313 |
| MEAN | 1.604 | .521 | .913 | .971 | .458 | .894 | .291 |
| SORTING | .721 | 1.199 | .851 | .808 | 1.215 | .959 | .941 |
| SKEWNESS | -.050 | -.159 | -.103 | .071 | -.188 | -.086 | .718 |
| KURTOSIS | .978 | 1.449 | 1.147 | 1.070 | 1.344 | 1.198 | .757 |

| | NOVEMBER 02 | | | | | | NOVEMBER 09 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | -.088 | .563 | .375 | .250 | .063 | .233 | .313 |
| MEAN | -.009 | .329 | .417 | -.033 | .208 | .182 | .496 |
| SORTING | 1.358 | 1.232 | 1.357 | 1.607 | 1.610 | 1.433 | 1.501 |
| SKEWNESS | -.003 | .168 | -.071 | -.165 | .018 | -.011 | .180 |
| KURTOSIS | .899 | .481 | 1.010 | 1.017 | 1.005 | .883 | .910 |

Table C4.0
Grain Size Characteristics

1986

STATION FOUR

| | JULY 16 | | | | | | JULY 24 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | .000 | -.125 | -.375 | -.188 | -.125 | -.163 | .175 |
| MEAN | -.325 | -.354 | -.592 | -.333 | -.262 | -.373 | .217 |
| SORTING | .931 | 1.296 | .671 | 1.291 | 1.066 | 1.051 | 1.090 |
| SKEWNESS | .324 | -.247 | .684 | -.187 | -.253 | .064 | .063 |
| KURTOSIS | .341 | 1.109 | .388 | 1.135 | 1.456 | .886 | 1.261 |

| | AUGUST 20 | | | | | | AUGUST 29 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | .163 | .163 | -.588 | -.563 | -.125 | -.190 | .125 |
| MEAN | -.342 | .054 | -.717 | -.429 | .362 | -.214 | .125 |
| SORTING | 1.128 | 1.010 | 1.153 | 1.283 | 1.460 | 1.207 | 1.218 |
| SKEWNESS | .188 | -.209 | -.130 | .149 | .351 | .070 | -.071 |
| KURTOSIS | .401 | 1.491 | .774 | 1.320 | 1.105 | 1.018 | .765 |

| | NOVEMBER 02 | | | | | | NOVEMBER 09 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | .263 | .063 | .263 | .000 | .038 | .125 | -.250 |
| MEAN | .392 | .209 | .359 | .146 | .346 | .290 | -.125 |
| SORTING | 1.178 | 1.062 | 1.086 | 1.119 | 1.253 | 1.140 | 1.124 |
| SKEWNESS | .112 | .212 | .104 | .203 | .301 | .187 | .210 |
| KURTOSIS | 1.380 | 1.819 | 2.163 | 1.455 | 1.033 | 1.570 | 1.668 |

Table C5.0
Grain Size Characteristics

1986

STATION FIVE

| | JULY 16 | | | | | | JULY 24 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | -1.013 | -.938 | -.275 | -.438 | -.125 | -.558 | 2.125 |
| MEAN | -.875 | -.992 | .117 | -.358 | .050 | -.412 | 1.563 |
| SORTING | 1.630 | .888 | 1.641 | 1.554 | 1.357 | 1.414 | 1.057 |
| SKEWNESS | .239 | .934 | .247 | .079 | .615 | .423 | -.602 |
| KURTOSIS | 1.336 | .533 | .783 | 1.155 | .496 | .861 | 1.288 |

| | AUGUST 20 | | | | | | AUGUST 29 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | 2.113 | 2.150 | 2.150 | 2.150 | 1.988 | 2.110 | .988 |
| MEAN | 2.038 | 2.125 | 2.121 | 2.092 | 1.792 | 2.034 | .809 |
| SORTING | .595 | .651 | .683 | 1.083 | .913 | .785 | 1.450 |
| SKEWNESS | -.353 | -.305 | -.327 | -.466 | -.465 | -.383 | -.205 |
| KURTOSIS | 1.335 | 2.367 | 2.139 | 3.921 | 1.415 | 2.235 | .664 |

