Final Report

Homer Spit Littoral Drift Studies

Prepared for

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SUMMARY

Homer Spit is a dynamic system in which change is a normal process. Natural changes can affect man's use of the area and man's activities may in turn modify the natural system. The spit is a sediment deposit which provides productive habitats for several biological species. Because these habitats are related to the sedimentary environments any changes to the sediment transport system may affect the resident organisms. The identification of shoreline erosion or accretion areas and the physical or biological assessment of proposed man-induced modifications to the system are dependent upon an understanding of sediment distribution and sediment transport patterns. The objectives of this investigation of the littoral sediment transport system of Homer Spit are to review the state-of-knowledge, to conduct preliminary field measurements of near-bottom currents, and to recommend further studies to provide suitable data to redress information deficiencies.

A field study to measure near-bottom currents in the subtidal zone adjacent to the spit was conducted in December, 1979. Six nearshore profiles were surveyed to characterize the topography of the intertidal and subtidal areas around the spit. Eight stations were located and occupied during various tidal stages to measure the near-bottom currents around the spit in the adjacent subtidal zone. These data are analyzed and used in conjunction with other sources (charts and aerial photography) in order to describe the physical character of the spit system and to identify sediment sources and transport patterns.

Homer Spit is a typical spit system in terms of the physical morphology and the sediment transport patterns. The exposed (southwest) and sheltered (northeast) coasts are distinctly different physical, geological and biological environments.

On the exposed coast the direction of littoral sediment transport is primarily towards the southeast and the movement of sand-sized material from alongshore and also possibly onshore is a result of wind-generated wave processes. The more sheltered environment of Coal Bay is a zone of fine-grained sediments (silts and clays) that are transported primarily in suspension. The transport directions in Coal Bay converge from the northeast along the north shore of Kachemak Bay and from the southeast along the north shore of Homer Spit. Because of deep water off the distal point of Homer Spit (Coal Point) it is believed that little sediment is transported around to the north shore from the more exposed south shore.

During the study period no currents, at 0.75 m (2.5 feet) above the sea bed, were observed greater than 30 cm/s, and this instantaneous velocity was recorded on only one occasion. The majority of the measured values are less than 10 cm/s, which is below the threshold velocity for the initiation of sand transport. The measured bottom current directions do not conform to a regular tide-induced water motion at the sites monitored. Although some tidal component can be tentatively identified it is believed that the primary forces controlling the bottom currents during the study period are related to wind-driven processes.

The primary focus of this report is the physical (geologic and oceanographic) environment. As many of the potential effects of man's activity relate to the marine organisms of the area, the available biological information base is also reviewed. The identification of information gaps in the present knowledge base of the geologic, oceanographic and biologic environments is used to develop recommendations for further studies. Because of the close interrelationship between organisms and habitat it is suggested that subsequent investigations be an integration of biological and physical studies. These investigations would span a 12-month period in order to characterize seasonal components of the natural system.

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1.0 INTRODUCTION AND OBJECTIVES

1.1 Introduction

The coastal zone of Homer Spit has been subjected to numerous natural and man-induced pressures in recent decades. The effects of the 1964 Good Friday earthquake resulted in major alterations to the natural system and in extensive damage to man-made structures. The commercial and recreational development of this spit has also resulted in modifications to the natural system by the construction of groins and harbor facilities. As requirements for future commercial and recreational developments will further affect the system it is important to evaluate accurately the exact nature of changes that would be incurred by individual facilities.

The spit system at Homer is an equilibrium feature that has been formed by, and continues to adjust to, the natural forces of winds, waves and tides that combine to redistribute the unconsolidated shore-zone sediments. Similarly, biological communities have developed in equilibrium with the physical environment. Man-induced changes to the availability and distribution of sediments can have a direct effect on the stability, of part or all, of the spit system and on individual or interrelated biological communities.

Homer Spit is a deposit of unconsolidated sediments and as such the major alterations that can be induced by man are related to changes in the existing distribution of the sediment or to changes in the sediment transport patterns. In particular, the effects of jetty or harbor construction and of dredging operations directly affect the sedimentary environment and thereby place stress on associated biological communities.

The prediction of changes to the sediment transport system and the effect that these would have on the marine organisms is a major component in the evaluation of the desirability of proposed developments. Accurate predictions and evaluations are dependent on the availability of an adequate data or information base concerning the existing natural system. The present investigation was initiated in part to identify primary deficiencies in the existing knowledge base for understanding the dynamics of Homer Spit.

Although the basic patterns of sediment movement and of natural changes in the form of the spit can be deduced by comparison with previous research investigations on similar features, little is known about the specific volumes of sediments involved in the transport system or about the actual dynamics of sediment movement. This investigation, therefore, focuses on these aspects in order to provide a framework for the development of further studies which can lead to a more complete understanding of the system and thereby enable more precise evaluation of the effects of proposed commercial and recreational projects.

1.2 Scope of Work

The study was instigated in order to evaluate the existing knowledge and data base for Homer Spit and to develop recommendations for further studies to redress primary information deficiencies. As part of the investigations a short field study was required to measure shore-zone currents for an initial evaluation of sediment transport patterns.

The results of the literature survey and of the field studies are used to evaluate the direction of littoral currents adjacent to Homer Spit. This information is of primary importance to an evaluation of the effects of changes to the intertial and subtidal sediment transport systems and to biological communities by dredging, by disposal of dredge materials or by construction of engineering structures.

As a result of the investigation a description of information and data gaps is provided to assist the Corps of Engineers in the development of requirements for additional studies to assess fully the physical and biological implications of proposed alterations to the natural system of Homer Spit.

The specific objectives of the study are:

- to review available literature on sediments and sediment transport and on the biology of the Homer Spit area
- to describe the existing sediment system and identify information gaps that require additional geological and biological studies
- to measure near-bottom current velocity and direction, at sites adjacent to Homer Spit between the shoreline and the -15 feet depth contour, at different stages of the tidal cycle.
- to present and discuss the field observations in terms of the transport of shore-zone sediments
- to describe additional study requirements.

The field study was undertaken in December, 1979, and a schedule of these investigations is given in Appendix A.

2.0 LITERATURE REVIEW

2.1 Geology and Oceanography

Several general accounts of the regional physical environment were written prior to 1960 but the first report that provides specific data on Homer Spit is a design memorandum for a small boat basin (U.S. Army Corps of Engineers, 1961). This report notes that a road onto the spit was constructed in 1927, but that this was predated by a railroad built in the 1890's. The railroad served a coal mine at Bluff Point and connected with a half-moon dock at the end of the spit (Coal Point), until operations ceased in 1907. This original dock was replaced by a new structure commenced in 1938 that was the forerunner of the present City Pier. Although a small boat basin was excavated in 1955, on the south side of the spit near the distal end, the entrance to this basin was closed frequently by sediment infilling during storms.

By 1960 the demand for a larger basin prompted the Corps of Engineers to investigate suitable alternative designs and locations for such a facility. The design memorandum notes that topographic and hydrographic surveys were conducted in 1949 and again in 1960. The memorandum recommends that the new basin be located on the north shore rather than on the south shore of the spit, due to the higher wave heights and higher wave energy levels predicted for the more exposed south-facing coast. This harbor was constructed on the north shore of the distal section in 1962.

In describing the geology of the area the report (U.S. Army Corps of Engineers, 1961) notes that a well drilled at the distal point of the spit reached 300 feet without encountering bedrock. The spit is described as a remnant of a terminal moraine and is composed of silts, sands, gravels and some boulders that overlay marine clays. The report contains the results and size analyses of a series of 5 bore holes that were drilled to depths of 44 feet near the distal end of the spit.

Local concern of shoreline changes on Homer Spit prompted a beach erosion study that was conducted by the Alaska Department of Natural Resources in the spring of 1963 (Stanley and Grey, 1963). The authors suggest that the littoral transport directions are towards the southeast on the southwest shore and towards the northwest on the northeast shore. The geomorphic description of the spit and the adjacent coasts is relatively detailed and on the southwest shore of the spit the report notes two significant trends:

(a) sediment sorting increases to the southeast, and

(b) the steepness of the beach increases to the southeast.

Four areas of erosion were identified from the geomorphic interpretation; of these only two were on the spit itself (downdrift of the most southerly groin, and at the public campsite on the northeast shore). The erosion at the proximal end of the spit was considered severe and this report recommended further studies to determine sediment transport rates. Although a brief erosion survey was conducted by the U.S. Geological Survey (Waller, 1964), plans for further studies were interrupted by the March 27, 1964 earthquake which resulted in major changes to the form of the spit. Several investigations focused on the response and recovery of the spit system to this major event.

One of the effects of the earthquake was to generate submarine slope failures along the flanks of the spit (Geo-Recon Inc., 1965). These slides near the distal end of the spit destroyed the small boat harbor and the deep draft wharf (Groenwald and Duncan, 1965). On the basis of a seismic reflection and refraction survey the Geo-Recon study found evidence of recent faulting and also found indicators that were interpreted as possible slope failure due to liquefaction.

A study by the U.S. Army Corps of Engineers on shoreline erosion following the earthquake (Groenwald and Duncan, 1965) provides information on the immediate effects of subsidence on the spit system. The authors note that, prior to the earthquake, there was an insufficient supply of sediment to maintain the spit system and that there was severe erosion downdrift of the groins. Following the earthquake the spit had subsided approximately 3 feet at the proximal end and 6 feet at the distal end. As the system had no high dunes or berms, 70 per cent of the backshore was flooded during spring tides. The primary effect of the earthquake in the areas of erosion was to accelerate the problem, and at the proximal end the groins were improved in an attempt to prevent further erosion or damage.

A more detailed survey of the effects of the earthquake by the U.S. Geological Survey (Waller, 1966; Stanley, 1966) differentiates between changes that were tectonic and those which were attributed to differential compaction or external spreading of sediments. This report provides a comprehensive account of the earthquake and its effects by Waller and an account of beach changes by Stanley, who had been involved in a pre-earthquake shoreline erosion study (Stanley and Grey, 1963). The tectonic subsidence of the spit increased from 2 feet in proximal sections to approximately 3 feet at the distal end. Superimposed on this was a compaction of between 1 and 4 feet which was most significant in the distal sections.

Stanley notes that the primary effects of the subsidence were to:

(i) increase sediment supply to the littoral system from the source areas (i.e. the bluffs to the west of the spit); and

(ii) permit storm waves to act on higher parts of the beach.

The southwest shore underwent recession on the order of 10 to 15 feet, with local maxima up to 30 feet and one case of 56 feet of retreat at the distal end, and new berms developed rapidly by erosion and reworking of the beach-face sediments. The input of sediment to the spit system due to accelerated erosion in the adjacent source areas provided material for natural beach restoration, but Stanley notes that little sediment migrated around the distal end onto the northeast shore.

An Environmental Impact Study for maintenance dredging of the small boat harbor (Schuck, 1972) notes that earlier dredging at the harbor entrance involved removal of 16,067 cubic yards in September, 1969. In reviewing the effects of further dredging at the harbor entrance and of the disposal of approximately 15,000 cubic yards of sediment, no assessment was made of the effects of these actions on the sediment transport system.

An engineering review of the stability of the Homer Spit shoreline (CH2M Hill Engineers, 1973) concludes that the southwest coast was undergoing accretion, the distal point was stable (with normal seasonal and storm-related erosion and accretion), and that sections of the northeast shoreline were retreating. These results confirm Stanley's observations (1966) and are based on an examination of 1965, 1969 and 1972 vertical aerial photography. The report also notes that the generalized conclusions regarding beach stability must be used cautiously as any section of shoreline may be potentially unstable in terms of coastal engineering development.

A U.S. Army Corps of Engineers final environmental impact statement on the small boat harbor (1974a) notes that the 1972-73 maintenance dredging involved removal of a total of 18,000 cubic yards of material, including removal of part of a pre-1964 breakwater. About 25 per cent of the material was disposed on an immediately adjacent intertidal section of the spit to the west of the small boat harbor, an area which was unstable due to sediment transport interruption by the harbor breakwater. The report provides a detailed synopsis of the history of the construction and maintenance of the small boat harbor from the initiation of the project in 1958.

Continued concern about the shoreline stability of the spit resulted in a beach erosion control feasibility study by the U.S. Army Corps of Engineers (1974b). The objective of the study was to define areas of erosion and to develop plans to control or protect areas where needed. The report concludes that following establishment of an equilibrium after the 1964 earthquake, "in general, no further erosion exists in the area." One area of previous concern, adjacent to the groins, was no longer considered a problem due to installation of rip rap by the State of Alaska Highways Department. The report provides relevant data on the processes acting on the spit, in particular comparing computed deepwater wave data from the southwest (Hs = 14.0 feet) and the northeast (Hs = 6.3 feet) for similar wind conditions, the difference in significant wave heights being due to fetch limitations in Kachemak Bay. The northeast winds, according to the report, produce a convergence of littoral drift in Coal Bay.

A land use study of the spit (Unwin, Scheber and Karynta, 1975) repeats the 1974 U.S. Army Corps of Engineers beach erosion control conclusions but adds that the topic, "...is still somewhat controversial. Some local residents maintain that the bay side of the Spit erodes while the inlet side builds."

As part of the environmental studies for oil and gas development on Lower Cook Inlet and Kachemak Bay, Hayes _et al_., (1976) describe the coastal morphology and processes of the area, including Homer Spit. Computed wave data in this report are of limited value for Homer Spit as only waves out of the southwest are considered. The study presents reconnaissance data from the spit and Coal Bay and describes the coastal features at a regional, and therefore generalized, level in terms of the expected impact of oil spills. In the same study series, Burbank (1977) presents Lagrangian current measurements for the Homer Spit area during November, 1975. At that time, strong (20 - 30 mph) winds out of the northeast produced surface and subsurface (50 feet) water movement to the westsouthwest with a westward movement on the northeast shore at the distal end of the spit during a flood tide. The observations suggested very small (≈1 nautical mile diameter) stationary eddies near the tip of the spit: a subsurface counterclockwise eddy on the north side and a surface clockwise eddy on the south side. It must be noted that these currents should not be confused with shore-zone wave-generated currents.

Dredging operations on Homer Spit were reviewed in 1977 (Dames and Moore, 1977). The activities are described in detail, including volumes of material removed and disposal locations. The report notes that the majority of sediment removal was from the small boat harbor entrance channel and that about 50,000 cubic yards were removed between 1965 and 1975, that a further 1,372 cubic yards were removed in 1976 and 12,000 cubic yards in 1977. Sedimentation at the harbor entrance is estimated at 6,000 to 7,000 cubic yards annually, based on dredging records. Construction of three groins to the southeast of the harbor is proposed to reduce the sedimentation problem.

The most recent report related to the development of the spit is a draft feasibility report and environmental impact statement for expansion of the small boat harbor (U.S. Army Corps of Engineers, 1979). The report notes that, in the vicinity of the proposed harbor expansion, "The exact nature of existing erosion and deposition patterns and the potential effects of the proposed project are unknown at the present time".

Despite the relatively large volume of literature on the physical character of Homer Spit the actual knowledge base is still very descriptive. In particular the lack of wave, nearshore current and shoreline change data prevents the development of an accurate description of the sediment transport system at this time. Much of the information that describes the spit in this report is derived from an inspection of charts, aerial photography and the field data collected in December 1979, rather than from the literature.

2.2 Biology

A number of reports have summarized the important commercial and recreational biological resources of the Kachemak Bay area in the vicinity of the Homer Spit (Trasky et al., 1977; Alaska Dept. Fish and Game, 1978; and Science Applications, Inc., 1979). These reports indicate the concerns over alterations to Kachemak Bay habitats, as the various commercial fisheries operating there grossed approximately $9.7 million to the fishermen in 1978. Recreational use of the area is also high because of the abundant resources and ease of access.

Detailed biological studies of the Homer Spit itself have not been conducted. Most studies involving the spit have been concerned with Kachemak Bay as a whole, with one or two sampling stations on or near the spit (Trasky et al., 1977; Blackburn, 1977; English, 1977; Haynes and Wing, 1977; Lees, 1978). Other on-going or recently completed studies have been limited in scope to a small area on or near the spit (D. Lees and R. Shimek, pers. comms.). Most of the studies have been descriptive approaches related to the Outer Continental Shelf Environmental Assessment Program and to State interest in offshore oil lease tracts. The few studies confined on or near the spit were related to small development projects. Because of this fragmentation of study effort, there is no comprehensive evaluation of the biota or even biological habitats present on the spit.

Studies that have sampled on the spit dealt with inter- and sub-tidal benthic organisms, (Lees, 1978, Lees, in prep.; Shimek, in prep.), fish surveys (Blackburn, 1977), postlarval king crab (Sundberg and Clausen, 1977) and marine birds (Erikson, 1977). The results of the benthic sampling indicate that there is a higher density of organisms on the east side of the spit than on the west side. The east side benthos is dominated by polychaetes, apparently in densities up to 20,000/m^2, while the subtidal on the west side is covered with an extensive mussel bed (Shimek, pers. comm.). Indications are that the pink salmon out-migration passes the spit in late May, although sampling was apparently not conducted prior to May 21 (Blackburn, 1977). Postlarval king crab were captured in the subtidal area (30 ft. depth) on the west side of the spit (i.e. Archimandritof Shoals) but were not captured on the east side (Sundberg and Clausen, 1977). There is apparently a strong seasonal component to epibenthic utilization (including crabs and shrimp) but this pattern has not been investigated (Shimek, Trasky, pers. comms.). The east side of the spit provides a feeding area for several species of shorebirds and dabblers in spring and fall, but utilization of the area is considered light and transitory (Erikson, 1977).

2.3 Spit Systems and Sediment Transport

The study of spit systems throughout the world has produced a large body of literature that describes the results of specific investigations (e.g., Guilcher and King, 1961; Kidson, 1963; Carr, 1965; Guilcher, 1965; Hayes et al., 1973; Robinson, 1975; Goldsmith, 1977). A recent review by Komar (1976, p. 25-29) provides a brief but accurate description of different types of spit systems. The spit as a depositional feature is discussed in numerous coastal geology or coastal process text books (King, 1972; Coates, 1973; Hayes and Kana, 1976; Davis, 1978) and the basic dynamics of spit growth and morphology are well understood.

The actual mechanics of sediment transport in the littoral zone are less clearly defined. Although many of the theoretical problems have been attacked (e.g. Komar, 1976, p. 203-226), there remain differences of opinion with respect to the relative roles of suspended and bedload sediment transport in the surf zone. At the present time the mechanics of transport are understood but the accurate prediction or measurement of transport rates and volumes requires further attention. The state-of-the-art provides techniques and methods for the estimation of rates and volumes of sediment transport that are sufficiently accurate for most investigations (e.g., Galvin, 1972; U.S. Army, Corps of Engineers, 1973; Galvin and Vitale, 1977; Komar, 1977, 1978).

3.0 THE PHYSICAL ENVIRONMENT OF HOMER SPIT

3.1 Introduction

Homer Spit is a deposit of unconsolidated sediments that has formed across Kachemak Bay in lower Cook Inlet (Fig. 3.1) in response to coastal processes. The spit is an area of active shore-zone sediment transport and undergoes physical changes in response to the coastal processes; in this sense it is a dynamic feature. The objective of this section is to describe briefly the physical environment of Homer Spit in terms of the coastal processes and the sediment transport system to provide a general account of the natural changes that occur on the spit.

3.2 Processes

Lower Cook Inlet is protected from waves generated on the North Pacific. The waves that act on the Homer Spit coast, therefore, are generated by local winds within the adjacent fetch areas ("fetch" being defined here as: 'the area of open water over which waves are generated by wind'). Observations of wind data from Homer Airport show that onshore winds for the south coast of the spit occur during 31% of the year, and for the north coast during 39% of the year (Table 3.1). There exists a strong seasonality in wind direction with northeast winds prevailing from September to April and southwest winds from May to August (Table 3.2, Fig. 3.2). Although the onshore winds are more persistent and also are of higher velocity on the north-facing coast, the fetch area is considerably less than that to the southwest (>100 miles vs. 15 miles). As a result wave heights and levels of wave energy are considerably greater on the south shore of the spit.

