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COASTAL PROCESSES AND MORPHOLOGY OF THE BERING SEA COAST OF ALASKA

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENTS

Much of our effort during the first year of our study (FY 76) was involved in regional characterization of the physical environment of the Bering Sea coast of Alaska. This included determination of net longshore transport directions (for the entire study area), characterization of coastal morphology, and reconnaissance of beach morphology and sediment characteristics (for the northern Bering Sea coast of Alaska and the Bristol Bay coast of the Alaska Peninsula) . In FY 77, these types of studies were extended to Pavlov Bay and Cold Bay on the Pacific coast of the Alaska Peninsula. These potential deep water ports may serve offshore petroleum exploitation of the Bristol Bay area in the future. The results of these types of studies can be used to obtain qualitative assessments of coastal stability, in preparing preliminary siting studies for coastal developments, and in the determination of the long-term directions of transport of particulate pollutants in the littoral system.

Storms pose major hazards to coastal developments along the Alaskan Bering Sea coast. Shallow offshore depths that characterize much of the eastern Bering Sea shelf (particularly the northern Bering Sea) make coastal areas susceptible to storm surges of large magnitude. During FY 76, debris lines that resulted from a particularly severe storm in 1974 were measured at many locations along the northern Bering Sea coast of Alaska. Debris-line elevations provide a combined measure of sea-level rise due primarily to wind stress, drop in barometric pressure, wave set-up and runup. Measured elevations ranged generally between 3 and 4.75 m. The highest debris lines were found along the eastern side of Norton Sound. Ice had begun developing along the shore and in shallow areas prior to the storm. Ice blocks, which were lifted by the rise in sea level, were driven ashore by wind and breaking waves and caused damage in the village of Unalakleet. Large logs floating offshore and in debris lines could also be driven shoreward and be battered against coastal structures. These potential consequences of storms in this environment pose hazards to coastal developments in addition to hazards resulting from flooding and wave activity alone.

Our study on the coastal effects of this major storm continued in FY 77 with investigations on amounts of coastal change in the vicinity of Nome. Tundra bluffs were eroded as much as 45 m. This erosion was, however, irregular in plan view. Shoreline changes were also complex. Giant cusps with a longshore wavelength averaging 413 m were replaced during the storm by giant cusps spaced 853m. The net effect of these changes was a complex pattern of shoreline erosion and accretion. For example, the shoreline accreted 50 m at one location while 150 m away the shoreline eroded 10 m. Interestingly, the net change was accretion. Similar changes were measured for a storm that occurred in 1950, but in this case the net change was erosion as expected. The accretion observed for the 1974 storm may be related to freeze-up processes, but the mechanisms are unknown.

A storm in September, 1977 caused a surge of nearly 2 m. Changes in beach and nearshore profiles that presumably resulted from this storm were again complex. One profile comparison indicated net accretion, whereas a profile located only 50 m away showed evidence of both substantial accretion and erosion. Coastal change is not, however, restricted to storm conditions in this environment. Giant cusps were observed to migrate along the coast at 5-6 m\day during the period 6/23/51 - 7/30/51. This migration caused as much as 50 m accretion at a given location over a period of several weeks.

Preliminary analysis indicate that beach changes in the vicinity of Nome are much more dynamic (and complex) than beach changes for most other coastal areas along the northern Bering Sea coast.

A wave climate model for the northern Bering Sea was developed and used to simulate wave characteristics during the 1974 storm. Wave measurements during high energy conditions are needed, however, to verify some assumptions used in the model. Wave measurements were made near Nome during the summer of 1977. Unfortunately only fair weather conditons were encountered during the measurement period.

One use of the kind of data we have provided is to establish a coastal development set-back line. That is, the appropriate government body would prohibit developments within areas subject to inundation by storm surge or undermining by coastal erosion. Additional input into this analysis must include the long-term rate of erosion. This question needs more study. For structures that must cross the coastline (e.g. pipelines) the maximum scour depth must be established for both storms and over the long-term. Our investigations of these problems had only begun.

II, INTRODUCTION

A. General Nature and Scope of Study

Prior to FY 76, little information was available on the coastal processes of the Bering Sea coast of Alaska. This was a significant gap in our knowledge in view of anticipated coastal and nearshore developments in support of offshore petroleum exploitation.

During the first year of our study (FY 76), much of our effort was involved with regional characterization of the physical environment of the coast. This included determination of net longshore drift directions (areas 1, 2 and 3 on Fig. 1), classification of coastal morphology (areas 1 and 3) and detailed reconnaissance of beach morphology and sediment characteristics (areas 1 and 3) , From these studies preliminary assessments have been made on coastal stability, sediment sources and sinks, and sediment transport pathways along the coast. These studies laid the groundwork for the more quantitative studies of coastal processes that followed.

During the second year of our study (FY 77), detailed investigations on coastal processes commenced in the Norton Sound area (Fig. 1 area 1) . These studies generally followed two directions. First, historical studies of the effect of storms on coastal change from aerial photographs, debris-line elevations, and computer simulations of wave characteristics for the particularly severe November, 1974 storm. Second, direct measurements were made during the FY 77 field season of the amounts of coastal change and of the nearshore wave characteristics. The wave measurement program was intended to be a field verification of the computer model. The direct measurements of coastal change was a first step toward relating amounts of coastal change with computed wave characteristics.

The ultimate objective of the study was to develop a quantitative understanding of those processes controlling coastal erosion and accretion for the diverse coastal types found along the Bering Sea, coast of Alaska. Our work on the quantitative aspects of the problem, however, had only just begun when funding was terminated. Work during FY 78 dealt with reduction of data gathered during FY 77.

B. Specific Objectives

1. Determination of the net longshore transport directions for the Bering Sea coast of Alaska (Fig. 1, areas 1, 2, and 3).

2. Characterization of the coastal morphology for the Bristol Bay coast of the Alaska Peninsula and the northern Bering Sea coast of Alaska (Fig. 1, areas 1 and 3),

3. Reconnaissance of beach morphology and sediment characteristics for the Bristol Bay coast of the Alaska Peninsula and the northern Bering Sea coast of Alaska (Fig. 1, areas 1 and 3).

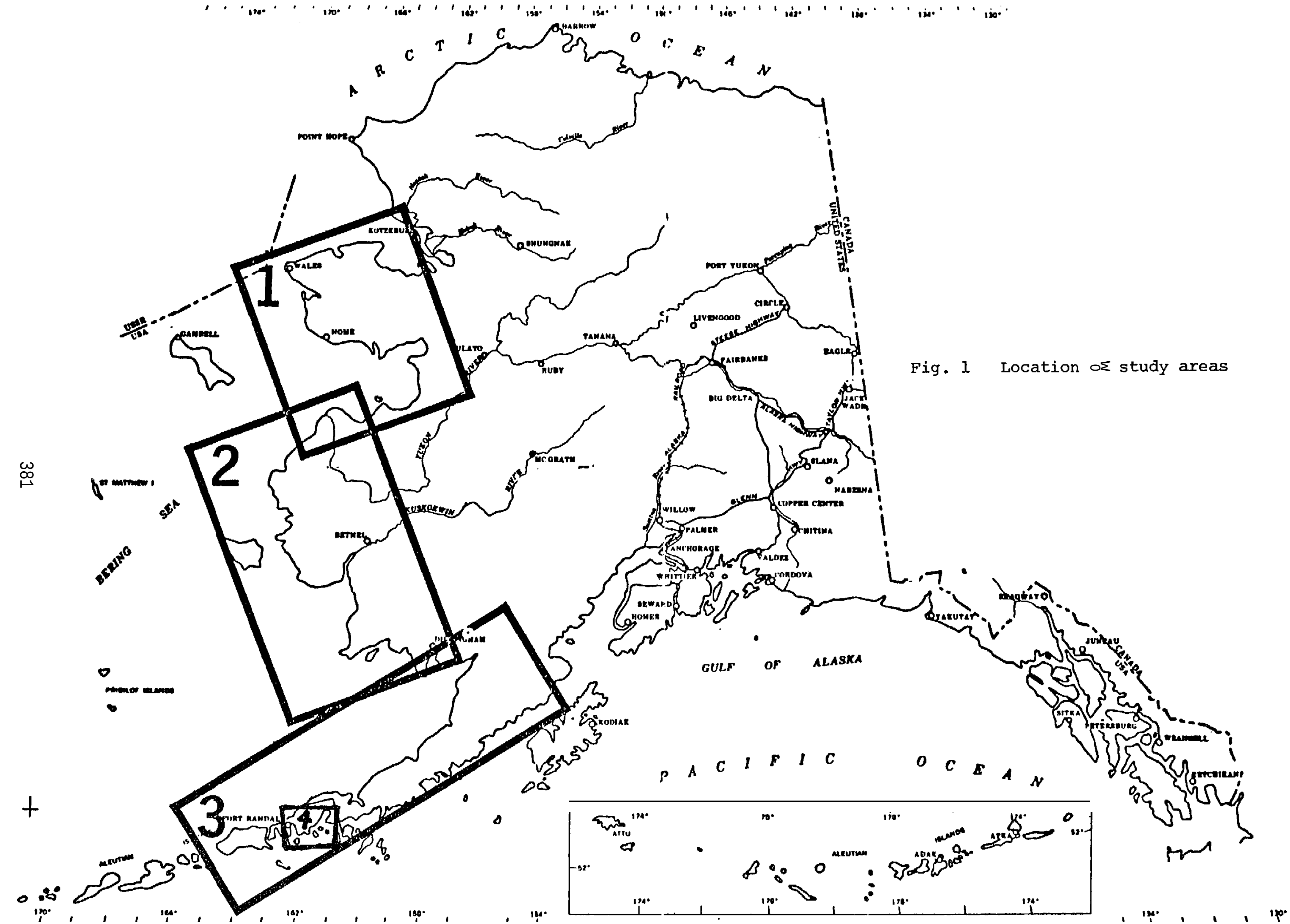


Fig. 1 Location of study areas

4. Determination of net longshore transport directions, coastal morphology, and beach and sediment characteristics for Pavlov and Cold Bays on the Pacific coast of the Alaska Peninsula (Fig. 1, area 4).

5. Measurement of debris line elevations along the northern Bering Sea coast of Alaska that resulted from the November, 1974 storm (Fig. 1, area 1).

6. Computer simulation of wave characteristics in the northeast Bering Sea during the 1974 storm (Fig. 1, area 1).

7. Measurement of amounts of coastal change in the Nome area that resulted from the November, 1974 storm (Fig. 1, area 1).

8. Remeasure beach and nearshore profiles during FY 76 and FY 77 in the northern Bering Sea study area (Fig. 1, area 1) .

9. Remeasure beach profiles during FY 76 and FY 77 in the southern portion of the Bristol Bay coast of the Alaska Peninsula study area (Fig. 1, area 3) .

10. In situ measurements of wave characteristics and sea level variations in the vicinity of Nome (northern Bering Sea) (Fig. 1, area 1) .

C. Relevance to Problems of Petroleum Development

One use of the type of data we present is in the establishment of a coastal development set-back line; that is, the appropriate government body would prohibit developments within areas subject to inundation by storm surge or undermining by coastal erosion. Additional input into this analysis must include the long-term rate of erosion of the coast. This is a question that needs more study . For structures that must cross the coastline (e.g. pipelines) the maximum scour depth must be established both for storms and over the long term. Our investigations of these problems had only begun.

III. CURRENT STATE OF KNOWLEDGE

Our previous work in the area has been briefly summarized in section II of this report (see also Sallenger, et al. , 1977, 1978) . Relevant work prior to FY 76 includes:

A. Greene (1970) observed longshore drift directions near Nome to be variable for June and July 1967, but predominantly to the east. Wave heights were generally low (≈30 cm), but storms during the late summer and fall were reported to produce high energy conditions.

B. The Draft E.I.S. for the Lost River Project reports that wave heights vary from approximately 30 cm in height up to 5 to 7 m with a theoretical maximum of 12 m off the mouth of the Lost River. Longshore transport is generally from west to east. Sediment transported during storm conditions greatly exceeds that transported under “normal” conditions.

C. The Corps of Engineers conducted several studies in the area including:

1. a report on flood protection and navigation improvement for Unalakleet.

2. National Shoreline Report which reports severe coastal erosion in Dillingham.

D. Several studies attempting to categorize coastal morphology at very small scales have been conducted (e.g. Putnam, 1960 and Dolan, 1967).

E. Additional studies include work on Quaternary marine transgressions and old strand lines (e.g. Hopkins, 1967) and several studies on beach placer deposits near Nome (e.g. Greene, 1970) and along the south shores of Bristol Bay (e.g. Berryhill, 1963).

IV. STUDY AREA

Our study area includes the Bering Sea coastal areas shown in Fig. 1. Also, some reconnaissance level studies have been done in Pavlov and Cold Bays on the south side of the Alaska Peninsula (Fig. 1, area 4). Most of our work, however, deals with the northern Bering Sea coast of Alaska (Fig. 1, area 1). See section IIB of this report for the locations of specific studies.

V. METHODS, RESULTS, DISCUSSION, AND CONCLUSIONS

Three separate reports have been prepared.

	Page Number
A. Coastal change along the northern Bering Sea coast of Alaska and the Bristol Bay coast of the Alaska Peninsula; by A. H. Sallenger.	7
B. Wave characteristics during the November, 1974 storm in the northern Bering Sea; by A. H. Sallenger.	38
C. Wave measurements and estimates of wave generated littoral transport; Nome, Alaska; by J. R. Dingier.	45

The first report (A) deals with objectives 5, 7, 8, and 9 (see section IIB). The second report (B) deals with objective 6. The third report (C) deals with objective 10. Our reconnaissance work (objectives 1-4) was discussed in detail in Sallenger, et. al., 1977.

A. COASTAL CHANGE ALONG THE NORTHERN BERING SEA COAST OF ALASKA AND THE BRISTOL BAY COAST OF THE ALASKA PENINSULA

A. H. Sallenger

STORM CHANGES IN THE NOME-SAFETY LAGOON AREA

NOVEMBER, 1974 STORM

Introduction

During the second week of November, 1974 a severe storm moved, across the Bering Sea and caused extensive damage to communities along the northern Bering Sea coast of Alaska (Fig'. 2). A detailed description of the meteorological characteristics of the storm is given in Fathauer (197S). At Nome, barometric pressure dropped 56 mb over a period of 26 hours and peak winds had a velocity of 111 km/hr from the south. Nearshore waves were reportedly 3-4 m in height. (See also "Wave characteristics during the November, 1974 storm in the northern Bering Sea", report B of this section)

The southerly winds and shallow offshore depths (e.g. mean depth of Norton Sound is approximately 20 m) contributed to a storm surge of large magnitude along the coast. Elevations of debris lines that resulted from this surge were measured at 30 locations distributed around the study area. Debris line elevation provides a measure of storm sea level rise due predominantly to the combined effects of drop in barometric pressure, wind set-up, wave set-up and run-up. Generally, the major portion of storm sea level rise can be attributed to wind set-up. The storm surge was superimposed on a spring high tide, but this was of relatively minor significance since the astronomical tide range for the region is low (e.g. the diurnal range at Nome is .49 m). Debris line elevations ranged from 3.25 m above mean sea level north of Norton Sound to nearly 5 m along the eastern flank of Norton Sound (Fig. 3) (data given in Sallenger, et. al., 1977). The maximum value is probably a result of the geometry of the Sound and compares in magnitude to disastrous storm surges caused by hurricanes on the Gulf of Mexico coast. At Nome, storm surge and waves overtopped a sea wall and caused nearly 15 million dollars in damage.

The storm occurred during freeze-up. The northern Bering Sea generally has greater than 80% ice coverage between late November and mid-May. This led to some interesting consequences in regard to coastal change and movement of coastal sediments.

Bluff Erosion

In the vicinity of Nome, bluffs 2-5 m in height extend along the coast for 40 km. These are generally composed of muds and are overlain by tundra vegetation. Vertical aerial photography is available for this region for June 17, 1974 and July 23, 1976. Except for the November, 1974 storm, no storm of sufficient magnitude to significantly erode the bluffs occurred during this period. Thus, comparisons of the relative positions of bluffs for these two times should yield the amount of change attributable to the 1974 storm. Using a zoom transfer scope, bluff positions were plotted for each time at a common scale of approximately 1:5700.

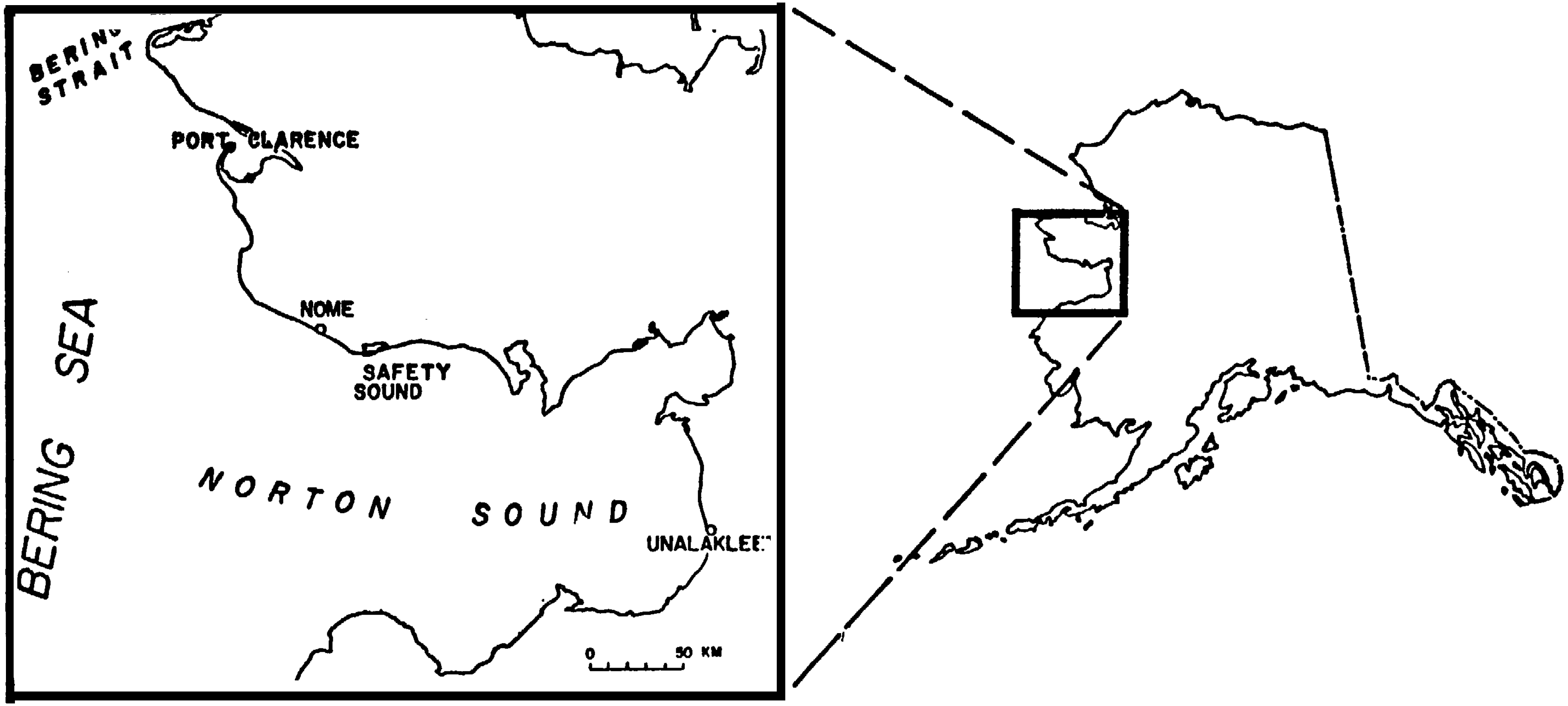


Fig. 2. Location of northern Bering Sea study area.

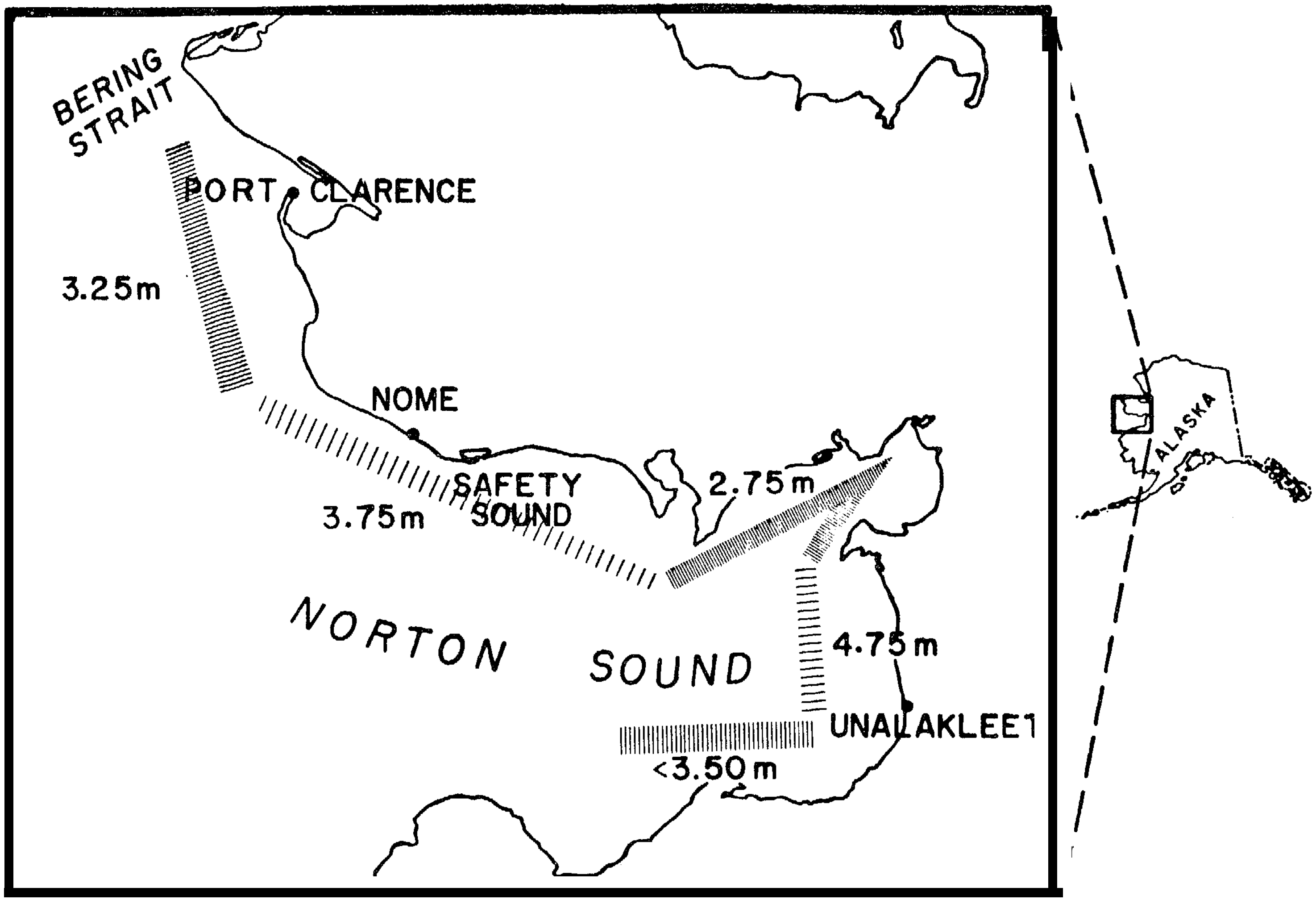


Fig. 3. **Summary** of measurements of debris line elevations. These are based on 30 measurements of debris line elevation distributed evenly around the study area. The elevations are referenced to observed sea level due to the paucity of predicted and measured tidal information for the area. This causes no large errors since the astronomical tide range for the region is relatively low. For example the diurnal range at Nome is .49 m. Consequently, to consider the measurements referenced to mean sea level would suggest maximum errors of approximately + 25 cm.

