Pacific Marine Science Report 78-23

CURRENT OBSERVATIONS IN THE CHANNELS OF THE CANADIAN ARCTIC ARCHIPELAGO ADJACENT TO BATHURST ISLAND

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ABSTRACT

The results of current meter measurements in Byam and Austin Channels and Crozier and Pullen Straits, all in the vicinity of Bathurst Island, N.W.T. are presented. The mean flow, long period oscillations and tidal oscillations are discussed. The records are dominated by tidal oscillations. It was found that mean flows averaged less than 5 cm s^{-1} while tidal oscillations could be as high as 30 cm s^{-1}.

The total transport in the channels is 0.2×10^6 m^3 s^{-1} which is less than 5% of the total exchange between the Arctic Ocean and the rest of the world ocean.

Year-long current records at two sites show augmented currents in late October and late December. Although these larger currents are probably associated with the atmospheric pressure difference between the Arctic Ocean and Lancaster Sound, no significant correlation was found.

The measured density stratification in Crozier Strait was used to compute internal wave modes and the current observations were fitted to these modes to determine the amplitudes of the lowest mode internal waves. Due to the very weak stratification, the internal tidal streams appear to be about 1/10 the amplitude of the barotropic tidal streams.

The rotation of the major axes of the tidal ellipses in close proximity to the bottom and the under-side of the ice were found to agree with theory which predicts the rotation to be determined by the sense of polarization of the rotating current vectors.

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1. INTRODUCTION

An interest in the currents of Byam and Austin Channels together with Crozier and Pullen Straits is a direct result of the Polar Gas proposal to transport natural gas by pipeline from the fields on Melville Island in the Northwest Territories to markets in southern Canada. The proposal included necessary crossings of a number of marine channels few of which had ever been studied from an oceanographic viewpoint. A detailed knowledge of currents was of particular importance to provide the knowledge for an adequate design of the pipeline and for suitable installation techniques at marine crossings.

The principals of the Polar Gas Project, through their consultants, Montreal Engineering Company Limited, entered into an agreement with the Frozen Sea Research Group (F.S.R.G.) of the Institute of Ocean Sciences, Patricia Bay, at Sidney, B.C. to conduct an oceanographic program in those channels where F.S.R.G. was equipped to operate. The principal goal was to obtain current measurements adjacent to the sea floor, as these were clearly needed to insure the integrity of the pipeline after installation, including consideration of movement of bottom sediments. It was also decided to measure currents adjacent to the sea ice in order to obtain information on the local movement of oil under ice as might occur in the event of an offshore oil well blowout in the Sverdrup Basin. Current measurements in Byam and Austin Channels in 1976 were limited to these two boundary regions by the need to fix the recording current meters to a rigid surface in order to obtain information on current direction. The close proximity of the north magnetic pole precluded the use of magnetic compasses, the normal direction reference built into current meters designed for use at more southern latitudes. In 1977 current measurements were taken in Crozier and Pullen Straits by which time a method of measuring currents at mid-depths as well as in the boundaries was available. Compared to Byam and Austin Channels a significantly greater proportion of the data obtained in Crozier and Pullen Straits was of oceanographic interest. This fact is reflected in the emphasis given in discussion of data which follows in this report.

In addition to current measurements data on tides and water structure (temperature and salinity profiles) were obtained.

a) Bathymetry

The waters of the Canadian Archipelago everywhere overly the continental shelf and separate the islands with numerous shallow channels. Depths are generally less than 600 metres although a few deeper basins exist as a result of glacial overdeepening. Flow through the Archipelago is limited by one or more sills. The geographical location of Byam and Austin Channels and Crozier and Pullen Straits is shown in Figure 1.

Byam and Austin Channels

The bathymetry of Byam and Austin Channels is illustrated in Figure 2. Austin Channel is the deeper of the two channels with a few locations reaching 250 metres. The limiting sill depth just to the north is about 200 metres. Connection to the Arctic Ocean from the north is restricted by a 400

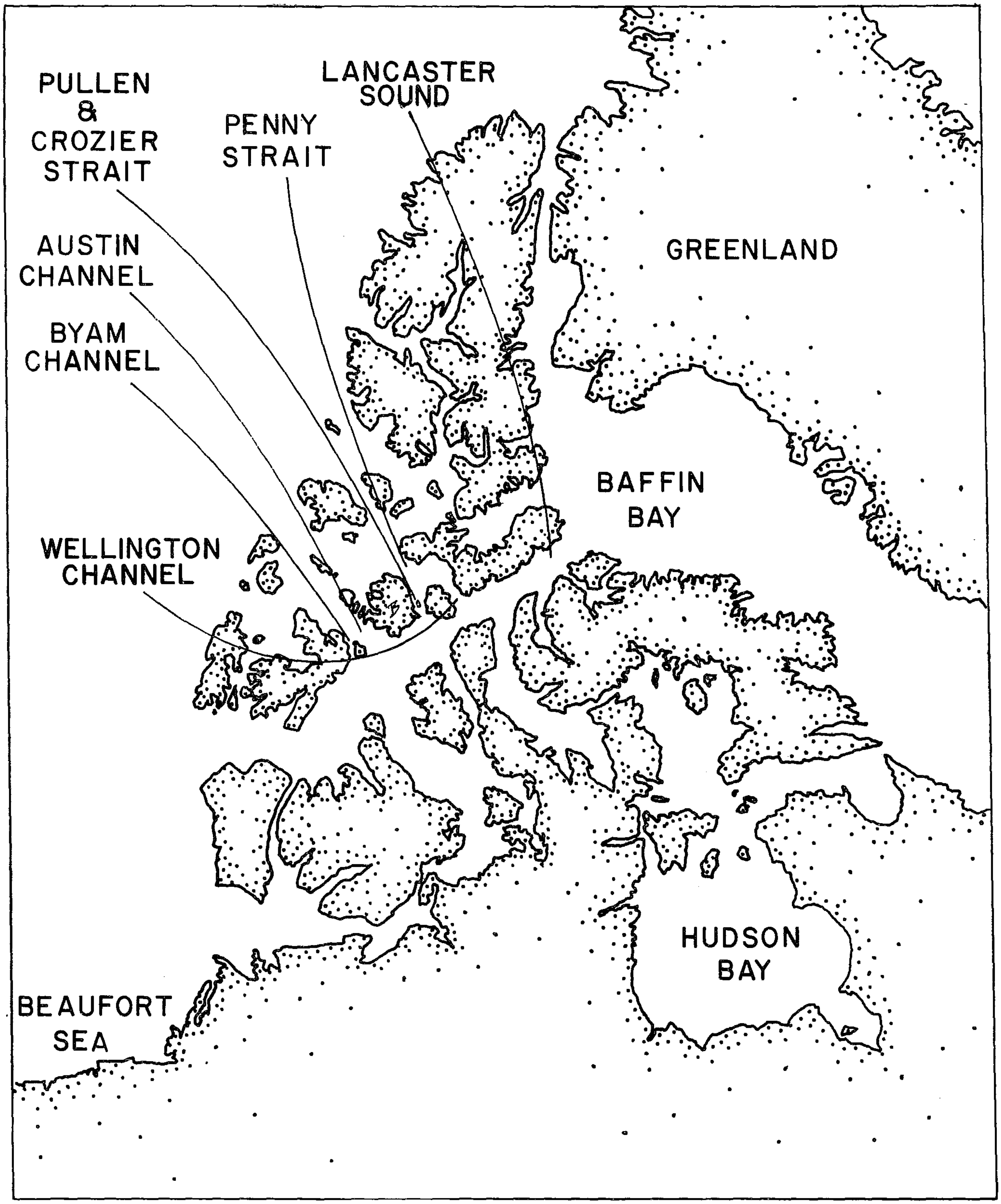


FIGURE 1. Geographical location of Channels.

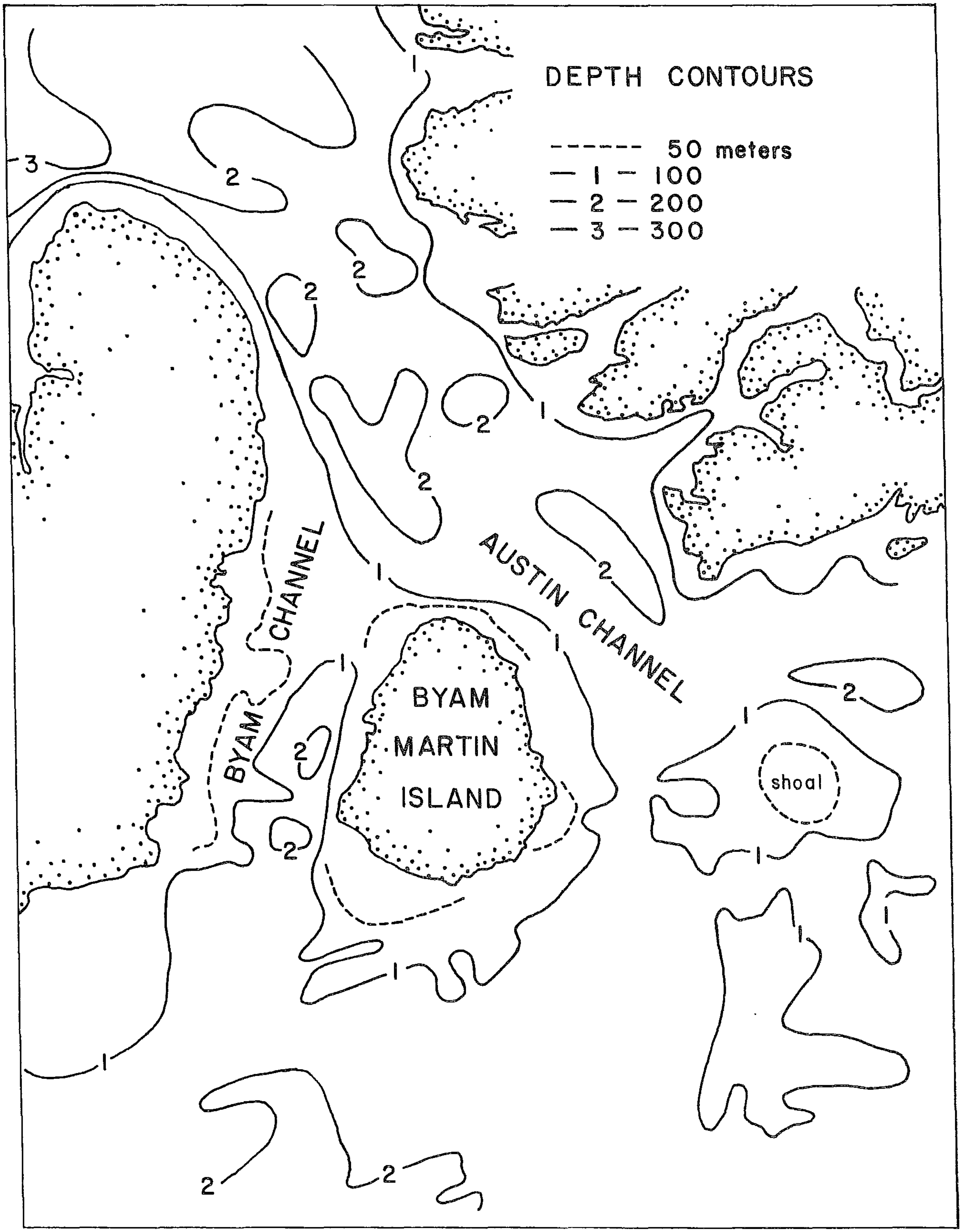


FIGURE 2. Bathymetry of Byam and Austin Channels

metre sill at the entrance to Prince Gustaf Adolf Sea. A shoal is centered at the south end of Austin Channel from which point depths west to Byam Martin Island barely exceed 100 metres. East of the shoal, depths are generally less than 150 metres. In Byam Channel a sill is located between the north end of Byam Martin Island and Melville Island to the west. Flow over this sill is restricted to depths slightly less than 100 metres. South of the Byam sill water depths increase to form a channel nearly 200 metres deep extending south to the deeper waters of Viscount Melville Sound. To the west Viscount Melville Sound communicates with the Arctic Ocean via M'Clure Strait to depths approaching 480 metres. The eastern end of Viscount Melville Sound becomes progressively shallower south of Austin Channel. To the east the Sound is connected to Baffin Bay via Barrow Strait and Lancaster Sound. Here water depths reach their minimum in Barrow Strait, whose estimated sill depth is 140 metres.

Crozier and Pullen Straits

The bathymetry of Crozier and Pullen Straits is illustrated in Figure 3. Crozier Strait is remarkably deep for its width, a feature which can probably be attributed to a geological fault extending along the axis of the strait. A sill whose depth probably does not reach 100 metres extends across Crozier Strait near Milne Island. Soundings in this area are limited to a single ship's track so that this depth is at best an educated guess although the existance of the sill is almost certain. Water depths to the east and north of Milne Island are unknown, but based on soundings farther north and east are probably not more than 50 metres. The trench comprising the major portion of Crozier Strait extends southward from the sill where it reaches a depth of 400 metres before it shoals again in McDougal Sound. The water continues to shoal into Barrow Strait where depths are generally between 100 and 200 metres. A cross-section from Milne Island to Barrow Strait is shown in Figure 4. In contrast to Crozier, Pullen Strait is shallow with maximum recorded depths near 75 metres. North of Pullen a limited number of soundings suggest water depth of less than 30 metres. Between Pullen Strait and McDougall Sound to the south water depths seldom exceed 100 metres until the trench associated with Crozier Strait is approached. To the south and east Crozier and Pullen Straits are separated from Baffin Bay to Barrow Strait with its sill depth near 140 metres. To the north Penny Strait, with its sill depth near 100 metres, separates Crozier and Pullen Straits from the various channels leading to the Arctic Ocean. Wellington Channel to the north and east provides a connection to the east end of Barrow Strait. This route contains a chain of islands and sills where water depths appear not to exceed 75 metres.

b) Current Meter Locations

A detailed chart of Byam and Austin Channels is given in Figure 5. The five current meter sites in each channel are labelled B1, A1 etc. A cross section of the two channels, given in Figure 6 shows the location of meters on the surface and sea floor at each site. Useful data were not recovered from all meters for a variety of reasons, thus the meters at B1 and B4 bottom and B3 top have been omitted from this figure. Similarly, a detailed chart and cross section of Crozier and Pullen Straits are presented in Figures 7 and 8 respectively. The cross section shows the position of the mid-depth current meters added for this study.

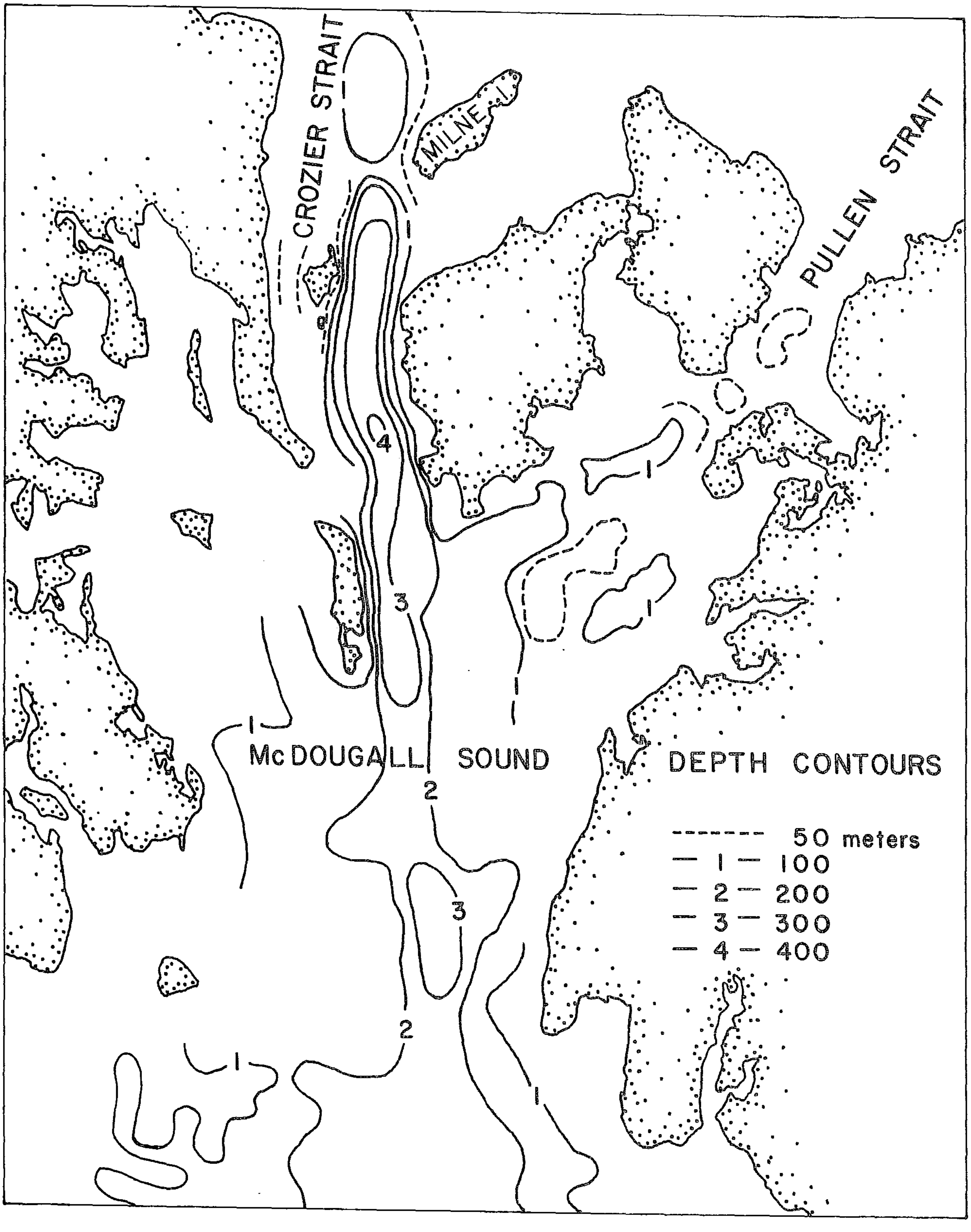


FIGURE 3. Bathymetry of Crozier and Pullen Straits.

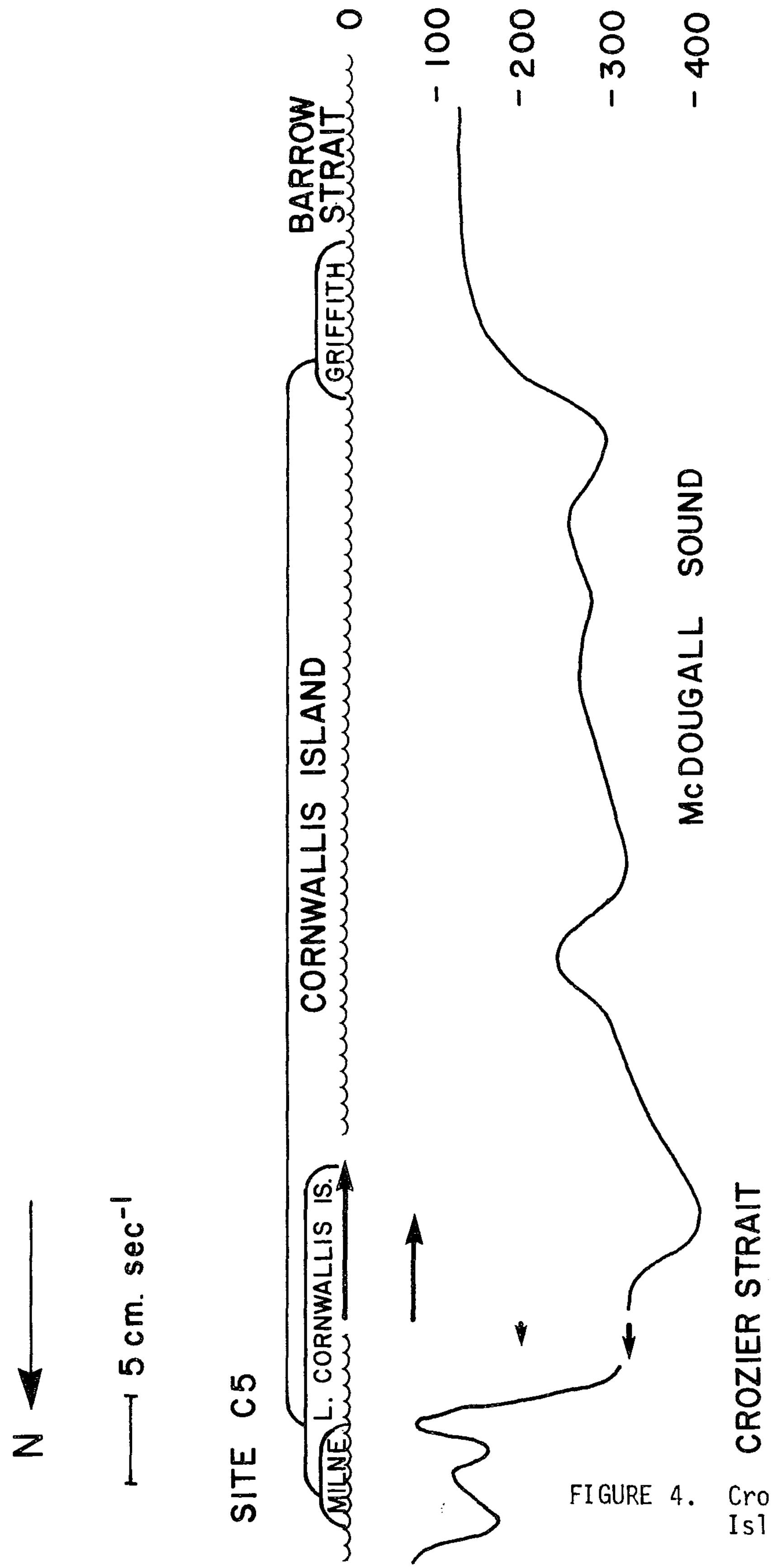


FIGURE 4. Cross-section, Milne Island to Barrow Strait.

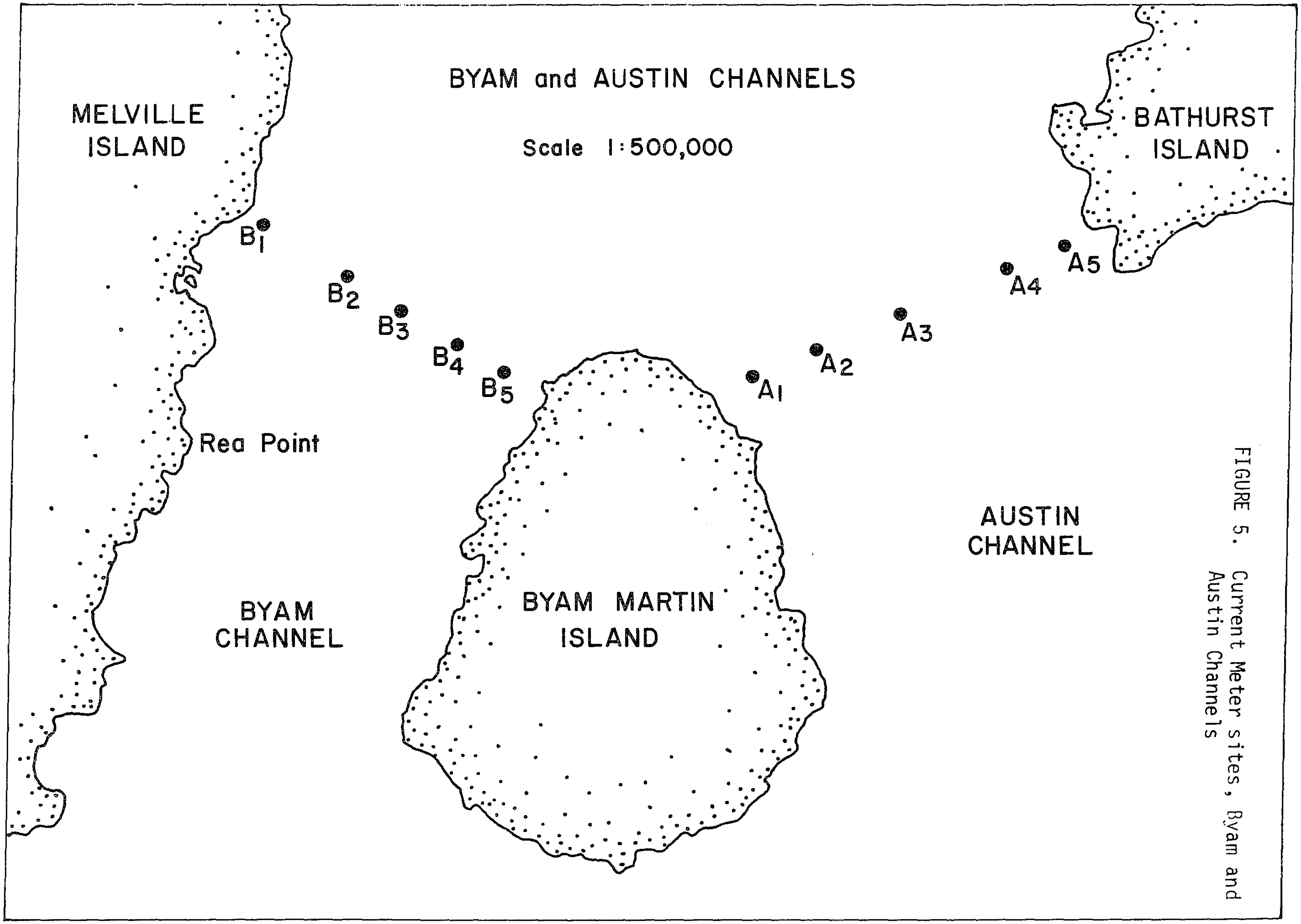


FIGURE 5. Current Meter sites, Byam and Austin Channels

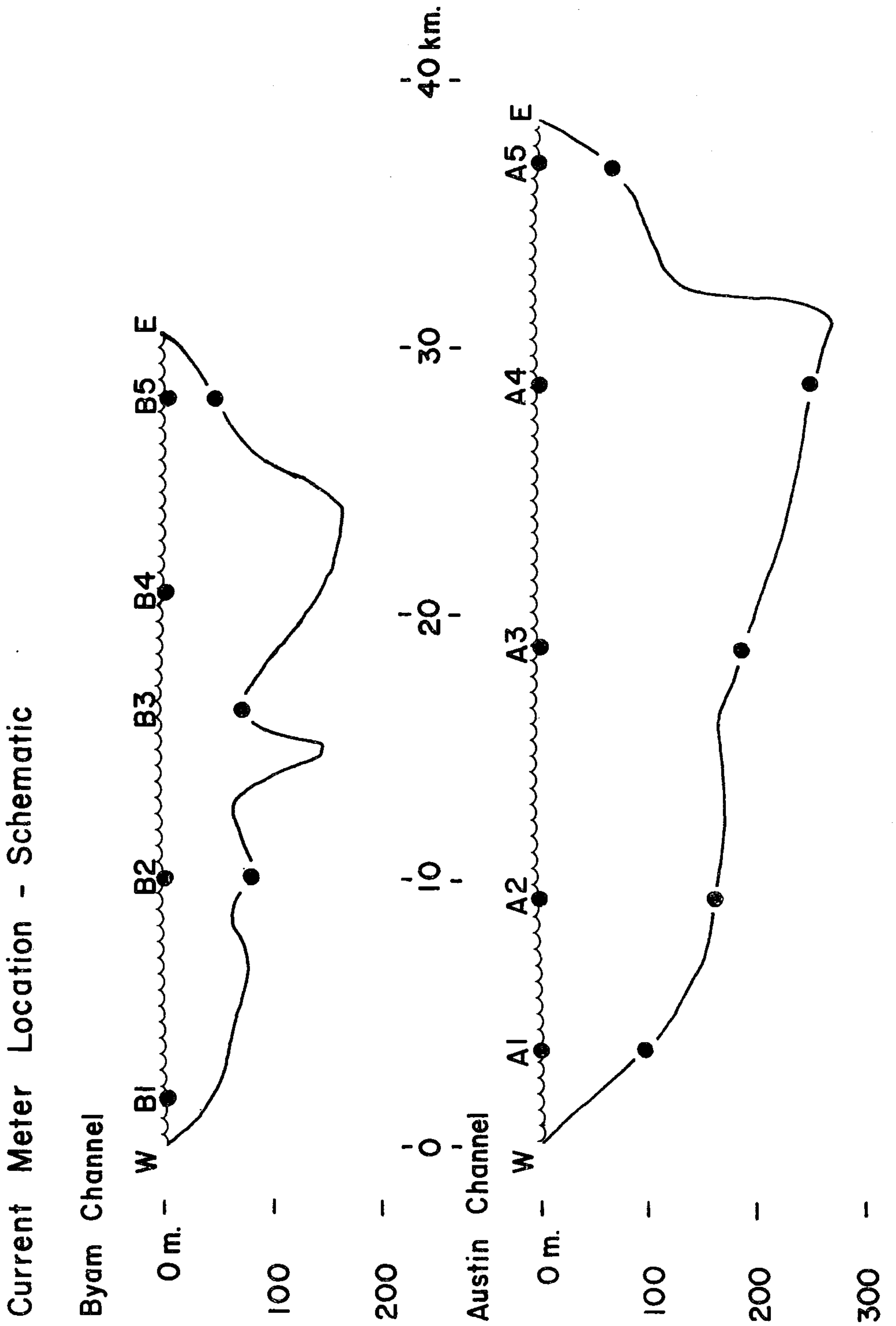


FIGURE 6. Current Meter distribution in Byam and Austin Channels.

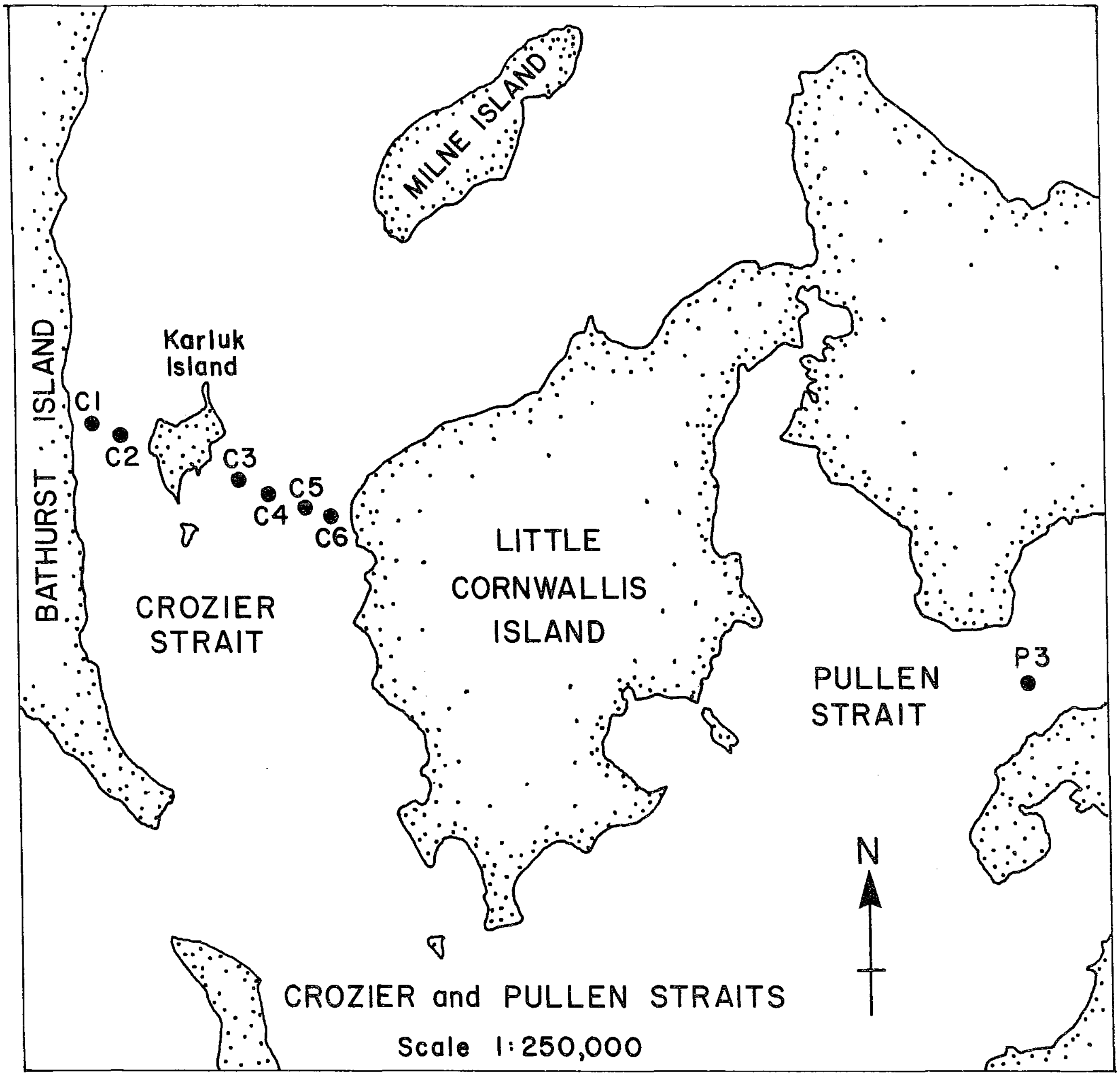


FIGURE 7. Current Meter sites, Crozier and Pullen Straits.

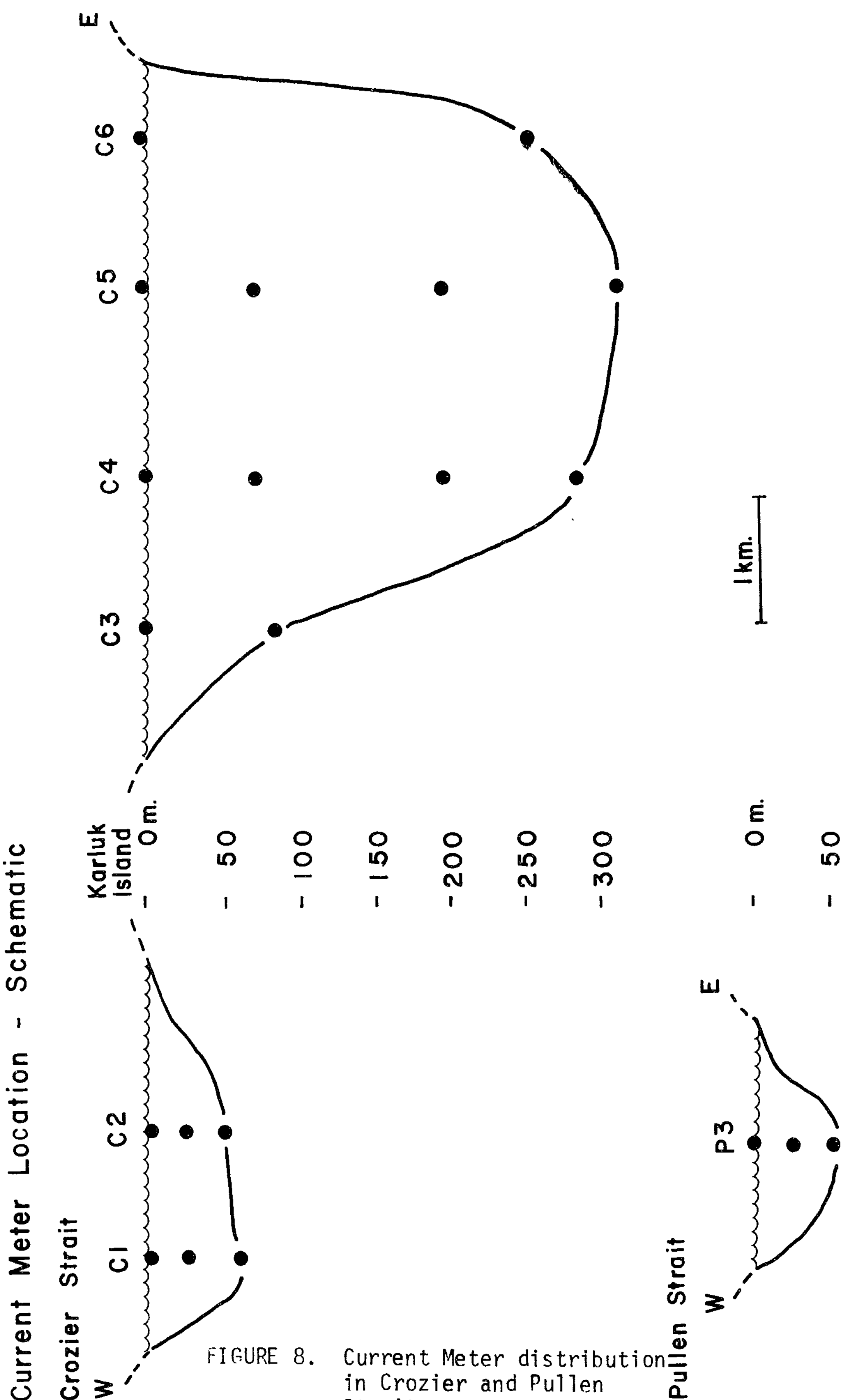


FIGURE 8. Current Meter distribution in Crozier and Pullen Straits.

The geographic location of each site was determined prior to installation of the current meters. The positions were later fixed with a Del Norte Range/Range system with slaves at two known geodetic survey markers. For each channel a different pair of geodetic markers was used. The master readout unit was carried in the tracked vehicles so that the distance to each slave could be determined while moving. The system was accurate to 5 metres and had a resolution of 1 metre. The current meters were deployed as close to the preselected position as ice conditions permitted and in each case the final location was noted.

c) <u>Instrumentation</u>

Current Meters

All recording current meters used were the same make and model: Aanderaa RC-4. Meters were modified in-house by replacing the large conventional 1 metre long vane by a smaller 10 cm long vane which, for mid-depth and bottom meters, was mounted below the pressure case with its axis of rotation coinciding with the axis of the pressure case. This modification permitted deployment of the meter through a 23 cm diameter hole drilled through the sea ice. For the sub-ice current meters the vane and rotor were separated from the pressure case containing the control and recording electronics. As an option, the meters could be equipped with sensors to measure temperature, conductivity and pressure in addition to current speed and direction. The performance specification for the meter is given in Table 1.