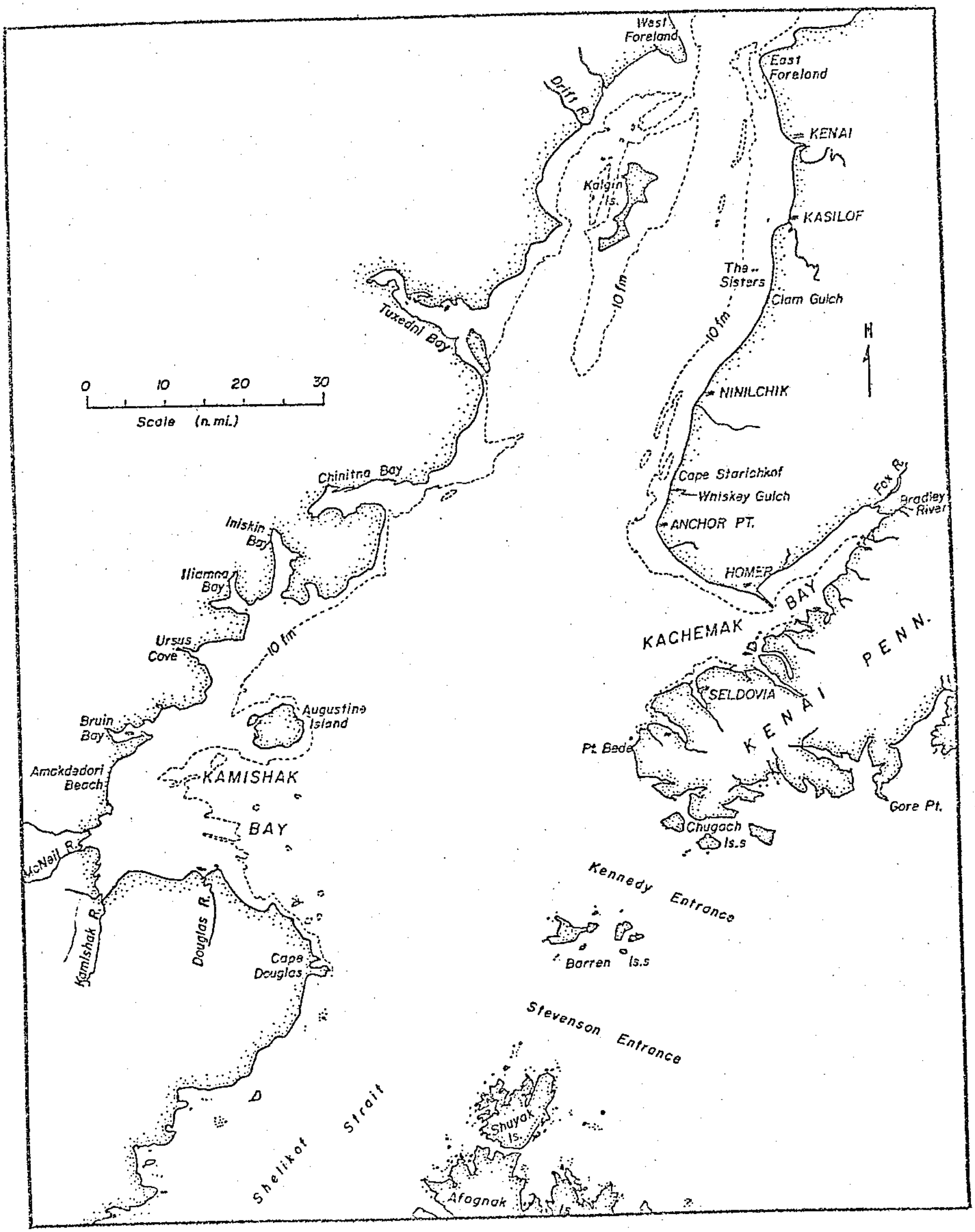


Figure 3.1 Index map of Lower Cook Inlet. Only the 10 fathom (20m) bathymetric contour is shown (from Burbank, 1977).

TABLE 3.1 Wind Direction Frequency, Homer Airport (from U.S. Army Corps of Engineers, 1961)

N	2%	
NNE	1%	onshore north coast: 39%
NE	11%	
ENE	12%	
E	8%	
ESE	7%	
SE	3%	
SSE	2%	
S	4%	
SSW	1%	onshore south coast: 31%
SW	5%	
WSW	6%	
W	11%	
WNW	4%	
NW	1%	
NNW	1%	
calm	21%	

TABLE 3.2 Monthly Prevailing Wind Direction, Homer Airport (from U.S. Army Corps of Engineers, 1961)

January	NE
February	NE
March	NE
April	NE
May	SW
June	WSW
July	WSW
August	WSW
September	NE
October	NE
November	NE
December	NE

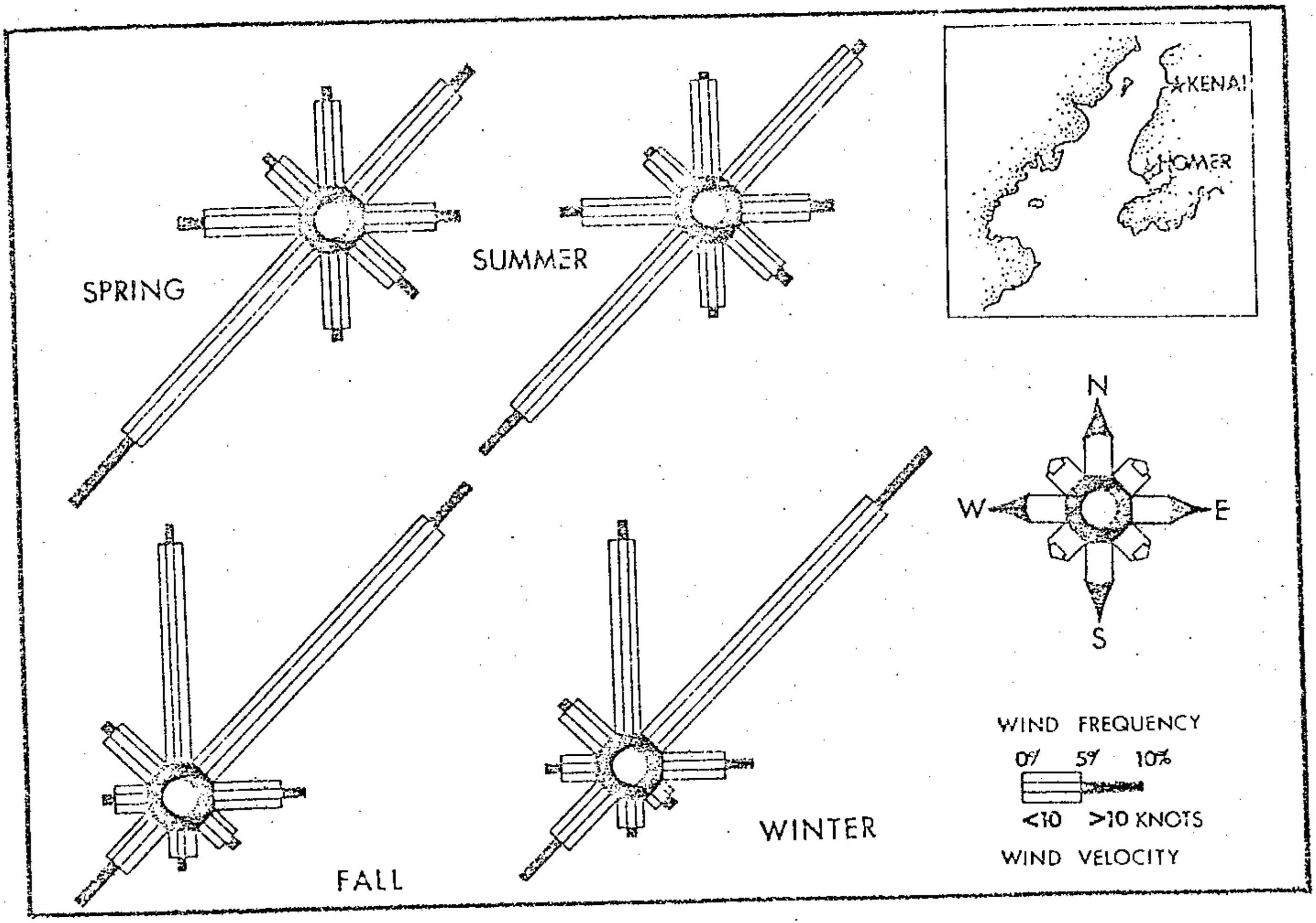


Figure 3.2 Seasonal variations in wind frequency distribution, based upon over 100,000 synoptic wind observations for Homer and Kenai (from Hayes et al., 1976).

Computed design wave heights at Homer Spit (U.S. Army, Corps of Engineers, 1961) provide values of 9.7 feet for waves from the southwest, and 4.6 feet for waves from the northeast. A later study (U.S. Army Corps of Engineers, 1974b) gives computed deep water significant wave heights for a nine hour 35-knot wind of 14.0 feet from the southwest and 6.3 feet from the northeast. Further computed data (Table 3.3) shows the strong seasonal variation in wave height and also the importance of southwest or west winds on the south coast of the spit.

TABLE 3.3

Predicted Maximum Wave Conditions
(significant wave height and period),
Using Synoptic Wind Observations
(after Bretschneider, 1971).

	Wave Height (feet)			Wave Period (seconds)		
	W	SW	S	W	SW	S
January	5.8	6.7	2.7	5.3	5.6	3.5
February	5.8	9.9	2.7	5.3	7.0	3.5
March	5.8	6.7	4.0	5.3	5.6	4.5
April	3.6	6.7	2.7	4.3	5.6	3.5
May	5.8	6.7	2.7	5.3	5.6	3.5
June	3.6	6.7	2.7	4.3	5.6	3.5
July	3.6	3.8	2.7	4.3	4.4	3.5
August	3.6	3.8	2.7	4.3	4.4	3.5
September	3.6	6.7	2.7	4.3	5.6	3.5
October	3.6	6.7	2.7	4.3	5.6	3.5
November	5.8	6.7	2.7	5.3	5.6	3.5
December	5.8	9.9	2.7	5.3	5.6	3.5

(from Hayes *et al.*, 1976)

A major characteristic of the wave climate is the frequency of storm-generated waves. In a summary of wind data from 1950 - 1954 (U.S. Army Corps of Engineers, 1961) 22 storms were identified with winds greater than 20 mph, predominantly during the period October to February. The storm winds blew from northeast to east or from southwest to west. The resulting storm-generated waves play an important role in littoral processes.

The general wave climate at Homer Spit can be described as one of:

(a) seasonal differences in wave generation with higher wave-energy levels in winter months

(b) spatial differences in wave heights with greater significant wave heights and wave-energy levels on the southwest-facing coast, and

(c) storm-wave activity in winter months.

The apparent net direction of littoral currents that is produced by the wind-generated waves is shown in Figure 3.3. The net current directions result from the shoreline orientation with respect to the onshore winds and these directions agree with net shore-zone sediment transport directions derived from vertical aerial photograph interpretation of beach ridges on the spit.

The tides of Kachemak Bay are mixed semi-diurnal and at Homer Spit have a range that varies considerably between neap and spring tides, from less than 10.0 feet to greater than 25.0 feet. In this macro-tidal environment one of the major effects of the water level changes on waves is to dissipate the available wave energy over a large vertical area. Wave energy is concentrated at high and low water levels during the slack tides, but with the rise and fall of the tides little time is available for waves to act at a particular level within the intertidal zone.

The wave-induced nearshore current pattern given in Figure 3.3 is markedly different from the circulation patterns described by Burbank (1977). The surface currents indicated by Burbank are offshore, that is seaward of the intertidal zone, and are net water movements related to the circulation within Kachemak Bay rather than in the shore zone of the coast. The net surface currents adjacent to Homer Spit (Figure 3.4) indicate an east to west current that follows the north coast of Kachemak Bay. No information is available, however, on the ebb and flood tide components of this

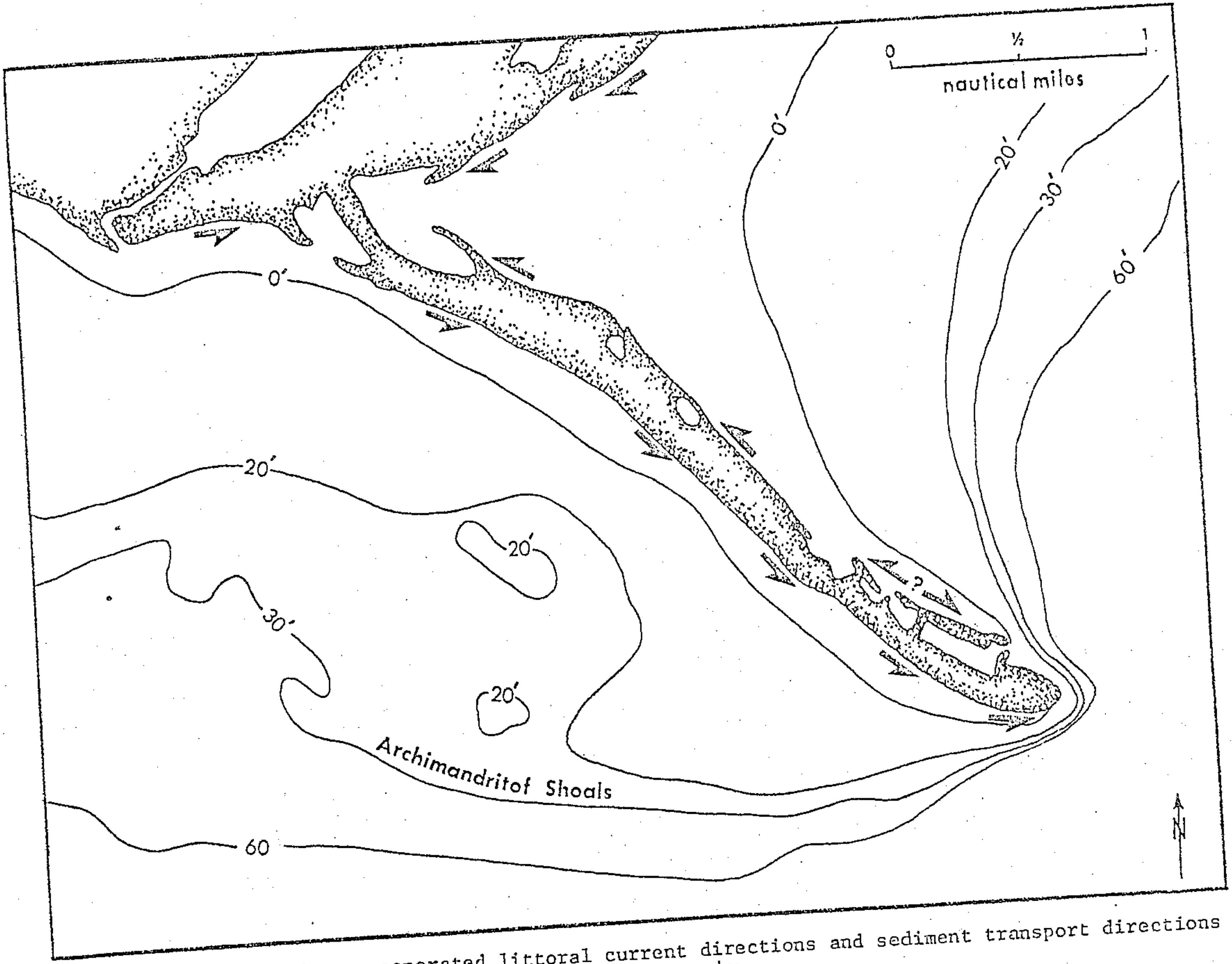


Figure 3.3 Inferred wave-generated littoral current directions and sediment transport directions interpreted from vertical aerial photography.

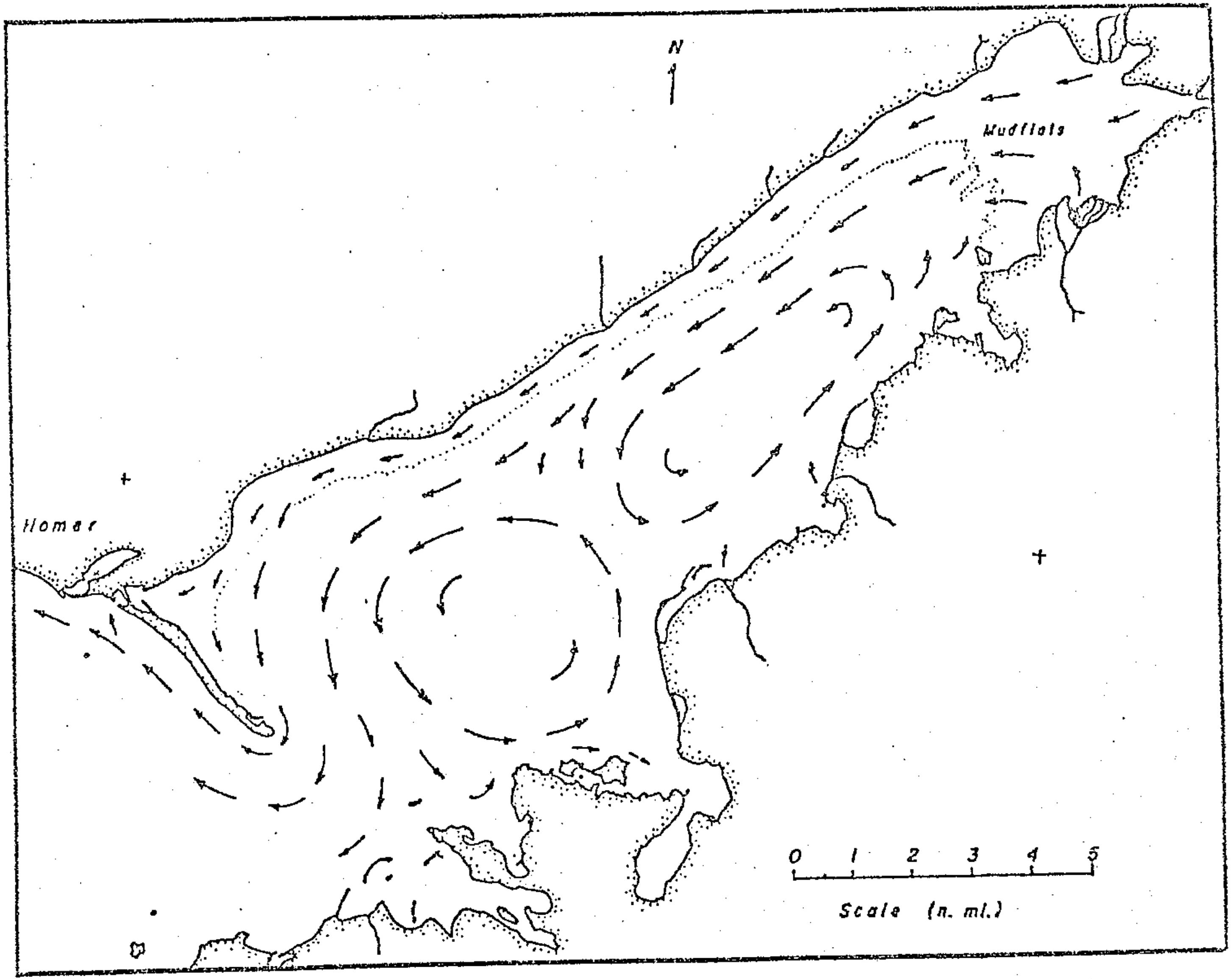


Figure 3.4 Surface currents in inner Kachemak Bay (from Burbank, 1977)

circulation pattern. Local currents measured adjacent to the spit provided evidence of gyres in the offshore zone (Fig. 3.5).

The current patterns given in Figures 3.4 and 3.5 cannot be related directly to the sediment transport system of the Homer Spit area. However, the movement of water into Coal Bay from the northeast along the north shore of Kachemak Bay (Figure 3.4) may be an important transport pathway of fine-grained suspended sediments. Of greater importance to the transport of coarser sediments (i.e. sand) is the energy input from waves. Although tidal currents can play a role in the redistribution of fine-grained material and can transport sand-sized sediments when current velocities are high (>50 cm/s), in the Homer Spit area there is no morphological evidence of tide-induced transport of sands within the intertidal zone.

In summary, the primary physical processes that affect the character of Homer Spit and the transport of littoral processes are related to waves. Tidal currents may be important in the transport of fine-grained sediments (muds) in suspension and the large tidal range causes the dissipation of wave energy over a large vertical area. The movement of sand-sized and coarser sediments is a function of wave-induced processes. Wave-energy levels are higher on the southwest-facing coast due to the larger fetch areas in that direction and there is a seasonal variation in wave-energy levels, with a winter maximum.