| | NOVEMBER 02 | | | | | | NOVEMBER 09 |
|---|---|---|---|---|---|---|---|
| SAMPLE | A | B | C | D | E | AVERAGE | C |
| MEDIAN | -.063 | -.513 | -.125 | .000 | 1.625 | .185 | 1.563 |
| MEAN | .112 | .008 | .208 | .296 | 1.000 | .325 | .709 |
| SORTING | 1.887 | 1.761 | 1.671 | 1.613 | 1.413 | 1.669 | 1.897 |
| SKEWNESS | .075 | .318 | .194 | .192 | -.545 | .047 | -.525 |
| KURTOSIS | .567 | 1.644 | .617 | .567 | .609 | .801 | .669 |

Table C6.0

OVERALL AVERAGES FOR GRAIN SIZES
1986

**STATION ONE**

| **SAMPLE** | **J 16** | **J 24** | **AVE** | **A 20** | **A 29** | **AVE** | **NOV 2** | **NOV 9** | **AVE** |
|---|---|---|---|---|---|---|---|---|---|
| MEDIAN | -.120 | .250 | .065 | .060 | .125 | .093 | -.645 | -.225 | -.435 |
| MEAN | -.371 | -.074 | -.223 | -.047 | .021 | -.013 | -.457 | -.117 | -.287 |
| SORTING | 1.220 | 1.313 | 1.267 | 1.136 | 1.142 | 1.139 | 1.196 | 1.310 | 1.253 |
| SKEWNESS | .200 | -.336 | -.068 | -.038 | -.137 | -.088 | .188 | .063 | .126 |
| KURTOSIS | .516 | -4.780 | -2.132 | .899 | .767 | .833 | 1.250 | 1.010 | 1.130 |

STATION TWO

| SAMPLE | J 16 | J 24 | AVE | A 20 | A 29 | AVE | NOV 2 | NOV 9 | AVE |
|---|---|---|---|---|---|---|---|---|---|
| MEDIAN | -1.843 | -1.525 | -1.684 | -.365 | -.938 | -.652 | -.595 | -1.475 | -1.035 |
| MEAN | -1.586 | -1.446 | -1.516 | -.306 | -1.234 | -.770 | -.578 | -1.600 | -1.089 |
| SORTING | .371 | .444 | .408 | .648 | .631 | .640 | .814 | .741 | .778 |
| SKEWNESS | 2.086 | -23.641 | -10.778 | 1.481 | 9.700 | 5.591 | -.025 | 8.280 | 4.128 |
| KURTOSIS | .014 | -.028 | -.007 | .492 | .034 | .263 | 1.004 | .042 | .523 |

STATION THREE

| SAMPLE | J 16 | J 24 | AVE | A 20 | A 29 | AVE | NOV 2 | NOV 9 | AVE |
|---|---|---|---|---|---|---|---|---|---|
| MEDIAN | -.219 | .375 | .078 | .893 | -.313 | .290 | .233 | .313 | .273 |
| MEAN | -.280 | .283 | .002 | .894 | -.338 | .278 | .182 | .496 | .339 |
| SORTING | 1.300 | 1.772 | 1.536 | .959 | 1.413 | 1.186 | 1.433 | 1.501 | 1.467 |
| SKEWNESS | .513 | -.164 | .175 | -.086 | -.056 | -.071 | -.011 | .180 | .084 |
| KURTOSIS | .385 | .934 | .659 | 1.198 | .757 | 977 | .883 | .910 | 997 |