Three different systems were used to mount the meters just below the sea ice, at mid-depths and on the sea floor respectively. These are shown diagramatically in Figure 9. For the sub-ice meters the rotor and vane were suspended from the sea ice with sufficient clearance between the bottom of the ice and the top of the rotor to allow for ice growth. This system measured current speed 15 to 20 cm below the ice bottom with current direction measured 15 cm deeper. The sensors were hard-wired to the Aanderaa data logger located below the ice a few metres away. This configuration is depicted in Figure 9 (a).

Mid-depth current meters were located in Crozier and Pullen Straits at 25, 75 and 200 metres depths depending on location with some sites lacking meters at mid-depth. Two lines of 3 mm diameter space lay were suspended from the land-fast sea ice from points 30 metres apart. These lines were brought together at the prescribed depth with the current meter at the point of the "V". The meter itself was hung from the centre of a 3.7 metre long boom with 11.4 kg weights at each end. The suspension lines were attached to the ends of the boom. This configuration (see Figure 9 (b)) provided excellent resistance to rotation. The current drag on the meter and suspension lines caused the meter to swing and rise to some small degree during the periods of stronger current flow. This motion was sensed by the pressure transducer included in the two 200 metre mid-depth meters. Any swinging motion appears to have a period of a few hours so that the resulting error in current speed is considered negligible. A test was conducted to determine if the suspension system would undergo high frequency modes of oscillation which would be recorded as erroneous (higher) current speeds. For this test a recording current meter was temporarily left suspended at a 200 metre depth for 72 hours with a scan rate of once every 30 seconds. No high frequency oscillations were detected.

TABLE 1.

Performance of Aanderaa RC-4 Current Meter

	Accuracy	Resolution (least count)		
Current speed	± 0.8	0.2/0.5	cm sec^{-1}	note 1,2
Current Direction (top)	± 5	0.5	degrees	note 3
Current Direction (mid)	± 5	0.5	degrees	note 3
Current Direction (bottom)	± 7	0.5	degrees	note 3
Temperature	± 0.1	0.03	°C.	
Conductivity	± 0.1	0.07	mmho cm^{-1}	
Pressure	± 7.0	0.7	decibars	
Salinity	± 0.15		‰	
Time Drift (Aanderaa)	± 2		sec day^{-1}	
(Sea Data)	± 2		sec day^{-1}	

Note 1. Accuracy as quoted in Models RC, -4 and RC, -5 Aanderaa Recording Current Meters. National Oceanographic Instrumentation Center Instrument Fact Sheet IRS-75002. U.S.A. Dept. of Commerce, Washington D.C., July 1974.

2. The value of resolution depends on the particular meter used.

3. Estimates of accuracy are subjective. The larger value for the bottom current meter reflects the use of the gyro.

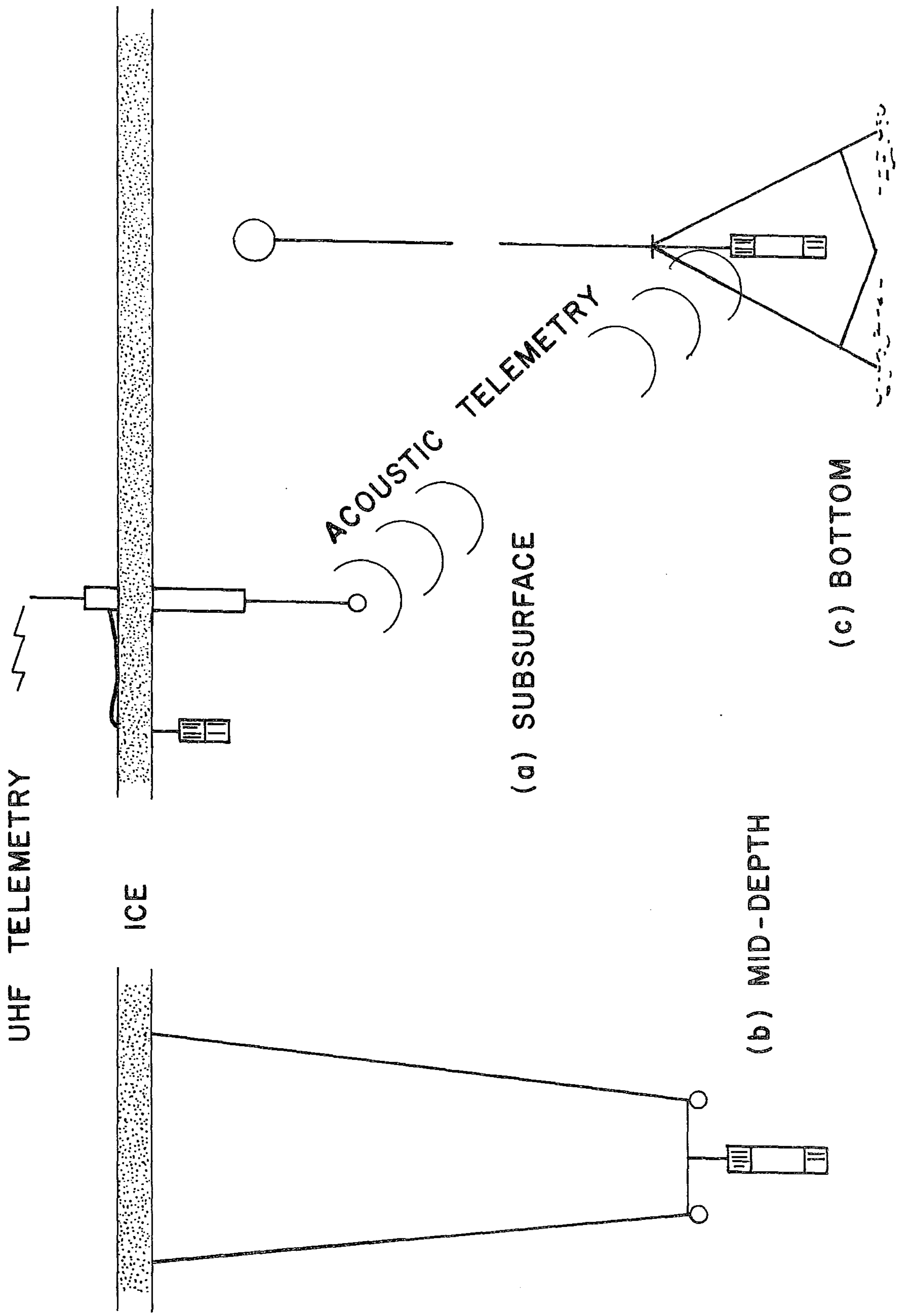


FIGURE 9. Mounting configurations.

As both the sub-ice and mid-depth meters were attached to land fast sea ice their azimuth was constant throughout the period of data recording.

Bottom current meters were suspended from the apex of a pyramid-shaped frame formed by four aluminum poles as depicted in Figure 9 (c). The azimuth of bottom meters was determined by measuring the fixed current meter orientation immediately after installation by releasing a gyro which was returned to the surface. A rotor measured the current speed 2 metres above the sea floor. The current direction was measured by a vane located 60 cm below the rotor.

The data sensed at the bottom current meters were transmitted hourly as a train of acoustic pulses which was received by a hydrophone installed with the subsurface current meter equipment package. These data, as well as hourly information collected by the sub-ice meter were relayed by an UHF radio transmitter to a receiver located on shore where data were recorded on a cassette magnetic tape, a part of a Sea Data model 610 system. The current meters simultaneously recorded data internally on magnetic tape. This redundancy in data recording provided an insurance against the high probability of losing a meter along with its internally recorded data. The internally recorded data however, were of higher quality than the telemetered data and so were used for analysis whenever possible. The mid-depth meters in Crozier and Pullen Straits used no data telemetry.

Tide Gauge

An 84 day tide record was obtained in Crozier Channel using an Aanderaa model WLR-4 water level recorder.

d) Data Record

The recording current meter mountings were designed to deploy the current meters through the sea ice using specially designed tracked vehicles. In general the meters were installed in early spring when ice thickness and visibility were adequate for operations. The sub-ice and mid-depth meters which were suspended from the sea ice were recovered before ice breakup in late June or early July. The bottom meters were designed to operate in place for one year although 5 of the 7 bottom meters in Crozier and Pullen Straits were recovered during the open water period of the same year in which they were installed. A bar graph showing duration of installation for each meter is shown in Figure 10.

The current data are best sumarized by histograms of current speed, current direction and number of occurences. Histograms were constructed for each of the current records and are reproduced in Appendix A. In these histograms the third dimension (number of occurences) is shown by a number occupying the appropriate position in the speed and direction grid. The speed columns span 3 cm s^{-1}, e.g. from 12.0 to 14.9 cm s^{-1}. The column at the right is the number of occurrences in each 10° direction band while the row at the bottom is the number of occurrences in each speed range.

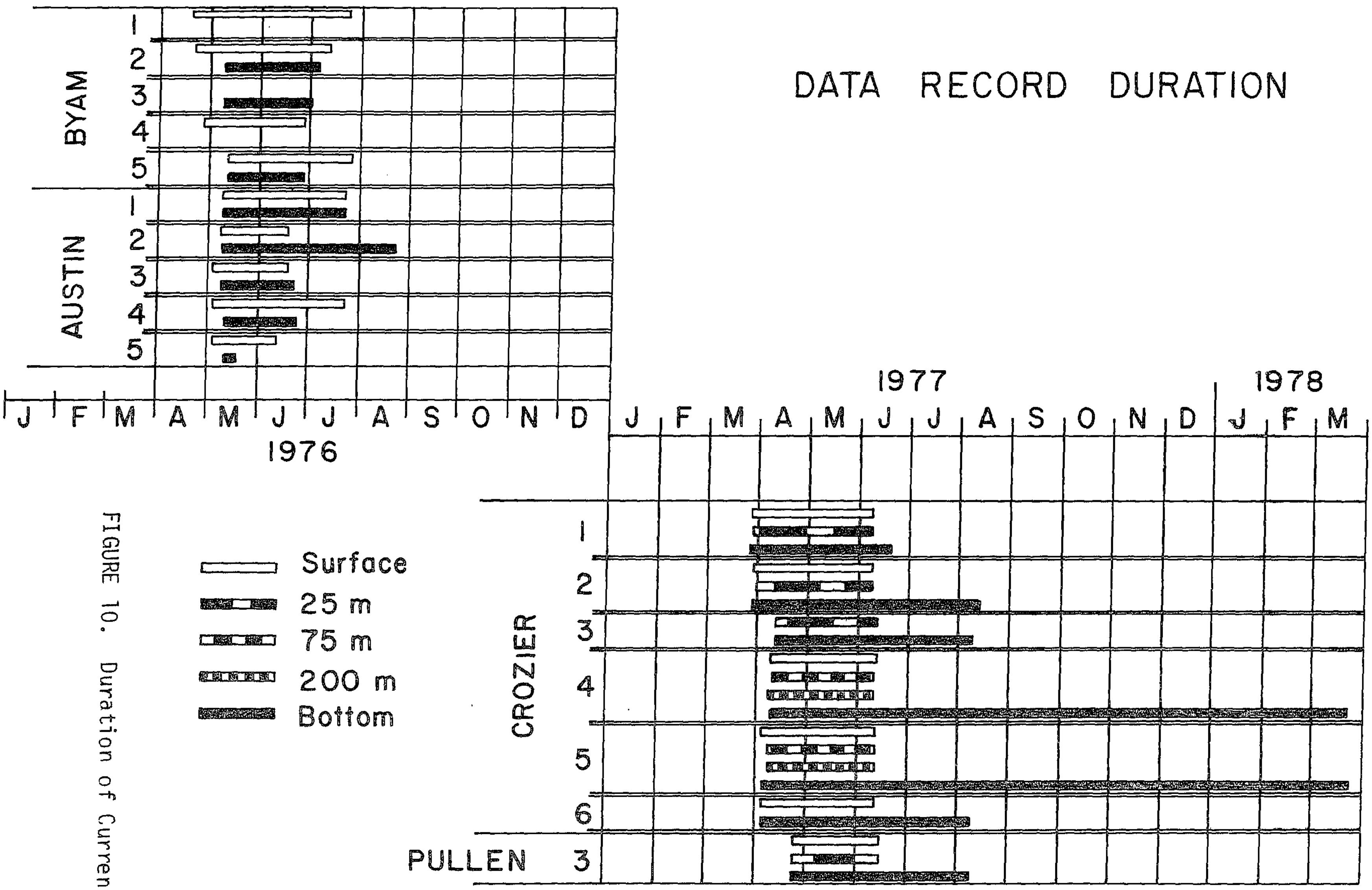


FIGURE 10. Duration of Current Records.

All the histograms exhibit a bimodal distribution in direction, generally oriented up and down channel. Such a distribution demonstrates frequent and consistent current reversals implying that the currents are dominated by tidal oscillations. Current speeds in Byam and Austin Channel are generally less than about 30 cm s^{-1} and in Crozier and Pullen Straits less than about 40 cm s^{-1}. Events where the hourly average currents substantially exceed these values occur in the data from Byam 2T where speeds up to 75 cm s^{-1} were recorded and Pullen 3B where one 50 cm s^{-1} event was registered.

Auto-spectra of the along-channel and cross-channel velocity components were computed to ascertain the distribution of kinetic energy with frequency. These spectra confirmed our initial speculations that the current records were dominated by tidal oscillations primarily along the channel axes since the along-channel spectra are more energetic in the tidal bands than the cross-channel spectra. Figure 11 is the auto spectrum from current meter C5 (75m depth). The axes are both linearly scaled to aid in recognition of the distribution of kinetic energy which is simply the area under the curve. All the resolvable oscillations are contained in the frequencies less than 6 cycles per day. Above this frequency the least count noise due to the finite digitization in speed inherent in the current meter, exceeds the signal:

$$\text{least count noise} = \left(\frac{PREC}{2}\right)^2 \frac{1}{\Delta f}$$

Here PREC is the precision of the speed values and Δf is the frequency step over which the spectral estimates are averaged. For these spectra we used Δf of 0.343 cpd and the precision of the Aanderaa Curent meter is $\pm$ 0.5 cm s^{-1} so that least count noise

$$= \left(\frac{0.5 \text{ cm s}^{-1}}{2}\right)^2 \frac{1}{.343 \text{ cpd}}$$

$$= 1.9 \times 10^{-1} (\text{cm s}^{-1})^2 \text{ d}$$

We shall therefore, in the following sections, limit our discussion to the characteristic of the mean flow, long period and tidal oscillations.

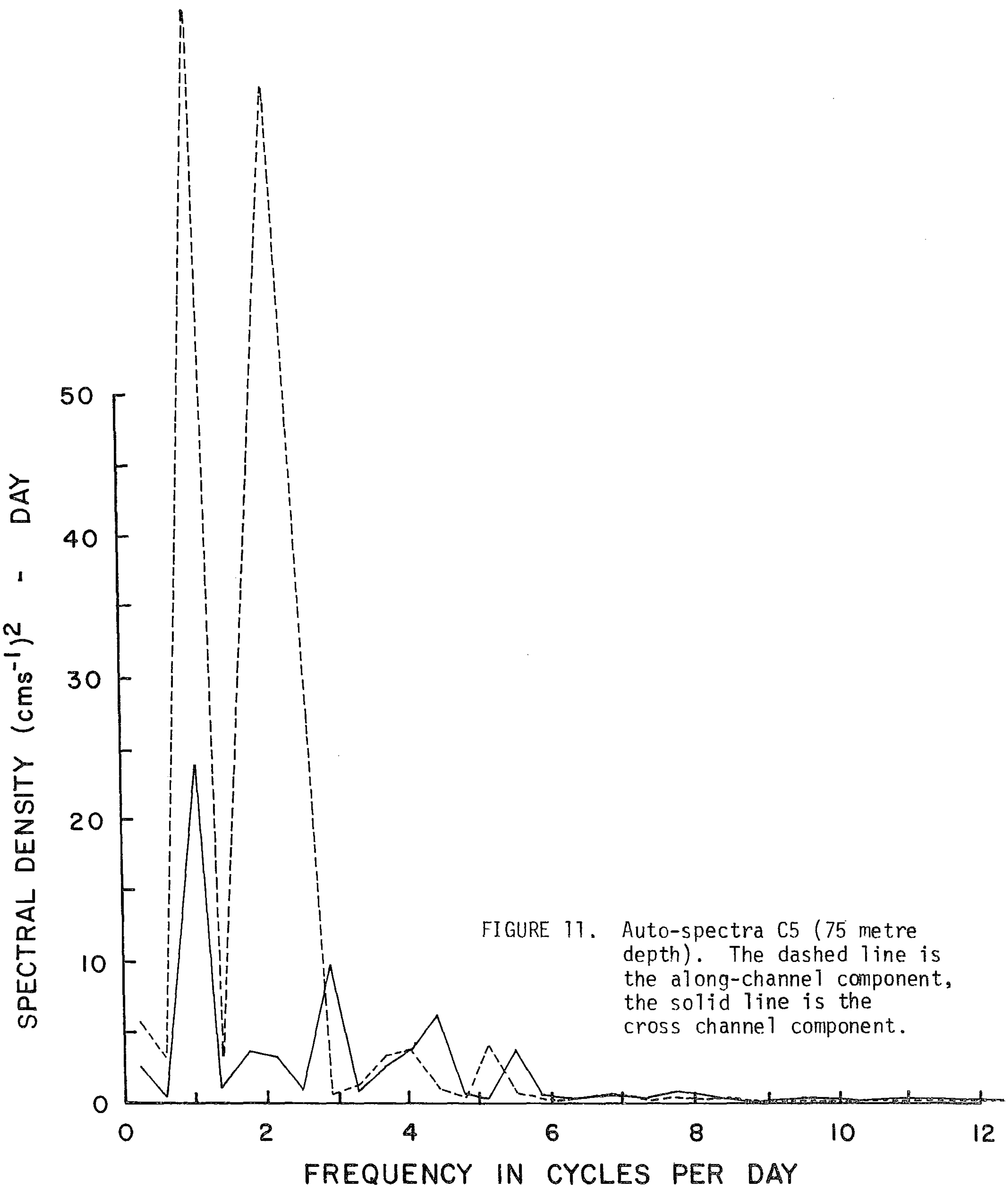


FIGURE 11. Auto-spectra C5 (75 metre depth). The dashed line is the along-channel component, the solid line is the cross channel component.

2. MEAN FLOW

The vector mean velocities at each current meter were determined over the entire length of each record. For most of the current records this constitutes an average value during the 3 or 4 months of late spring and early summer. We comment on the results of such averages while attaching no "annual mean" significance to them.

In Byam and Austin Channels the current meters were either suspended with the rotors 0.15 metres below the ice or 2 metres above the bottom. The current meters, at surface and bottom locations, due to their proximities to the boundaries, do not supply data which are necessarily representative of the free stream flow. We feel that great caution must be observed in trying to interpret these current records, nevertheless we proceed to do so after a brief discussion of some of the pitfalls.

a) The nature of current measurements made within the boundary layer

In a turbulent rotating ocean the boundary layer is composed of two parts. The inner boundary layer is the logarithmic or constant flux layer where the familar law of the wall applies:

$$u = \frac{u_*}{k} \ln \frac{z}{z_o} \qquad 2.1$$

where u is the fluid velocity, u_* is the friction velocity, k is Von Karman's constant, z is the distance from the boundary and z_o represents a roughness length. u_* is representative of the stress at the boundary and is equal to $\sqrt{\tau/\rho}$ where τ is the boundary stress.

The outer boundary layer or Ekman layer is thought to begin at a distance of $fz/u_* = 0.03$ in the atmosphere (Tennekes, 1973) where f is the Coriolis parameter. This corresponds to a distance of about 2 m from the boundary in the ocean. At this distance some sort of planetary boundary layer dynamics hold which include the effect of the earth's rotation.

In Ekman's original solution, the velocity at the boundary is zero and asymptotically approaches the free stream or geostrophic velocity away from the boundary. The velocity in the boundary decreases with proximity to the boundary so that the Coriolis force decreases. This causes a modification of the flow direction from perpendicular to the pressure gradient (geostrophic balance) to more nearly down the pressure gradient. The equations used to arrive at this solution are

$$-fv = A_z \frac{\partial^2 u}{\partial z^2} \qquad 2.2$$

$$fu = A_z \frac{\partial^2 v}{\partial z^2} - \frac{1}{\rho} \frac{\partial p}{\partial y} \qquad 2.3$$

where u is the eastward (x) and v is the northward (y) component of velocity and A_z is the eddy viscosity.

If the fluid outside the boundary layer is in geostrophic equilibrium then $f\,u_g = \frac{-1}{\rho}\frac{\partial P}{\partial y}$ and the solution for the velocity in the boundary layer can be written

$$u = u_g \; (1 - e^{-az} \cos az) \qquad 2.4$$

$$v = u_g \; e^{-az} \sin az \qquad 2.5$$

where $a = \sqrt{f/2A_z}$ and u_g is the easterly flowing geostrophic velocity.

A hydograph of the velocity vectors within the Ekman boundary layer is shown in Figure 12. The velocity vector veers to the left as well as decreasing in magnitude with decreasing distance from the boundary. At the boundary, or the inner limit of the Ekman layer, the angle of veering is 45° to the left of the geostrophic flow. The horizontal mass transport over the depth of the Ekman layer has a component perpendicular to the geostrophic flow.

This lateral transport must be compensated by a return flow in a laterally bounded ocean. In the case of wind driven ocean currents, the lateral (or cross isobar) transport in the atmosphere-ocean Ekman layer is compensated by an opposite transport in the bottom boundary layer. However, in a sea covered with land-fast ice, the Ekman veering is in the same (down pressure gradient) direction in both the surface and bottom Ekman layers, necessitating a return flow at some intermediate depth. The presence of the ice cover, therefore, changes the usual single vortex secondary circulation to a twin vortex secondary circulation with the vortex axes directed along the channel.

Since the surface and bottom current meters were positioned either within the inner boundary layer or in the inner reaches of the planetary boundary layer, we expect them to sense the full effect of the Ekman veering. The mean current vector should be oriented 45° to the left of the channel axis or equivalently with the direction of the mean flow away from the boundaries. The mean current vectors are shown in Figures 13 and 14. The Byam-Austin vectors can only be compared with the orientation of the channels as measured from charts, see Figure 2. However, the mean vectors from Crozier and Pullen Straits exhibit no consistent change in direction between mid-depths (200 and 75 m) and the surface and bottom. In no case can the near-boundary mean vectors be thought of as displaying a 45° rotation to the left of the mean flow.

Although there is some ambiguity due to an estuarine-like flow, in general the current vectors from Crozier and Pullen Straits show only a very slight decrease in magnitude between mid depth and the surface and bottom meters. This is especially clear at Crozier 1 and Crozier 5 where no apparent variation in the magnitude of the mean vector is measured between surface and mid depth.

The dynamics of the boundary layers in these channels clearly do not correspond to the classical Ekman formulation. Since the current measurements from Byam and Austin Channels have all been made within the boundary layers we seek further for applicable models, the use of which might permit extrapolation of current measurements to the "free stream".

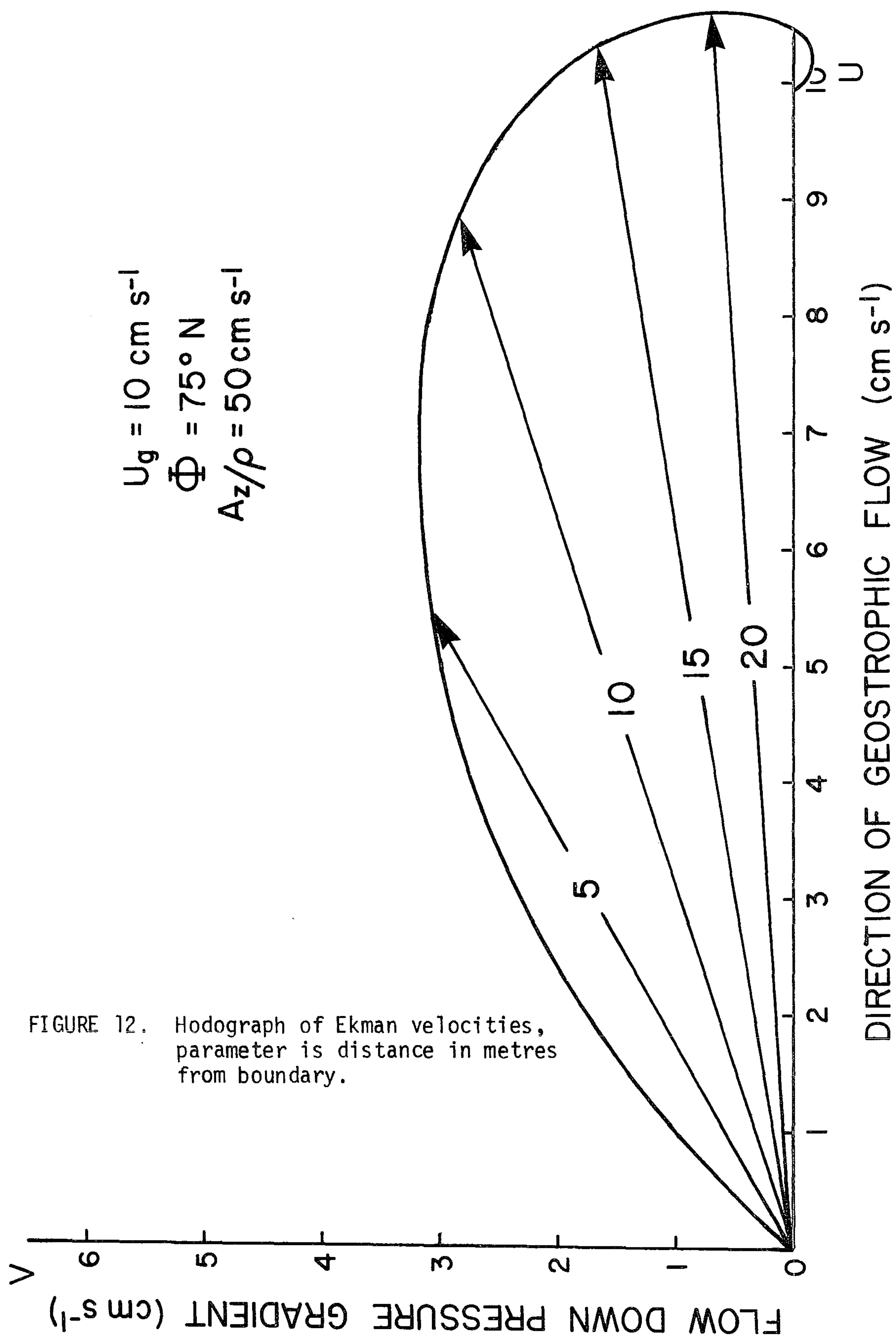


FIGURE 12. Hodograph of Ekman velocities, parameter is distance in metres from boundary.

The Ekman formulation is based on several assumptions: steady flow, fully developed boundary layer justifying the neglect of the non-linear accelerations, a constant eddy viscosity and a homogeneous or gravitationally neutrally stable fluid. Recently, several authors have examined planetary boundary layers including one or more of the effects which Ekman neglected. Madsen (1977) used linear equations of motion but introduced an eddy viscosity which increased linearly with distance from the boundary. In his steady state solution he found a turning angle of about 10° and a much larger velocity shear than predicted by the constant eddy viscosity formulation. We can interpret Madsen's results (which were developed for the wind driven planetary boundary layer) to imply that the current magnitude is roughly 2/3 that of the free stream flow at a distance of about 0.01 ku_*/f from the boundary. Typical values of u_* are in the neighbourhood of 0.5 to 1.0 cms $^{-1}$ so that the distance at which 2/3 of the free stream speed is achieved at 75° N. is roughly 13 to 28 cm from the boundary.

A second possible explanation for the absence of the Ekman layer beneath the ice lies in the contribution of buoyancy or convective effects to the turbulent kinetic energy of the boundary layer. Convection in the ice-water boundary layer is driven by the rejection of salt from growing sea ice. The convectively driven vertical motions work, in effect, to enhance the viscosity by augmenting momentum exchange between the sea and the ice. Deardorff (1972) has shown that the region over which the buoyancy dominates the mean shear contribution to the turbulent kinetic energy can be expressed in terms of the Obukhov length, L.

$$L = \frac{\rho_o \; u_*^3}{gk \; \langle\rho' w'\rangle} \qquad 2.6$$

where ρ_o = mean water density in the boundary layer

u_* = friction velocity

g = acceleration of gravity

k = Von Karman's constant

ρ' = fluctuations in fluid density

w' = fluctuations in vertical velocity

and $\langle\rho' w'\rangle$ = vertical density flux.

The dynamics of a neutrally stable Ekman layer were shown to be inapplicable for values of $Z_i/L < -1.5$ where Z_i is the depth of the pycnocline. McPhee and Smith (1975) have shown that the vertical density flux due to ice growth can be expressed as

$$\langle \rho' \; w' \rangle_{surface} = \rho_{ice} \; (\Delta S) \; d/10^3 \qquad 2.7$$

where ρ_{ice} is the ice density, ΔS is the salinity difference in °/₀₀ between the ice and the water and d is the growth rate expressed in cm s^{-1}. The ice growth rate may, in turn, be estimated using the heat flow equation

$$\frac{dq}{dt} = \rho_i \, C_p \, k \, \frac{dT}{dZ} \qquad 2.8$$

where $\rho_i \, C_p \, k$ = the thermal conductivity

$\frac{dq}{dt}$ = the heat flux

$\frac{dT}{dZ}$ = the temperature gradient within the sea ice

The ice growth rate is then

$$d = \frac{C_p k}{L_a} \frac{\Delta T}{\Delta Z} \qquad 2.9$$

where L_a is the latent heat of fusion of sea ice. A rough calculation for a 1 m thick ice sheet and a 20°C temperature difference yields an ice growth rate of about 1.2×10^{-5} cm s^{-1}.

Finally, the ratio Z_i/L may be expressed in terms of the depth of the pycnocline and the friction velocity by using 2.6, 2.7 and 2.9,

$$Z_i/L = \left(\frac{Z_i}{u_*^3}\right) \quad (1.12 \times 10^{-4} \text{ cm}^2 \text{ s}^{-3}). \qquad 2.10$$

For a pycnocline depth of 30 metres and a friction velocity of 0.5 cm s^{-1}

$$Z_i/L = -2.7 \quad < -1.5$$

Deardorff showed that the lateral component of velocity in a convective planetary boundary layer is an order of magnitude smaller at $Z_i/L = -4.5$ than in the neutral case. In addition, the shear is confined to the region within 1/10 of the pycnocline depth from the boundary rather than 1/2 the pycnocline depth as in the neutrally stable case. Convection due to sea ice growth therefore may also, potentially, minimize the boundary effects under the ice.

In summary, we are quite simply too ignorant of the dynamics which apply in the surface and bottom boundary layers to attempt any sort of extrapolation to the free stream. We therefore report all current measurements, volume transports and tidal streams from these meters without modification; we assume that the boundary layer is infinitesmal, keeping in mind that this will tend to lower our transport estimates and have an adverse effect on the computation of internal tide modes.

b) Mean Vectors

The data from the bottom current meters in Byam and Austin Channels were telemetered by an acoustic link to a surface unit and then transmitted to a shore based receiving station. The completeness of the record suffered, especially in the acoustic transmission, so that data recovery from this system ranged between 97% and about 50%. We have assumed that the gaps in the records are more or less random and have computed mean flows from these incomplete records. All the other current data were recovered from the internally recording Aanderaa current meters.

Although the current records are dominated by tidal oscillations, by averaging over many tidal cycles, the mean flow can be ascertained. The mean current vectors for the full lengths of the records were computed and are displayed in Figures 13 and 14. The channel cross sections are through the current meter moorings which lie in a straight line, and the tail of each vector is located at the position where the measurement was made. With the notable exception of Crozier West, the transverse or cross-channel variation in the direction of mean currents is slight. What are probably effects of very shallow water are noticeable at the edges of Byam Channel where the currents are directed across the channel.

In both Byam and Austin Channels, the surface currents appear to be more nearly oriented along the channel axis (as indicated by the double-headed orientation arrow) than the bottom currents. The Crozier Strait West vectors imply a relatively strong southward flow on the western side and a weak northeast flow on the eastern side. There is very little vertical shear noticeable. Crozier Strait East exhibits a pronounced vertical shear in the water column with currents below about 150 m flowing northward. The one mooring in Pullen Strait showed flow at nearly right angles to the channel axis which implied there is very little net mass flux through this strait.

The most revealing current records are those from Crozier Strait East. Here the general southward flow through the Arctic Archipelago is reflected in the surface currents while the weaker northward currents nearer the bottom likely constitute a return flow of estuarine nature. This circulation is probably caused by an effective sill depth of between 100 and 150 metres. Figure 4 is a north-south section through McDougall Sound and Crozier Strait. The north-south components of the current vectors from site C5 are drawn and illustrate how the bottom topography to the north of Crozier Strait limits the southward flow. We do not have enough hydrographic data to address the possibility that the northward near-bottom flow is a return flow driven by entrainment of deeper water into the southward flowing upper layer. In any case the effective sill depth between Cornwallis and Bathurst Islands appears to be about 150 metres.

The vertical shear present in the Crozier East currents were compared with the geostrophic shear due to baroclinicity or the slope of the isopycnal surfaces. It is the geostrophic shear integrated from a "level of no motion" which is the classical method of measuring ocean currents. The first equation of motion assuming steady flow, insignificant non-linear accelerations and frictionless flow is

$$fv = \frac{1}{\rho}\frac{\partial p}{\partial x} \qquad 2.11$$

where f is the coriolis parameter, V is the northward velocity component, ρ is the mean density, and $\partial p/\partial x$ is the west to east pressure gradient. If

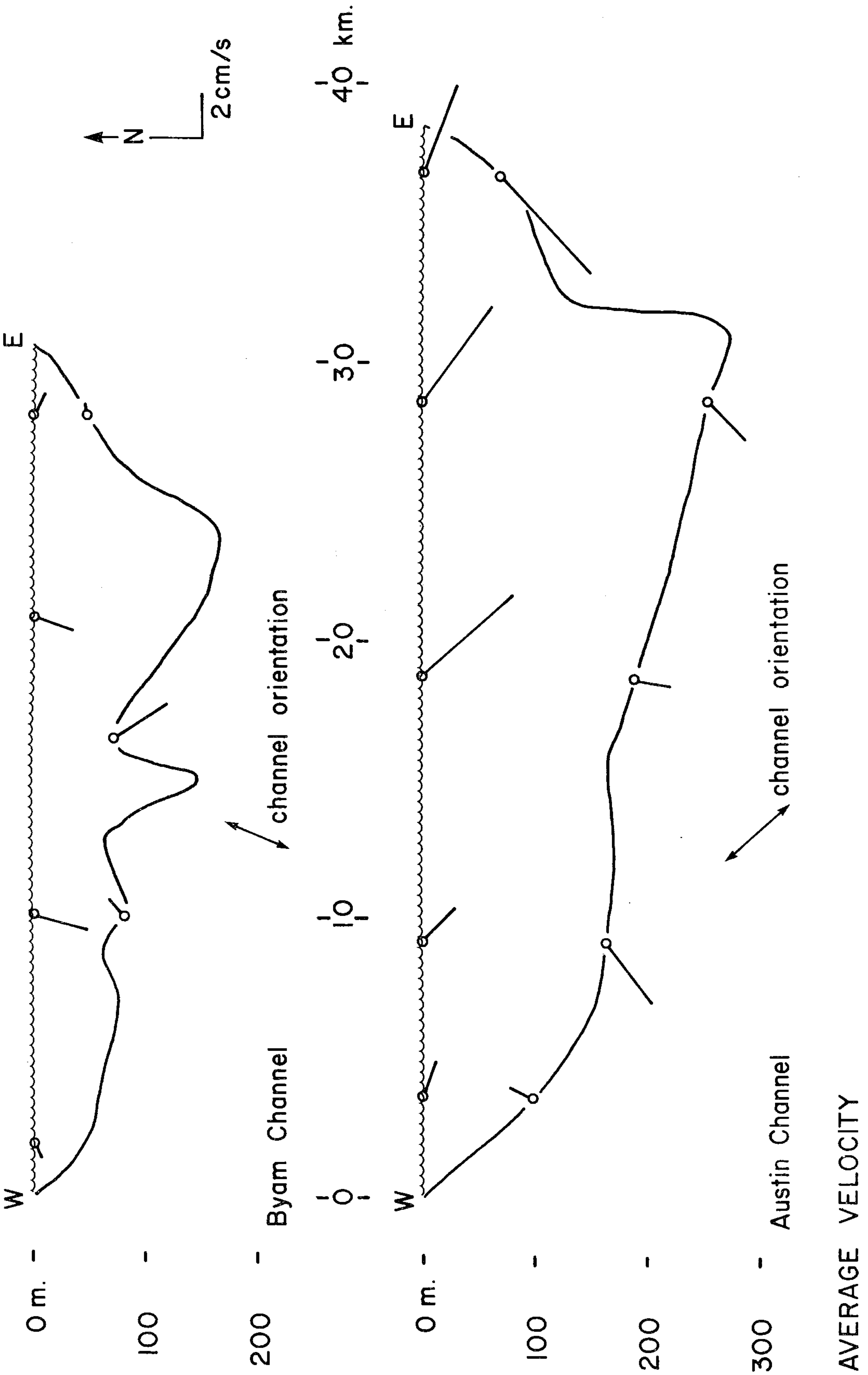


FIGURE 13. Mean Vectors, Byam and Austin Channels.

