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DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

AN ANALYSIS OF OCEANOGRAPHIC AND METEOROLOGICAL CONDITIONS FOR CENTRAL LOWER COOK INLET, ALASKA

By

M. L. Rappeport

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Cook Inlet, Alaska is a large north-easterly trending estuary in south-central Alaska that extends from Anchorage to the Gulf of Alaska. Lower Cook Inlet is the southern part of this estuarine system and is geographically separated from the northern section by constriction of the estuary at the Forelands (Fig.1a).

Kalgin Island occupies a central position within this neck and tends to form a natural northern boundary for lower Cook Inlet. On the south, a natural boundary can be drawn by a line connecting Cape Douglas with the Barren Islands, the Chugach Islands and Kenai Peninsula.

The submarine physiography of Lower Cook Inlet is complex (Bouma,unpub.) (Fig.1b). The dominant geomorphic features are; the main axial trough (Cook Trough), two secondary submarine valleys (unnamed and Kachemak Trough) which together with the Cook Trough intersect a triangular-shaped region (Cook Plateau) to the south, bordering shallow shelf regions (The Ninilchik, Chugach and Chinitna Platforms) and a gentle arcuate ramplike feature in the south (Cook Ramp) which slopes sharply downward towards deeper waters entering via Shelikof Strait and Stevenson, and Kennedy Troughs. Within the Cook and Kachemak Troughs, water depths average 60-80 meters with occasional small depressions that reach depths between 80 and 100 m.

The unnamed north-northeasterly trending valley entrenched into the Ninilchik Platform between Kachemak and Cook Troughs starts at the rim of Cook Ramp (100 m contour) and extends some 40 kilometers before flattening out onto Ninilchik Platform. Over the broad platform regions, depths gradually reach 40 m before sloping downward into those troughs (Fig. 2). Water depths over the Cook

Ramp are equivalent to the main troughs but southward of the Cook Ramp, the depths increase and approach 200 m within the central portions of Shelikof Strait, Stevenson and Kennedy Entrances.

Surficial sediments (Sharma and Burrell, 1970; Bouma and others; 1976, 1977a,b; 1978a,b) are generally fine to medium sands which appear to incompletely carpet a relic glacially deposited substrate composed of coarse gravels, cobbles, and occasional small boulders. The sandy mobile sediments fine southwards ranging from 0.5 mm to 0.05 mm in grainsize (pers. comm. Robert Orlando). The finest sized sand and coarse silt are found at the base of Cook Ramp. These unconsolidated sandy sediments and relic glacially washed morainal lag deposits overlie a planned highly folded non-marine sedimentary rocks of Tertiary age. The unconsolidated sediments represent the residual deposition from five periods of Pleistocene glaciation (Karlstrom, 1964) and modern sedimentary processes. Previous work on the thickness of Quaternary fill (Bouma and others, 1978;Rappeport,1980) and subbottom structures (Bouma and Hampton, 1976) has shown that there existed extensive fluvial activity on the platform regions during interglacial and post-glacial times. The evidence consists of numerous partly or completely-filled channels seen in the seismic records while sediment transport activity and associated winnowing of the transgressive glacial lag deposits can be inferred from the presence of buried large-scale bedforms (Fig.3a,3b,3c).

The hydrodynamic and sediment transport environment during the early to mid-Pleistocene within lower Cook Inlet appears to have been different than the currently prevailing hydrodynamic regime (see Fig. 3c, where buried bedforms and surface bedforms exhibit different asymmetry). The distribution, morphology, and transport of the sediments in Lower Cook Inlet and the extent to which deposition can be attributed to the recent environment and the amount that must be attributed to an earlier environment (i.e. relic sediments) has therefore been the subject of much study and controversy (Bouma and others, 1977a,b; 1978a,b; 1979; Whitney, 1979; Hein and others, 1979; Rappeport,1980).

Regional Circulation and Currents

Cook Inlet is characterized by a strong semi-diurnal tidal pattern of the mixed variety due to its relatively high latitude. Although by convention, Cook Inlet is considered an estuarine system, its hydrodynamic behavior is more like a large embayment particularly during winter conditions (Muench and others, 1978). A strong non-tidal mean flow (Alaskan current) moves northwesterly along the shelf break off the Kenai Peninsula throughout the year and plays a significant role in the overall circulation pattern in Lower Cook Inlet.

In general, marine waters of the Alaskan current enter lower Cook Inlet via Kennedy and Stevenson Entrances driven by the flooding tide. A portion of this water moves up the inlet along its eastern flank due to the strong high latitude-Coriolis forces. At the vicinity of the Forelands, the flood currents cross over to the west side of the inlet as the result of shoreline geometry, both above and below Kalgin Island. Ebb currents flow along the eastern shore in Upper Cook Inlet, then swing westward at the Forelands but still pass Kalgin Island on its eastern side.

In lower Cook Inlet, the ebb flow hugs the western shore with some of the surface flow moving into Kamishak Bay behind Augustine Island before rejoining the remaining ebb current off Cape Douglas. From this point, the currents flow swiftly out Shelikof Strait. Small gyres both counter-clockwise (Wennekens and others, 1975), and clockwise (Gatto, 1976), have been reported as well as evidence of some cross inlet flow (Fig.4a,4b). As 70-80 percent of the fresh water and sediment presently entering the inlet comes from the discharges of the Susitna River and Knik Arm of upper Cook Inlet (Burbank, 1974), the western ebb flow contains the predominant sediment-laden waters and within this flow sediment deposition occurs as a function of decreasing tidal velocities. The fine clay and silt sized materials because of the swift tidal currents within the inlet, tend to bypass the inlet and be carried out Shelikof Strait to be deposited in the Aleutian trench beyond Kodiak Island (Gatto, 1976).

Recent work (Muench and others,1978; Muench and Schumaker,1980) utilizing STD and current meter arrays deployed in the spring-summer of 1973 and in the fall-winter of 1978 has shown that the regional mean flow exhibits (1) a concentrated southward flow along the western shore of Lower Cook Inlet of water from Upper Cook Inlet which has been diluted by river input, (2) an intense westerly flow across the lower inlet which originates from Kennedy Entrance, exits via Shelikof Strait, and is bathymetrically steered in a cyclonic sense during its transit across the inlet, and (3) a slow northward drift in eastern Lower Cook Inlet. Their analysis, supported by the conclusions of Bouma and others (1977b, 1978a) suggests that much of the mean flow plus some of the tidal waters entering in Kennedy and Stevenson troughs are bathymetrically steered along the contours from east to west at the base of the arcuate Cook Ramp while a smaller flow volume moves up-contour following the natural funneling of the unnamed secondary trough entrenched into Ninilchik Platform. The southward flowing sediment laden mean flow along the west side of the inlet is interpreted by Muench and others(1978) to be an estuarine system due to the fresh water input in upper Cook Inlet. The slow northward drift is a replacement flow for waters entrained in the southerly flowing current. Their results suggest the following pertinent facts for spring or summer conditions in Lower Cook Inlet.

1. Deep flows are decoupled from near surface flows and for those stations with deep current meter moorings (Stations 3, 4, 5, 7) the deep flows were cross-isobath.

2. M_2 tidal components are dominant with most tidal energy propagating along the isobaths in the east and much more weakly in the western portions. A station in the central portion of the inlet (Station 26) showed nearly zero tidal current energy for which they had no explanation.

3. Non-tidal mean flows are dominated by meteorological events having time scales of the order of 3-4 days.

4. Non-tidal flows are generally stronger near the surface than near bottom and appear to be stronger on the west side of the inlet than on the east.

5. The instantaneous flow field is dominated by tidal and periodic meteorological events and the mean flow is an order of magnitude weaker than either of the above.

Interpretation of these results suggests that the eastern side of the inlet is strongly tidally dominated with tidal ellipses being extremely elongated. In the central portions of the inlet, the prevailing hydrodynamic regime is still tidally dominated but the surface tidal current ellipses are more rounded (rotary). Short-term meteorological events may contribute significantly but the mean flow is still on order of magnitude weaker than the tidal flow. On the western side, the tidal ellipses are once more elongated but the overall tidal current strength is weaker, however, the mean flow constituents can be highly significant as they act in more normal estuarine mode.

The overall circulation therefore exhibits several distinct water mass boundaries and accompanying flow discontinuities. These boundaries are often marked by a distinct foam line and associated debris. There is usually a strong color variation across the boundaries. The major flow divisions (tidal rips) have been labeled, the west rip, the mid-channel rip, and the east rip. Burbank (1977, cited in Dames and Moore, 1978) recognized the mid-channel rip to be the approximate division between clear oceanic waters and the more turbid freshwater outflow from upper Cook Inlet.

The net result of these hydrodynamic interactions suggests that lower Cook inlet is generally well-mixed and has only very poorly developed density stratification and that would mostly apply during peak river discharge (April to October) (Gatto, 1976). STD profiles (Dames and Moore, 1978) and vertical distributions constructed from STD profiles (Muench and others, 1978,Muench and Schumacher,1980) support this conclusion. Their data shows that for the spring-summer conditions when maximum freshwater discharge occurs, the vertical variations in salinity (σ_t) were only in the order of 1-2 ppt and in temperature ($T^{o}(C)$) only 2-4^{o}C from surface to bottom. Therefore density stratification is minimal and the water masses are well mixed vertically.

Tides as previously mentioned are the primary driving forces for the overall circulation within Cook Inlet. The diurnal tidal height ranges from some 4.2 m (14 ft) at the inlet mouth to over 9 m (30 ft) in the vicinity of Anchorage. Extreme tidal ranges (spring tides in conjunction with high winds) can produce sea-level changes in excess of 12 m in Knik Arm,within Upper Cook Inlet (Britch, 1976). The semidiurnal wave front moves 240 km up the inlet in about 4.5 hours with a 12 hr cycle. Lower Cook Inlet is characterized by an approximate one meter tidal range differential (Evans, 1972) between the eastern and western shores as observed in the inlet mouth region (5.8 m and 5.0 m respectively). The highest reported tide (7.9 m) in this portion of the inlet occurs along the Kenai Peninsula and the lowest is 1.8 m with a mean range of 5.5 m and an extreme range of 9.75 m (Alaska OCS Office, 1976). Surface current velocity measurements are sketchy, however Wagner and others (1969) , report that mean maximum velocity reaches 3.8 knots (196 cm/s) with a peak maximum velocity in excess of 6.5 knots (335 cm/s) at monthly tidal extremes. Surface currents up to 8.0 knots (412 cm/s) have been reported by Visser (1969). Dames and Moore (1978) reported peak surface currents at the site of the lower Cook Inlet C.O.S.T. well for the period July-September 1977 in the range of 2.8 - 3.2 knots (145 cm/s - 166 cm/s). The coriolis effects at this high latitude, the strong tidal currents, and inlet geometry produce considerable turbulence throughout the entire water column (Burrell and Hood, 1967).

Wind and Wave Regime

Two large fronts-(the Pacific Arctic and Pacific Polar) are responsible for the generation during the winter season of moderate to severe cyclonic storms (Trasky and others, 1977). These storms travel west to east along the Aleutian Chain and then stall in the Gulf of Alaska. Some are locally generated within the Gulf itself. The fronts are normally prevented from migrating northward by the positioning of a constant high-pressure system over the interior landmass. Storms associated with these fronts can generate winds comparable to hurricane force (>75 knots) but Evans and others (1972) suggest that within the enclosed Cook Inlet such high winds are less frequent and are more likely a brief gust rather than of sustained duration. During the summer, infrequent small cyclonic storms arise with a typical resident time of 2-4 days (pers. obs. M. Rappeport). Wind data from a site within the central portion of lower Cook Inlet (Dames and Moore, 1978) during June-September, 1977 shows that average wind speeds exceeded 25 knots for 01.9, 02.0, 16.0, 26.2 percent of the time, respectively, although the percent frequency of maximum wind gusts exceeding 25 knots were

05.7, 08.0, 21.8 and 44.5 percent, respectively. Muench and others (1978) indicated that based upon their hydrologic measurements, the mean currents within lower Cook Inlet for the spring and summer months were heavily affected by events having time scales in the order of 3-4 days to which they attribute to local or regional meteorological events. During this spring-summer fair weather pattern the high wind speeds associated with these small cyclonic storms or local meteorological events came down the inlet (52 percent), from the Gulf (10 percent), or through the west from the vicinity of Lake Iliamna area (38 percent) (Dames and Moore, 1978).

Based upon synoptic wind observations at Homer and Kenai (Trasky and others, 1977), observations from a site near Anchor Point taken regularly from aboard the ferry Tustamena (Carsola, 1975) and wind measurements from the DSV Ocean Ranger (Dames and More, 1978) a seasonal wind pattern can be summarized as follows (Figs. 5,6):

During fall-winter, the dominant wind directions are from the north or northeast but a portion of the time come from the east and occasionally the west. The spring-summer season brings winds from the south-southwest predominantly but a fairly significant portion of the time, the winds come from the north-northwest or northeast. Westerly winds are sometimes strong in March and April originating from a large area in the Alaska Range between Iliamna and Kamishak Bays. During such westerly winds, (called Chinook winds) peak wind velocities in excess of 100 knots have been reported and associated wave heights in excess of 20 feet (BLM Lower Cook Inlet Final Environmental Impact Statement, 1976).

There is little available information on wave and swell characteristics within Lower Cook Inlet. Published data and significant wave height analysis (Dames and Moore, 1978; Carsola, 1975; Trasky and others, 1977) suggest that significant wave heights in excess of 0.6 m (2 ft) for the area just west of Kachemak Bay occurred less than 20 percent of the time (Figs 7-16). Detailed wave refraction analysis presented by Carsola in his report to the Shell Oil Company in regards to a site location within lower Cook Inlet ($59^{o}36'$N, $151^{o}53'$W) showed that except for a narrow window through Shelikof Strait, swell from the Gulf of Alaska did not appear to be able to propagate into eastern central Lower Cook Inlet. The Barren Islands and the narrow entrances (Kennedy and Stevenson) seem to block long period deep ocean swell from propagating into the inlet. Carsola employed estimated fetch distances, wind and directional frequency information for constructing a wave spectrum according to a modified Miles-Phillips mechanism. From this, significant wave height ($H_{1/3}$) and average wave period (T) were computed.

Analysis of figures 5-7 reveals that from May through July the average wind and wave conditions for the central to eastern interior of the inlet are generally mild to moderate with only infrequent small squalls or weak gales present. However the period from August through February marks a period of increasing higher mean wind speeds with accompanying higher significant wave heights but August wave periods remain generally less than 6 seconds. These small wave periods are most likely the result of the small fetch lengths that are available for the August wind directions for this period. Lastly, however when the winds are shifting from northerly to west or southwesterly during March-April, the longer available fetch lengths and mean higher wind speeds are responsible for rough conditions in the inlet. It is worth noting that August and September of 1977 showed fairly frequent storm activities (Dames and Moore, 1978) and that data from the report of Carsola (Table 1) showed that for 1/71-10/72 a selection of extreme wind events as reported by the personnel aboard the Tustamena at their regular observation point (one mile north of Point Pogiloshi light) suggest that extreme storm events are not uncommon in Lower Cook Inlet. Such storms exhibit mean winds in the range of 35-45 kts and significant wave heights in the approximate range of 6-10 feet (Figs.6,7).