Bluffs were eroded as much as 45 m. The erosion was, however, irregular in plan view, ranging from O to 45 m east of Nome where bluffs are 1.5 to 2 m high and 0-18 m west of Nome where bluffs are 3-5 m high. An example of this irregular pattern of erosion is shown in Fig. 4A where an embayment separated by two promontories was eroded into a once linear bluff. That the bluff was linear prior to the storm is confirmed by pre-storm photography. Depth to permafrost inland from the coast ranges from approximately .5 to .8 m depending on the composition of overlying material, but is much deeper near the coast and on the beaches (Greene, 1970) . Variations in the lateral proximity of permafrost to the bluffs prior to the storm may have contributed to the observed non-uniform amount of erosion.

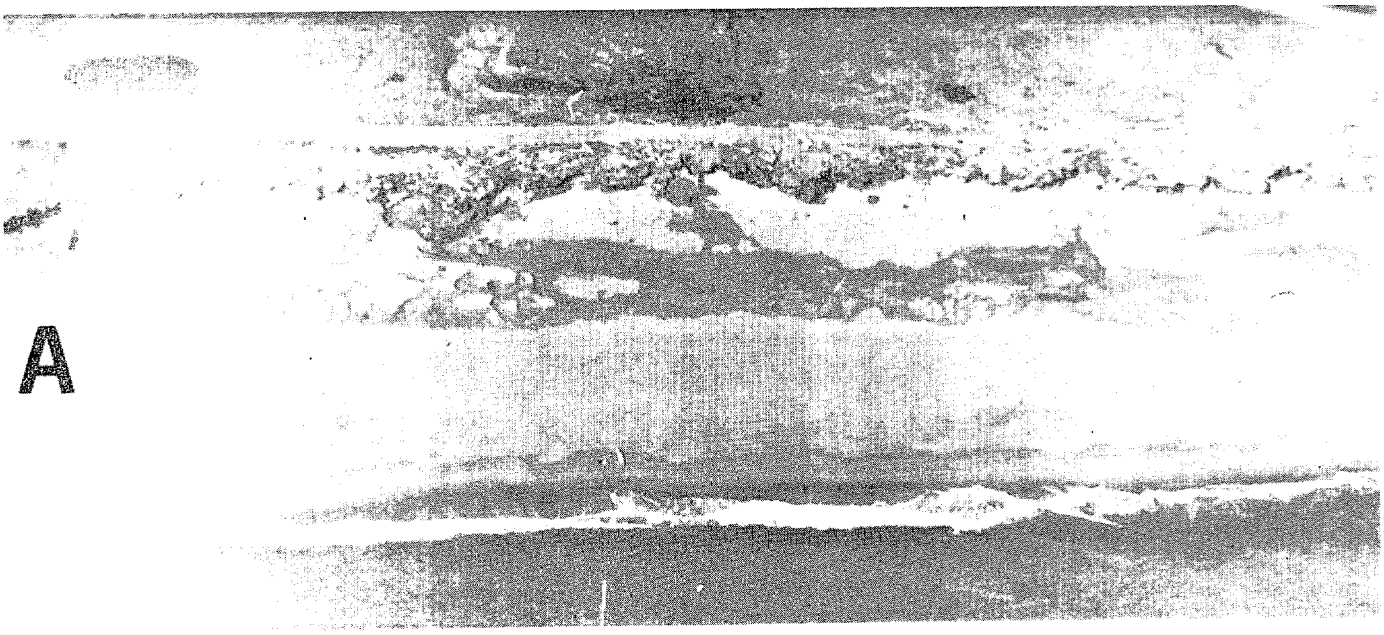
The surface of the platform to the left of the observer in Fig. 4B was presumably at or near the surface of permafrost prior to the storm. A .5-1.0 m thick layer of sediment and tundra that laid on top of the platform was stripped off by the storm waves whereas the frozen material below was resistant to modification. These platforms were best developed at the promontories discussed above. The photograph was taken in July, 1975 about one month of ice free conditions after the storm. No longer having the insulating protection of the overburden, the platform had eroded away by solifluction and other processes by the summer of 1976.

Shoreline Changes

Shoreline changes were complex. Along the barrier spit enclosing Safety Sound (Fig. 2) , vertical aerial photographs are available for 17 June 1974 and 9 September 1975. In this area, nearshore ice generally protects the beaches from modification by waves until mid-June. Since the storm occurred during freeze-up, the ice-free interval between the storm and post-storm photographs was approximately three months. Except during storm conditions, wave energy in this environment is quite low. For example, during the summers of 1976 and 1977 wave heights were generally 0.3-0.6 m or less, except during the latter part of the ice free season (late September through November) when storms were frequent. Greene (1970) reported similar measurements. Furthermore, repetitive profile measurements during the summers of 1976 and 1977 showed that coastal change was minimal except during storms. No large storms occurred during the interval between the storm and post-strom photographs or during the pre-storm photographs and the storm. Thus , comparisons of shoreline positions between the two sets of photographs may provide a reasonable measure of shoreline change attributable to the major 1974 storm.

Prior to the storm, giant cusps with a longshore wavelength averaging 413 m were observed (Fig. 5). Giant cusps are crescentric and regularly spaced shoreline features similar in form to beach cusps, but are an order of magnitude or more larger and are generally associated with offshore bars. The pre-storm cusps observed, however, were not obviously associated with a bar. A bar was visible on aerial photographs through the sea surface, but it was sinuous and irregular in plan view with no apparent relation to the cusps. However, there may have been an inner bar present that was not visible in the photography. The pre-storm cusps were apparently destroyed by the storm and were replaced by

A



B

Fig. 4. A. Aerial view of the post-storm bluff. Note the embayment and two promontories on the left. This was a result of nonuniform erosion during the storm (see text). B. Ground view of one of the promontories shown in Fig. 3A. Note the platform to the left of the observer. Presumably, the surface of the platform was at the surface of permafrost prior to the storm. The unfrozen overburden was stripped off by storm waves.

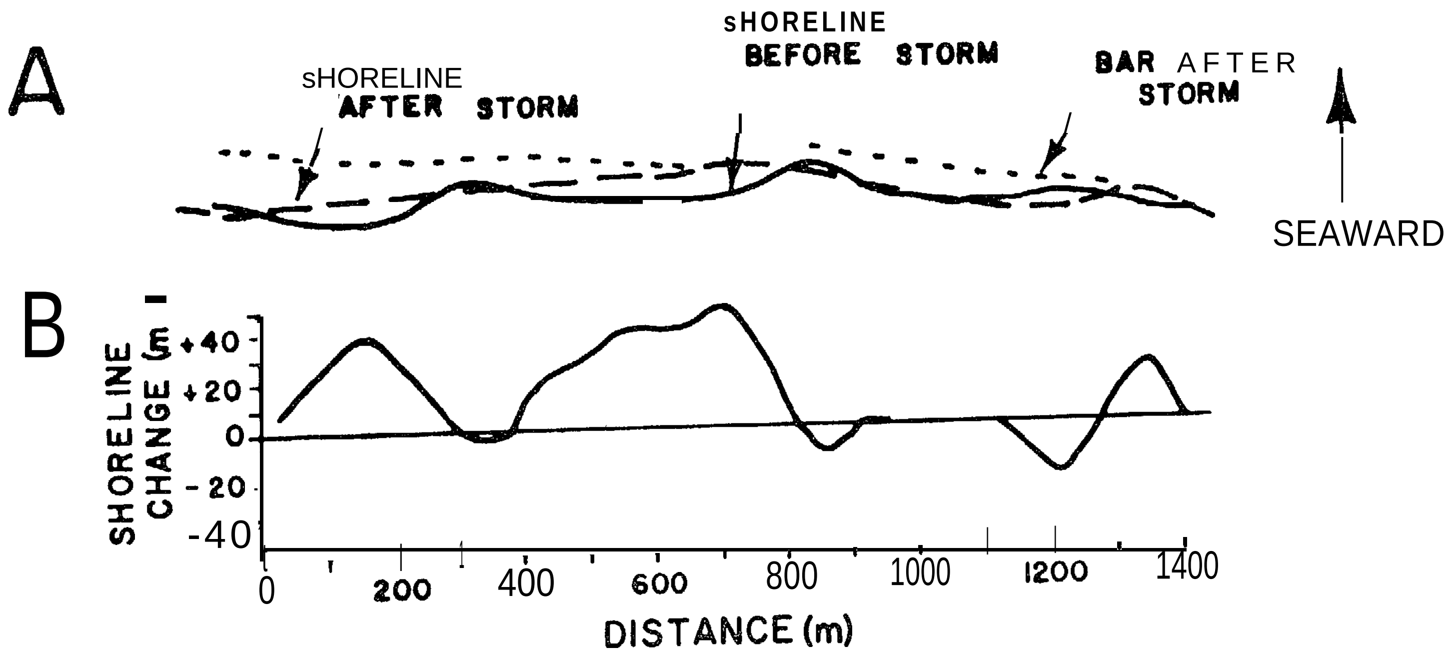


Fig. 5. An example of shoreline changes that resulted from the 1974 storm. Note the complex pattern and that the net change is accretion.

much larger giant cusps spaced 863 m (Fig. 5). Oblique bars that were obviously associated with the new cusps were observed on the post storm photography. The net effect of these changes was a relatively complex pattern of erosion and accretion. For example, the shoreline accreted 50 m at one location while 150 m away the shoreline eroded 10 m. Interestingly, the net change was accretional.

The giant cusps also controlled the location and extent of overwash; the overwash extending farther landward opposite embayments of the rhythmic shoreline topography (Fig. 6). In the same manner, giant cusps appeared to control the erosion of coastal vegetation. For example, in Fig. 6 it is seen that the beach grass closely parallels the form of the giant cusps. On the Outer Banks of North Carolina, Dolan (1971) made a similar observation. The regular spacing of breaches in a dune ridge following a storm matched the spacing of giant cusps.

COMPARISONS OF SHORELINE CHANGES BETWEEN THE 1974 AND NOVEMBER, 1950 STORMS

Shoreline comparisons based on photography from August 28, 1950 and June 22, 1951 showed similar changes in giant cusps. A relatively severe storm with southwesterly winds was recorded at Nome on November 10, 1950. On the pre-storm photography giant cusps spaced 363 m were observed (Fig. 7). These were replaced by very large cusps spaced 1.7 km, presumably as a result of the storm. Again a complex pattern of erosion and accretion resulted where at one location the shoreline eroded 41 m while 140 m away the shoreline accreted 12 m. In contrast to the 1974 storm, however, the net change was erosional.

The net accretion associated with the 1974 storm is perplexing. The comparisons of photography for both the 1950 and 1974 storms had good control. Numerous stable irregularities on the lagoon shoreline were used to match scales and orientation. Also, the trends for each storm were generally evident on all photographs compared.

It is interesting that air temperatures preceding each storm were quite different. They remained well below 0° C on the five days preceding the 1974 storm with daily minimums as low as -23° C (Fig. 8). Preceding the 1950 storm air temperatures were much warmer and generally above 0° C. When sea water temperature falls below its freezing point, an ice foot will begin to develop along the shoreline. An ice foot can form by a number of mechanisms (see for example Joyce, 1950). One of these is the freezing of spray and swash on the foreshore. By this process a rampart is built composed of ice and sediment which protects the foreshore from modification by waves. During storms, an ice foot of large proportions can be formed (Rex, 1964). For the 1974 storm, however, the optium temperatures for ice foot formation existed prior to the storm. There may have been a thin covering of sea ice present in Norton sound prior to the storm. The southerly winds could have pushed this ice against the south facing beaches. Perhaps these freeze-up processes contributed in some manner to the shoreline accretion observed for the 1974 storm. The mechanism is, however, unclear. The source of sediment may have been from the wide storm surf zone, but it is difficult to perceive

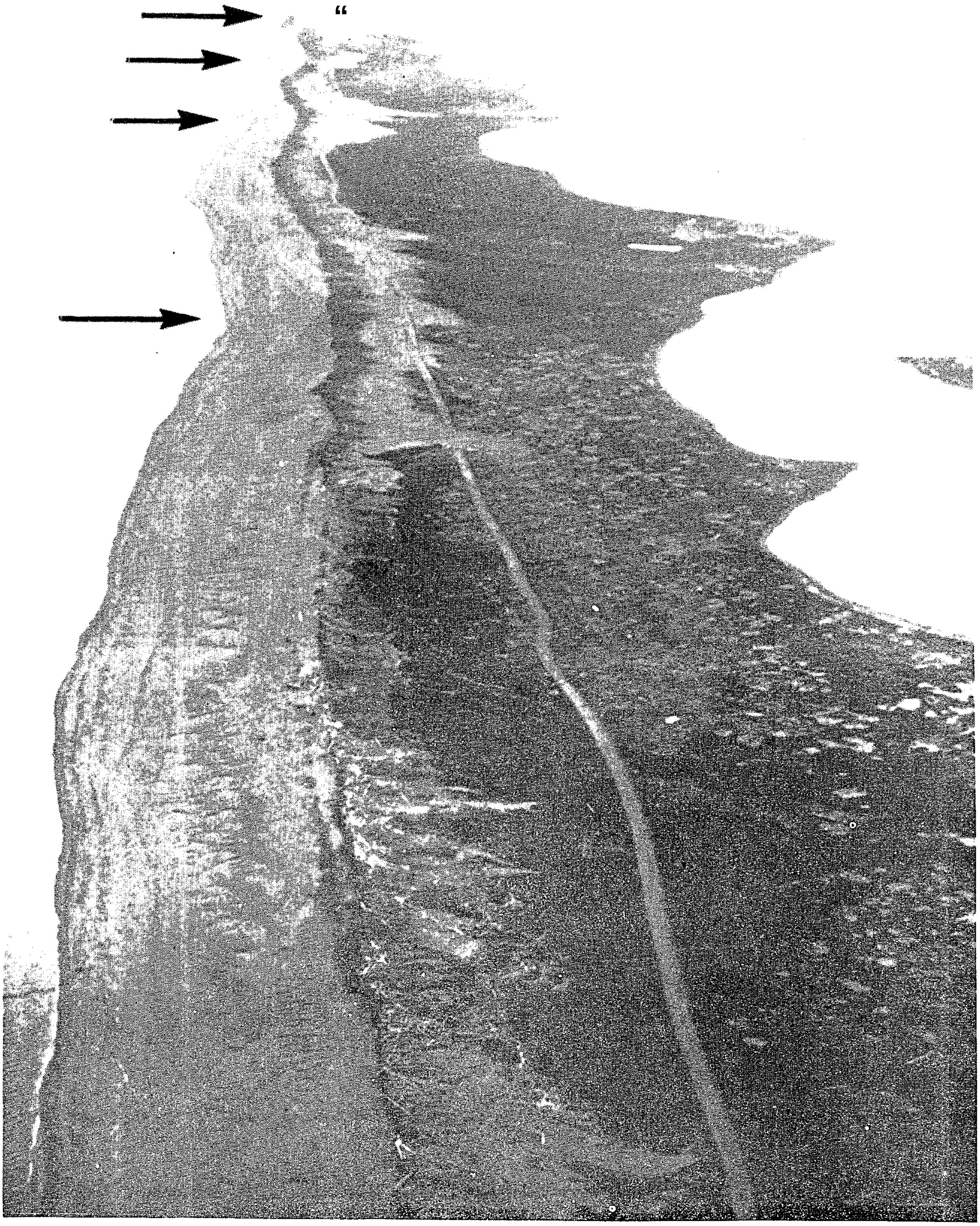


Fig. 6. Post-storm aerial view of the barrier spit enclosing Safety Sound. Note the maximum extent of overwash is opposite the embayments (arrows) of the rhythmic shoreline topography. Also, the beach grass line parallels the rhythmic shoreline.

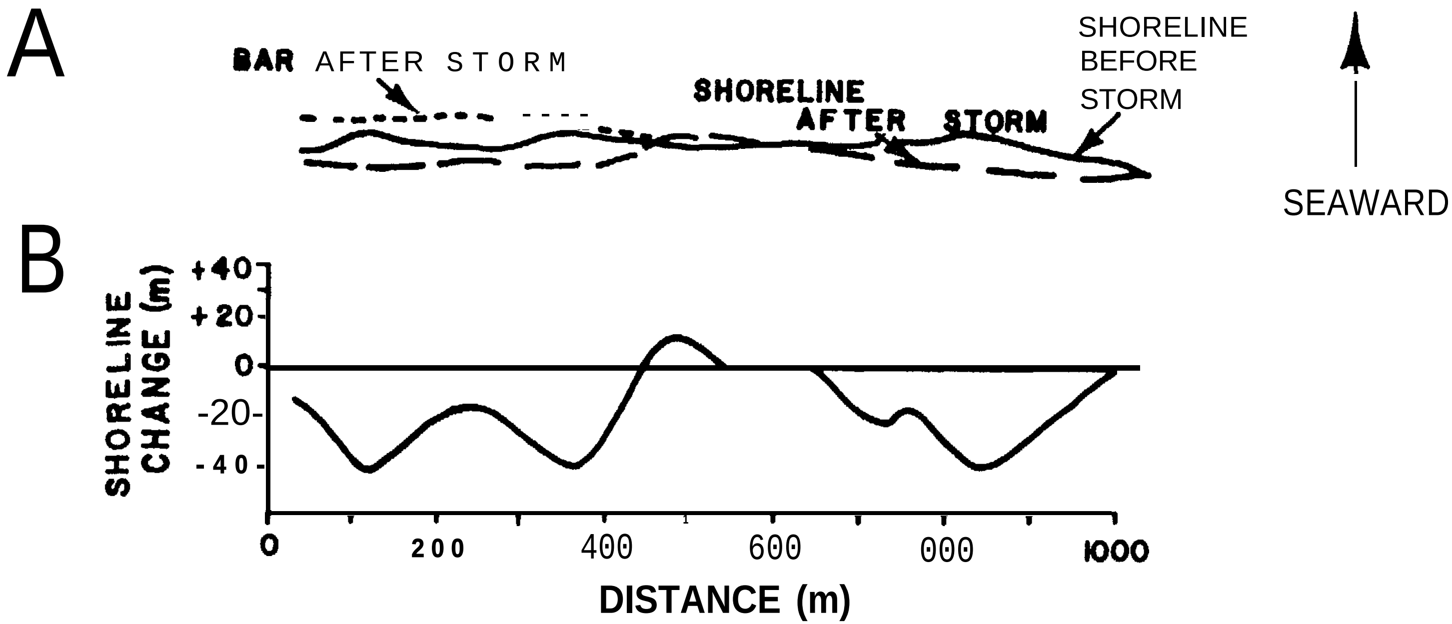


Fig. 7. An example of shoreline changes that resulted from the November, 1950 s tom. Note the complex pattern and that the net change is erosion.

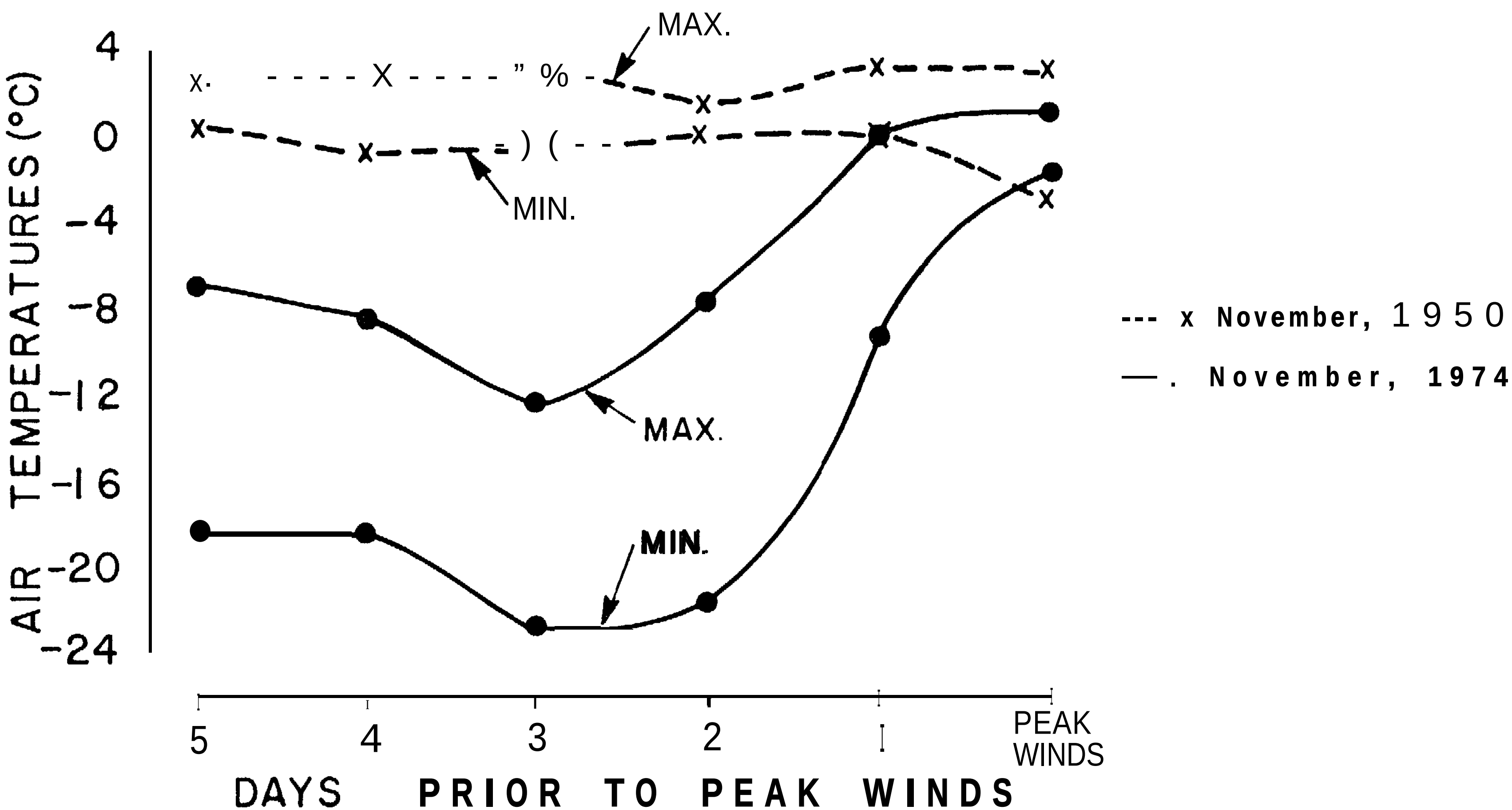


Fig. 8. Maximum and minimum daily air temperatures preceding the 1976 and 1950 storms .

how sufficient sediment would be displaced landward to account for the observed large scale changes. Furthermore, it appears that these potential ice effects were not capable of preventing modification of the landward parts of the barrier by storm surge and waves (Fig. 6).