3.3 Sediments

The growth and maintenance of Homer Spit is a function of the balance between the supply of sediment to the system and the removal of sediment by natural processes or man's action (e.g. dredging). The primary sources of supply are:

- sediments derived from the erosion of adjacent coasts or from streams and rivers that are transported alongshore by littoral processes

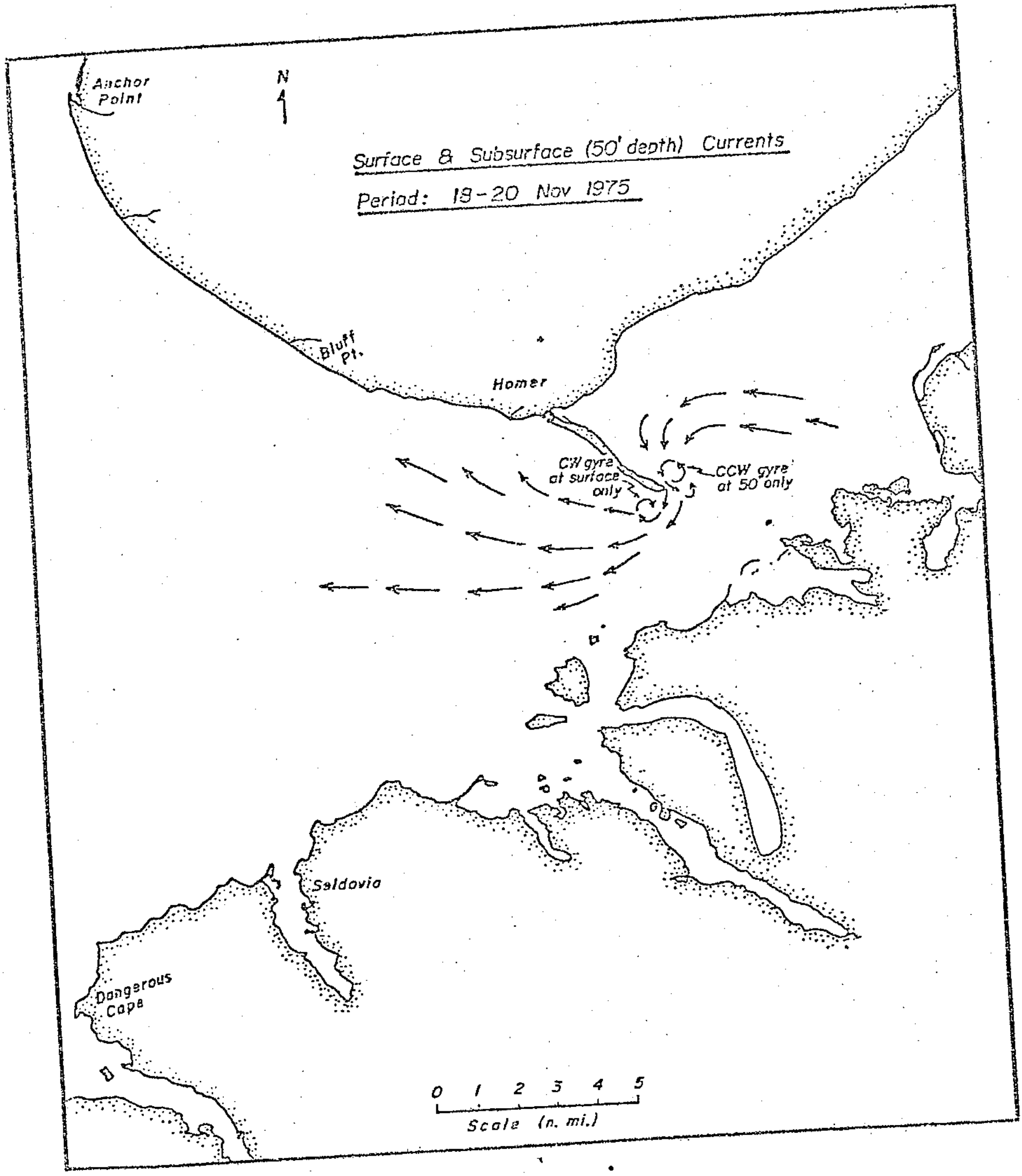


Figure 3.5 Surface and subsurface (50 ft.; 15 m depth) currents during 18-20 November, 1975 (from Burbank, 1977).

- sediments transported landwards into the shore zone from adjacent offshore areas, and
- sediments in suspension that settle out of the water column in low-energy environments.

The erosion of unconsolidated sediments from adjacent cliffs to the northwest of the spit is a major source of sand and coarse material. This material is transported alongshore to the southeast by longshore (wave-induced) currents directly into the spit system. No data are available from published sources on rates of cliff retreat, so that at this time no estimates can be made of the volume of material supplied from this source. Erosion of the coasts to the northeast of the spit and transport to the southwest into Coal Bay would be at lower rates, as this is a more sheltered wave environment.

Sediment can also be supplied to the shore zone by the onshore movement of material from the adjacent sea bed. In the Homer Spit area it is possible that sediments could be moved landwards and into the littoral zone from the Archimandritof Shoals (located on Fig. 3.3). The depths at low water are generally less than 20 feet over much of the shoals and during periods of high waves it is likely that sediments are transported landward by wave-induced bottom currents. Again little is known about this process from published sources.

The supply of fine-grained material (silts and clays) results primarily from the settling of suspended sediments out of the water column. Much of the upper part of Kachemak Bay is characterized by mud flats, with the sediments presumably derived from river input associated with adjacent glaciers. This fine-grained material is transported into the area by tide- or wind-generated currents and is deposited in the Coal Bay area during slack tides or during calm periods. Some transport of sand-sized sediments in the upper intertidal zone at Coal Bay is evident from the vertical aerial photographs as two small spits have grown across the inner part of the Bay to partially enclose Mud Bay.

Consideration of the sediment sources and the transport system of Homer Spit involves both the onshore (coastal erosion; rivers) and offshore (sea bottom sediments; suspended sediments) movement of material. The determination of volumes and rates of transport involves estimation of the sediment budget, which includes removal of material from the system. At the distal end of the spit (Coal Point) sediments transported alongshore to the southeast are carried around to the north shore and are also carried into deeper water off the spit and lost to the system. The volumes of material that are transported around Coal Point into the north shore are not accurately known, but the dredging figures indicate that in the order of 8,000 cubic yards are trapped annually in the entrance to the small boat basin. This volume includes material that settles out of suspension as well as sediments transported alongshore by littoral processes.

Erosion of beach material during storms or the resuspension of muds in Coal Bay by wave or tide-induced processes also contributes to the loss of material to the offshore zone. Although the spit system is relatively stable according to certain sources (i.e. inputs are approximately equal to losses) no firm data are available on the sediment budget that would allow prediction of future changes due to present-day movements of material.

3.4 Spit Dynamics and Shoreline Change

The interaction of processes with the sediments to produce a spit system can be characterized in a relatively simple model. Usually the more exposed coast is one of sediment bypassing as material is transported alongshore to accumulate at the distal point and/or on the more sheltered backshore of the spit. This lee shore is usually an area of sediment accumulation. The net result of a stable or slowly eroding exposed coast with an accreting sheltered coast is a slow migration of the entire spit system into more sheltered waters. Providing that there is continued input of material from alongshore or onshore a spit will slowly grow into deeper water by extension of the distal point. Also, as noted above, spits tend to slowly migrate landwards (in this case to the northeast) if there is a limited supply of material, but can prograde seawards (i.e. to the southwest) if there is a net surplus of sediment.

Following the 1964 earthquake the south shore of the spit apparently prograded due to a temporary excess of available sediments transported into the shore zone by accelerated erosion of cliffs to the northwest. This temporary abundance of sediment enabled the spit to recover rapidly from the effects of subsidence and to build new berms (storm ridges) on the upper beach. Recent studies have concluded that the spit is now stable and is not undergoing major erosion (U.S. Army Corps of Engineers, 1974b). Major changes are relatively easy to identify but the accurate determination of slow trends requires comparison of survey data and/or aerial photography. As neither of these has been undertaken, it is not possible to state definitively what are the present trends. However, changes are evident in the proximal area and a section of the road is presently (December, 1979) undergoing erosion in an area immediately to the southeast of protective rip rap that has been installed to combat erosion.

Although no data are available to substantiate a conclusion, it would appear that parts of the southwest shore of the spit have a deficit sediment budget and are slowly retreating. This retreat is most evident in northwest sections where the road closely approaches the shore. A cursory inspection of 1977 aerial photography also indicates that the southeast section of this shore adjacent to the small boat harbor has prograded slightly. This would imply that sediments are transported through the proximal section (a zone of sediment bypassing) and are accumulating in the distal portion of the south shore. The net effect of these changes, if they are real trends, is to slightly alter the shoreline orientation, a response that may be due to changes in nearshore wave refraction patterns caused by subsidence following the 1964 earthquake. Substantiation of these possible trends is an important aspect in identification of the present-day dynamics of the spit system.

Within the intertidal zone sediments move alongshore by the effects of wave-induced littoral currents and also migrate onshore and offshore as wave conditions vary. Periods of storm-wave activity usually result in a seaward movement, or erosion, of beach material which is stored in the nearshore or lower intertidal zone. This erosion phase is followed by a period of recovery as sediments migrate landwards during calmer wave conditions. As storms are more prevalent during winter months there is often a seasonal pattern of prevailing erosion in winter and accretion in summer months. Therefore, superimposed on possible long term changes are seasonal or storm-related cycles of shoreline change that often make identification of trends difficult.

4.0 FIELD INVESTIGATIONS - DECEMBER, 1979

4.1 Objectives

A 5-day field program was designed to collect data that would (i) provide basic information on shore-zone currents, and (ii) identify specific items for future more detailed investigations. The field plan included measurement of near-bottom currents at several representative sites around Homer Spit within the intertidal and adjacent subtidal zones. Measurements were to be taken at various stages of the tide in order to obtain a representative data set for a complete tidal cycle at the selected sites.

4.2 Field Operations

A 25-foot hydro-jet, shallow-draft, aluminum boat was chartered for the field study. The craft proved very suitable for this type of operation, although blocking of the water intake by sea ice caused the engine to overheat on occasions. Positions were fixed by sextant angles and plotted on hydrographic charts.

Bottom depths and profiles were recorded on a Raytheon DL-719B strip-chart survey echo sounder, using a gunwale-mounted transducer.

Stations were marked with a buoy-light system to enable relocation during darkness. At each station a weighted and buoyed Hydro Products 950S savonius rotor current meter was lowered to the bottom and currents were recorded at a depth of 2.5 feet above the sea bed. The current velocity and direction were indicated on an analog output and visually observed for approximately a five-minute period to obtain qualitative average values.

In addition, minimum and maximum observed velocities were noted on the field data sheets. Hourly wind velocity and direction data for the study period were obtained from the Homer Harbor Master's station. These measurements, recorded adjacent to the Small Boat Harbor, are relatively free of topographic modification and for process studies on Homer Spit are preferable to data collected at the Homer airport.

4.3 Field Data and Discussion

4.3.1 Nearshore Profiles

The locations of the surveyed nearshore topographic profiles are given on Figure 4.1 and the actual profile traces are presented in Figures 4.2 to 4.7. The profile scales have not been rectified at this time for (i) depth with respect to low water datum (this datum is indicated on the vertical axis), or (ii) boat speed. These two factors must be taken into account when making direct comparisons between profile traces.

Within Coal Bay (Profiles No.2 and No.3; Figs. 4.3 and 4.4) the sea floor gradients are very low and the bottom is virtually flat. On the inner bay (Profile No.3) a break of slope can be identified at approximately the low water datum, with a slightly steeper gradient to seaward and a virtually horizontal gradient in the lower intertidal zone. Perpendicular to the northeast coast of the spit (Profile No.2) the low offshore gradients change landward to a slightly steeper slope at approximately 5 feet below the low water datum. The intertidal slope remains constant until the steep beach-face in the upper intertidal zone.

Although Profiles No.2 and No.1 are adjacent to each other there is a marked steepening of the nearshore and offshore gradients to the southeast. Profile No.1 (Fig. 4.2) adjacent to the Small Boat Harbor has a comparatively

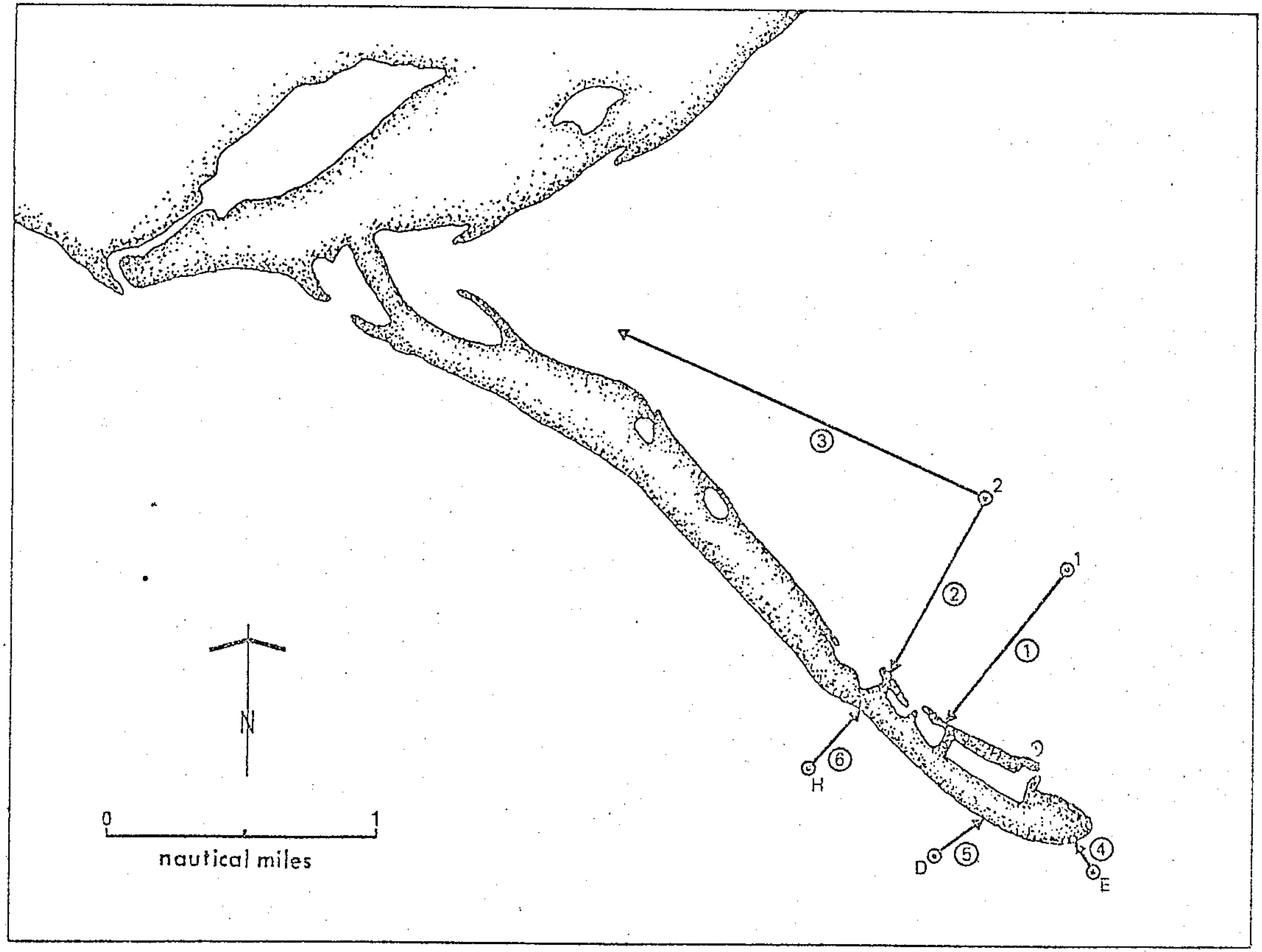


Figure 4.1 Location of echo sounder profile lines given in Figures 4.2 to 4.7.
Letters and uncircled numbers refer to buoy locations fixed by sextant angles.

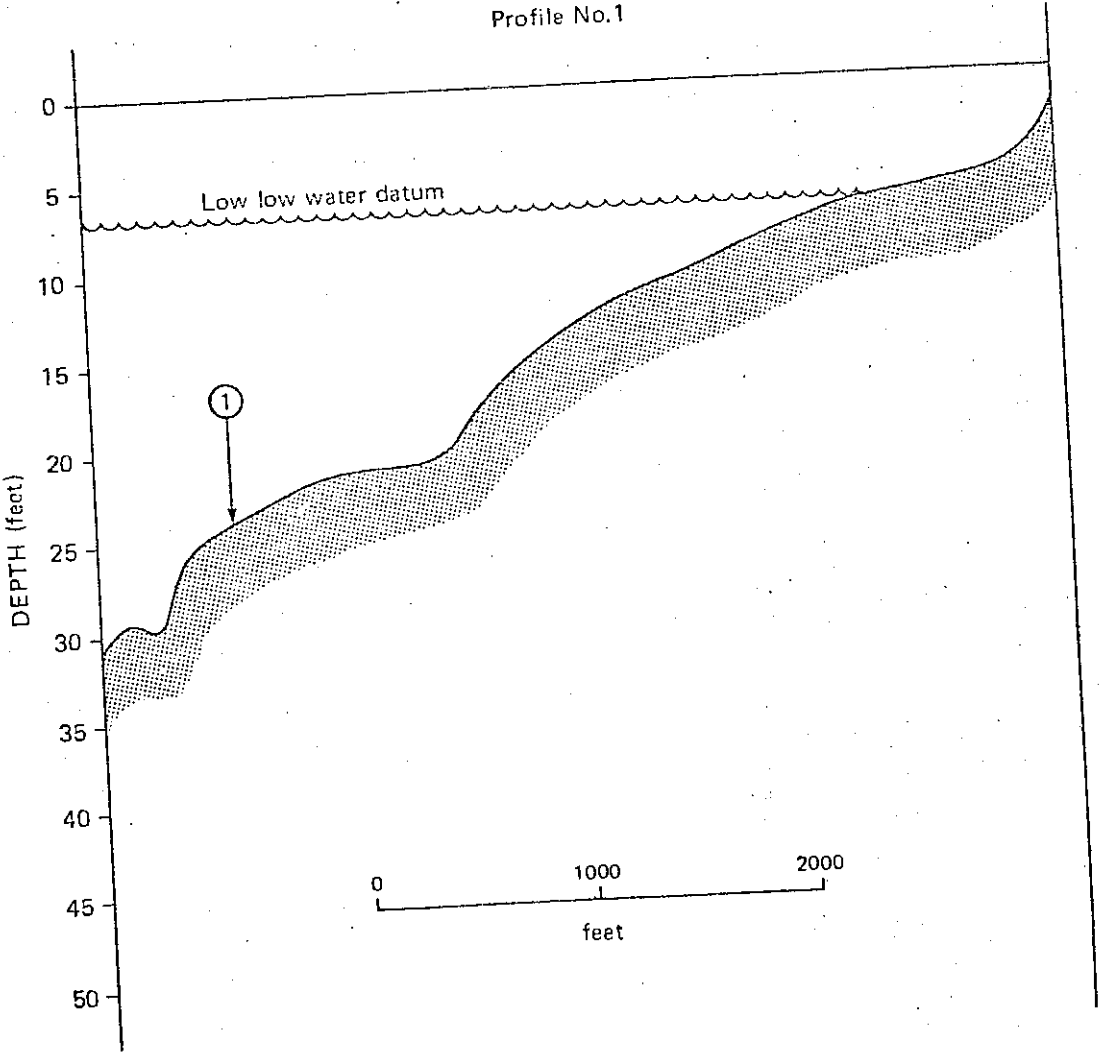


Figure 4.2 Nearshore profile No. 1.

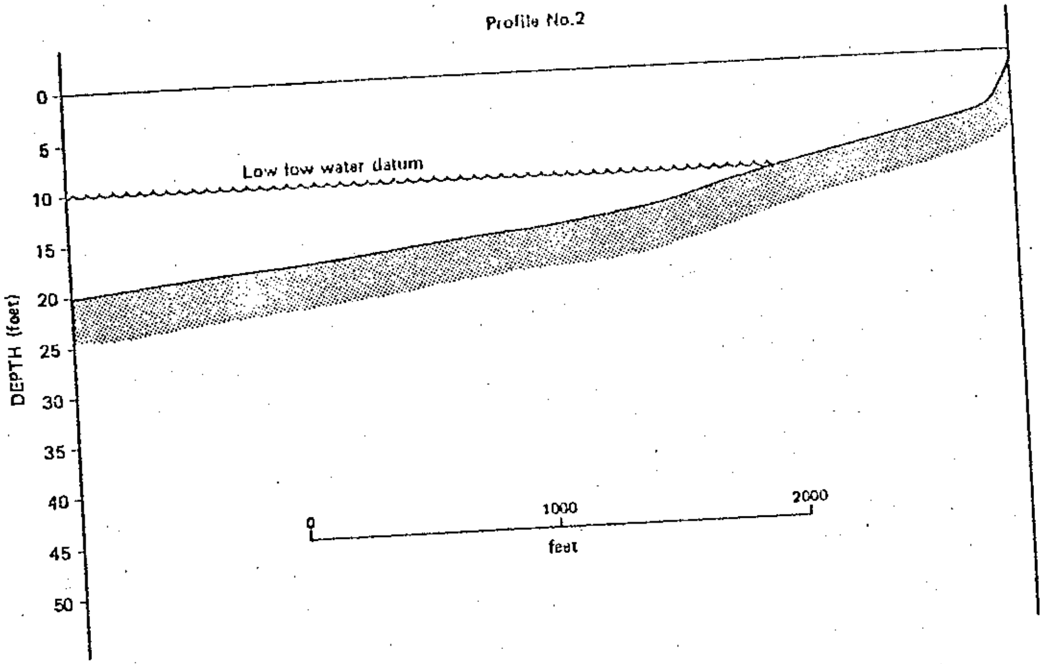


Figure 4.3 Nearshore profile No. 2.