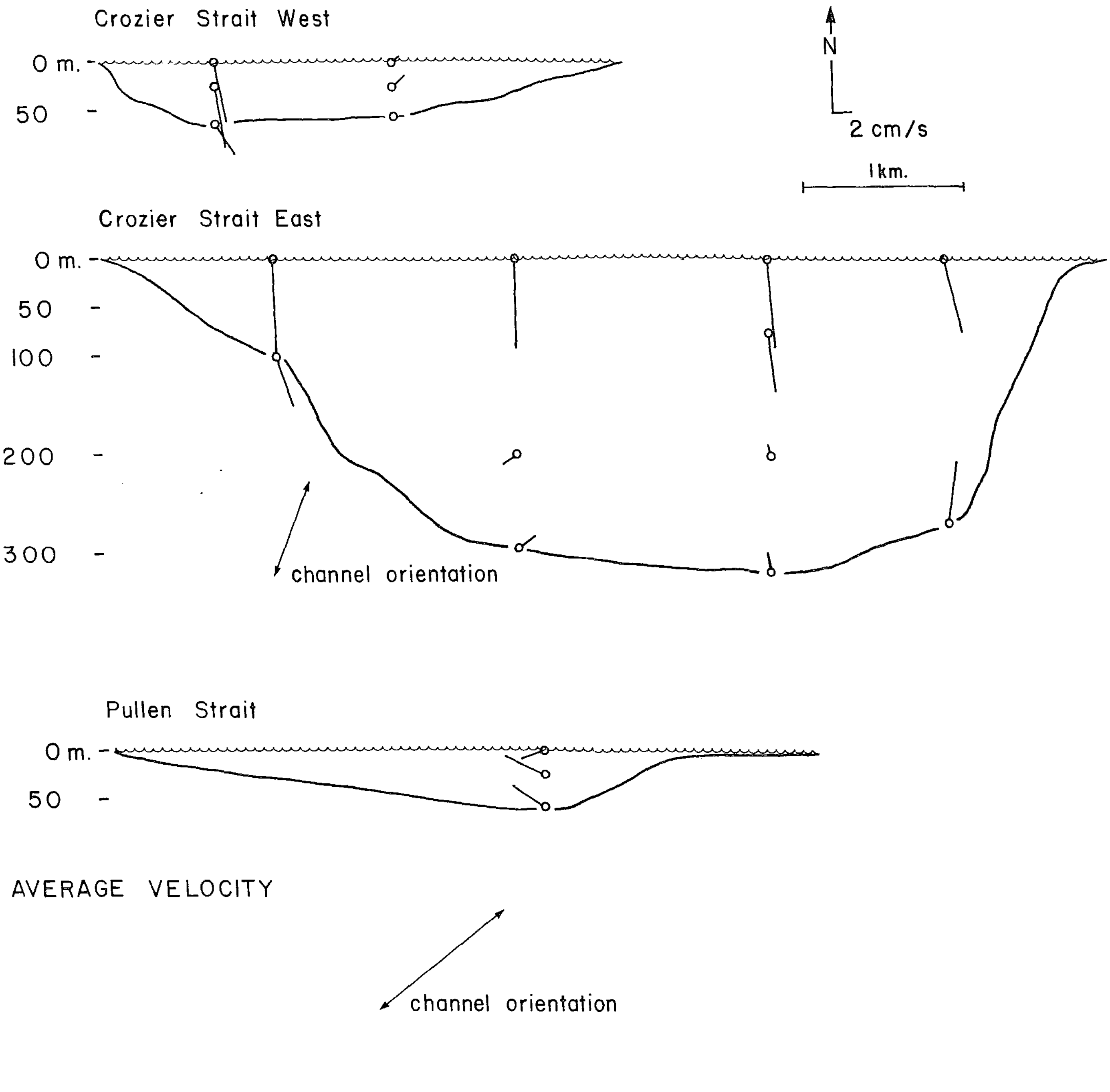


FIGURE 14. Mean Vectors, Crozier and Pullen Straits.

2.11 is differentiated with respect to z,

$$f\rho \frac{\partial v}{\partial z} + fv \frac{\partial \rho}{\partial z} = \frac{\partial^2 p}{\partial x \partial z} \qquad 2.12$$

The hydrostatic or 3rd equation of motion is

$$\frac{\partial p}{\partial z} = -\rho g \qquad 2.13$$

where z is vertically up and g is the acceleration of gravity which when inserted in 2.12 yields

$$f\rho \frac{\partial v}{\partial z} + fv \frac{\partial \rho}{\partial z} = -g \frac{\partial \rho}{\partial x} \qquad 2.14$$

which is the first thermal wind equation.

The second term in 2.14 is two to three orders of magnitude smaller than the first which can be demonstrated by inserting typical values:

$$f\rho \frac{\partial v}{\partial z} \Big/ fv \frac{\partial \rho}{\partial z} = \frac{\frac{1}{v}\frac{\partial v}{\partial z}}{\frac{1}{\rho}\frac{\partial \rho}{\partial z}} \simeq \frac{\Delta v/v}{\Delta \rho/\rho}$$

A 50% to 100% change in velocity is usually present over the depth of the water column while the change in density is usually less than 1%. Neglect of the second term in 2.14 is, therefore justified, so that

$$\frac{\partial v}{\partial z} = -\frac{g}{\rho f}\frac{\partial \rho}{\partial x} \qquad 2.15$$

2.15 defines the geostrophic shear in terms of the cross-stream gradient of density. Comparison of the shear computed from CTD measurements across Crozier Strait with the measured mean shear showed that the mass field could account for only a few percent of the measured shear. This is due to the very weak vertical stratification caused by strong tidal currents. Weaker stratification necessitates more strongly sloping isopycnals to provide a given geostrophic shear. However the slope of the isopycnals is limited by a criterion of baroclinic stability so that the maximum geostrophic shear which will be computed is proportional to the vertical stratification. The classical geostrophic measurements are, therefore, of little use in this region of very weak stratification.

c) Transports

The components of the mean vectors parallel to the channel axes were computed in order to construct mean isotach cross sections for the computation of mean transports for the period April - June (shown in figures 15 and 16). The isotachs were constructed by linearly interpolating between

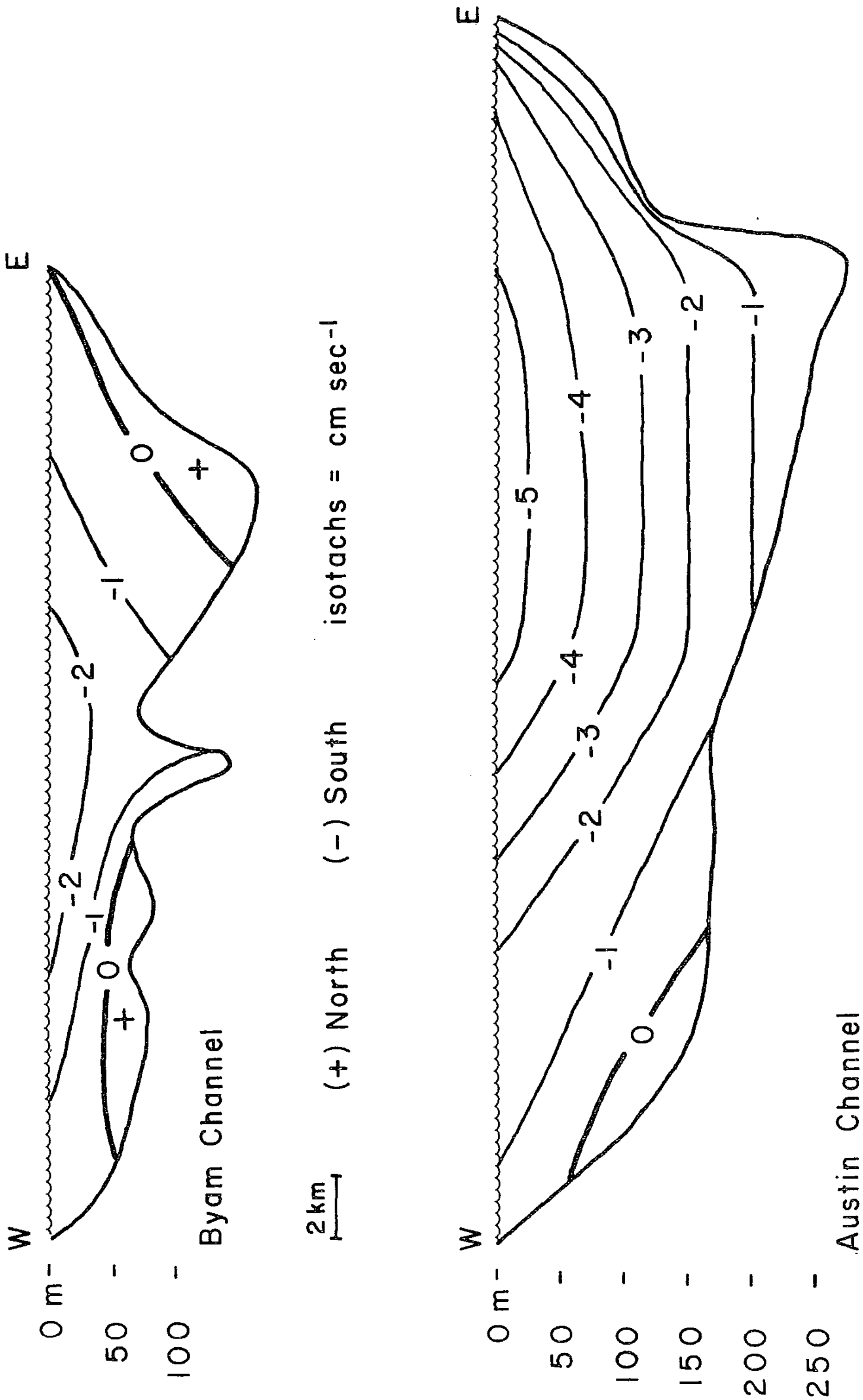


FIGURE 15. Isotachs, Byam and Austin Channels.

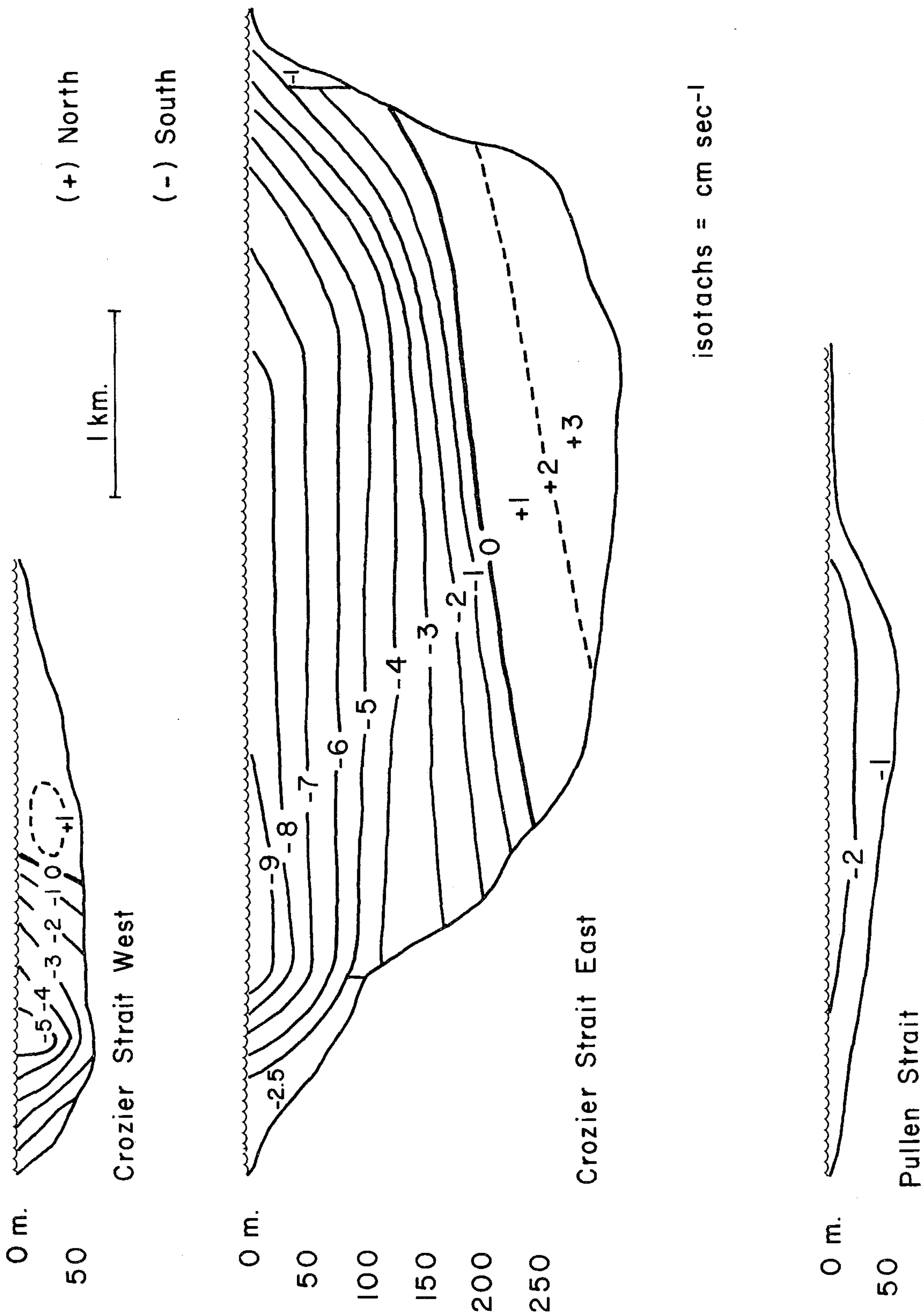


FIGURE 16. Isotachs, Crozier and Pullen Straits.

the current meter locations and the transports were computed by measuring the areas within the speed ranges. With the exception of Pullen Strait where the mean flow was directed nearly perpendicular to the channel axis, each of the channels is dominated by southward flow while areas of mean northward flow are never completely absent. Both channels in Crozier Strait have the southward flow concentrated toward the western shore as one would expect on a rotating earth. The Byam and Austin Channel records do not indicate such an effect, but the lack of completeness of these latter data must be borne in mind.

The transports estimated for the 5 channels are listed in Table 2. The estimates are based on the entire length of the current records which are usually about 2 or 3 months long. There are two current records which span nearly one year's operation: C4B and C5B. From these records (cf Figure 29) we can see that the flow in Crozier Strait is more energetic during the winter. We might, therefore, be justified in augmenting the transport estimates of Table 2, but we chose to limit our computation to the sampling time over which we have full coverage.

TABLE 2

VOLUME TRANSPORTS

Byam Channel	-1.95	$x10^4$	m^3s^{-1}
Austin Channel	-14.03	$x10^4$	m^3s^{-1}
Crozier Strait West	-0.20	$x10^4$	m^3s^{-1}
Crozier Strait East	-4.23	$x10^4$	m^3s^{-1}
Pullen Strait	-0.19	$x10^4$	m^3s^{-1}

3. LONG PERIOD OSCILLATIONS

In this section we briefly deal with the observed current oscillations of greater than 24 hour period. Such oscillations are usually ascribed to meterological forcing planetary or topographic Rossby waves or a general seasonal or climatic cycle. Of particular interest in the examination of the long-period oscillations are the year-long current records made at sites C4 and C5 near the bottom.

Daily average current vectors were computed and plotted along a time axes (stick diagrams) for each of the current meter records. The daily vectors from Byam and Austin Channels are shown in Figures 17, 18, 19 and from Crozier and Pullen Straits in Figures 20 through 28. In these diagrams north is toward the top of the page and the length of the vector is proportional to the speed.

All the stick diagrams show that the daily average currents are generally in the direction of the mean currents (cf Figures 13, 14) but are modulated in amplitude over a period of 28-31 days as is the case for C4 surface or about 14 days as shown in the stick diagram from C3 bottom. These modulations might be ascribed to fortnightly and monthly tidal components, which when superimposed can account for differences in daily average current speeds of up to 11 cm s^{-1}, according to tidal analyses performed on the current records (see Section 4). However recent investigations (W. Crawford, pers. comm.) have shown that the fortnightly and longer tidal constituents require several years of records to be properly resolved. We therefore cannot dismiss these fluctuations as tidally induced, particularly in light of their varying phases.

a) Horizontal variations

The stick diagrams as well as the mean current vectors, for Byam and Austin Channels show that the currents in the centre of the channels are stronger than near the lateral boundaries. This effect is not present in Crozier Strait. The probable explanation for this difference in current fields lies in the differing channel shapes. Byam and Austin Channels are relatively shallower than Crozier Strait. Byam and Austin Channels also have gently sloping sides while the lateral boundaries of Crozier Strait are relatively steep. The surface current meters in Crozier Strait are, therefore further removed from both the lateral boundaries and the bottom. For a homogeneous fluid, the current speed will be greater in deeper water where the frictional effects of the bottom and ice cover must act over a deeper water column.

b) Vertical Variations

The currents are generally coherent in the vertical at each site where more than one current record was obtained. There does appear to be a change in flow regime at about 100-150 metre depth in Crozier Strait which is exemplified by Figure 24, the stick diagram from C5. Here the records at 75 metres and 200 metres depth appear to be well correlated if one considers a mean shear of about 6 cm s^{-1}/125 metres between the two current meters.

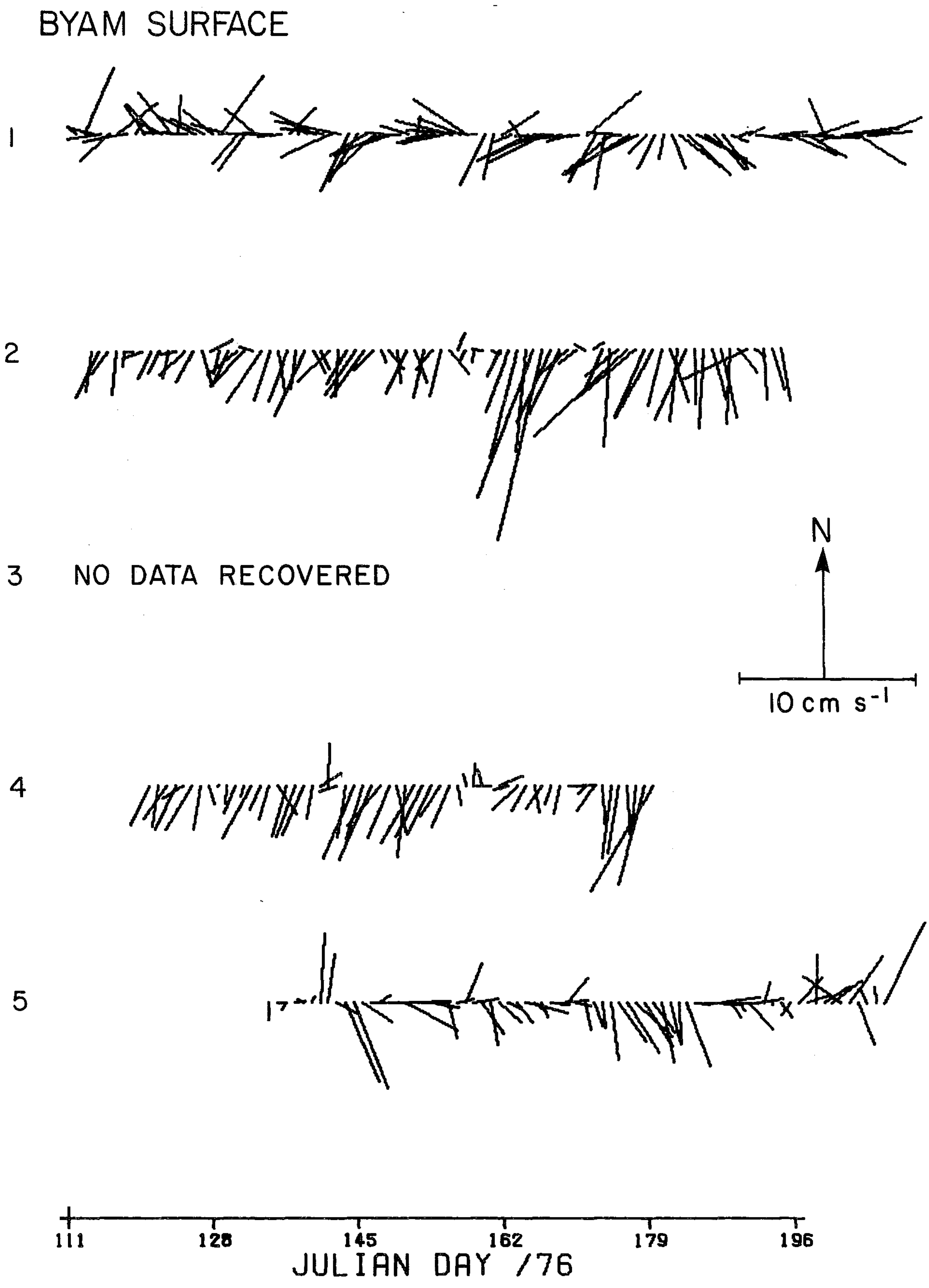


FIGURE 17. Daily average current vectors, Byam Channel surface.

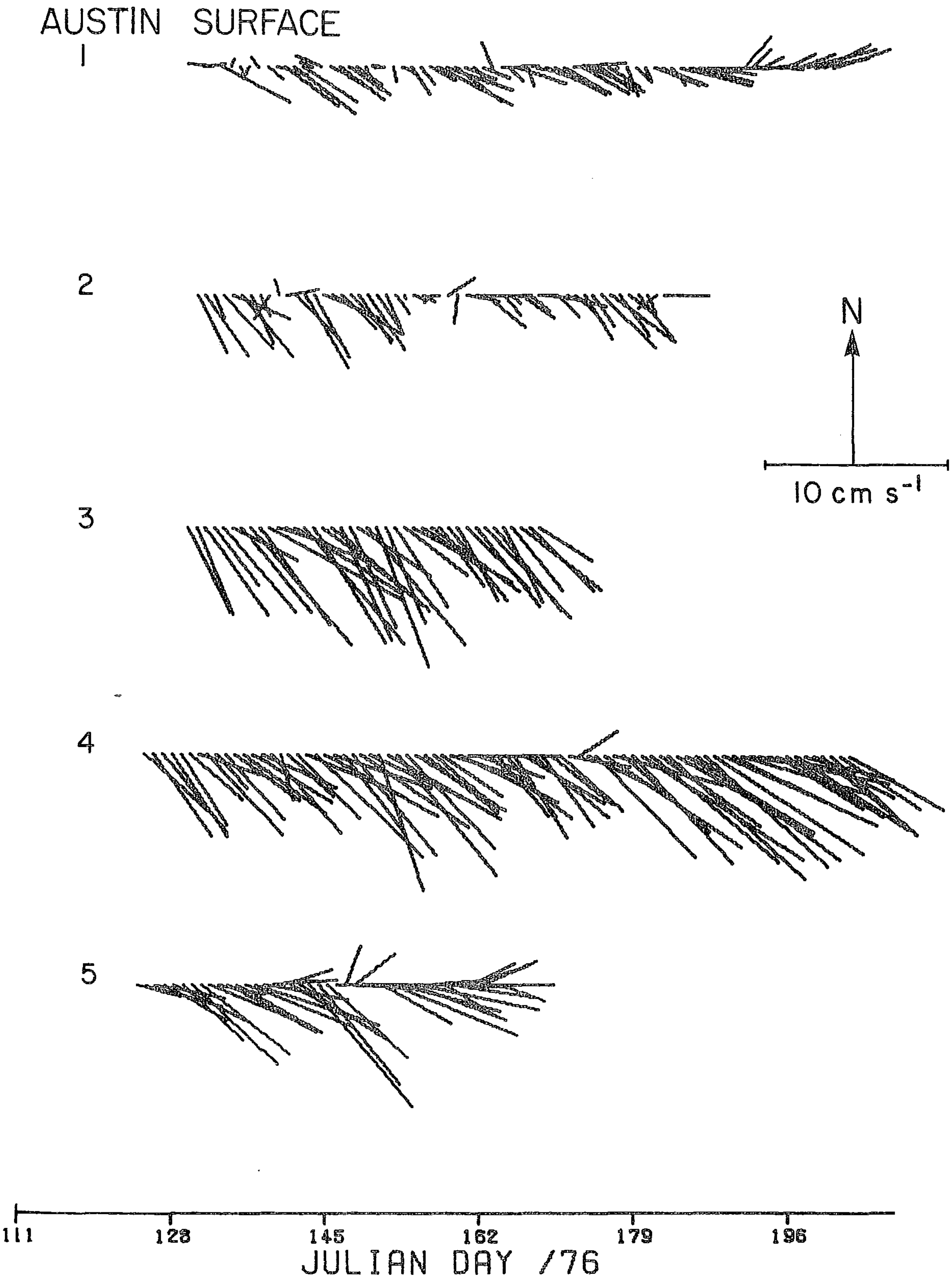


FIGURE 18. Daily average current vectors, Austin Channel surface.

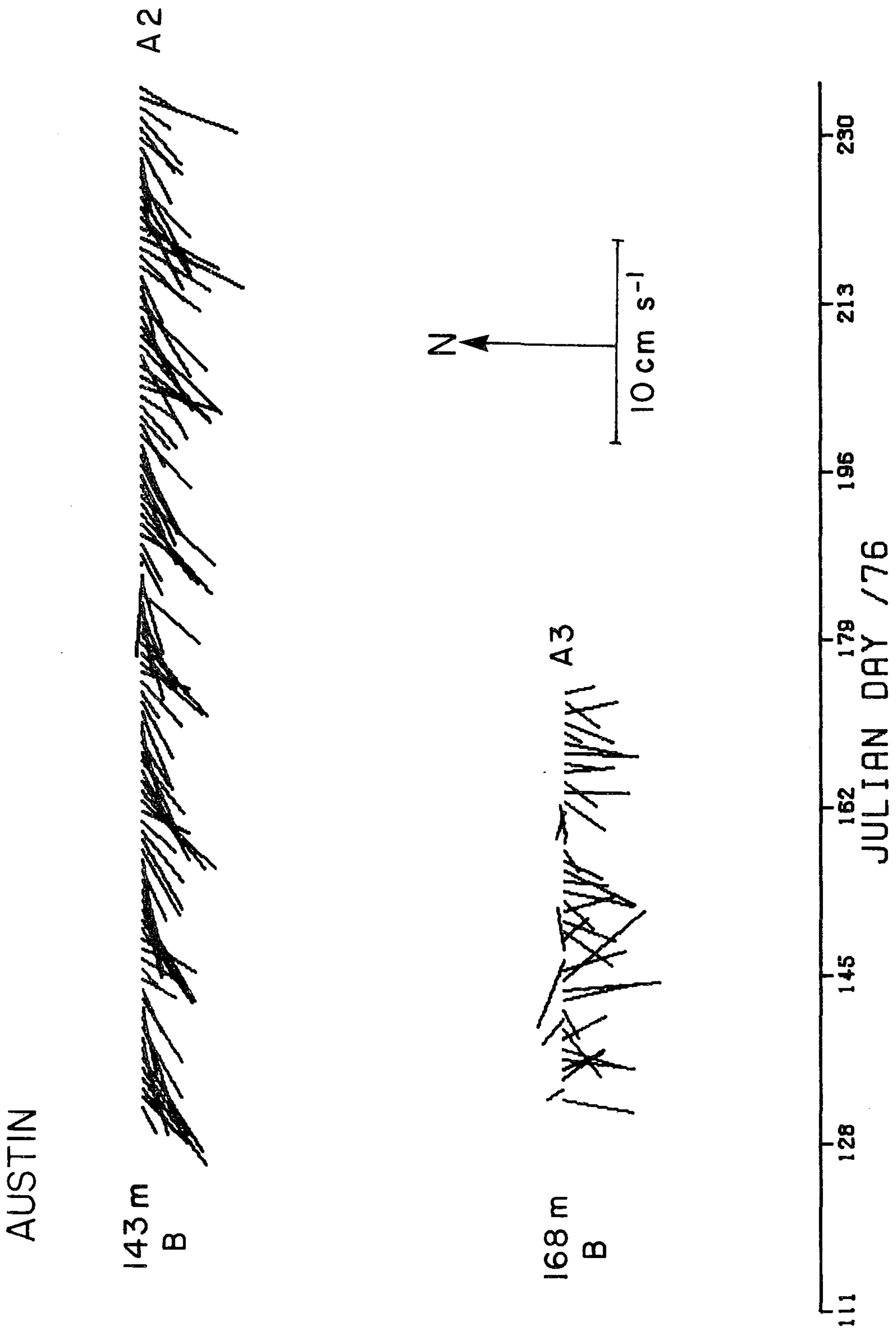


FIGURE 19. Daily average current vectors, Austin Channel, bottom.

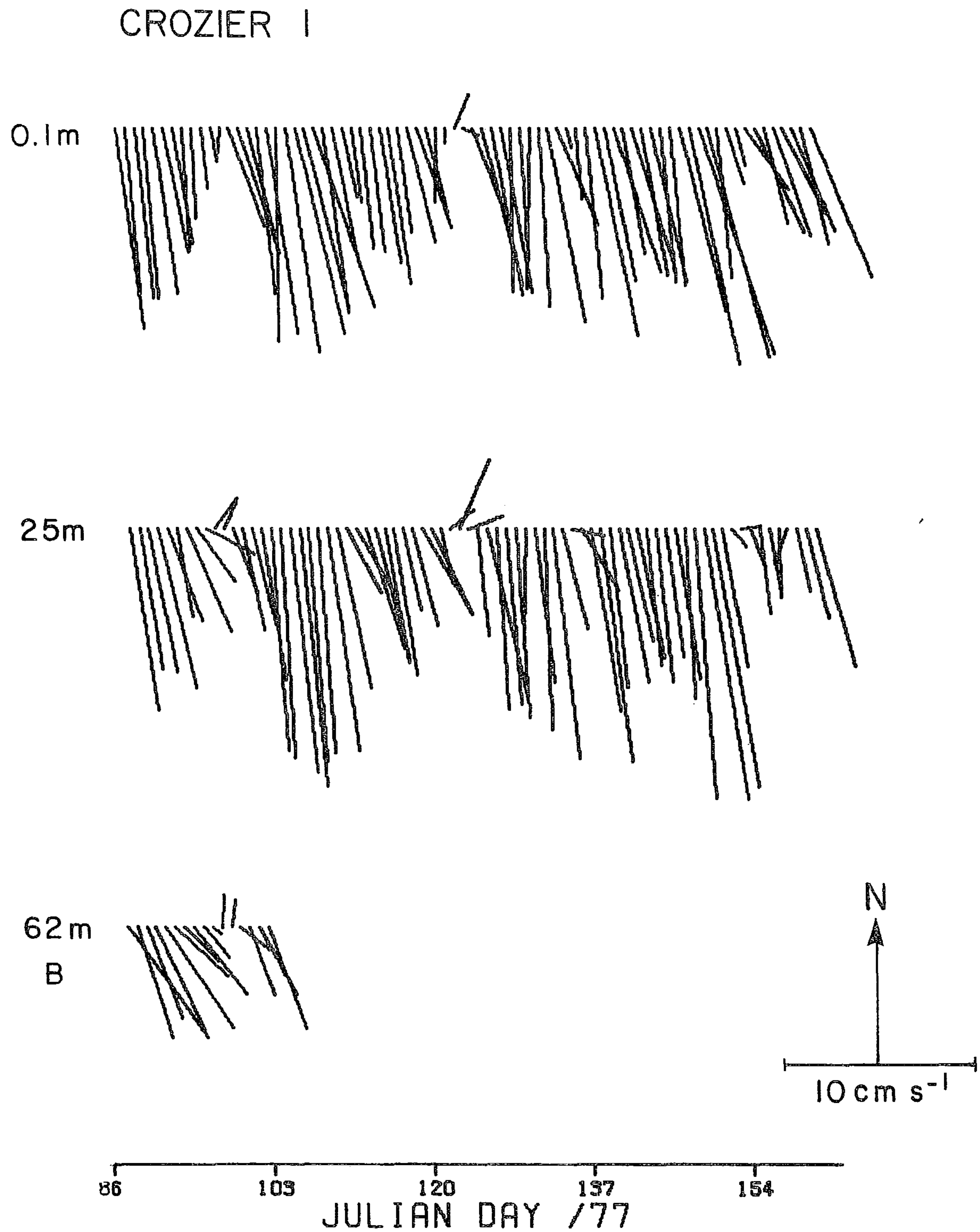


FIGURE 20. Daily average current vectors, Crozier Strait, site 1.

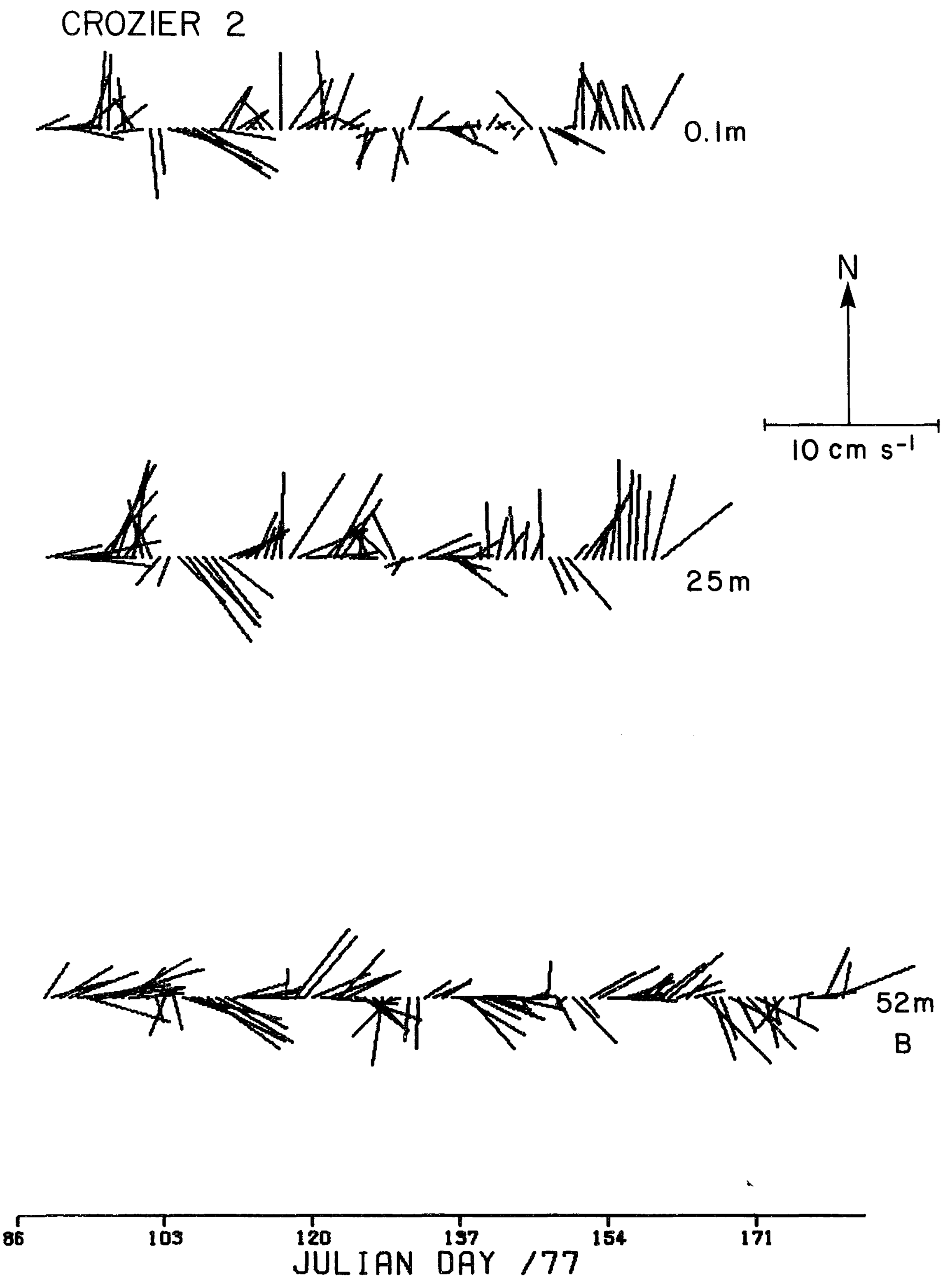


FIGURE 21. Daily average current vectors, Crozier Strait, site 2.

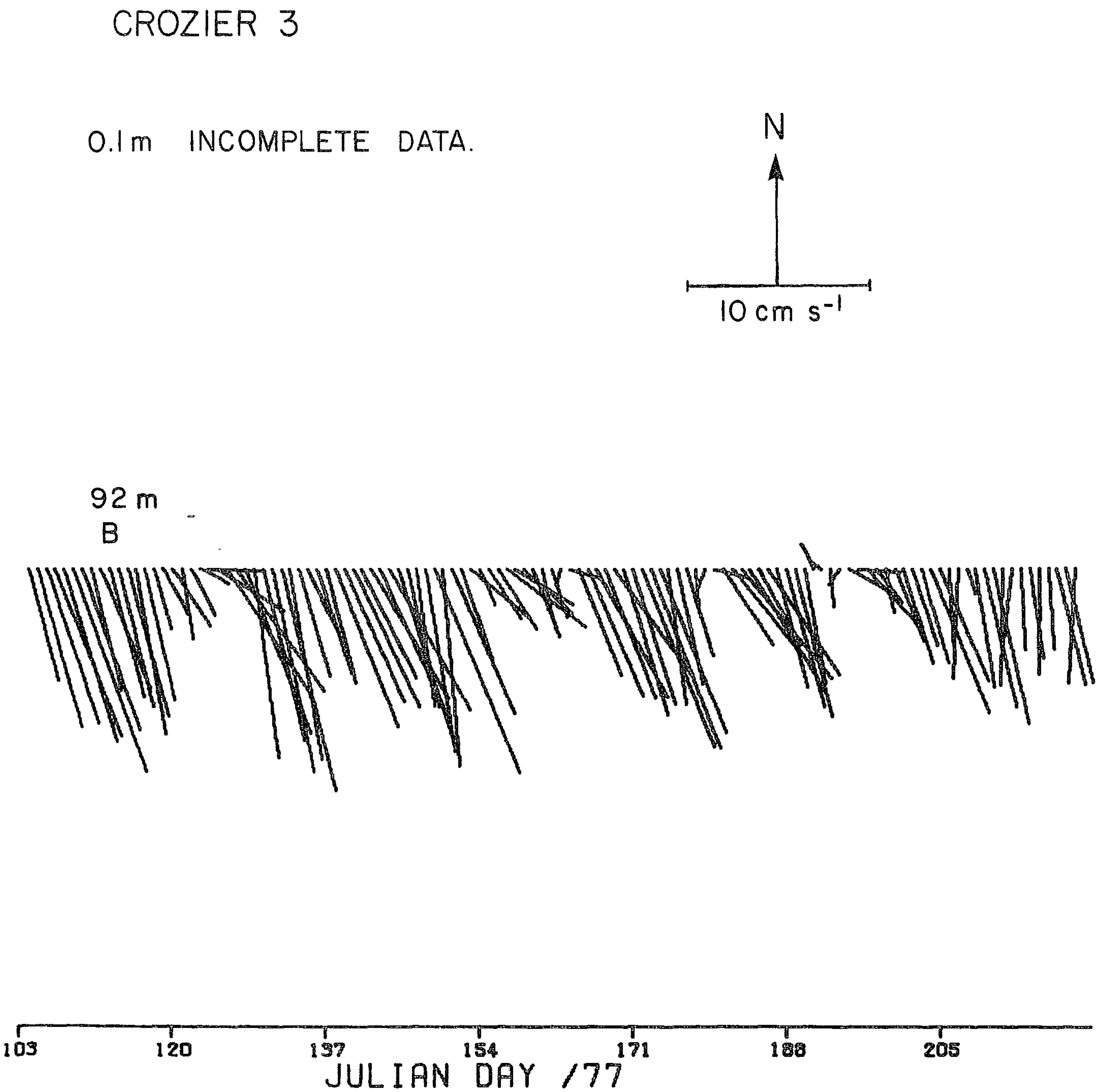


FIGURE 22. Daily average current vectors, Crozier Strait, site 3.