Perhaps post-storm accretion occurred prior to the post-storm photography. Nearshore ice generally protects the beaches until mid-June. Thus, there was approximately a three month interval between the storm and the post storm photography during which the shoreline could prograde. However, it is questionable that there would be up to 50 m of accretion beyond the pre-storm shoreline as a result of normal rebuilding processes following the storm. Post-storm accretion cannot, however, be ruled out.

SEPTEMBER, 1977 STORM

A moderately severe storm was recorded at Nome in early September, 1977. A debris line at Nome harbor that resulted from this storm was approximately 2 m above MSL. Beach and nearshore profiles were measured in the Nome area during the third week of August and were remonitored during the second week of October. (Methods used in profiling are given in an appendix immediately following this report.) Comparisons of these profiles show the amount and character of coastal change that occurred during this period. Presumably, much of the change can be attributed to the September storm.

Two of these comparisons from Safety Lagoon are shown in Figs. 9 and 10. The locations of these profiles are shown in Fig. 11. The profile lines are parallel and 50 m apart, and are oriented approximately normal to the shoreline trend.

The comparison shown in Fig. 9 indicates that the net change was accretion. A bar was formed approximately 25o m seaward of the normal shoreline. In contrast, Fig. 10 shows that only 50 m away there was both substantial erosion and accretion. Again, a bar has formed. The sediment may have been supplied from erosional areas both seaward and shoreward of the bar. The foreshore slope has been decreased as would be expected during a storm, yet this decrease in slope was the result of accretion. Other profile comparisons in the area showed the same types of complex changes.

Obviously, nearshore changes in this environment are quite complex,

NON-STORM CHANGES IN THE NOME-SAFETY SOUND AREA

The wave climate of the northern Bering Sea is dominated by locally generated sea. Swell waves generated in the southern Bering Sea are greatly reduced in magnitude by refraction and frictional dissipation over the wide continental shelf before reaching the coast. Thus, in the absence "of strong onshore winds, nearshore wave conditions can be quite low. This low wave energy probably accounts for the very small scale changes observed in profiles measured at the beginning and end of the 1976 field season, a period during which no storms occurred. (See Sallenger et. al., 1977)

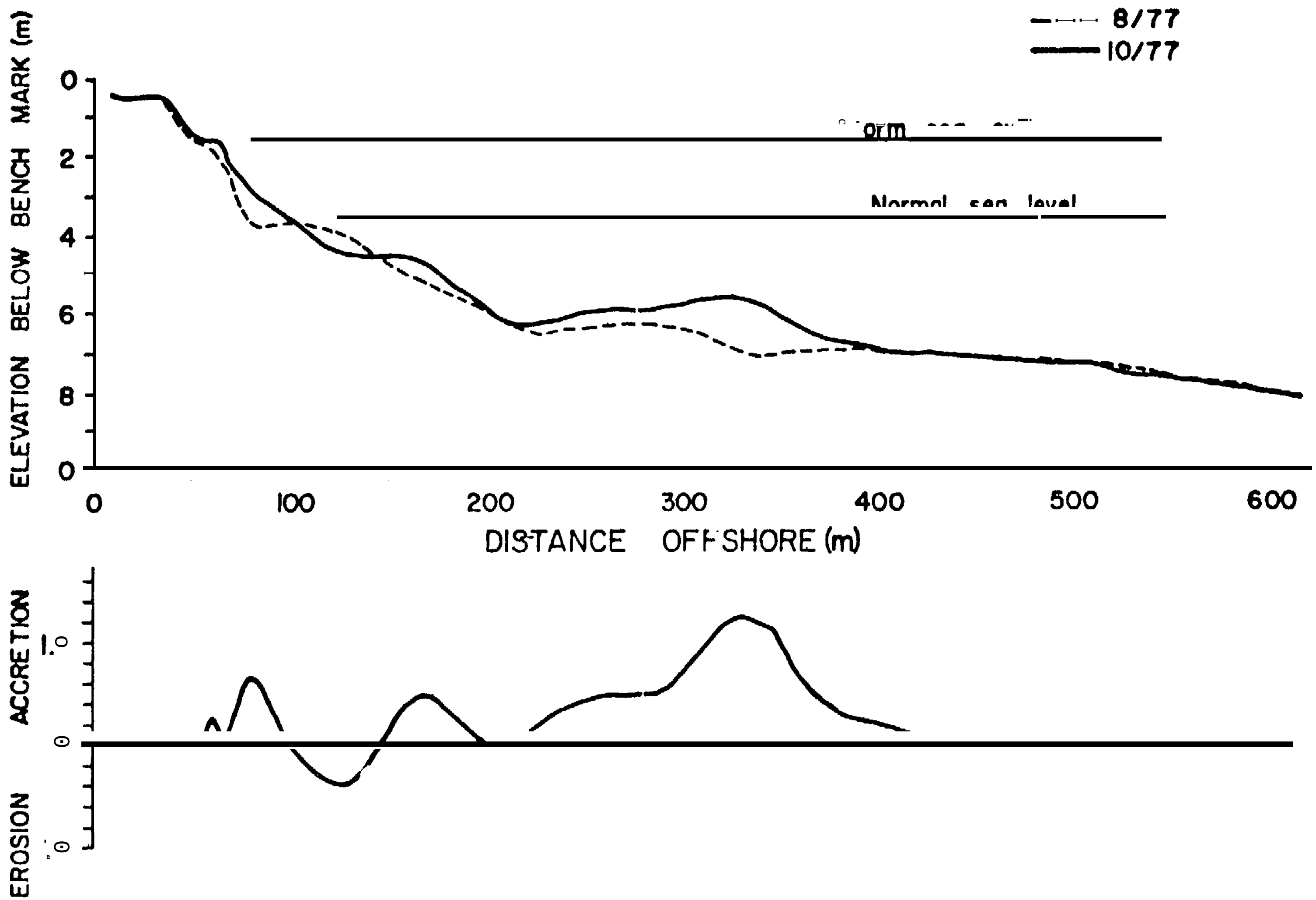


Fig. 9. Beach and nearshore profile comparison.

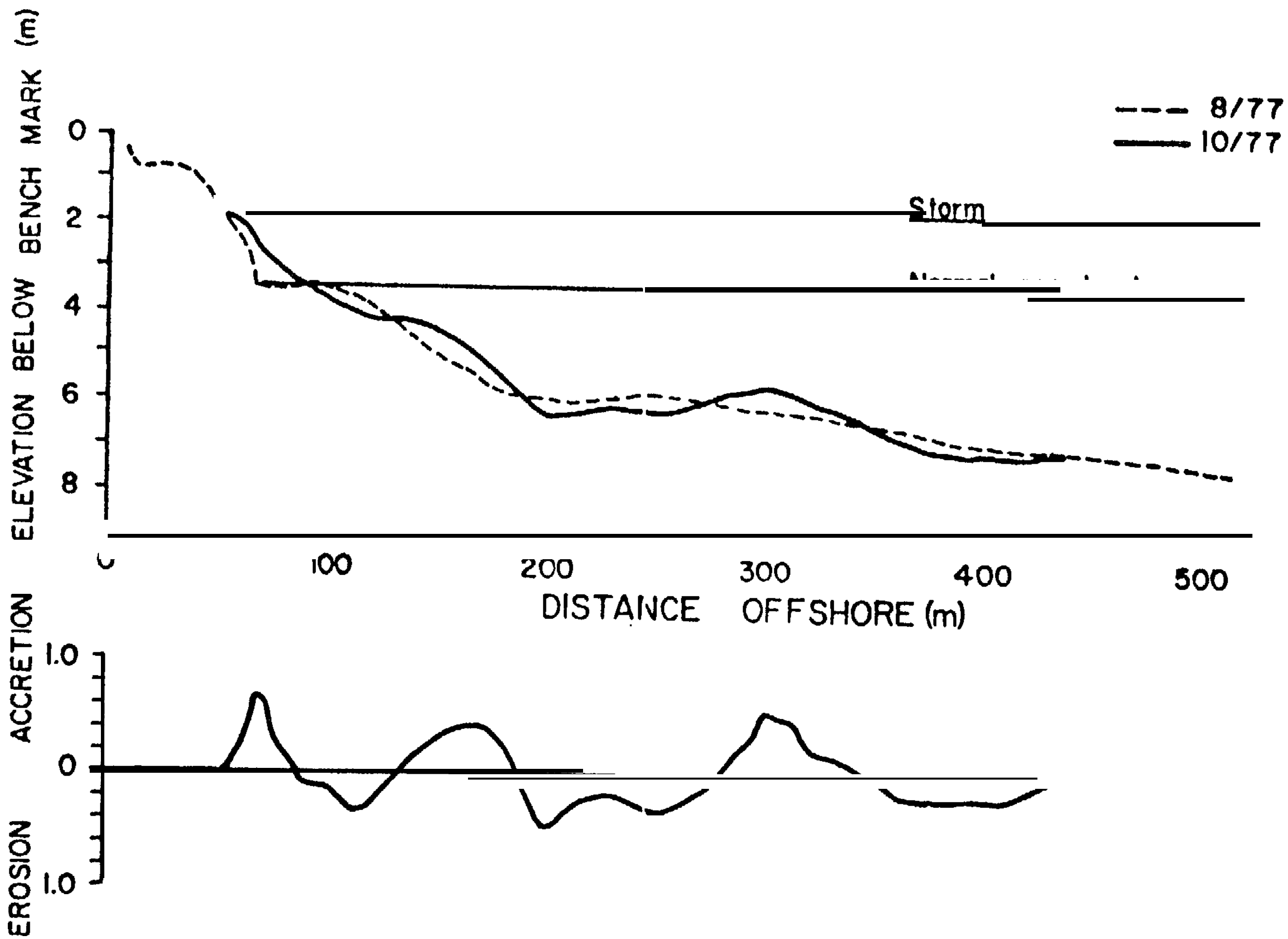


Fig. 10. Beach and nearshore profile comparison.

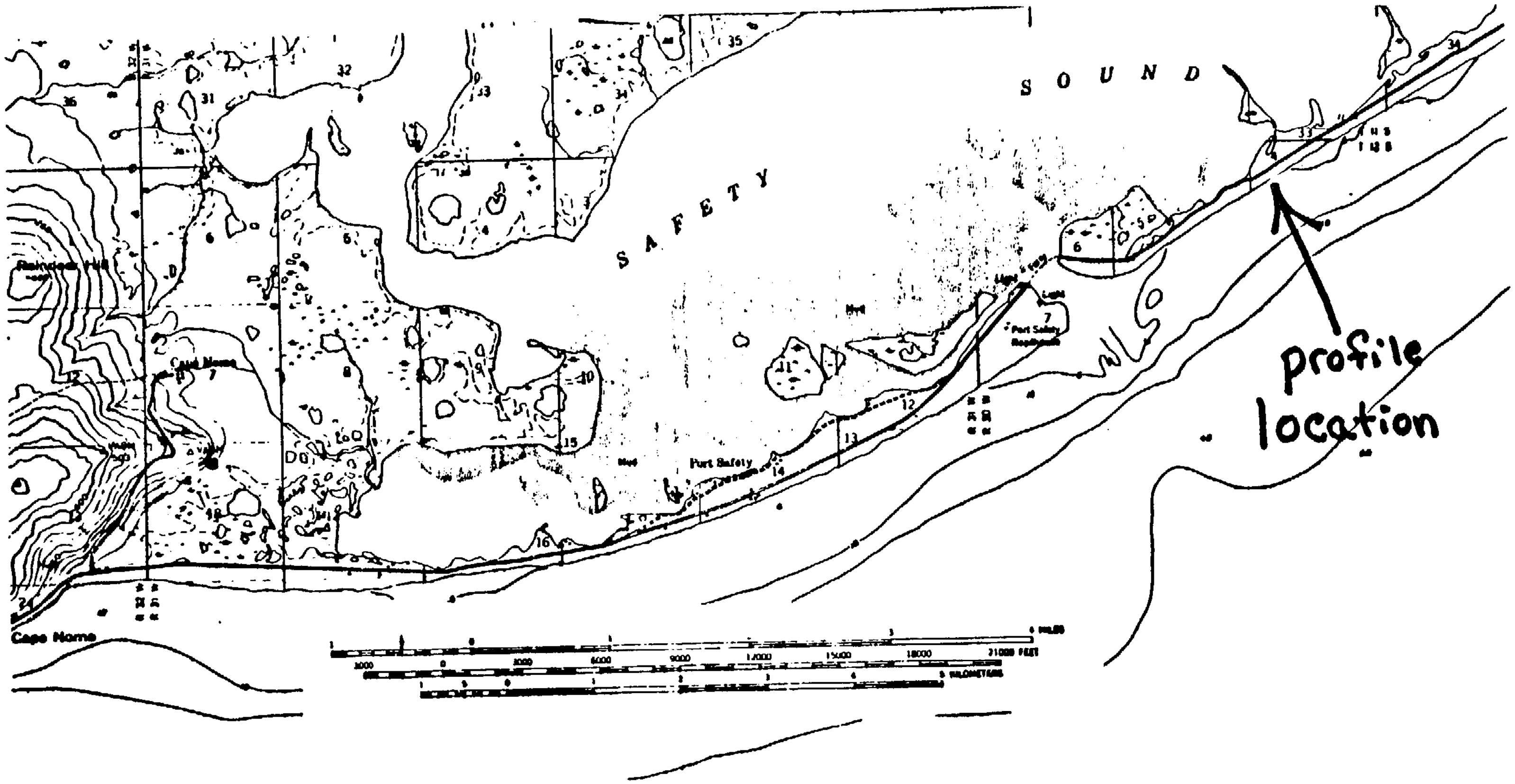


Fig. 11. Location of both profiles shown in figures 9 and 10. They are oriented normal to the shoreline and are 50 m apart.

This is not to imply, however, that coastal change occurs only during severe storms. Vertical aerial photography is available for 6/23/51, 7/13/51 and 7/30/51 for a portion of Safety spit (Fig. 2). Giant cusps spaced 1.7 km were observed on the 6/23/51 photography. These cusps were apparently formed as result of the severe November, 1950 storm as has been discussed earlier. A comparison of shoreline positions in the vicinity of the cusp horns is shown in Fig. 12. Winds were dominantly from the southwest during the period covered by the photography. Locally generated waves caused a net transport to the east along the coast. In response to this transport, the cusps migrated along the coast at 5-6 m/day. This migration caused as much as 50 m accretion at a given location over a period of several weeks.

COMPARISON OF BEACH CHANGES IN THE NOME-SAFETY LAGOON AREA TO OTHER BEACHES IN THE NORTHERN BERING SEA

Beaches in the Nome-Safety Sound area are composed of sands and pebbly sands, whereas most other beaches along the northern Bering. Sea coast are composed of coarser sediments (sandy gravels and coarser) (Sallenger, et. al., 1977). Examples of the coarse grained beaches are 1) the reach from the York Mountains (located in between Bering Strait and Port Clarence) to the entrance to Norton Sound, and 2) the east coast of Norton Sound.

The morphology of these coarse grained beaches is quite different than that of the finer grained beaches in the Nome-Safety Sound area 1) Giant cusps are generally absent so the response of these beaches can be considered a two dimensional problem relative to that of Nome-Safety Sound beaches. 2) Nearshore bars are generally absent. 3) These beaches are characterized by a very prominent storm berm (see Sallenger, et. al., 1977).

During the 1974 storm, these coarse beaches were built vertically to an elevation approximately equal to that of the storm-swash run-up. This was determined by comparing the elevations of debris lines, which approximate the elevation of storm run-up, "with post-storm berm crest elevations (Fig.13) . Under non-storm conditions, low wave heights (averaging approximately 30 cm) and the low tidal range (diurnal range is .5 m) essentially prevents the storm berms from being reworked. In fact, measurements of profiles located on coarse grained beaches at the beginning and end of the 1976 field season (a period during which no storms occurred) showed that there was essentially no change in the profiles, (Sallenger, et. al., 1977).

In the Port Clarence area, profiles were measured again during the 1977 field season. Comparative plots for two profiles are shown in Fig. 14 and Fig. 15 . The locations of these profiles are shown in Fig. 16. (Methods used in measuring profiles are given in an appendix following this report] Most of the change in beach elevation is confined to the mid and lower foreshore (most of the change for the backshore shown in B12 (Fig. 15) is spurious due to 1) the linear interpolation between data points and 2) the different densities of data

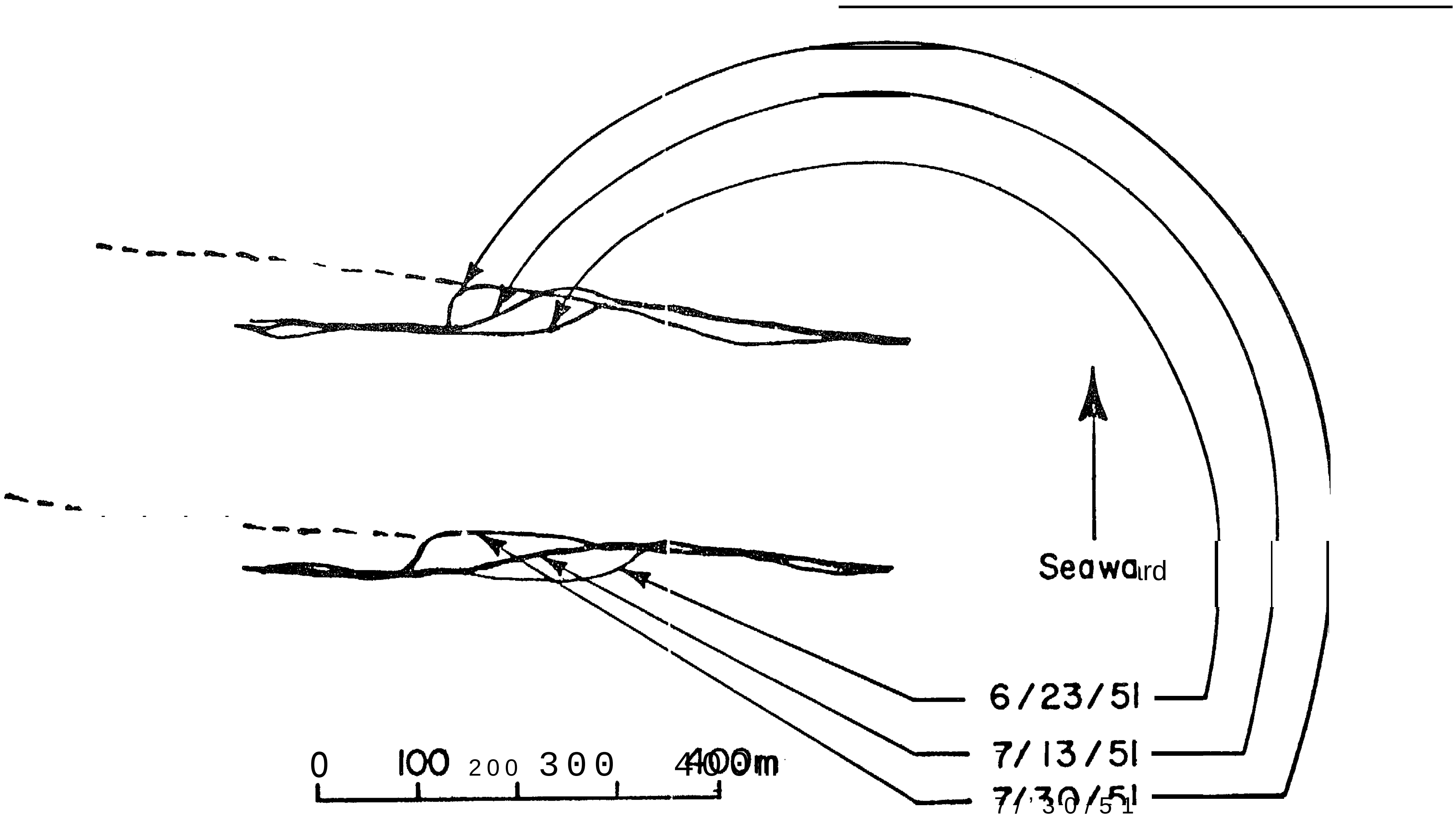


Fig. 12. Migration of giant cusps.

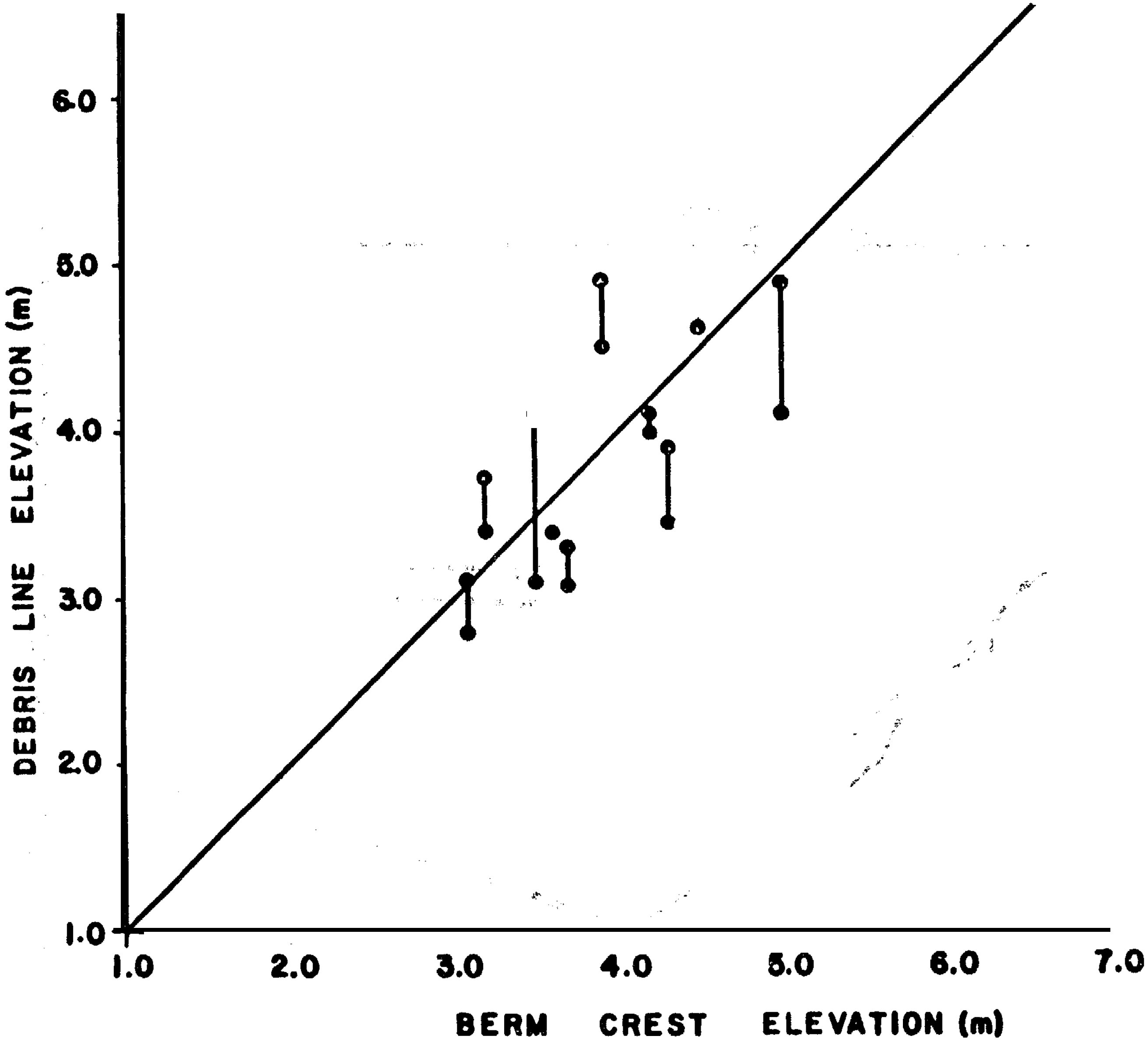


Fig. 13. line elevations plotted versus berm <rest elevations at the same locations.