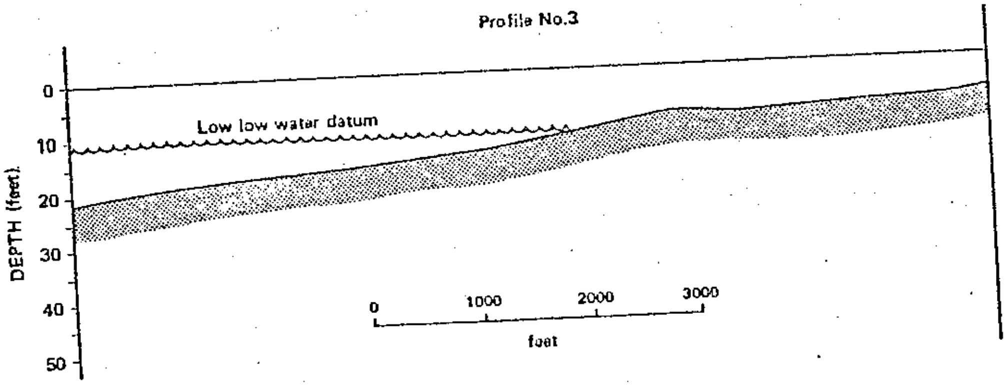


Figure 4.4 Nearshore profile No. 3.

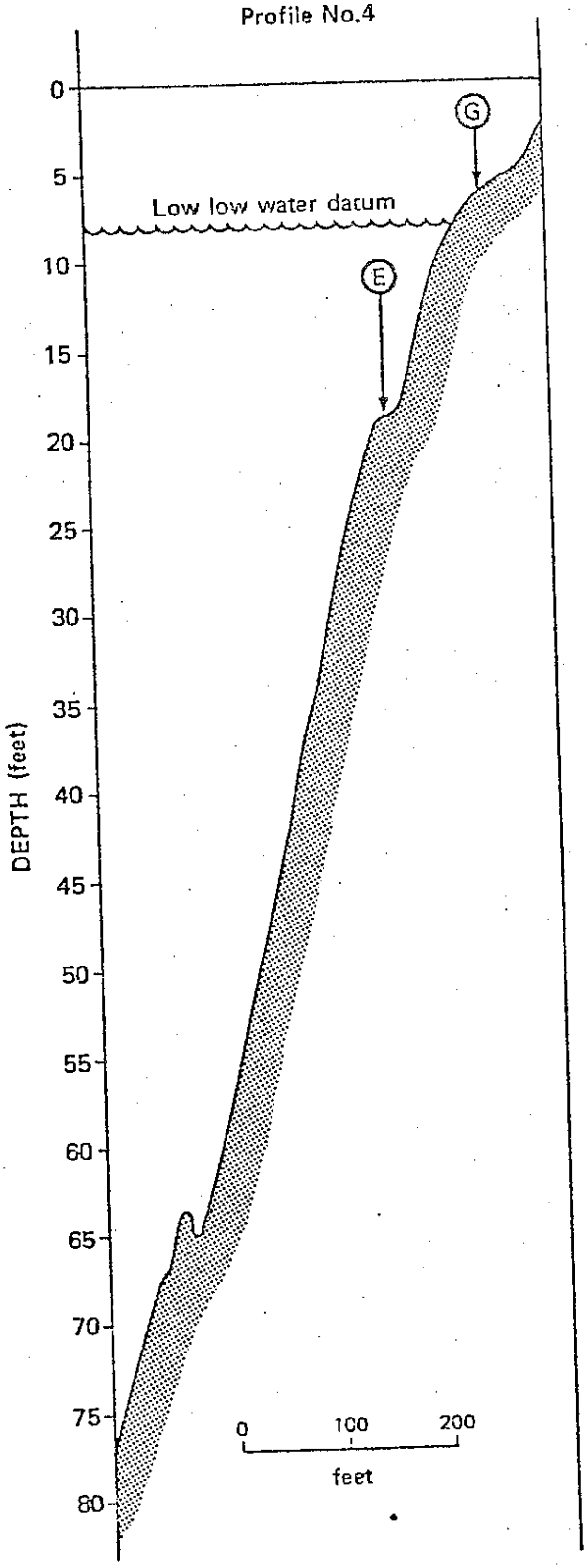


Figure 4.5 Nearshore profile No. 4.

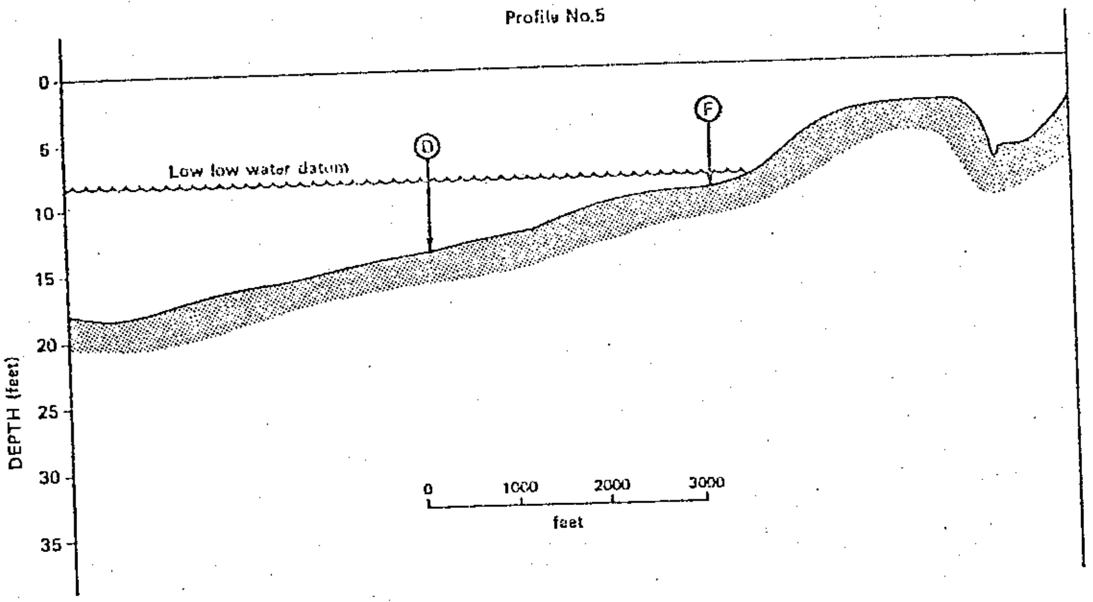


Figure 4.6 Nearshore profile No. 5

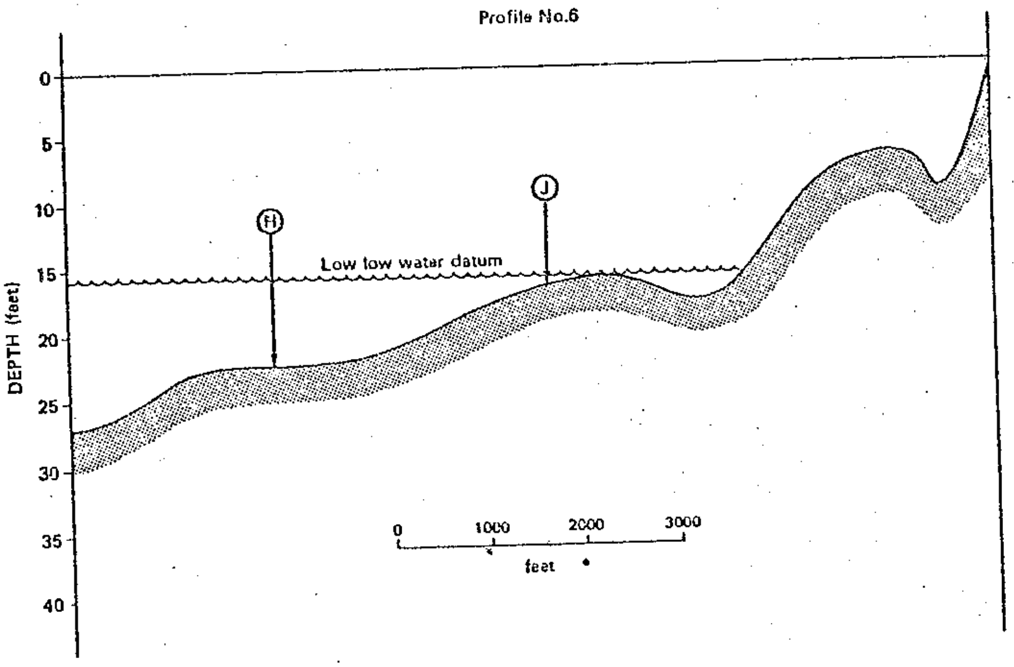


Figure 4.7 Nearshore profile No. 6

steep profile below the low water datum, a narrow, flatter, lower intertidal zone (the low-tide terrace) and a steep beach-face slope on the upper intertidal zone (this upper slope is part of the artificial harbor structure).

The north shore profiles indicate a major change in physiography from the flat nearshore and intertidal profiles within the central part of Coal Bay (No.2 and No.3) to steep offshore and nearshore slopes with a narrow intertidal zone towards the distal end of the spit. This change between Profiles No.2 and No.1 is indicative of a change in sedimentary environments related to the inherited drowned valley topography. Profile No.3 is located on an eroded valley bench whereas Profile No.1 was surveyed across the subaqueous seaward extension of the spit system which grew from the northwest into deeper water.

In spit systems where there is transport of sediments around the distal point from the exposed to the sheltered shore there commonly exists a subaqueous shoal or lobe of sediment on the more sheltered shore. The absence of this feature (see inset NOAA chart 16645) indicates that relatively small volumes of sediment are transported in the subtidal zone around the distal point onto the northeast shore.

It appears, therefore, that Homer Spit has grown across a relatively shallow flat subaqueous valley bench into deep water. The growth of the spit to the southeast has been limited by a major slope change that occurs on the steep northwest side of the drowned valley. Much of the sediment that is transported towards the distal point along the southwest shore is deposited in deep water.

The profile off the distal point (No.4; Fig.4.5) shows the extremely steep slopes adjacent to the end of the spit. The slope break at 10 feet below the low water datum may be related to a pre-1964-earthquake shoreline, as this feature would have been at the low water line at that time. The lower break of slope, at 55 feet below the low water datum could be possibly related to slumping associated with the 1964 earthquake. This interpretation of the two breaks of slope is conjectural and should be treated as such. The most important aspect of this distal profile is the extremely steep subtidal gradient. Further spit growth towards the southeast is largely precluded by the large volumes of sediment that would be necessary to prograde the shoreline into this deep water.

On the exposed south shore the two profiles (No.5 and No.6; Figs. 4.6 and 4.7) are similar in many respects. Both show a shallow offshore profile (across the Archimandritof Shoals), a break of slope at about the low water datum, a large intertidal bar and a steep beach-face slope in the upper intertidal zone. A seaward one-mile extension of Profile No.6 (not included in Fig. 4.7) shows a break of slope at 10 feet and an undulating bottom topography across the shoals with water depths varying between 12 and 15 feet below the low water datum. A similar break of slope at -10 feet is indicated near the seaward limit of Profile No.5.

The intertidal bars have a low-angle seaward-facing slope and a steep onshore slope that is typical of wave-formed bars that migrate landwards. The bar on Profile No.5 is larger (both higher and wider) than that farther to the northwest, as this is in a more exposed wave environment.

The Archimandritof Shoals are part of the shallow subaqueous valley bench that characterizes the entire north shore of Kachemak Bay. The orientation of Homer Spit parallels the submarine contours and the northwest coast of the bay, and is aligned to waves that approach out of the southwest. The spit owes its origin to the presence of this submarine bench that made possible the accumulation of unconsolidated sediments in relatively shallow water.

4.3.2 Winds and Waves

Throughout the study period, winds were consistently out of the northeast with average velocities predominantly between 10 and 20 mph (Fig. 4.8). Visual offshore wave observations taken daily from the boat in the immediate vicinity of the southeast tip of Homer Spit showed a direct correlation with the wind characteristics. Offshore significant wave heights were predominantly 2 to 3 feet, with periods of 2 to 3 seconds and a wave direction out of the northeast. Maximum significant wave heights of 6 feet with periods up to 4 seconds were observed on December 12 when wind velocities increased to 20 - 30 mph.

The consistency of the winds during the study period was characteristic of the wind regime at that time of year. The direction varied only between 20° and 60° and locally the northeast-facing coast of Homer Spit was exposed to the full effect of the onshore waves. The formation of shore-zone ice on the sea surface, commencing on December 12, caused complete attenuation of the incident waves so that shore-zone breakers were absent and no wave energy was dissipated in the shore zone. The southwest-facing coast of the spit was sheltered from incident waves throughout the study period and little or no wave action was observed on the beaches. Breaker heights at the shore on this coast were generally less than 0.5 feet.

Homer Spit is different from the majority of spits found elsewhere as the "sheltered" shore has a relatively large fetch area offshore. In many instances the lee shores are very sheltered wave-energy environments that have marshes and only poorly developed intertidal beaches. At Homer the northeast coast has no marshes and is subject to wave action, sediment reworking and longshore transport during periods of northeast winds.

The relationship between the wave character and nearshore sediment movement is a critical factor in understanding transport rates. Wind-generated waves affect the sea bed when the water depth is equal to or less

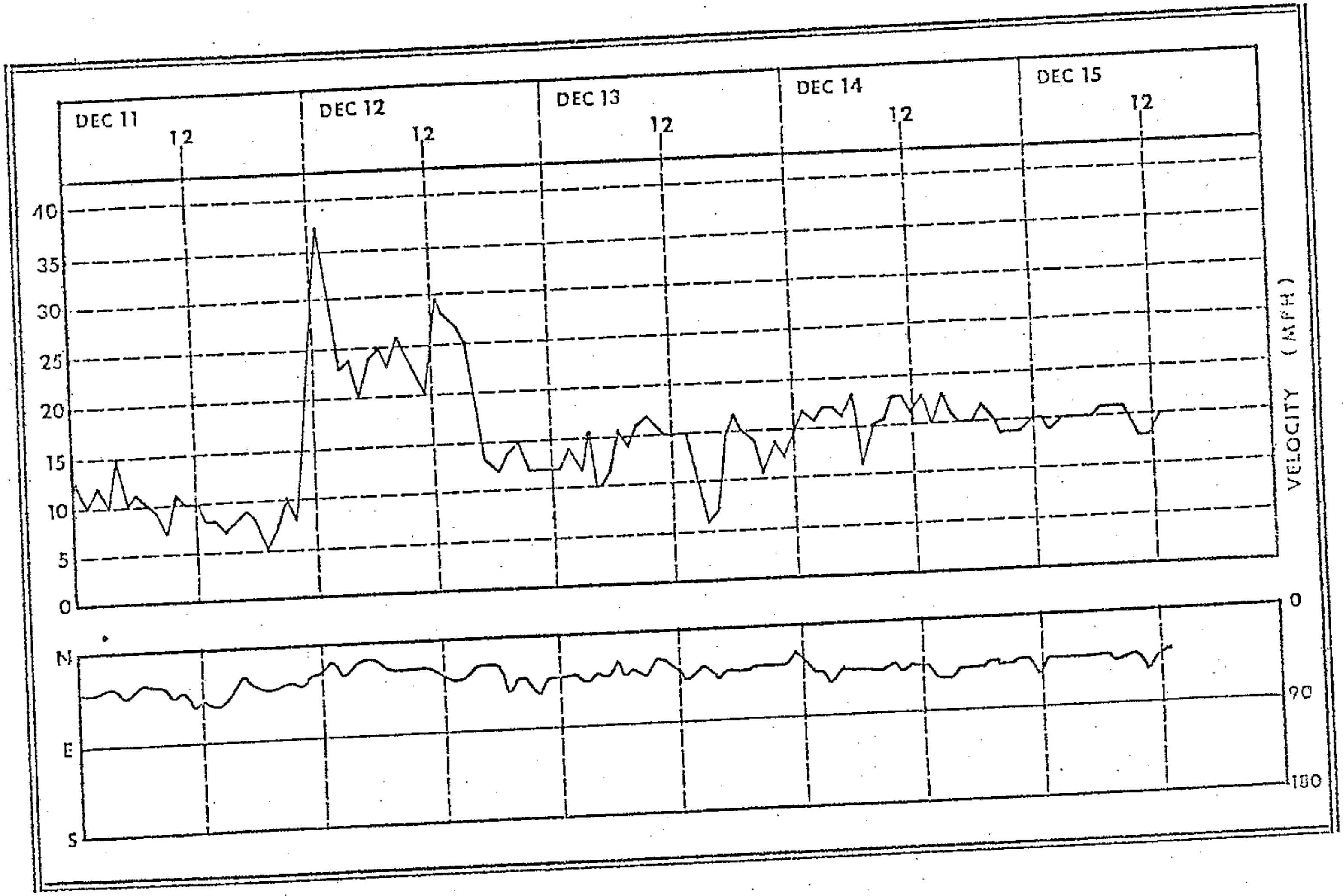


Figure 4.8 Hourly wind velocity and direction values measured on Homer Spit during the field study. Data obtained from the Homer Harbor Master's Station.

than half the wave-length. At this depth the wave is also subject to refraction. From very generalized computations, using wave period as the basic parameter, 6 second waves (which have an assumed wave length of 184 feet) feel the sea bed in depths of approximately 100 feet but are not significantly altered (refracted) until the water depth decreases to 50 feet. Similarly, a 4 second wave feels bottom in approximately 40 feet and is strongly refracted in 20 feet water depths. Thus any southwest waves over the Archimandritof Shoals at low tide with a period of 4 seconds or greater affect the bottom and are refracted at distances of 2 miles or greater from the shoreline. This means that wave-induced movement of bottom sediments over the shoals is likely to occur whenever wave periods are in the order of 4 seconds or greater.

Using wave height as the basic parameter, with the 14.0 foot design wave height for the southwest coast of the spit bottom movement of sand could occur in water depths of 121 feet (37 m or 20 fathoms). As this is an infrequent wave height, of more practical value is the maximum annual significant wave height, of 9.9 feet (Hayes et al., 1976) which gives a depth of 87 feet (26.5 m or 14.5 fathoms) for sand transport. From these generalized computations sand transport in water depths of 90 feet would be expected to occur on at least one occasion each year, whereas transport in depths of 50 feet would be common during periods of strong storm winds (>20 mph) in winter months. The slope break between the Archimandritof Shoals and deeper water varies between approximately 30 and 60 feet (10 and 20 m). Transport of sand-sized sediment on the shoals is therefore possible during all periods of storm-wave activity generated by southwest winds.

On the northeast coast, although wave periods of 4 seconds are less common the nearshore zone is extremely shallow and therefore shorter period waves can be refracted and are able to induce sediment motion in the nearshore area. Using the 6.3 foot design wave height for this coast the bottom movement of sand-sized sediments could occur in water depths of 47.5 feet (14.5 m or 8 fathoms). Smaller wave heights of the order of 4 feet, which are more frequent, would affect bottom sediments in water depths of less than 20 feet throughout Coal Bay during winter months.

It is evident from consideration of wave characteristics in this area and of nearshore topography adjacent to the spit that wave-induced transport of bottom sediments is probable during periods of strong (>20 mph) wind velocities. The exact relationship between the forcing processes and local bottom sediment movement is dependent upon (i) the wind direction and velocity, (ii) water depths and tide stage, and (ii) the availability and size of sediments for redistribution.

The amount of littoral transport generated by breaking waves is controlled by nearshore sediment size, breaker height and breaker angle. Breaker heights and angles are, to a large extent, determined by offshore bathymetry which refracts the incoming waves. Where offshore banks are extensive and topographically complex, such as the Archimandritof Shoals, wave refraction can produce local anomalies in transport directions and magnitudes.

From the brief observations made during the field study it is not possible to make any definitive statements concerning the effects of wave action on littoral or nearhsore sediment transport. The observations do indicate, however, that wave activity must be considered a major controlling process in evaluating the sediment transport system on and adjacent to the spit.

4.3.3 Nearshore Bottom Currents

The location of the current stations is given on Figures 4.9 and Stations D through J are also indicated on the profiles presented in Figures 4.5 to 4.7 (pages 4-6 and 4-7). The actual observed data are listed by station in Appendix B. To relate the observed currents with respect to (i) the tidal stage, and, (ii) the location of the station, the data have been plotted on a series of diagrams (Figs. 4.10 to 4.19).