The yearly distribution of these storms, although based upon selected data (Carsola, 1975) and reported data for only 4 months in central Lower Cook Inlet (Dames and Moore, 1978) suggest a weak bimodality in extreme storm activity. One period exists from March-April and the other is centered around August and September although October should probably be included in the latter. The rest of the year although storm activity overall may at times be even higher, the actual severity of the storm is likely to be weaker. The spring period of extreme storms suggests association with the swing to westerly SW and WNW winds during this time (Figure 5) while the later summer-early fall period of extreme storm activity probably reflects the strong pressure gradients associated with the land-sea interface. Evans (1972) cites a viva-voce' from Harold W. Searby of the National Weather Service, NOAA, Anchorage, in which he states that storms with winds of 50-75 kts occur mostly during winter and that winds of 75-100 kts could occur. Carsola (1975) suggests that based upon his windchart analysis of synoptic wind and storm measurements that a 1 in 100 year storm could possess sustained winds of 120 kts or higher within lower Cook Inlet. Sustained wind speed is not a well defined parameter but it can be assumed to encompass a significant portion of the overall time of a storm's passage through the inlet. These times range from 12-48 hours.

Carsola (1975) generated estimated significant wave parameters from mean wind spectra data from the Tustamena and calculated maximum fetch distances to a site located off Anchor Point. His maximum estimated fetch length was 100 nm in a SSW direction to this site. Using a modified Miles-Phillips 70-component spectrum method, he calculated that significant wave heights in excess of 5' occurred only during late winter and early spring and middle to late summer and heights in excess of 8' did not occur. He also estimated that such wind-generated waves had periods grouped between 2 and 7 seconds (Figures 8-10) (Table 2).

This simulated wave spectrum did not allow for swell entering from the Gulf of Alaska but Carsola acknowledges that large swell from the SW may be capable of reaching the site near Anchor Point by passing through Shelikof Strait although the actual width of such a window is small.

Inspection of Figure 2 shows that large swells from the Gulf of Alaska can propagate into the region of the Geoprobe deployment site (GDS) without major loss of energy if they move through Kennedy Entrance. The Barren Islands inhibit some of the swell and refraction around the islands would severely diminish waves moving into the inlet via Stevenson Entrance. The large swells entering via Kennedy would be slightly refracted by the Kenai Peninsula and thus be able to reach the site with most of their energy intact. Another dominant swell direction would be wave moving up Shelikof

Strait. Therefore small windows of 130° to 150° and 190°-210° exist for the propogation of large Gulf of Alaska swells. In addition to swell, southeasterly winds blowing from the Gulf together with SW blowing up the inlet from Shelikof Strait region allow for the development of significant wind-generated waves. Although these two directional windows are narrow, they can be considered having fetch lengths of sufficient length to allow nearly fully developed wind waves to be generated under the 12-48 hours mean wind estimates appropriate for the large storms (Fig. 17).

Given a minimum mean steady wind speed of 40 knots, minimum duration 12 hours, unlimited fetch, deep water wave forecasting charts (plate 1-A, Ippen, 1966, p. 182) show that waves of 18-20 ft height and 10-11 s period could be generated with a fetch of only 160 nautical miles. Although maximum wave heights of 17 and 18 feet were reported by Dames and Moore (1978) for two storms during August and September and thus are comparable in height, the average storm generated significant wave heights would be less due to refraction losses and frictional losses as the waves propagate through the narrow windows. Similar wave heights but with smaller periods may be generated as a result of flood tidal current steepening of wind generated waves moving southward in front of winds from the north. Thus it is not unreasonable to expect that storm waves with heights 8-14 ft and periods of between 6-10 sec reflect typical SE or SW storm activity in central Cook Inlet.

In summary, it is subjectively possible to expect that on a yearly-basis some 2-4 percent of the time, large storm activity is present within the inlet which may affect the mobility of the bottom sediments. The most extreme conditions in terms of sediment transport would occur when storm winds and waves come from the SW or SE (probability of 0.005 to .020 of the time) in conjunction with spring tides (33 percent of the lunar cycle) yielding an overall probability of extreme sediment motion of between .0017 and .007 of the year. These probabilities are likely a factor of 2-3 lower than they should, due to probable post-storm return flows generated by the excess water mass forced up into the upper portions of the inlet by the SE or SW winds.

These storm-surge large mean flows together with spring tides would lengthen the overall time of maximum sediment mobility by at least a factor 2-3 times. Thus the overall maximum sediment transport frequency on a yearly basis might be expected to be 1/2 and 2 percent of the time.

Based upon the previous qualitative analysis, it is reasonable to assume that waves generated by large Gulf of Alaska storms or large low pressure systems can be subjectively estimated as to have sustained significant wave heights from 8-14 feet and periods between 6-10 seconds. The shorter period waves would represent those waves generated by winds blowing out of the North while the longer period waves probably represent storm generated swell entering the inlet via Shelikof Strait or Kennedy and Stevenson Passage.

Linear wave theory was employed to estimate bottom orbital motion for such storm waves. This technique has been used by Komar, Neudeks and Kulm (1976) for estimating wave motion on the Oregon shelf; by Amos and Collins (1978) for estimating the response of sediment in a intratidal environment to superimposed wave motion on a basic tidal current system and by McClennen (1973) in estimating bottom erosion effects of waves on the New Jersey continental shelf.

Linear wave theory (small-amplitude) yields for a sinusoidal progressive wave a solution for the second order partial differential equation of motion of:

$$U = \frac{agk\cosh k(z + h)}{G\cosh kh}\cos (kx - \quad t) \qquad (1)$$

$k = 2\pi/L$
$G = 2\pi/T$
T = period
h = depth
$a = H/2$ (H = wave height)

the wave length, wave period and depth are related by:

$$L = \frac{gT^2\tanh (2\pi h/L)}{2} \qquad (2)$$

where

$$L_o = \frac{gT^2}{2\pi} \qquad (_o) = \text{deep water} \qquad (3)$$

is the deep water result when $\tanh (2\pi h/L)$ goes to 1

NOW

$$L = L_o \left(\tanh \left(\frac{2\pi h}{L_o}\right)\right)^{1/2} \qquad \text{Komar, et al (1976)} \quad (4)$$

can be used to estimate L rather than by some iterative solution from eq. (2).

The maximum horizontal velocity associated with wave-motion near the bottom can be determined from eq. (1).

$$U_m = \frac{H}{T\sinh (2\pi h/L)} \qquad (5)$$

Using this relationship together with the estimated wave parameters of the preceding section and a minimum bottom threshold velocity of 10 cm/s (Komar, et al, 1976) which corresponds to the initiation of motion of fine sand, wave base estimates were determined for various wave heights and periods (Tables 3a , 3b, and 3c).

As can be seen in these tables, the effect of wave period in maximum orbital bottom velocities is far greater than wave height. Under the threshold criteria assumed, a wave base depth of 30 m approximately corresponds to waves with a 6 m period and various wave heights, 50 m for waves of 8 sec period and varying heights and 70 m for waves of 10 sec period and again varying wave heights. Figures 18a,18b,18c show the portions of lower Cook Inlet which would be affected by waves with the characteristics shown in the three tables.

A comparison between the projected wave ray windows for all periods waves and a recent coastal zone study by Hayes and others (1977), shows fair correspondence. In their study, Hayes determined which portions of the shoreline of lower Cook Inlet are subjected to the highest wave energies based upon the presence of erosional scarps in bedrock. The wave windows and high wave energy shorelines as mapped by the erosional scarps show a close association. This suggests that indeed relatively large wave energies can be expected in the central portion of lower Cook Inlet.

Amos, C.L. and Collins, M.B., 1978, The combined effects of wave motion and tidal currents on the morphology of intertidal ripple marks: The Wash, U.K., journ. sed. Pet., vol. 48, no. 3, p 849-856.

Bureau of Land Management, 1976, Lower Cook Inlet, Final draft environmental impact statement, Anchorage, Alaska, 3 vol.

Bouma, A.H. and Hampton, M.A., 1976, Preliminary report on the surface and shallow subsurface geology of lower Cook Inlet and Kodiak Shelf, Alaska, U.S. Geological Survey Open-file report 76-695, 36p.

Bouma, A.H.,Hampton, M.A.,Wennekens, M.P. and Dygas, J.A., 1977a, Large dunes and other bedforms in lower Cook Inlet, Alaska, Preprints Offshore Technology Conference, paper 2737, p. 79-85.

Bouma, A.H., Hampton, M.A. and Orlando, R.C., 1977b, Sand waves and other bedforms in lower Cook Inlet, Marine Geotechnology, vol. 2, p. 291-308.

Bouma, A. H.,Hampton, M.A., Frost, T.P., Torresan, M.E., Orlando, R,C. and Whitney, J.W., 1978a, Bottom characteristics of lower Cook Inlet, Alaska, U.S. Geological Survey Open-fille report, 78- ,92p.

Bouma, A. H., Rappeport, M.L., Orlando, R.C. and Hampton, M.A., 1980, Identification of bedforms in lower Cook Inlet, Alaska, Sedimentary Geology, vol. 26, p 157-177.

Bouma, A.H., Hampton, M.A., Rappeport, M.L., Whitney, J.W., Teleki, P.G., Orlando, R.C. and Torresan, M.E., 1978b, Movement of sand waves in lower Cook Inlet, Alaska, Preprint 10th Offshore Technology Conference, paper 3311, p. 2271-2285.

Britch, R.P., 1976, Tidal currents in Knik Arm, Cook Inlet, Alaska, MS thesis, University of Alaska Inst. of Water Rsources, Anchorage, Alaska,

Burbank, D.C., 1974, Suspended sediment transport and deposition in Alaskan coastal waters, Univ. Alaska, Inst. Marine Sci., 222p.

Burbank, D.c.,1977, Circulation studies in Kachemak Bay and lower Cook Inlet, Environmental studies of Kachemak Bay and lower Cook Inlet, v. 3, Rept. Alaskan Fish and Game Dept., Anchorage , Alaska, 207p.

Burrell, D.C., and Hood, D.W., 1967, Clay-inorganic and organic-inorganic assosociation in aquatic environments, Part II, Feb'66 to June'66, Program rept. R67-3 to Atomic Energy Commission, Inat. Marine Sci., Univ. Alaska, Fairbanks, Alaska, 275p.

Carsola, A.J., 1975, Oceanographic/Meterological study of the lower Cook Inlet, Alaska, Lockheed Missiles and Space Co. Inc., Rept. to Shell Oil Co.

Dames and Moore, Inc., 1978, Drilling fluid dispersion and biological effects study for the lower Cook Inlet C.O.S.T. well, Atlantic Richfield co., REPORT prepared by Dames and Moore, INc., Anchorage, Alaska, 309p.

Evans, C.D., Buck, E.H., Buffler, R.T., Fisk, S.G., Forbes, R.B. and Parker, W.B., 1972, The Cook Inlet Environment- a background study of available knowledge, Univ. Alaska, Resource and Science Center, Alaska Sea Grant Program, Anchorage, Alaska, 137p.

Gatto, L.W., 1976, Baseline data on the oceanography of Cook Inlet, Alaska, C CRREL rept. 76-25, U.S. Army Cold Regions research and eng. lab., Hanover, New Hampshire

Hayes, M., Brown, P., and Michel, J., 1977, Coastal morphology and sedimentation, Lower Cook Inlet Alaska, IN: Trasky (editor) Environmental studies of Kachemak Bay and lower Cook Inlet, Alaska, Rept. Fish and Game Dept., Anchorage , Alaska, vol. 2, 107p.

Hein, J.R., Bouma, A.H., Hampton, M.A., and Ross, C.R., 1979, Clay Minerology , fine-grained sediment dispersal and inferred current patterns, lower Cook Inlet and Kodiak Shelf, Alaska, Sedimentary Geology, vol. 24., p. 291-306.

Ippen, A.T. (ed.), 1966, Estuary and coastline hydrodynamics, McGraw Hill Co., 744p.

Karlstrom, N.V., 1964, Quaternary geology of the Kenai Lowlands and glaciation of the Cook Inlet region, Alaska, U.S. Geological Survey Prof. Paper no. 443, 69p.

Komar, P.D., Neudeck, R.H. and Kulm, L.D., 1972, Observations and significance of deep-water oscillation ripple marks on the Oregon continental shelf, IN: D.J.P. Swift, D.B. Duane and O.H. pilkey (editors) Shelf sediment transport: process and pattern, Dowden, Hutchinson and Ross, Stroudsburg, Pa., p. 601-620.

McClennin, C.E., 1973, New Jersey continental shelf near-bottom current meter records and recent sediment activity, Journ. Sed. Pet., vol. 43, no. 2, p 371-380.

Muench, R.D., Mofjeld, H.O., Charnell, R.L., 1978, Oceanographic conditions in lower Cook Inlet Alaska; spring and summer 1973, Journal Geophys. Res., vol. 83, p 5090-5098.

Muench, R.D. and Schumaker, J.D., 1980, Physical oceanographic conditions in the northwest Gulf of Alaska, NWGOA synthesis report (draft), 160p.

Rappeport, M.L., 1980, Depositional environments and Quaternary Sedimentary units within lower Cook Inlet, Alaska - a high-energy tidally dominated embayment along the pacific margin of the United States, IN: Quaternary depositional environments of the Pacific Coast, Pacific Coast Paleogeography Symposium no. 4, Pacific section, SEPM, April , 9, 1980, 73-88.

Rappeport, M.L., Cacchione, D.A., Bouma, A.H. and Drake, D.E., 1979, Seafloor microtopography, tidal current characteristics and bottom boundary-layer time-series data, Cook Inlet, Alaska, (abs), EOS, Amer. Geophys. Union, Trans, vol. 60., no. 18., p. 285.

Sharma, G.D. and Burrell, D.C., 1970, Sedimentary environment and sediments of Cook Inlet, Alaska, AAPG Bull., vol. 54, no. 4, p 647-654.

Visser, R.C., 1969, Platform design and construction in Cook Inlet, Alaska, Journ. Petrol. Tech., p 411-420.

Wagner, D., Murphy, R.S., Behlke, C.E., 1969, A program for Cook Inlet, Alaska for the collection, storage and analysis of baselime environmental data, Inst. Water REsources, Univ. Alaska, rept. 1wr-7, Fairbanks, Alaska, 248p.

Wennekins, M.P., Flagg, L.B., Trasky, L., Burbank, D.C., Rosenthal, R., and Wright, F.F., 1975, Kachemak Bay ,a status report, Alaskan Dept. Fish and Game, Anchorage, Alaska.

Whitney, J.W., Noonan,W.G., Bouma, A.H. and Hampton, M.A., 1979, Lower Cook Inlet,Alaska : Do those large sand waves migrate?, 11th Offshore Technology Conference, paper 3484,p 1071-1082.

Table 1.

Dates	Wind Speed (knots)	Direction	Observed $H_{1/3}$ mean/max
1/7/71	52	N	5-8
4/13/71	60	N	12-20
11/10/71	37	NW	1-3
11/23/71	37	NNW	3-5
1/5/72	37	N	3-5
1/12/72	44	N	3-5
1/18/72	30	NNW	8-12
2/9/72	37	NE	5-8
2/16/72	52	W	8-12
2/22/72	37	NE	3-5
3/28/72	44	W	8-12
4/13/72	37	W	5-8
7/9/72	37	S	5-8
9/16/72	52	W	5-8
9/30/72	44	W	8-12
6/16/77			9 (13)
8/7/77			9 (17)
9/2/77			9 (18)

Reported Storm wave heights and directions from Carsola (1975) and Dames and Moore (1978). Wave heights are in feet and represent mean and max significant heights. Corresponding reported surface wind speeds are also listed.