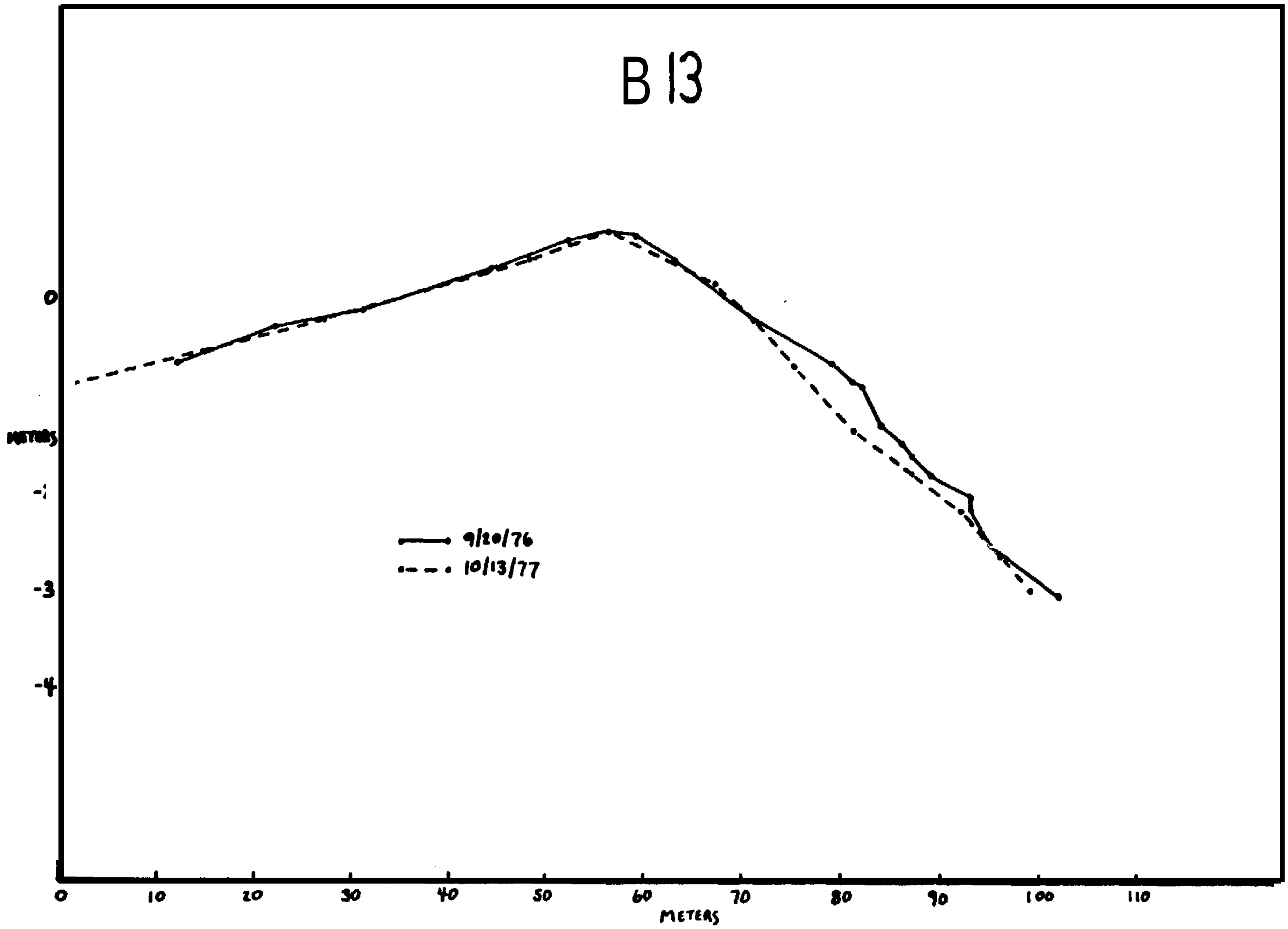


Fig. 14. Beach profile comparison from the Port Clarence area.

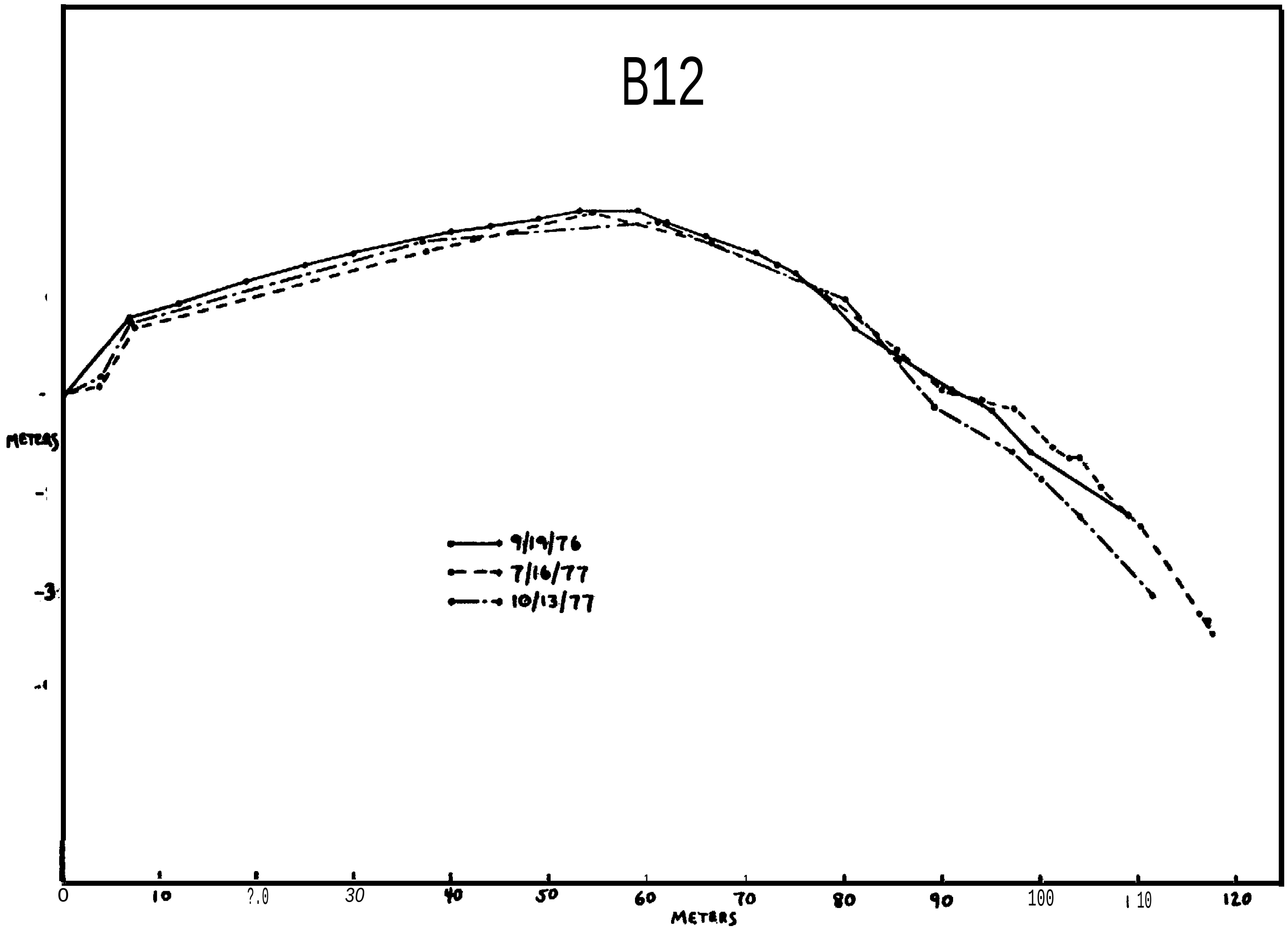


Fig. 15. Beach profile comparison from the Port Clarence area.

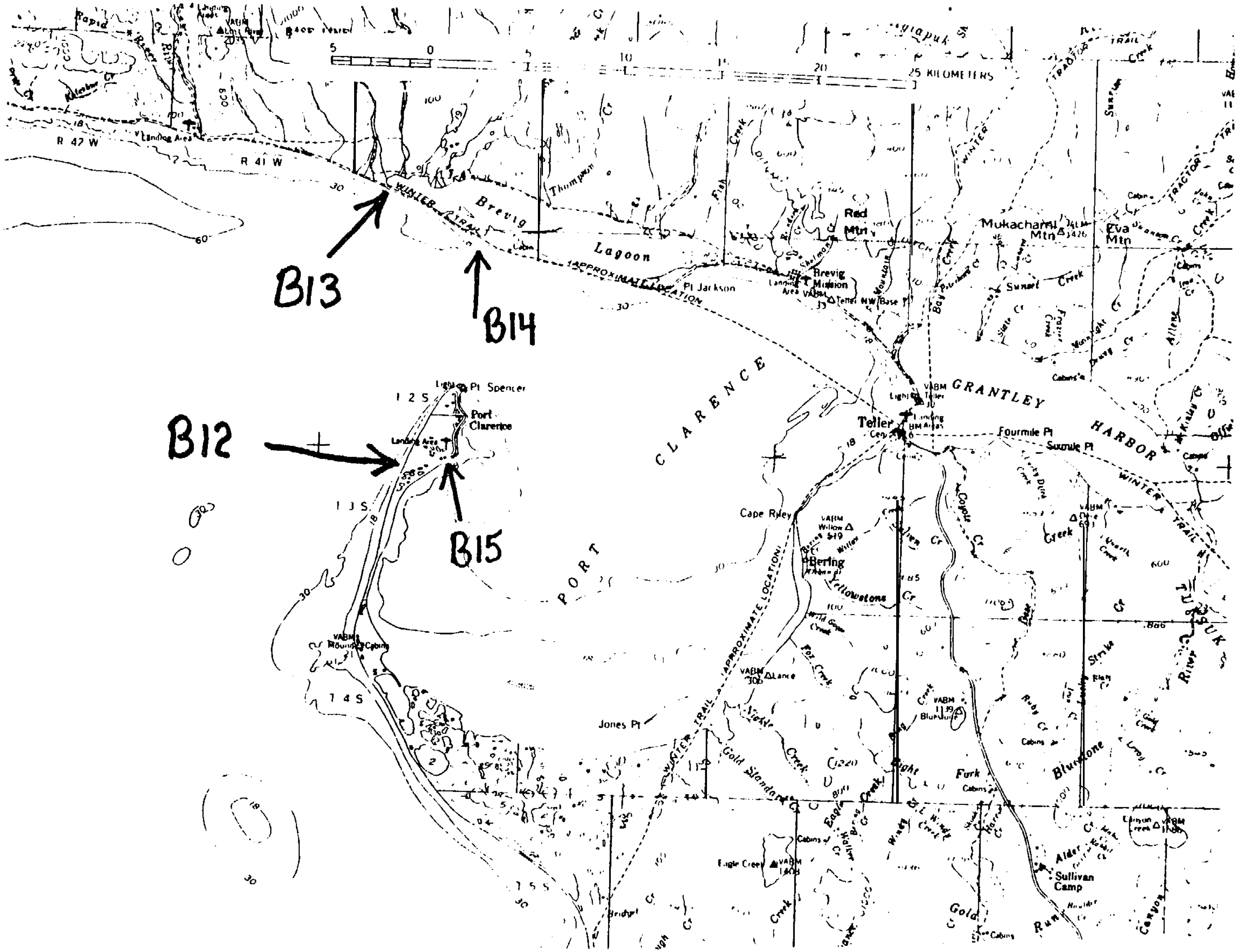


Fig. 16. Location of some of our Port Clarence area profiles. Locations of all profiles given in Sallenger, et. al., 1977.

on the backshore for different surveys). A relatively small amount of accretion is observed between the fall 1976 profile and the July 1977 profile (Fig. 15). This is probably a result of 1) ice foot formation during freeze-up of 1976 and 2) reworking by relatively small waves. Erosion of the foreshore is observed between the July and October 1977 profiles (Fig. 14 and Fig. 15). This is probably the result of the September, 1977 storm discussed in the previous section.

Large scale shoreline changes over short time periods, such as observed for the Nome-Safety Lagoon area, are not apparent for the coarse grained beaches (based on preliminary analyses of aerial photographs). This is due primarily to the absence of giant cusps along the fine grained beaches. The magnitude of long term change is, however, unknown.

COMPARISON OF BEACH CHANGES ALONG THE BRISTOL BAY COAST OF THE ALASKA PENINSULA TO THE NORTHERN BERING SEA COAST OF ALASKA

During our reconnaissance of the Bristol Bay coast of the Alaska Peninsula in September 1976, beach profiles were measured. Selected profiles south of Pt. Moller were remeasured during August, 1977.

Similar to the Nome-Safety Sound area, beaches south of Port Yeller are generally composed of sand sized material and giant cusps and nearshore bars are common (Sallenger, et. al., 1977). (Sediments, however, are volcanic rock fragments, whereas sediments in the Nome-Safety Sound area are primarily quartz and garnet sands)

In contrast to the coarse grained beaches of the northern Bering Sea, berm crests are between 1-2 m above mean higher high water (Sallenger, et. al., 1977). Wave energy appears to be higher along the southern portion of the Alaska Peninsula than Norton Sound (due to a greater effective fetch and deeper offshore bathymetry). Consequently, berms are probably reworked during spring tides, whereas berms of the coarse grained beaches in the northern Bering sea are reworked only during severe storms.

Examples of compared profiles are shown in Figs. 17-20. The locations of the profiles are shown in Fig. 21. Three of the profiles show erosion (Figs. 17, 19 and 20). The maximum amount of erosion is in excess of one meter. However one profile shows nearly 1 m of accretion. The same type of complex changes observed in the Nome-Safety Sound area (involving giant cusps) are probably also active in this environment.

In view of 1) the relatively high incident wave energy, 2) relatively frequent reworking of berms, and 3) analyses of compared profiles, beach changes appear to be much more dynamic along the southern Bristol Bay coast of the Alaska Peninsula than beach changes along the northern Bering Sea coast of Alaska. However, our data base is limited.

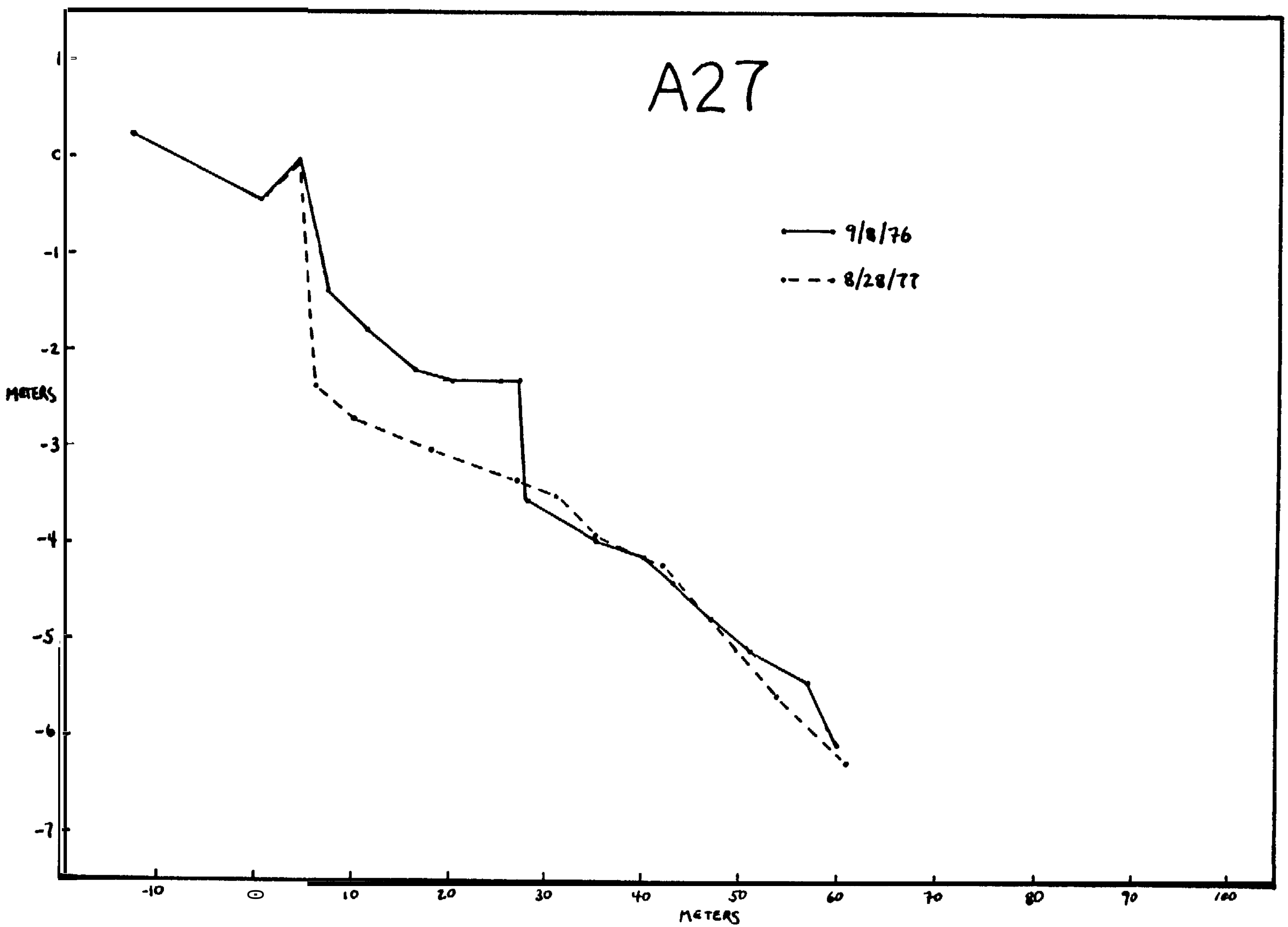


Fig. 17 Beach profile comparison from the Alaska Peninsula.

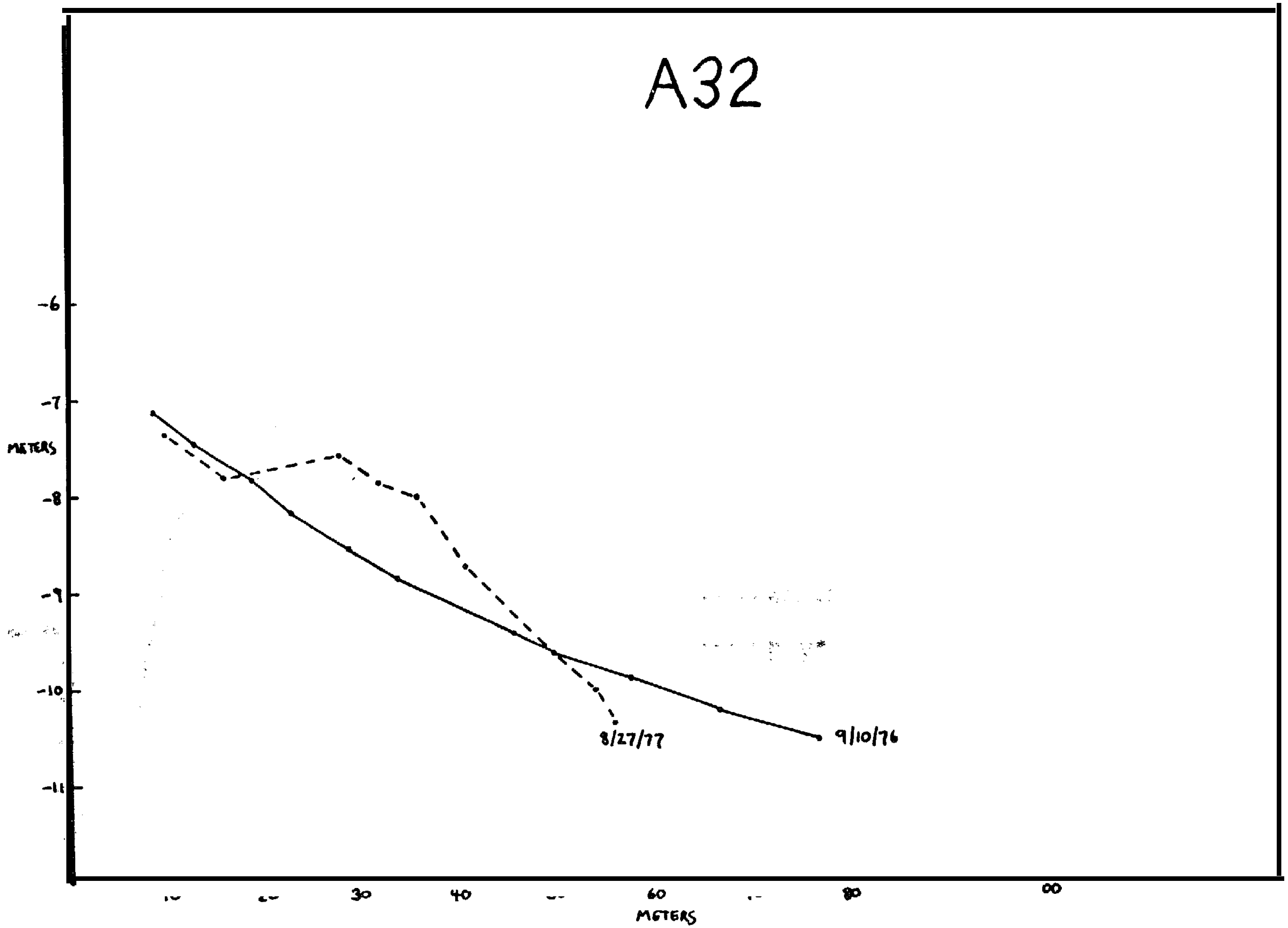


Fig. 18. Beach profile comparison from the Al Peninsula.