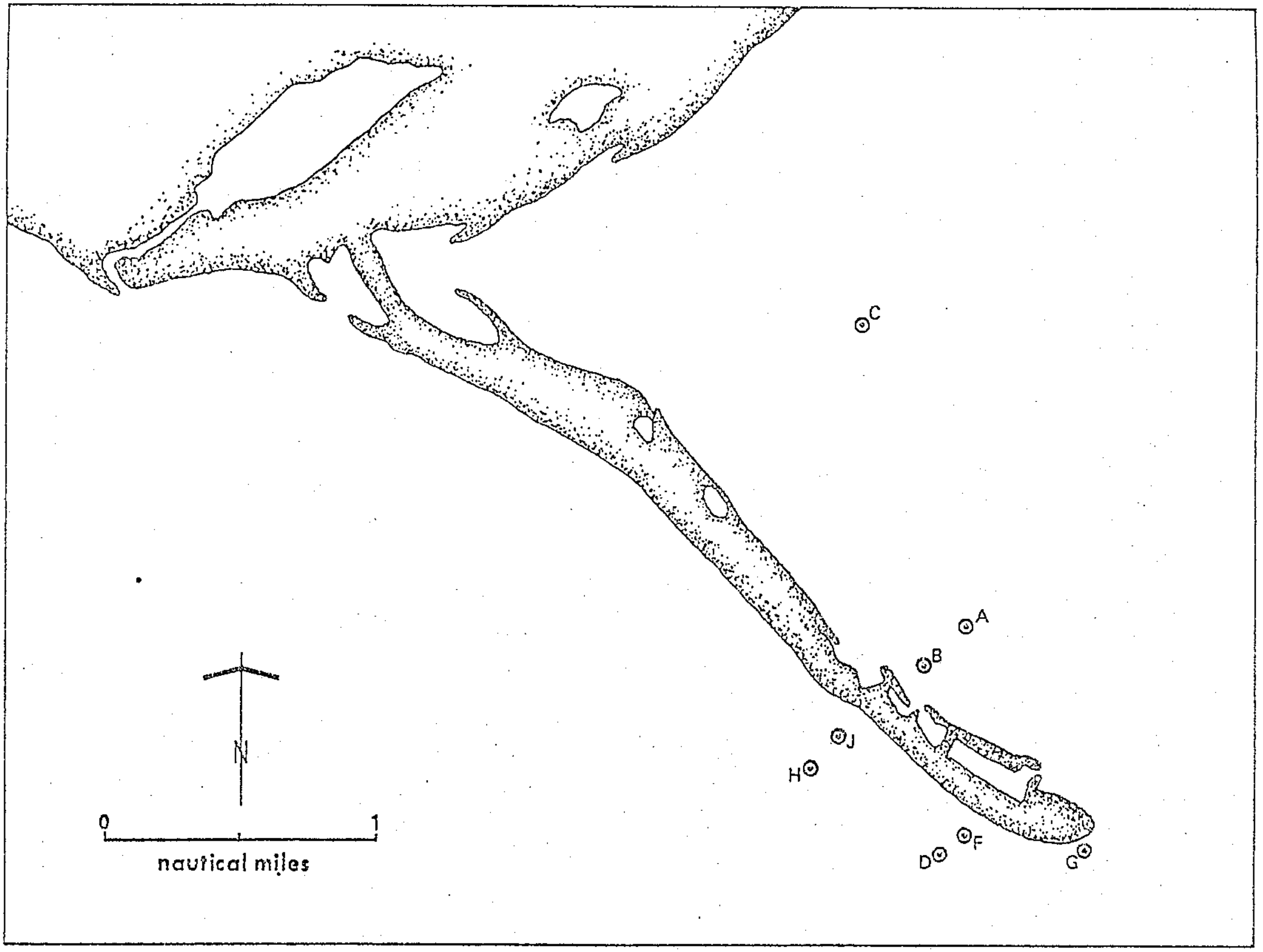


Figure 4.9 Location of bottom current measurement stations. Stations were marked by buoys and fixed by sextant angles.

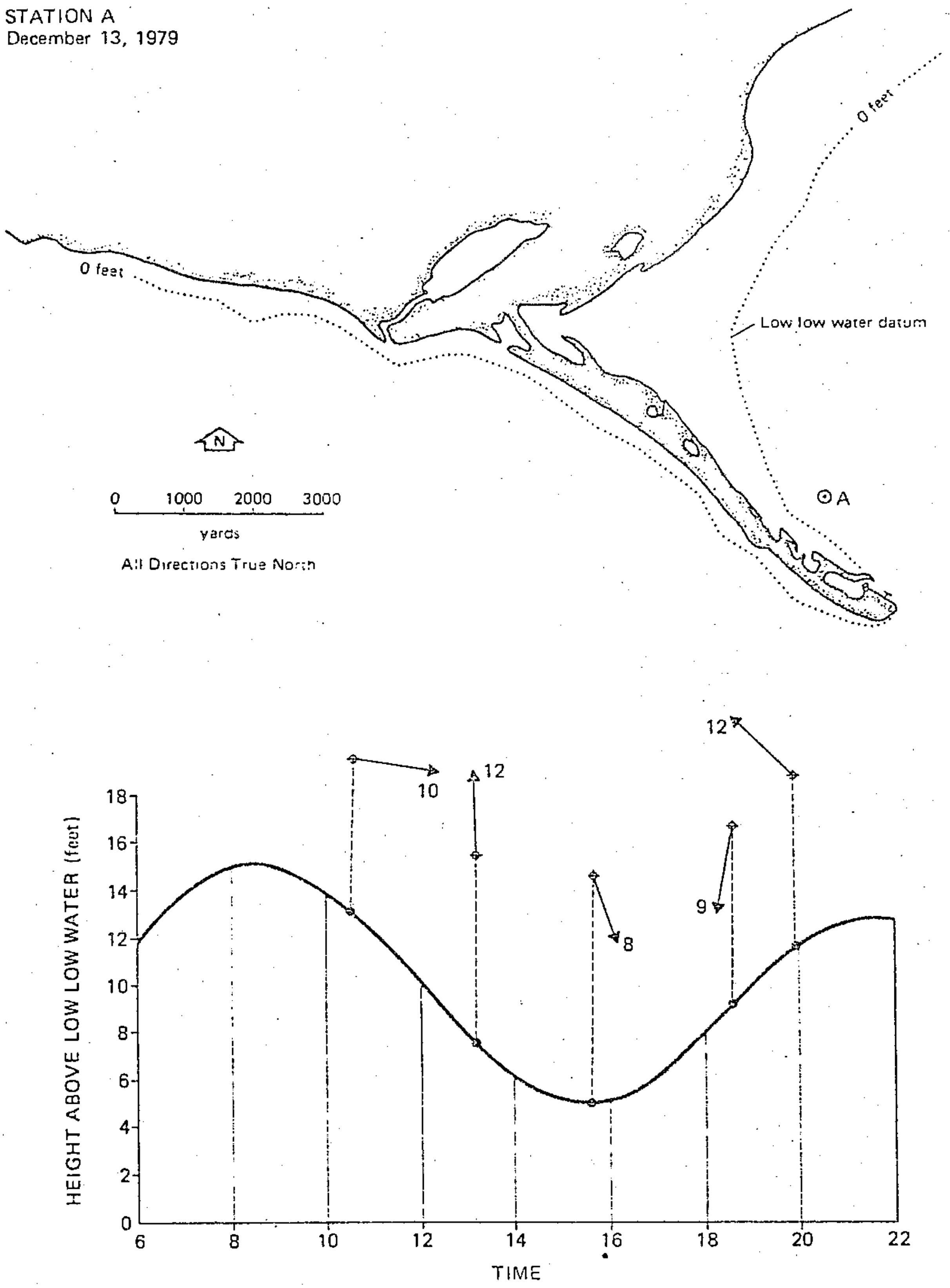


Figure 4.10 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station A, December 13, 1979. The data are plotted on the lower diagram with reference to predicted water level.

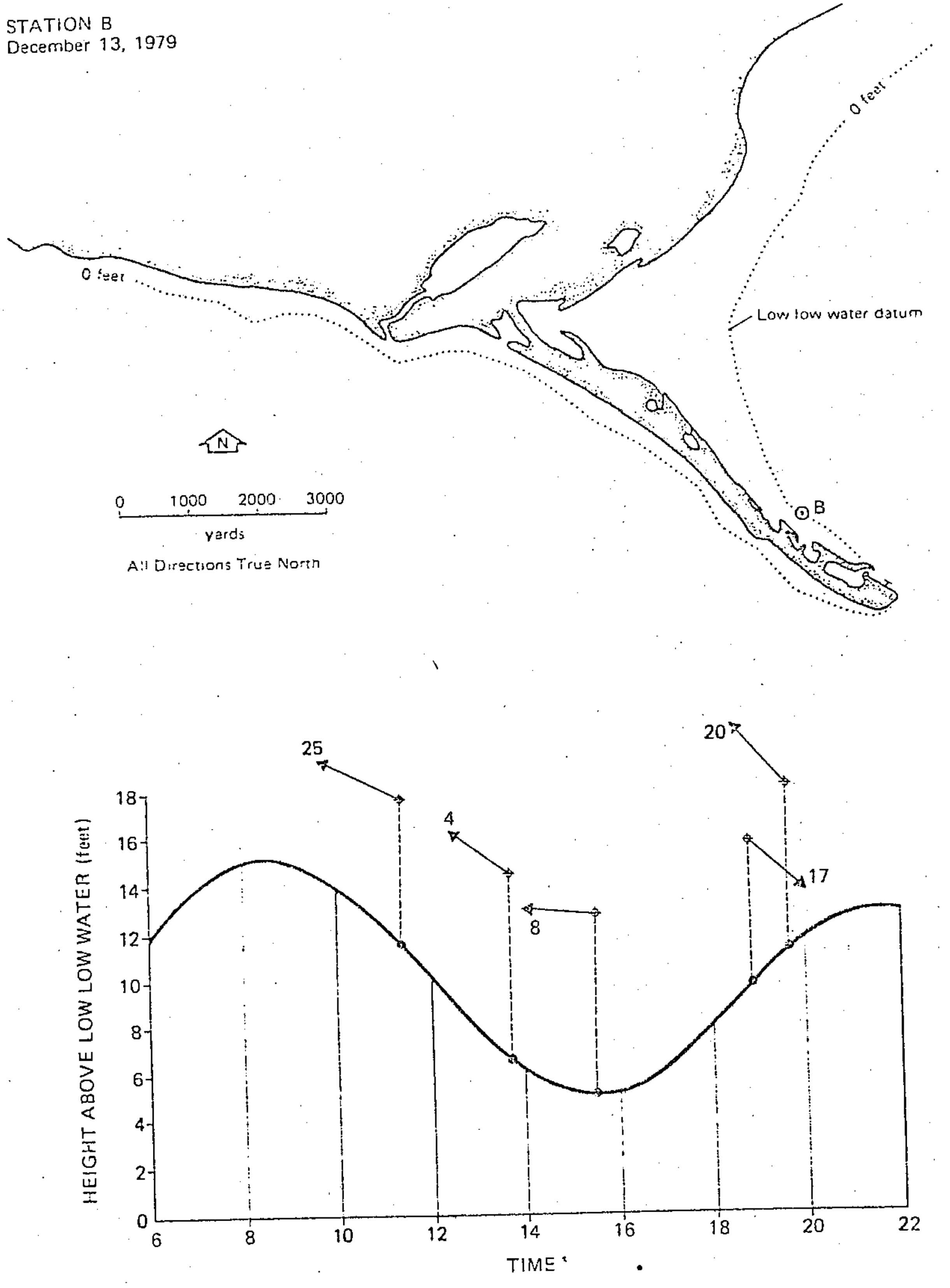


Figure 4.11 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station B, December 13, 1979. The data are plotted on the lower diagram with reference to predicted water level.

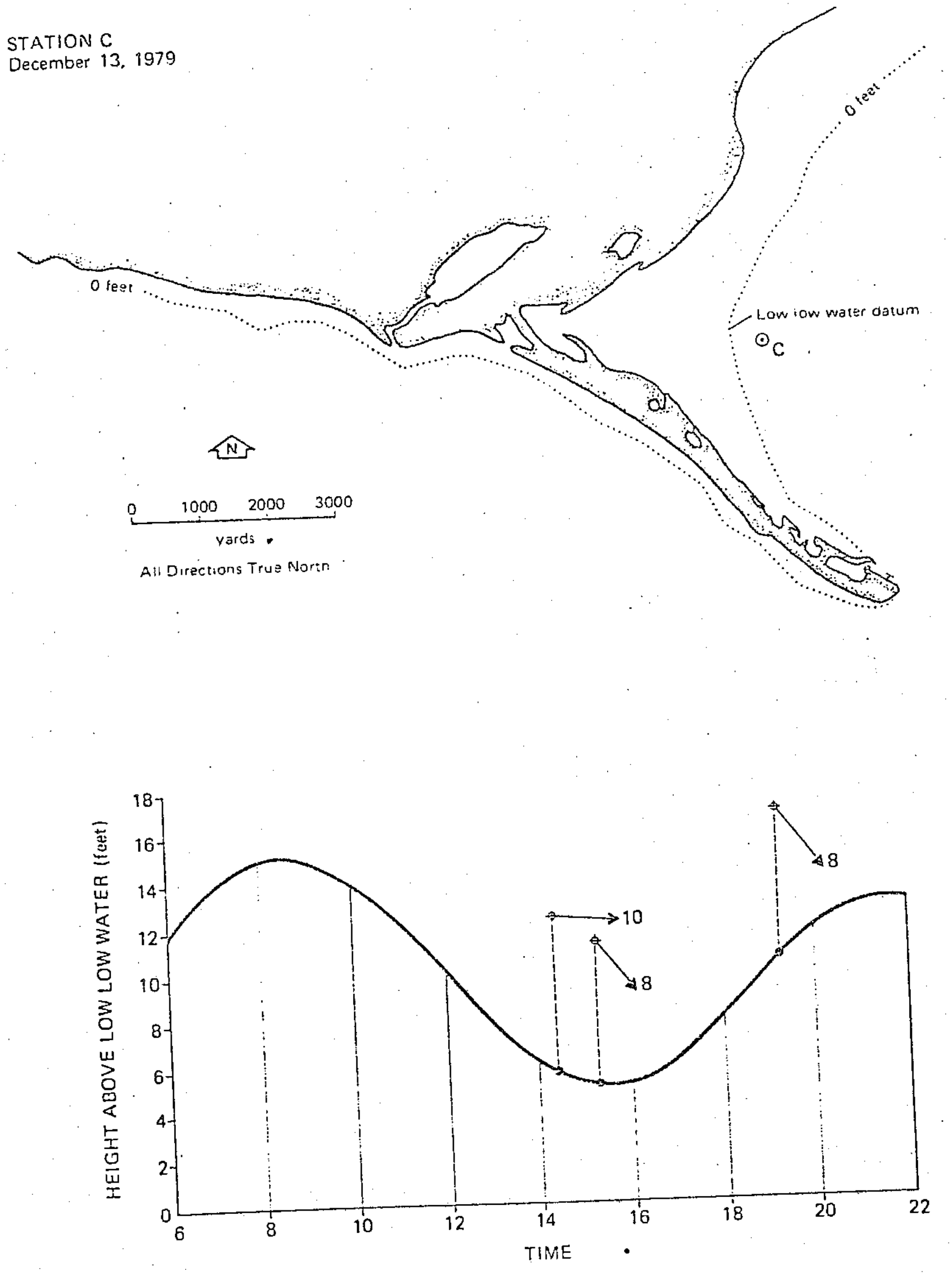


Figure 4.12 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station C, December 13, 1979. The data are plotted on the lower diagram with reference to predicted water level.

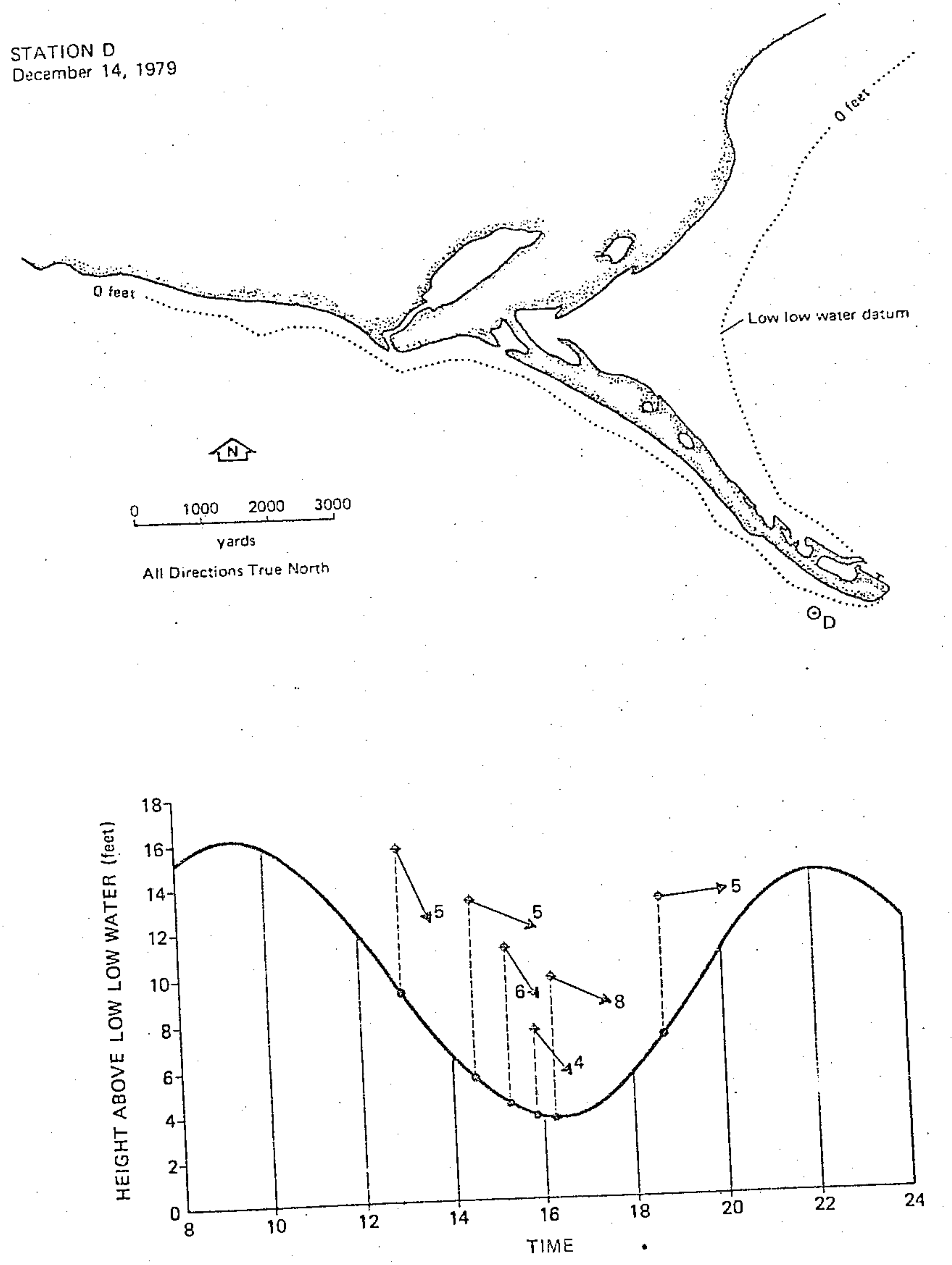


Figure 4.13 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station D, December 14, 1979. The data are plotted on the lower diagram with reference to predicted water level.