TABLE 2. (percent frequency)

WAVE PERIOD (T) (in seconds) \ SIGNIFICANT WAVE HEIGHT ($H_{1/3}$) (in feet)	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8
7–8								
6–7								
5–6							1.5	0.6
4–5				2.5	3.1	1.2		
3–4	14.6	14.6	8.6	1.2				
2–3	37.3	0.6						
1–2								
0–1	13.4							

Wave spectrum summary data generated from the Ferry Tustamena data by Carsola, 1975.

Table 3a

30 meters isobath

Wave height				
244 cm	8.9	28.4	44.1	8 '
305 cm	11.1	35.5	55.1	10 '
366 cm	13.4	42.6	66.1	12 '
427 cm	15.6	49.7	77.1	14 '
	6.0	8.0	10.0	

Mean Wave Period (seconds)

Table 3b

50 meter isobath

Wave height				
244 cm	1.0	8.2	20.1	8 '
305 cm	1.2	10.3	25.1	10 '
366 cm	1.4	12.3	30.2	12 '
427 cm	1.7	14.4	35.2	14 '
	6.0	8.0	10.0	

Mean Wave Period (seconds)

Table 3c

70 meter isobath

Wave height				
244 cm	0.1	2.3	9.1	8 '
305 cm	-	2.9	11.4	10 '
366 cm	-	3.5	13.7	12 '
427 cm	0.2	4.1	15.9	14 '
	6.0	8.0	10.0	

Mean wave Period (seconds)

Tables 3a,3b,3c - maximum orbital wave motion at the seabed in cm/s calculated from the linear wave theory and modifications presented by Komar and others, 1972. (three selected depths)

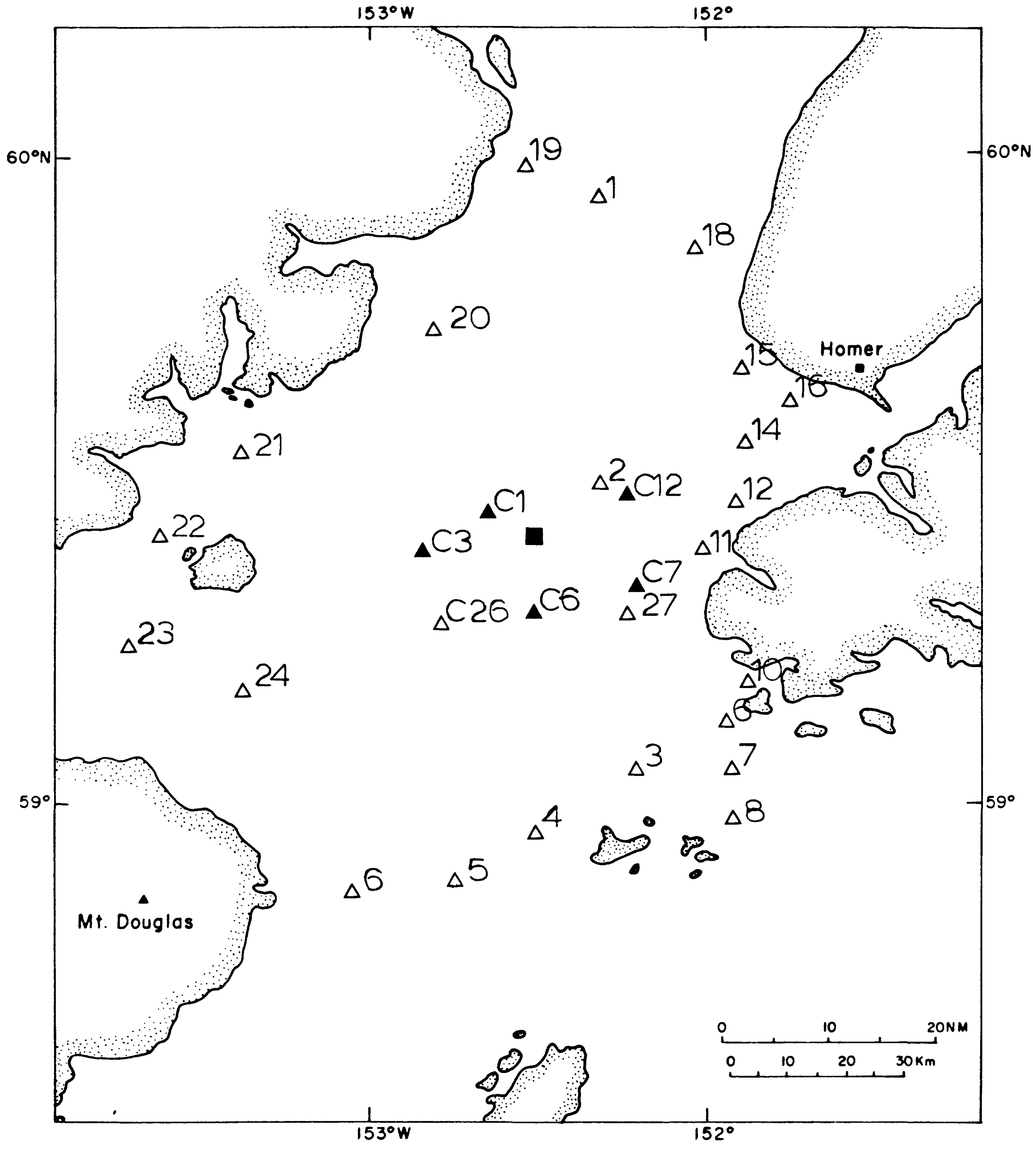

Figure 1 - Location map of Cook Inlet, Alaska - ▲ represent current meter array sites (Muench and others, 1973). ■ represents position of Arco Petroleum Corporation drilling rig - 'Ocean Ranger ' during spring-summer 1978. △ CTD stations

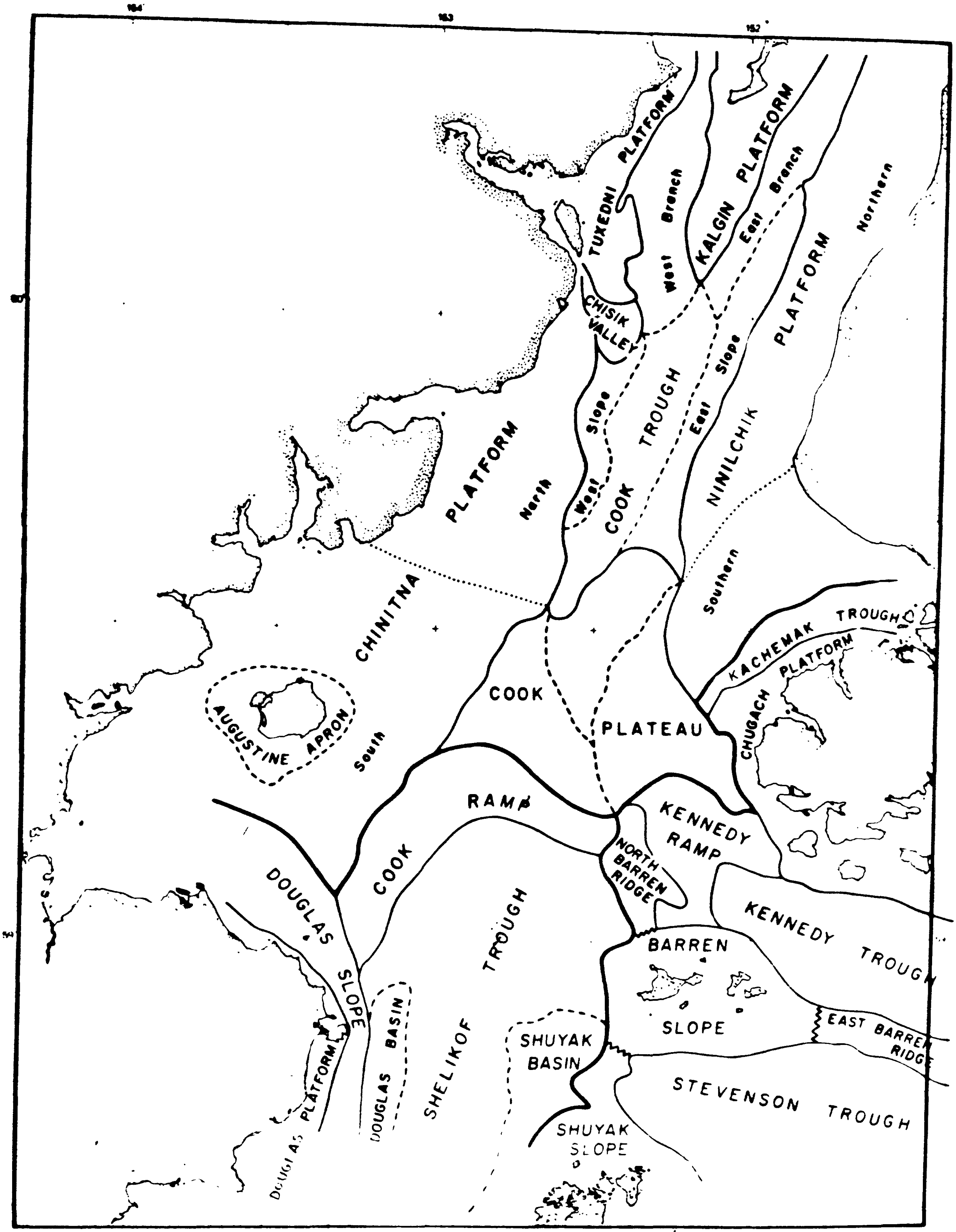

Figure 1b. Map showing major physiographic regions and named physiographic features of lower Cook Inlet