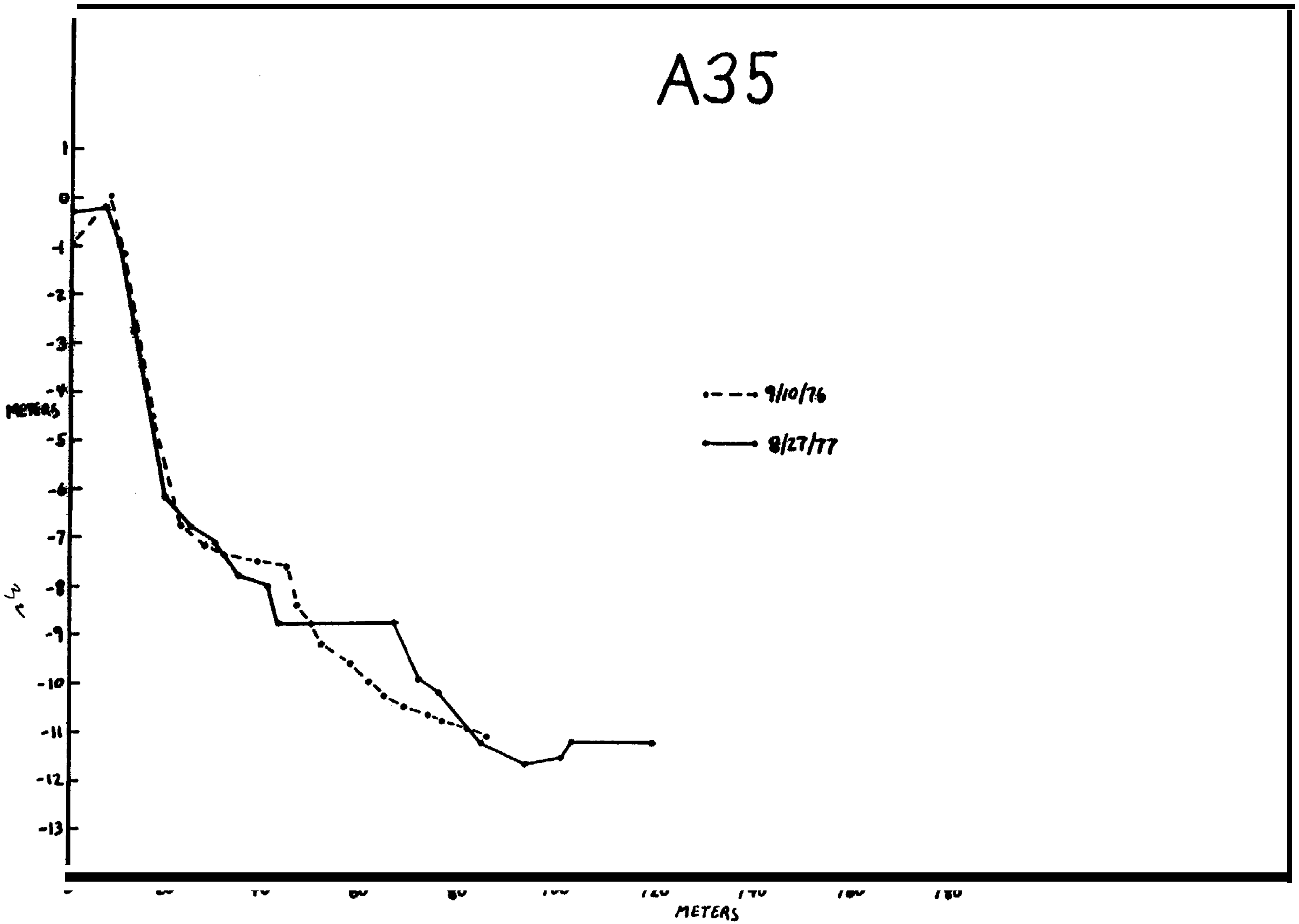
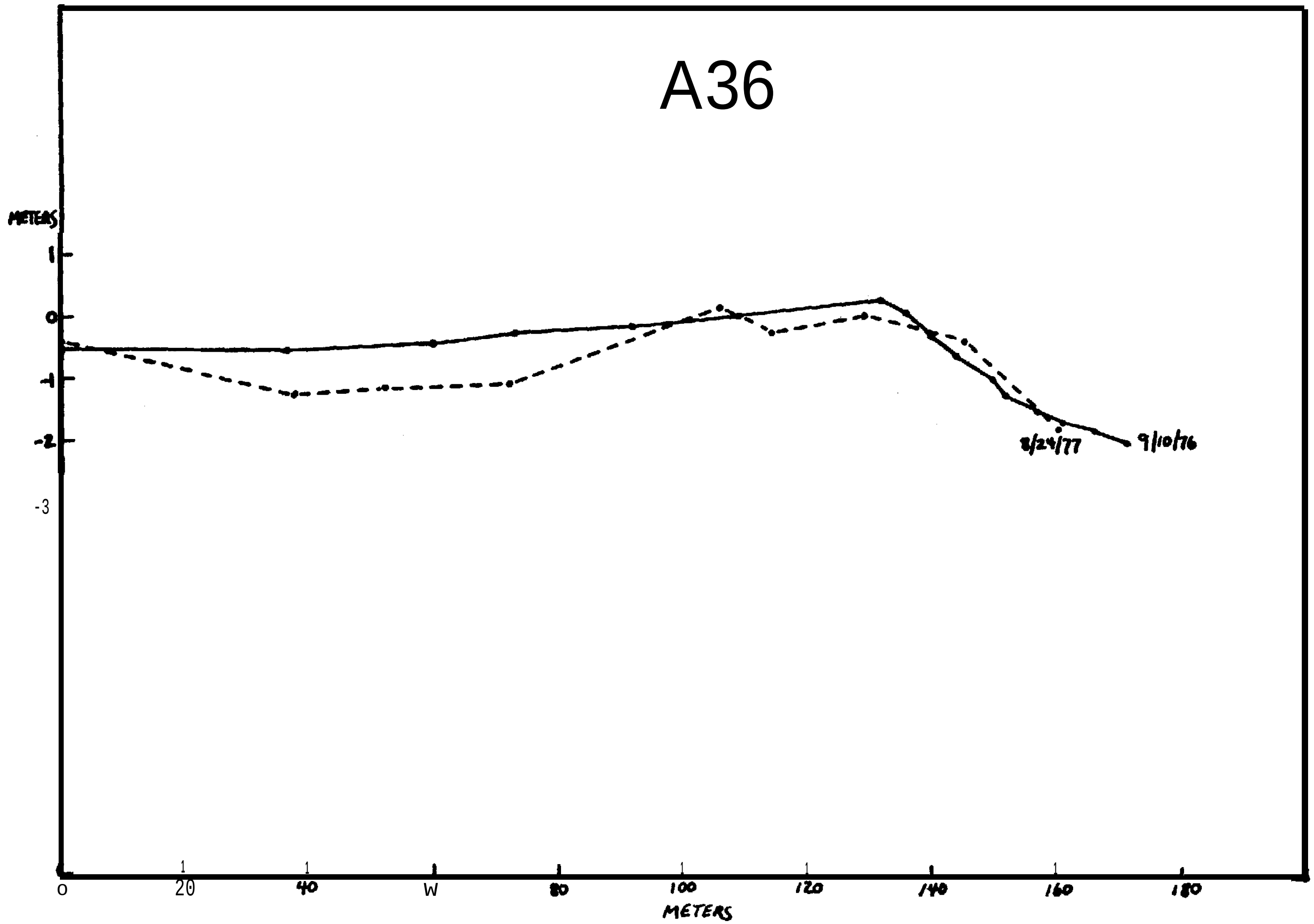


Fig. 19. Beach profile comparison from the Alaska Peninsula.



Fiq. 20. Beach profile comparison from the Alaska Peninsula.

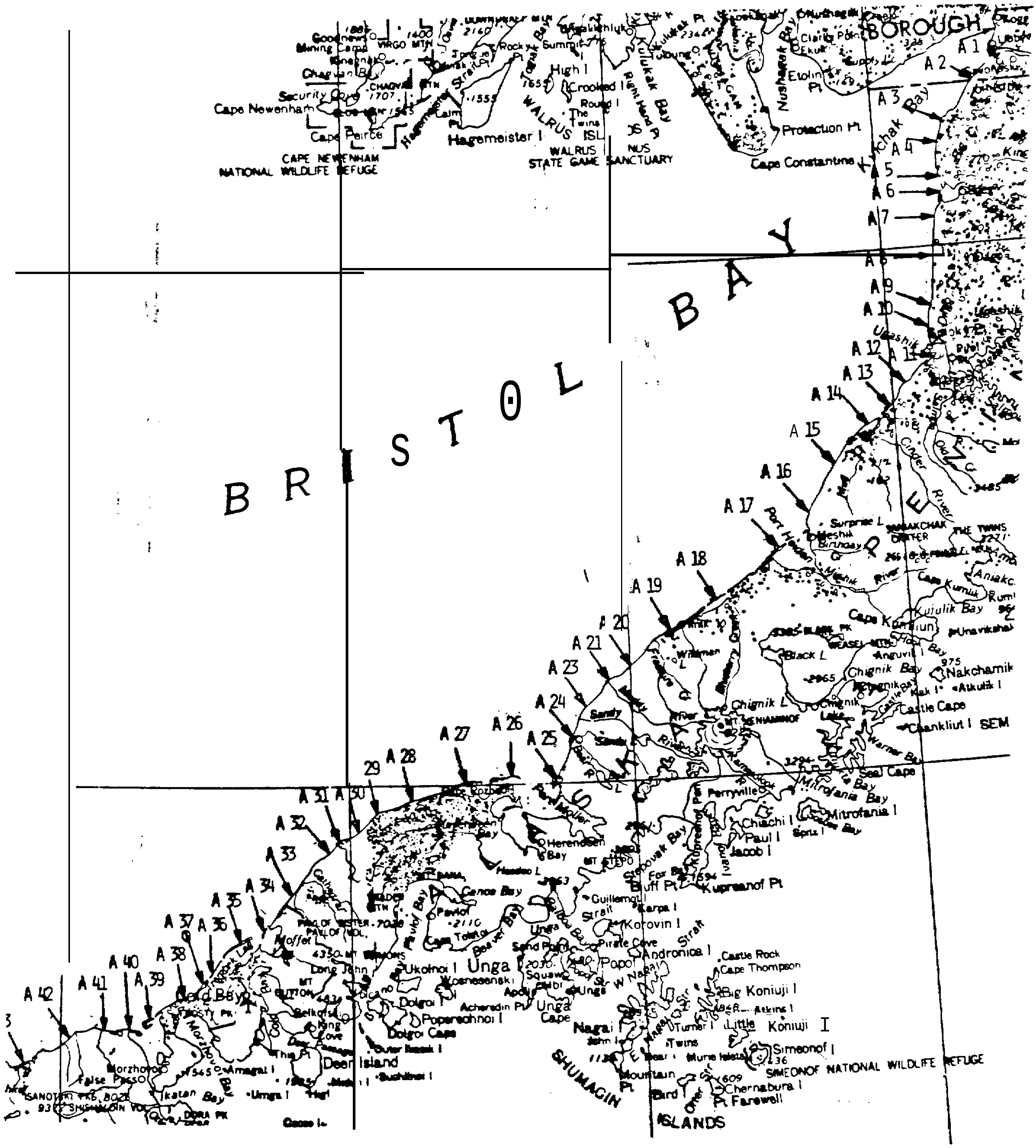


Fig. 21. Locations of Alaska Peninsula profiles.

APPENDIX

METHODS USED IN MEASURING BEACH AND NEARSHORE PROFILES

Because of the acquisition of new and more accurate instrumentation for the 1977 field season, different techniques were used in the 1976 and 1977 field seasons for measuring beach and nearshore profiles. (Note: in some locations, e.g. Alaska Peninsula, only beach profiles were measured) .

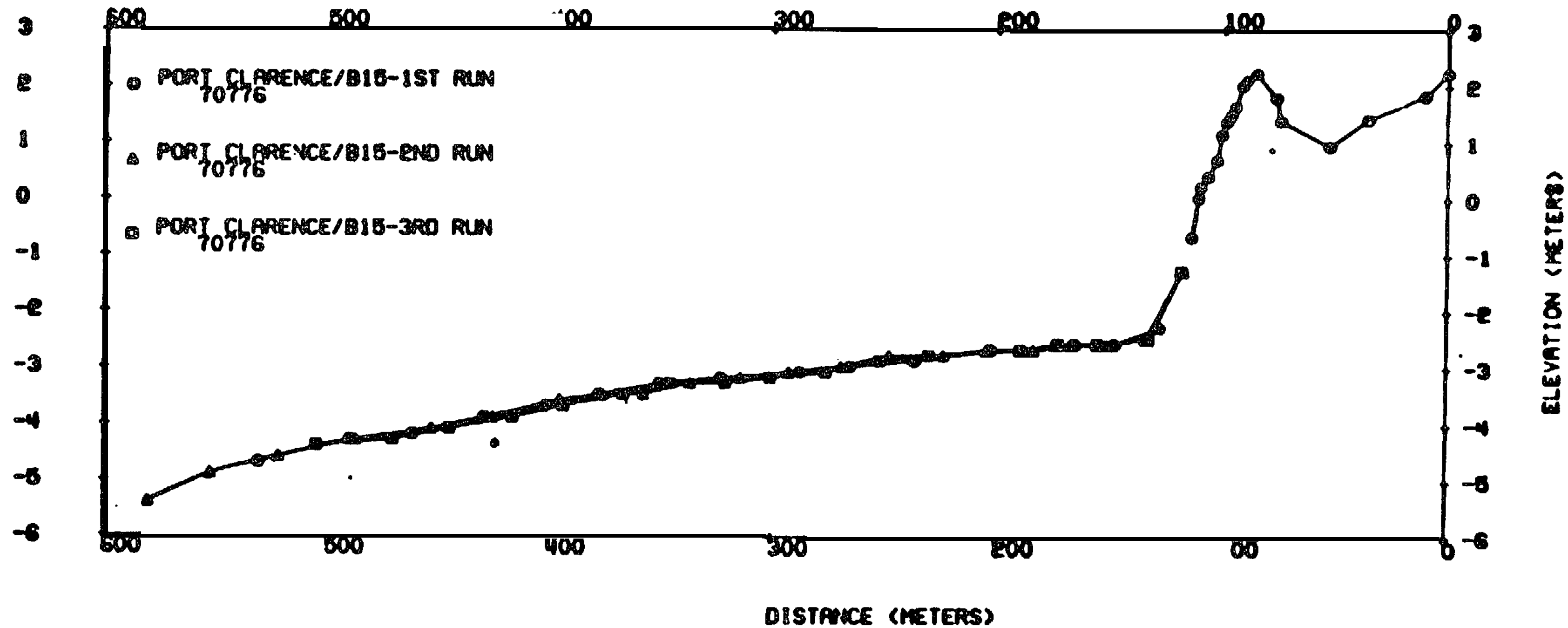
Methods used during 1976 field season

The onshore part of each profile was surveyed using a level and stadia rod. A permanent marker was driven into the ground at the shoreward end to each profile to permit reoccupation of the profiles on subsequent trips. Whenever possible, this stake was located behind the beach in the tundra to minimize the chance of loss. In all cases the stake height was measured so the profiles could be vertically referenced to a fixed point (the stake top) . A second stake was placed seaward of the reference stake to serve as a backup marker and to keep the stadia rod carrier on the profile line. Horizontal distances were obtained using special range finding cross hairs in the level. With this technique horizontal resolution is at least + 1 m at all distances. Elevations were read to 1 cm. The elevation—of sea level with respect to the level was measured and used to tie together onshore and offshore parts of the profile.

After the onshore profile was completed, two navigation flags were also placed on the profile line. One flag was located at the level (usually at the berm crest), and the other was (generally) placed near the water line. A perpendicular to the profile line was shot from the level to locate a third flag down the beach. This last flag was situated on the order of 100 m from the level. Then the boat, with precision fathometer mounted amidships, slowly ran at constant speed toward the beach using the two navigation flags to stay on course. At intervals of a few to tens of seconds the angle to the third flag was measured with a sextant and corresponding mark made on the fathometer record. During the first trip (1976 field season) offshore profiles were run in triplicate; on the second trip multiple passes were made only on occasion. Sextant readings were made to the nearest 10 minutes; resolution, therefore, varies with position along the profile line. The fathometer record can be read to 0.1 m when the sea is perfectly calm. Superimposed wave motion adds uncertainty to this reading because it is not easy to completely remove the wave component from the fathometer record. A comparison of three beach and nearshore profiles run at the same location on the same day is shown in Fig. 22. It is clear the method produced reproducible results.

Methods used during 1977 field season

Nearshore portions of a profile were monitored with a precision fathometer mounted in a 5.8 m inflatable boat powered by twin 40 h. p. engines. The electro-optical distance measuring capacity of the Total



BEACH PROFILES - NORTON SOUND, ALASKA

Fig. 22. Beach Profile number B 15 (near Port Clarence, Alaska): 7 July 1976 profile. Offshore portion taken in triplicate to determine reliability of the profiling technique. Origin of the x-axis is the onshore reference stake. Origin of the z-axis is sea level. Gap indicates break between onshore and offshore parts of the profile.

Station (Model 3801A; Hewlett-Packard) was used for positioning the boat on profile lines. The Total Station measured the horizontal distance to the boat as the boat moved shoreward along a profile line. The instrument has a range of 1.6 km under average conditions and an accuracy of ± (4.9 mm + 3 cm per 300 m) for slope distance and 30" for zenith angle. The horizontal distance is computed internally from slope distance and zenith angle. The onshore portions of the profiles were measured using the vertical and horizontal distance capabilities of the Total Station.

B. WAVE CHARACTERISTICS DURING THE NOVEMBER 1974 STORM IN THE NORTHERN BERING SEA

Asbury H. Sallenger

Swell waves undergo extensive refraction and frictional dissipation as they propagate across the wide, shallow continental shelf of the northern Bering Sea. For example, eight-second swell waves, moving northeast from the southern Bering Sea, will begin to be influenced by the bottom nearly 300 nm south of Nome (Fig. 23). Thus, sea waves, those in the process of generation, dominate the coastal wave climate. During storms, these sea waves can apparently build to relatively large dimensions and the shallow shelf contributes to storm surges of large magnitude. For example, during a storm in November 1974, waves were reportedly 3 to 4 m at Nome and debris lines were left nearly 5 m above mean sea level in the Unalakleet area (see Sallenger, et al., 1977 and section V A of this report).

I have attempted to simulate the wave characteristics during the 1974 storm using the refraction program developed by Dobson (1967) and modified by Thrall (1973) to include the effects of continuous wave generation. To some extent, Thrall (1973) followed the computer logic outline by St. Denis (1969). I have modified the program further by incorporating the effects of frictional dissipation using the method of Bretschneider and Reid (1954).

The program is based on linear small-amplitude progressive wave theory. This leads to the following assumptions. 1) Wave amplitude is small relative to wave length. 2) Wave profile can be approximated by a sinusoid. 3) Flow is two-dimensional, irrotational, in viscid, incompressible, and fluid is of constant density. Other assumptions are: 1) bottom contours are smooth; 2) energy is not transmitted along wave crests; 3) water surface is a plane; 4) diffraction and reflection are negligible; 5) friction factor is equal to .01.

Inputs into the computer program were: 1) a 4.2 nm grid of depths of the northeastern Bering Sea, and 2) initial fetch length, wind velocity, and wind direction as determined from surface pressure weather charts. The initial fetch length was sufficiently small so that the waves would initially be in deep water (i.e., the ratio of water depth and wavelength was less than .5). The program propagates waves across the shelf to the shoreline in discrete increments incorporating the effects of refraction, shoaling, bottom friction, and wave generation.

Two conditions are presented: 1) southerly winds at 47 knots at 1800 BST on November 11, 1974 (interpolated from weather charts) and 2) south westerly winds (200°) at 57 knots at 0100 BST on November 12. As a first approximation, the increase in depth over the shelf due to storm surge was considered uniform. Two meters and three meters were used for condition 1 and 2, respectively. For each condition, waves were propagated over the maximum fetch length indicated on the respective surface pressure charts. This assumes that the fetch length and wind characteristics were fixed in time and space. Thus, results should provide the maximum wave heights that should result from an individual

Fig. 23. Contours showing where waves of a given period will begin being influence by the bottom (contours in seconds).

condition. One could change the wind velocity and direction in increments as the waves are propagated (that is, as the storm moves northward) . This, in many cases, would decrease the wave height since the wind would no longer be blowing parallel to most orthogonal. As will be shown, this exercise did not appear to be warranted, since the resulting wave heights appeared to be lower than what was observed in nature even when using the maximum condition.

Plots of wave orthogonal (lines which are everywhere normal to wave crests) for the two conditions are shown in figures 24 and 26. An interesting feature of both these plots is the extensive convergence of orthogonal offshore of the Yukon Delta (see the areas where four adjacent orthogonal abruptly terminate) . Here one would expect relatively large wave heights and confused seas which may pose hazards to navigation.

Wave heights along the shoreline for these two conditions are shown in figures 25 and 27. In figure 25 (wind 47 knots) wave heights reach a maximum of ≈2.5 m near the Bering Strait and then decrease to about one meter in the Nome area. For the higher winds (57 knots, fig. 27) wave heights in the Nome area were 2 m in height which, as expected, is substantially larger than those for condition 1, but is significantly lower than wave heights reported for Nome during the storm (≈3-4 m).

It is very difficult to obtain an accurate measurement of wave height from the shore by visual means alone. Thus, the difference in computed versus observed wave heights may not necessarily indicate a problem with the model. However, models such as the one used here have not, to my knowledge, been verified. This is particularly true, I believe, for the case of waves undergoing bottom influences and wave generation, simultaneously, over relatively long distances and shallow depths. Clearly, more field measurements are needed to substantiate these shallow water wave models. Changes may be required in both the basic equations and in the computer logic (i.e., how and in what sequence the equations are applied] . We have obtained some wave measurements in the Nome area (see section V C of this report) . Unfortunately, these were under relatively low energy conditions. There is a need for measurements both along the coast and in deep water under high wind (and well defined fetch) conditions.