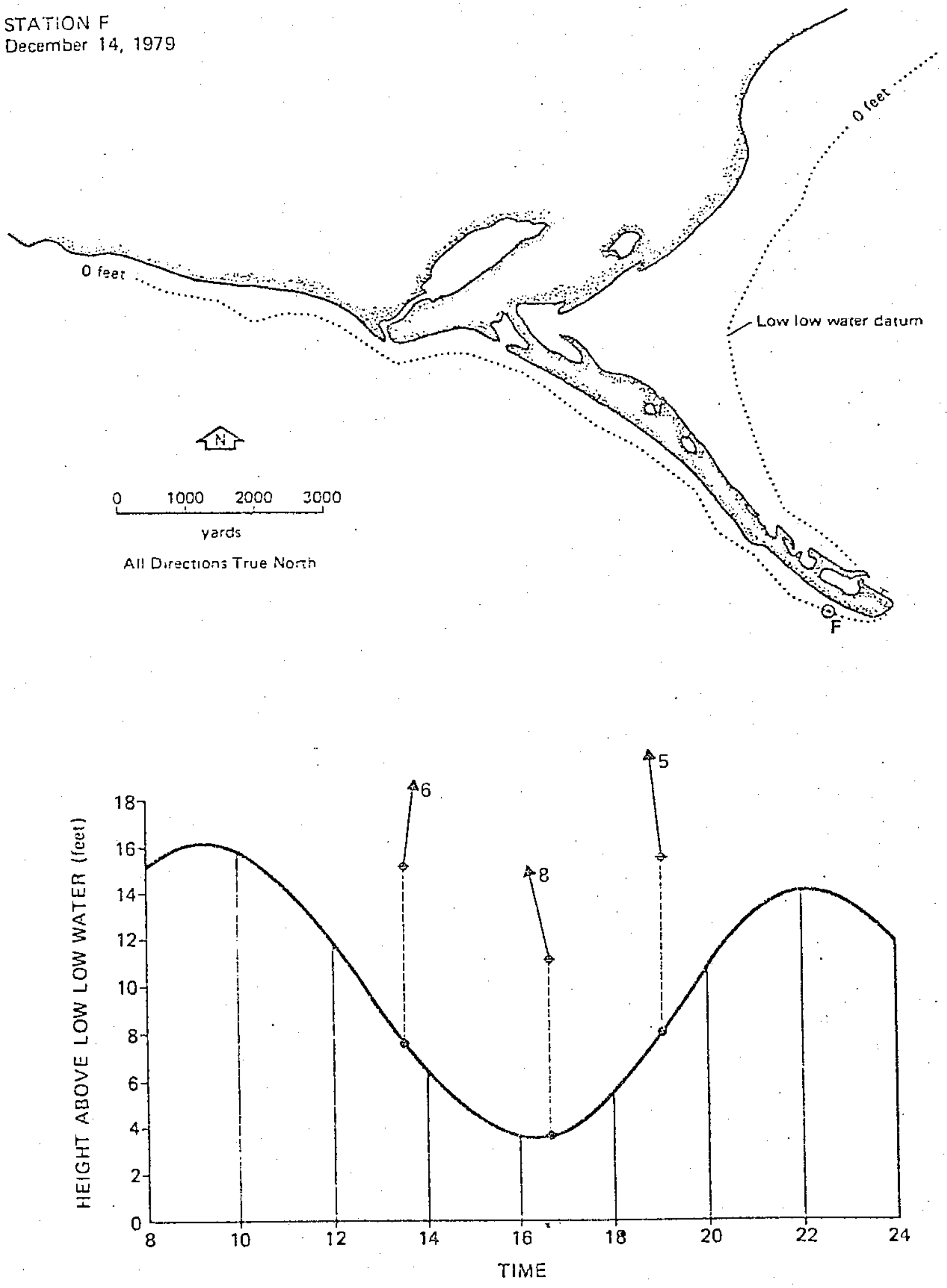


Figure 4.14 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station F, December 14, 1979. The data are plotted on the lower diagram with reference to predicted water level.

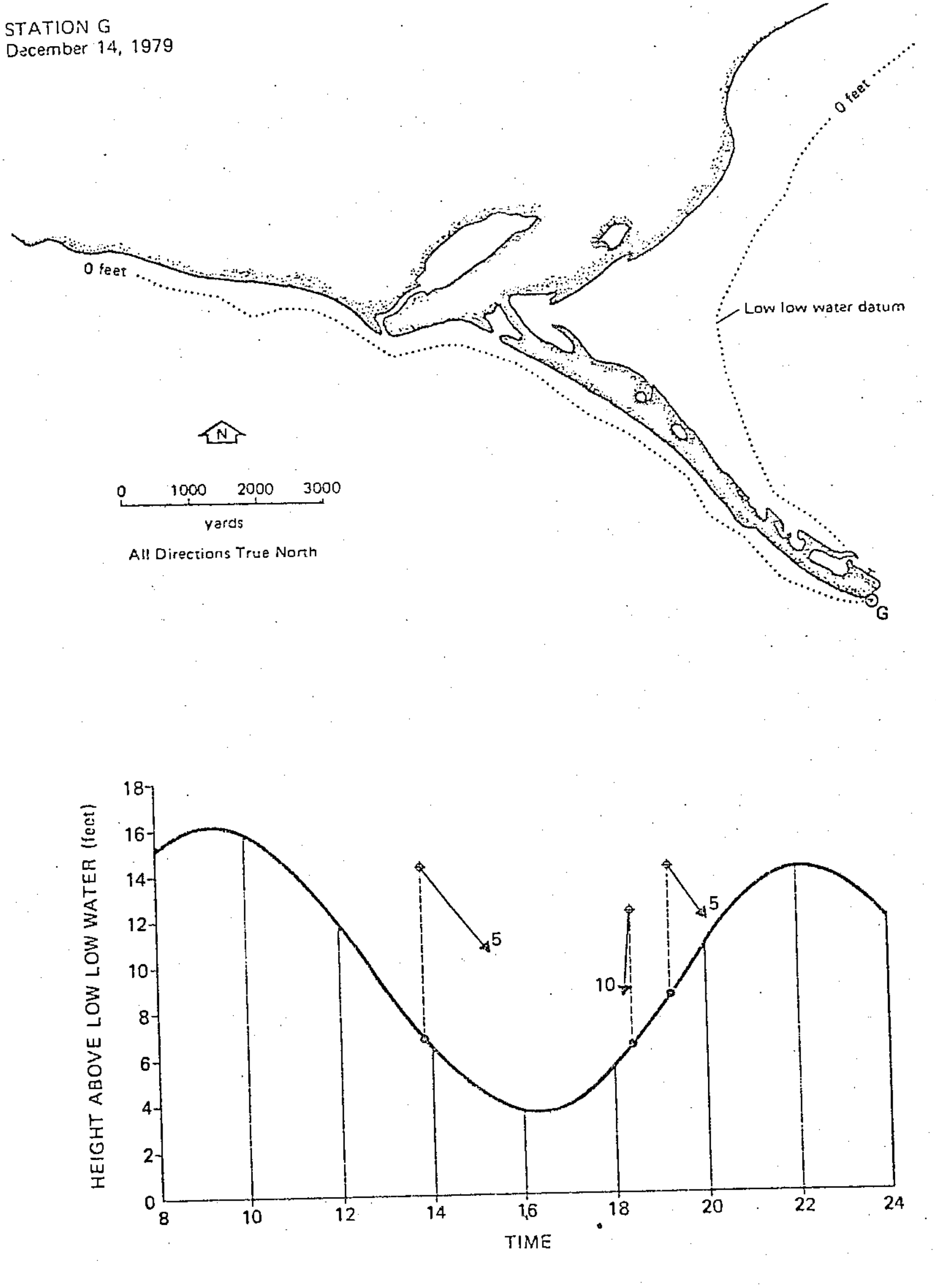


Figure 4.15 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station G, December 14, 1979. The data are plotted on the lower diagram with reference to predicted water level.

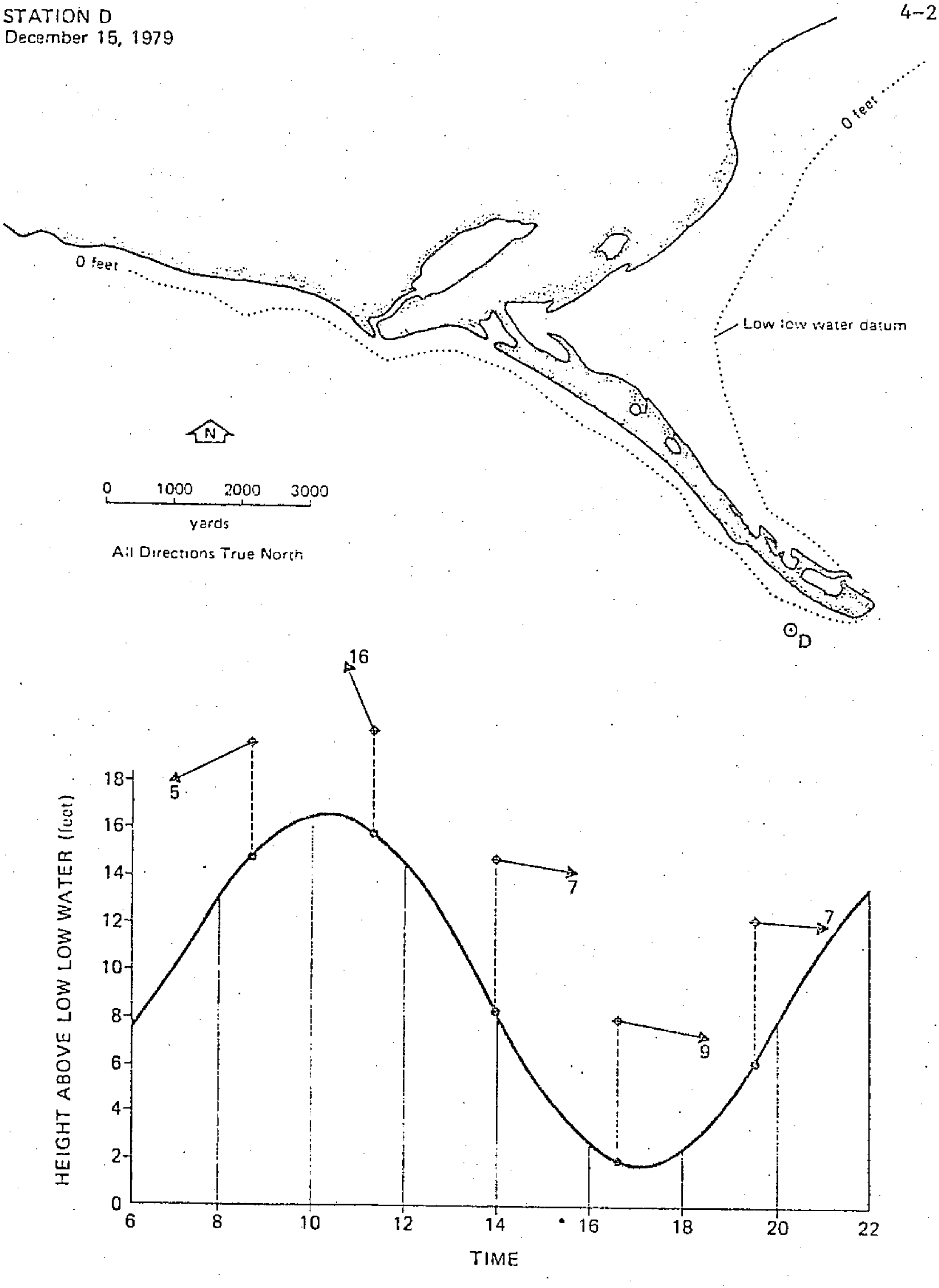
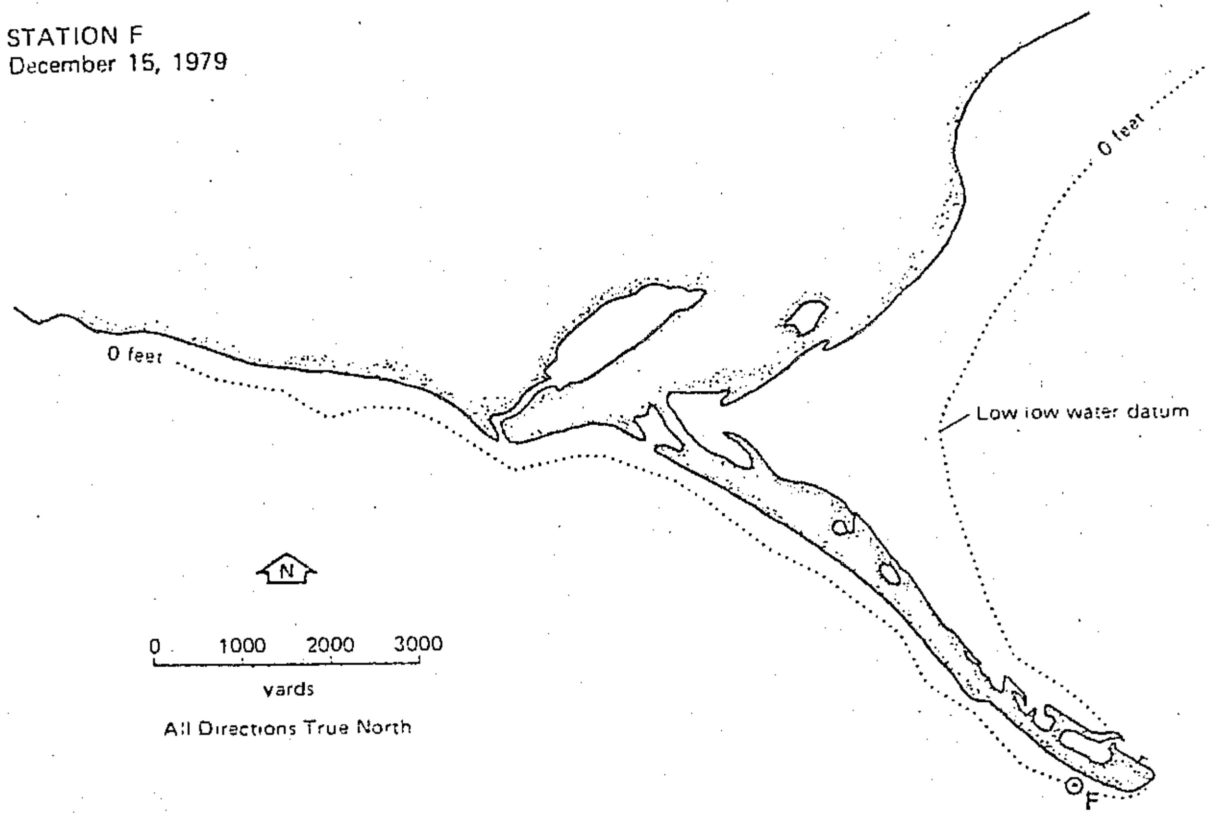


Figure 4.16 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station D, December 15, 1979. The data are plotted on the lower diagram with reference to predicted water level.



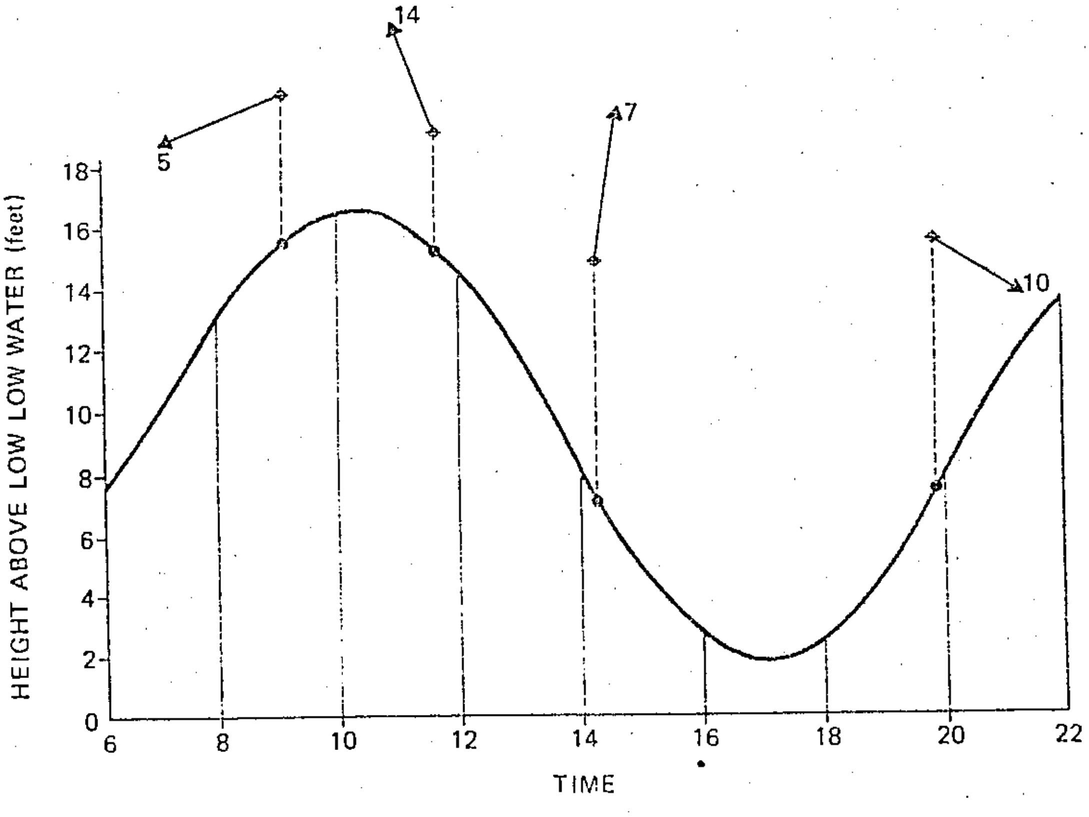


Figure 4.17 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station F, December 15, 1979. The data are plotted on the lower diagram with reference to predicted water level.

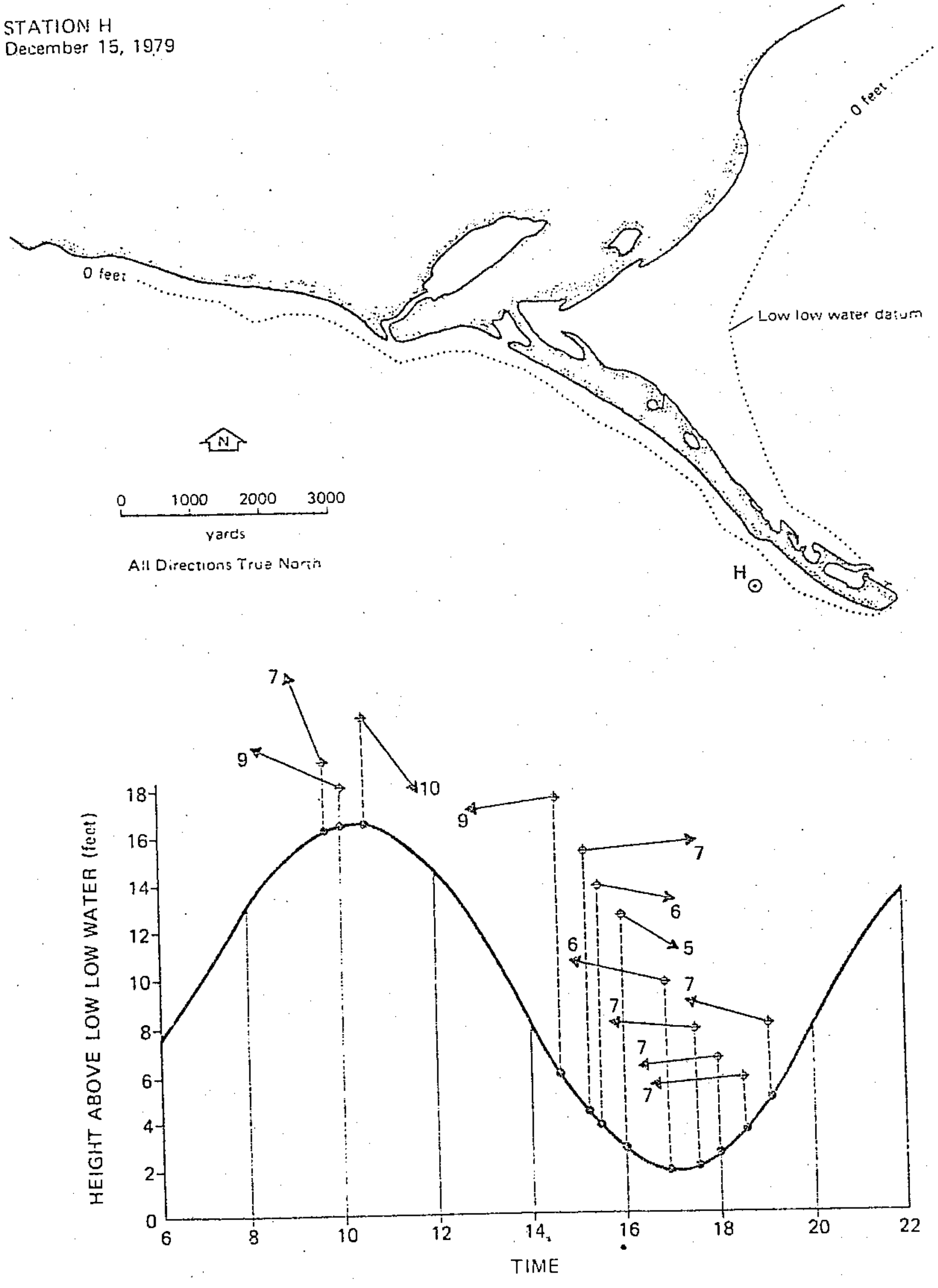


Figure 4.18 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station H, December 15, 1979. The data are plotted on the lower diagram with reference to predicted water level.