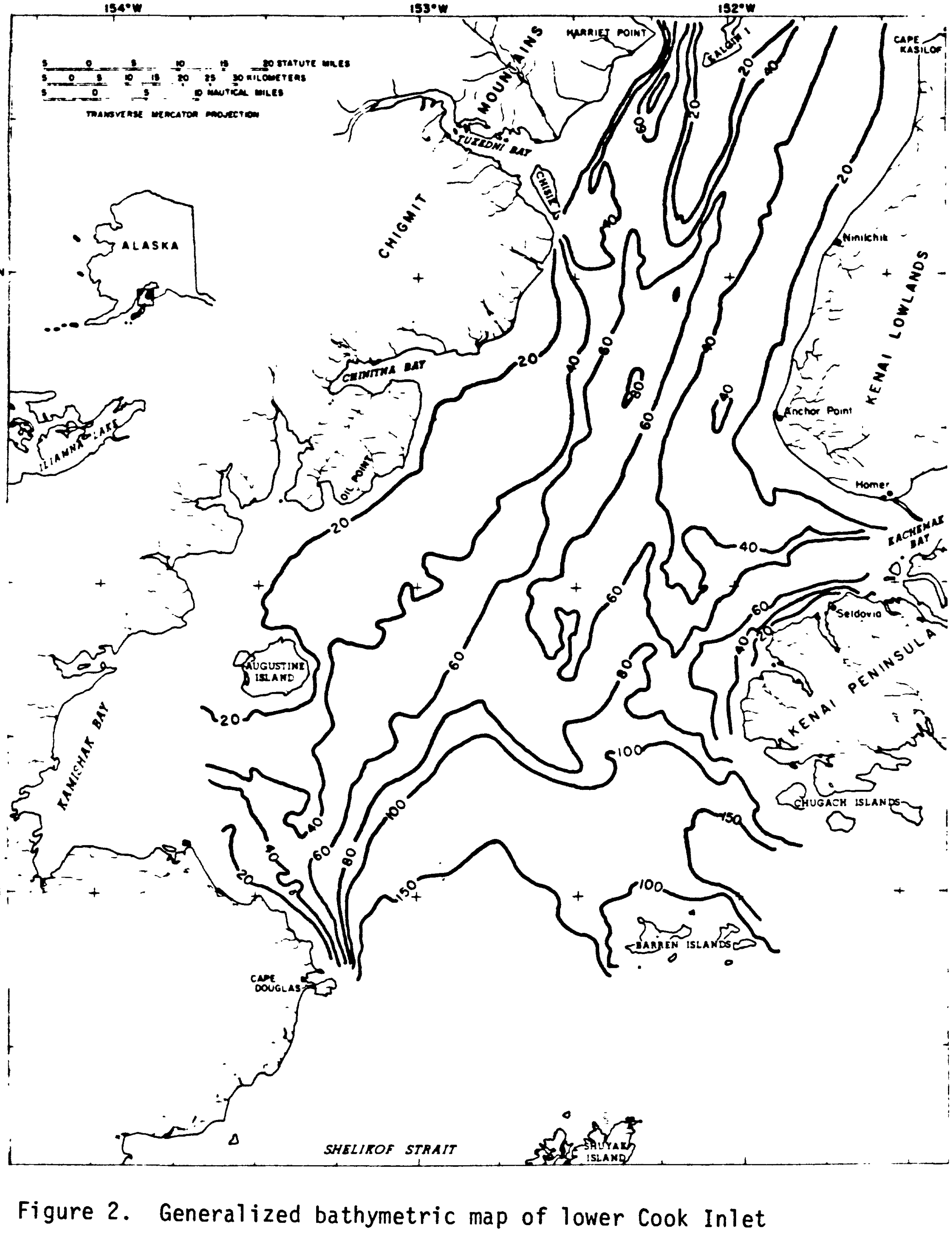

Figure 2. Generalized bathymetric map of lower Cook Inlet

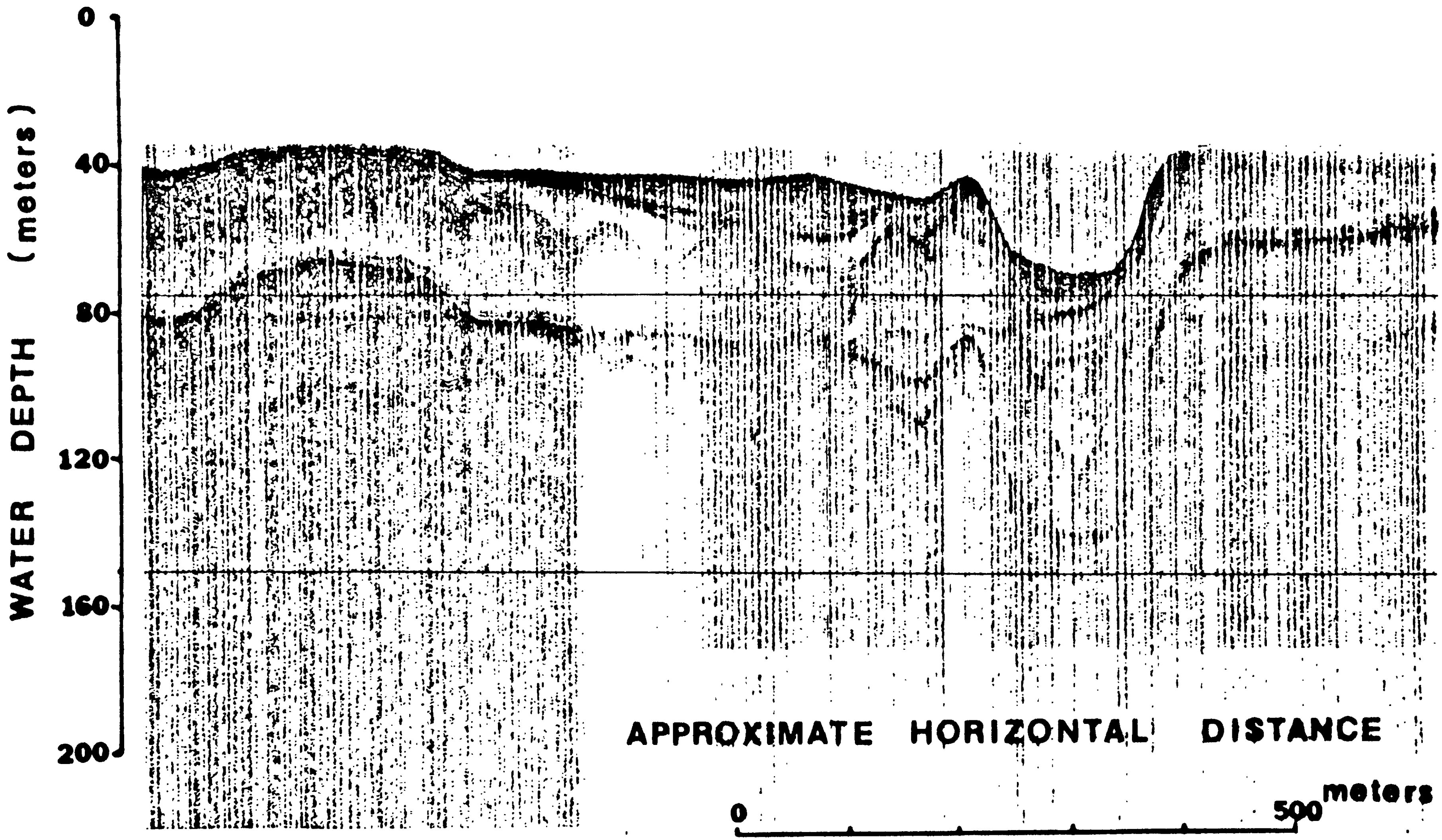

Figure 3a - Seismic reflection record (uniboom) showing the character of the glacial trough exiting from Tuxedni Bay with main channel fill and large -scale fill within apparently older channels. North is to the left

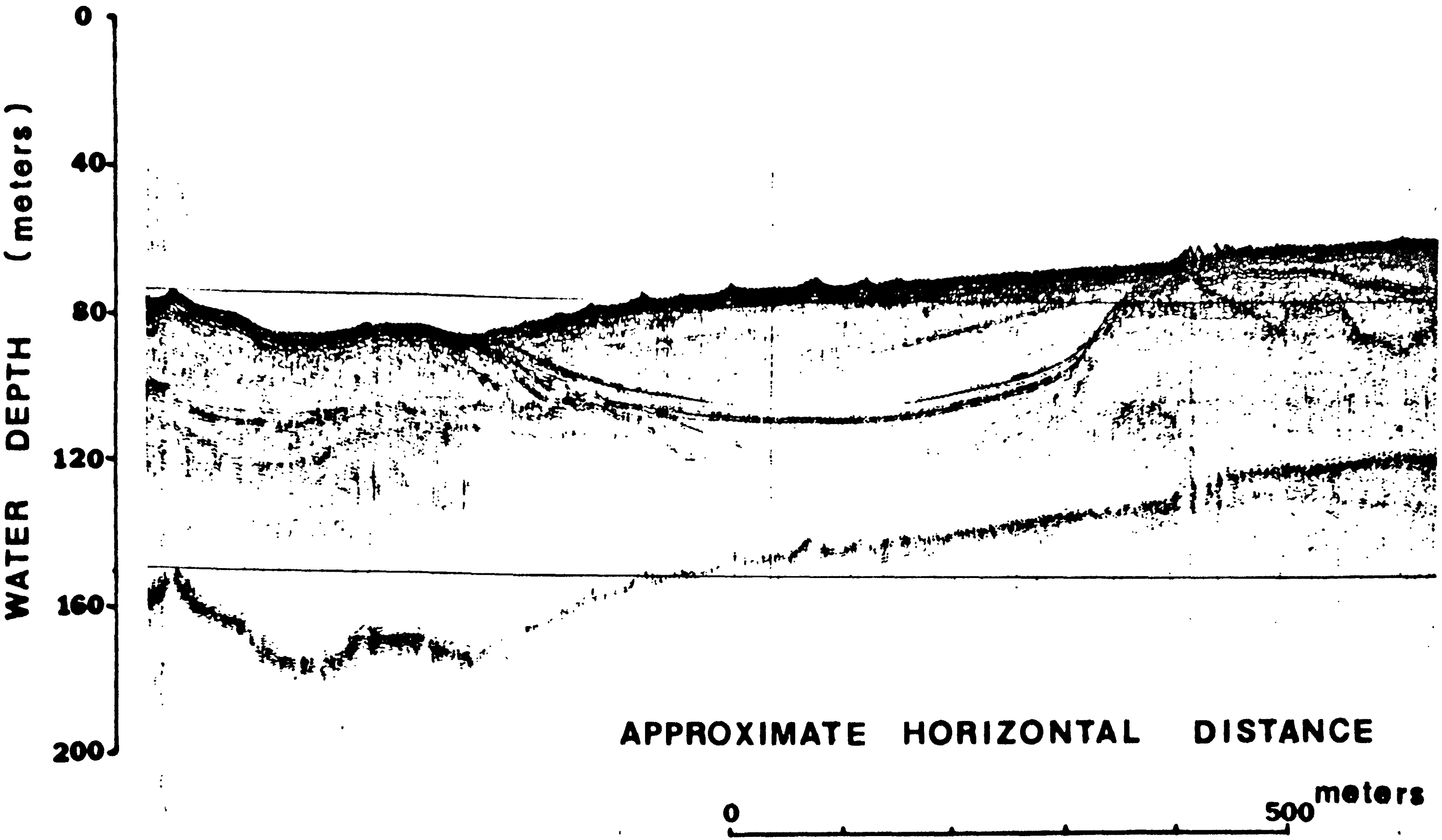

Figure 3b - Large depression filled with laminated silt and sand with active sand waves on surface. Thickness of fill is over 40 meters and represents less than several thousand years of deposition. North is to the left.

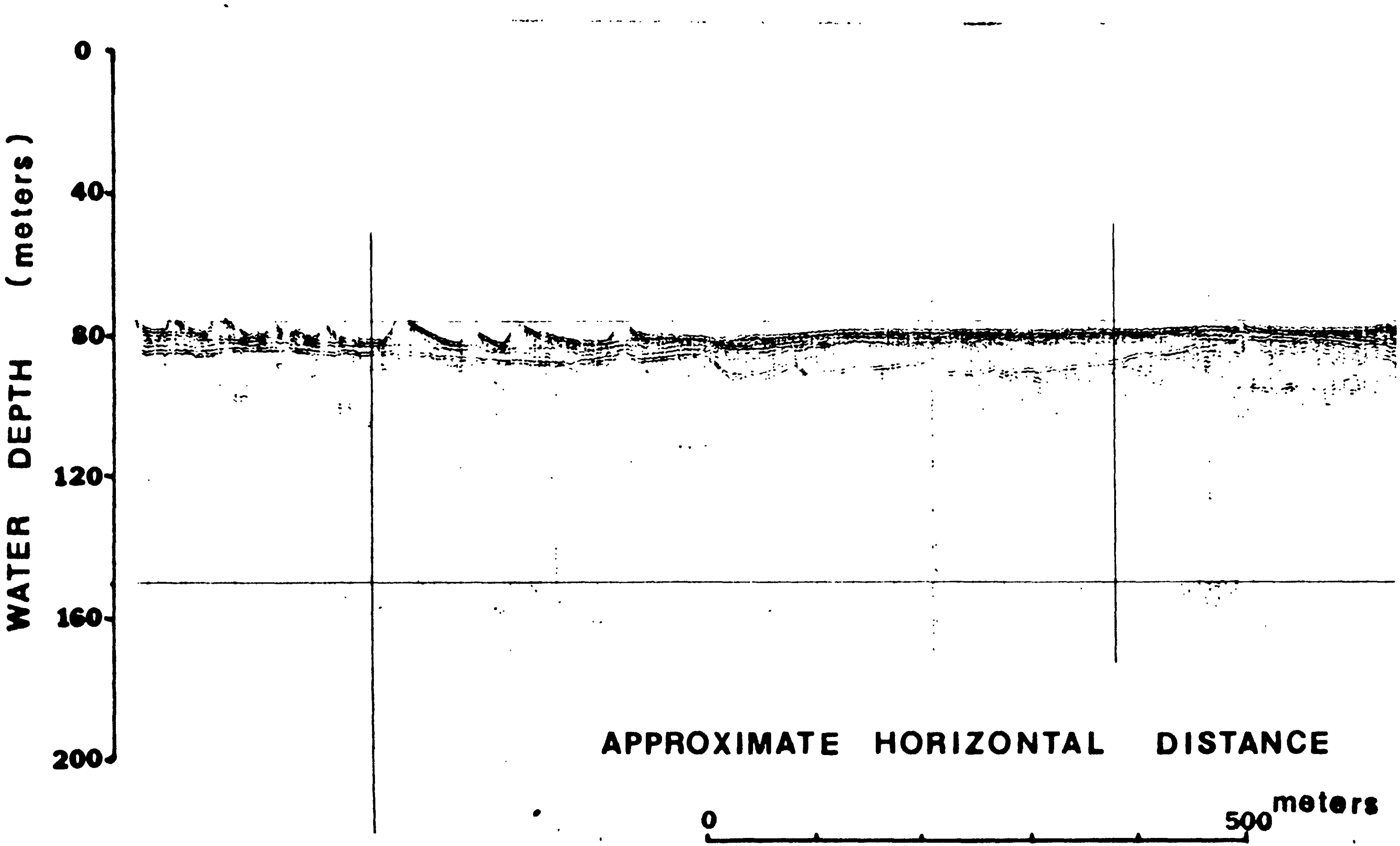

Figure 3c - Modern active sand waves overlying what appears to be buried sand waves, Note the reverse asymmetry between the relic sand waves and the modern ones.

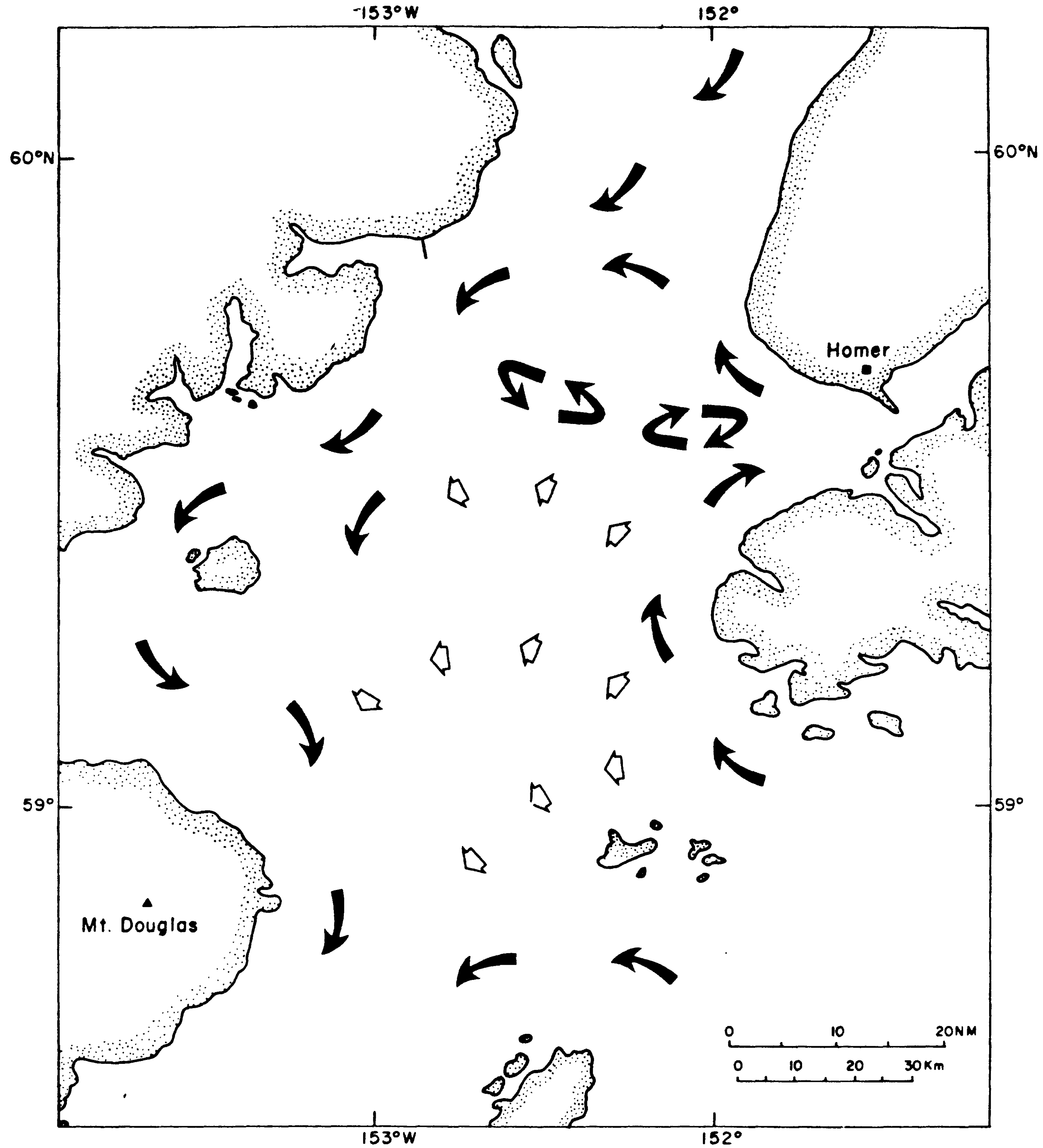

Figure 4a. Generalized mean surface current pattern (after Burbank,1974)