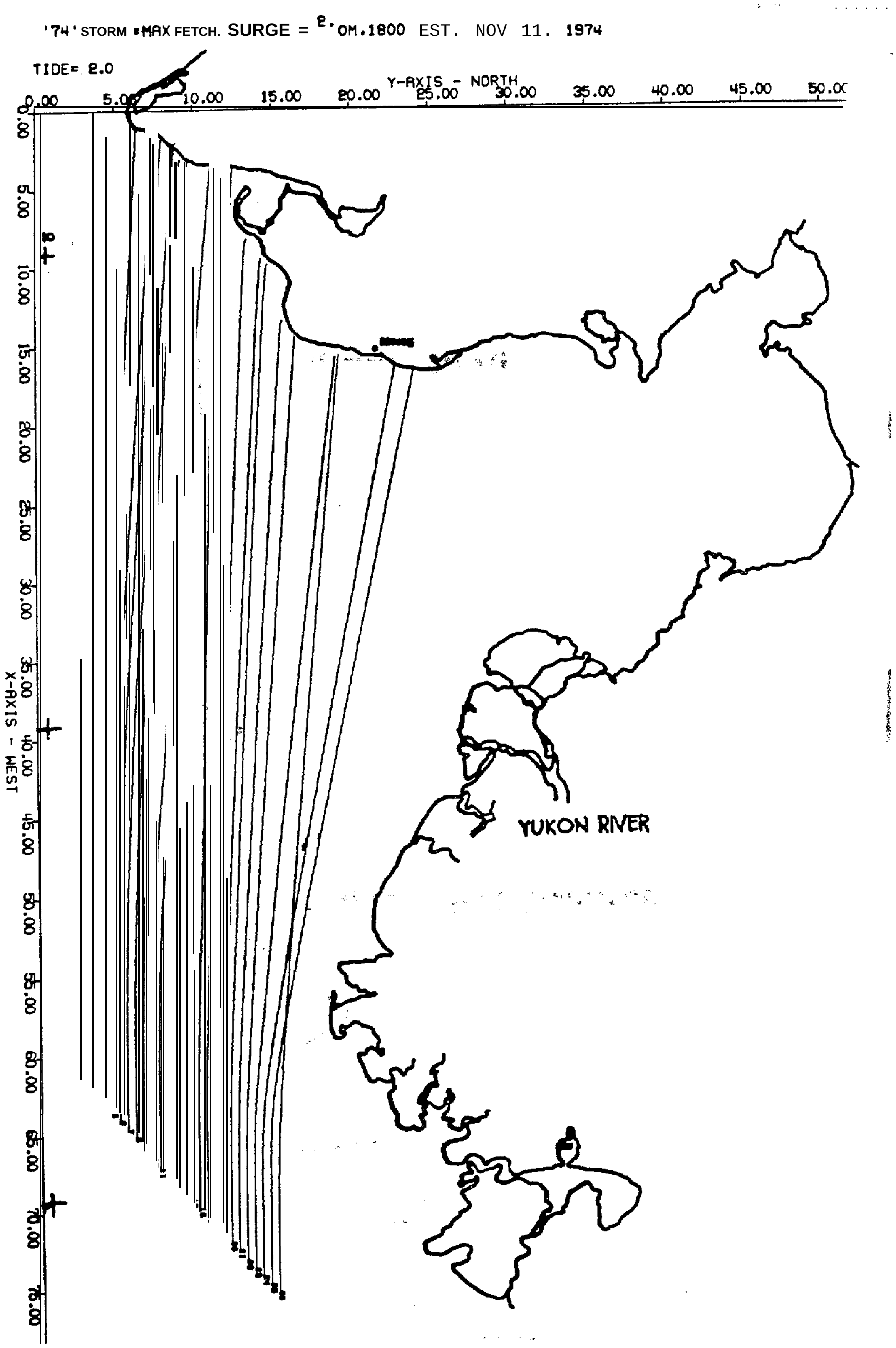


Fig. 24. Plot of wave orthogonal for condition 1 (see text).

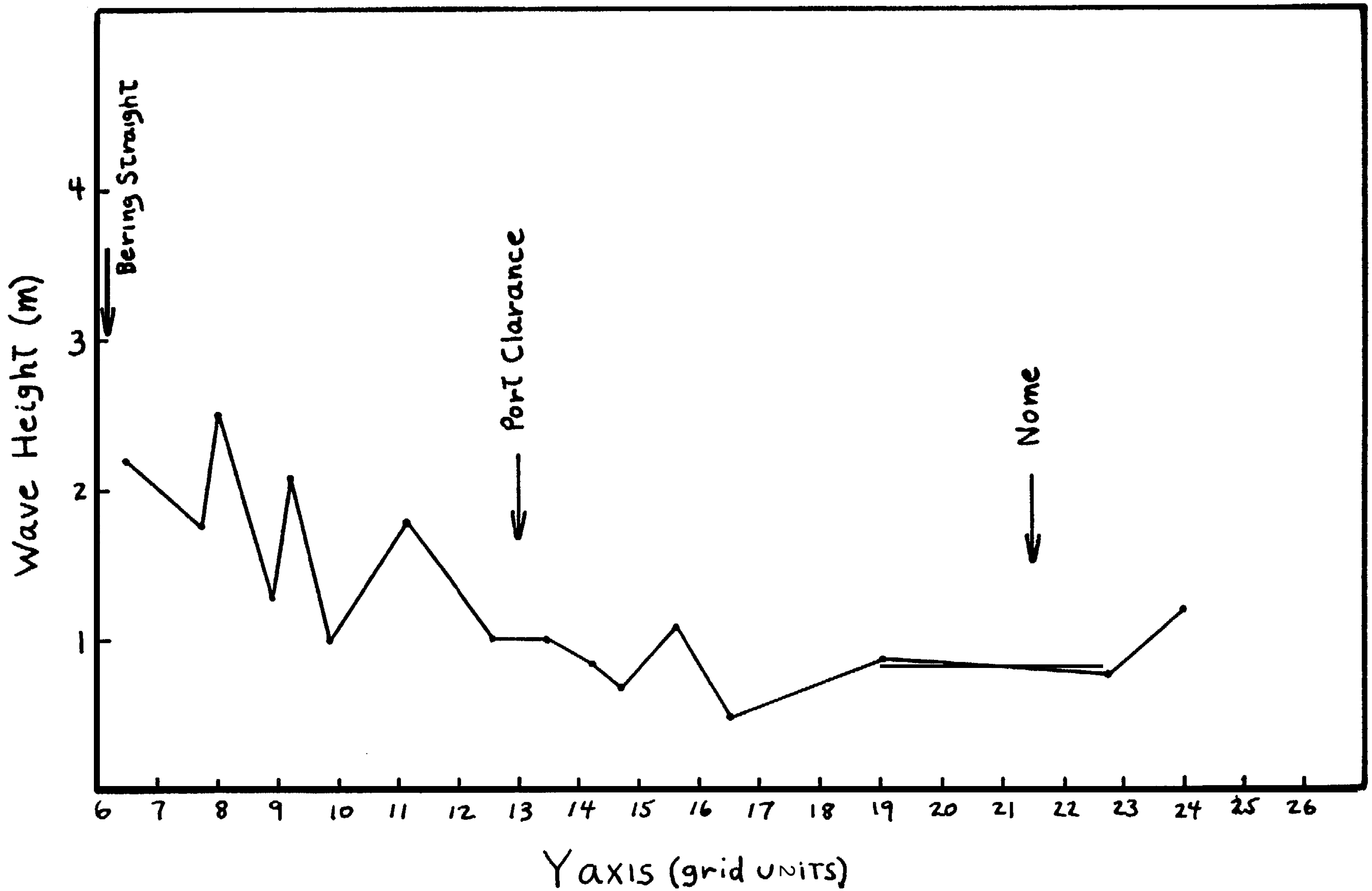


Fig. 25. Plot of computed wave heights along the shoreline for condition 1. Shoreline position is the intercept of the y-axis given here with the shoreline in fig. 24.

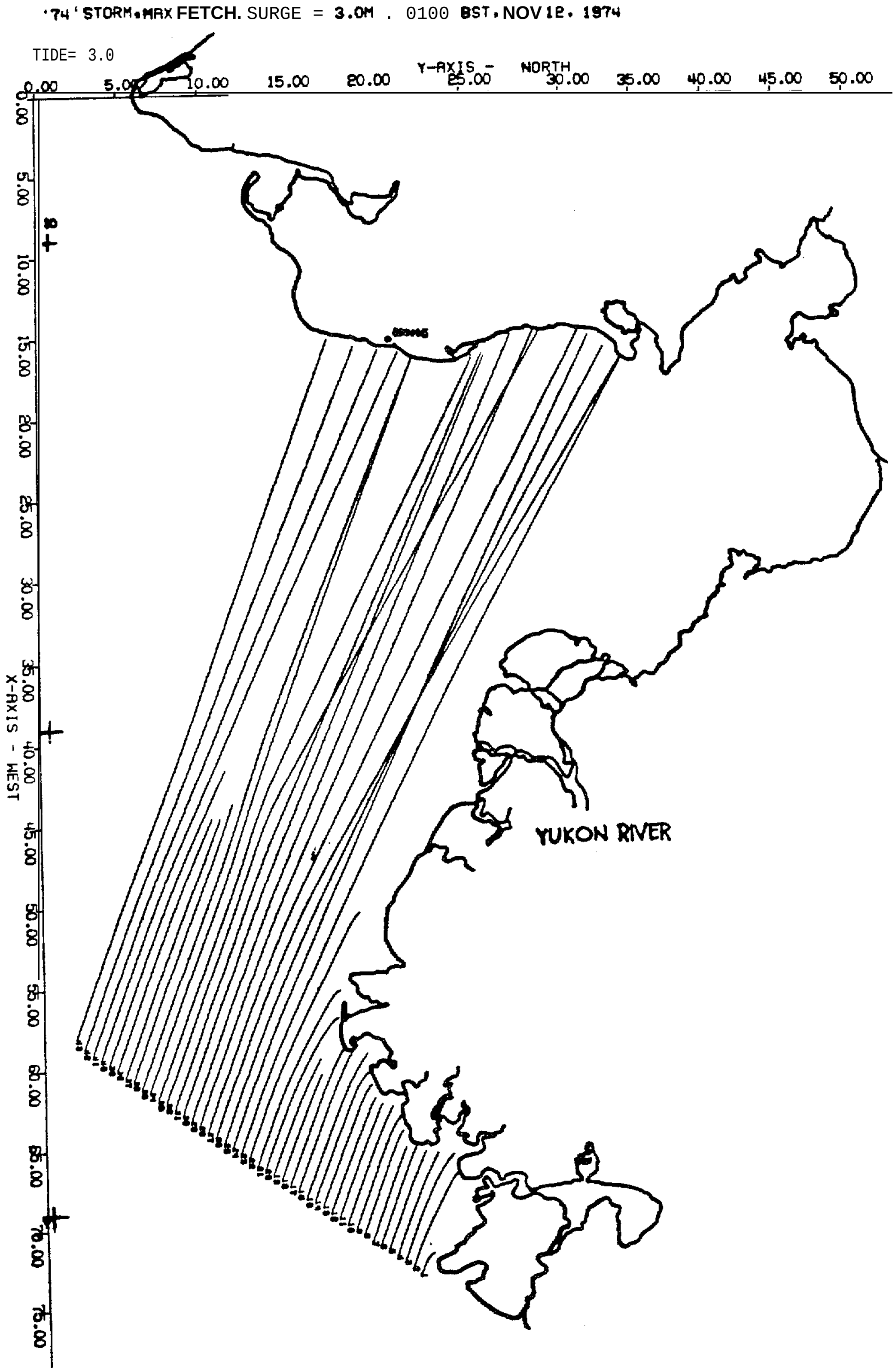


Fig. 26. plot of wave orthogonal for condition 2 (see text).

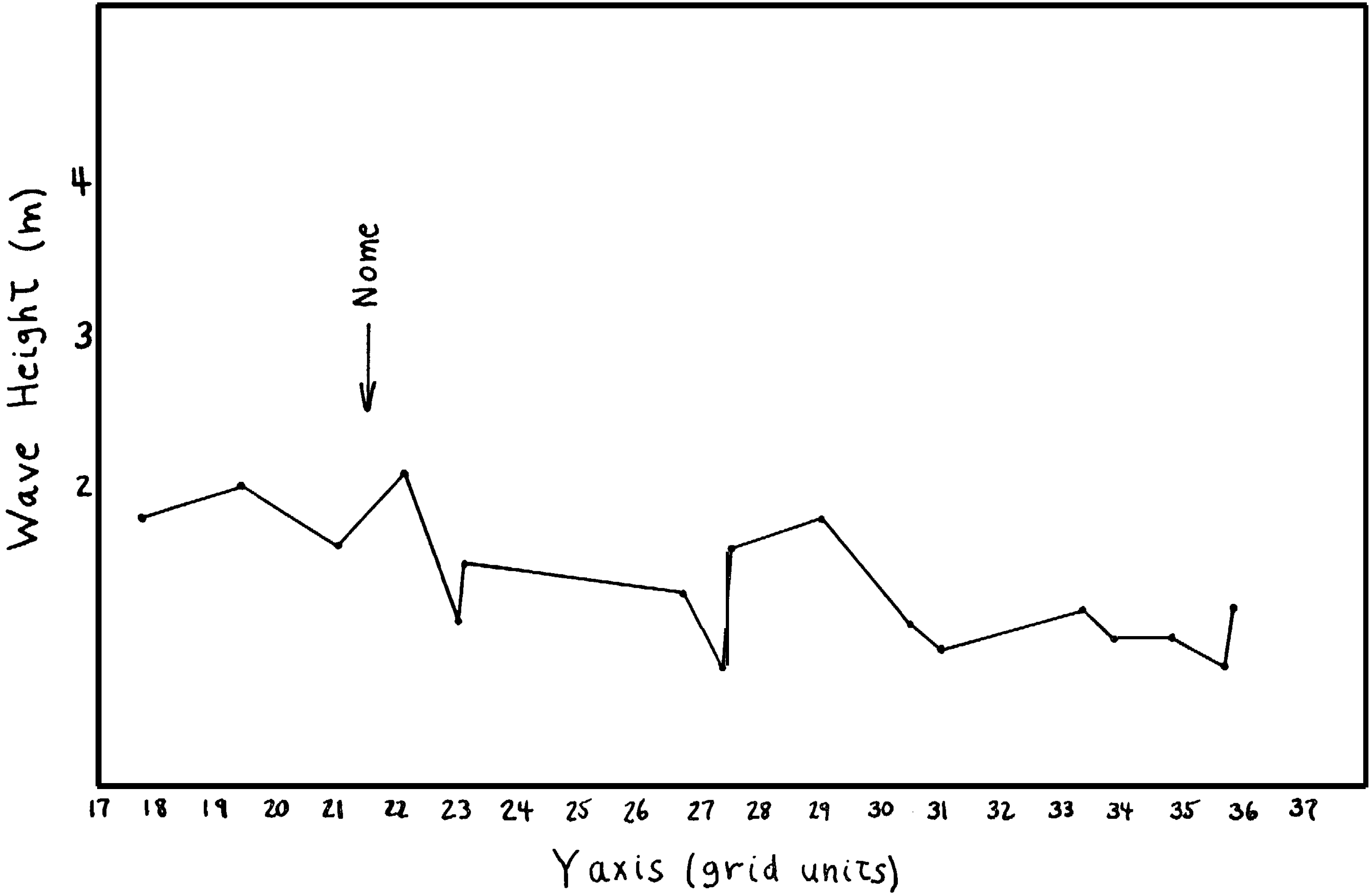


Fig. 27. Plot of computed wave heights along the shoreline for condition 2. Shoreline Position is the intercept of the y-axis given here with the shoreline in fig. 26.

WAVE MEASUREMENTS AND ESTIMATES OF WAVE-GENERATED LITTORAL TRANSPORT; NOME, ALASKA

John R. Dingier

None, Alaska is located on the coast of Norton Sound, a shallow arm of the northern Bering Sea (Figure 1). Because the area is remote, very little is known about local coastal processes. Recently, however, research in the region has increased dramatically in conjunction with the possibility of large-scale oil exploration and recovery. The purpose of this part of OCSEAP Research Unit 431 was to determine wave conditions and sediment transport rates in the nearshore during the ice-free months. It was hoped that the study period would include both fair and stormy weather, but only fair weather conditions were monitored the first field season (1977). The following season's field work was cancelled because of a paucity of funds.

The position of land forms around the Bering Sea (Figure 1) strongly suggests that most waves reaching the Nome area will be generated either locally or in the southern Bering Sea. Although waves could reach the area from the Pacific Ocean, the Aleutian Islands probably absorb most of that wave energy. The location of St. Lawrence and Nunivak Islands further restricts the amount of wave energy reaching None; only waves approaching from directions betweeen 193° and 229°N will be able to enter Norton Sound.

Wave generation depends on three factors: wind speed, wind duration, and fetch. During the summer, measurements taken by the Corps of Engineers in Nome showed that wind speed was low and direction variable. This means that most locally generated waves will have short periods and small heights since fetch lengths are short except from the south.

During July and August, 1977, wave pressure measurements were made in 7 m of water near Nome in order to determine the littoral transport rate along the adjacent coastline (Figure 2). Data were collected from a four-sensor array and transmitted to a shore-based recording station using a Shelf and Shore (SAS) System (Lowe, et al, 1973). The SAS System operated every six hours, and a total of 796, 10 minute time series were recorded at four series per transmission (Table 1). A scan of the time series showed that the wave period was generally short and wave height low during the study period, but that occasional higher energy events occurred (Sallenger, et al, 1978).

Spectral analysis of 183 of the raw data records produced 420 wave trains (spectral peaks) for which wave period, height, and direction were calculated (Table 2). Peak wave periods ranged from 3.9 to 18 sec with a median of 6.7 sec. Wave heights ranged from 2 to 162 cm with a median of 16 cm. The total wave energy for each record, which was obtained by averaging the appropriate Fourier coefficients from the four sensors, ranged from 8 to 5500 cm^2 with a median of 130 cm^2 (Table 1).

Wave trains approached the study site from directions between 126° and 229°N (Figure 3). Waves of periods greater than 6 sec almost exclusively came from the window between the two islands (236 out of 259 wave trains), whereas shorter period waves came from a wider range of directions (only 63 out of 167 wave trains came from within the window). This wave pattern is reasonable, given the location of Nome and the summer wind patterns in the area. Locally generated waves, which come from a wide range of directions, are short in period: Longer period waves originate in the southern Bering Sea or, perhaps, in the Pacific Ocean.

The littoral transport rate, the rate at which sediment moves alongshore inside the surf zone is readily estimated from spectral wave parameters. The sediment transport rate, for reasons listed in Komar (1976, p. 206), is expressed here as an immersed weight transport rate I_1 and is given by

$$I_1 = K(ECn)_b \sin\alpha_b \cos\alpha_b . \qquad (1)$$

In Equation 1, K is a dimensionless proportionality Coefficient equal to 0.77, E is the wave energy, Cn is the wave group velocity, α is the angle between the wave crest and a line parallel to the shoreline. and b is a subscript that denotes breaking wave conditions. The equation

$$I_1 = (\rho_s - \rho) g a' S_1 \qquad (2)$$

relates I_1 to the longshore volume transport rate of sand S_1. In Equation 2, ρ_s is the sediment density, ρ is the fluid density, g is the acceleration of gravity, and a′ is a correction factor for the pore space of the beach sand (taken as 0.6).

The computer, using wave parameters at the array, calculated I_1 for each of the 420 peak frequencies. The wave trains were not refracted to the breaker zone; in this situation, using wave parameters at the array does not change I_1 within experimental error. For the 420 wave trains, I_1 ranged from $-7.5*10^8$ to $7.2*10^7$ dynes/see with eastward transport ocurring 78% of the time. The average sediment transport rate for the summer was $1.3*10^6$ dynes/sec toward the east. Easterly transport is consistent with the transport direction determined from the coastal morphology that was observed by other members of this group.

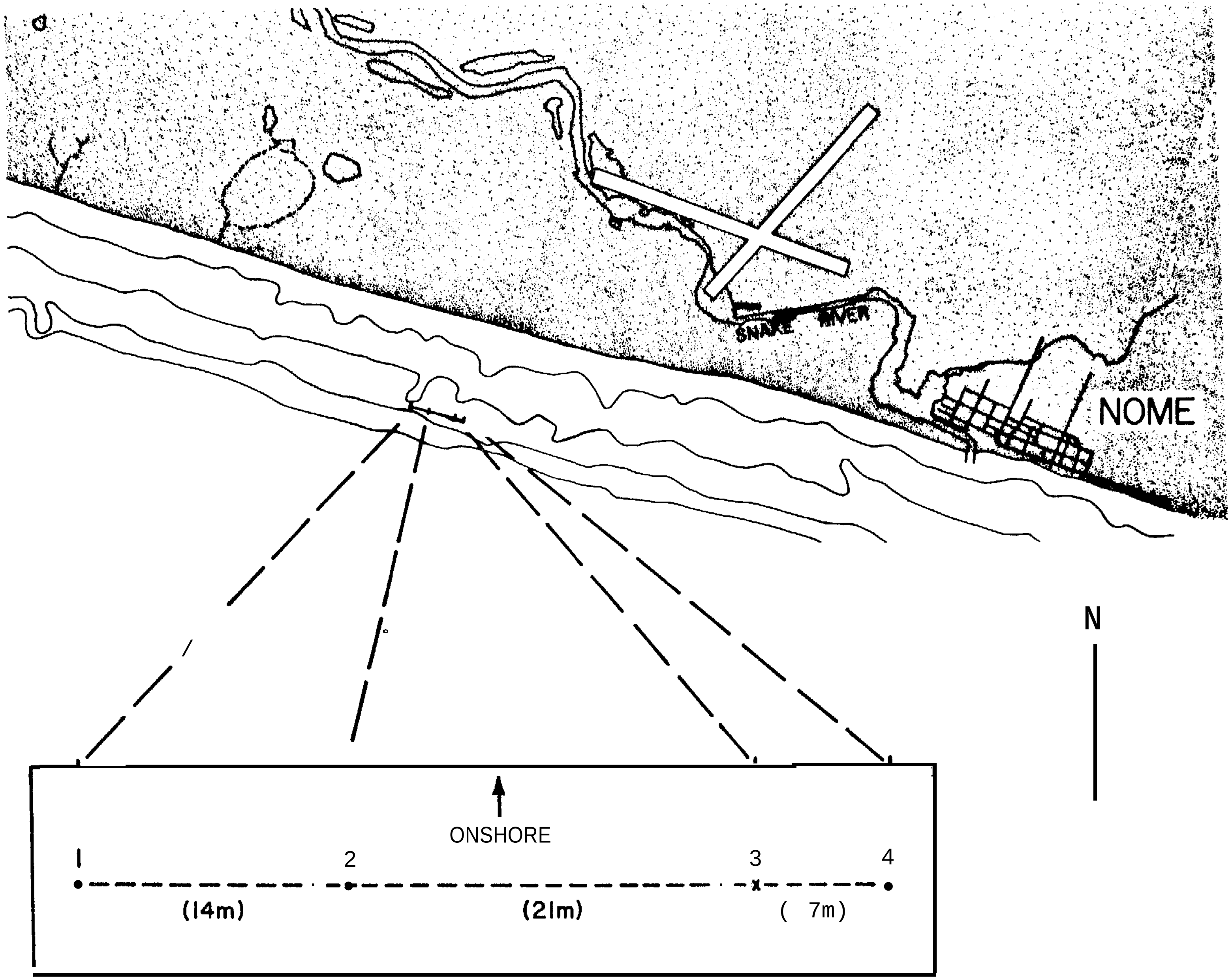


Figure 28. Wave array location relative to Nome, Alaska. Insert shows sensor locations with the "x" representing the spar location.