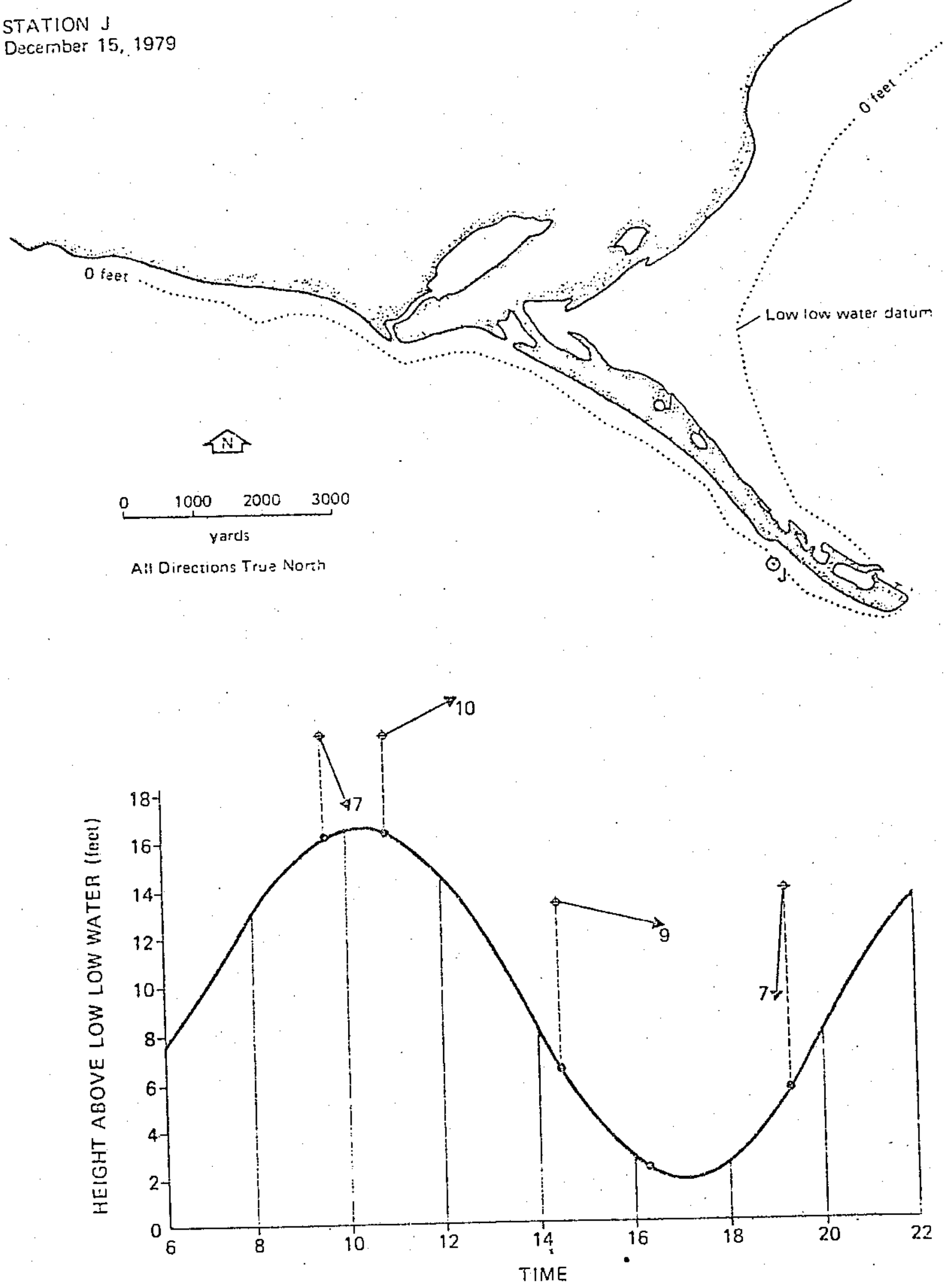


Figure 4.19 Bottom current direction (arrow) and velocity (in cm/s given at the tip of the direction arrow) for Station J, December 15, 1979. The data are plotted on the lower diagram with reference to predicted water level.

The most significant observations are that at no time did averaged velocities exceed 25 cm/sec (0.48 kts) and that the directions did not change cyclically in correspondence with the tide stages. A maximum instantaneous velocity of 30 cm/sec (0.58 kts) was observed on one occasion (Station A, December 13; 11.25). Of the 52 observations, on only 7 occasions did the average velocity exceed 10 cm/sec (0.19 kts).

Bed load sediment transport is initiated by bottom currents in the order of 20 cm/sec for mud, 30 to 40 cm/sec for fine sands (0.125 - 0.25 mm diameter) and 40 to 50 cm/sec for medium sands (0.25 - 0.5 mm diameter). If the current measurements recorded during the field investigation are representative of the combined water motion due to waves and tides, it is apparent that velocities were insufficient to initiate transport of sediments coarser than mud (silts and clays). As wave heights were low (<3 feet) during the measurement periods and as the analog output was visually averaged to filter out wave-induced water motion, the observed values are believed to be representative of normal (non-wave) currents. From this it may be speculated that tides are unlikely to be a major factor in the reworking and redistribution of sand-sized and coarser sediments. Although this statement must be regarded as tentative due to the limited number of observations, it can be considered indicative of the fact that waves and not tides are the major forcing factor in the initiation of transport and in the redistribution of coarse bottom sediments.

Material that is carried in suspension (silts and clays) is transported by currents and is deposited in areas where current velocities decrease below a critical level. Deposition can occur in sheltered environments or at times of slack water. The accumulation of silt and clays in the shore zone is therefore restricted to low energy environments such as bays or lagoons. This explains the lack of mud deposits on the exposed southwest coast and their occurrence in the more sheltered areas of Coal and Mud Bays.

When all of the data from the three stations (A, B and C) monitored on the north shore (Figs. 4.10, 4.11 and 4.12) are considered, no definite trends are evident that could be related to tide-induced currents. At Station A the current direction was completely variable. At Station B, inshore of Station A, the current flowed predominantly to the northwest, parallel to the shoreline, during both ebbing and flooding tides. Although only 3 measurements were made at Station C, in the center of Coal Bay adjacent to the ice-edge, these data indicated a southeast current. If only mid-ebb and mid-flood direction data points are considered it is possible to isolate a current reversal at Stations A and B (Figs. 4.20 and 4.21). However, an ebb flow to the northwest and a flood current to the southeast is the opposite of that which would be expected from a tide-induced water motion. If the data from Station C is representative of water movement during periods of northeast winds the inferred current pattern is one of wind-driven currents on the northshore of Coal Bay at these times. This would indicate that on this coast the circulation pattern is a combination of wind-driven and tide-generated currents. Longer term measurements would be necessary to confirm this initial conclusion.

Data collected from the southwest nearshore zone on December 14 show a southeast movement parallel to the shoreline at Station D (Fig. 4.13), an onshore movement at Station F (Fig. 4.14 inshore of Station D), and an offshore movement to the southsoutheast at Station G (Fig. 4.15) adjacent to the distal point of the spit. None of the measurements indicate a distinctive tidal component in the current direction and the onshore current pattern at Station F is almost certainly wave-induced.

The data from Station D on December 15 (Fig. 4.16) could be interpreted as a cyclical tidal current, as the direction reversed from flood to ebb during the first cycle. However, the direction measured on the second flood tide did not change from that recorded on the previous ebb. The currents inshore of D at Station F (Fig. 4.17) show a similar trend, although with an onshore movement during the ebb tide.

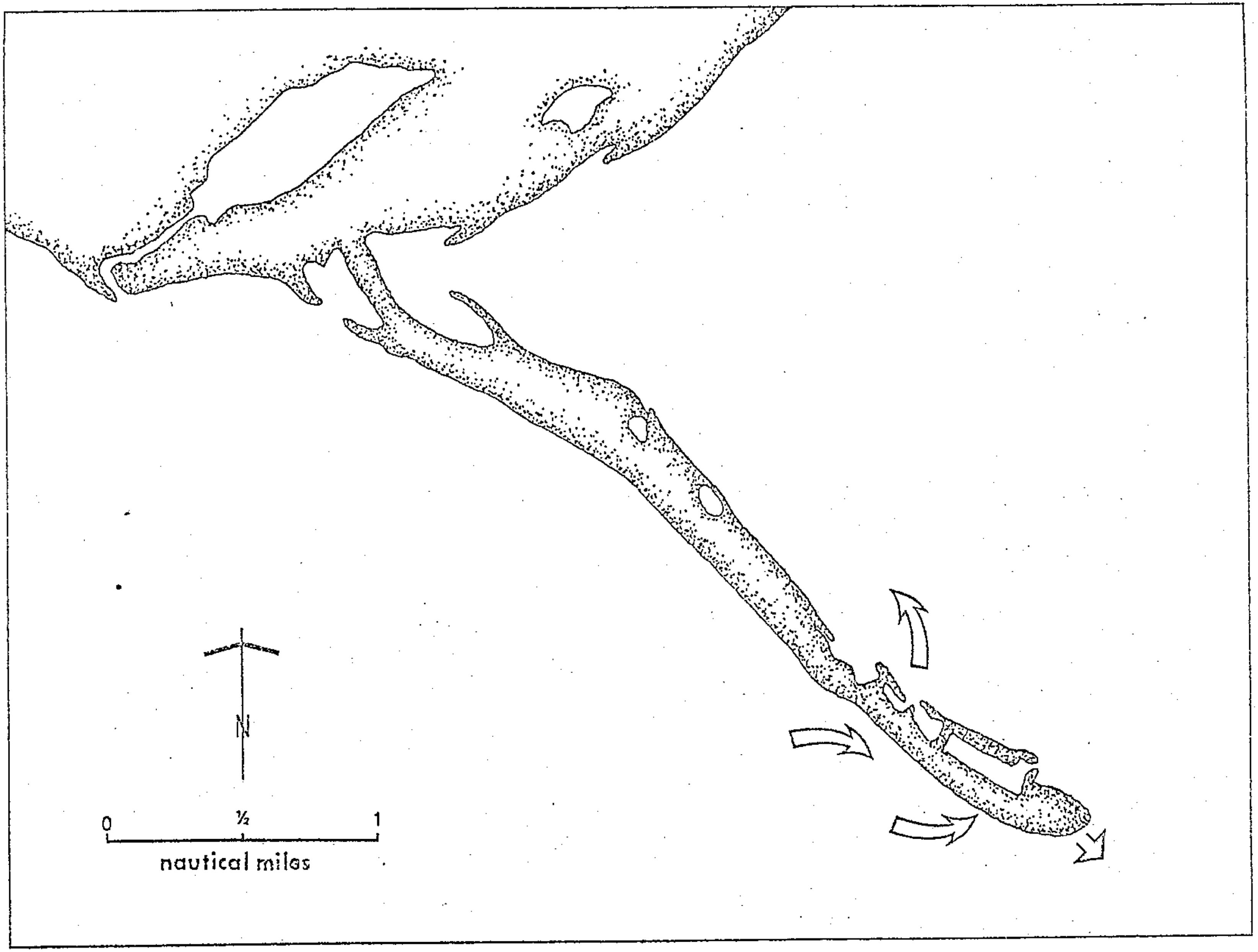


Figure 4.20 Compilation of current direction for all data at mid-ebb tide stage.

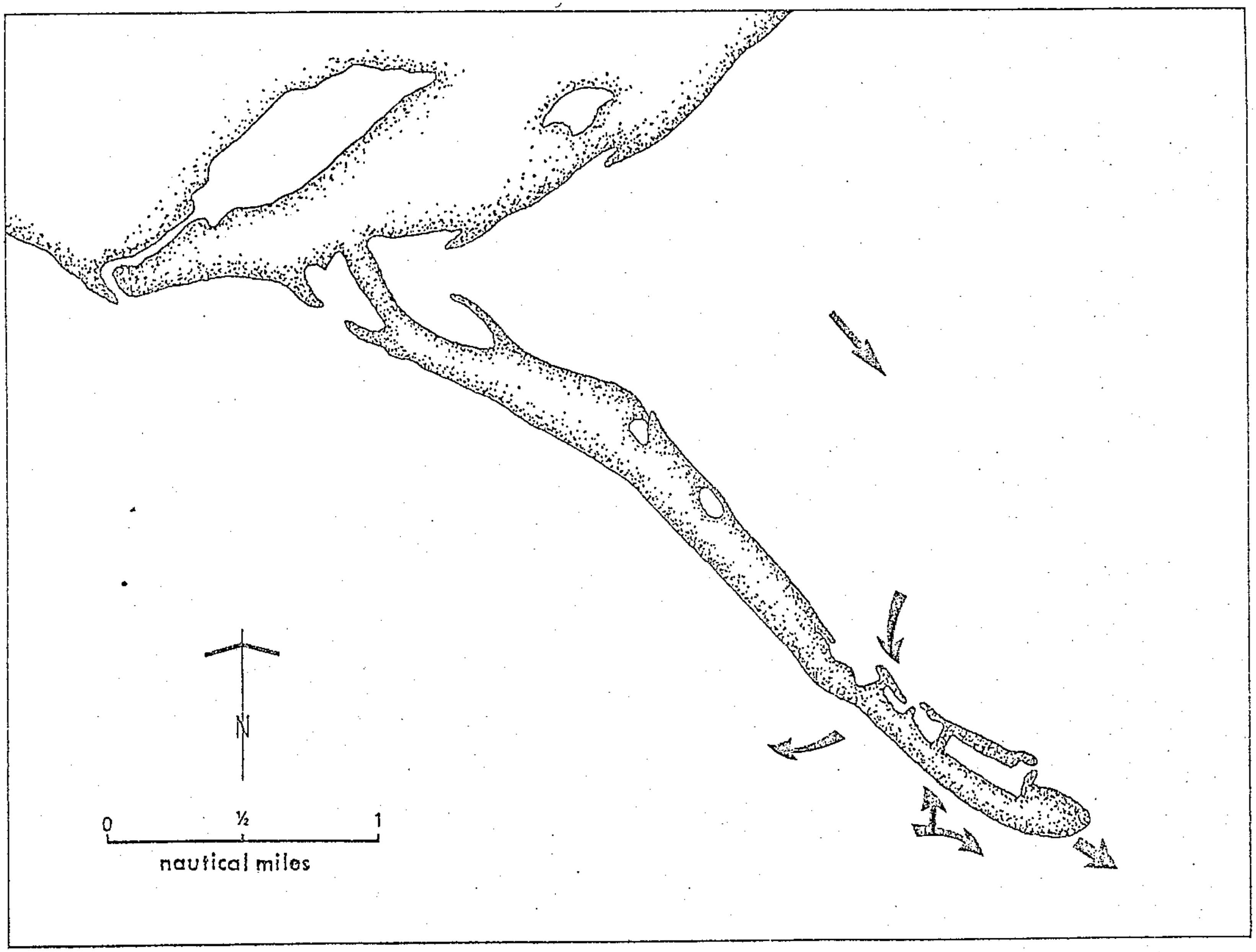


Figure 4.21 Compilation of current direction for all data at mid-flood tide stage.

At Station H a detailed series of measurements over a 12-hour period showed several current direction reversals (Fig. 4.18) and are an indication of the complexity of nearshore water motion in this area. This observation may, however, be a function of the higher frequency of observations at this site. This station was sheltered from the northeast winds and the water movement was predominantly parallel to the shoreline. Inshore from H at Station J (Fig. 4.19) the current direction varied between offshore and parallel to the shoreline towards the southeast.

Generalizations or conclusions from the current directions on the southwest shore are very difficult. There is no clear single dominant water motion common to each site, although if all the values are considered together 20 of the 39 measurements show a net direction towards the southeast quadrant, and 10 towards the northwest. This indicates that the predominant current directions are parallel to the shore, a trend which is emphasized further if the onshore current data from the inshore station at F are excluded.

If only mid-ebb and mid-flood direction data from the southwest coast are considered (Figs. 4.20 and 4.21) it is possible to identify a reversal at Station H and J on December 15th. However the patterns of current direction are not simple and at Stations D and G the mid-ebb and mid-flood currents tended to the southeast on both days.

In the absence of more detailed data the tentative conclusions that can be drawn at this time are that:

- within Coal Bay a northwest to southeast current on the north shore was observed that may be related to currents generated by the persistant northeast winds which are characteristic of the winter months
- on the south shore the water motion appears complex, although southeast currents predominated with a secondary northwest component; both directions paralleling the shoreline.

The observations show that a study of wind and tide generated currents within Coal Bay is important to the development of an understanding of suspended sediment transport patterns in that area. On the south shore wave-induced currents are of greater importance to a determination of the onshore-offshore and alongshore transport of sand-size material in the intertidal zone and on the Archimandritof Shoals.

4.4 Sediment Transport Directions

The data and information discussed above provide several significant indicators that assist in the interpretation of the littoral transport system of Homer Spit. In particular, the inferred net directions of sediment transport shown on Figure 3.3 are representative of the intertidal movement of material. At this time no estimates of the rates of transport can be given as this requires a more detailed data base.

The erosion of the coast to the northwest of the spit and possibly the reworking of sediments on the Archimandritof Shoals provides material that is transported into the spit system. Along the southwest coast the sediment transport direction in the intertidal and adjacent subtidal zones is primarily alongshore towards the southeast. This transport is a result of wave-induced processes that are in turn the function of southwest winds.

The majority of the sediment that is transported to the distal point of the spit is transported into deep water and it is believed that relatively small amounts are carried around the point onto the northeast shore. The material which is moved around the point would be transported within the narrow intertidal and adjacent subtidal zones.

The growth of beach ridges on the northeast coast indicates a southeast to northwest transport direction in the upper intertidal zone on this shore. This direction is also indicated by the growth of a small spit towards the northwest across Mud Bay. No information exists for evaluation of transport directions in the lower intertidal or subtidal zones and it is possible that movement may be in the same, opposite, or even in both, directions.

The primary source of the fine-grained (silts and clay) sediments in Coal Bay is believed to be from coastal erosion and/or rivers in upper Kachemak Bay. These sediments are transported towards the southwest along the north shore of the bay and have accumulated in the relatively sheltered environment on the lee side of the spit. This transport direction is indicated by a small spit that has grown towards the southwest across Mud Bay to nearly join that which developed towards the northwest. Coal Bay and Mud Bay are a zone of convergence of the transport directions on this coast. The transport mechanisms are a combination of wave processes, tide-generated currents and wind-driven currents.

5.0 RECOMMENDATIONS FOR FURTHER STUDY

5.1 Introduction

The prediction of natural change and of changes that result from man's development on Homer Spit and the assessment of the consequences of change on shoreline stability and on biological communities depends primarily on a thorough understanding of the sediment budget and of the sediment transport system of the spit. To achieve a satisfactory level of knowledge would require a study of the sediment sources and losses, the transport processes, the transport patterns, and the biological environment.

5.2 Sediment Transport and Biological Data Base

In order to provide an accurate understanding of the sediment transport system of Homer Spit, additional field work and modelling would be necessary to:

a. determine amounts of sediment input to the system; that is suspended load input from local streams and rivers and bed load inputs from shore erosion and possibly offshore sources.

b. determine paths and environmental mechanisms of suspended and bed load transport.

c. determine sites of deposition and rates of deposition of suspended and bed load material.

Because of the complexities associated with the nearshore system (high spatial and temporal variability of environmental conditions) an adequate understanding can only be realized with a combined field and modelling study.

Effects of dredging and disposal of dredged materials on biological communities have been widely studied. Direct effects include removal of resident organisms during disposal of dredged material. Of greater impact may be the habitat alterations caused by both activities. The removal of a benthic habitat may cause transient species (such as predators or spawners) to avoid the altered area because of the temporary loss of prey or habitat and possibly because of the work activity itself. Studies that must deal with the impact of habitat alteration should first consider the status of the resident populations, expected effects of the proposed alteration on these populations and the rate of population recovery from the alteration. A second consideration would be the effects on transient populations, which often have a strong seasonal pattern in their habitat requirements.

An outline of the ideal data and information base necessary to assess environmental change includes the following topics:

(a) Sediment Sources and Losses

- coastal erosion or river input and alongshore transport into the system
- suspended sediment concentrations of adjacent marine waters
- onshore transport from adjacent sea floor areas
- offshore transport from the system to deeper waters

(b) Transport Processes

- alongshore or onshore/offshore movement of coarse sediments by (i) wave-induced currents, and (ii) tide-induced currents
- movement of suspended sediments (silts and clays) by marine currents
- effects of storm waves and storm surges on normal transport processes

(c) Transport Patterns

- identify zones of:
    - (i) erosion
    - (ii) sediment bypassing
    - (iii) sediment accumulation
- directions of transport by the marine and littoral processes
- gross and net volumes of material transported

(d) Biological Communities

- habitat identification
    - geographical limits
    - physical (geological) and chemical character
    - type and volume of macroalgae and sea grasses
    - status of resident and transient populations
    - seasonal use by dominant species
    - infaunal assemblage
- identify effects and recovery rates due to habitat alteration (removal and burial)
- identify time and size of significant seasonal migrations

The primary physical processes that require investigation are wave-induced and tide-induced water motion in the intertidal and adjacent subtidal zones. The nature of the sedimentary and the biological environments depends upon these processes. Although ideally it would be desirable to collect accurate data at numerous sites over a full range of environmental conditions (i.e., seasonal changes and aperiodic storm events) it is possible to obtain adequate data without resorting to an extensive and expensive field monitoring program.