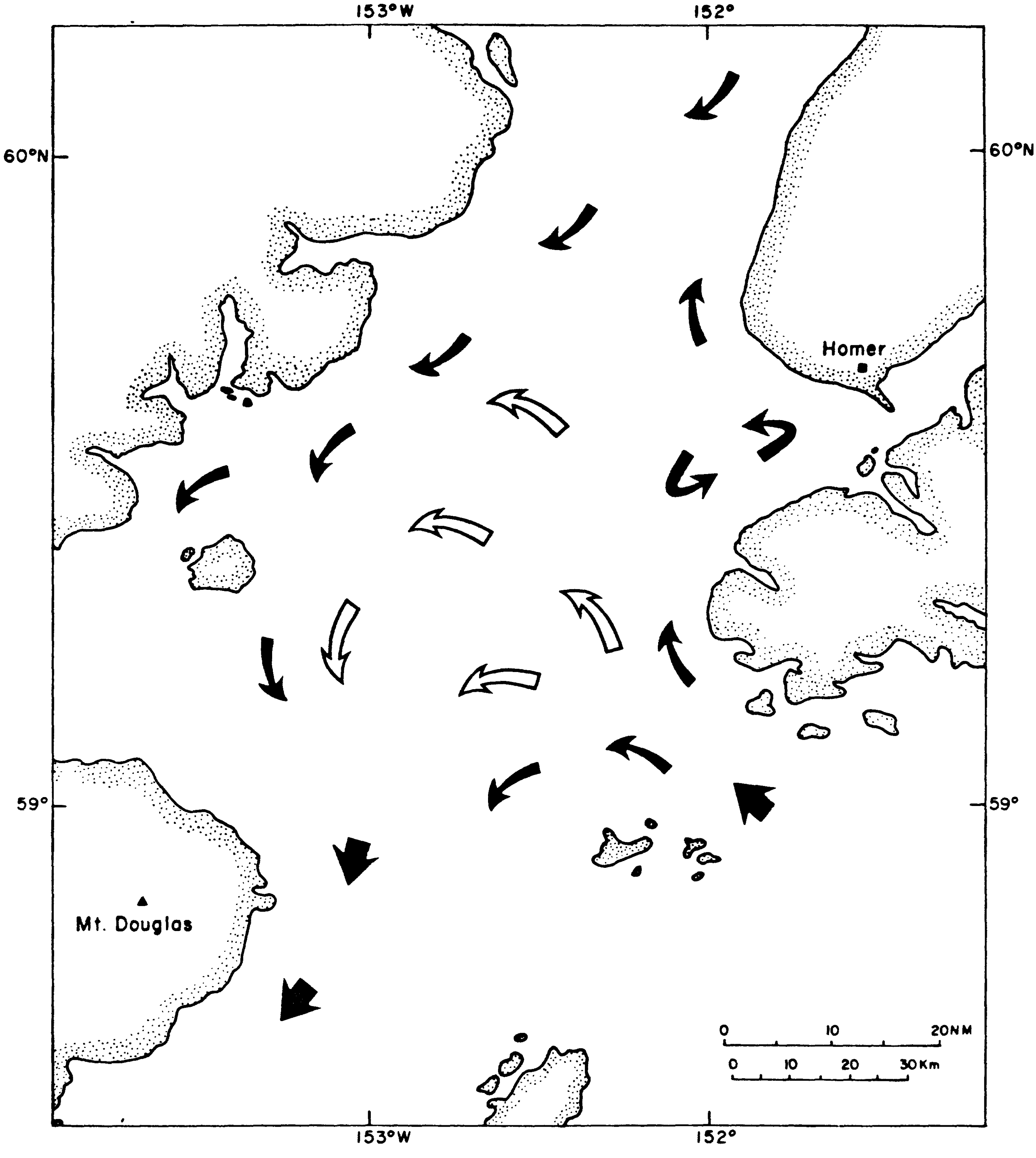

Figure 4b. Generalized mean surface current pattern (after Muench and others, 1978 and Muench and Schumaker, 1980)

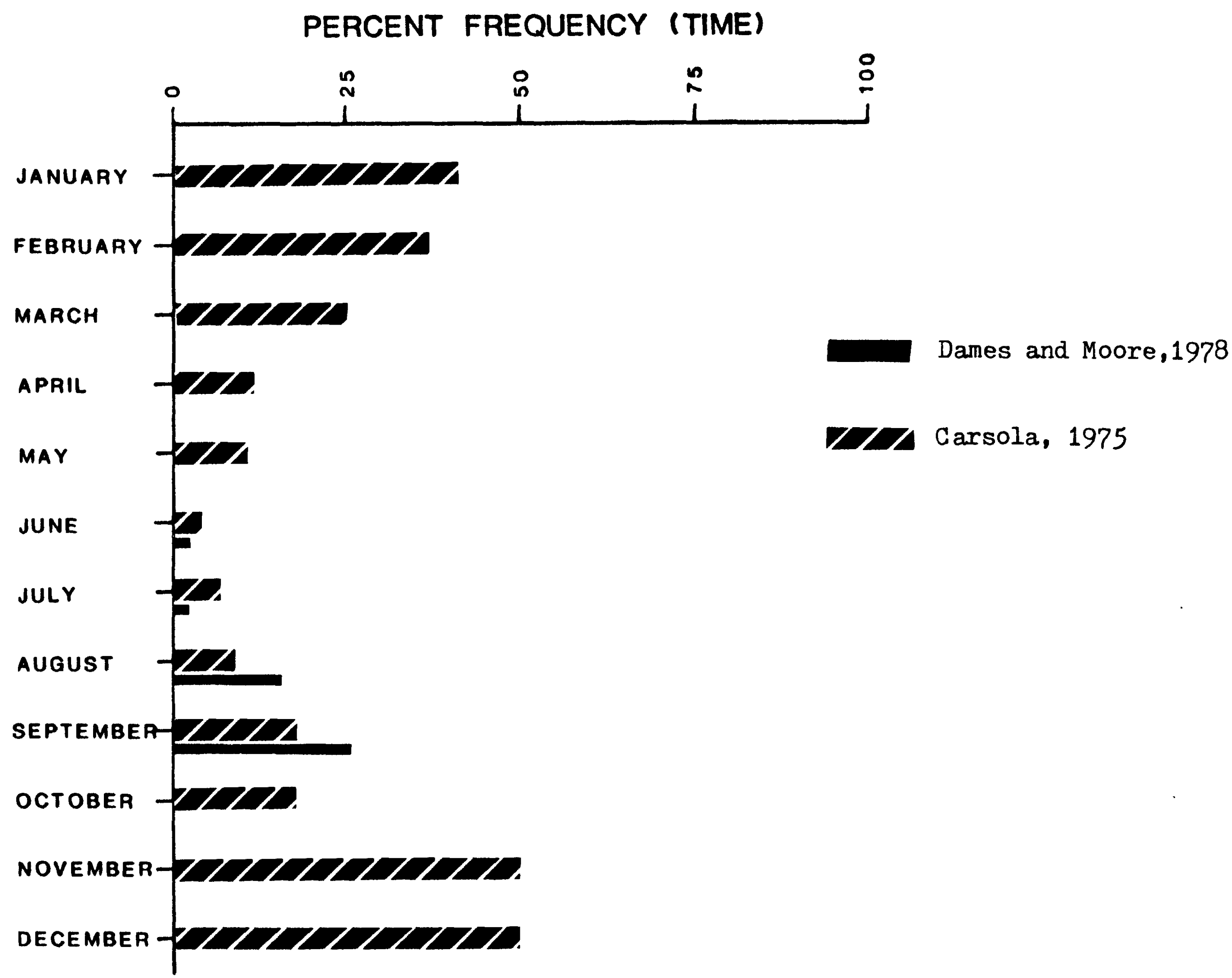

Figure 5. Windspeeds in excess of 25 knots by month

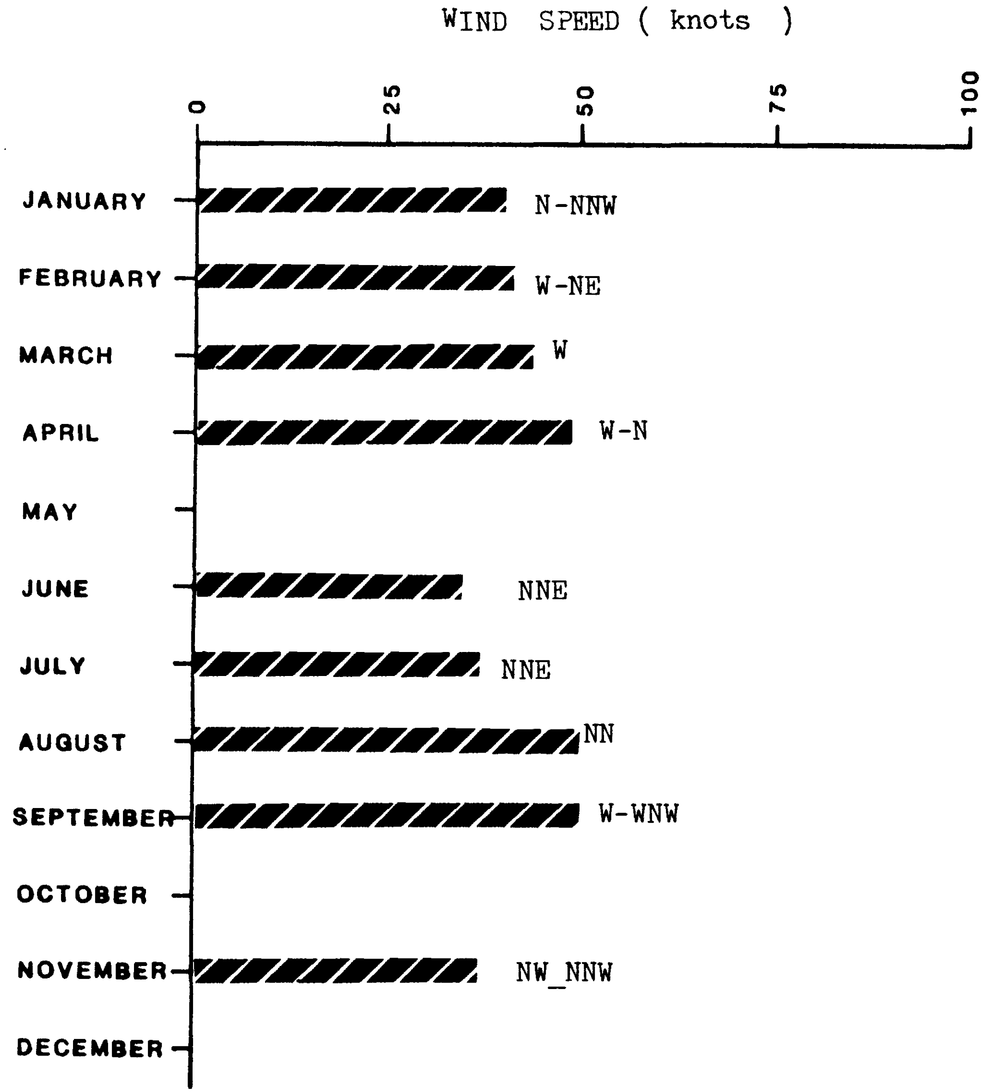

Figure 6. Projected mean extreme winds (summary of Carsola, 1975 and Dames and Moore, 1978 data) - (wind directions shown above)

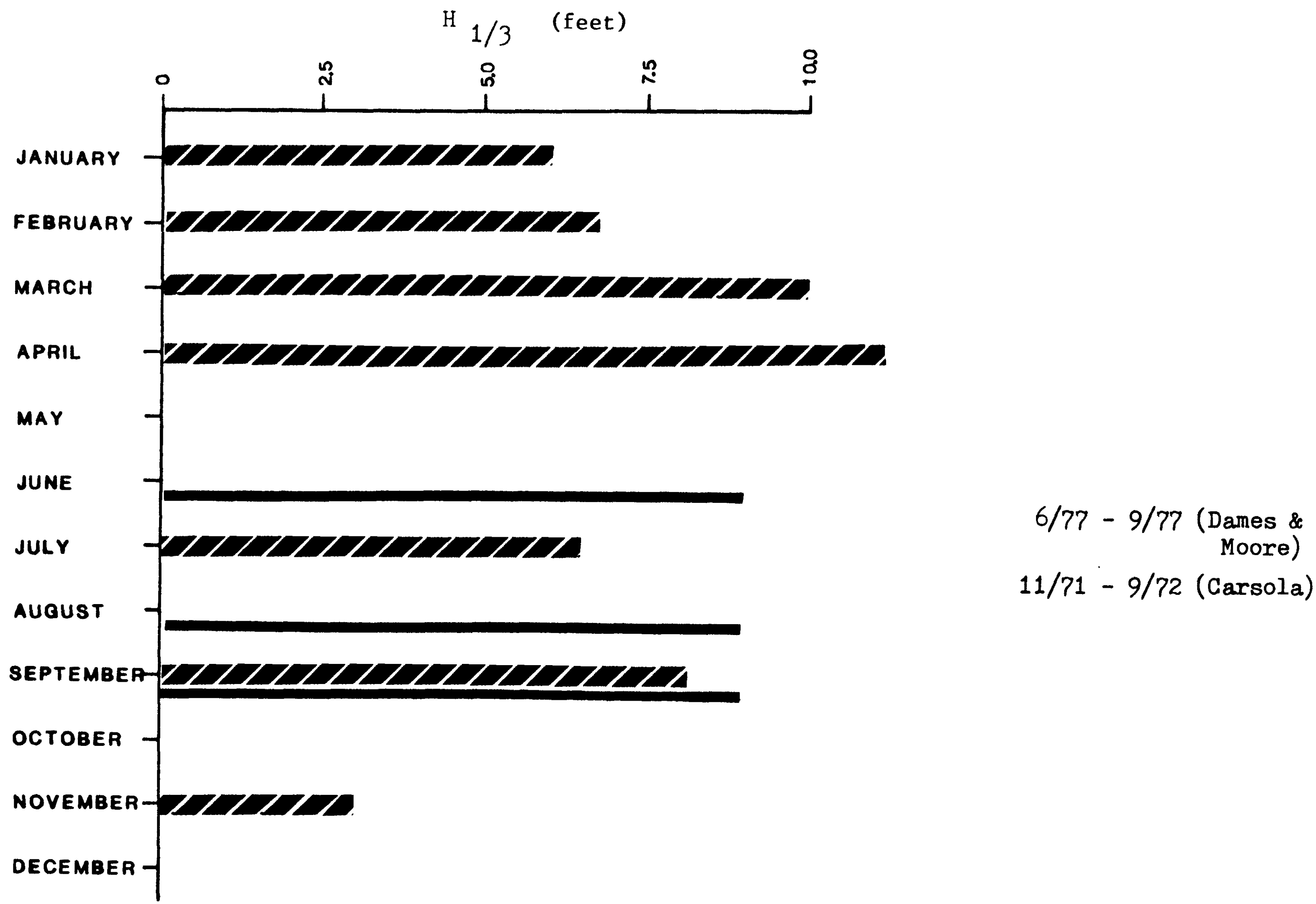

Figure 7. - Maximum significant wave heights.