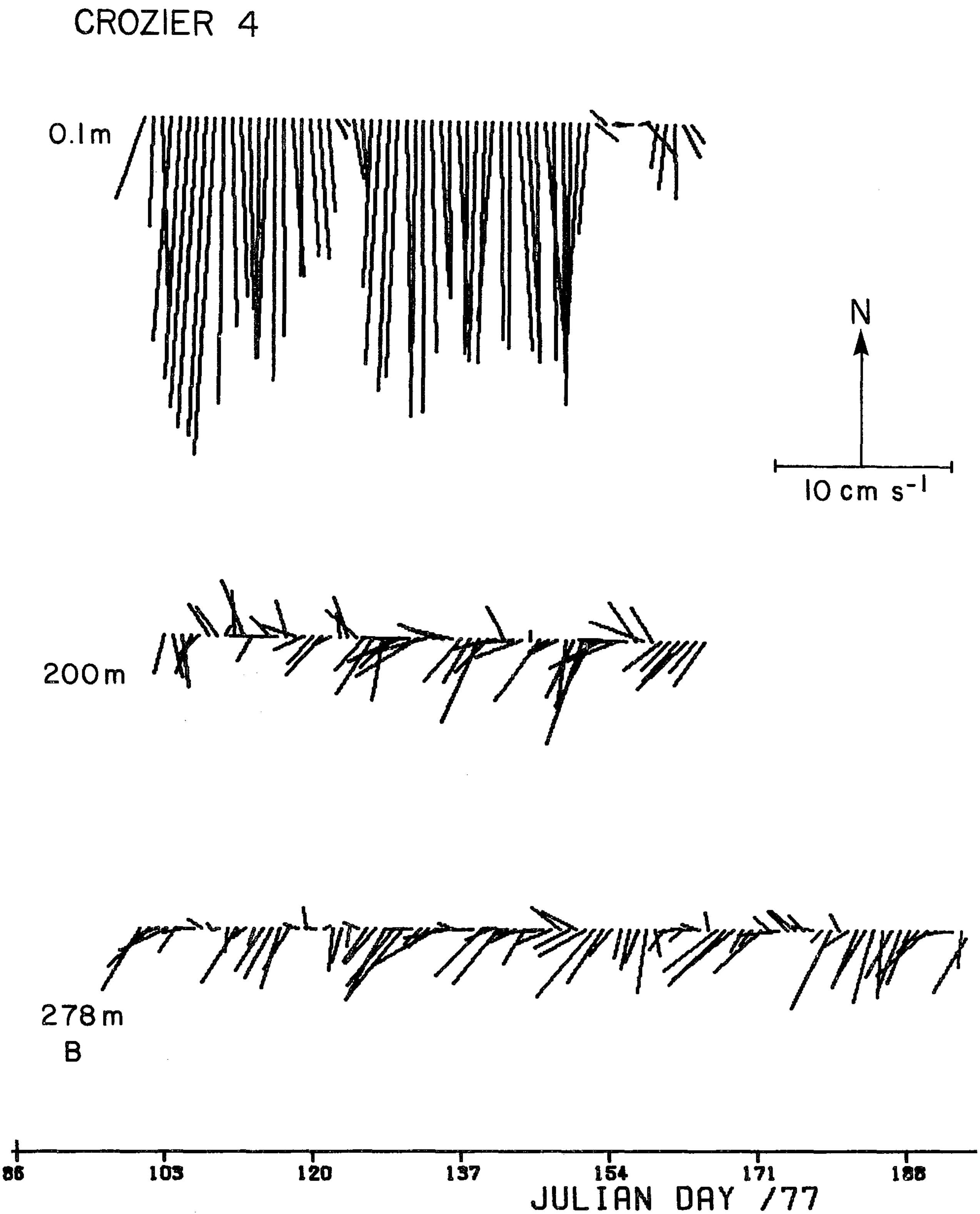


FIGURE 23. Daily average current vectors, Crozier Straite, site 4.

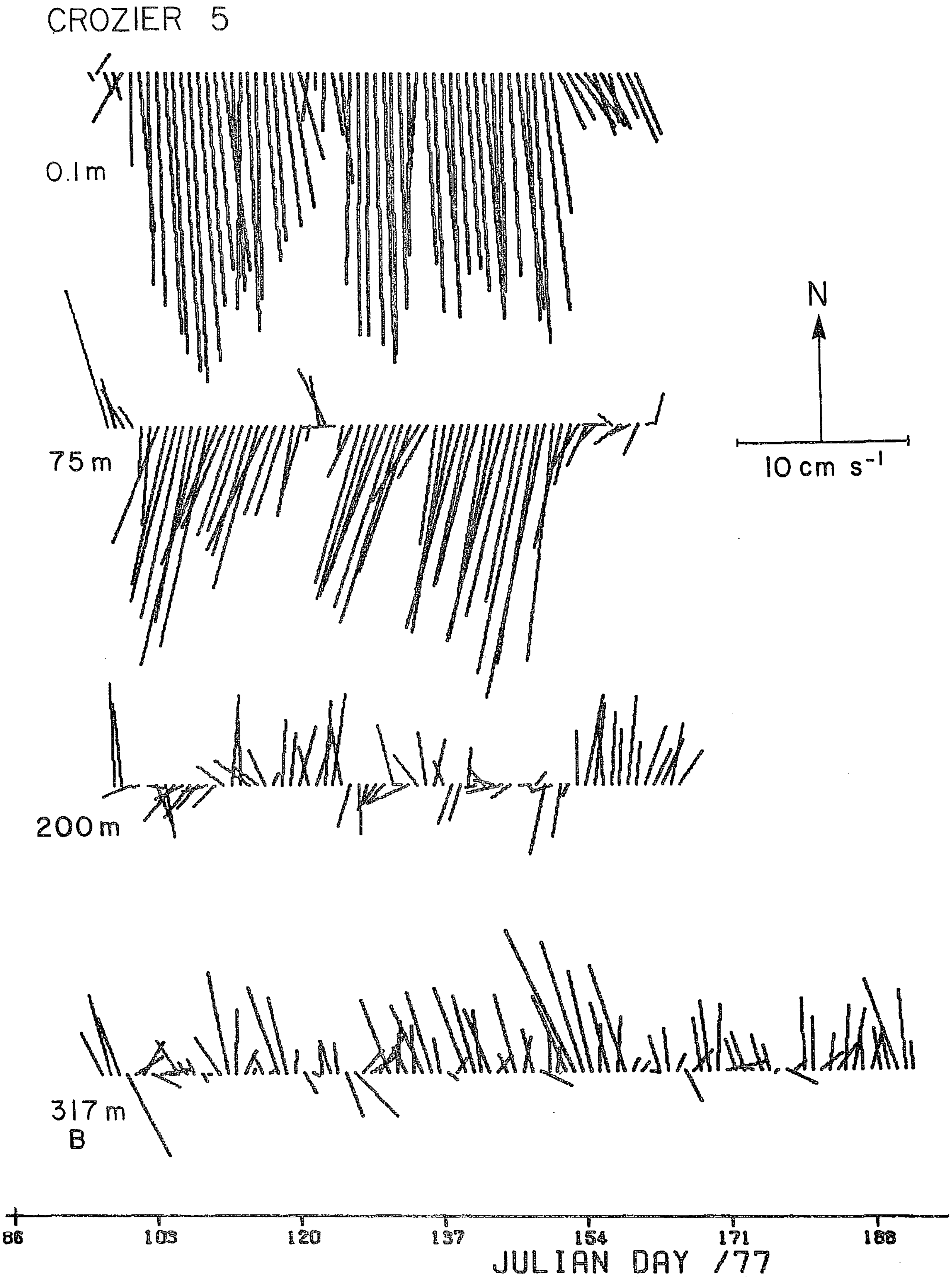


FIGURE 24. Daily average current vectors, Crozier Strait, site 5.

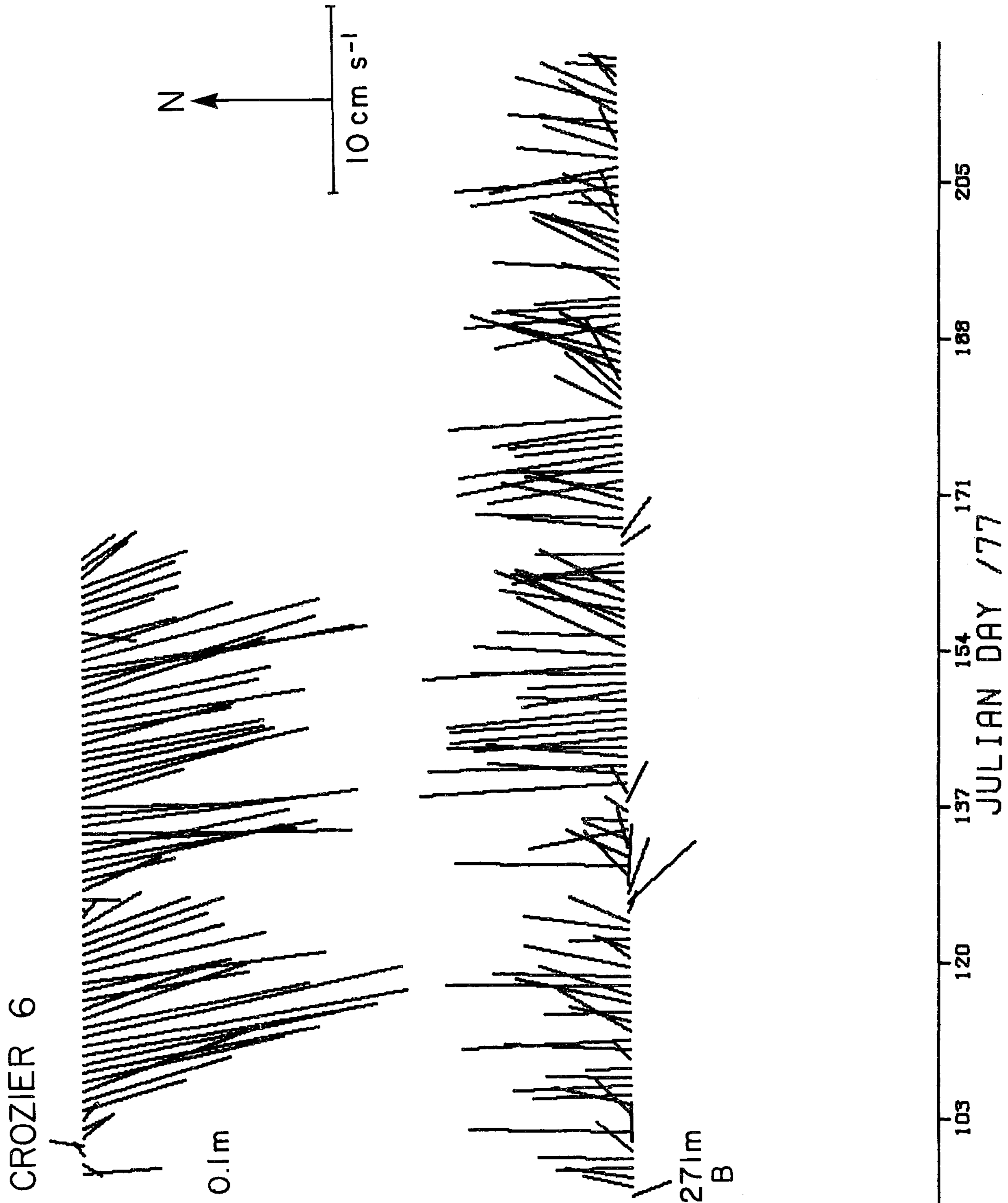


FIGURE 25. Daily average current vectors, Crozier Strait, site 6.

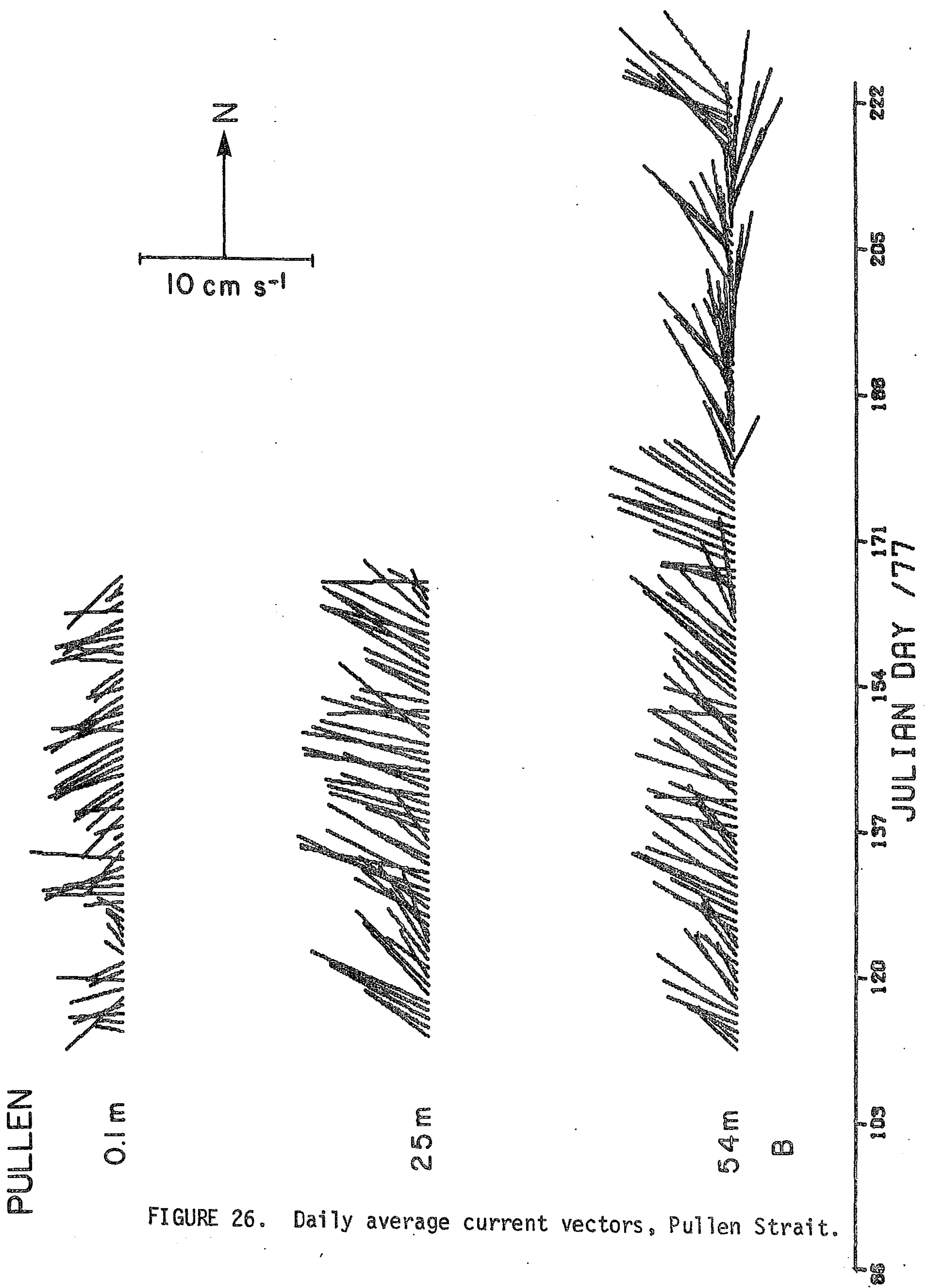
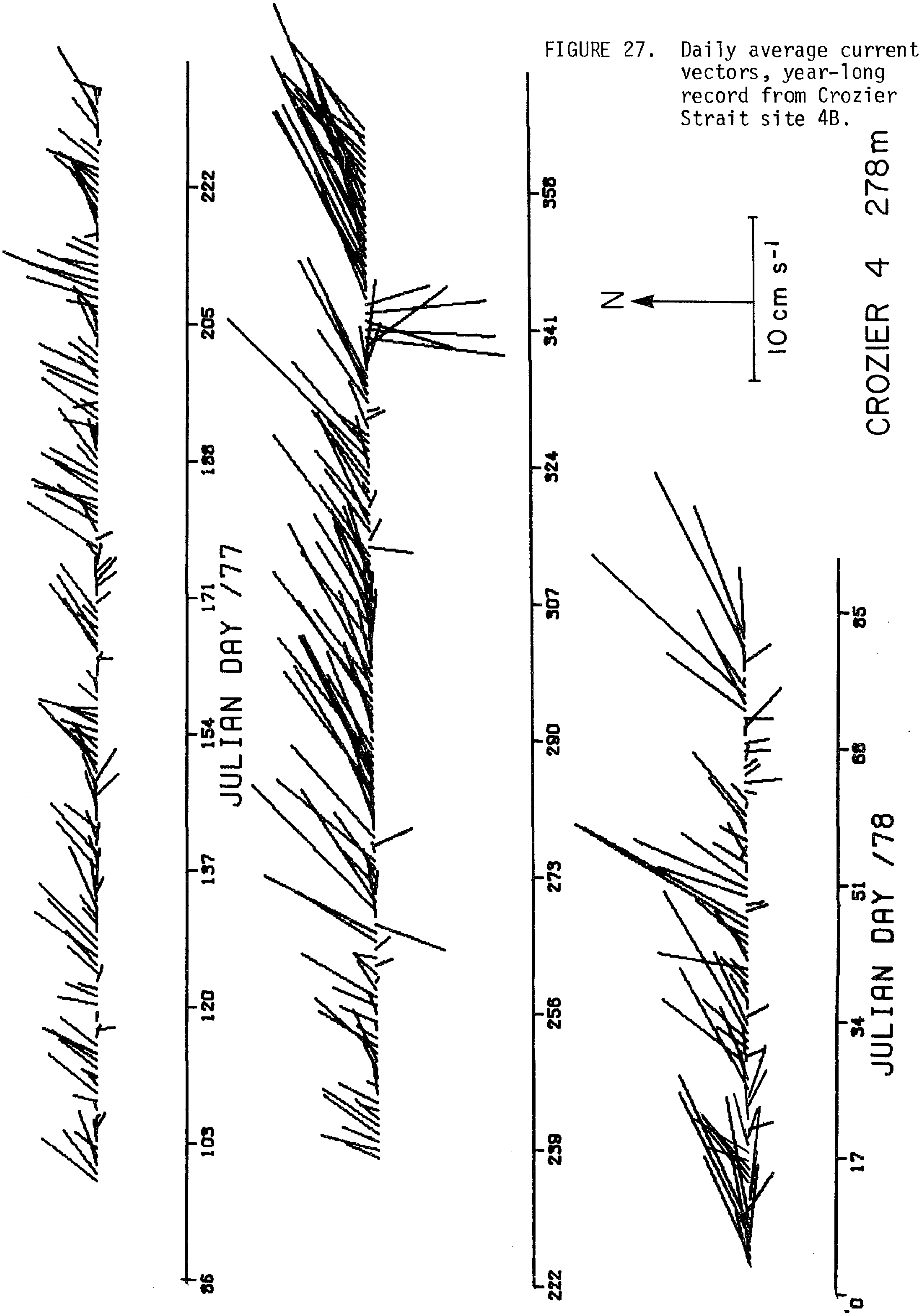


FIGURE 26. Daily average current vectors, Pullen Strait.

FIGURE 27. Daily average current vectors, year-long record from Crozier Strait site 4B.



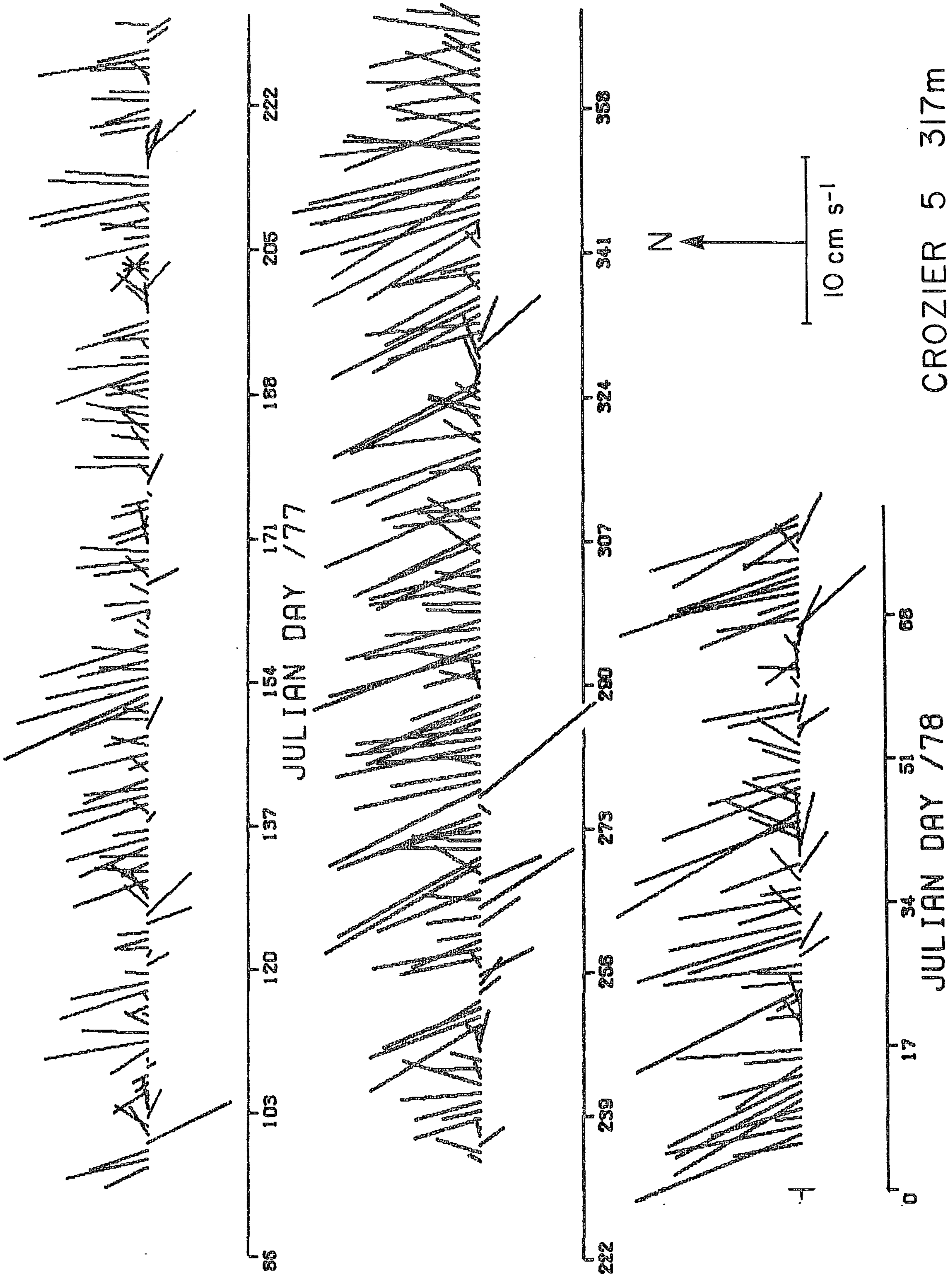


FIGURE 28. Daily average current vectors, year-long record from Crozier Strait site 5B.

However, both the mean flow and the monthly and fortnightly oscillations are much smaller (about 20%) at 200 metres than at 75 metres depth. Both the diurnal and semi-diurnal tidal oscillations at the two meters are nearly identical. The difference in the upper and lower regimes is therefore manifested in oscillations of period longer than a few days, corresponding to length scales (i.e. particle excursions) of greater than about 5 km if we take an approximate amplitude of a 10 day wave as 1 cm s^{-1}. It is no surprise that this length scale corresponds with the characteristic length scale: the width of Crozier Strait. Oscillations which have particle excursions greater than the characteristic size of the system will, of course, be strongly influenced by the local topography. It is most likely the effective sill depth of 100 metres in Queens Channel which causes the presence of the two flow regimes in Crozier Strait.

Between 75 metres and 317 metres depth the sign of the oscillations appears to change so that the daily average currents are out of phase. An increase in southward flow at 75 metres is accompanied by an increase in northward flow at 317 metres. This relationship is unclear at C4 but appears quite strongly at C6 where the surface and 271 metre current records are nearly 180° out of phase. We are unable to explain this phase change with depth in terms of internal wave theory which predicts a phase change at about 40 metres depth (see Section 4).

c) Seasonal Variations

The daily vectors from the year-long records at current meters near the bottom at C4 and C5 are shown in Figures 27 and 28. Although the general orientation of the two sets of vectors differs by about 60° the two records are quite well correlated particularly with respect to the long term variation in flow between the spring and fall. The flow is enhanced at both current meters beginning about September (Julian day 243). From these figures the flow appears to remain relatively energetic until January (particularly noticeable at C4) when the currents weaken slightly and taper almost to the values of the previous spring by March 1978.

In order to better examine this apparent seasonal variation, we computed weekly average current speeds at the two meters and plotted these versus time after applying a 3 point running mean to smooth the records. Figure 29 shows the results from the meters at sites C4 and C5. The two records display a very similar seasonal cycle with weekly averages ranging from 3 cm s^{-1} to 8 cm s^{-1}. While this range is small in absolute terms, the percent variation is striking. The peaks occur around Halloween and Christmas with a minimum between these during late November. The periods between April and September and from February through March are characterized by weekly average speeds of about 2 cm s^{-1}.

We sought to illuminate the seasonal cycle evident in the long current records by comparing it with atmospheric cycles of pressure and wind stress. We first recorded the sea level atmospheric pressure gradients over 450 km at 75°N, 95°W, in the vicinity of Resolute. For this and the other atmospheric data required we used 6 hourly charts prepared by Arctic Weather Central of Environment Canada. The gradients were obtained by the number of isobars crossed in a north-south and an east-west direction. Weekly average

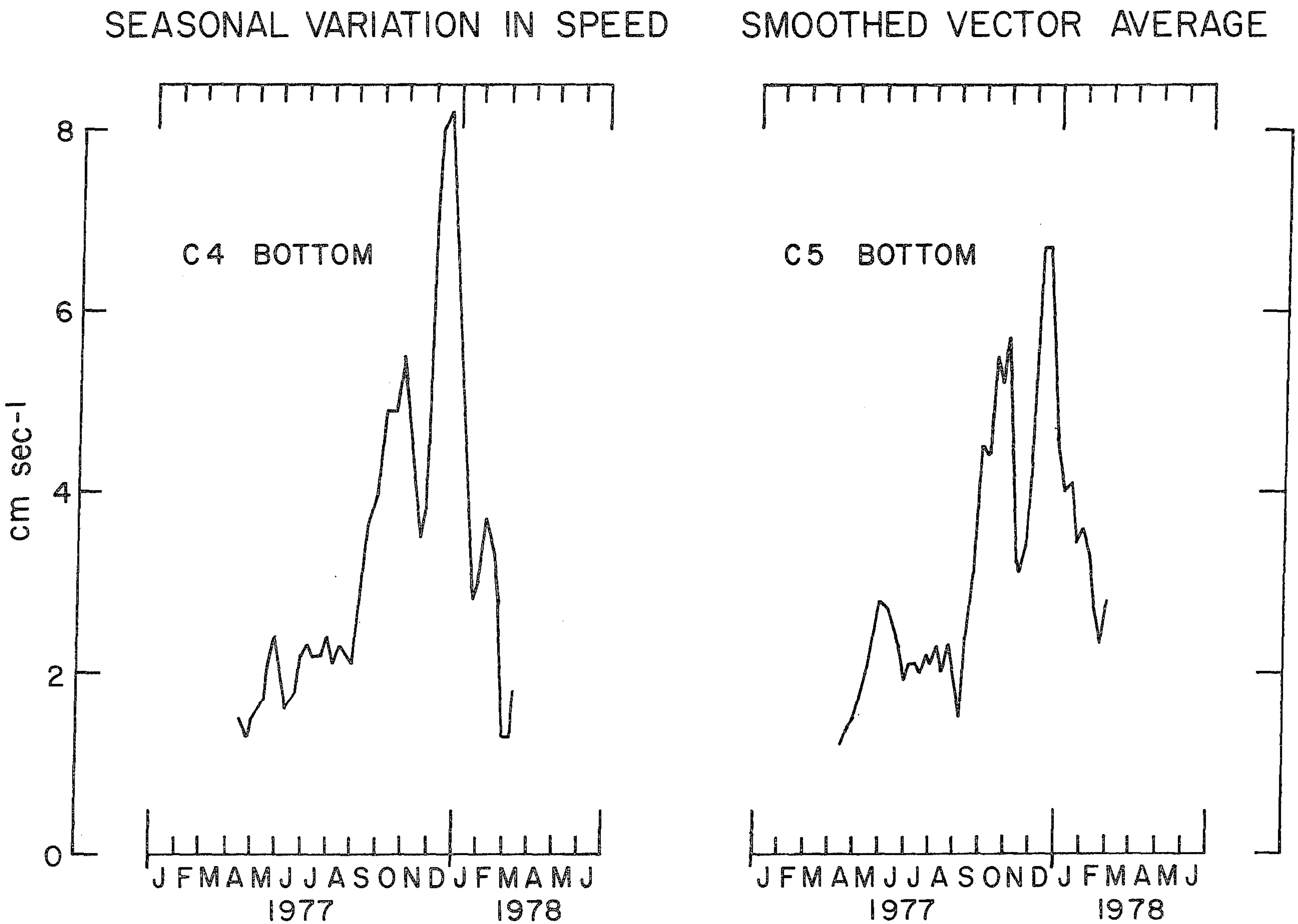


FIGURE 29. Weekly average current speeds, C4B and C5B.

pressure gradients were computed as well as the geostrophic wind components. Comparison of the flow speeds at C4B and C5B was made with the component of wind stress along Crozier Strait:

$$\underset{\sim}{\tau} \cdot \hat{e} = \left[e_x |u_g| u_g + e_y |v_g| v_g \right] \rho_a C_D \qquad 3.1$$

In 3.4 τ is the surface wind stress vector, $\hat{e}$ is the unit vector along the axis of Crozier Strait, u_g and v_g are the components of the geostrophic wind in the east and north directions, ρ_a is the density of air and C_D is the geostrophic drag coefficient. ($\rho_a C_D$ has a value of about 1.9×10^{-6} g cm^{-3}). We found no correlation between the along-channel wind stress and the long current records; not surprising since the channels are covered with land-fast ice for 9 months of the year. We next sought the sort of correlations found by Mountain, et al (1976) where the flow through Barrow Canyon was found to be driven by the atmospheric pressure gradient parallel to the Canyon axis. The atmospheric pressure gradient along the channel was computed from

$$\nabla P \cdot \hat{e} = e_x \frac{\partial p}{\partial x} + e_y \frac{\partial p}{\partial y} \qquad 3.2$$

and once again no correlation was found with the current records.

In order to refine our method of calculating pressure gradients we next compiled the pressure difference between Isachsen and Pond Inlet, i.e. two established meteorological stations. Once again no correlation was found between the atmospheric variations and those of the currents. It should be noted, however, that all the potential atmospheric driving forces calculated shared a large peak in common with the currents in December. The heightened intensity of atmospheric and oceanic motions in the winter is not, we feel, sufficient basis to conclude a causal relationship.

We are left with the impression that the variations shown in Figure 29 are caused by variations in the atmospheric circulation. We have not, however, been successful in isolating the atmospheric driving force or the appropriate scale over which it acts. It is likely that oscillations in the Central Arctic Basin are manifested as variations in flow through the archipelago, but we are unable to investigate this liklihood with existing data.

4. TIDAL FLOW

The most cursory examination of the current records from Byam and Austin Channels and Crozier and Pullen Straits reveals that they are dominated by tidal frequency oscillations. Figures 30 a,b,c,d,e and f are cross sections at 4 hour intervals in Crozier Strait East showing isotachs as measured by ten current meters over a tidal cycle. The flow regime alters drastically during the 24 hour period. Between 1400 and 1800 hrs there is an indication of a northward flowing jet which, initially on the eastern side, has its axis displaced to the western side during this 4 hour interval. There is also a consistent indication of a phase change with depth in the current oscillations since the near bottom flow is generally opposite to the flow at mid-depths and at the surface. Such a phase change suggests the presence of internal waves of tidal period.

The records were subjected to tidal stream analysis which computes the tidal ellipses for the separable constituents as well as some statistical properties of the records. The analyses show that, on the average, the tidal flows account for 75% of the variance of the records, and when the mean flow is included about 70% of the kinetic energy. Power spectra for several records were also computed and similarly showed that the variance was concentrated at the tidal frequencies. Figure 11 shows the power spectrum for current meter C5 (75 m depth) and is typical of all the records. Since most of the current measurements were made under land-fast sea ice, meteorological forcing of the ocean through direct wind stress (at least near tidal frequencies) is absent. We therefore expect a fairly "pure" tidal signal which is discussed in this section.

a) Tidal Heights

Tide gauges have been deployed in this region by various agencies. The general high quality of tide gauge data however, permits some intercomparison of these data. We consider here, very briefly, the nature of the surface tides in the region between Melville and Devon Islands.

The surface tides can be characterized by the "form number", the ratio of the two largest diurnal to the two largest semi-diurnal constituents, namely $\frac{K_1 + O_1}{M_2 + S_2}$. The ratio assumes values of 0.2 to 0.5 in this region which typify a mixed, mainly semi-diurnal tide in which there are two unequal highs and lows daily.

The propagation of the four largest constituents of the surface tide can be illustrated by examining the Greenwich phase at several stations in the region, (see Figure 31). The phases for each constituent are not entirely self consistent, so that phase differences over larger distances only should be accepted. For the K_1 M_2 and S_2 constituents, the source of the tidal energy appears to be Barrow Strait and Lancaster Sound to the east. This implies

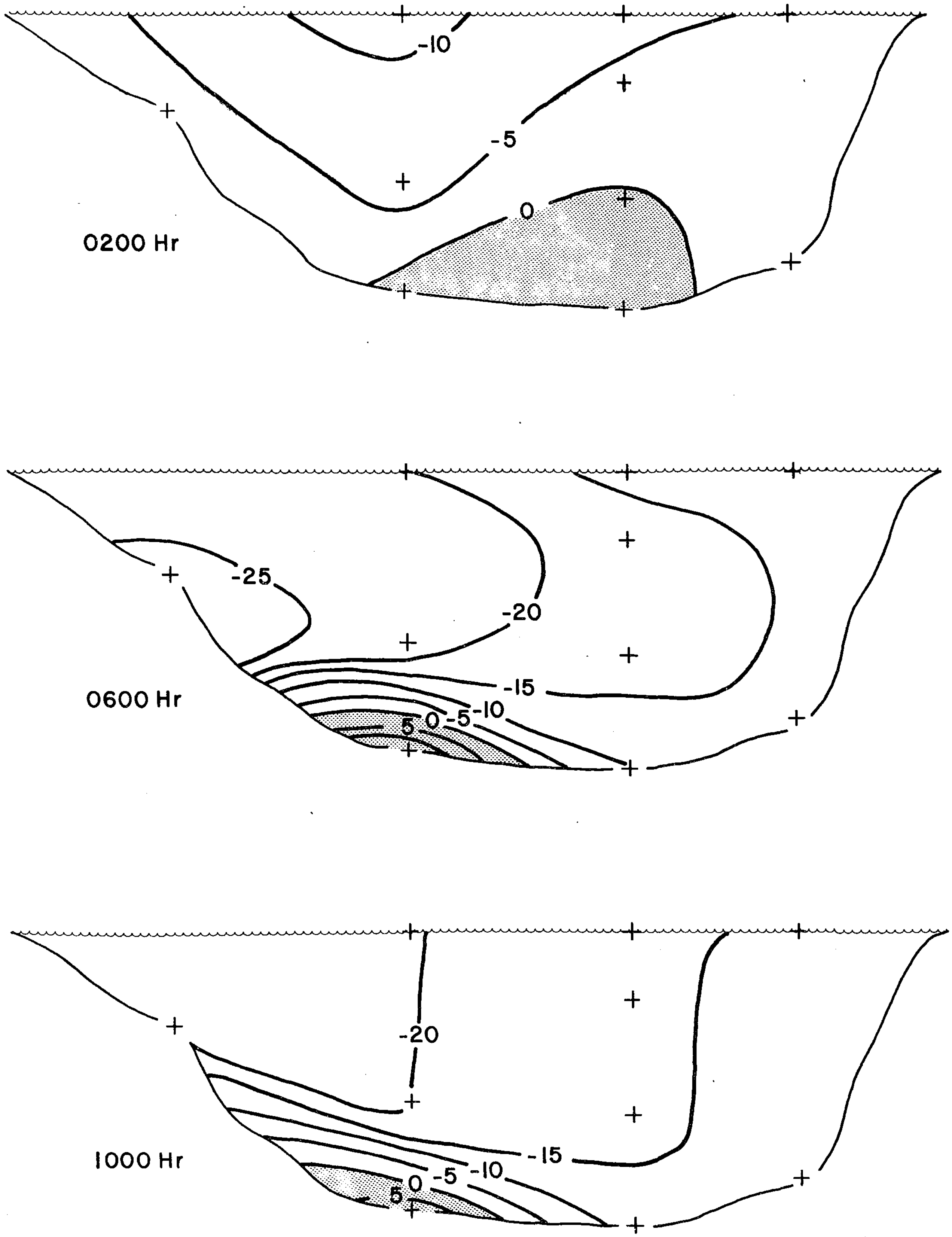


FIGURE 30. a-c Cross section of Crozier Strait east. Isotachs at 0200, 0600 and 1000 hours.