Table C6.0 Con't

STATION FOUR

| SAMPLE | J 16 | J 24 | AVE | A 20 | A 29 | AVE | NOV 2 | NOV 9 | AVE |
|---|---|---|---|---|---|---|---|---|---|
| MEDIAN | -.163 | .175 | | -.190 | .125 | -.033 | .125 | -.250 | -.063 |
| MEAN | -.373 | .217 | | -.214 | .125 | -.045 | .290 | -.125 | .083 |
| SORTING | 1.051 | 1.090 | | 1.207 | 1.218 | 1.212 | 1.140 | 1.124 | 1.132 |
| SKEWNESS | .064 | .063 | | .070 | -.071 | -.001 | .187 | .210 | .198 |
| KURTOSIS | .886 | 1.261 | | 1.018 | .765 | .891 | 1.570 | 1.668 | 1.619 |

STATION FIVE

| SAMPLE | J 16 | J 24 | AVE | A 20 | A 29 | AVE | NOV 2 | NOV 9 | AVE |
|---|---|---|---|---|---|---|---|---|---|
| MEDIAN | -.558 | 2.125 | .784 | 2.110 | .988 | 1.549 | .185 | 1.563 | .874 |
| MEAN | -.412 | 1.563 | .575 | 2.034 | .809 | 1.421 | .325 | .709 | .517 |
| SORTING | 1.414 | 1.057 | 1.236 | .785 | 1.450 | 1.118 | 1.669 | 1.897 | 1.783 |
| SKEWNESS | .423 | -.602 | -.089 | -.383 | -.205 | -.294 | .047 | -.525 | -.239 |
| KURTOSIS | .861 | 1.288 | 1.075 | 2.235 | .664 | 1.449 | .801 | .669 | .735 |

Table C7.0

FINAL GRAIN SIZE AVERAGES

STATION ONE

| MONTH | JULY | AUGUST | NOVEMBER | AVERAGE |
|---|---|---|---|---|
| PHI@5 | -1.859 | -1.807 | -2.365 | -2.010 |
| PHI@16 | -1.809 | -1.289 | -1.457 | -1.518 |
| PHI@25 | -.298 | -.868 | -1.125 | -.764 |
| PHI@50 | .065 | .093 | -.435 | -.093 |
| PHI@75 | .659 | .877 | .480 | .672 |
| PHI@84 | 1.077 | 1.158 | 1.032 | 1.089 |
| PHI@95 | 1.741 | 1.675 | 1.801 | 1.739 |
| MEDIAN | .065 | .093 | -.435 | -.093 |
| MEAN | -.223 | -.013 | -.287 | -.174 |
| SORTING | 1.267 | 1.139 | 1.253 | 1.220 |
| SKEWNESS | -.068 | -.088 | .126 | -.010 |
| KURTOSIS | -2.132 | .833 | 1.130 | -.056 |

STATION TWO

| MONTH | JULY | AUGUST | NOVEMBER | AVERAGE |
|---|---|---|---|---|
| PHI@5 | .000 | .000 | -.994 | -.331 |
| PHI@16 | -2.251 | -1.932 | -2.251 | -2.144 |
| PHI@25 | -2.721 | -1.394 | -1.794 | -1.970 |
| PHI@50 | -1.684 | -.652 | -1.035 | -1.124 |
| PHI@75 | -1.098 | -.022 | -.294 | -.471 |
| PHI@84 | -.614 | .274 | .018 | -.108 |
| PHI@95 | -.012 | .580 | .396 | .321 |
| MEDIAN | -1.684 | -.652 | -1.035 | -1.124 |
| MEAN | -1.516 | -.770 | -1.089 | -1.125 |
| SORTING | .407 | .639 | .778 | .608 |
| SKEWNESS | -10.777 | 5.590 | 4.127 | -.353 |
| KURTOSIS | -.007 | .263 | .523 | .260 |

STATION THREE

| MONTH | JULY | AUGUST | NOVEMBER | AVERAGE |
|---|---|---|---|---|
| PHI@5 | -1.963 | -1.883 | -1.905 | -1.917 |
| PHI@16 | -1.813 | -.945 | -1.142 | -1.300 |
| PHI@25 | -1.528 | -.519 | -.644 | -.897 |
| PHI@50 | .078 | .290 | .273 | .214 |
| PHI@75 | 1.344 | 1.232 | 1.532 | 1.369 |
| PHI@84 | 1.739 | 1.489 | 1.887 | 1.705 |
| PHI@95 | 2.316 | 1.928 | 2.782 | 2.342 |