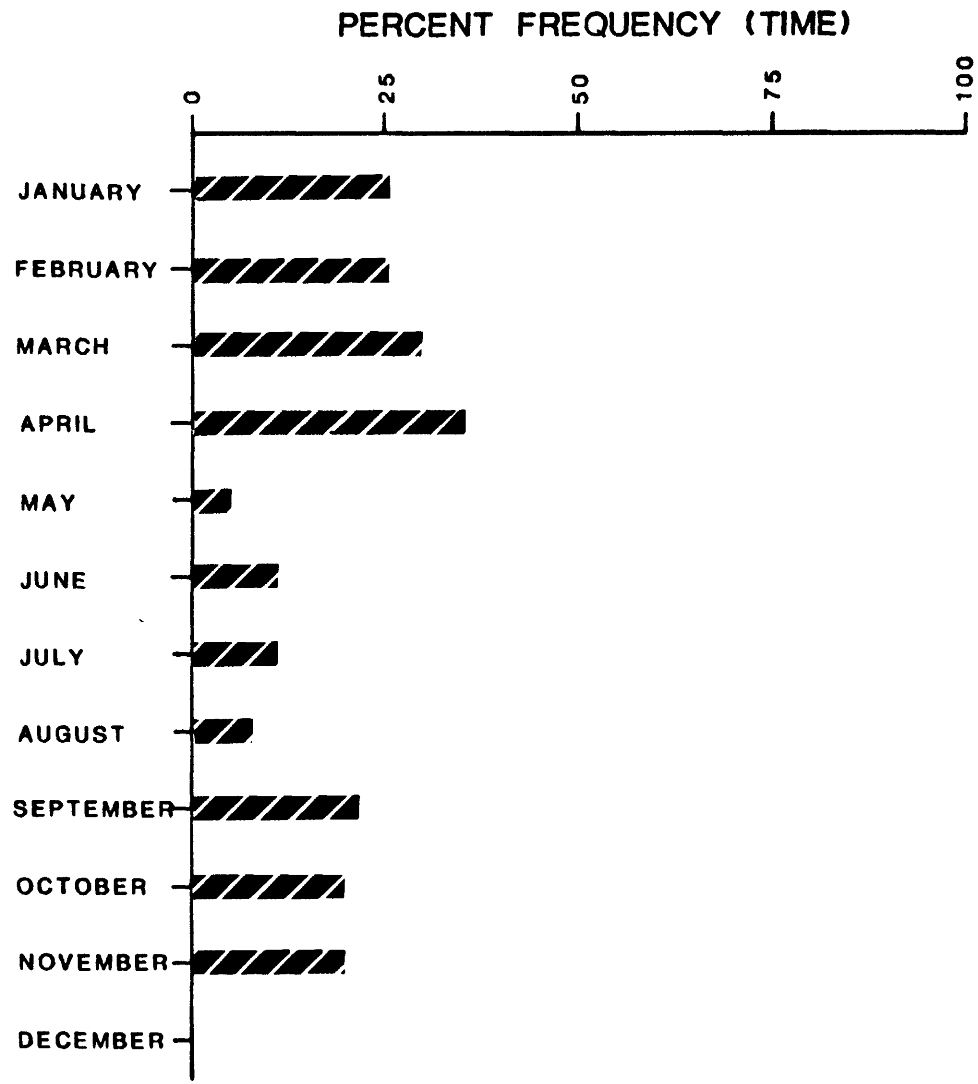

Figure 8. - Significant wave heights greater than 2 '
(after Carsola, 1975).

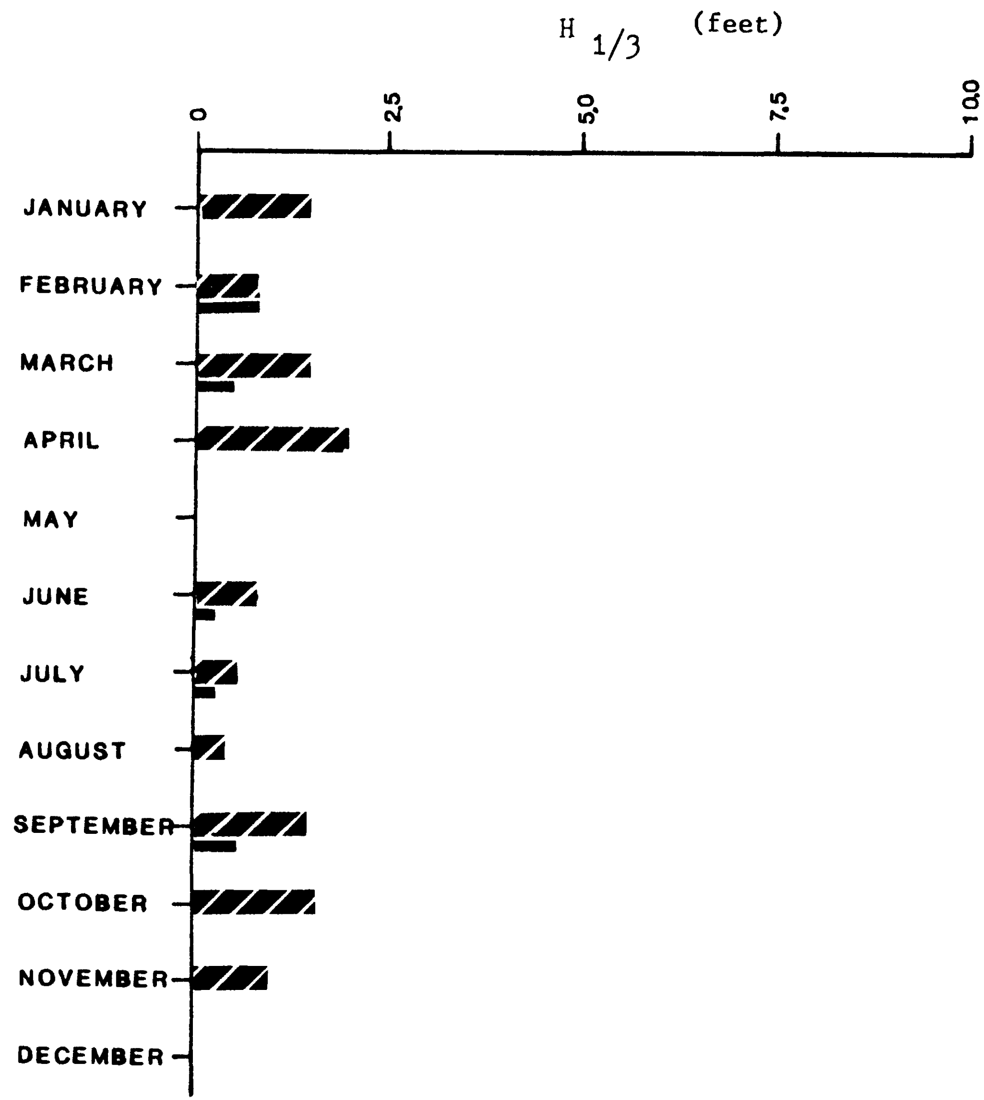

Figure 9. - Significant wave heights greater than 3' ( ) and greater than 6' ( ) after Carsola, 1975

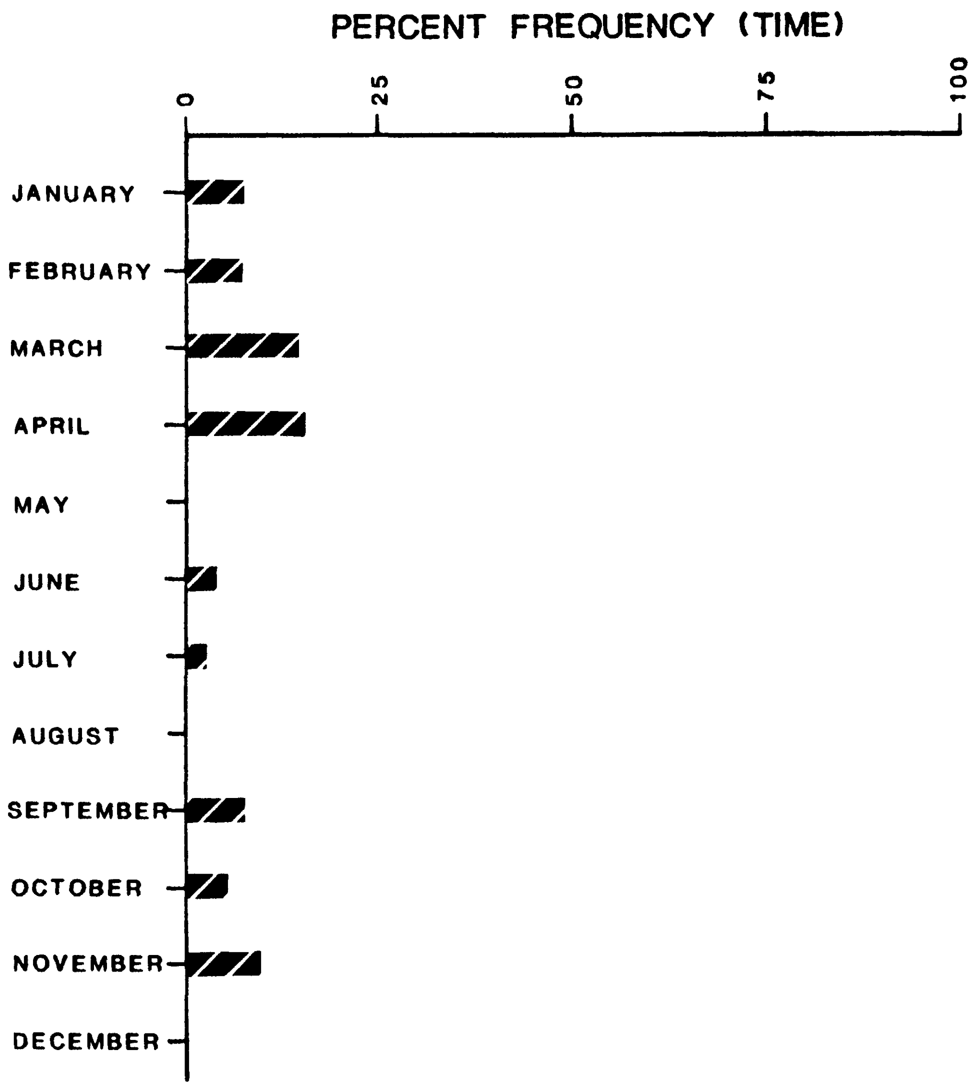

Figure 10. - Percent frequency of significant wave heights in excess of 4' (Carsola,1975)

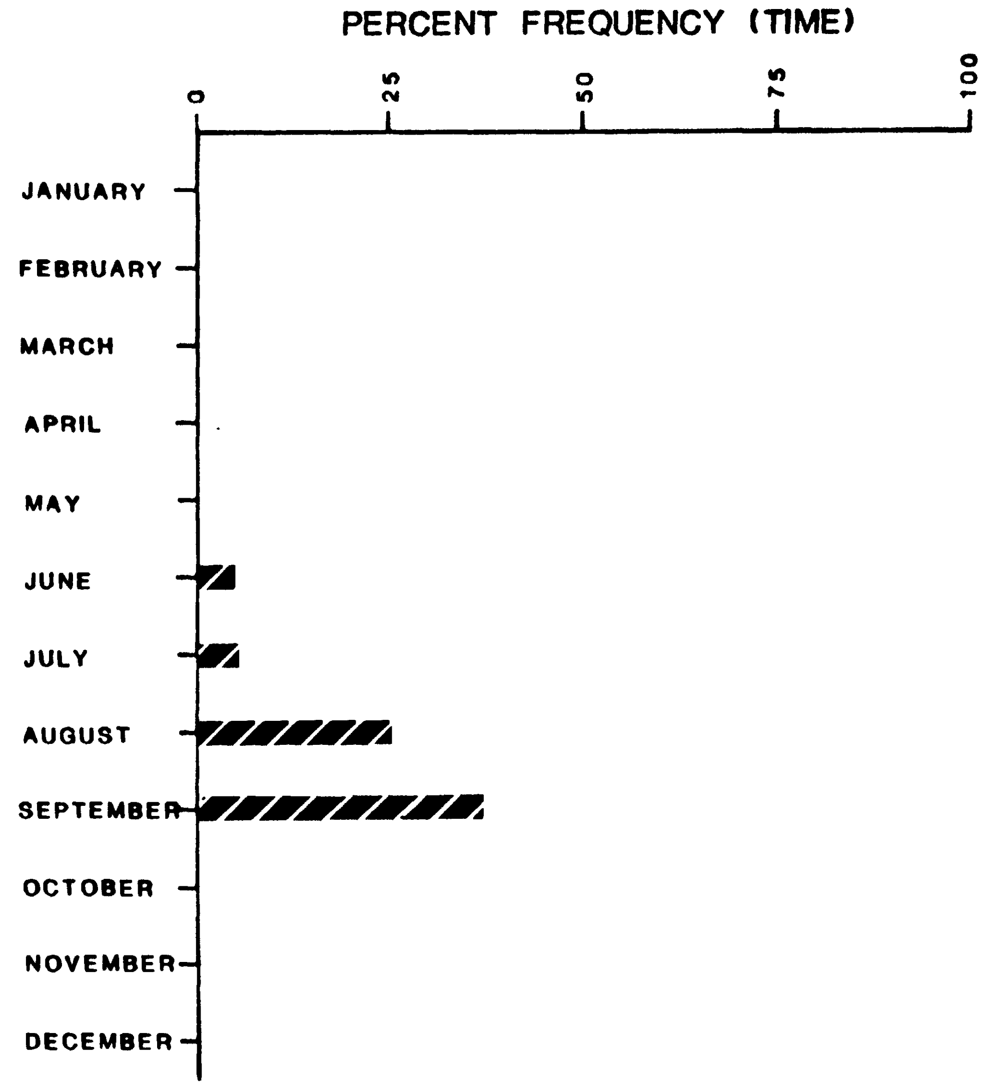

Figure 11. - Percent frequency of significant wave heights in excess of 3' (Dames and Moore, 1978)

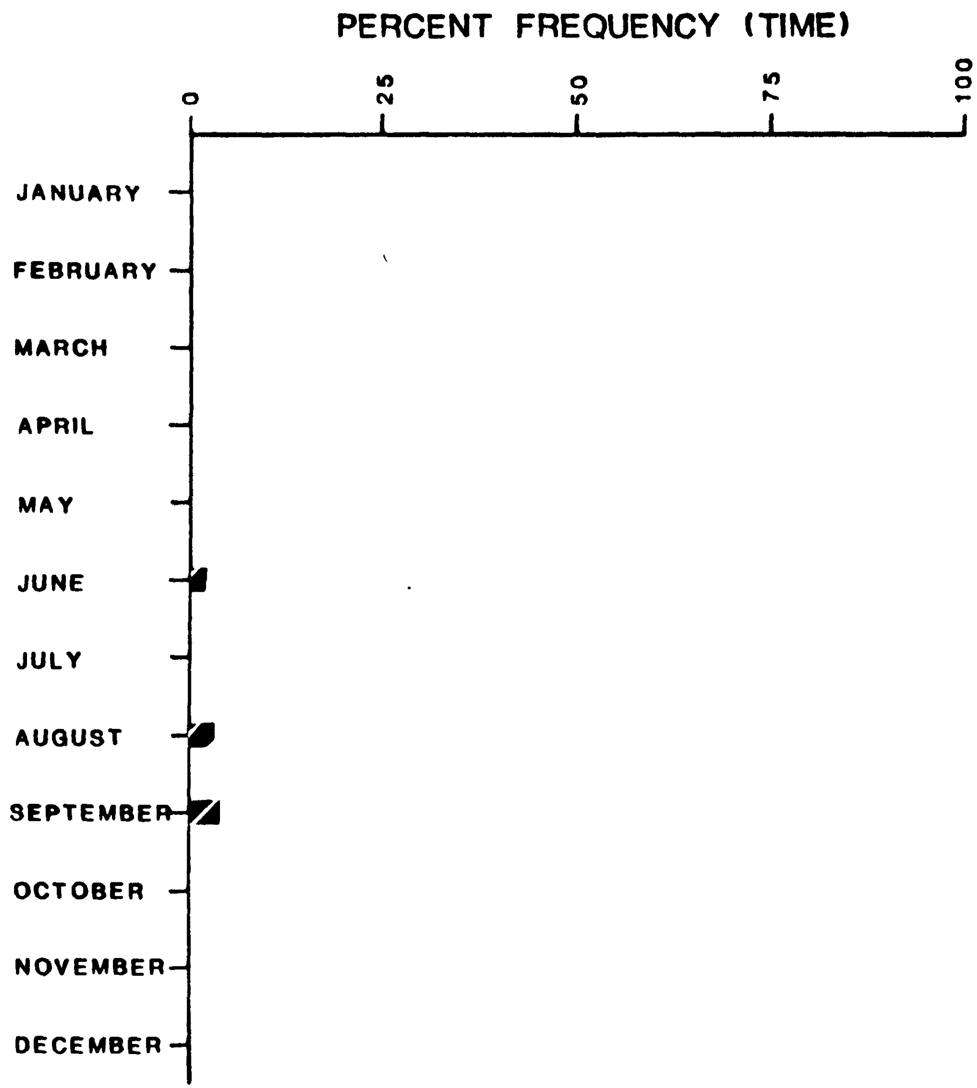

Figure 12. - Percent frequency of significant wave heights in excess of 6' (Dames and Moore, 1978)