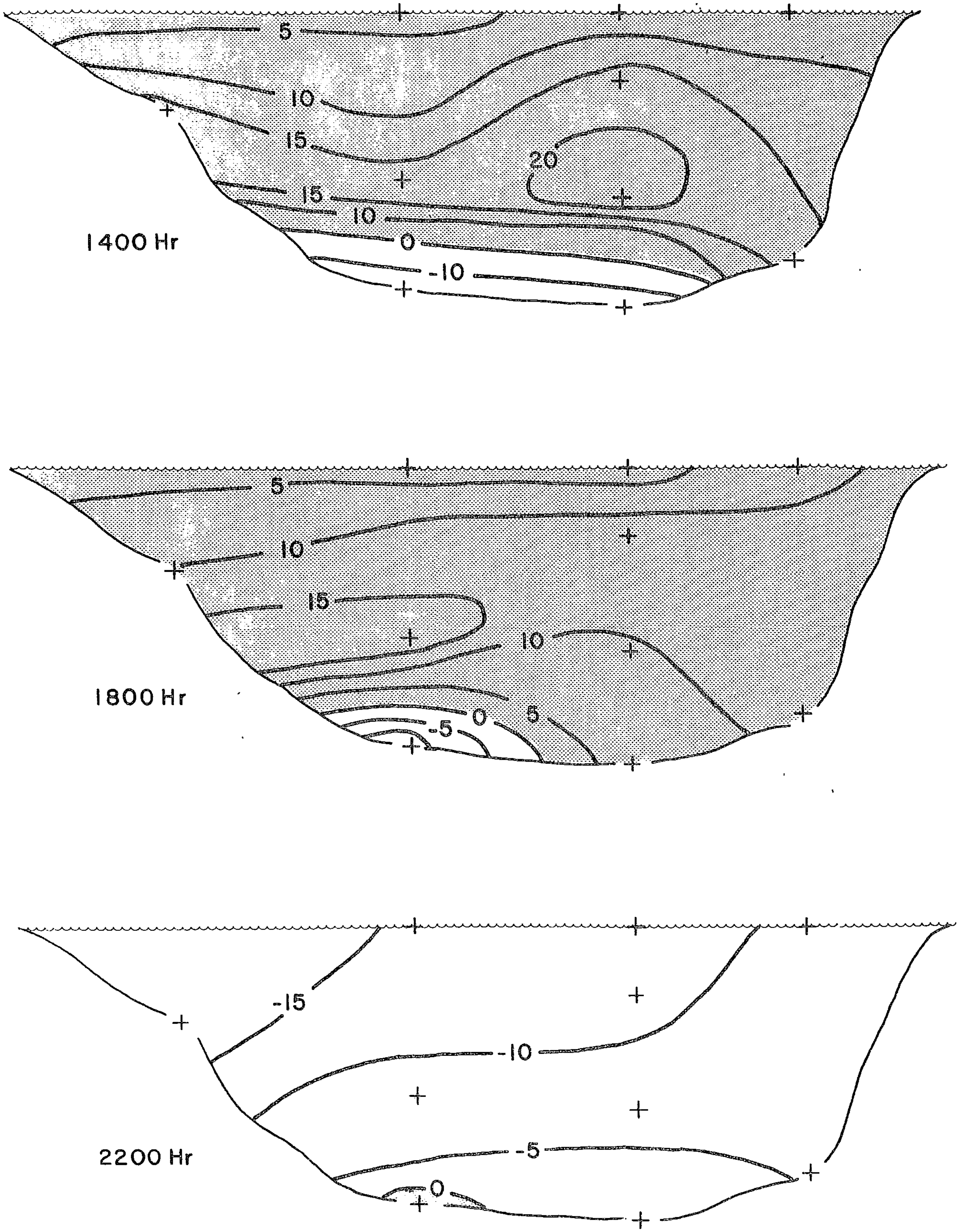


FIGURE 30. d-f Cross section of Crozier Strait east. Isotachs at 1400, 1800 and 2200 hours.

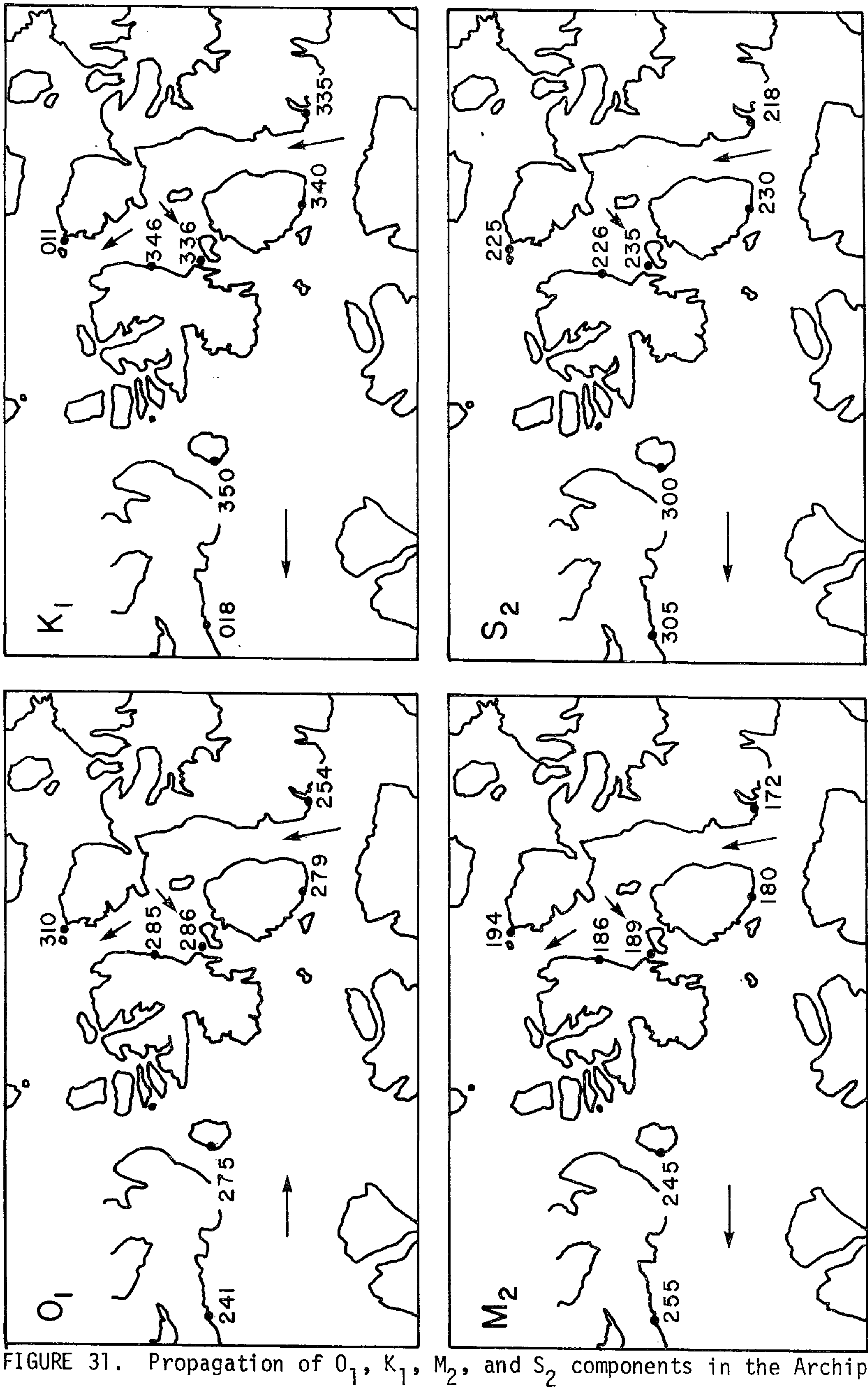


FIGURE 31. Propagation of O_1, K_1, M_2, and S_2 components in the Archipelago.

that the bulk of the tidal energy propagating into the Central Arctic is of Baffin Bay or Atlantic origin. The O_1 component cophase chart suggests that tidal energy at this frequency enters the region from both the Beaufort Sea to the west and Baffin Bay to the east.

All the tidal components display phases in the region of Cornwallis Island which imply propagation north through Wellington Channel. The O_1, M_2, and S_2 waves appear to round the northern shore of Cornwallis Island and propagate southward through Crozier and Pullen Straits. The O_1, K_1 and M_2 waves also appear to propagate northwards from Wellington Channel into Queen's Channel and through Penny Strait.

Since there is roughly a 180° phase difference in the tidal currents (Table 5) and the tidal heights (Figure 31) for the semi-diurnal components, the tide propagates as a progressive wave southward through Crozier Strait. For the diurnal components, on the other hand there is roughly a 70° phase difference between the heights and the currents which implies substantial reflection; the diurnal waves are nearly standing waves. The current data are, of course, representative of a vector time series. The data are inherently noisy relative to tidal height data and different instruments and deployment configurations frustrate attempts at intercomparison of varied experimental results. With this caution in mind, we venture to deal with the tidal currents in the remainder of this section.

b) Tidal Currents

Of the forty-one current meters deployed, seventeen were positioned with rotors about 15 cm below the ice. The bottom of the ice is not smooth and the flow is unsteady. The resulting time-dependent boundary layer seriously modifies the free stream time-dependent flow. The seventeen bottom current records too, must be influenced by the boundary.

Bergstrom and Cogley (1976) have investigated unsteady boundary layers in rotating flows of near-inertial frequency. Their results are applicable to tidal streams in wide channels where there is a significant cross-stream oscillation. Such an oscillation is manifested as a relatively large minor tidal-ellipse axis, i.e., the flow is not rectilinear but composed of clockwise and counterclockwise rotating components which combine to form an elliptical current hodograph with time as the parameter. Bergstrom and Cogley found that the deflection of the current from the free stream direction in the boundary layer is dependent upon the polarization or the sense of rotation of the free stream flow. This is contrary to the steady case where the veering in the Ekman layer is determined by the nature of momentum transfer between the ocean and the bottom (or the ice) and the rotation of the earth. They predict the major axes of the tidal ellipses in the boundary layers should lie to the left of the free stream ellipse axes in clockwise polarized flow and to the right of the free-stream ellipse axes in counterclockwise polarized flow. They also predict the decrease of ellipse size (the decrease in current speed) at various positions in the boundary layer. Their use of a constant viscosity, however, probably limits the applicability of the near boundary current speed predictions and the quantitative prediction of near-boundary

TABLE 3.

TIDAL STREAM ANALYSIS ON CURRENT RECORDS (1511 HOUR) FROM C4B.

	NAME	SPEED	MAJOR	MINOR	INC.	G
1	Z0	.00000000	.022	.000	52.6	360.0
2	MM	.00151215	.003	-.002	135.6	65.1
3	MSF	.00282193	.008	.002	107.8	25.2
4	ALP1	.03439657	.005	-.000	48.6	294.8
5	2Q1	.03570635	.003	.001	17.8	123.5
6	Q1	.03721850	.013	-.001	57.7	234.1
7	O1	.03873065	.044	-.002	77.6	331.2
8	NO1	.04026859	.004	.001	60.5	349.5
9	K1	.04178075	.063	-.005	74.2	91.2
10	J1	.04329290	.003	-.000	99.6	127.0
11	OO1	.04483084	.012	.003	56.0	355.1
12	UPS1	.04634299	.011	-.001	31.9	176.9
13	EPS2	.07617732	.006	.000	57.1	77.5
14	MU2	.07768947	.002	-.000	38.2	188.6
15	N2	.07899925	.008	-.001	65.0	12.9
16	M2	.08051140	.027	-.001	88.0	37.4
17	L2	.08202355	.004	-.001	83.0	73.9
18	S2	.08333333	.024	-.003	81.2	85.1
19	ETA2	.08507364	.006	-.001	36.1	164.7
20	MO3	.11924206	.004	-.002	48.7	16.4
21	M3	.12076710	.002	-.000	100.7	225.9
22	MK3	.12229215	.010	-.001	79.0	135.4
23	SK3	.12511408	.004	-.001	90.4	144.5
24	MN4	.15951065	.002	-.001	17.3	117.6
25	M4	.16102280	.006	-.002	58.7	169.4
26	SN4	.16233258	.002	-.000	15.9	183.1
27	MS4	.16384473	.006	-.003	67.6	181.3
28	S4	.16666667	.001	.001	42.8	154.0
29	2MK5	.20280355	.003	.001	31.8	33.9
30	2SK5	.20844741	.002	.000	87.0	23.5
31	2MN6	.24002205	.002	.000	84.5	24.4
32	M6	.24153420	.002	.000	109.8	118.6
33	2MS6	.24435613	.003	.001	70.1	65.5
34	2SM6	.24717807	.002	-.001	108.8	73.9
35	3MK7	.28331495	.002	-.001	73.8	3.3
36	M8	.32204560	.001	-.000	62.9	347.2

ellipse orientations. We can assume, however, that the sense of rotation of the tidal ellipses near the boundaries relative to the free-stream ellipses is dependent upon the polarization, either clockwise or counterclockwise, of the free-stream flow. Additionally, the superposition of the various tidal constituent ellipses and the steady flow cause instantaneous measurements of the near-boundary currents, in order to elucidate the nature of the Ekman layer, to be of little value. In fact, near-boundary current profiels were measured and demonstrated no consistent Ekman veering and a barely perceptible decrease of current speed upon approaching the ice.

All the current records were subjected to tidal stream analysis and the complete analyses are available upon request. As a sample of the relative magnitudes of the various components however, the analysis from current meter C4B is presented in Table 3. The tidal record is dominated by the O_1, K_1, M_2 and S_2 components which account for about 1/2 of the tidal energy (or 2/3 of the current amplitude), the rest being distributed among the other components, the largest of which is an order of magnitude smaller than the K_1 component.

The clockwise and counterclockwise rotating components of the current are combined in these analyses to produce tidal ellipses the rotational sense of which can be determined by the sign of the minor axis. A negative minor axis implies clockwise rotation and a positive minor axis implies counter-clockwise rotation. Godin (1972) and Foreman (1978) present a full explanation of the computational method and manipulation used in computing the tidal ellipses.

INC. is the angle in degrees between the northern semi-major axis of the tidal ellipse and the eastward direction measured counterclockwise. Its specification therefore follows standard mathematical convention for the measurement of angles. G is the Greenwich phase lag in degrees between the time the current vector lies along the northern semi-major axis and the time of maximum value of the tidal potential at Greenwich.

Tables 4 through 6 list the tidal ellipse parameters for each of the current records. The ellipse axes are drawn in the proper orientations with their centres at the appropriate locations on the channel cross sections in the Figures of Appendix B. The Greenwich phases appear near each of the ellipses. In Crozier Strait both the orientation and size of the ellipse axes are different at mid-depth locations from those at near-boundary locations, i.e. at the surface and bottom locations. As expected the tidal oscillations are somewhat damped near the upper and lower boundaries. The ellipse orientations at the surface and bottom locations are up to 30° to the left of the mid-depth locations which would be expected according to Bergstrom and Cogley if the free stream currents were polarized clockwise. The tables listing the ellipse parameters show that the free stream (mid-depth) ellipses do indeed display a clockwise rotation for 21 out of 24 current records. One of the exceptions is a case where the minor axis is computed as zero indicating a rectilinear oscillation and the other two exceptions are for the semi-diurnal constituents at site C2. The set of observations in Crozier and Pullen Straits therefore constitutes a convincing verification of the work by Bergstrom and Cogley.

The major axes of the mid-depth tidal ellipses are all directed

TABLE 4. TIDAL ELLIPSE PARAMETERS, BYAM AND AUSTIN CHANNELS

AUSTIN CHANNEL

CURRENT	M_2				S_2				K_1				O_1			
METER	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G
A 1 T	3.5	+2.3	162	334	1.5	+1.0	128	352	5.9	-0.2	179	061	3.7	-0.3	179	341
A 2 T	3.0	+2.1	81	284	1.9	+0.3	99	343	5.6	-0.2	148	052	3.3	-0.1	146	344
A 2 B	3.6	+2.4	41	248	1.3	+0.6	159	100	7.4	+2.2	38	281	5.2	+1.8	29	204
A 3 T	2.2	+2.0	143	003	1.7	+0.4	109	011	4.7	-0.4	138	058	3.2	+0.1	136	006
A 4 T	2.9	+2.5	25	224	1.3	+0.9	92	351	4.8	+0.3	142	063	2.9	+0.4	140	348
A 5 T	5.0	+2.7	142	336	2.0	+1.0	148	027	6.8	+1.4	139	047	3.7	+1.7	127	335

BYAM CHANNEL

B 1 T	3.8	+1.1	55	008	2.1	+0.6	58	050	1.9	+0.4	76	066	1.3	+0.4	65	001
B 2 T	8.2	-1.1	78	010	2.9	+0.1	76	048	3.9	-1.5	82	067	1.8	-0.5	72	340
B 4 T	6.6	+0.8	73	021	2.7	+0.3	83	068	2.9	0.0	75	076	2.0	+0.5	69	352
B 5 T	5.9	+1.5	84	012	3.0	+1.0	91	061	3.4	+0.2	95	082	2.1	-0.1	102	359

TABLE 5. TIDAL ELLIPSE PARAMETERS, CROZIER STRAIT

CROZIER STRAIT - WEST

CURRENT	M_2				S_2				K_1				O_1			
METER	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G
C 1 T	8.1	0.5	102	026	4.6	0.1	98	052	12.5	0.3	102	040	9.4	-0.1	106	348
C 1 M 25	11.9	-0.9	93	022	6.7	-0.2	93	050	17.6	-1.2	92	038	13.0	-0.9	92	343
C 1 B 62	8.4	1.5	122	009	6.5	0.2	124	052	8.2	-0.1	118	049	7.0	-0.7	119	338
C 2 T	9.2	2.1	110	000	5.6	0.6	107	021	10.8	-0.7	118	013	6.7	-0.6	112	322
C 2 M 25	13.5	2.5	87	004	8.0	0.4	82	021	15.4	-1.1	92	008	9.5	-0.9	96	314
C 2 B 56	8.6	3.0	97	357	5.5	0.6	98	020	11.5	-1.1	108	012	5.2	-1.3	113	304

CROZIER STRAIT - EAST

CURRENT METER	M_2 MAJ	M_2 MIN	M_2 θ	M_2 G	S_2 MAJ	S_2 MIN	S_2 θ	S_2 G	K_1 MAJ	K_1 MIN	K_1 θ	K_1 G	O_1 MAJ	O_1 MIN	O_1 θ	O_1 G
C 3 T																
C 3 B 92	7.1	-0.4	94	344	4.0	-0.7	98	022	10.3	-0.1	100	029	6.1	-0.2	94	325
C 4 T	4.8	1.0	90	006	2.2	0.8	92	044	8.1	-0.3	93	054	5.0	0.2	97	358
C 4 M 200	8.1	-0.7	83	012	4.3	-0.1	80	039	11.9	-0.4	78	042	7.3	-0.8	80	353
C 4 B 278	2.9	-0.4	85	013	2.7	0.0	81	042	6.5	-1.3	73	067	4.7	-0.7	73	355
C 5 T	4.0	1.0	102	014	2.1	0.3	105	053	7.0	0.2	96	053	4.7	0.5	94	003
C 5 M 75	7.4	-0.1	77	007	4.0	0.0	76	040	10.4	-0.8	83	049	6.8	-0.4	82	354
C 5 M 200	8.4	-0.4	86	010	4.4	-0.3	86	049	9.7	-0.9	84	052	6.2	-0.8	89	357
C 5 B 317	4.6	1.2	128	021	2.8	0.7	122	053	7.6	-0.1	124	073	5.5	-0.3	123	002
C 6 T	5.3	0.5	110	017	2.3	0.3	125	062	8.8	0.0	107	053	6.4	0.3	102	359
C 6 B 271	5.2	1.2	109	018	3.0	0.6	108	052	8.3	0.3	106	058	4.9	-0.2	101	359

TABLE 6. TIDAL ELLIPSE PARAMETERS, PULLEN STRAIT

CURRENT	M_2				S_2				K_1				O_1			
METER	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G
P 3 T	10.3	-1.1	46	050	4.7	-0.5	39	074	10.0	-1.5	42	058	5.9	-0.2	39	344
P 3 M 25	15.9	-2.1	42	020	7.4	-0.9	38	048	15.4	-2.9	36	041	8.8	-0.7	35	329
P 3 B 54	11.8	1.5	62	017	5.2	1.0	53	051	11.9	-0.4	52	043	6.8	0.6	53	323

along the axes of the channels. It is of interest to note that this is also true in Pullen Strait where mean flow through the channel is nearly absent. The tidal oscillations are primarily up and down the channels since the minor axes of the tidal ellipses are generally much smaller than the major axes. The semi-diurnal ellipses from Austin Channel, on the other hand, are nearly circularly polarized, particularly for the M_2 component. The major and minor axes are barely distinguishable. Since this is the case for all the records from Austin Channel we have no reason to doubt this local phenomenon. The M_2 ellipses from Austin Channel also demonstrate the difficulty of computing the Greenwich phase when the major and minor axes of the tidal ellipses are poorly differentiated.

We have searched extensively for an explanation for the apparent absence of frictional effects on the mean flow while the tidal flow is strongly and consistently influenced by boundary friction. The explanation still eludes us. We can demonstrate the difference by examining the kinetic energies of the mean flow and the tidal oscillations at locations 15 cm from the boundary (surface) 2 metres from the boundary (bottom) and in the free stream at distances of 25 to 150 metres from the closest boundary. The partition of kinetic energy among the mean flow, the tidal oscillations and the residual is shown in Table 7. In the free-stream flow 81% of the kinetic energy is contained within the tidal oscillations which are 13.5 times as energetic as the mean flow. Near the boundaries, however, the proportion of the kinetic energy in the tidal oscillation decreases drastically. It therefore appears that the boundaries have a much stronger effect on the tidal oscillations than on the mean flow. These data imply that the effective boundary layer thickness for the tidal flow is greater than that for the mean flow.

The tidal streams can be characterized by a form number in much the same way as the tidal heights. The form numbers are computed with the sizes of the major ellipse axes for the four major tidal constituents. The average of the tidal stream form numbers in Byam and Austin Channels and Crozier and Pullen Straits is 1.4 which is characteristic of a mixed mainly semi-diurnal tide. The form number for the tidal streams is between 3 and 7 times larger than that computed for the tidal heights. The tidal currents, therefore, have a significantly stronger diurnal component than the tidal heights. Figure 31 on page 50 shows a large phase difference for the diurnal components (~30°) between Wellington Channel and Penny Strait. For the semi-diurnal components, the phase difference is roughly 10°. The larger phase difference in the diurnal oscillations will provide a larger sea surface slope and could force stronger diurnal oscillations.

The absence of a strong M_2 signal in current records in locations where it dominates tidal height records has been noted at other locations north of 75°, e.g. the West Spitsbergen Current (Greisman, 1976). The possibility therefore remains that this is not a localized phenomenon. Explanation in terms of the critical latitude for internal waves however, appears to be inapplicable in this region due to the relatively small internal tides discussed below.

The current data in Byam and Austin Channels do not permit resolution of internal oscillations. The data set from Crozier and Pullen Straits, however, contains measurements made at several mid-depth locations as well as CTD casts

TABLE 7

% KINETIC ENERGY OF THE TIDAL AND MEAN FLOWS

CROZIER STRAIT

	MEAN	TIDAL	RESIDUAL	$\frac{TIDAL}{MEAN}$
SURFACE	29	55	16	1.90
MID-DEPTH	6	81	13	13.5
BOTTOM	11	64	25	5.82

performed hourly over the tidal cycle. Knowledge of the tidal oscillations at several levels as well as the tidal mean density structure is, therefore available so that the modal structure for the internal waves can be determined. It must be borne in mind in what follows however, that most of the current measurements were made within the frictional boundary layer. The influence of friction on the near-boundary tidal oscillations is certain to affect the results of the internal tide-modal decomposition.

Internal Waves

The mode structures are the vertical standing waves between the surface and the bottom which modulate the amplitude of the oscillations of vertical excursion and vertical and horizontal particle velocities associated with the wave motion. The equation whose eigenfunctions are the internal modes is:

$$\frac{d^2w}{dz^2} + \frac{N^2(Z) - \omega^2}{\omega^2 - f^2} K_h^2 \quad w = o \qquad 4.1$$

where w is the vertical particle velocity of the wave

$N(z)$ is the Vaisala frequency, which varies with depth
ω is the wave frequency
f is the Coriolis parameter
K_h is the horizontal wave number

For a constant Vaisala frequency, $\frac{N^2(Z) - \omega^2}{\omega^2 - f^2}$ is a constant and the eigenfunctions for the vertical velocity are sines and cosines. The boundary conditions of $w = 0$ at $z = 0, -H$ eliminate the cosines so that

$$w = A_1 \sin \frac{n\pi}{H} z \qquad 4.2$$

where n is the internal mode number. The mode structure of the vertical excursions is identical to that of the vertical particle velocities while the mode structure for the horizontal velocities is the z derivative of the vertical velocity modes, i.e.

$$u \propto \frac{dw}{dz} \qquad 4.3$$

where u is the horizontal particle velocity. The mode structures of the horizontal currents are, therefore cosines in z

$$u = A_2 \frac{n\pi}{H} \cos \frac{n\pi}{H} z \qquad 4.4$$

The vertical excursions and particle velocities of long internal waves in a constant N fluid are zero at the boundaries and maximum at mid-depth while the horizontal particle velocities are maximum at the surface and bottom and zero at mid-depth. The constant N condition is rarely met, however, so 4.2 must be solved for $N=N(z)$.

The tidally averaged density profile in Crozier Strait was computed and equation 4.2 numerically solved using a program developed by Fryer for Coastal Zone Oceanography, Institute of Ocean Sciences, Patricia

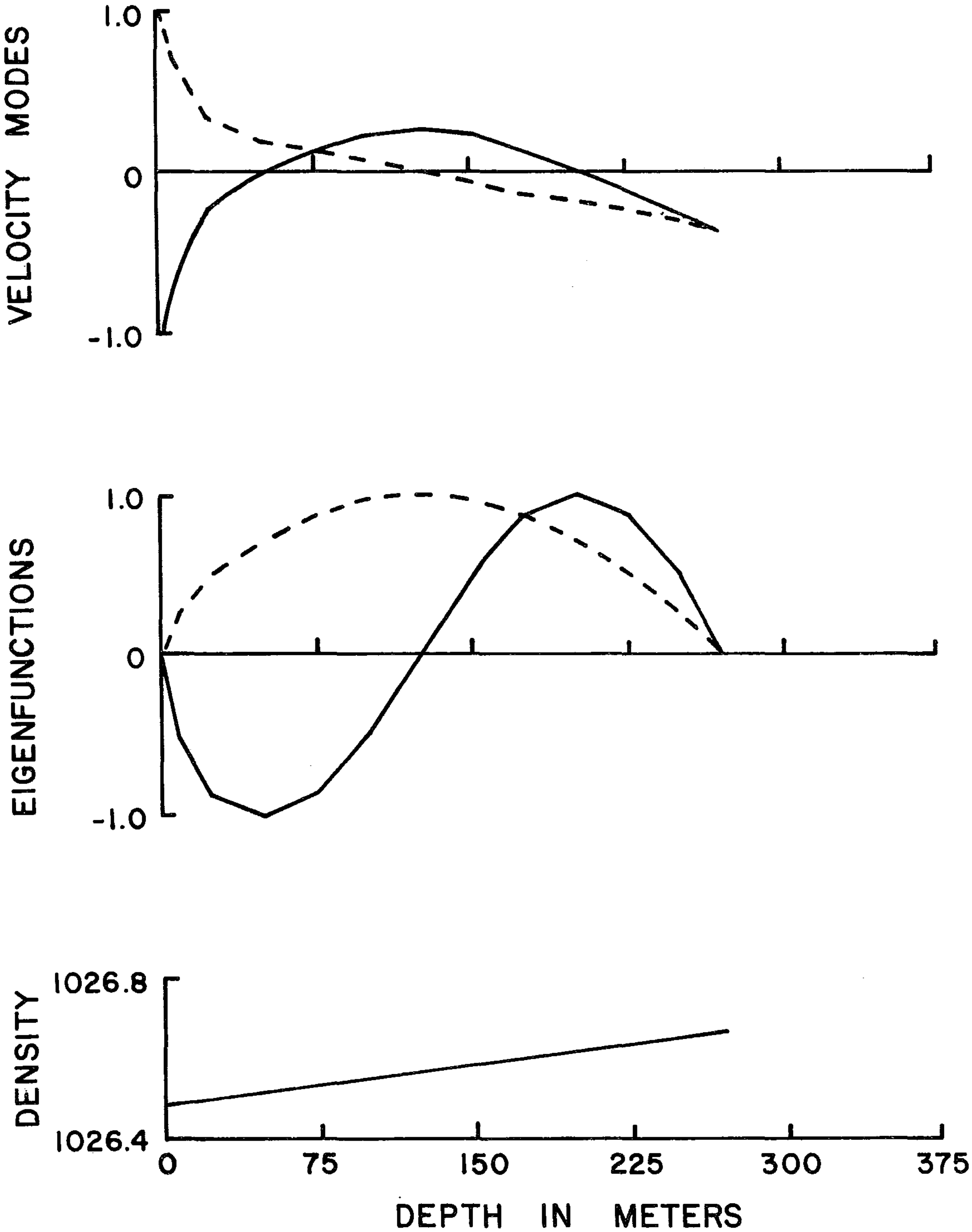


FIGURE 32. a Mode structures, constant $\frac{\partial \rho}{\partial z}$ Eigenfunctions are the structures of the vertical excursions of the waves, the velocity modes are the structures of the horizontal velocity. Broken curve is first mode; solid curve, second mode.

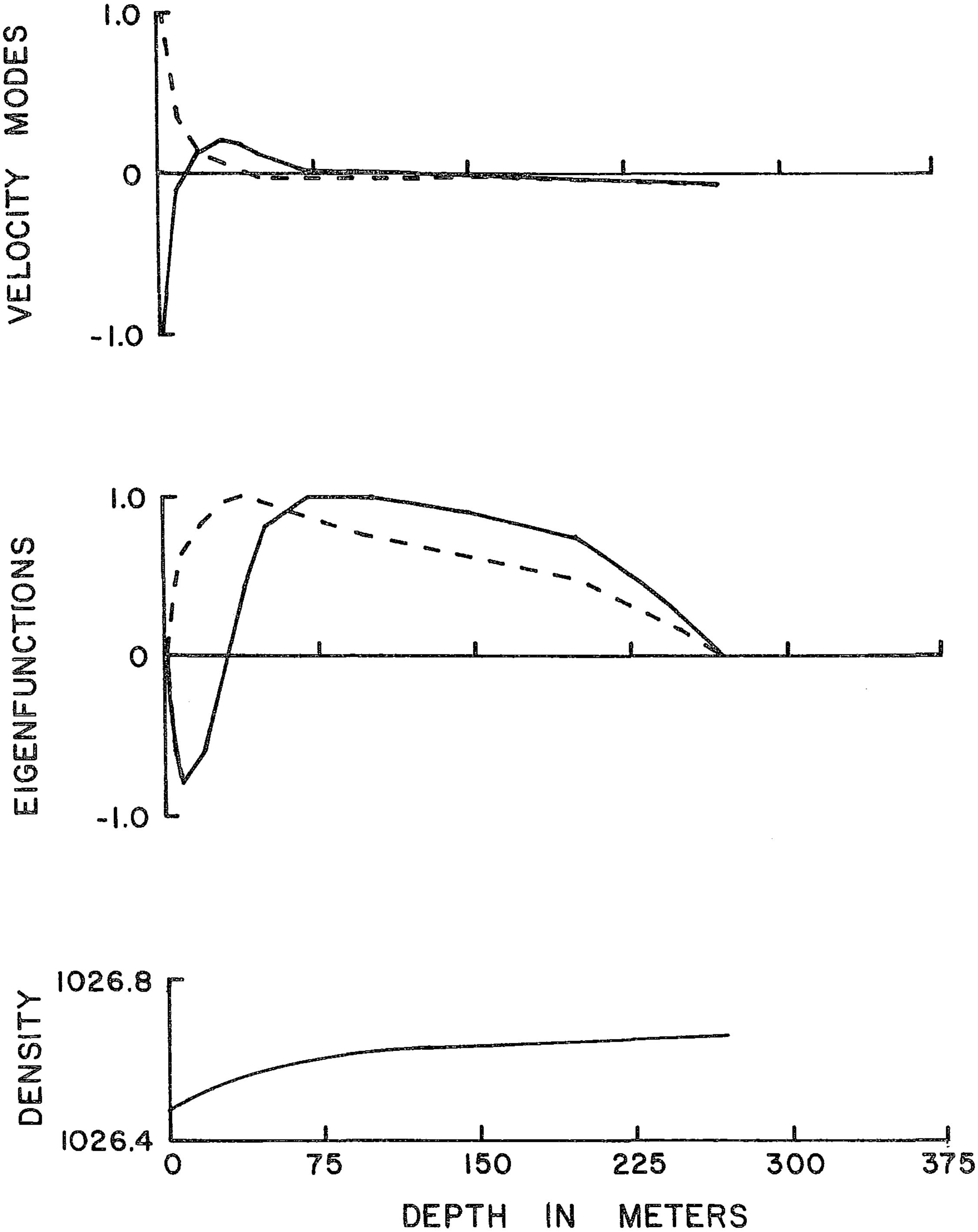


FIGURE 32. b Same as 32a except realistic ∂ρ/∂z.

Bay. We compared the modal structures computed by this method for the approximation of a constant density gradient (nearly a constant Vaisala frequency) and the actual stratification which is stronger near the surface. The total density difference between the surface and the bottom was held constant. The results of the computation for the first two internal modes are shown in Figure 32 a and b. The mode structure is clearly strongly affected by a relatively small change in the shape of the density profile. It should be borne in mind that relatively large variations in the Vaisala frequency are present over a tidal cycle at a given depth ($\sim 0.5 \times 10^{-3}$ s^{-1}) while the total difference in Vaisala frequency between surface and bottom is only $\sim 1.5 \times 10^{-3}$ s^{-1} . In the following modal decomposition we use a modal structure which was computed according to the method of Roberts (1975) utilising a smooth exponential fit to the Vaisala frequency profile Figures 33, a and b.

The observations of the tidal currents at each frequency must now be decomposed into a barotropic and one or more baroclinic modes. Since the eigenfunctions are orthogonal a linear combination of them will fit the observations exactly. In particular, with current data from 4 levels it is possible to precisely reproduce the observations with a barotropic and the first three baroclinic modes, by solving a set of simultaneous equations at each site for each frequency:

$$X_{jk} = U_{ji} A_{ik} \qquad 4.5$$

where X_{jk} is the size of the semi-major axis of the tidal ellipse of the k th constituent at depth j

U_{ji} is the amplitude factor from the modal structure for the i th internal mode at depth j

A_{ik} is the amplitude of the i th internal mode for the k th tidal constituent

This method, in providing an exact fit, furnishes no statistical confidence which is particularly unfortunate with these data most of which were recorded within a boundary layer. In fact such large values for the amplitudes of the internal modes were computed that severe doubts were cast on the suitability of the method.

An altogether more satisfactory procedure for modal decomposition is due to Freeland (personal communication). By computing one fewer mode amplitude than possible with the number of current meters at one location he introduces a redundancy which provides for the best least square fit of n-2 internal modes to an array of n current observations. The method multiplies the data from each meter with a weight computed from the modal structure. The weighted data sets can then be Fourier transformed and combined to yield the amplitude of the modes. We have modified Freeland's method slightly by first performing the tidal stream analysis on each data set and then weighting the amplitudes and phases of the tidal ellipse major axes.

In more detail, a matrix of the mode structure is constructed, e.g.

$$U_{ji} = \begin{pmatrix} 1 & 1 & 1 \\ 2 & -0.6 & -0.7 \end{pmatrix}$$

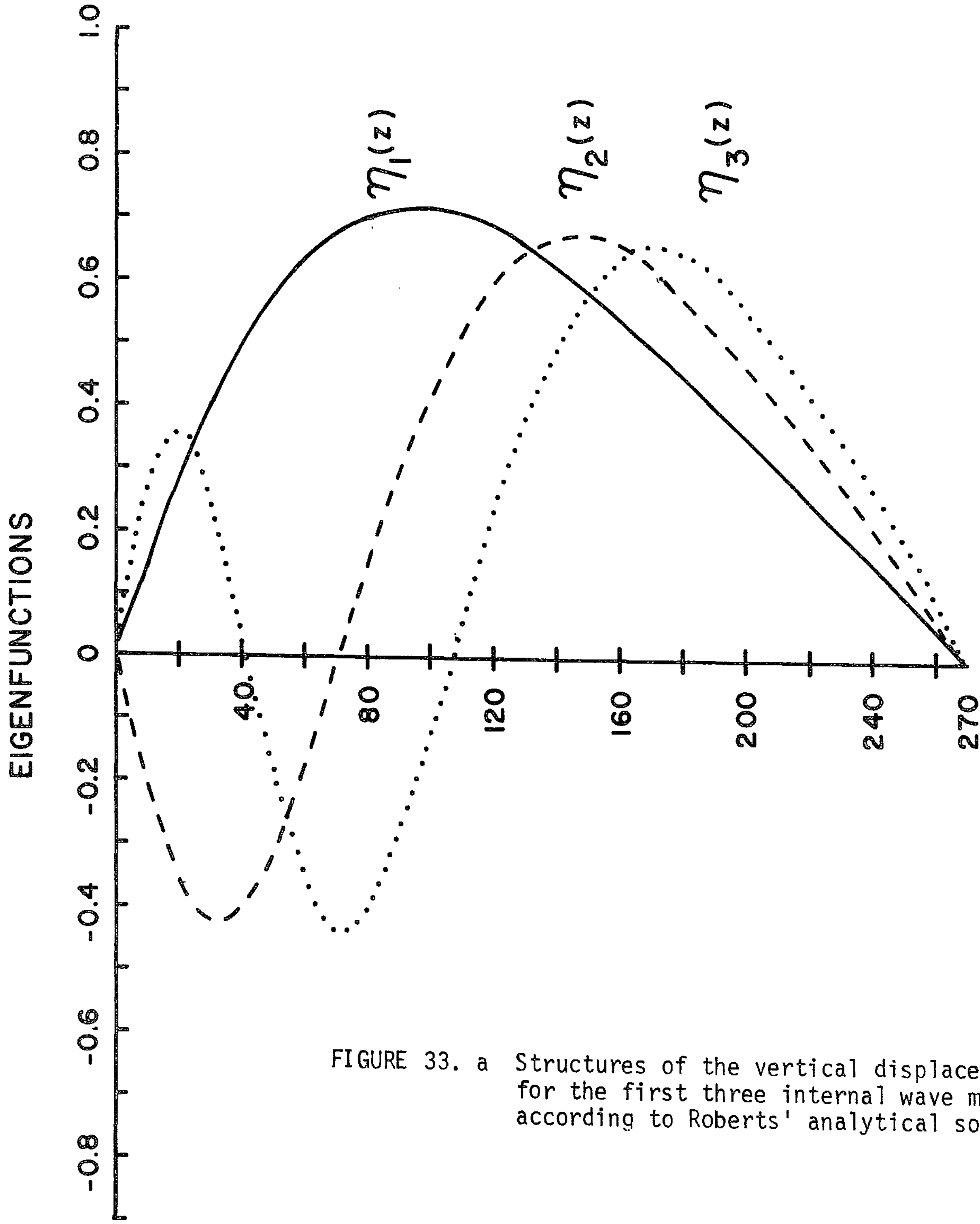


FIGURE 33. a Structures of the vertical displacements for the first three internal wave modes according to Roberts' analytical solution.