Table C7.0 Con't

| MONTH | JULY | AUGUST | NOVEMBER | AVERAGE |
|---|---|---|---|---|
| MEDIAN | .078 | .290 | .273 | .214 |
| MEAN | .002 | .278 | .339 | .206 |
| SORTING | 1.536 | 1.186 | 1.467 | 1.396 |
| SKEWNESS | .175 | -.071 | .084 | .063 |
| KURTOSIS | .659 | .977 | .897 | .844 |

STATION FOUR

| | | | | |
|---|---|---|---|---|
| PHI@5 | -1.665 | -1.835 | -1.710 | -1.737 |
| PHI@16 | -1.197 | -1.402 | -.875 | -1.158 |
| PHI@25 | -.807 | -.973 | -.550 | -.777 |
| PHI@50 | .006 | -.033 | -.063 | -.030 |
| PHI@75 | .572 | .744 | .534 | .617 |
| PHI@84 | .955 | 1.300 | 1.185 | 1.147 |
| PHI@95 | 1.849 | 1.709 | 2.362 | 1.973 |
| MEDIAN | .006 | -.033 | -.063 | -.030 |
| MEAN | -.078 | -.045 | .083 | -.013 |
| SORTING | 1.070 | 1.212 | 1.132 | 1.138 |
| SKEWNESS | .064 | -.001 | .198 | .087 |
| KURTOSIS | 1.074 | .891 | 1.619 | 1.195 |

STATION FIVE

| MONTH | JULY | AUGUST | NOVEMBER | AVERAGE |
|---|---|---|---|---|
| PHI@5 | -.815 | -1.149 | -2.348 | -1.437 |
| PHI@16 | -.953 | .287 | -1.627 | -.764 |
| PHI@25 | .052 | .579 | -1.278 | -.216 |
| PHI@50 | .784 | 1.549 | .874 | 1.069 |
| PHI@75 | 1.493 | 2.248 | 2.173 | 1.971 |
| PHI@84 | 1.896 | 2.428 | 2.303 | 2.209 |
| PHI@95 | 2.642 | 2.695 | 2.935 | 2.757 |
| MEDIAN | .784 | 1.549 | .874 | 1.069 |
| MEAN | .575 | 1.421 | .517 | .838 |
| SORTING | 1.236 | 1.118 | 1.783 | 1.379 |
| SKEWNESS | -.089 | -.294 | -.239 | -.207 |
| KURTOSIS | 1.075 | 1.449 | .735 | 1.086 |

Table C8.0

SUMMARY OF THE OVERALL AVERAGE SLOPES AND

AND THE OVERALL AVERAGE GRAIN SIZE CHARACTERISTICS

| STATION | SLOPE | | MEAN | | MEDIAN | | SORTING | |
|---|---|---|---|---|---|---|---|---|
| | (A) | (S) | SIZE | PHI | SIZE | PHI | TYPE | PHI |
| 1 | 1:7.1 | 1:5.8 | VCS | -.17 | VSC | -.09 | MOD | 1.22 |
| 2 | 1:8.5 | 1:7.6 | GRAN | -1.13 | GRAN | -1.12 | WELL | .61 |
| 3 | 1:8.2 | 1:7.9 | CS | .21 | CS | .21 | MOD | 1.40 |
| 4 | 1:9.7 | 1:7.4 | VCS | -.01 | VCS | -.03 | MOD | 1.14 |
| 5 | 1:9.2 | 1:8.4 | CS | .84 | MS | 1.38 | MOD | 1.38 |

GRAN = GRANULE
VCS = VERY COARSE SAND
CS = COARSE SAND
MS = MEDIUM SAND

WELL = WELL SORTED
MOD = MODERATELY SORTED