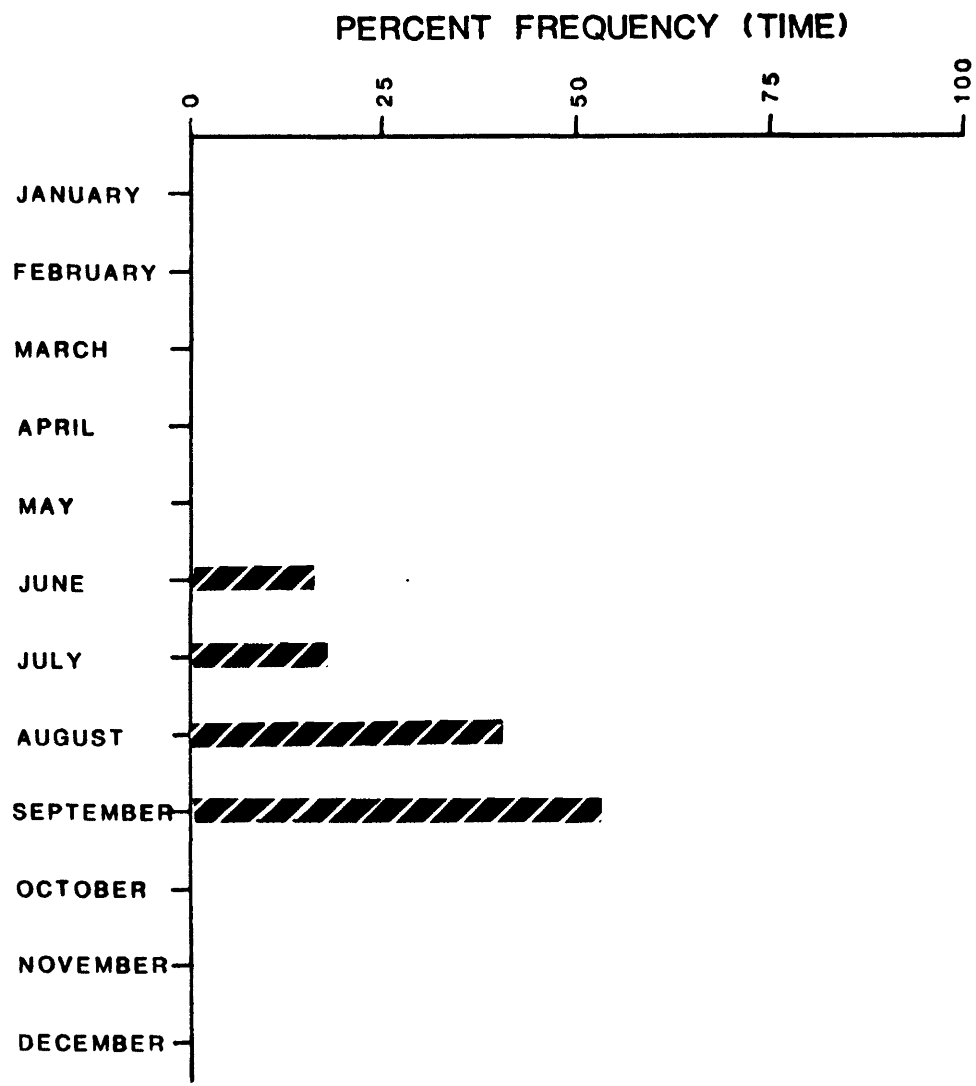

Figure 13. - Percent frequency of significant wave heights in excess of 2' (0.6 m) based upon wave rider data from buoy near C.O.S.T well (Dames an Moore, 1978)

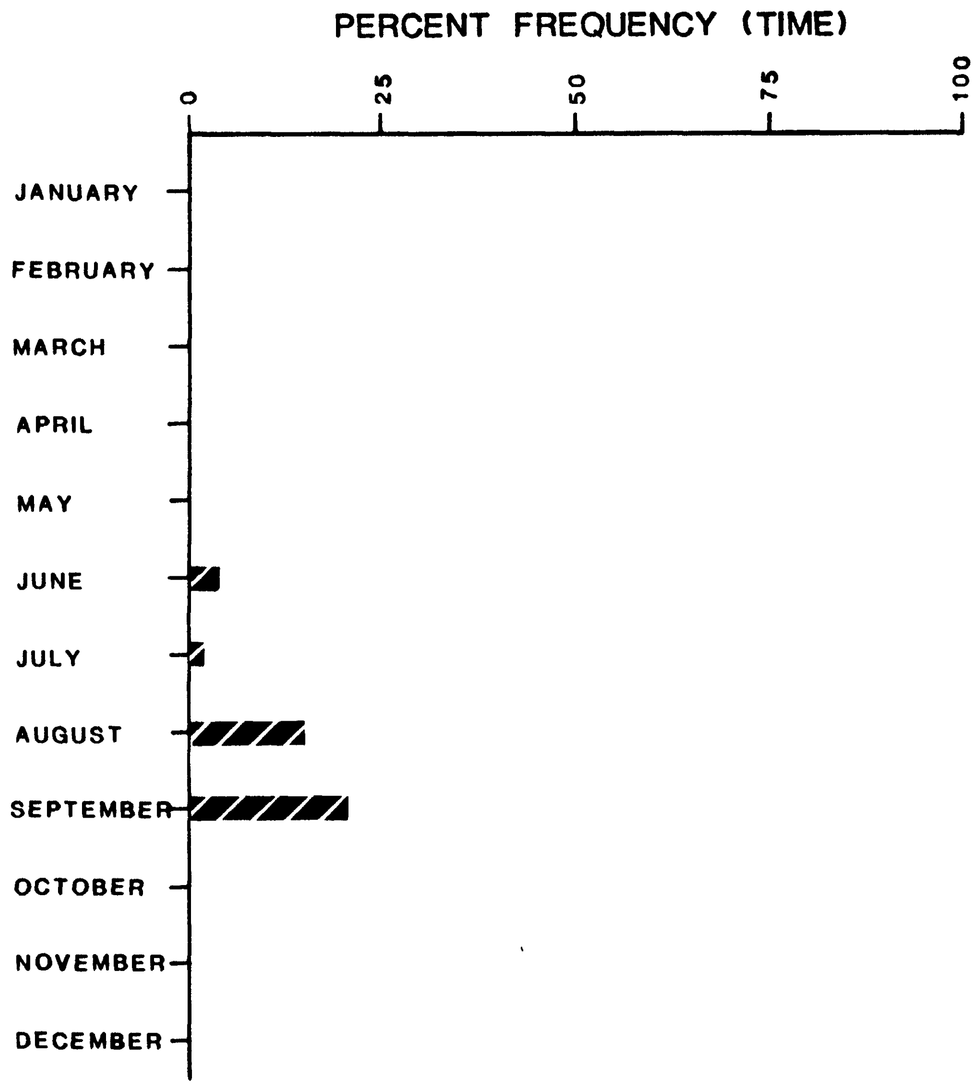

Figure 14.- Percent frequency of significant wave heights in excess of 4' (1.2m) based upon wave rider buoy data from location adjacent to the C.O.S.T well (Dames and Moore, 1978)

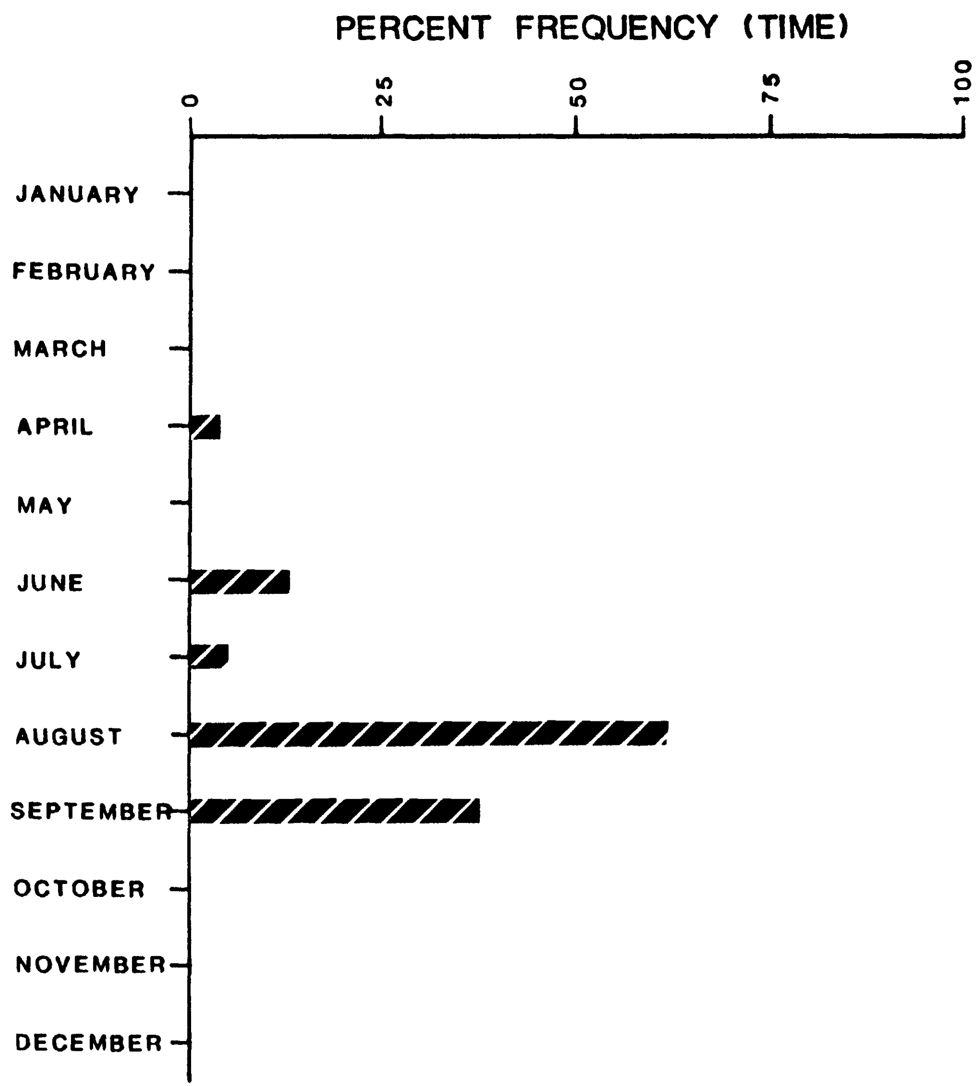

Figure 15. Percent frequency of reported wave periods in excess of 6 seconds (Dames and Moore,1978, Carsola, 1975)

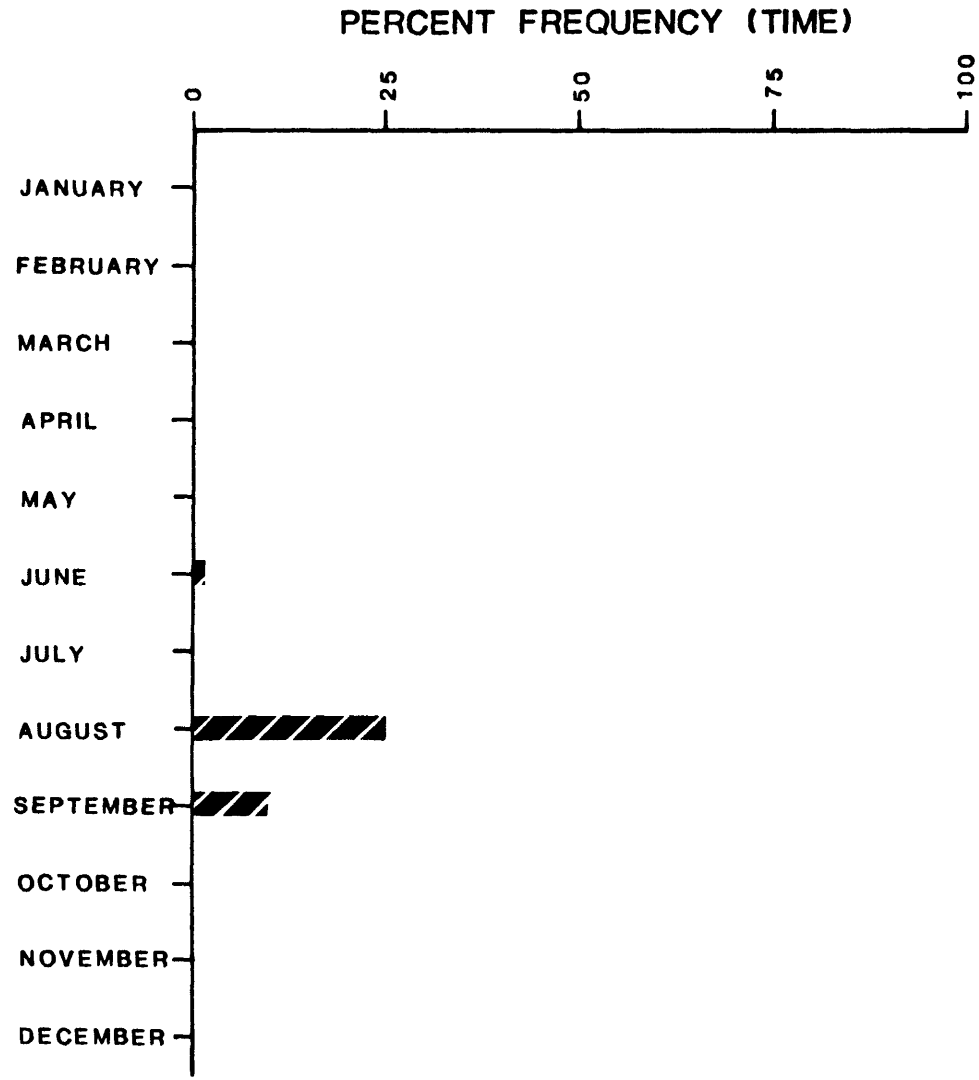

Figure 16.- Percent frequency of wave periods in excess of 8 seconds (Carsola, 1975; Dames and Moore,1978)