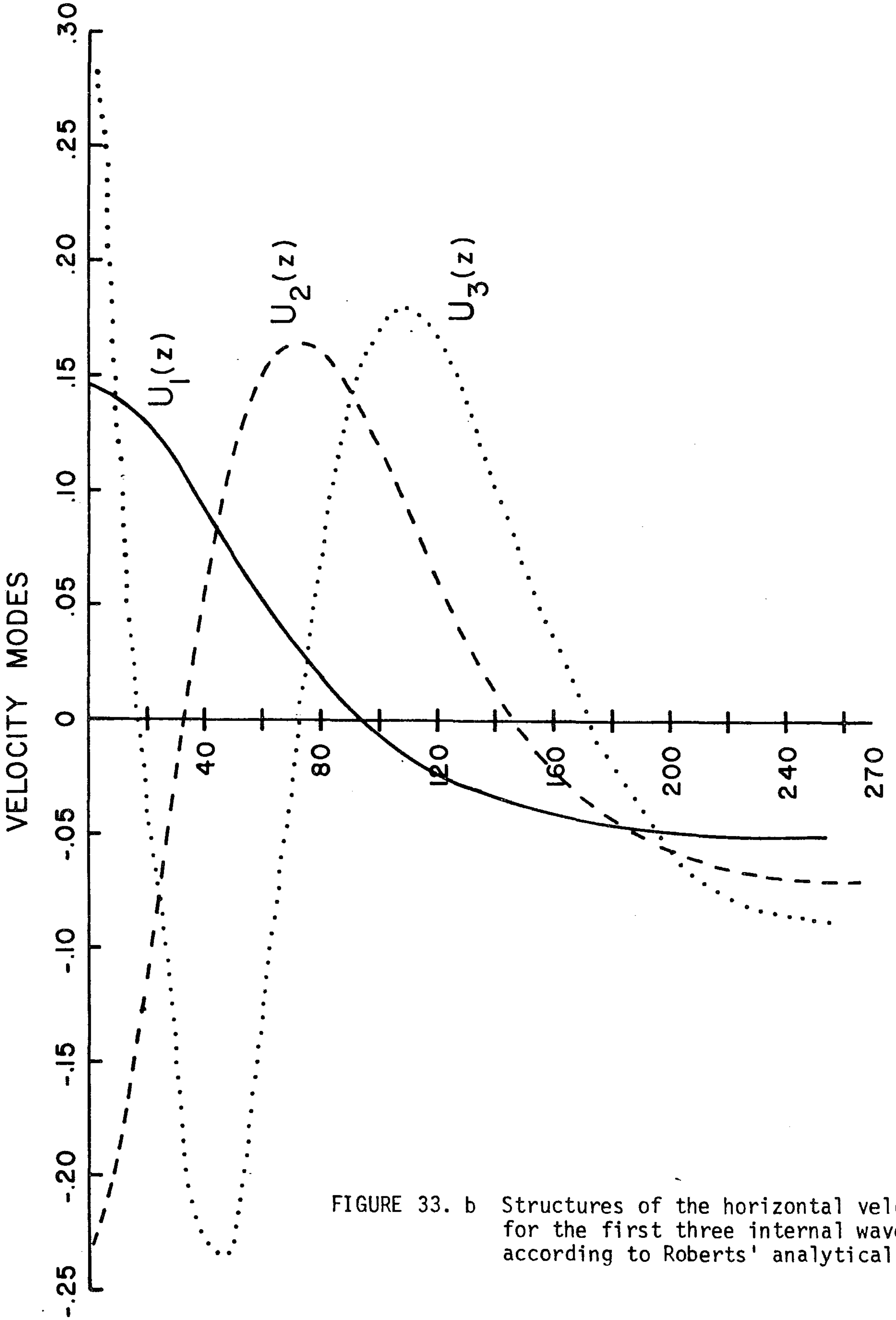


FIGURE 33. b Structures of the horizontal velocities for the first three internal wave modes according to Roberts' analytical solution.

Here the first row represents the structure of the zero th or barotropic mode which is constant with depth and the second row represents the relative current magnitudes at the depths of observation of three current meters for the first internal mode.

The matrix equation

$$X = UA \qquad 4.5$$

must be solved as in the first method, but now U is a non-square matrix of mode structures. In order to solve for A, the modal amplitudes, an inverse of U must be computed. Freeland demonstrates that the Moore-Penrose inverse will provide the best fit of modal amplitudes to the data in the least squares sense, and,

$$U^{-1} = U^T \left[U\, U^T \right]^{-1} \qquad 4.6$$

$$A = U^{-1} X \qquad 4.7$$

Each of the values in the matrix X is complex, i.e., has an amplitude and phase which correspond to the size of the semi-major ellipse axis and G respectively. The modal decomposition utilizing this method produces results which are intuitively quite satisfying for a weakly stratified fluid even though the data quality for this sort of computation is severely limited by the placement of the current meters in the boundary layers. Table 8 lists the surface currents arising from the various internal modes. The amplitudes of the internal modes are generally about an order of magnitude smaller than the barotropic mode. It was possible to compute the amplitude of the second internal mode only at site C5. Here, for each of the tidal constituents, the amplitude of the second mode was found to be considerably larger than the amplitude of the first mode. This is somewhat unusual and is almost certainly due to the location of the measurements. The mid-depth meters always displayed larger tidal oscillations than the surface and bottom meters which were located in the boundary layers. The mode which best fits such an increase in tidal velocities near mid-depth is the second (see Figure 33). We therefore feel that the amplitude of the second mode has been greatly exaggerated. In fact the internal oscillation in Crozier and Pullen Straits, in particular (and probably in the nearly homogeneous tidal channels near Bathurst Island in general) appear to account for less than 5% of the tidal kinetic energy.

It should perhaps be pointed out as a post script that internal tides of some significance <u>are</u> sustainable in the weak stratifications of the channels near Bathurst Island. We can quickly examine the Richardson Number criterion for stability in a stratified shear flow:

$$R_i = \frac{\frac{-g}{\rho}\frac{\partial \rho}{\partial z}}{(\partial u/\partial z)^2} = \frac{N^2}{(\partial u/\partial z)^2} > 1/4 \qquad 4.8$$

TABLE 8. SURFACE CURRENTS FOR BAROTROPIC AND BAROCLINIC TIDE WAVES, CROZIER STRAIT.
(Freeland's Method)

SITE	O_1			K_1			M_2			S_2		
	BT	1st	2nd	BT	1st	2nd	BT	1st	2nd	BT	1st	2nd
C 1	9.75	+0.29		12.60	+0.88		9.68	-1.17		6.22	-1.55	
C 2	7.16	-0.15		12.83	-1.51		10.59	-0.91		6.47	-0.60	
C 3	6.00			10.00			7.00			4.00		
C 4	5.74	-0.71		8.91	-0.74		5.68	0.83		3.17	-0.94	
C 5	6.07	-0.14	-1.24	9.10	+0.02	-2.15	6.61	-0.71	-1.97	3.62	-0.52	-1.03
C 6	5.50			8.55			5.25			2.65		
P 3	7.36	-1.31		12.82	-2.54		13.03	-2.42		5.93	-1.06	

Using values for the Vaisala frequency from Crozier Strait and assuming the shear occurs over 50 m of water column

$$\delta u < (\delta z)\ (2)\ (N) \simeq 0.1\ \mathrm{m\ s^{-1}}$$

About 10 cm s^{-1} over 50 m depth or 2 x 10^{-3} s^{-1} shear can be maintained before the onset of instability. We therefore have no a priori justification in minimizing the importance of internal tide-related currents in this region.

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APPENDIX A

CURRENT HISTOGRAMS

The following histograms were prepared for each, complete current meter record. The number of occurences within a speed and direction range is located in the corresponding row and column. The marginal distributions for the speed ranges summed over all direction ranges is located at the bottom of the page, while the marginal distribution for the direction ranges summed over all speed ranges is located at the right-hand side of the page.

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM Ø   Ø4Ø82ØØ476 GMT 1(T) 23Ø6 BYAM CHANNEL 1   753271Ø5252 6Ø   V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	6	29	8																							43
1Ø- 19	4	2Ø	18																							42
2Ø- 29		22	27	9																						58
3Ø- 39	9	44	64	32																						149
4Ø- 49	4	55	49	13																						121
5Ø- 59	12	63	29	2																						1Ø6
6Ø- 69	6	63	1Ø																							79
7Ø- 79	7	32	6																							45
8Ø- 89	14	36	5																							55
9Ø- 99	3	14	6																							23
1ØØ-1Ø9	1	6	3																							1Ø
11Ø-119	2	13	7																							22
12Ø-129	2	16	6																							24
13Ø-139	1	13	13																							27
14Ø-149	2	19	21	1																						43
15Ø-159	1	15	19	2																						37
16Ø-169		5	8																							13
17Ø-179		11	18	2																						31
18Ø-189	3	16	15	5																						39
19Ø-199	4	15	7	2																						28
2ØØ-2Ø9	2	18	16	5																						41
21Ø-219	12	35	67	7	2																					123
22Ø-229	31	116	114	52	13																					326
23Ø-239	26	86	49	1Ø																						171
24Ø-249	4	19	1Ø	2																						35
25Ø-259	2	22	13																							37
26Ø-269	3	24	9	1																						37
27Ø-279	9	19	11																							39
28Ø-289	7	32	12																							51
29Ø-299	4	16	9																							29
3ØØ-3Ø9	6	2Ø	5	1																						32
31Ø-319	17	57	4																							78
32Ø-329	7	58	11																							76
33Ø-339	4	28	5																							37
34Ø-349		9	1																							1Ø
35Ø-359	2	12	8																							22
	217	1Ø78	683	146	15	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	2139

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   167

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM Ø 16Ø722Ø476 GMT 2(T) 1998 BVAM CHANNEL 2 753Ø21Ø5Ø87 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	9	2Ø	34	2Ø	4		1					1														89
1Ø- 19	1	1Ø	22	6	3		2	1																		45
2Ø- 29	7	17	39	18	9																					9Ø
3Ø- 39	1	16	39	18	11																					85
4Ø- 49	1	2Ø	2Ø	14	5		1		1																	62
5Ø- 59		12	17	9	1		1																			4Ø
6Ø- 69		11	12	1																						24
7Ø- 79		2																								2
8Ø- 89	1	5	5	3	1		1																			16
9Ø- 99		5	6	1			1																			13
1ØØ-1Ø9		7	2	1																						1Ø
11Ø-119	2	4	2	1																						9
12Ø-129	1	7	5	1																						14
13Ø-139	2	13	6	1	1																					23
14Ø-149	4	18	12	3	1		2																			4Ø
15Ø-159	1	14	18	2	1																					36
16Ø-169	1	7	13	3		2	1																			27
17Ø-179	4	36	39	27	6	3	2	2	2							1										122
18Ø-189	9	43	62	54	29	11	6	7	2	3	3	2	1				1			1						234
19Ø-199	3	18	4Ø	46	17	6	4	3	3			4														144
2ØØ-2Ø9	4	36	97	65	18	1Ø	9	4	5	1		1		1								1				252
21Ø-219	1	22	35	22	8		1		1																	9Ø
22Ø-229	2	12	2Ø	7	3	3	1	1		1															1	51
23Ø-239	1	11	8	5		1																				26
24Ø-249		8	4	2	2					1																17
25Ø-259	1	5	4	2		1																				13
26Ø-269		8	5	1																						14
27Ø-279		9	5		1	1			1																	17
28Ø-289	1	4	1				1																			7
29Ø-299		12	2	1	1		2																			18
3ØØ-3Ø9	3	13	6																							22
31Ø-319	2	15	7	2	1	1																				28
32Ø-329	4	16	5	11	1	1	2	1																		41
33Ø-339	1	24	2Ø	11	3	1	1	1																		62
34Ø-349	3	21	1Ø	7	2	1		1		1																46
35Ø-359	7	37	32	12	11		1																			1ØØ
	77	538	655	377	14Ø	42	4Ø	21	15	7	3	8	1	1	Ø	1	1	Ø	Ø	1	Ø	1	Ø	Ø	1	193Ø

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 68

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM 85 1223100576 GMT 2(B) 1396 BYAM CHANNEL 2 75302105087 60 395TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9		3	1	1		3	2		2																	12
10- 19	2	8	5	2			1	2																		20
20- 29	2	8	4	2	1	1		3																		21
30- 39	2	26	5	1	1				1																	36
40- 49	4	19	16	1		1																				41
50- 59	4	36	30	10																						80
60- 69	4	23	20	8	1																					56
70- 79	5	36	46	12																						99
80- 89	1	32	59	20	1																					113
90- 99		15	15	4																						34
100-109	1	27	32	10																						70
110-119	1	14	9	1																						25
120-129	3	14	5																							22
130-139	1	4	5																							10
140-149	1	7	2	1																						11
150-159	2	6	2																							10
160-169		5	1																							6
170-179	1	5	3	2		1																				12
180-189	2	4	2	1																						9
190-199		3	5																							8
200-209		4	1																							5
210-219	1	9	6	2																						18
220-229		9	14	5	1		1																			30
230-239	1	9	22	4	3																					39
240-249	4	23	22	10	2																					61
250-259	3	26	27	10	1																					67
260-269	3	22	20	11	1																					57
270-279	2	18	13	6	1																					40
280-289	3	15	22	9																						49
290-299	1	8	4	3	1																					17
300-309	1	7	10	3																						21
310-319	1	6	7	2																						16
320-329		7	3	3																						13
330-339		6	3	1				1																		11
340-349	1	4	8																							13
350-359	1	5	2						1																	9
	58	473	451	145	14	6	4	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1161

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 51

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM 62   2422100576 GMT 3(B) 1274 BYAM CHANNEL 3   75269104574 60 216TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	1	3	9	17	4	3																				37
10- 19		3	13	13	7	1	1																			38
20- 29		4	11	6	4																					25
30- 39		1	3	2																						6
40- 49		4	5	4																						13
50- 59		4	10	2																						16
60- 69		4	10	4																						18
70- 79		7	12	3																						22
80- 89		1	3	1																						5
90- 99	1	1	3	1																						6
100-109		3	2	3																						8
110-119		4	4	5																						13
120-129		3	9	8	4																					24
130-139	1	4	11	33	5																					54
140-149		2	10	27	9	2																				50
150-159	1	5	14	20	6		2																			48
160-169	1	6	18	21	6																					52
170-179		5	14	18	12		1																			50
180-189	1	5	13	22	14	1		1																		57
190-199		4	12	11	10		1																			38
200-209			2	5	8	1																				16
210-219		2	3	4	4																					13
220-229		3	2	2	2	1	1																			11
230-239		1		1	1																					3
240-249	1	5	1	4																						11
250-259		3	4																							7
260-269	1	3	1																							5
270-279		1	2																							3
280-289			1	1																						2
290-299		3	4	3																						10
300-309		2	3						1																	6
310-319		3	3			1																				7
320-329		1	1	2																						4
330-339		2	13	1																						16
340-349	1	3	8	3	1																					16
350-359			5	9	1																					15
	9	105	240	256	99	10	6	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	727

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   1

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM Ø 4Ø2128Ø476 GMT 4(T) 1464 BYAM CHANNEL 4 752691Ø4574 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1Ø	34	27	9																						8Ø
1Ø- 19		17	21	4																						42
2Ø- 29	8	49	61	15	4	1																				138
3Ø- 39	4	27	32	4	2																					69
4Ø- 49	3	18	9	2																						32
5Ø- 59	2	17	6	1																						26
6Ø- 69	1	11	2																							14
7Ø- 79	1	1																								2
8Ø- 89		3	1																							4
9Ø- 99	1	5	1				1																			8
1ØØ-1Ø9	1	5																								6
11Ø-119	1	3																								4
12Ø-129	1	6				1																				8
13Ø-139	3	4	2		1																					1Ø
14Ø-149	3	7	3	1																						14
15Ø-159	1	7	4	3	1																					16
16Ø-169	1	5	8	5																						19
17Ø-179	2	25	25	8	2																					62
18Ø-189	8	32	61	42	8	3	1	1	1																	157
19Ø-199	1	34	47	28	15				1																	126
2ØØ-2Ø9	11	57	95	49	13		1	1																		227
21Ø-219	5	38	37	13	8																					1Ø1
22Ø-229	2	19	17	2	1	1	1																			43
23Ø-239	5	14	1																							2Ø
24Ø-249	3	7	1																							11
25Ø-259		5																								5
26Ø-269	1	5	3																							9
27Ø-279	2	5	2	1			1																			11
28Ø-289	5	4		1																						1Ø
29Ø-299	2	1	2																							5
3ØØ-3Ø9	2	1Ø	2																							14
31Ø-319	6	1Ø	7																							23
32Ø-329	4	1Ø	2																							16
33Ø-339	4	17	5	1																						27
34Ø-349	1	9	2																							12
35Ø-359	7	25	11	1																						44
	112	548	497	19Ø	55	6	5	2	2	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1417

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 47

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM Ø 522Ø12Ø576 GMT 5(T) 176Ø BYAM CHANNEL 5 752551Ø4378 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	2Ø	39	25	2Ø	7	1																			113
1Ø- 19	2	13	23	27	5	4																				74
2Ø- 29		2Ø	31	19	8	4	1																			83
3Ø- 39		31	29	11	1																					72
4Ø- 49	1	26	12	6																						45
5Ø- 59	1	16	11	5	1																					34
6Ø- 69	2	2Ø	1Ø	7	1																					4Ø
7Ø- 79		11																								11
8Ø- 89		2	5	2	1																					1Ø
9Ø- 99	6	18	4	1	1																					3Ø
1ØØ-1Ø9		16	4	1																						21
11Ø-119		1Ø	3																							13
12Ø-129	2	17	13	1																						33
13Ø-139	1	23	7																							31
14Ø-149	1	22	18	11	5																					57
15Ø-159	3	39	33	2Ø	4	3																				1Ø2
16Ø-169	3	53	39	24	6	3																				128
17Ø-179	7	34	38	23	3	2																				1Ø7
18Ø-189	1Ø	51	63	25	9	1	3				1															163
19Ø-199	6	29	16	4	4	1																				6Ø
2ØØ-2Ø9	5	26	21	6		1	1	1																		61
21Ø-219	2	12	16	5																						35
22Ø-229	1	13	7	2	1																					24
23Ø-239		6	6	1																						13
24Ø-249	1	8	4	2																						15
25Ø-259	2	2	3		1																					8
26Ø-269	1	2	4	2																						9
27Ø-279	1	5	3																							9
28Ø-289			5	1																						6
29Ø-299		5	8	3																						16
3ØØ-3Ø9		4	6	3	1																					14
31Ø-319		6	11	2																						19
32Ø-329		12	13	2																						27
33Ø-339		11	17	6	2																					36
34Ø-349	1	5	7	8	4																					25
35Ø-359		15	18	16	2	4	1																			56
	6Ø	6Ø3	547	271	81	3Ø	7	1	Ø	Ø	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	16Ø1

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 159

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM 44 4822120576 GMT 5(B) 1141 BYAM CHANNEL 5 75255104378 60 504T V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	7	6	1																						15
1Ø- 19		11	15	2																						28
2Ø- 29		7	15	5																						27
3Ø- 39	1	9	18	12	4	2																				46
4Ø- 49		18	31	3Ø	2Ø	6																				1Ø5
5Ø- 59		9	25	23	7	5	1																			7Ø
6Ø- 69		14	18	11	5	3	1																			52
7Ø- 79		4	3																							7
8Ø- 89	1	4	8	1																						14
9Ø- 99		9	2																							11
1ØØ-1Ø9		1	3																							4
11Ø-119		4	2																							6
12Ø-129		7	3																							1Ø
13Ø-139		3	1																							4
14Ø-149		7	5																							12
15Ø-159		9	5																							14
16Ø-169		6	11	2																						19
17Ø-179	1	11	8	2																						22
18Ø-189		7	13	4	1																					25
19Ø-199	1	7	12	5																						25
2ØØ-2Ø9		3	12	3	6																					24
21Ø-219		6	13	11	6	1																				37
22Ø-229		5	2Ø	16	23	2																				66
23Ø-239	1	19	23	15	11	1																				7Ø
24Ø-249	1	11	13	5	6	2																				38
25Ø-259	4	17	9	3																						33
26Ø-269		6	6	1																						13
27Ø-279		11	1																							12
28Ø-289	1	7	1																							9
29Ø-299		7	1																							8
3ØØ-3Ø9		3																								3
31Ø-319		5	3																							8
32Ø-329		5	1																							6
33Ø-339		7	1																							8
34Ø-349		8																								8
35Ø-359	1	7	4																							12
	13	282	312	152	89	22	2	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	872

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 7

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS Ø 1Ø171ØØ576 GMT I(T) 1732 AUSTIN CHANNEL I 752521Ø35Ø1 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
																										25
Ø- 9	4	14	7																							9
1Ø- 19	1	7	1																							36
2Ø- 29	5	2Ø	1Ø	1																						59
3Ø- 39	9	29	14	7																						6Ø
4Ø- 49	5	29	22	3	1																					65
5Ø- 59	7	28	29	1																						5Ø
6Ø- 69	1	26	17	6																						25
7Ø- 79	2	16	6	1																						75
8Ø- 89	4	41	21	9																						127
9Ø- 99	4	48	62	11	2																					77
1ØØ-1Ø9	7	24	31	12	2	1																				2Ø8
11Ø-119	5	48	88	53	13	1																				147
12Ø-129	5	58	36	35	13																					33
13Ø-139	5	15	1Ø	3																						25
14Ø-149	7	17	1																							33
15Ø-159	6	25	2																							7
16Ø-169	5	2																								14
17Ø-179	6	8																								24
18Ø-189	1Ø	14																								13
19Ø-199	2	9	2																							23
2ØØ-2Ø9	2	15	6																							24
21Ø-219	2	12	9	1																						32
22Ø-229	2	19	11																							38
23Ø-239	5	18	12	1	2																					49
24Ø-249	1	15	25	6	2																					53
25Ø-259	3	12	25	11	2																					69
26Ø-269		12	26	24	6	1																				79
27Ø-279	5	23	21	21	8	1																				28
28Ø-289	2	6	7	12	1																					48
29Ø-299	6	11	2Ø	6	5																					21
3ØØ-3Ø9	4	13	3	1																						14
31Ø-319	3	1Ø	1																							13
32Ø-329		12	1																							22
33Ø-339	3	18	1																							15
34Ø-349	3	1Ø	2																							19
35Ø-359	2	17																								
	143	7Ø2	529	225	57	4	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	166Ø

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 72

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS1Ø8 Ø6231ØØ576 GMT 1(B) 1723 AUSTIN CHANNEL 1 75252 1Ø35Ø1 6Ø 771TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	2	21	11	1																						35
1Ø- 19		6	7																							13
2Ø- 29	2	14	5																							21
3Ø- 39	5	2Ø	1Ø	1																						36
4Ø- 49		12																								12
5Ø- 59		1Ø	3																							13
6Ø- 69		15	3																							18
7Ø- 79		6	4	1																						11
8Ø- 89	1	13	6																							2Ø
9Ø- 99		1Ø	6																							16
1ØØ-1Ø9	1	9	18	16	3																					47
11Ø-119		12	23	21	1Ø			1																		67
12Ø-129		12	19	12	3																					46
13Ø-139		2	9	6	2	1																				2Ø
14Ø-149		5	6	4	4																					19
15Ø-159		7	5	2	1																					15
16Ø-169		2	4																							6
17Ø-179		7	2	2																						11
18Ø-189		4	1																							5
19Ø-199	1	4	4		1	1																				11
2ØØ-2Ø9	1	2	4	1		1																				9
21Ø-219		4	3	1																						8
22Ø-229		7	2																							9
23Ø-239		5	2	3		2																				12
24Ø-249		6	7			1	1																			15
25Ø-259	2		2																							4
26Ø-269		1	3	1	1	1	1																			8
27Ø-279		4	6	1	1				1																	13
28Ø-289		4	2	1	3	1		1																		12
29Ø-299	1	9	6	5	5	3	2																			31
3ØØ-3Ø9		9	5	4	6	3	2	1																		3Ø
31Ø-319		5	6	11	3	2	2	2																		31
32Ø-329		15	8	1	4																					28
33Ø-339	1	16	18	1Ø	2																					47
34Ø-349	2	24	17	9	1																					53
35Ø-359	2	35	13	6																						56
	21	342	251	121	5Ø	16	8	5	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	815

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 16

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS Ø 2216Ø9Ø576 GMT 2(T) 129Ø AUSTIN CHANNEL 2 752641Ø3387 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	3	8	1																							12
1Ø- 19	4	7																								11
2Ø- 29	3	13	1																							17
3Ø- 39	3	18	2																							23
4Ø- 49	2	26	5																							33
5Ø- 59	4	31	4																							39
6Ø- 69	6	32	8	1																						47
7Ø- 79	1	15	3	1																						2Ø
8Ø- 89	3	27	5																							35
9Ø- 99	1	3Ø	11	1																						43
1ØØ-1Ø9		27	15			1																				43
11Ø-119	3	15	14	1																						33
12Ø-129		29	46	4	1	1																				81
13Ø-139	1	33	61	24	3																					122
14Ø-149	3	24	64	54	8																					153
15Ø-159	4	18	21	18	1Ø	1																				72
16Ø-169	1	1Ø	6	1	1																					19
17Ø-179		13	1		1																					15
18Ø-189	3	11	2																							16
19Ø-199	1	6																								7
2ØØ-2Ø9		5	1																							6
21Ø-219		2	3																							5
22Ø-229	1	9	1	1																						12
23Ø-239		9	7																							16
24Ø-249	1	13	13		1																					28
25Ø-259	1	12	4	1																						18
26Ø-269	2	19	13		1																					35
27Ø-279	1	22	9	2																						34
28Ø-289	1	16	12	2																						31
29Ø-299	3	16	26	2																						47
3ØØ-3Ø9	4	23	32																							59
31Ø-319	3	21	7	2																						33
32Ø-329	2	16	1Ø	1																						29
33Ø-339	3	7	6	1																						17
34Ø-349	3	6																								9
35Ø-359	5	14																								19
	76	6Ø3	414	117	26	3	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1239

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 51

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS142 1822080576 GMT 2(B) 2518 AUSTIN CHANNEL 2 752641033387 60 454TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	3	22	12	3																						40
10- 19	5	32	13	4																						54
20- 29	3	36	31	6	1																					77
30- 39	5	30	24	12	1																					72
40- 49	3	34	30	17	1																					85
50- 59	3	21	23	5	1																					53
60- 69	5	46	37	12	5																					105
70- 79	3	42	26	7	5	1																				84
80- 89	3	32	18	9	1																					63
90- 99	3	21	5	5																						34
100-109	2	11	7	1																						21
110-119	3	7	3	1																						14
120-129	4	5	5																							14
130-139		10	1	2																						13
140-149	1	4	2																							7
150-159		12	4																							16
160-169	1	15	11	2																						29
170-179		14	15	13	1																					43
180-189	1	21	8	8	2																					40
190-199	2	29	75	38	10	1																				155
200-209	3	54	70	62	32	6																				227
210-219	5	26	41	49	43	9																				173
220-229	1	26	28	32	36	10	5																			138
230-239	2	23	30	36	27	16	7																			141
240-249	2	26	23	45	24	18	6	3																		147
250-259	2	39	38	25	26	20	17	1																		168
260-269	2	17	20	5	23	17	11	3																		98
270-279	2	16	6	6	2	10	5																			47
280-289	1	28	16	2		1	3																			51
290-299	4	18	6	2																						30
300-309	1	10	7	1																						19
310-319	3	18	9	4																						34
320-329		13	20	5	2																					40
330-339	6	18	12	2	1																					39
340-349	1	23	14	2	1																					41
350-359	4	16	4	7																						31
	89	819	694	430	245	109	54	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2447

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 71

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS 0 3417080576 GMT 3(T) 973 AUSTIN CHANNEL 3 75282103216 60 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9		1	1																							2
10- 19		1																								1
20- 29		1	1																							2
30- 39		6																								6
40- 49																										0
50- 59	2	12	1																							15
60- 69		5	9																							14
70- 79		2	5																							7
80- 89	3	19	9	1																						32
90- 99		10	16	1																						27
100-109	1	20	12	1																						34
110-119	4	22	27	5																						58
120-129	12	48	58	19	4																					141
130-139	7	29	57	57	10	5																				165
140-149	1	29	56	50	31	5																				172
150-159	2	14	28	16	9	7																				76
160-169	1	9	11	3																						24
170-179	1	8	10																							19
180-189	1	11	6	1																						19
190-199	1	3																								4
200-209	1	9	5																							15
210-219		8	4	1																						13
220-229		5	2																							7
230-239		7	3	1																						11
240-249		6	4																							10
250-259		2	2																							4
260-269	1	8	5																							14
270-279		8	5																							13
280-289		2	2																							4
290-299		5	2	1																						8
300-309		6	6																							12
310-319	1	6	4																							11
320-329	1	7	3																							11
330-339		1	1																							2
340-349		3																								3
350-359	4	3	1																							8
	44	336	356	157	54	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	964

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 9

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS168   3Ø221ØØ576 GMT 3(B) 1Ø29 AUSTIN CHANNEL 3   75282lØ3216 6Ø 844TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		6	2																							8
1Ø- 19	1	1																								2
2Ø- 29	1	5																								6
3Ø- 39		5																								5
4Ø- 49	1	4																								5
5Ø- 59	2	2	2																							6
6Ø- 69	1	4																								5
7Ø- 79	3	4		1																						8
8Ø- 89	1	8		1																						1Ø
9Ø- 99	2	6	6																							14
1ØØ-1Ø9	6	12	13	6	3	1																				41
11Ø-119	1	1Ø	13	18	9																					51
12Ø-129		1Ø	17	14	13	6	2																			62
13Ø-139		8	17	1Ø	8		1																			44
14Ø-149	4	15	21	2Ø	8																					68
15Ø-159	1	7	14	9	7																					38
16Ø-169	2	14	8	7	5																					36
17Ø-179	5	15	21	9	8																					58
18Ø-189	3	13	14	5	1																					36
19Ø-199	1	16	7		1																					25
2ØØ-2Ø9	3	24	7																							34
21Ø-219		15	7																							22
22Ø-229		22	5																							27
23Ø-239	2	12	9																							23
24Ø-249	2	13	7	1																						23
25Ø-259	2	7	5																							14
26Ø-269	1	15	13	2																						31
27Ø-279	1	11	16	2																						3Ø
28Ø-289	3	11	6	14	1																					35
29Ø-299	3	13	19	16	7	2																				6Ø
3ØØ-3Ø9		14	16	13	11																					54
31Ø-319		9	7	17	7	3																				43
32Ø-329	2	4	9	5	8																					28
33Ø-339		7	5	5	2																					19
34Ø-349		6	2																							8
35Ø-359		2	3																							5
	54	35Ø	291	175	99	12	3	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	984

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   22

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS Ø 4519Ø3Ø576 GMT 4(T) 19Ø2 AUSTIN CHANNEL 4 753Ø21Ø3Ø1Ø 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	3	11	4																							18
1Ø- 19	3	7	1																							11
2Ø- 29	4	6	4																							14
3Ø- 39	4	14	4																							22
4Ø- 49	5	2Ø	6	1																						32
5Ø- 59	5	21	14	3	1																					44
6Ø- 69	1	17	8	1																						27
7Ø- 79	1	19	15	4																						39
8Ø- 89	3	25	42	1Ø	1																					81
9Ø- 99	3	4Ø	39	26	1																					1Ø9
1ØØ-1Ø9		8	21	11	4																					44
11Ø-119	2	54	96	47	21	1																				221
12Ø-129	1	41	112	73	34	4																				265
13Ø-139	2	39	9Ø	79	54	12																				276
14Ø-149		34	67	65	38	11	3																			218
15Ø-159	3	17	24	28	9	4																				85
16Ø-169	2	8	8	3	1	1																				23
17Ø-179	1	19	16	3																						39
18Ø-189	4	15	13	3																						35
19Ø-199	1	6	1																							8
2ØØ-2Ø9	1	13	4	2		1																				21
21Ø-219	2	1Ø	5	2																						19
22Ø-229	3	8	4																							15
23Ø-239	1	12	8	2																						23
24Ø-249	3	12	7																							22
25Ø-259		1	2	1																						4
26Ø-269	1	8	1Ø	2																						21
27Ø-279	2	7	4																							13
28Ø-289		7	3																							1Ø
29Ø-299	3	5	6																							14
3ØØ-3Ø9		7	2																							9
31Ø-319	1	8																								9
32Ø-329	2	15	2																							19
33Ø-339	4	12	1																							17
34Ø-349		7	1																							8
35Ø-359	6	17	6																							29
	77	57Ø	65Ø	366	164	34	3	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1864

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 38

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS240   4222100576 GMT 4(B) 1045 AUSTIN CHANNEL 4   75302103010 60 118TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	1	3	3		1																					8
10- 19	1	2	2																							5
20- 29	2	1																								3
30- 39	1	2	3																							6
40- 49	1	1																								2
50- 59			1																							1
60- 69	1		5																							6
70- 79	2		2																							4
80- 89		2	3	1																						6
90- 99		2	4	1																						7
100-109			6	1																						7
110-119	1	4	9	1	1																					16
120-129		2	10	5	3	1																				21
130-139		6	23	8	6	1																				44
140-149	1	2	9	8	5																					25
150-159		4	5	7	6	1																				23
160-169	2	4	9	9	5																					29
170-179	2	4	9	7	4	5	2																			33
180-189		4	15	16	8	8	1																			52
190-199	1	4	13	9	4	6	1																			38
200-209	2	5	9	5	1	3																				25
210-219	2	13	6	4	2	2																				29
220-229	1	5	8	1	3	1																				19
230-239		4	10		1	1																				16
240-249	1	6	7	3		1																				18
250-259		2	5		1																					8
260-269		5	5	2	1																					13
270-279		3	4	3	1																					11
280-289	2		4	2	1																					9
290-299		6	15	4	4																					29
300-309		7	8	7	6		1																			29
310-319		1	10	12	4	7	2	1																		37
320-329		8	9	9	15	8	5	1																		55
330-339	2	2	7	4	6	7	3		1																	32
340-349	1	3	1	5	1	6	2			1																20
350-359	2	6	3			1	1																			13
	29	123	242	134	90	59	18	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	699

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   11

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS Ø 5817Ø2Ø576 GMT 5(T) 998 AUSTIN CHANNEL 5 75315102492 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
																										14
Ø- 9	1	7	6																							5
1Ø- 19		5																								23
2Ø- 29	4	16	3																							18
3Ø- 39	4	9	4	1																						16
4Ø- 49		6	8	2																						24
5Ø- 59		9	11	2			2																			34
6Ø- 69	1	7	17	5	3	1																				14
7Ø- 79	1	6		2	1	4																				41
8Ø- 89		7	15	8	1	8	2																			65
9Ø- 99		8	16	18	12	9	2																			34
1ØØ-1Ø9		4	11	3	8	6	2																			56
11Ø-119		5	21	12	13	5																				94
12Ø-129		19	33	2Ø	14	6	2																			75
13Ø-139	2	9	24	26	1Ø	4																				124
14Ø-149	1	22	36	37	24	4																				62
15Ø-159		11	23	2Ø	5	3																				18
16Ø-169		3	6	8	1																					15
17Ø-179		1	7	6	1																					22
18Ø-189		2	11	5	3		1																			8
19Ø-199	1	2	3	2																						3
2ØØ-2Ø9		1	2																							5
21Ø-219		1	3	1																						3
22Ø-229		3																								2
23Ø-239		2																								1
24Ø-249			1																							Ø
25Ø-259																										3
26Ø-269		1	2																							2
27Ø-279		1	1																							2
28Ø-289		1	1																							6
29Ø-299		2	3	1																						19
3ØØ-3Ø9		5	7	4	2	1																				25
31Ø-319		4	14	3	3	1																				56
32Ø-329		15	16	15	7	2	1																			46
33Ø-339	2	13	11	1Ø	7	3																				25
34Ø-349	1	8	8	6	2																					29
35Ø-359	6	13	3	6	1																					
	24	229	327	223	118	57	12	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	99Ø

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 8

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS 54 5422100576 GMT 5(B) 148 AUSTIN CHANNEL 5 75315102492 60 304TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9																										Ø
1Ø- 19																										Ø
2Ø- 29		1																								1
3Ø- 39			1																							1
4Ø- 49																										Ø
5Ø- 59		1	1																							2
6Ø- 69			1	1																						2
7Ø- 79			1		1																					2
8Ø- 89																										Ø
9Ø- 99				2																						2
1ØØ-1Ø9																										Ø
11Ø-119																										Ø
12Ø-129				3																						3
13Ø-139					1																					1
14Ø-149				2	1																					3
15Ø-159					1		1																			2
16Ø-169		1		1																						2
17Ø-179						1				1																2
18Ø-189				1	1		2	1			1															6
19Ø-199		1	1	1		1	2																			6
2ØØ-2Ø9			1																							1
21Ø-219			1	2	1																					4
22Ø-229		1	1	1	3																					6
23Ø-239				2	1																					3
24Ø-249			1	3	5	1																				1Ø
25Ø-259					1	2	1	1																		5
26Ø-269		1			1	3	3	1																		9
27Ø-279						2	1		1	1																5
28Ø-289		1	1				1																			3
29Ø-299		1																								1
3ØØ-3Ø9						1	1																			2
31Ø-319			1																							1
32Ø-329																										Ø
33Ø-339					1																					1
34Ø-349																										Ø
35Ø-359																										Ø
	Ø	8	11	19	18	11	12	3	1	2	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	86