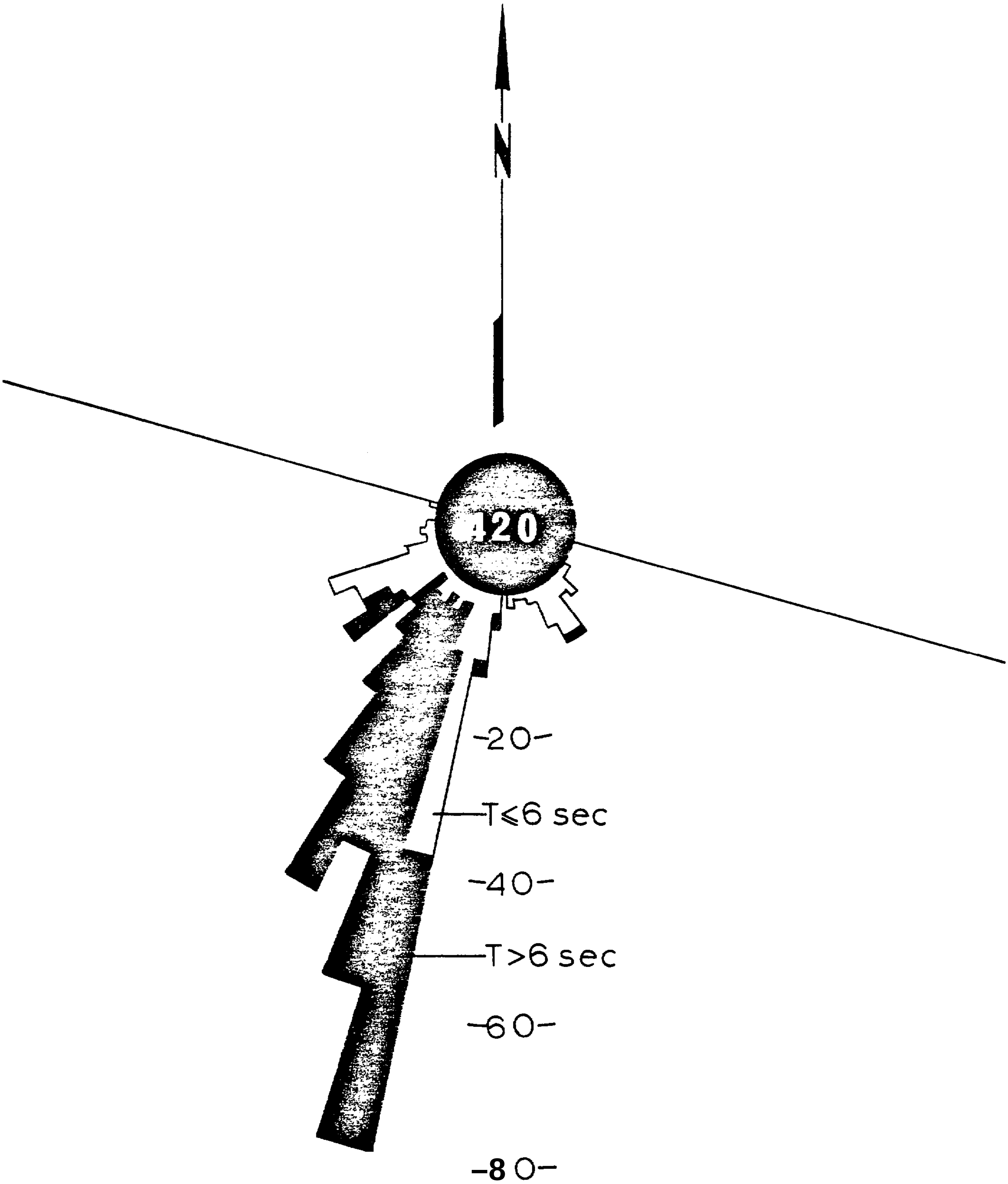


Figure 29. Rose diagram for wind directions as a function of period. Solid line at 106°N represents the array and shoreline orientation.

TABLE 1

Summary information for the 200 transmissions during July, August and September, 1977. Empty spaces in the last two columns mean that wave spectra were not run.

Column headers:

= Experiment number

D = Date

T = Time (Bering Standard Time)

h = Mean water depth (cm)

E_T = Average total energy for the four sensors (cm^2).

NO.	DATE	TIME (BST)	h (cm)	'T (cm^2)
N001	9JUL77	1630	716	15
N002	9JUL77	2230	700	16
N003	10JUL77	0430	716	26
N004	10JUL77	1030	674	30
N005	10JUL77	1630	707	42
N006	10JUL77	2230	707	87
N007	11JUL77	0430	712	55
N008	11JUL77	1030	691	27
N009	11JUL77	1630	719	22
N010	16JUL77	0040		
N011	16 JuL77	0640	707	1610
N012	16JUL77	1240	696	3416
N013	16JUL77	1840	713	118
N014	17JUL77	0040	731	149
N015	17 JUL77	0640	701	103
N016	17JUL77	1240	694	78
N017	17 JUL77	1840	705	174
N018	18JuL77	0040	729	138
N019	18 JUL77	0640	698	76
N020	18JUL77	1240		
N021	18 JuL77	1840		
N022	19JUL77	0040	741	251
N023	19 JUL77	0640	696	44
N024	19JUL77	1240		
N025	19 JUL77	1840	698	4260
N026	20JUL77	0040	737	235
N027	20JuL77	0640	703	158
N028	20JUL77	1240		
N029	20JUL77	1840	716	130
N030	21 JUL77	0040	754	149
N031	21 JUL77	0640		
N032	21 JUL77	1240	712	47
N033	21 JUL77	1840	699	35
N034	22 JUL77	0040	743	37
N035	22JUL77	0640	706	1028
N036	22 JUL77	1240	708	8
N037	22JuL77	1840	700	9
N038	23 JUL77	0040	726	12
N039	23JuL77	0640	694	16
N040	23 JUL77	1240	692	637
N041	23 JuL77	1840	691	970
N042	24JUL77	0040	707	80
N043	24JuL77	0640	681	1461
N044	24 JUL77	1240	688	129
N045	24JUL77	1840	692	1633
N046	25 JUL77	0040		
N047	25 JuL77	0640		
N048	25 JuL77	1240	692	1114
N049	25 JuL77	1840	721	195
N050	26JUL77	0040	712	111
N051	26JUL77	0640	711	83

NO.	DATE	TIME (BST)	h (cm)	'T2 (cm)
N052	26JuL77	1240	**693**	130
N053	26JUL77	1840	**735**	311
N054	27 JuL77	0040	**706**	290
N055	27 JUL77	0640	**711**	92
N056	27 JuL77	1240	**677**	65
N057	27 JuL77	1840	**723**	432
NO58	28 JuL77	0040	**687**	41
N059	28 JuL77	0640	**693**	45
N060	28 JUL77	1240	**667**	92
N061	28 JUL77	1840	**714**	260
N062	29 JuL77	0040	**696**	239
N063	29 JuL77	0640	**696**	173
N064	29JUL77	1240	**673**	130
N065	29JuL77	1840	**715**	1225
N066	30JUL77	0040	**717**	2846
N067	30JUL77	0640	**699**	130
N068	30JUL77	1240	**683**	1258
N069	30JUL77	1840	**710**	611
N070	3 1JUL77	0040	**720**	35
N071	31 JUL77	0640	**698**	808
N072	3 1JUL77	1240	**695**	73
N073	31 JUL77	1840	**705**	45
N074	1AUG77	0040	**730**	3987
N075	1AUG77	0640	692	824
N076	1AUG77	1240		
N077	1AUG77	1840	683	540
N078	2AUG77	0040		
N079	2AUG77	0640	679	1208
N080	2AuG77	1240	702	1033
N081	2AuG77	1840	689	2194
N082	3AUG77	0040	746	1389
N083	3AUG77	0640	705	865
N084	3AUG77	1240	730	66
N085	3AUG77	1840	705	50
N086	4AUG77	0040	744	99
N087	4AUG77	0640	697	134
N088	4AUG77	1240	702	184
N089	4AUG77	1840	672	661
N090	5AUG77	0040	714	1208
N091	5AUG77	0640	679	1397
N092	5AUG77	1240	697	1824
N093	5AUG77	1840	683	2204
N094	6AUG77	0040	704	3228
N095	6AuG77	0640	684	2801
N096	6AUG77	1240	683	4782
N097	6AUG77	1840	701	1723
N098	7AUG77	0040	708	*2988*
N099	7AuG77	0640	698	1316
N1OO	7AUG77	1240	700	1133
N101	7AUG77	1840	732	3022
N1 02	8AUG77	0040	728	1928

NO.	DATE	TIME (BST)	h (cm)	'T2 (cm)
N103	8AuG77	0640	733	2315
N104	8AuG77	1240	732	855
N105	8AuG77	1840	763	189
N106	9AuG77	0040	740	28
N107	9AUG77	0640	725	166
NI08	9AUG77	1240	700	93
N109	9AUG77	1840	716	2510
NIIO	1 0AUG77	0040	702	3022
N111	10AUG77	0640	699	1928
N112	1 0AUG77	1240	693	2315
N113	10AUG7 7	1840	733	855
N114	1 1AUG77	0040	718	189
N115	11 AUG77	0640	709	245
N116	1 1AUG77	1240	691	916
N117	11 AUG77	1840	722	267
N118	1 2AuG77	0040	711	1145
N119	12AUG7 7	0640	687	1208
N120	1 2AuG77	1240	683	1761
N121	12AuG7 7	1840	716	255
N122	13AUG77	0040	719	144
N123	13AUG7 7	0640	701	94
N124	13AUG77	1240	697	125
N1 25	13AUG77	1840	714	99
N126	14AUG7 7	0040	725	52
N127	14AUG7 7	0640	702	77
N128	14AUG7 7	1240	703	94
N129	14 AUG77	1840	712	42
N130	15AUG77	0040	705	735
N131	15 AUG77	0640		
N132	15AuG7 7	1240		
N133	15 AUG77	1840		
N134	16AuG77	0040	658	275
N135	16 AUG77	0640	677	884
N136	16AUG77	1240	677	267
N137	16AUG77	1840	674	766
N138	17AUG7 7	0040	703	843
N139	17 AUG77	0640	670	2058
N140	17AUG7 7	1240	685	1140
N141	17 AUG77	1840	694	2454
N142	18AUG7 7	0040	740	2061
N143	18 AUG77	0640		
N144	18AuG7 7	1240		
N145	18 AUG77	1840		
N146	19AUG7 7	0040	691	1947
N147	19AUG7 7	0640	651	5486
N148	19AUG77	1240	682	422
N149	19 AUG77	1840	662	488
N150	20AUG7 7	0040	712	306
N151	20AUG77	0640	690	548
N152	20 AUG77	1240	724	57
N153	20 AuG77	1840	704	57

NO.	DATE	TIME (BST)	h (cm)	‘T2 (cm)
N154	21 AUG77	0040	717	22
N155	2 1AUG77	0640	680	11
N156	21 AUG77	1240	699	28
N157	21 AUG77	1840	701	1420
N158	22 AuG77	0040	709	10
N159	22 AUG77	0640	687	444
N160	22AUG7 7	1240	710	25
N161	22 AuG77	1840	718	73
N162	23 AuG77	0040	722	442
N163	23 AuG77	0640	709	47
N164	23 AUG77	1240	710	1086
N165	23AUG7 7	1840	736	120
N166	24AUG77	0040	714	26
N167	24 AuG77	0640	712	21
N168	24AUG77	1240	704	16
N169	24AUG77	1840	733	25
N170	25 AuG77	0040	704	18
N171	25 AuG77	0640	702	33
N172	25 AUG77	1240	697	193
N173	25 AUG77	1840	743	53
N174	26AuG77	0040	713	36
N175	26AUG7 7	0640	723	23
N176	26 AUG77	1240	699	80
N177	26 AUG77	1840	746	22
N178	27 AUG77	0040	723	24
N179	27AUG7 7	0640	728	31
N180	27 AuG77	1240	701	18
N181	27 AuG77	1840	735	15
N182	28AUG77	0040	724	14
N183	28 AuG77	0640	708	105
N184	28 AUG77	1240	686	210
N185	28 AUG77	1840		
N186	29 AuG77	0040		
N187	29AUG77	0640	687	199
N188	29AuG77	1240	678	82
N189	29 AUG77	1840	691	82
N190	30AUG7 7	0040	715	56
N191	30AUG77	0640	690	112
N192	30AUG77	1240	692	60
N193	30AUG7 7	1840	685	67
N194	31 AUG77	0040	721	78
N195	31 AUG77	0640	690	71
N196	31AUG77	1240	707	56
N197	31 AUG77	1840	693	34
N198	1SEPT77	0040	737	39
N199	1 SEPT77	0640	696	24
N200	1SEPT77	1240	723	20

TABLE 2

Spectral parameters for the 420 wave trains. The frequencies corresponding with the listed frequency bands are given in Table 3.

Column headers:
EXP = The experiment number (see Table 1)
Bs = The frequency band on the low frequency side of a peak.
Be = The frequency band on the high frequency side of a peak.
Bp = The peak frequency.
T = The peak period (see).
ANGLE = The approach angle ("N).
H = The rms waveheight for the peak frequency (cm).
H' = The rms wave height for the whole peak (cm)
11 = The littoral sediment transport rate (dynes/sec).

EXP	Bs	Be	Bp	T (sec)	ANGLE (deg)	H (cm)	H" (cm)	I1 (dyn/sec)
N001	7	13	12	5.5	210	4.1	7.4	0. 103 e+07
N001	13	18	14	4.7	244	3.7	?.5	0. 623e+06
N001	3	7	5	14.0	211	2.3	3.5	0. 227e+07
N002	8	15	11	6.1	207	4.9	8.9	0. 13?e+0?
N002	15	18	17	3.9	254	3.5	5.6	0. 336e+06
N002	3	8	7	9.8	207	2.3	4.0	0. 670e+06
N003	11	18	12	5.5	201	5.8	11.5	0.108e+07
N003	8	11	10	6.7	227	5.0	7.5	0.315 e+07
N003	4	8	7	9.8	219	3.6	5.4	0. 336e+07
N004	4	12	8	8.5	229	8.?	13.9	0. 139e+08
N004	12	18	13	5.1	216	3.5	7.0	0. 372e+06
N005	5	12	8	8.5	223	9*3	16.5	0.226e+08
N005	12	18	14	4*7	235	3.1	6.8	0.498e+06
N006	5	13	8	8.5	219	9.2	16.9	0.197e+08
N007	4	15	9	7.5	224	9*3	17.2	0.146e+08
N008	4	10	9	7.5	218	5.8	9.5	0.569e+07
N008	10	13	11	6.1	223	5.5	8.4	0.257e+07
N008	16	18	17	3.9	204	3.2	5.0	0.108e+06
N008	13	16	15	4.4	233	3.1	5.8	0.278e+06
N009	6	18	10	6.7	219	6.2	12.6	0.487e+07
N009	4	6	5	14.0	213	2.2	2.7	0.228e+07
N01l	2	10	9	7.5	198	19.9	49.1	0.127e+08
N012	10	18	16	4.1	196	65.8	150.3	-0.521e+07
N012	4	10	7	9.8	197	31.0	64.8	0.843e+07
N013	5	12	9	7.5	235	9.8	19.3	0.181e+08
N013	12	18	13	5*1	253	9.0	23.0	0.560e+07
N014	11	18	15	4.4	235	14.'3	29.1	0.197e+07
N014	4	11	9	7.5	209	10.5	18.8	0.173e+08
N015	16	18	17	3.9	245	10.5	16.8	-0.104e+05
N015	14	16	15	4.4	237	9*7	14.3	0.211e+07
N015	4	12	10	6.7	234	9.0	17.9	0.856e+07
N015	72	14	13	5.1	192	7.8	11.9	0.210e+07
N016	4	11	9	7*5	236	9*4	16.2	0.170e+08
N016	11	18	13	5.1	249	7.9	19.3	0.402e+07
N017	15	18	16	4.1	286	14.7	24.9	0.299e+07
N017	10	15	14	4.?	263	14.0.	26.8	0.841e+07
N017	8	10	9	7.5	221	& 2	10.6	0.127e+08
N017	3	8	7	9.8	210	4.2	6.9	0.254e+07
N018	5	12	11	6.1	235	14.1	22.0	0.257e+08
N018	12	18	14	4.7	242	13.2	26.7	0. 103e+08
N019	14	18	16	4.1	252	9.7	17.7	0.254e+07
N019	12	14	13	5.1	240	8.0	11.7	0.426e+07
N019	5	12	9	7.5	211	6.6	14.3	0.495e+07
N021	4	15	12	5.5	256	19.:3	37.3	0.295e+08
N021	15	18	16	4.1	264	14.6	26.8	0.583e+07
N022	11	18	15	4.4	248	9.1	20.8	0.353e+07
N022	5	11	8	8.5	207	6.0	12.2	0.534e+07
N023	5	12	7	9.8	208	5.9	11.0	0.596e+07
N025	13	17	16	4.1	196	64.3	120.6	0.128e+08
N025	8	13	12	5.5	799	41.1	81.1	0.569e+08

EXP	Bs	Be	Bp	T (sec)	ANGLE (deg)	H (cm)	H' (cm)	I1 (dyn/sec)
N025	4	/ 3	7	9.8	197	"35.7	59.3	0.473e+08
N026	10	18	12	5.5	245	18.9	42.0	0.351e+08
N026	4	10	9	7.5	203	6.2	10.9	0.425e+07
N027	11	18	14	4.7	241	15.2	33.3	0.125e+08
N027	8	11	10	6.7	233	7.5	11.8	0.557e+07
N027	3	8	7	9.8	209	5.0	7.5	0.478e+07
N029	6	15	12	5.5	240	14.6	27.3	0.193e+08
N029	15	18	17	3.9	270	8.9	16.4	0.125e+07
N029	4	6	5	14.0	203	2.8	3.6	0.201e+07
N030	12	18	13	5.1	226	15.2	30.6	0.158e+08
N030	6	12	11	6.1	237	11.0	18.2	0.136e+08
N030	4	6	5	14.0	216	2.4	3.h	0.242e+07
N032	13	18	14	4.7	247	9.1	15.0	0.450e+07
N032	6	13	12	5:5	239	7.0	12.5	0.460e+07
N032	3	6	5	14.0	205	1.7	2.7	0.402e+06
N033	10	18	14	4.7	243	7.0	15.1	0.300e+07
N033	5	10	9	7.5	217	4.2	6.1	0.242e+07
N034	10	18	13	5.1	245	?.2	15.8	0.395e+07
N034	6	10	8	8.5	213	3.0	5.0	0.134e+07
N034	3	6	5	14.0	222	1.9	2.9	0.178e+07
N035	4	10	9	7.5	198	15.5	35* 5	0.424e+07
N036	12	18	17	.3.9	194	2.7	4.1	0.505e+05
N036	9	12	10	6.7	206	2.7	4.1	0.623e+06
N036	6	9	8	8.5	212	2.?	4.2	0.722e+06
N036	3	6	5	14.0	197	1.8	3.0	0.175e+06
N037	6	14	10	6.7	210	4.4	7.4	0.115e+07
N037	4	6 6	5	14.0	211	1.5	2.1	0.846e+06
N037	14	18	16	4.1	194	1.2	2.3	0.661e+04
N038	8	18	12	5.5	202	4.6	8.4	0.609e+06
N038	3	8	6	11.5	202	2.2	3*9	-0.201e+06
N039	4	9	7	9.8	201	3.9	6.3	0.558e+06
N039	9	18	12	5.5	197	3.8	8.5	0.193e+06
N040	2	11	10	6.7	198	13.1	33.2	0.728e+07
N041	14	16	15	4.4	193	28.2	44.4	-0.175e+07
N041	12	14	13	5.1	192	21.7	33.6	-0.874e+06
N041	3	12	11	6.1	194	17.6	43.2	-0.107e+07
N042	11	18	16	4.1	241	12.s	24.0	0.430e+07
N042	6	11	8	8.5	210	3.8	7.2	0.150e+07
N042	3	6	5	14.0	204	1.9	2.9	0.418e+06
N043	12	18	1?	3.9	192	47.5	95.0	0.155e+07
N043	9	12	11	6.1	204	22.6	38.0	0.147e+08
N043	6	9	8	8.5	200	18.3	30.6	0.144e+08
N043	3	6	5	14.0	204	15.9	27.1	0.465e+08
N044	16	18	17	3.9	198	14.5	22.7	0.148e+06
N044	12	16	15	4.4	147	14.1	24.9	-0.463e+07
N044	4	12	10	6.7	207	4.2	8.4	0.813e+06
N045	8	18	12	5.5	199	35.2	108.6	0.114e+07
N045	6	8	7	9.8	200	21.8	28.5	0.587e+08
N045	3	6	5	14.0	195	11.4	21.8	-0.747e+07
N048	10	18	14	4.7	153	32.6	85.3	-0.353e+08

EXP	Bs	Be	Bp	T (sec)	ANGLE (deg)	H (cm)	H' (cm)	I1 (dyn/sec)
N048	2	10	9	7.5	201	23.1	42.0	0.206e+08
N049	13	18	15	4.4	183	1:3.9	29.3	-0.279e+07
N049	6	13	9	7.5	207	13.3	26.7	0.138e+08
N050	4	15	9	7* 5	205	14.2	26.2	0.179e+08
N050	15	18	160	4.1	175	8.2	14.9	-0.152e+07
N051	4	18	10	6.7	209	11.7	24.9	0.128e+08
N052	11	18	14	4.7	153	14.2	30.2	-0.105e+08
N052	4	11	9	7.5	217	?.2	12.5	0.553e+07
N053	4	18	14	4*7	147	17.6	49.7	-0.175e+08
N054	7	14	1:3	5* 1	152	20.6	32.2	-0.324e+08
N054	14	18	16	4.1	157	20.4	37.6	-0.166e+08
N054	4	7	6	11.5	195	1.9	3.3	-0.560e+06
N055	12	15	13	5.1	149	8.9	15.5	-0.615e+07
N055	9	12	11	6.1	147	7.2	10.5	-0.388e+07
N055	5	9	8	8.5	214	3.2	5.9	0.135e+07
N056	10	?8	17	3*9	156	10.1	21.3	-0.255e+07
N056	5	10	8	8.5	214	4*2	6.7	0.218e+07
N0.57	4	10	7	9.8	203	11.4	23.5	0.156e+08
N058	12	16	14	4*7	147	7.4	10.4	-0.280e+07
N058	4	12	8	8.5	205	5.5	10.6	0.388e+07
N059	4	14	8	8.5	209	8.3	14.6	0.124e+08
N060	11	18	15	4.4	197	13.1	25.3	-0.558e+06
N060	5	11	9	7*5	211	4.3	?* 9	0.226e+07
N061	11	18	16	4.1	148	21.8	42.5	-0.462e+07
N061	4	11	8	8.5	215	?1.0	16.2	0.238e+08
N062	9	15	11	6.1	204	19.6	36.3	0.100e+08
N062	b	9	8	8.5	214	9.6	13.3	0.173e+08
N063	14	18	17	3.9	151	15.6	30.0	-0.448e+07
N063	9	14	1"j	5.1	201	10.4	21.5	0.973e+06
N063	5	9	8	8.5	213	7.0	10.9	0.883e+07
N063	3	5	4	18.0	218	2.1	2.?	0.232e+07
N064	16	18	17	3*9	167	12.8	20.0	-0.109e+07
N064	12	16	15	4*4	197	12.0	2009	-0.134e+07
N064	4	12	10	6.7	210	9.1'	18.5	0.496e+07
N065	10	12	11	6.1	200	26.0	38.1	0.211e+08
N065	12	15	14	4.7	196	25.5	47.4	0.381e+07
N065	3	10	9	7.5	207	21.6	43.9	0.426e+08
N066	12	14	13	5.1	197	37.7	59.1	0.831e+07
NO 66	3	12	10	6.7	199	32.0	74.0	0.192e+08
N067	6	18	10	6.7	200	16.0	31.3	0.146e+08
N067	4	6	5	14.0	207	2.8	4.1	0.197e+07
N068	9	12	10	6.7	196	21.2	39.5	0.122e+07
N068	1	9	8	8.5	200	19.0	40.9	0.282e+08
N069	12	?4	13	5.1	198	17.6	27.5	0.426e+07
N069	4	12	9	7.5	203	14.7	34.5	0.222e+08
N071	3	?2	11	6.1	198	?7.0	41.0	0.531e+07
N072	4	15	8	8.5	212	8.2	15.8	0.103e+08
N073	6	18	9	7.5	223	9.4	?8.2	0.154e+08
N073	4	6	5	14.0	213	2.2	3.3	0.219e+07
N074	12	lb	15	4.4	196	57.0	96.2	-0.272e+07