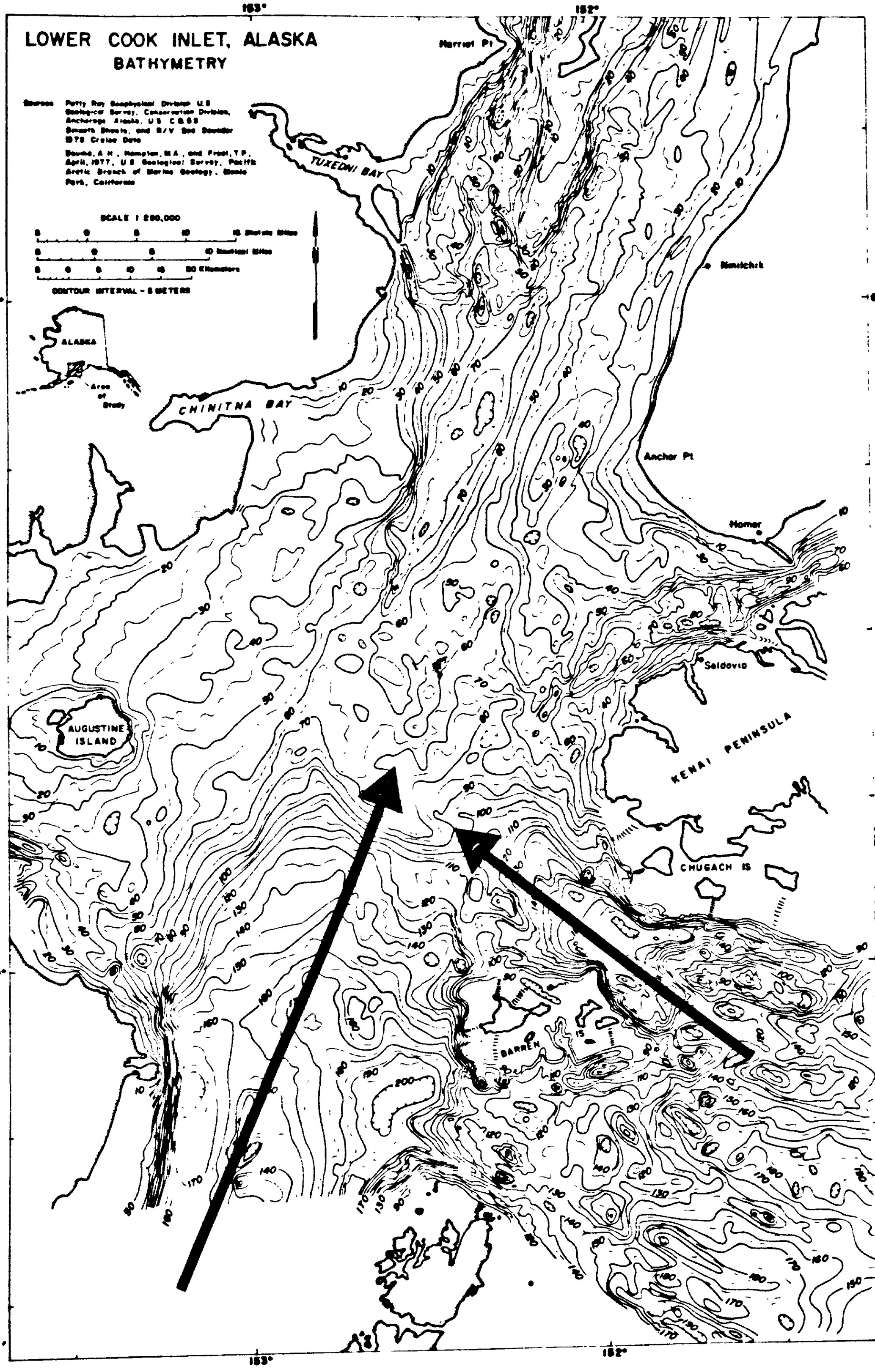

Figure 17. - Principal swell directions for long period waves entering lower Cook Inlet

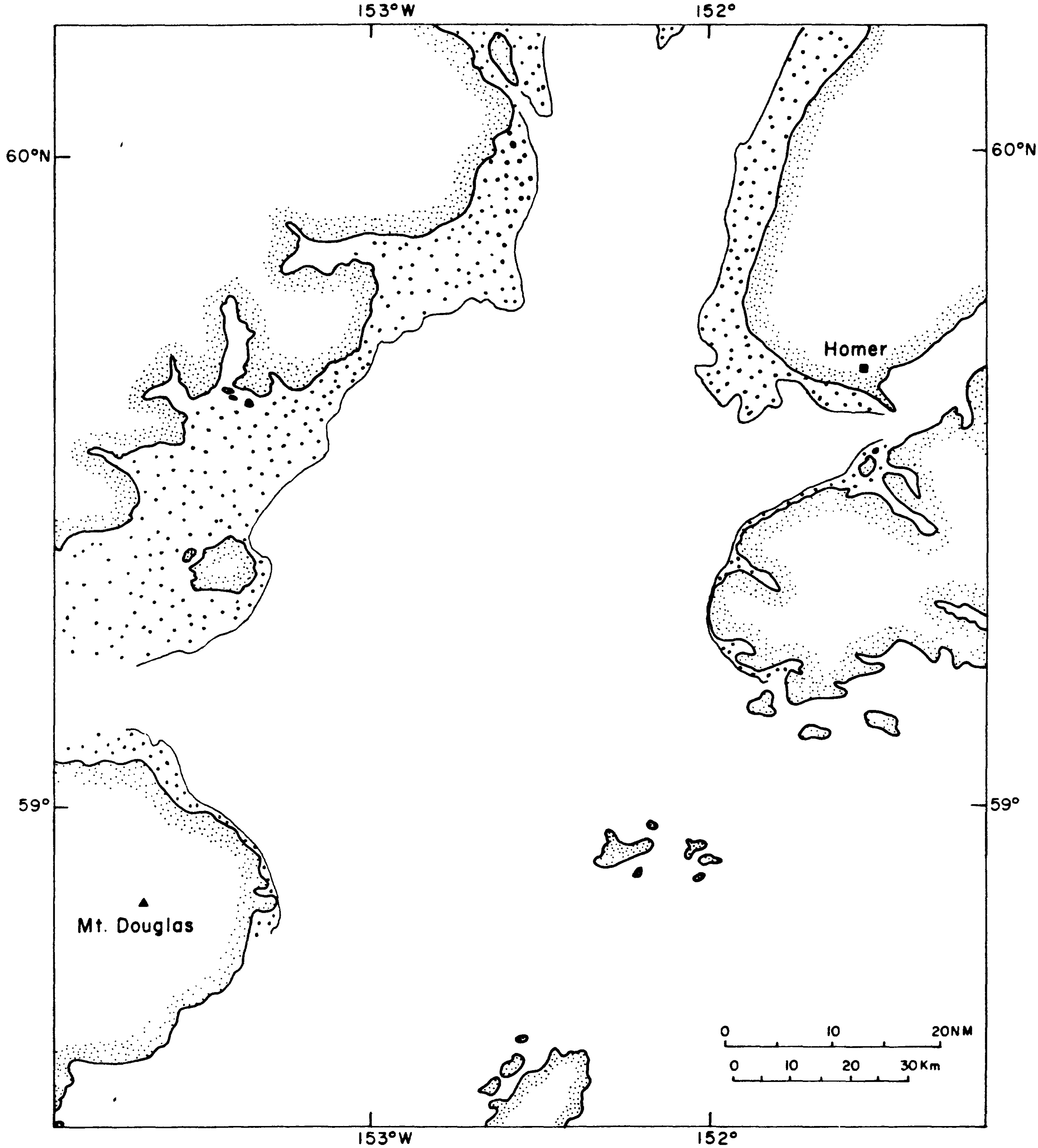

Figure 18a. Stipple pattern indicates the portion of seafloor in lower Cook Inlet affected by waves with six second periods.

(30m contour interval or less)

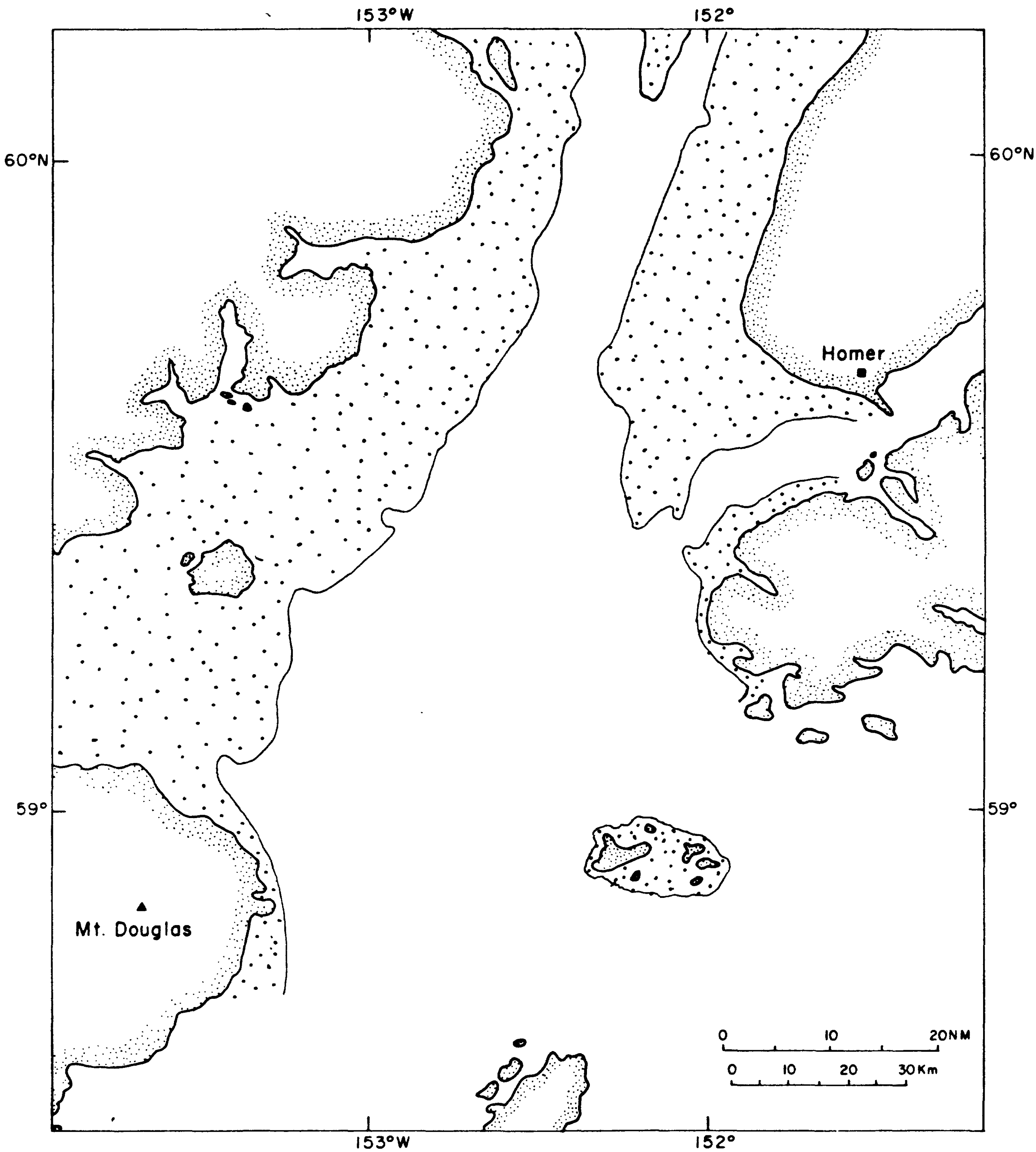

Figure 18b. Stipple pattern indicates the portion of seafloor in lower Cook Inlet affected by waves with periods of eight seconds. (50m contour interval or less)

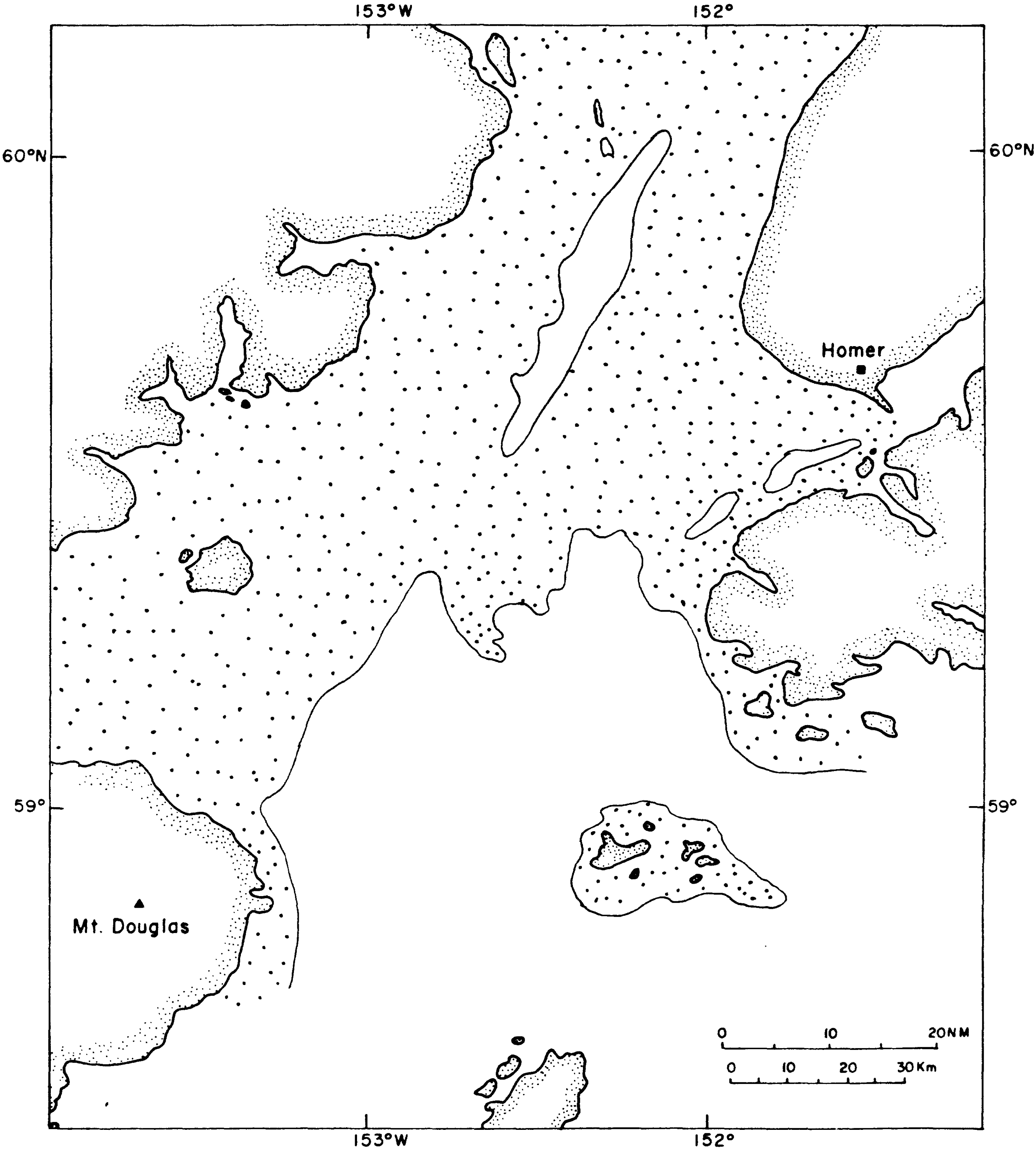

Figure 18c. Stipple pattern indicates the portion of seafloor of lower Cook Inlet affected by waves with periods of ten seconds. (70m contour interval or less)