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) Ø

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø ØØ2327Ø377 GMT 1(T) 1822 CROZIER STRAIT 1 75316 97222 6Ø 377 V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
											CMS/SEC															
Ø- 9		9	14	8	8	5	5	1	2	1																53
1Ø- 19		2	4	3		1																				1Ø
2Ø- 29		1	4	1	2																					8
3Ø- 39			3	1																						4
4Ø- 49			2																							2
5Ø- 59		2	3																							5
6Ø- 69		2	1																							3
7Ø- 79		2	3																							5
8Ø- 89	1	5	2																							8
9Ø- 99		9	2																							11
1ØØ-1Ø9		9	2																							11
11Ø-119		9	8																							17
12Ø-129	3	31	8	1	1																					44
13Ø-139	5	12	3	4	1																					25
14Ø-149		5	11	14	5																					35
15Ø-159	1	7	13	2Ø	37	26	7																			111
16Ø-169	1	7	27	61	89	116	119	47	14	5																486
17Ø-179	1	11	31	52	5Ø	52	83	59	33	9	2															383
18Ø-189	1	16	36	19	9	5	7	5		1																99
19Ø-199		7	11																							18
2ØØ-2Ø9	1	9	4																							14
21Ø-219	1	6	6																							13
22Ø-229		1Ø	2																							12
23Ø-239		2	3																							5
24Ø-249		4	3																							7
25Ø-259	1	6	3	1																						11
26Ø-269	3	1	1																							5
27Ø-279	1	1	4																							6
28Ø-289		1	6																							7
29Ø-299		1	2																							3
3ØØ-3Ø9		2	3	1																						6
31Ø-319	3	5	7	6																						21
32Ø-329		4	25	21	7	1	1																			59
33Ø-339		6	3Ø	41	27	19	8	15	3																	149
34Ø-349		9	4	9	4	6	9	1	3	1																46
35Ø-359	1	1Ø	14	21	17	14	14	11	4	1																1Ø7
	24	223	3Ø6	284	258	245	253	14Ø	59	18	2	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1812

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 1Ø

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 25   Ø12228Ø377 GMT 1(M) 1799 CROZIER STRAIT   1 75316 97222 6Ø 627TC V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
												CMS/SEC														
Ø- 9		14	11	11	21	15	15	17	13	6	8	4	1			1										137
1Ø- 19	2	6	7	5	12	9	6	4	1																	52
2Ø- 29		14	6	5	7	5	2																			39
3Ø- 39		3	4	5	6	2																				2Ø
4Ø- 49		3	3		2																					8
5Ø- 59	1	2	2	1																						6
6Ø- 69		3	4		1																					8
7Ø- 79		1																								1
8Ø- 89			2																							2
9Ø- 99		4	4																							8
1ØØ-1Ø9		1																								1
11Ø-119		5	3	1																						9
12Ø-129		2	3	1																						6
13Ø-139		6	2																							8
14Ø-149	3	13	1Ø	3	2																					31
15Ø-159	2	25	19	25	18	6	1																			96
16Ø-169	1	12	34	39	34	42	29	21	6	4																222
17Ø-179		17	11	22	44	55	9Ø	84	78	45	34	2Ø	2													5Ø2
18Ø-189	1	7	6	14	19	39	33	58	38	26	15	4	2													262
19Ø-199		3	3	5	8	3	1																			23
2ØØ-2Ø9			4	2																						6
21Ø-219	2	4	2	1																						9
22Ø-229		1	1																							2
23Ø-239		3	1																							4
24Ø-249	1		1																							2
25Ø-259																										Ø
26Ø-269																										Ø
27Ø-279			1																							1
28Ø-289		1																								1
29Ø-299		1	2																							3
3ØØ-3Ø9		1	1																							2
31Ø-319		2		1																						3
32Ø-329	1	1	2																							4
33Ø-339		3	2		1																					6
34Ø-349		5	6	8	7	1		1	2	4			2													36
35Ø-359	3	21	21	26	29	22	2Ø	21	21	13	17	11	12	7	4	1										249
	17	184	18Ø	176	212	2ØØ	199	2Ø8	159	98	74	4Ø	19	7	4	2	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1779

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   2Ø

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 62   Ø3Ø127Ø377 GMT 1(B)   429 CROZIER STRAIT   1 75316 97222 6Ø   568TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		3	1																							4
1Ø- 19																										Ø
2Ø- 29		2					1																			3
3Ø- 39		1																								1
4Ø- 49																										Ø
5Ø- 59	1																									1
6Ø- 69		4																								4
7Ø- 79			1																							1
8Ø- 89		2																								2
9Ø- 99		1	1																							2
1ØØ-1Ø9		1	2	1																						4
11Ø-119	1	2	6	5	2		1																			17
12Ø-129		4	4		2	2	2																			14
13Ø-139		1	9	2	1Ø	12	2	1																		37
14Ø-149		2	8	2Ø	16	1Ø	8	2	1																	67
15Ø-159		2	3	1Ø	14	7	5	3																		44
16Ø-169			5	1Ø	7	9	5	2																		38
17Ø-179		4	1	2	2	4																				13
18Ø-189			1	3	3																					7
19Ø-199		2	1	1			1																			5
2ØØ-2Ø9		2	2																							4
21Ø-219																										Ø
22Ø-229																										Ø
23Ø-239		1	1																							2
24Ø-249			2																							2
25Ø-259			3																							3
26Ø-269		1	3																							4
27Ø-279																										Ø
28Ø-289		2	3																							5
29Ø-299			4	3																						7
3ØØ-3Ø9		1	6	5																						12
31Ø-319	1	2	1Ø	5	3																					21
32Ø-329		4	5	7	4	1	2																			23
33Ø-339	1	5	12	15	4	4	2																			43
34Ø-349		4	5	6	5	3	2																			25
35Ø-359		3	2	2	4		1																			12
	4	56	1Ø1	97	76	52	32	8	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	427

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   2

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø Ø6Ø23ØØ377 GMT 2(T) 1767 CROZIER STRAIT 2 74315 97198 6Ø 563 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	2	11	17	17	7	6	4	1																		65
1Ø- 19		7	3	5	1																					16
2Ø- 29	2	8	21	12	5																					48
3Ø- 39	1	8	27	7	1																					44
4Ø- 49		4	11	6																						21
5Ø- 59		7	12	7																						26
6Ø- 69		5	5	1																						11
7Ø- 79		4	12	3																						19
8Ø- 89		2	1Ø	7	1																					2Ø
9Ø- 99	1	1	8	4	1																					15
1ØØ-1Ø9		3	7	2	1																					13
11Ø-119		4	9	5	8																					26
12Ø-129	2	4	4	12	16	1	1																			4Ø
13Ø-139	1	7	1Ø	14	27	7																				66
14Ø-149		1	13	32	51	38	16	4																		155
15Ø-159	2	18	23	57	39	3Ø	24	6	1																	2ØØ
16Ø-169	3	37	44	27	19	9	1Ø	9	3																	161
17Ø-179	3	28	1Ø	1Ø	8	3	3	4	1																	7Ø
18Ø-189	2	12	11	13	6	2			3																	49
19Ø-199		5	4	1	6																					16
2ØØ-2Ø9		4	5	6																						15
21Ø-219		1	7	1	1	1																				11
22Ø-229		3	3	1																						7
23Ø-239		2	2																							4
24Ø-249		2	2																							4
25Ø-259			3	2	1																					6
26Ø-269		3	2																							5
27Ø-279		6	2	1																						9
28Ø-289		3	2	1																						6
29Ø-299		4	4	1																						9
3ØØ-3Ø9	1	4	6	1																						12
31Ø-319	1	9	1Ø	4		1																				25
32Ø-329	2	14	13	3Ø	13	2	7	2	2																	85
33Ø-339		8	28	5Ø	82	67	41	4Ø	19	1Ø	3															348
34Ø-349		5	8	9	2	7	5		1																	37
35Ø-359	1	19	21	12	2Ø	12	1Ø	2																		97
	24	264	38Ø	361	316	187	121	68	3Ø	1Ø	3	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1764

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 3

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 25 0719300377 GMT 2(M) 1750 CROZIER STRAIT 2 74315 97198 60 66TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	3	7	15	19	35	32	51	27	30	28	17	9	4	6												283
10- 19	1	7	25	29	16	18	9	17	9	10	2	2														145
20- 29	1	8	8	14	11	3	7	2																		54
30- 39	1	5	15	6	8	1																				36
40- 49		6	14	11	6																					37
50- 59		3	7	8																						18
60- 69		3	4	9	1																					17
70- 79	2	4	1	5	1																					13
80- 89		3	5	11	1																					20
90- 99		6	2	9	1	1																				19
100-109		2	3	4																						9
110-119		1	5	6	4																					16
120-129	2	7	4	7	4	6	1																			31
130-139		2	2	1	7	7	2																			21
140-149		4	2	2	5	3	6	3																		25
150-159	1	9	3	4	4	10	14	9	1	2																57
160-169		18	6	10	8	6	11	12	6	2																79
170-179		22	20	25	34	27	44	37	17	30	10	3														269
180-189	1	23	11	21	10	9	13	19	19	12	14	8														160
190-199	2	6	1	3	2	1	3	4	1		1															24
200-209	1	9	3	4	2	3	5	1	2	3	2															35
210-219		6	7	7	4	5	1	1																		31
220-229		4	8	8	1	3																				24
230-239		3	3	1	1																					8
240-249		4	2	5	1																					12
250-259		5	5	4																						14
260-269		2	2	3	1																					8
270-279		1	5		1																					7
280-289			1																							1
290-299		2	6																							8
300-309	1	2	4	2																						9
310-319		2	2	3																						7
320-329		4	6	8																						18
330-339		3	5	3	2																					13
340-349		2	9	14	5	2	2	1																		35
350-359		6	11	20	21	17	16	15	8	13	13	10	14	4												168
	16	201	235	286	197	157	185	151	94	106	61	32	18	10	0	0	0	0	0	0	0	0	0	0	0	1749

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 1

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 52   Ø918290377 GMT 2(B) 2259 CROZIER STRAIT   2 74315 97198 6Ø 6Ø3TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	7	21	39	43	28	3Ø	1Ø	1																	18Ø
1Ø- 19	2	5	12	12	8	5	4	3	4																	55
2Ø- 29		4	8	1Ø	5	3	2	1																		33
3Ø- 39	2	5	5	11	7				2																	32
4Ø- 49		2	8	6	2																					18
5Ø- 59			7	8	2																					17
6Ø- 69	1	1	7	12	5	1																				27
7Ø- 79			4	4	2		1																			11
8Ø- 89		3	1	4	6	4																				18
9Ø- 99			4	6	7	2	2																			21
1ØØ-1Ø9	2	1	1	9	7	7	4																			31
11Ø-119		1	1	9	1Ø	18	6	1	1																	47
12Ø-129	3	1		5	12	17	11	4	4		2															59
13Ø-139	2	1		5	13	18	19	13	5	2	1															79
14Ø-149	2	1	2	5	18	21	26	9	7		1															92
15Ø-159	1	6	7	24	38	36	29	15	1Ø	5																171
16Ø-169	1	9	14	29	23	6	8	7	1Ø	3	2															112
17Ø-179	3	11	16	15	6	2	3	11	9	3	1	1	1													82
18Ø-189	3	2Ø	8	8	3	4	1Ø	1Ø	6	4	2	1														79
19Ø-199	4	8	6	7	4	1	1	9	3	2	2															47
2ØØ-2Ø9	1	4	7	11	2	2	5			1																33
21Ø-219		2	4	4	3	1	1																			15
22Ø-229		4	2	6	2																					14
23Ø-239		1	3	1	4																					9
24Ø-249		8	4	2				1																		15
25Ø-259		1	3	1																						5
26Ø-269	1	4	1	2																						8
27Ø-279	3	7	4	3																						17
28Ø-289	3	2	7	1																						13
29Ø-299		4	4	3																						11
3ØØ-3Ø9		3	3	8																						14
31Ø-319	2	9	9	8																						28
32Ø-329	2	9	12	7	4	1		1	1																	37
33Ø-339	3	1Ø	11	1Ø	7	1	5	4																		51
34Ø-349	6	1Ø	17	22	27	19	22	3	3	1																13Ø
35Ø-359		25	36	61	63	39	37	13	5																	279
	48	189	261	382	337	241	227	116	71	21	11	2	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	19Ø7

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   352

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø 12Ø413Ø477 GMT 3(T) 1439 CROZIER STRAIT 3 753Ø5 971Ø4 6Ø 98 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9																										Ø
1Ø- 19		2																								2
2Ø- 29																										Ø
3Ø- 39																										Ø
4Ø- 49																										Ø
5Ø- 59		1																								1
6Ø- 69																										Ø
7Ø- 79																										Ø
8Ø- 89																										Ø
9Ø- 99																										Ø
1ØØ-1Ø9																										Ø
11Ø-119																										Ø
12Ø-129																										Ø
13Ø-139																										Ø
14Ø-149																										Ø
15Ø-159					1																					1
16Ø-169				3	5																					8
17Ø-179					8	2	4	2																		16
18Ø-189	34	19Ø	31Ø	289	193	13Ø	1Ø3	78	39	12																1378
19Ø-199			1	2	3	1																				7
2ØØ-2Ø9		1	1																							2
21Ø-219		1	1																							2
22Ø-229	1																									1
23Ø-239																										Ø
24Ø-249																										Ø
25Ø-259																										Ø
26Ø-269																										Ø
27Ø-279																										Ø
28Ø-289		1																								1
29Ø-299																										Ø
3ØØ-3Ø9		1																								1
31Ø-319																										Ø
32Ø-329																										Ø
33Ø-339																										Ø
34Ø-349																										Ø
35Ø-359		2																								2
	35	199	313	294	21Ø	133	1Ø7	8Ø	39	12	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1422

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 17

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 92 16Ø113Ø477 GMT 3(B) 2833 CROZIER STRAIT 3 753Ø5 971Ø4 6Ø 29T V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		29	23	22	2Ø	11	13	7	4	1																13Ø
1Ø- 19	3	16	17	16	18	9	9	7	2	1																98
2Ø- 29	5	1Ø	4	14	6	6	9	1Ø	1	1																66
3Ø- 39		12	4	3	2	3	2	1	2		1															3Ø
4Ø- 49	2	5	4	3	1	2	1		1	1																2Ø
5Ø- 59	1	2	2																							5
6Ø- 69	1	8	5	2	1																					17
7Ø- 79		4	4																							8
8Ø- 89	1	3	4	1	1	1																				11
9Ø- 99	1	1Ø	5	1	1	2																				2Ø
1ØØ-1Ø9	1	5	4		2		1																			13
11Ø-119	1	14	11	6	3	2																				37
12Ø-129	4	16	17	22	8	1	2	1			1															72
13Ø-139	3	17	26	23	2Ø	6	7	4	5																	111
14Ø-149		25	44	4Ø	48	26	19	11	5	3																221
15Ø-159	1	29	4Ø	66	53	37	32	21	9	4																292
16Ø-169	1	25	44	69	66	57	44	21	13	1																341
17Ø-179	2	24	47	73	86	6Ø	4Ø	24	9	1																366
18Ø-189	4	18	45	45	71	61	18	14	1																	277
19Ø-199	1	1Ø	18	28	3Ø	1Ø	9	5	1		1															113
2ØØ-2Ø9		13	12	25	12	3	1		2	1																69
21Ø-219	2	1Ø	14	1Ø	11	1		1																		49
22Ø-229		8	8	5																						21
23Ø-239	1	4	3	1	1																					1Ø
24Ø-249	3	2	5	2	1																					13
25Ø-259	1	7	6	2																						16
26Ø-269	1	4	1																							6
27Ø-279		6	2	1	1																					1Ø
28Ø-289		5	5																							1Ø
29Ø-299		4	6	1	1																					12
3ØØ-3Ø9	1	6	7	4	2			1	1																	22
31Ø-319	3	8	14	4	1	1																				31
32Ø-329	1	11	8	2	2		1																			25
33Ø-339		21	36	13	6	9	2	1	2																	9Ø
34Ø-349	3	16	18	12	3	1	3	3	4																	63
35Ø-359		14	32	34	18	11	6	5	1																	121
	48	421	546	552	496	322	219	137	63	14	3	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	2821

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 12

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø 2ØØ61ØØ477 GMT 4(T) 1573 CROZIER STRAIT 753Ø3 97Ø8Ø 6Ø 178 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		6	5	5	6	6																				28
1Ø- 19	2	1	1	1	2																					7
2Ø- 29	3	4	2	7	7	1																				24
3Ø- 39	2	11			1																					14
4Ø- 49	2	3	2	1	1																					9
5Ø- 59	1	7	1	1																						1Ø
6Ø- 69	1	5	1																							7
7Ø- 79	1	8	5																							14
8Ø- 89	2	5		1																						8
9Ø- 99	1	5	2																							8
1ØØ-1Ø9	1	6																								7
11Ø-119	3	1																								4
12Ø-129		6	5																							11
13Ø-139		7	2																							9
14Ø-149	1	1Ø	9																							2Ø
15Ø-159		17	13	4	4	1																				39
16Ø-169	3	26	28	22	16	4	1	1																		1Ø1
17Ø-179	3	2Ø	51	73	84	52	48	24	3	1																359
18Ø-189	4	19	57	74	11Ø	1Ø3	97	54	25	1Ø																553
19Ø-199	2	17	25	2Ø	15	15	7	4																		1Ø5
2ØØ-2Ø9	3	6	15	5			1																			3Ø
21Ø-219	1	7	5	3	1																					17
22Ø-229	3	6	1																							1Ø
23Ø-239	2	8	2																							12
24Ø-249		4																								4
25Ø-259	1		1																							2
26Ø-269	1	4																								5
27Ø-279			1																							1
28Ø-289	2	3																								5
29Ø-299			2																							2
3ØØ-3Ø9	2	4	1																							7
31Ø-319		5	4	1																						1Ø
32Ø-329	3	8	6	1				4																		22
33Ø-339		4	2	3	4	5	4	4																		26
34Ø-349	1		3	1		3	1																			9
35Ø-359		7	5	3	4	5	2																			26
	51	25Ø	257	227	255	195	161	91	28	11	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1526

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 47

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO2ØØ   22ØØ12Ø477 GMT 4(M) 1533 CROZIER STRAIT   753Ø3 97Ø8Ø 6Ø 453TCPV6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	8	12	16	16	13	13	4	4	5	1															93
1Ø- 19	1	9	9	9	15	9	4	8	1Ø	1																75
2Ø- 29		9	9	8	1Ø	2	5	6	3	1																53
3Ø- 39		7	9	5	2	1	2	3																		29
4Ø- 49	1				2	2																				5
5Ø- 59		3	4	1	1																					9
6Ø- 69		1	1	1																						3
7Ø- 79		6		2																						8
8Ø- 89		3	1	2																						6
9Ø- 99	1	3																								4
1ØØ-1Ø9		2	1																							3
11Ø-119		6	1																							7
12Ø-129		9	3																							12
13Ø-139	1	3																								4
14Ø-149	1	6	4																							11
15Ø-159		8	9	2																						19
16Ø-169	1	11	5	1																						18
17Ø-179	2	22	14	14	1																					53
18Ø-189	1	26	46	32	1Ø	1	3	1																		12Ø
19Ø-199	1	44	38	56	55	18	19	12	6	4	1															254
2ØØ-2Ø9	3	17	28	33	34	22	25	13	7	4	3															189
21Ø-219	3	8	16	25	13	8	1	2																		76
22Ø-229	1	1Ø	13	9		2																				35
23Ø-239	2	8	4		1																					15
24Ø-249		11	2	2																						15
25Ø-259		13		1																						14
26Ø-269		11		1																						12
27Ø-279		4	3	1																						8
28Ø-289	2	7	1																							1Ø
29Ø-299	1	8	1																							1Ø
3ØØ-3Ø9	2	9	3																							14
31Ø-319	1	6	5	1																						13
32Ø-329	1	9	8	4																						22
33Ø-339	1	13	9	4		2																				29
34Ø-349	1	15	24	21	1Ø	9	3	1		1																85
35Ø-359	2	23	27	35	25	18	12	7	1	2	2															154
	31	359	311	288	195	1Ø7	87	57	31	18	7	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1491

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   42

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO278   24Ø9Ø9Ø477 GMT 4(B)   8319 CROZIER STRAIT 4   753Ø3 97Ø8Ø 6Ø   443TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	18	25	32	63	71	53	25	14	7	1																3Ø9
1Ø- 19	2Ø	49	49	85	119	79	41	16		1	1															46Ø
2Ø- 29	22	6Ø	48	113	1Ø2	81	44	17	4	1																492
3Ø- 39	19	51	68	7Ø	84	48	26	12	4	3																385
4Ø- 49	19	37	6Ø	77	1Ø1	36	23	5	6		1															365
5Ø- 59	18	34	51	92	82	33	2Ø	13		1																344
6Ø- 69	7	17	28	44	38	15	7	6	1	4	1															168
7Ø- 79	14	22	54	6Ø	44	23	7	7	1																	232
8Ø- 89	8	28	39	58	21	8	6	2	1	3	1															175
9Ø- 99	6	18	3Ø	41	14	4	1		2																	116
1ØØ-1Ø9	4	18	27	27	5	2	1																			84
11Ø-119	12	26	28	11	3	2																				82
12Ø-129	1Ø	21	18	11	1																					61
13Ø-139	5	15	19	6	1																					46
14Ø-149	6	18	21	6																						51
15Ø-159	22	27	23	9	2																					83
16Ø-169	27	62	36	37	1Ø	8																				18Ø
17Ø-179	34	71	66	54	39	32	4	2	1																	3Ø3
18Ø-189	33	65	46	54	44	27	6	1																		276
19Ø-199	45	69	59	5Ø	52	29	14	5	1																	324
2ØØ-2Ø9	35	68	57	53	39	1Ø	4	2																		268
21Ø-219	8	18	13	13	6	3	1																			62
22Ø-229	7	22	12	7	1	1																				5Ø
23Ø-239	6	11	7	2	1																					27
24Ø-249	3	6	2																							11
25Ø-259	3	6	6																							15
26Ø-269	2	3			1																					6
27Ø-279	1	5																								6
28Ø-289	2	2																								4
29Ø-299	3	7																								1Ø
3ØØ-3Ø9	3	2	1																							6
31Ø-319		3		2																						5
32Ø-329		3	4																							7
33Ø-339	2	3	4	1																						1Ø
34Ø-349	4	9	4	4	6	1																				28
35Ø-359	6	14	11	24	26	21	4	2	2																	11Ø
	434	916	925	1Ø79	915	52Ø	234	1Ø4	3Ø	14	4	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	5175

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   3144

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø 282ØØ6Ø477 GMT 5(T) 16Ø7 CROZIER STRAIT 753ØØ 97Ø51 6Ø 864 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		6	8	4	1	2	1																			22
1Ø- 19	2	1	3	4	3	1																				14
2Ø- 29	2	2	4	3	1																					12
3Ø- 39		8	9	1	2																					2Ø
4Ø- 49	1	1Ø	6																							17
5Ø- 59	2	7	4	1																						14
6Ø- 69		2	2																							4
7Ø- 79		5																								5
8Ø- 89		2	3																							5
9Ø- 99	1	3	2																							6
1ØØ-1Ø9	2	5	2																							9
11Ø-119		2	2																							4
12Ø-129		4	4	1																						9
13Ø-139	2	7	1	4	1																					15
14Ø-149	2	6	11	4	5	1																				29
15Ø-159	3	18	17	16	6	11	3																			74
16Ø-169	7	15	43	38	4Ø	27	21	5																		196
17Ø-179	2	2Ø	48	67	92	82	59	25	1Ø																	4Ø5
18Ø-189	5	27	46	88	1Ø1	97	47	27	1Ø	5																453
19Ø-199	4	14	19	14	16	5	3																			75
2ØØ-2Ø9		6	14	6	3	1																				3Ø
21Ø-219	1	5	2	4	2																					14
22Ø-229		5	3	2																						1Ø
23Ø-239		4	4																							8
24Ø-249		3	1																							4
25Ø-259		1	2																							3
26Ø-269	2	1		1																						4
27Ø-279	1	2	2																							5
28Ø-289		1	1																							2
29Ø-299	1	1	1																							3
3ØØ-3Ø9	1	8	3																							12
31Ø-319		6	5	1																						12
32Ø-329	1	5	5	5		1	1																			18
33Ø-339		3	7	9	8																					27
34Ø-349	1		4	7	3																					15
35Ø-359			9	3		1	2																			15
	43	215	298	283	284	229	137	57	2Ø	5	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1571

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 36

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 75 3018070477 GMT 5(M) 1609 CROZIER STRAIT 75300 97051 60 259TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	3	17	25	26	15	10	15	7	8	1																127
10- 19	2	10	17	4	5	2	2	2	1																	45
20- 29	4	15	5	6	3	2																				35
30- 39	1	7	2	2	4		1																			17
40- 49	2	3	5																							10
50- 59		2	4																							6
60- 69		5	2																							7
70- 79		5	2	2																						9
80- 89	1	3	4																							8
90- 99	1	1	1																							3
100-109		2																								2
110-119		4	1																							5
120-129		1	2																							3
130-139		4	3																							7
140-149	1	7	2	1																						11
150-159	3	12	4	2																						21
160-169	1	3	10	9	1																					24
170-179	2	7	22	17	12	5	1																			66
180-189	1	13	34	46	49	37	32	21	3																	236
190-199	2	12	45	65	87	62	56	50	39	17	3															438
200-209	1	8	25	39	33	19	10	5	2	2																144
210-219	1	12	21	18	7	7	1	1																		68
220-229	2	8	9	6	2	1																				28
230-239	3	4	7	4																						18
240-249	1	3	4	3	1																					12
250-259	2	4	4																							10
260-269	1	4	1	1																						7
270-279	1	4	1	3	1																					10
280-289		8	3	2	2	1																				16
290-299	1	3	2																							6
300-309		4	2	1																						7
310-319	3	4	4	1																						12
320-329	1	9	4																							14
330-339	2	12	5	4		2																				25
340-349	3	13	13	7	1	5		2																		44
350-359		16	16	14	9	7	5	5	6	1																79
	46	249	312	285	232	161	123	95	59	21	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1586

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 23

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO2ØØ   3ØØØØ7Ø477 GMT 5(M) 1634 CROZIER STRAIT   753ØØ 97Ø51 6Ø 269TCPV6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	3	23	33	38	38	24	13	9	13	11	1															2Ø6
1Ø- 19	3	25	24	14	11	6	3	3	4																	93
2Ø- 29	2	14	6	4	2	1																				29
3Ø- 39	2	7	7	3	2	4																				25
4Ø- 49	3	9	3	4																						19
5Ø- 59	1	4	3	1	1																					1Ø
6Ø- 69	2	1Ø	2	1																						15
7Ø- 79	4	7	1	1																						13
8Ø- 89	1	8	1	3																						13
9Ø- 99	3	8	1																							12
1ØØ-1Ø9	2	6	3																							11
11Ø-119	3	11	2																							16
12Ø-129	5	1Ø	2																							17
13Ø-139	5	12	1																							18
14Ø-149	1	7	4																							12
15Ø-159	4	14	14	2																						34
16Ø-169	3	2Ø	25	9	1																					58
17Ø-179	1	23	18	19	3	2	1		1																	68
18Ø-189	6	28	32	33	27	15	7	8	1	1																158
19Ø-199	3	37	46	43	33	36	18	7																		223
2ØØ-2Ø9	5	23	26	7	7	8	2																			78
21Ø-219	3	8	1Ø	6	1																					28
22Ø-229	2	6	8	2																						18
23Ø-239	4	8	1	1																						14
24Ø-249	3	8	3	1																						15
25Ø-259		2	1	1																						4
26Ø-269	2	3	5																							1Ø
27Ø-279		5	1																							6
28Ø-289	3	5																								8
29Ø-299		5	2																							7
3ØØ-3Ø9	1	4	1																							6
31Ø-319	3	8	2																							13
32Ø-329	2	7	5																							14
33Ø-339	2	7	3	1	1																					14
34Ø-349	3	2Ø	2Ø	9	5	2	1	1																		61
35Ø-359	4	31	36	39	42	32	25	15	7	3	1															235
	94	433	356	242	177	13Ø	7Ø	45	26	15	2	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	159Ø

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   44

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO317 32ØØØ5Ø477 GMT 5(B) 84Ø5 CROZIER STRAIT 5 753ØØ 97Ø51 6Ø 586TC V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
													CMS/SEC													
Ø- 9	13	62	98	33	9	2	2	5	3	2			1													23Ø
1Ø- 19	9	5Ø	49	2Ø	3			2	1	1	1															136
2Ø- 29	11	57	49	23	2					1			1													144
3Ø- 39	21	58	58	7	1																					145
4Ø- 49	19	69	49	11	4																					152
5Ø- 59	12	57	46	9	1																					125
6Ø- 69	11	57	25	1Ø																						1Ø3
7Ø- 79	12	75	45	9	1																					142
8Ø- 89	11	62	39	13	2																					127
9Ø- 99	24	99	63	1Ø	1																					197
1ØØ-1Ø9	15	56	47	17	3	2																				14Ø
11Ø-119	17	7Ø	63	26	4	2	3																			185
12Ø-129	19	97	116	45	18	2	2	1																		3ØØ
13Ø-139	13	1Ø1	111	63	27	13	4	2																		334
14Ø-149	17	84	13Ø	84	56	16	6	2	2																	397
15Ø-159	27	115	184	124	6Ø	24	8		1																	543
16Ø-169	15	74	96	43	25	7	2																			262
17Ø-179	7	35	44	1Ø	2	1	1	1																		1Ø1
18Ø-189	8	21	13	2	1	2																				47
19Ø-199	2	18	7	1																						28
2ØØ-2Ø9	3	8	5	1	1																					18
21Ø-219	4	1Ø	5																							19
22Ø-229	1	5	1																							7
23Ø-239	5	8	1																							14
24Ø-249	6	14	2																							22
25Ø-259	1	3	1																							5
26Ø-269	3	3	1																							7
27Ø-279	4	7	2																							13
28Ø-289	2	9	1		1	1		1	1																	16
29Ø-299	1Ø	3Ø	8	3	2		1	2	1		1															58
3ØØ-3Ø9	15	27	32	15	8	4	7	5	3	2	1	1														12Ø
31Ø-319	11	6Ø	87	69	78	51	31	6	7	3	2	1														4Ø6
32Ø-329	18	93	2Ø4	272	215	134	67	27	1		1	1	1													1Ø34
33Ø-339	2Ø	132	266	3Ø3	252	122	54	17	8	3	1															1178
34Ø-349	17	96	136	119	62	33	29	12	4				1													5Ø9
35Ø-359	12	93	123	68	26	13	9	5	3	1	2		1													356
	415	1919	2214	1411	865	429	226	88	35	13	9	3	5	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	7632

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 773

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø 36ØØØ4Ø477 GMT 6(T) 1672 CROZIER STRAIT 6 75288 97Ø29 6Ø 257 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	17	9	7	2																					36
1Ø- 19	2	8	1																							11
2Ø- 29	2	15	9	2	1																					29
3Ø- 39	2	1Ø	6	1																						19
4Ø- 49	5	8	5	1																						19
5Ø- 59		2	1																							3
6Ø- 69	2	3	1																							6
7Ø- 79		5	4	1																						1Ø
8Ø- 89	1	1	5	2																						9
9Ø- 99		3	2	3																						8
1ØØ-1Ø9		1	2	2																						5
11Ø-119		5	2	4																						11
12Ø-129	1	7	8	3	1																					2Ø
13Ø-139	3	5	13	7	5																					33
14Ø-149	1	14	25	26	14	5																				85
15Ø-159		14	41	43	46	28	14	3	1																	19Ø
16Ø-169		16	37	74	117	81	54	33	13	3																428
17Ø-179	2	8	29	46	67	49	31	13	9	5																259
18Ø-189	1	15	31	38	36	21	9	5	2																	158
19Ø-199		5	12	2	4		1																			24
2ØØ-2Ø9		3	12	4	1																					2Ø
21Ø-219		3	2	1																						6
22Ø-229		4	3	2																						9
23Ø-239		6	3																							9
24Ø-249		4																								4
25Ø-259		4	2	1																						7
26Ø-269		2	1																							3
27Ø-279		1	1																							2
28Ø-289		4																								4
29Ø-299		2	1																							3
3ØØ-3Ø9	1	1	2																							4
31Ø-319		1	6	1	2																					1Ø
32Ø-329	3	7	1Ø	11	11	5	1	1																		49
33Ø-339	3	15	18	22	2Ø	11	6	3	1																	99
34Ø-349		3	5	3	2	1																				14
35Ø-359	3	11	15	7	5	2																				43
	33	234	325	315	334	2Ø3	116	58	26	8	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1652

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 2Ø

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO271 4017030477 GMT 6(B) 3022 CROZIER STRAIT 6 75288 97029 60 459TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	4	43	68	41	33	23	23	13	3	2																253
10- 19	10	43	39	15	4	2	3	4	3	1	2															126
20- 29	11	52	17	6	1			1	1		1															90
30- 39	10	65	22	2				2																		101
40- 49	6	52	23	2						1																84
50- 59	3	34	8																							45
60- 69	3	26	13																							42
70- 79	10	23	17	1																						51
80- 89	11	47	14	1																						73
90- 99	12	46	17	1																						76
100-109	7	38	13	5																						63
110-119	5	28	20	6																						59
120-129	3	16	26	10	1																					56
130-139		31	36	13	3	1																				84
140-149	6	31	35	25	5	2	3	1																		108
150-159	5	23	43	42	30	11	5																			159
160-169	3	32	44	38	26	8	1		1																	153
170-179	4	8	22	9	8	4	1																			53
180-189	1	8	6		1																					16
190-199	1	4	3		1																					9
200-209	4	3																								7
210-219	3	5																								8
220-229	1	2																								3
230-239	2	4																								6
240-249		1	1																							2
250-259		4	1																							5
260-269	1	3	1																							5
270-279	3	3	3																							9
280-289	1	10	2	1																						14
290-299	3	11	6																							20
300-309	2	12	11	3					1	1																30
310-319		6	11	2																						19
320-329	5	19	45	22	5	2	1	4	2																	105
330-339	1	28	54	60	25	18	7	5	1			1														200
340-349	5	25	74	66	57	37	31	14	2																	311
350-359	2	30	101	105	113	68	38	16	6	3																482
	148	818	807	481	320	184	116	61	21	8	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2968

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 54

103

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

PUL Ø 4418210477 GMT 3(T) 1324 PULLEN STRAIT 3 75265 96Ø59 6Ø 542 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		3		2																						5
1Ø- 19		1	1	1																						3
2Ø- 29	1	7	11	7	1																					27
3Ø- 39		9	29	23	17	1Ø	7	2																		97
4Ø- 49		1Ø	21	41	46	47	26	17	3																	211
5Ø- 59		15	16	18	13	4	1																			67
6Ø- 69		6	9	2	2																					19
7Ø- 79		3	5	3																						11
8Ø- 89		2	3																							5
9Ø- 99		1																								1
1ØØ-1Ø9		4	3																							7
11Ø-119	1	3	1																							5
12Ø-129		1																								1
13Ø-139		2																								2
14Ø-149	1	1																								2
15Ø-159	1	4	1																							6
16Ø-169	1	4																								5
17Ø-179	3	2	1																							6
18Ø-189	2	9	3																							14
19Ø-199		7	2		1																					1Ø
2ØØ-2Ø9		16	7	13	13	1																				5Ø
21Ø-219	4	11	18	32	26	19	9																			119
22Ø-229		22	21	25	46	31	16	1Ø																		171
23Ø-239	2	11	17	29	33	29	23	7	2																	153
24Ø-249		7	18	29	37	3	9																			1Ø3
25Ø-259	2	8	1Ø	32	13	2	1																			68
26Ø-269		3	9	15	7	1																				35
27Ø-279		8	12	8	2																					3Ø
28Ø-289		2	8	8	1																					19
29Ø-299		3	4	5																						12
3ØØ-3Ø9		5	1Ø	2																						17
31Ø-319		2	6	1																						9
32Ø-329		3	5	5																						13
33Ø-339		2	3																							5
34Ø-349		1																								1
35Ø-359	1	6	4	1																						12
	19	2Ø5	258	3Ø2	258	147	92	36	5	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1322

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 2

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

PUL 25   4ØØ221Ø477 GMT 3(M)   134Ø PULLEN STRAIT   3 75265 96Ø59 6Ø   192TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		5	4	2	1																					12
1Ø- 19		7	5	3	2	1																				18
2Ø- 29		8	6	1Ø	7	5	2	2																		4Ø
3Ø- 39	1	12	18	27	16	19	3Ø	32	22	27	8	9	5	2												228
4Ø- 49	1	7	11	11	14	15	14	21	11	8	11	7	6	2												139
5Ø- 59		6	2	13	6	5	3	2	3	2	1															43
6Ø- 69	1	1	2	4	4	1	1																			14
7Ø- 79		3	3	1	1																					8
8Ø- 89		1	1	2	1	1																				6
9Ø- 99			2																							2
1ØØ-1Ø9																										Ø
11Ø-119		1																								1
12Ø-129																										Ø
13Ø-139		2																								2
14Ø-149																										Ø
15Ø-159	1																									1
16Ø-169																										Ø
17Ø-179		2																								2
18Ø-189			1																							1
19Ø-199		3																								3
2ØØ-2Ø9		4	5																							9
21Ø-219		12	1																							13
22Ø-229	2	26	12	18	12	4	6	5	4	2																91
23Ø-239	1	2Ø	15	21	13	13	37	34	16	17	9	2														198
24Ø-249		1	1	7	14	29	25	27	2Ø	18	1Ø	6	2													16Ø
25Ø-259		2	3	2	14	18	13	13	11	8	1															85
26Ø-269		1	2	12	11	17	18	4	4																	69
27Ø-279		2	4	14	14	14	12	3																		63
28Ø-289			3	3	4	4	5																			19
29Ø-299			7	6	7	4	3																			27
3ØØ-3Ø9			4	3	8	5																				2Ø
31Ø-319		1	1	8	2	1																				13
32Ø-329			5	4	2	3																				14
33Ø-339		4	2	1	3	1																				11
34Ø-349		1	2	5	5																					13
35Ø-359		4	3	1	2	1																				11
	7	136	125	178	163	161	169	143	91	82	4Ø	24	13	4	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1336