EXP	Bs	Be	Bp	T (sec)	ANGLE (deg)	H (cm)	H" (cm)	11 (dyn/see)
N074	10	12	11	6.1	197	37.9	54.0	0.211e+08
N074	6	10	9	8.5	197	30.1	56.4	0.156e+08
N074	2	6	4	18.0	196	28.1	45.1	-0.270e+08
N075	6	10	9	?.5	197	14.4	27.8	0.131e+08
N077	6	11	10	6.7	20 '3	10.8	23.5	0.752e+07
N077	3	6	5	14.0	199	8.4	16.0	0.102e+08
N079	2	8	7	9.8	201	13.7	32.5	0.788e+07
N081	1	14	13	5.1	197	:3"3.1	83.2	0.908e+07
N082	6	9	8	8.5	199	16.3	30.1	0.216e+08
N082	3	6	5	14.0	196	12.7	24.6	0.275e+07
N083	3	10	9	7.5	201	15.5	35.0	0.235e+08
N084	10	18	11	6.1	240	11.5	20.8	0.171e+08
N084	5	10	8	8.5	214	5.9	12. ?	0.713e+07
N085	5	13	9	7.5	219	8.1	14.3	0.116e+08
N085	13	18	15	4.4	248	4.5	9.1	0.594e+06
N086	12	15	14	4,?	141	8.7	14.1	-0.106e+07
N086	4	12	10	6.7	220	8.2	14.6	0.877e+07
N087	5	12	9	7.5	216	6.6	12.7	0.762e+07
N087	12	14	13	5.1	241	6.0	8.6	0.170e+07
N088	12	18	16	4.1	184	16.3	35.8	-0.284e+07
N088	6	12	9	7.5	228	8.6	13.2	0.142e+08
N089	9	15	14	4.7	193	21.2	46.6	-0.327e+06
N089	3	9	8	8.5	207	11.1	24.8	0.922e+07
N090	3	16	15	4.4	196	33.1	74.9	-0.769e+07
N091	11	17	15	4.4	192	40.0	84.0	-0.161e+08
N091	4	11	7	9.8	196	21.8	47.1	0.193e+07
N092	11	16	15	4.4	197	41.1	80.3	-0.340e+08
N092	7	11	9	7* 5	197	21.1	43.1	0.175e+08
N092	4	7	6	11.5	195	17.6	32.4	-0.364e+07
N092	1	4	3	25.0	197	15.7	29.4	0.238e+08
N093	10	13	12	5.5	194	32.6	51.5	-0.306e+08
N093	6	1.0	9	7.5	195	22.6	44.4	-0.413e+07
N093	4	6	5	14.0	195	19.0	29.8	-0.174e+08
N093	1	4	3	25.0	196	17.3	33.2	0.274e+06
N094	7	13	12	5.5	197	32.6	74.7	-0.264e+05
N094	2	7	5	14.0	197	22.5	51.5	0.512e+07
N095	8	12	11	6.1	193	"31.4	62.3	-0.664e+06
N095	4	8	7	9.8	187	27.6	54.8	-o. 111e+09
N095	1	4	.3	25.0	185	24. ?	46.3	-0.749e+09
N096	11	15	14	4.7.	196	58.5	104.7	-0. 361e+07
N096	6	11	10	6.7	198	38.5	80.1	0.134e+08
N096	3	6	5	14.0	197	34.4	56.6	0.206e+08
N097	6	12	10	6.7	198	23.0	51.7	0.136e+08
N097	1	6	4	18.0	196	15.5	36.4	0.811e+07
N098	15	18	17	3.9	196	71. ?	118.5	-0.510e+07
N098	12	15	14	4.7	196	44.8	73.7	0.861e+06
N098	9	12	10	6.7	197	31.1	57.2	0.224e+08
N098	4	9	8	8.5	196	25.2	53.4	0.162e+07
N099	9	11	10	6.7	200	21.4	33.7	0.201e+08
N099	5	9	8	8.5	197	15.4	31.6	0.516e+07

EXP	Bs	Be	Bp	T (sec)	ANGLE (deg)	H (cm)	H' (cm)	11 (dyn/see)
N099	1	5	3	25.0	195	13.5	28.2	-0.156e+08
N100	3	11	10	6.7	198	18.8	42.6	0.933e+07
N101	2	11	10	6.7	199	19.0	45.8	0.117e+08
N102	8	11	10	6.7	196	28.4	50.0	0.484e+07
N102	6	8	7	9.8	198	23.5	37.6	0.239e+08
N102	1	6	5	14.0	196	21.7	47.2	0.134e+08
N103	2	7	6	11.5	196	18.0	41.4	-0. 257e+07
N104	13	17	16	4.1	250	7.0	13.3	0. 6 12e+06
N104	11	13	12	5*5	235	6.6	8.8	0. 350e+07
N104	7	11	9	7.5	217	5.4	8.6	0.5 18e+07
N104	4	7	6	11.5	222	2.2	3.0	0. 193e+07
NI05	12	18	13	5.1	251	9.0	19.4	0.506e+07
N105	10	12	11	6.1	234	5.3	6.9	0.256e+07
N105	4	7	6	11.5	214	4. 7	5*7	0.687e+07
NI05	7	10	9	7.5	228	4.1	6.8	0.279e+07
N106	12	17	16	4.1	248	5.8	10.4	0.765e+06
N106	4	10	9	7. 5	217	4.1	7.2	0.278e+07
N106	10	12	11	a. 1	235	4.0	5.7	0.197e+07
N107	10	18	17	3.9	162	26.2	35.1	-0.187e+08
N107	8	10	9	7.5	207	4.3	6.1	0.172e+07
N107	4	8	7	9.8	212	3.8	6.4	0.321e+07
N108	11	18	16	4.1	154	13.4	25.8	-0.565e+07
N108	K	11	7	9.8	212	5.1	8.2	0.671e+07
N109	13	161	15	4.4	195	44.8	73* 0	-0.180e+08
N109	10	13	12	5.5	197	28.4	49.5	0.241e+07
NI09	6	10	9	?. 5	198	22.4	44.5	0.204e+08
N109	4	6	5	14.0	196	20.3	30.4	-0.584e+07
N110	12	15	14	4.7	197	45.1	77. 3	-0.231e+05
N110	9	12	11	6. 1	196	36. 9	58.9	0.559e+07
NIIO	6	9	8	8.5	197	31.2	49.5	0.402e+08
N110	3	6	5	14.0	196	25. 3	41.4	0.711e+07
N111	5	13	11	6.1	197	27.2	62.6	0.280e+07
N112	2	8	7	9.8	197	19.9	47.6	0.146e+08
N113	5	7	6	11.5	202	14.2	21.0	0.555e+08
N114	4	8	7	9.8	213	13.3	18.3	0.489e+08
N115	5	11	9	7.5	202	9.6	21.7	0.122e+08
N115	1	4	3	25.0	197	6.2	10.5	0.404e+07
N116	10	18	17	3.9	196	41.8	78.6	-0.235e+08
N116	4	10	7	9.8	202	15.7	32.2	0.286e+08
N117	15	18	17	3.9	169	23.3	37.9	-0. 116e+08
Nil?	11	15	14	4.7	176	15.7	25.1	-0.527e+07
N117	4	11	8	8.5	208	7. 8	14.5	0.946e+07
N118	8	11	9	7.5	200	17.7	31.8	0.211e+08
N118	5	8	7	9.8	199	14.2	25.0	0.139e+08
N119	14	17	16	4.1	195	32.4	58.5	-0.285e+07
N119	11	14	12	5.5	197	22.2	39.4	-0.544e+07
N119	8	11	10	6.7	200	17.7	30.6	0.113e+08
N119	5	8	6	11.5	198	15.6	25.1	0.610e+07
N120	10	17	16	4.1	197	46.1	85.4	-0.188e+08
N120	8	10	9	7.5	198	23.9	35.0	0.185e+08

EXP	Bs	Be	Bp	T (sec)	ANGLE (deg)	H (cm)	H" (cm)	I1 (dyn/sec)
N120	6	8	7	9.8	198	21.7	31.0	0.181e+08
N120	4	6	5	14.0	198	19.1	27.5	0.332e+08
N121	13	15	14	4.7	149	21.0	27.9	-0.188e+08
N121	8	13	12	5.5	146	19.8	29.3	-0.199e+08
N121	5	8	7	9.8	221	962	11.0	0.227e+08
N122	12	18	16	4.1	134	13.4	28.3	-0.303e+07
N122	10	12	11	6.1	149	?0.5	14.5	-0.571e+07
N122	4	10	8	8.5	212	8.8	15.1	0.128e+08
N123	9	16	14	4.7	147	9.8	20.4	-0.472e+07
N123	5	9	8	8.5	206	7.1	11.3	0.713e+07
N124	12	18	16	4.1	144	15.2	29.5	-0.881e+07
N124	4	12	8	8.5	217	5.8	11.6	0.724e+07
N125	16	18	17	3.9	183	11.?	18.1	-0.982e+06
N125	9	16	14	4.7	148	11.0	22.0	-0.480e+07
N125	4	9	8	8.5	218	7.7	9.5	0.123e+08
N126	4	10	8	8.5	209	7.6	12.4	0.106e+08
N126	10	13	11	6.1	196	6.4	11.1	0.212e+07
N126	13	17	15	4.4	132	5.3	11.0	-0.480e+06
N127	11	18	17	3.9	145	11.1	22.2	-0.345e+07
N127	8	11	9	7.5	215	S.0	8.6	0.427e+07
N127	4	8	7	9.8	208	4.9	6.9	0.374e+07
N128	12	18	15	4.4	143	13.2	23.9	-0.775e+07
N128	8	12	10	6.7	223	5.9	11.2	0.397e+07
N128	4	8	7	9.8	215	5.2	8.1	0.648e+07
N129	5	11	8	8.5	215	5.4	9.8	0.631e+07
N129	11	15	14	4.7	149	4.6	7.9	-0.609e+06
N130	14	18	15	4.4	139	34.5	60.3	-0.302e+08
N130	8	14	13	5.1	192	30.0	53.3	-0.271e+08
N130	4	8	7	9.8	211	5.3	8.3	0.431e+07
N134	10	16	14	4.7	196	25.1	41*5	-0.225e+07
N134	5	10	8	8.5	210	4.9	9.0	0.283e+07
N135	9	lb	13	5.1	197	30.4	63.6	-0.289e+08
N135	3	9	8	8.5	200	11.6	25.6	0.685e+07
N136	9	18	13	5.1	194	19.5	45.6	-0.824e+07
N136	6	9	8	8.5	218	4.3	6.4	0.357e+07
N137	2	15	12	5.5	192	30.8	61.2	-0.398e+08
N137	15	1?	16	4.1	196	29.2	44.9	-0.110e+08
N138	10	15	12	5.5	190	35.8	60.3	-0.389e+08
N138	4	10	9	7.5	'195	12.6	25.7	0.162e+07
N 139	4	12	11	6.1	194	34.7	71.1	-0.356e+07
N140	3	11	9	7.5	209	30.8	55.1	0.717e+08
N141	7	11	9	7.5	203	35.7	62.8	0.368e+08
N141	5	7	6	11.5	194	20.2	31.0	0.282e+08
N142	15	18	17	3.9	197	55.6	95.2	0.296e+07
N142	11	15	14	4.7	196	39.2	66.7	0.324e+07
N142	7	11	9	7.5	196	28.0	53.6	0.264e+08
N142	4	7	6	11.5	197	18.3	31.7	0.977e+07
N146	7	15	13	5.1	194	44.8	90.4	-0.125e+08
N146	4	7	6	11.5	196	14.2	26.3	0.114e+07
N146	2	4	3	25.0	199	13.0	21.3	0.480e+08

EXP	Bs	Be	Bp	T (sec)	ANGLE (deg)	H (cm)	H' (cm)	I1 (dyn/sec)
N147	6	1:?	12	5.5	191	82.0	119.5	-0.763e+08
N147	1.3	18	16	4.1	191	81.1	162.0	-0.484e+07
N147	3	6	5	14.0	163	32.3	49.7	-0.502e+09
N148	6	17	13	5.1	194	29.3	55.6	-0. 114e+08
N149	7	18	10	6. 7	211	34.3	62.0	0.709e+08
N149	.3	7	6	11.5	209	3.3	6.5	0.166e+07
N150	5	18	11	6.1	192	27.7	49. 2	0.112e+08
N151	12	14	13	5.1	194	17.9	28.4	0.128e+07
N151	3	12	11	6.1	198	17.2	34.8	0.141e+07
N152	5	13	11	6.1	212	8.3	15.2	0.413e+07
N152	13	18	16	4.1	155	7.5	15.0	-0.136e+07
N153	15	17	16	4.1	159	8.0	12.1	-0.120e+07
N153	5	13	11	6.1	200	7.8	13.6	0.185e+07
N153	13	15	14	4.7	149	6.7	9.9	-0.797e+06
N154	14	18	17	3.9	133	5.4	9.3	-0.456e+06
N154	8	14	12	5. 5	196	4.5	8.5	0.293e+06
N154	4	8	7	9.8	210	1.7	2.9	0.346e+06
N155	4	10	7	9.8	205	4.1	6.2	0.271e+07
N155	10	15	13	5.1	219	1.9	4.0	0.170e+06
N156	3	11	7	9.8	212	6.8	9.0	0.914e+07
N157	3	8	7	9.8	196	16.7	.35.8	0.276e+08
N158	4	10	6	11.5	207	4.1	6.4	0.350e+07
N158	14	18	17	3*9	242	2.4	4.3	-0.107e+05
N158	10	14	12	5.5	234	1.9	3.6	0.244e+06
N159	3	7	6	11.5	200	9*7	18.2	0.107e+08
N160	4	10	6	11.5	213	7.7	10.4	0.255e+08
N160	10	12	11	6.1	208	2.0	3.2	0.286e+06
N161	4	10	7	9.8	210	15.5	17.7	0.429e+08
N161	10	15	12	5.5	244	9.0	14.4	0.765e+07
N161	15	18	17	3*9	252	4.8	8.7	0.305e+06
N162	9	12	11	6.1	197	12.7	22* ?	0.100e+08
N162	7	9	8	8.5	199	11.1	16.1	0.349e+07
N162	4	7	6	11.5	196	7.6	14.2	0.241e+07
N163	10	14	12	5*5	253	6.3	11.2	0.288e+07
N163	3	10	8	8.5	206	4.2	8.4	0.190e+07
N164	3	10	9	7*5	198	16.:3	38.4	0.500e+07
N165	9	14	13	5.1	200	7.8	16.2	0.296e+07
N165	2	9	8	8.5	203	6.2	12.4	0.375e+07
N166	8	15	10	6.7	239	5.9	11.7	0.492e+07
N166	15	17	16	4.1	248	3.8	5.9	0.358e+06
N166	4	8	7	9.8	199	3.1	5.1	0.861e+06
N167	12	16	13	5. 1	246	%.6	7.5	0.152e+07
N167	9	12	11	6.1	202	4.5	7.7	0.157e+07
N167	3	9	7	9.8	212	4.1	6.1	0.210e+07
N168	3	11	8	8.5	210	4.7	8.3	0.353e+07
N168	11	14	13	5.1	243	2.6	4.8	0.377e+06
N169	6	13	9	7.5	209	5.5	11.1	0.126e+07
N169	13	16	14	4*7	252	4.1	6.7	0.831e+06
N169	3	6	5	14.0	219	2.7	3.7	0.386e+07
N170	7	13	?0	6. 7	200	6.0	9.2	0.104e+07

EXP	Bs	Be	Bp	T (sec)	ANGLE (deg)	H (cm)	H' (cm)	I1 (dyn/see)
N170	13	18	17	3.9	243	3.0	6.5	0.178e+06
N170	3	7	6	11*5	213	2.1	3.4	0.985e+06
N171	4	13	12	5.5	249	4.2	8.5	0.122e+07
N1?2	7	1?	15	4.4	141	6.5	14.4	-0.728e+06
N172	4	7	6	11.5	217	3.1	5.1	0.310e+07
N173	15	18	17	3.9	251	5.3	8.9	0.470e+06
N173	3	9	7	9.8	201	3.9	7.3	0.154e+07
N173	9	12	11	6.1	200	3.6	5.9	0.311e+06
N173	12	15	14	4.?	261	3.6	6.8	0.342e+06
N174	12	18	16	4.1	126	4.9	10.0	-0.391e+05
N174	4	8	7	9.8	202	4.3	6.3	0.170e+07
N174	8	12	11	6.1	201	3.1	5.8	0.454e+06
N175	10	18	15	4.4	134	4.8	10.2	-0.493e+06
N175	3	10	7	9.8	203	3.6	6.9	0.195e+07
N17b	9	17	15	4.4	248	5.0	11.0	0.595e+06
N176	4	9	7	9.8	198	3.6	5.9	0.162e+07
N177	4	10	8	8.5	204	4.9	8.0	0.209e+07
N177	10	17	16	4.1	248	2.9	6.6	0.151e+06
N178	10	17	15	4.4	251	4.3	8.5	0.507e+06
N178	4	10	8	8.5	205	3.6	6.9	0.135e+07
N179	5	11	8	8.5	204	3.6	?.2	0.106e+07
N179	11	14	13	5.1	137	2.7	4.8	-0.184e+06
N180	4	6	5	14.0	220	3.0	3.7	0.546e+07
N180	6	11	7	9.8	206	2.8	4.7	0.106e+07
N180	11	15	14	4.7	248	2.5	4.2	0.192e+05
N181	4	11	8	8.5	209	3.0	6.0	0.848e+06
N182	7	12	9	7.5	208	2.5	4.7	0.663e+06
N182	4	7	6	11.5	215	2.4	3.7	0.156e+07
N182	12	18	17	3.9	194	2.4	4.7	0.176e+04
N183	11	18	17	3.9	234	16.2	27.?	0.727e+07
N183	4	6	5	14.0	220	2.8	3.7	0.391e+07
N183	6	11	7	9.8	205	2.8	5.1	0.108e+07
N184	9	18	12	5.5	222	18.2	40.0	0.302e+08
N184	7	9	8	8.5	215	3.1	4.7	0.169e+07
N184	4	7	5	14.0	228	2.8	4.5	0.450e+07
N187	7	17	13	5.1	243	14.3	36.3	0.149e+08
N187	5	7	0	11.s	208	2.8	4.3	0.166e+07
N187	3	5	4	18.0	215	2.4	3.3	0.199e+07
N188	6	18	14	4.7	219	9.8	24.0	0.421e+07
N188	3	6	5	14.0	213	1.7	2.9	0.151e+07
N189	13	18	16	4.1	229	10.0	20.9	0.318e+07
N189	8	13	12	5.5	243	7.2	12.5	0.493e+07
N189	3	8	6	11.5	210	3.3	5.7	0.277e+07
N190	9	13	11	6.1	241	7.2	11.?	0.637e+07
N190	7	9	8	8.5	206	2.8	4.2	0.572e+06
N190	4	7	5	14.0	210	2.4	3.9	0.151e+07
N191	12	18	16	4.1	191	14.7	27.5	0.187e+07
N191	6	12	11	6.1	226	4*3	7.9	0.168e+07
N191	4	6	5	14.0	202	3.2	3.8	0.214e+07
N192	14	18	17	3.9	208	10.9	16.9	0.859e+06

EXP	Bs	Be	Bp	‾ (see;	ANGLE (deg)	H (cm)	H′ (cm)	I1 (dyn/sec)
N192	7	14	11	6.1	241	5.8	11.5	0.346e+07
N192	4	7	6	11.5	213	2.1	3.2	0.104e+07
N193	12	18	17	'?.9	245	10.7	20.1	0.170e+07
N193	9	12	11	6.1	230	4.5	7.1	0.206e+07
N193	4	9	5	14.0	204	2.6	'5*0	0.868e+06
N194	8	14	13	5.1	238	8.6	15.3	0.518e+07
N194	4	8	7	9.8	205	2.2	4.4	0.547e+06
N195	12	18	17	3.9	202	11.3	21.1	0.208e+07
N195	8	12	11	6.1	223	6.3	10.2	0.425e+07
N195	4	8	6	11.5	207	3.3	5.1	0.271e+07
N196	8	13	12	5.5	224	7.5	14.0	0.424e+07
N196	13	18	15	4.4	206	?*3	15.7	0.101e+07
N196	4	8	6	11.5	213	3.5	5.6	0.379e+07
N197	13	18	16	4.1	211	5.5	11.7	0.771e+06
N197	11	13	12	5.5	218	5.3	8.?	0.214e+07
N197	9	11	10	6.7	237	5.2	7.6	0.392e+07
N197	3	9	7	9.8	212	3*7	6.6	0.224e+07
N198	8	13	12	5.5	226	6.9	11.3	0.416e+07
N198	13	17	15	4.4	212	5.2	10.7	0.630e+06
N198	4	8	7	9.8	209	3.7	5.3	0.236e+07
N199	9	14	11	6.1	237	5.7	10.0	0.372e+07
N199	14	17	16	4.1	215	4.6	7.9	0.421e+06
N199	4	9	8	8.5	209	2.2	4.2	0.559e+06
N200	9	18	11	6.1	232	5.3	11.3	0.319e+07
N200	4	9	7	9.8	208	2*9	5.2	0.163e+07

TABLE 3

Frequencies and periods associated with the 18 bands from the spectral analysis.

Column headers:
B = Band number
f = Frequency (see^{-1})
T = Period (see).

B	f	T
1	0.00879	113.8
2	0.02441	4100
3	0.04004	25.0
4	0.05566	18.0
5	0.07129	14.0
6	0.08691	1105
7	0,10254	9.8
8	0.11816	8.5
9	0.13379	7.5
10	0.14941	6.7
11	0.16504	6.1
12	0.18066	5.5
13	0.19629	5*I
14	0.21191	4*7
15	0.22754	4*4
16	0.24316	4.1
17	0.25879	3.9
18	0.27441	3.6

VI. NEEDS FOR FURTHER STUDY

A. Storms and their effects on the Bering Sea coast of Alaska should be studied in greater detail. These studies should include additional studies on the frequency and magnitude of storm surge and extreme wave conditions.

B. Long-term changes in shoreline position should be assessed in greater detail.

C. In order to properly evaluate the output of the wave model, we need direct measurement of a wide spectrum of wave energies. At least one more field season of wave measurement is necessary.

D. OCSEAP should consider maintaining a medium-level study on coastal processes of the southern portion of the Bristol Bay coast of the Alaska Peninsula. This is a critical area in view of its high biological productivity (e.g. Izembek Lagoon) and its proximity to potential deep water ports on the south side of the Peninsula.

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