The program that is outlined in sections 5.3 and 5.4 below would provide a basic set of data, both actual measurements and computed values, which would enable the satisfactory prediction and assessment of changes to the existing environment. Although the physical and biological requirements are given separately below, these are not intended to be separate programs. In order to achieve a coherent knowledge base for environmental assessment the two disciplines should be coordinated into a single, integrated study. In addition to providing relevant and related data sets, an integrated study would enable (i) physical and biological scientists to understand each others' requirements accurately, and (ii) the development of a single field logistics program that would minimize manpower and equipment requirements and prevent duplication of effort.

5.3 Physical Study Requirements

The measurement or computation of actual bed load or suspended load sediment transport rates and volumes is not practical for littoral and nearshore environments. In order to develop a useful information base it is necessary (i) to measure relevant parameters, (ii) from this data to determine patterns and distributions, and (iii) to compute a sediment budget for the system under investigation. Although this approach is an indirect one, it can provide the necessary understanding with which to solve questions related to changes in the sediment transport system.

A field investigation for sediment budget analysis involves studies at different times of the year in order to account for seasonal variations in the shore-zone energy levels and to measure the response of the system to these variations. This is particularly important in the Lower Cook Inlet area where there is a distinct seasonal pattern of wind velocity and direction which directly affects shore-zone processes and sediment transport. Ideally some of the critical parameters, particularly the wave climate and winds, should be monitored continuously and concurrently for a 12-month period. As no water-level data are available for Homer Spit, it would also be valuable to install at least one tide gauge over the same 12-month period.

In addition to these primary parameters, field studies would be necessary at several times during the year to measure suspended concentrations of sediment, near-bottom currents, seasonal nearshore and intertidal topography, and the effects of storms on nearshore and intertidal topography. The local distribution and character of sediments probably changes little through time so that only a single sediment sampling program would be necessary.

An ideal field investigation would involve the deployment of instruments to monitor waves, currents and tides as outlined in Figure 5.1. Deep-water waves should be monitored in depths of approximately 120 feet off the southwest coast and 60 feet on the northeast coast. Wave accelerometer buoys would be particularly suitable for this phase of a study, with 20-minute records at 3-hour intervals. Shallow-water measurements of instantaneous velocity and direction related to wave-induced nearshore currents could be monitored using meters installed in 15 to 20-foot water depths on both sides of the spit. These data would permit correlation of deep and shallow-water waves in order to precisely calibrate sediment transport models. Both wave-measurement systems entail very high degrees of accuracy for observations every 3 hours for 6 months without maintenance.

In Coal Bay current measurement at three sites (Fig. 5.1) is recommended using wave-filtering meters in approximately 20-foot water depths. Current meters can provide a 3-hour sample of current direction and velocity for a one-year period with accuracies of 5° and ±1 cm/s. Of great importance in

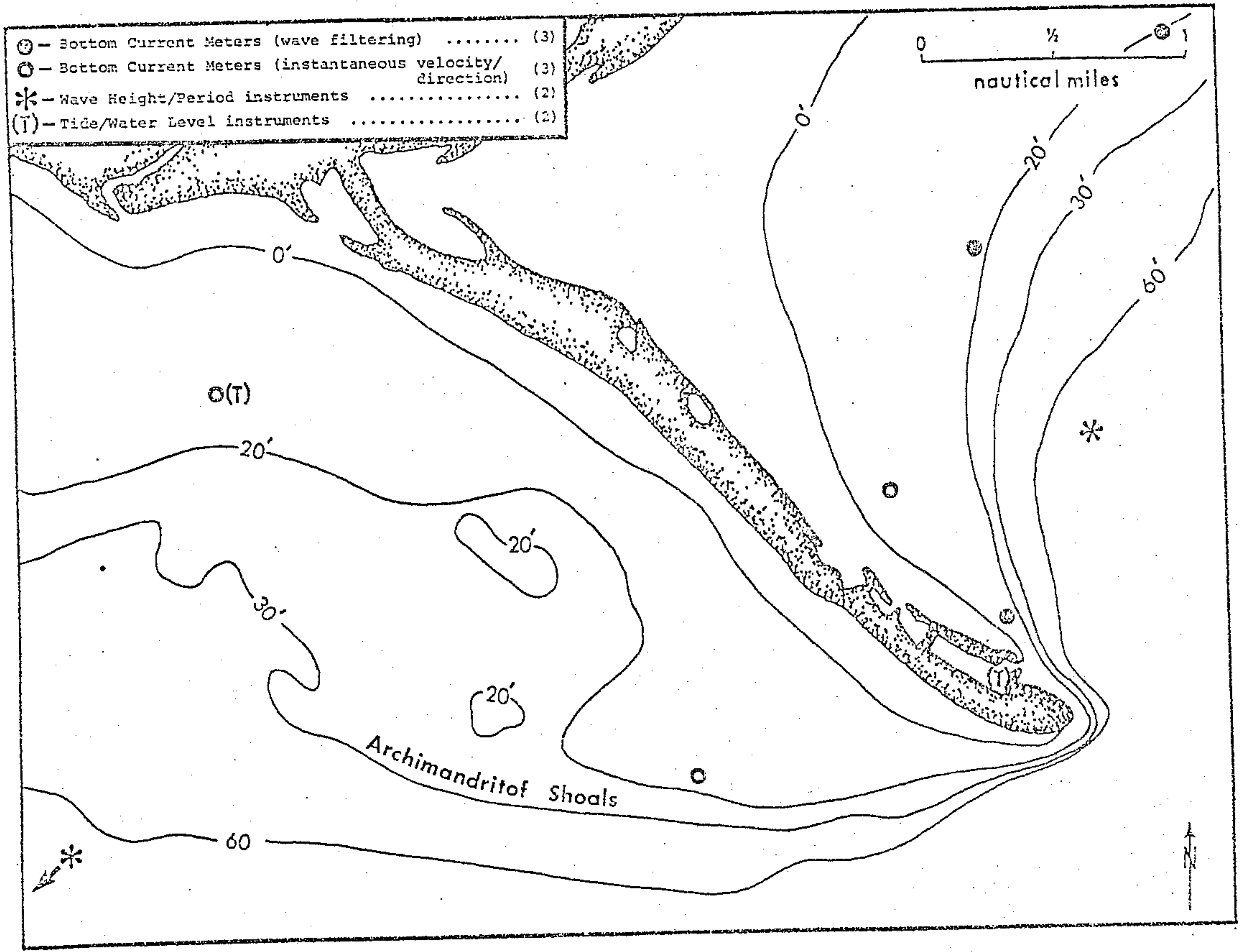


Figure 5.1 Suggested instrumentation locations for detailed process investigations

this instrument would be the timing accuracy which should be in the order of ±2 s/day (±12 minutes over a one-year period). A tide gauge could be installed offshore on the southwest coast and within the small-boat harbor on the northeast coast.

A beach profiling network with temporary bench-marks could be established across the spit using precise levelling. Position-fixing of echo-sounder profiles to provide location accuracies of ±2 m would be necessary for suitable bathymetric mapping at a minimum 500-m interval for wave-refraction modelling.

The field studies noted above would provide data on the processes and morphology that characterize the system. Additional necessary information would include adjacent shoreline erosion rates, stream or river sediment concentrations and shoreline changes of the spit itself. These data could be obtained from field measurements, aerial photography analysis or from literature sources.

The field investigations could be planned to include four series of observations and measurements. A spring (May) component would include the deployment of instruments. Further field periods in summer (September) and winter (January) would provide necessary seasonal data and a final investigation in the following year (May) would include instrument retrieval. The majority of the field work could be undertaken from small workboats (25' or less) but the instrument deployment and retrieval would require a larger (40 to 50 foot) vessel in order to handle heavy bottom-anchors for the wave and current meters.

From the data base estimates of suspended and bed load sediment inputs to the system could be computed, and the actual distribution of sediment types mapped. Long-term (i.e., non-cyclical) changes in the sediment distribution patterns would define zones of erosion, stability and accumulation which indicate transport sources and sinks. The identification of cyclical or seasonal changes is critical as these seasonal variations are frequently of greater magnitude than long-term changes in a system. Although the above information provides the basic inputs to a sediment budget assessment, a knowledge of process characteristics is an essential element to an understanding of how and why the sediment budget operates.

Modelling of the physical processes (winds, waves and tides) is an essential tool with which field data can be reduced to meaningful information. Simple data analysis methods may be adequate for a description of the magnitude and frequency of changes in the character of a parameter. The application of theoretical concepts to suitable data can, however, provide a more meaningful understanding of the processes that control sediment transport rates and direction. The application of wave refraction models is such an example that has proved of great value in bridging the gap between wave data and transport regimes. In addition, correlation between concurrent wave and wind data sets can enable modelling of wind data from previous years to hindcast longer-term wave climates or individual storm events. As in any analysis, a longer-term data set is of more value than one from a single year. In this storm-wave environment hindcasting would provide useful information on the frequency, magnitude and role of these high-energy events.

The sediment budget analysis described above involves field data collection, modelling of measured processes and an interpretation of this data in order to provide an accurate understanding of the system. It is advisable to monitor winds, waves and tides for a 12-month period in order to provide a solid data set. The additional field data could be collected during four studies that would be representative of seasonal variations in both processes and morphology. With the application of hindcast techniques this one-year data set could be extended to provide information over a longer time period and thereby enable a comprehensive study to be completed within a one-year field period.

5.4 Biological Study Requirements

Because of the present lack of comprehensive biological information on the Homer Spit, a wide variety of studies would be necessary to fully assess the biological implications of alterations to the spit and to surrounding habitats. Two types of studies would be required; one would deal with siting concerns, and the other with scheduling concerns.

5.4.1 Siting Concerns

Since a primary concern is to define the effects of habitat alteration on inter and subtidal biological communities, a logical study plan could proceed as follows:

a. Develop a detailed habitat map of the inter and subtidal areas on and near the spit. This map would identify both dominant and limited habitats and could help with siting concerns to minimize effects on sensitive habitats. The map could be developed from an analysis of environmental parameters at various inter and subtidal levels possibly including an analysis of physical and chemical parameters such as sediment type along with biological parameters such as type and quantity of macroalgae and sea grasses present. One field session would be required in mid to late summer to conduct the survey.

b. Define the infaunal assemblages associated with the above habitats that have a high probability of being affected. Based on the results of the habitat map and known development plans, relatively few habitats may actually need to be sampled. Sampling with standard techniques should be conducted during the summer, possibly during one field session. Since the processing of benthic samples is extremely time-consuming, the sampling program would have to be planned carefully to avoid unnecessary sampling yet obtain sufficient samples to quantify adequately the biota associated with the particular habitats of interest. Seasonal sampling of each study location is desirable but greatly increases costs and may not significantly affect the conclusions.

c. In situ experiments, such as various types of substrate alteration, should be conducted concurrently with (b) above to assess the immediate effects of, and recovery rates from, certain habitat alterations on the species assemblages present. These experiments could consist of burial and excavation of small sections of particular habitats to evaluate recovery rates. Existing altered areas of known age should be incorporated in the study program to further estimate recovery rates. These experiments should be initiated during the first field session and monitored seasonally or even bimonthly for a minimum of one year. A longer monitoring period may be necessary depending on the rate of recovery.

The above study should provide a means to predict effects on benthic communities and give some idea of recovery rates from a proposed development in a particular location on the spit.

5.4.2 Scheduling Concerns

An appropriate study to identify seasonal sensitivity would be to define and quantify the seasonal use of the inter and subtidal areas by epibenthic crustaceans. Many of these are commercially important in the area and loss of limiting habitat could affect population size. At this time, the extent of use by large crustaceans is not known, but is thought to be significant and highly seasonal. The timing of biological use could affect scheduling of proposed work plans. Field effort over an entire year, with a four to six-week spacing between sampling trips, may be necessary to define accurately epibenthic use of the area.

A similar study could be conducted to determine the time and size of the pink salmon out-migration as it passes the spit. Pink salmon juveniles feed extensively in shallow water in the inter and subtidal areas. Dredging and disposal activity in these areas during the period of maximum concentration could reduce prey populations and disrupt feeding patterns with an unknown effect on the pink salmon. Knowledge of the migration timing could again help schedule work activities to avoid possible conflicts with juvenile out-migration. Field effort would need to be concentrated over the mid-spring to mid-summer periods with a minimum of biweekly and possibly weekly samplings.

Because of documented low use, studies directed solely at marine birds or mammals may not be appropriate. Bird usage of the habitats as feeding areas could be documented as a portion of the above study on benthic assemblages. Changes in bird usage patterns could possibly occur in response to increased construction activities or loss of prey habitat.

6.0 CONCLUSIONS

The assessment and prediction of natural or man-induced changes to the physical form and to the biological communities that characterize Homer Spit is primarily dependent upon an understanding of the sediment transport system of the spit. The information and data base at this time is not adequate for an accurate evaluation of the geological and biological dynamics of the system. In the absence of this foundation, evaluations of the effects of proposed man-induced modifications to the system must necessarily be speculative.

On the basis of this initial study it is possible to provide a description of primary features of the system. The spit is characterized by a higher-energy, exposed southwest facing shore and a lower-energy, more sheltered northeast coast. On the exposed coast littoral transport is predominantly to the southeast and results from wave-induced processes. In Coal Bay on the north coast the intertidal and subtidal movement of fine-grained sediments results from a combination of wind-, wave- and tide-generated currents. In this Bay there is a convergence of sediment transport in the upper intertidal zone towards Mud Bay. It is apparent that relatively small volumes of sediment are transported from the south shore into Coal Bay due to deep-water conditions at the distal point of the spit (Coal Point).

Near-bottom currents measured during this study were of low-velocity (<25 cm/s), even on the north shore which was subject to strong wave-activity during the study period. From the field observations it is suggested that wave rather than tidal processes are of greater importance to the transport of coarse-grained (sand) sediments.

APPENDIX A

Trip and Field Schedule

The intertidal and subtidal zones of Homer Spit are areas of active sediment transport and any action that involves modification of the transport patterns should be evaluated to determine secondary effects on shoreline stability and on the biological communities. In addition direct effects that result from dredging or from dredge-spoil disposal may result in temporary, or even long-term, modification of the geological or biological character of an area.

Further studies would be required to provide a suitable knowledge base from which accurate impact assessments could be derived. It is recommended that such studies involve both (i) geologic, oceanographic and biologic field investigations and (ii) a modelling component to determine a sediment budget for the system. The physical and biological character of the system varys seasonally and a study program that covers a 12-month period would be necessary to identify these seasonal components.

A-1 Trip Schedule:

December 10	meet with Corps; travel to Homer
December 11-15	conduct field study
December 16	travel to Anchorage

A-2 Field Schedule:

December 11	. launched boat and deployed survey markers . profiled 3 echo-sounder lines (#1, 2 & 3) . work curtailed due to 4 foot seas
December 12	. retrieved one buoy . boat work abandoned due to 6 foot seas . met with Harbor Master, Port Master and Homer City Manager
December 13	. reinstalled and surveyed in 3 station buoys on northeast coast of spit (Stations A, B & C) . occupied the three current meter stations over a 9-hour period from mid-ebb tide to mid-flood tide
December 14	. work delayed initially due to severe ice conditions within harbor and subsequently to current meter malfunction . installed and surveyed in 3 station buoys on southwest coast of spit (Stations D, F & G; Station E installed but abandoned due to very steep nearshore slope) . profiled 2 echo-sounder lines (#4 & 5) . occupied the three current meter stations over a 6-hour period from mid-ebb tide to mid-flood tide

December 15	- installed and surveyed in 2 station buoys (Stations H & J) - profiled one echo-sounder line (#6) - occupied 4 current meter stations (Stations D, F, H & J) over an 11-hour period from high-flood tide to the following mid-flood tide

APPENDIX B

Field Investigation Data Sheets

HOMER SPIT LITTORAL TRANSPORT STUDY: December 1979

Station: A

Depth ± Low Water Datum -7.5 feet

DATE	TIME	DEPTH (feet)	TIDE STAGE	$\overline{X}$ VELOCITY (cm/sec)	$\overline{X}$ DIRECTION (true North)
13th	10:45	22.0	falling	10	94°
13th	13:15	15.5	falling	12	354°
13th	15:40	12.0	low tide slack	8	164°
13th	18:40	15.5	rising	9	189°
13th	19:50	18.5	rising	12	314°

HOMER SPIT LITTORAL TRANSPORT STUDY: December 1979

Station: B

Depth ± Low Water Datum 0.0 feet

DATE	TIME	DEPTH (feet)	TIDE STAGE	$\overline{X}$ VELOCITY (cm/sec)	$\overline{X}$ DIRECTION (true North)
13th	11:25	12.0	falling	25	294°
13th	13:40	5.0	falling	4	304°
13th	15:30	6.5	low tide slack	8	274°
13th	18:50	10.5	rising	17	129°
13th	19:40	9.5	rising	20	319°

HOMER SPIT LITTORAL TRANSPORT STUDY: December 1979

Station: C

Depth ± Low Water Datum -7.0 feet

DATE	TIME	DEPTH (feet)	TIDE STAGE	$\overline{X}$ VELOCITY (cm/sec)	$\overline{X}$ DIRECTION (true North)
13th	14:20	13.0	falling	10	94 °
13th	15:15	12.0	low tide slack	8	144 °
13th	19:15	16.5	rising	8	144 °

HOMER SPIT LITTORAL TRANSPORT STUDY: December 1979

Station: D

Depth ± Low Water Datum - 5.5 feet

DATE	TIME	DEPTH (feet)	TIDE STAGE	$\overline{X}$ VELOCITY (cm/sec)	$\overline{X}$ DIRECTION (true North)
14th	13:00	14.0	falling	5	159°
14th	14:30	10.5	falling	5	114°
14th	15:10	8.0	falling	6	149°
14th	15:40	7.3	falling	4	144°
14th	16:05	7.2	low tide slack	8	114°
14th	18:45	11.0	rising	5	84°
15th	08:45	19.7	rising	5	244°
15th	11:20	21.0	falling	16	339°
15th	14:00	14.5	falling	7	99°
15th	16:30	6.5	low tide slack	9	99°
15th	19:30	10.5	rising	7	94°

HOMER SPIT LITTORAL TRANSPORT STUDY: December 1979

Station: F

Depth ± Low Water Datum 0.0 feet

DATE	TIME	DEPTH (feet)	TIDE STAGE	$\bar{X}$ VELOCITY (cm/sec)	$\bar{X}$ DIRECTION (true North)
14th	13:30	8.5	falling	6	004°
14th	16:15	3.7	low tide slack	8	344°
14th	18:55	7.2	rising	5	354°
15th	09:00	14.5	rising	5	249°
15th	11:30	17.0	falling	14	339°
15th	14:10	9.5	falling	7	009°
15th	16:30	too	shallow	—	—
15th	19:45	6.5	rising	10	124°

HOMER SPIT LITTORAL TRANSPORT STUDY: December 1979

Station: G

Depth ± Low Water Datum 0.0 feet

DATE	TIME	DEPTH (feet)	TIDE STAGE	$\overline{X}$ VELOCITY (cm/sec)	$\overline{X}$ DIRECTION (true North)
14th	13:55	7.0	falling	5	144°
14th	16:30	3.5	low tide slack	10	184°
14th	18:30	5.5	rising	5	144°
14th	19:15	9.0	rising	3	84°

HOMER SPIT LITTORAL TRANSPORT STUDY: December 1979

Station: H

Depth ± Low Water Datum - 7.0 feet

DATE	TIME	DEPTH (feet)	TIDE STAGE	$\overline{X}$ VELOCITY (cm/sec)	$\overline{X}$ DIRECTION (true North)
15th	09:35	23.5	rising	7	339°
15th	10:00	24.5	high tide slack	9	294°
15th	10:30	25.0	high tide slack	10	144°
15th	14:30	15.0	falling	9	284°
15th	15:10	12.3	falling	7	84°
15th	15:30	11.2	falling	6	104°
15th	16:00	9.5	falling	5	124°
15th	16:50	8.5	low tide slack	6	284°
15th	17:30	8.7	low tide slack	7	274°
15th	18:00	9.0	rising	7	264°
15th	18:30	10.0	rising	7	264°
15th	19:00	11.0	rising	7	284°

HOMER SPIT LITTORAL TRANSPORT STUDY: December 1979

Station: J

Depth ± Low Water Datum - 0.5 feet

DATE	TIME	DEPTH (feet)	TIDE STAGE	$\overline{X}$ VELOCITY (cm/sec)	$\overline{X}$ DIRECTION (true North)
15th	09:30	18.0	rising	7	159°
15th	10:35	19.0	falling	10	64°
15th	14:25	9.5	falling	9	104°
15th	16:10	3.5	falling	8	124°
15th	19:15	6.0	rising	7	184°

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