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   4

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

PUL 54   4816200477 GMT 3(B)   2717 PULLEN STRAIT   3 75265 96059 60   233TC V6

CMS/SEC

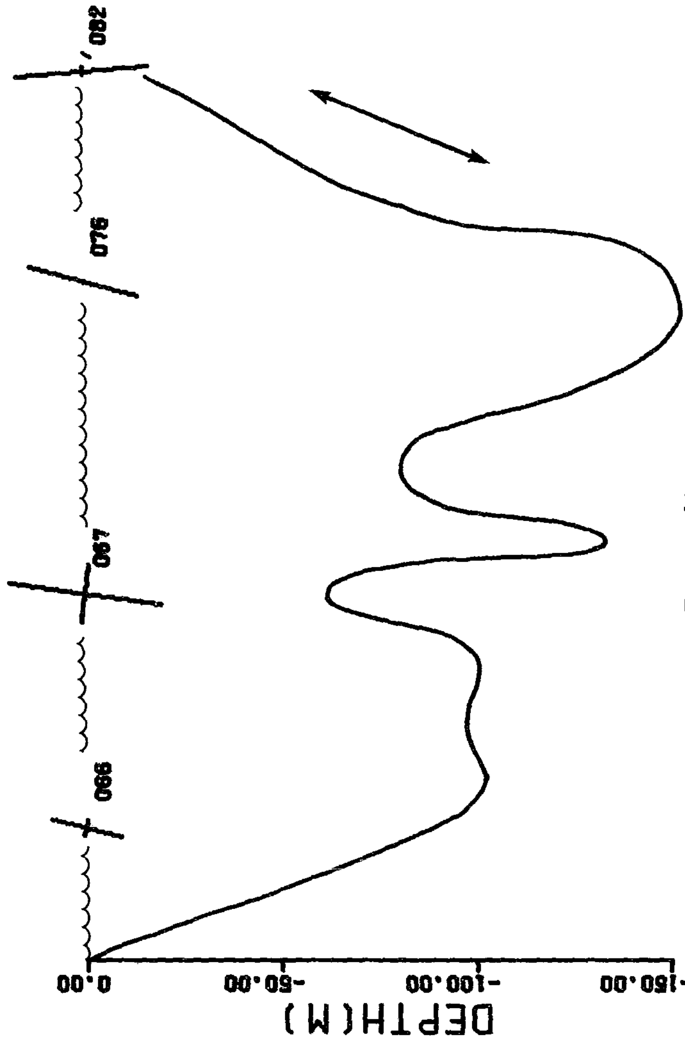
DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	1	4	3	13	4	5	4	5	2	5	2		1	5	2											56
10- 19		6	11	13	19	16	14	13	10	10	4	5	3	3												127
20- 29		6	8	14	19	28	36	33	25	17	3	6	3	4	2											204
30- 39	1	9	16	25	22	25	27	26	16	12	4	4	6	4	3	1										201
40- 49		11	13	9	6	9	3	4	5	9	6	6	2	3	3											89
50- 59		6	6	2	1	3	1	1	1	3	3	2	1			1										31
60- 69	2	7	8	3	2				4	3	3	1	1		1		1									36
70- 79		8	4	1	1							1														15
80- 89		4	7	4																						15
90- 99		2	6	2	1																					11
100-109	2	1	4																							7
110-119	1	3	2	1																						7
120-129	2	3		5	1																					11
130-139	1	3	2	3	1																					10
140-149		3	6	3	1																					13
150-159		2	9	8	2	1		1																		23
160-169		3	9	9	4	3	1	1																		30
170-179	1	2	11	3	8	8	2																			35
180-189		4	15	15	16	8			2																	60
190-199	1	6	8	14	16	3	5																			53
200-209	1	3	16	8	18	8	12		1		1															68
210-219		6	17	17	20	6	7	3	3																	79
220-229	1	5	12	26	29	21	6	7	1																	108
230-239		11	36	64	78	53	28	9	2	1																282
240-249		10	28	36	21	15	16	9	1	1																137
250-259		19	39	48	28	14	11	7	3																	169
260-269	1	9	24	30	33	7	6	1																		111
270-279		12	27	24	20	5		2																		90
280-289	1	2	36	24	7	3	1																			74
290-299		2	17	28	11		1																			59
300-309	1	6	26	20	28	10																				91
310-319		7	28	42	41	23	2	1																		144
320-329	1	7	17	21	21	27	1	2	1																	98
330-339		5	8	12	12		2	1					2													42
340-349	1	7	10	7	10	7	1		3		2		1	1	1											51
350-359		5	9	21	8	7	2	3	2	1	4	1	1	1												65
	19	209	498	576	509	315	189	129	82	62	32	26	21	21	12	2	1	0	0	0	0	0	0	0	0	2703

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC)   14

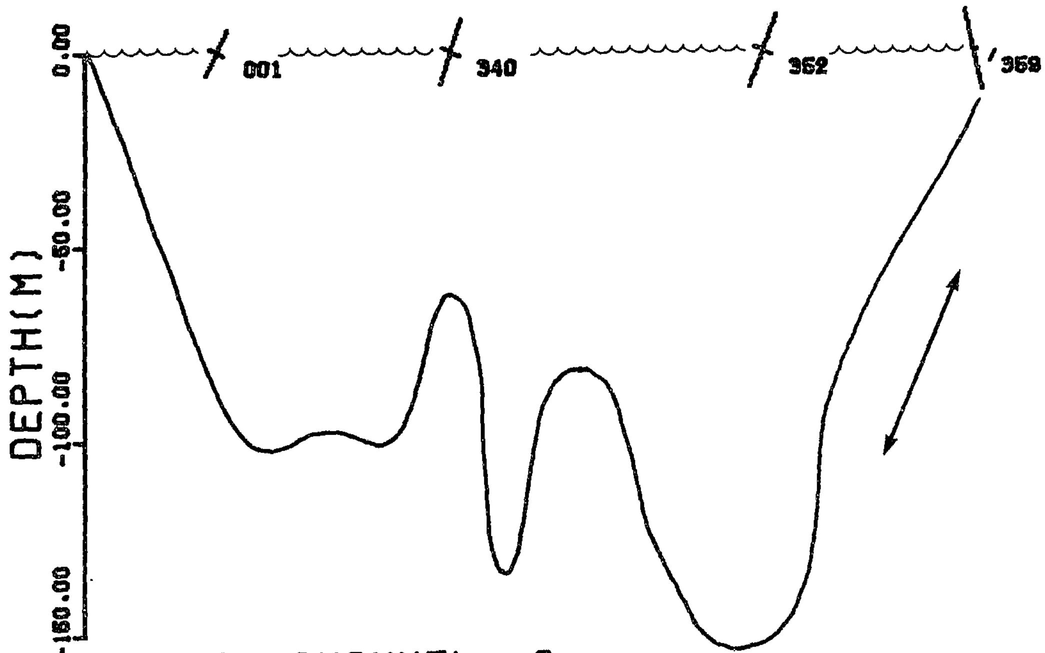
APPENDIX B

TIDAL ELLIPSES

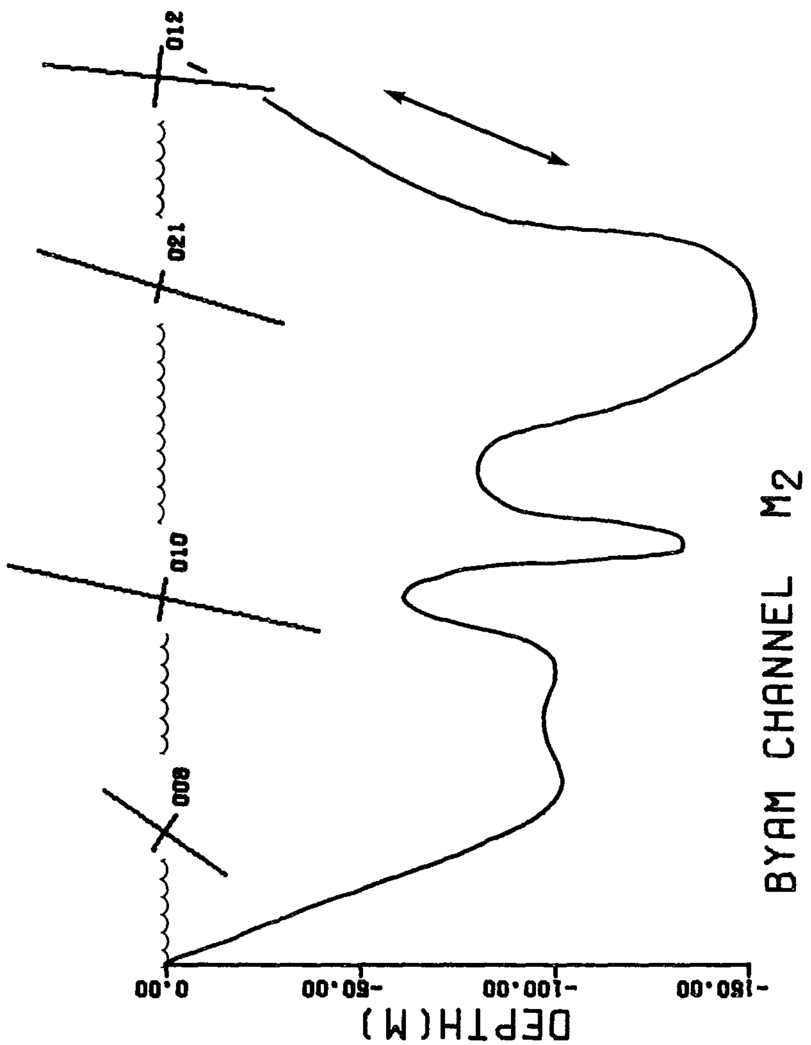
In the following, each channel is portrayed in four cross sections, one for each of the major tidal constituents. The major and minor axes of the ellipses are shown located at the appropriate current meter positions. The lengths of the axes are proportional to the current speed with 1 cm representing 4 cm s^{-1} . North is towards the top of the page and the orientation of the channels relative to north-south is indicated by the double-headed arrows. The major axes of the ellipses usually lie along or close to the channel orientation. The numbers beside each set of ellipse axes is G, the Greenwich phase.

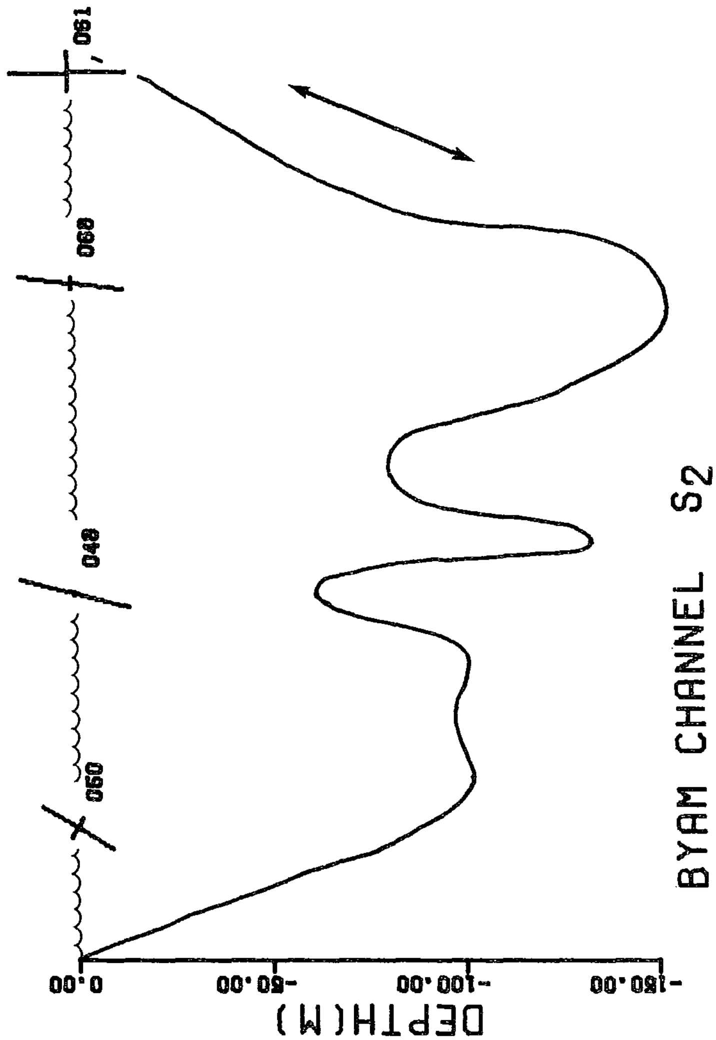


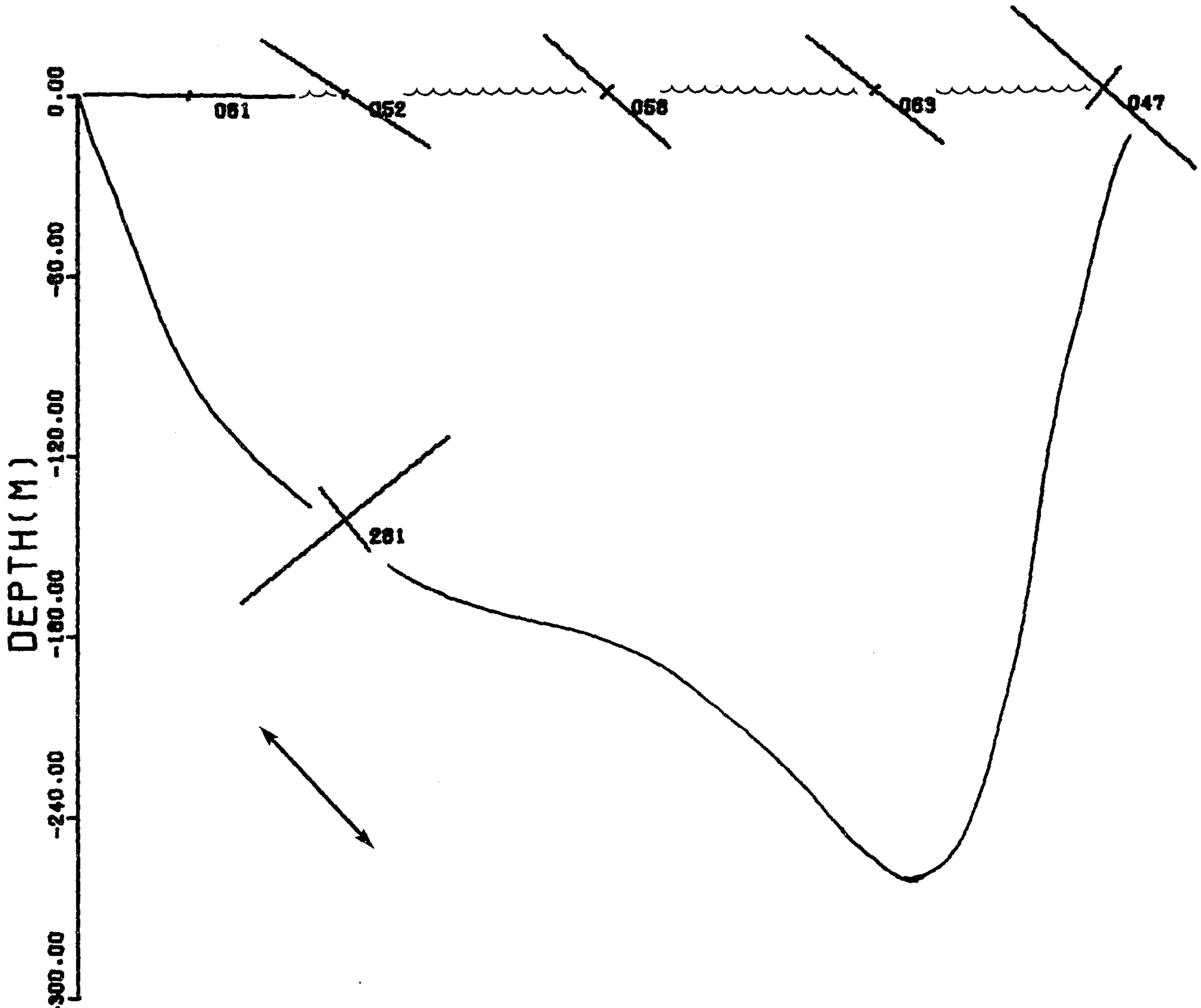
BYAM CHANNEL K_1



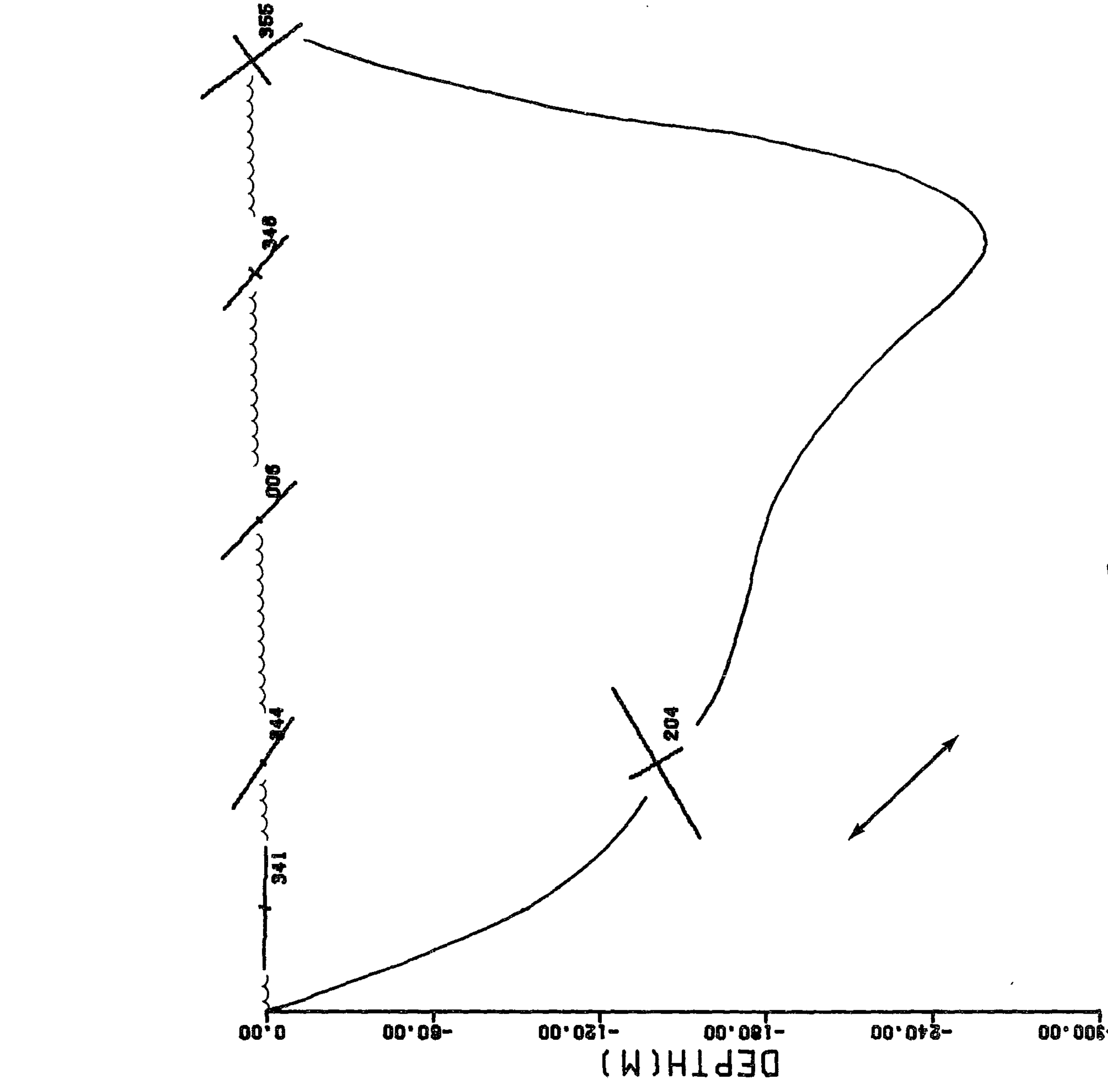
BYAM CHANNEL O_1


008
010
021
012
DEPTH(M)
0.00
-50.00
-100.00
-150.00
BYAM CHANNEL M_2

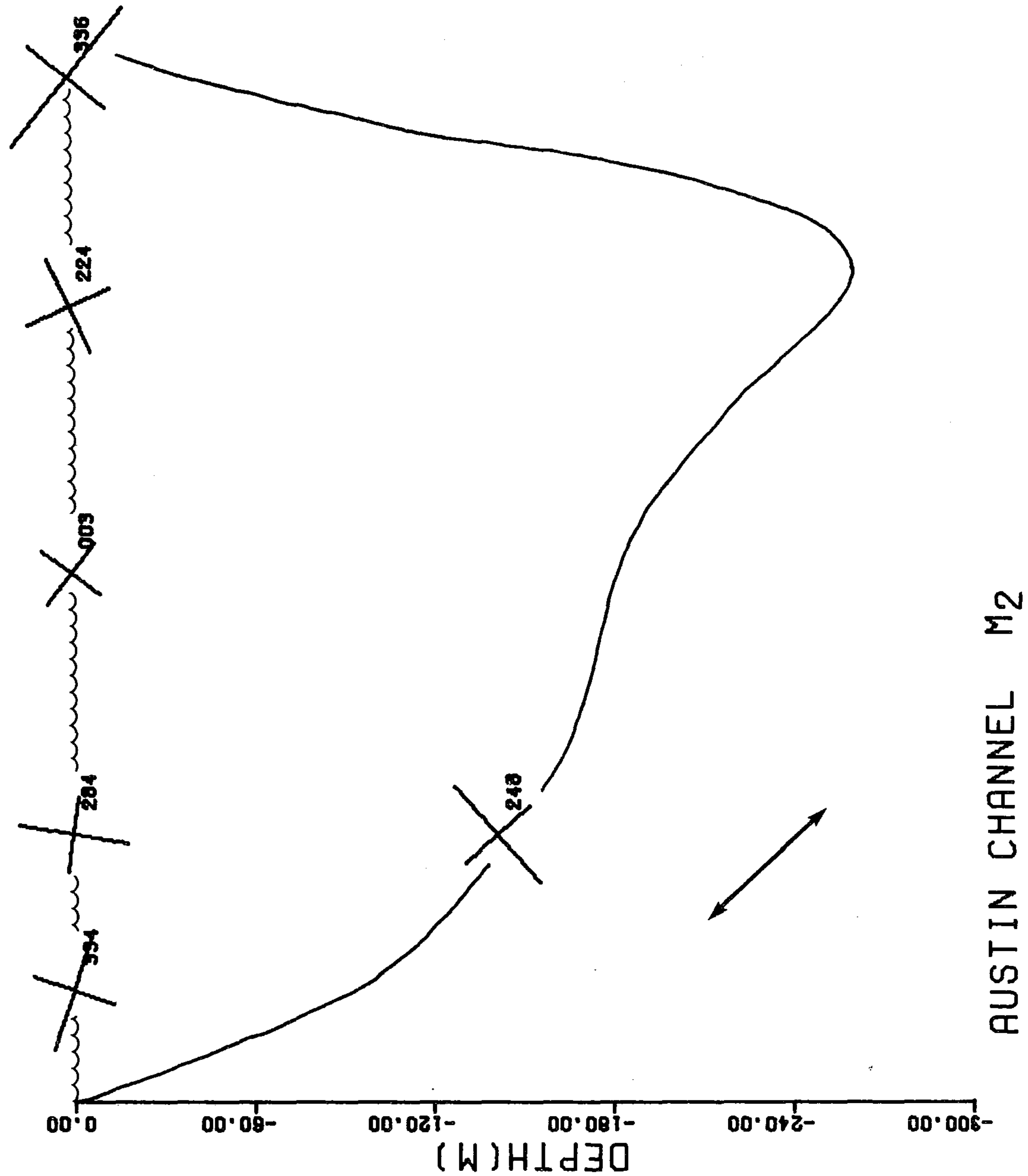

BYAM CHANNEL S_2
DEPTH(M)
0.00
-50.00
-100.00
-150.00



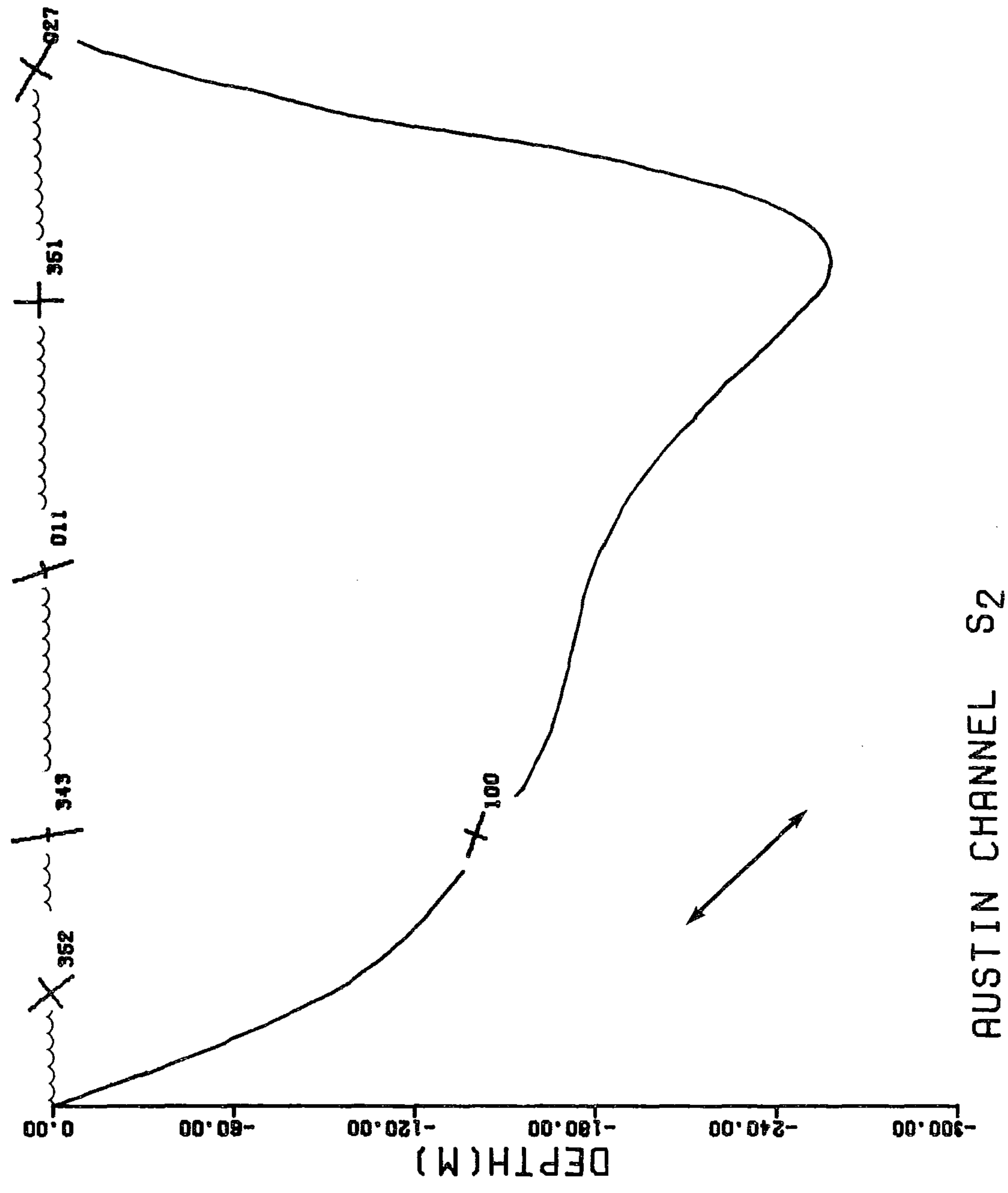
AUSTIN CHANNEL K_1



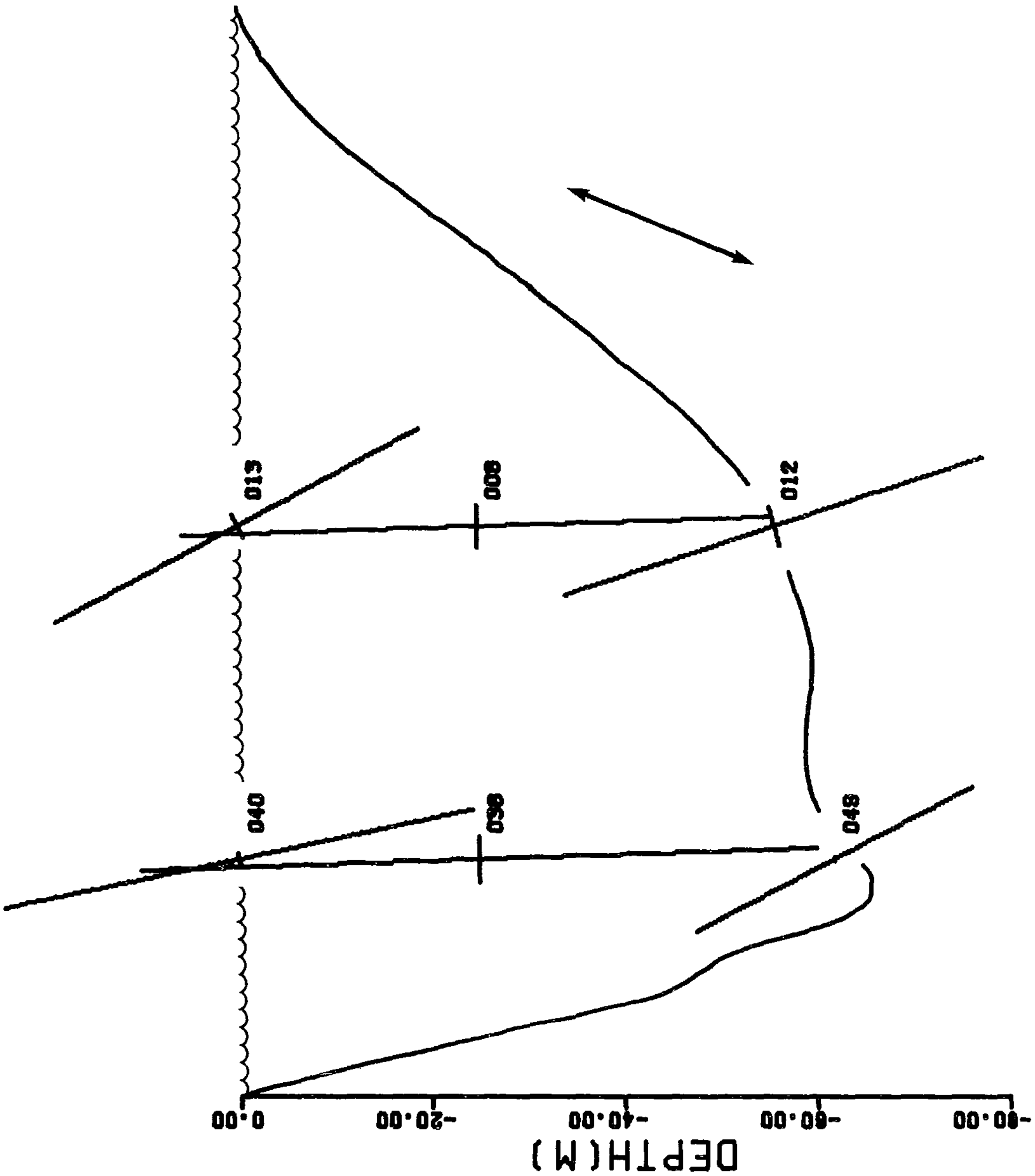
AUSTIN CHANNEL O_1



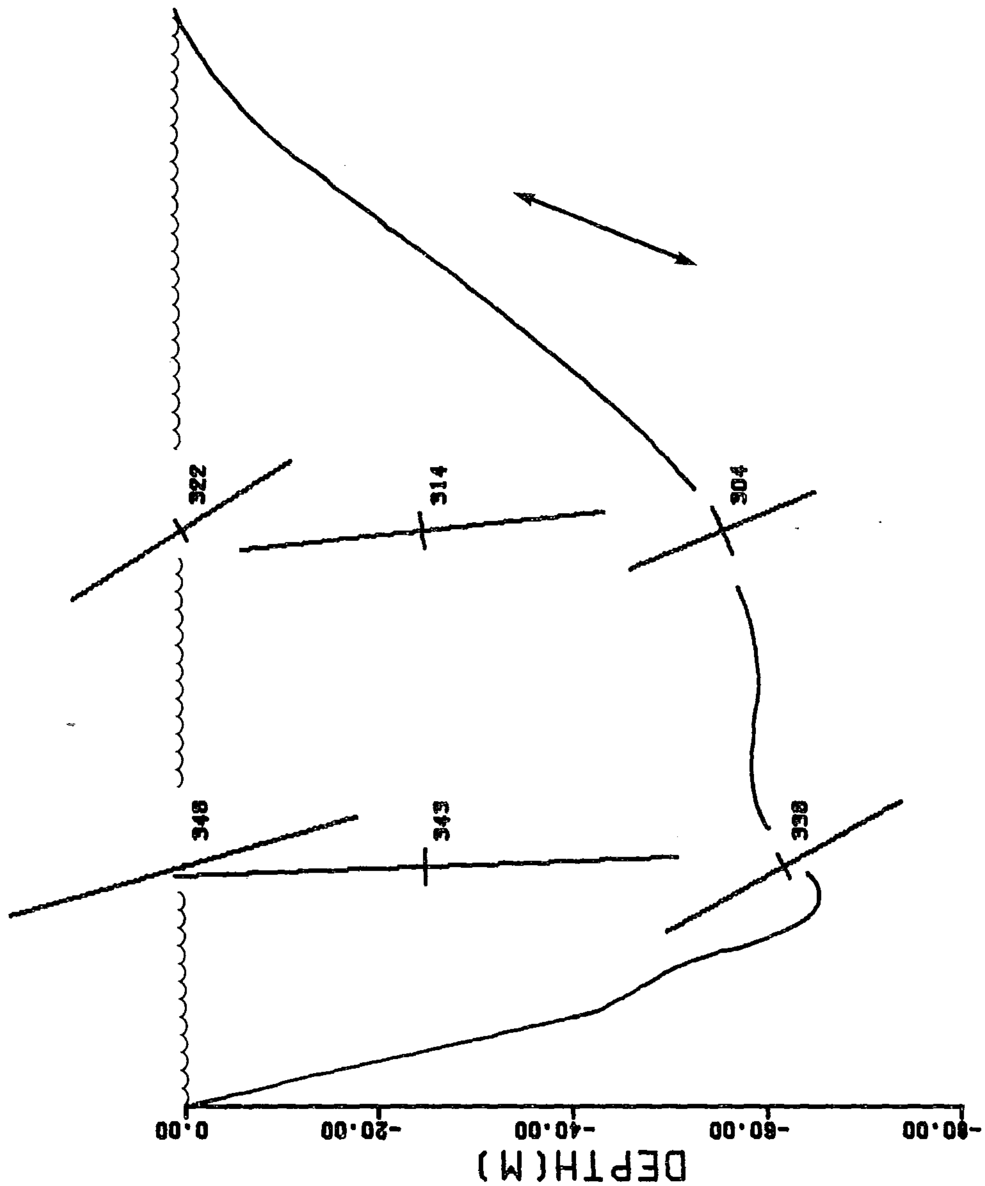
AUSTIN CHANNEL M_2
DEPTH(M)
0.00
-60.00
-120.00
-180.00
-240.00
-300.00
354
284
003
224
336
248



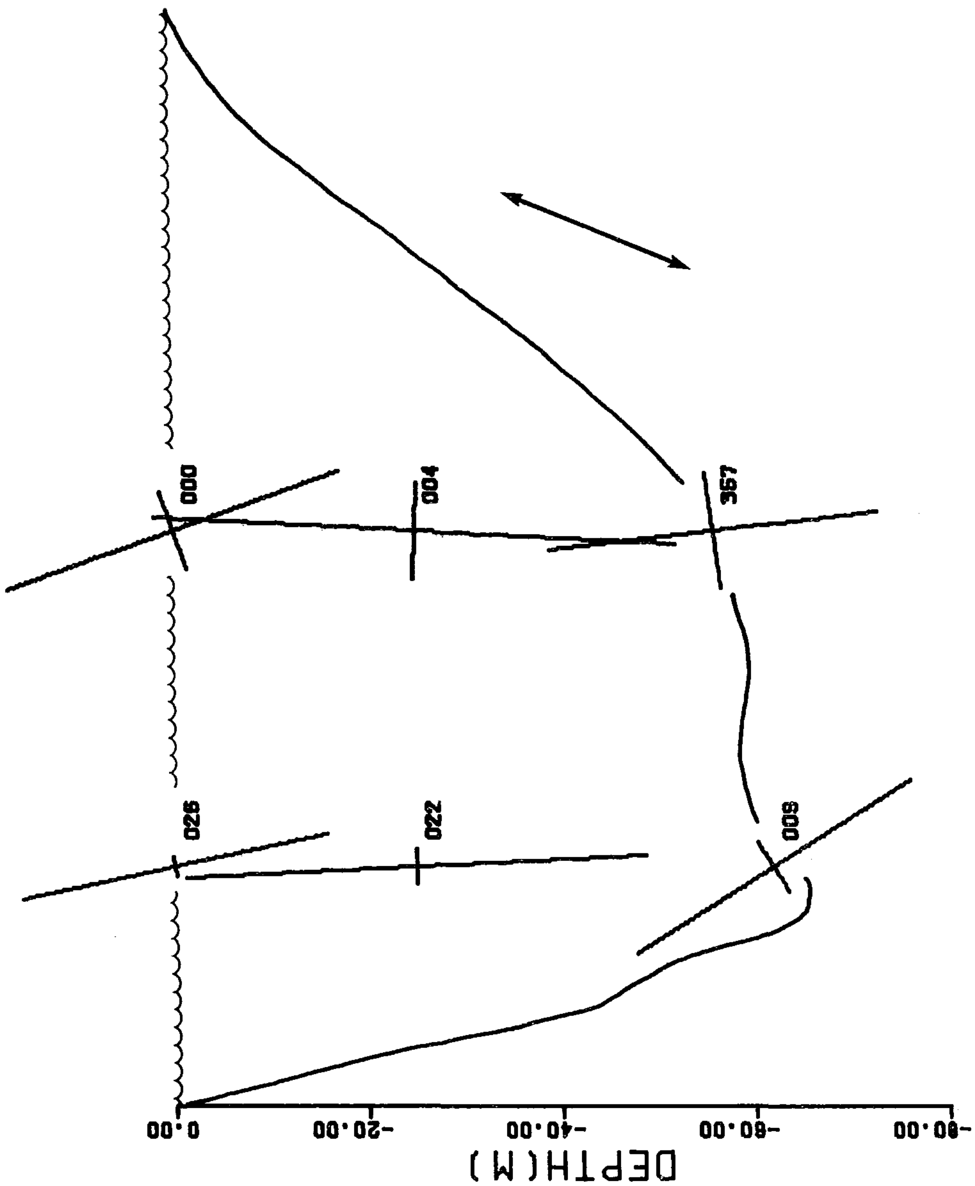
AUSTIN CHANNEL S2
DEPTH(M)
0.00
-60.00
-120.00
-180.00
-240.00
-300.00
027
361
011
343
362
100



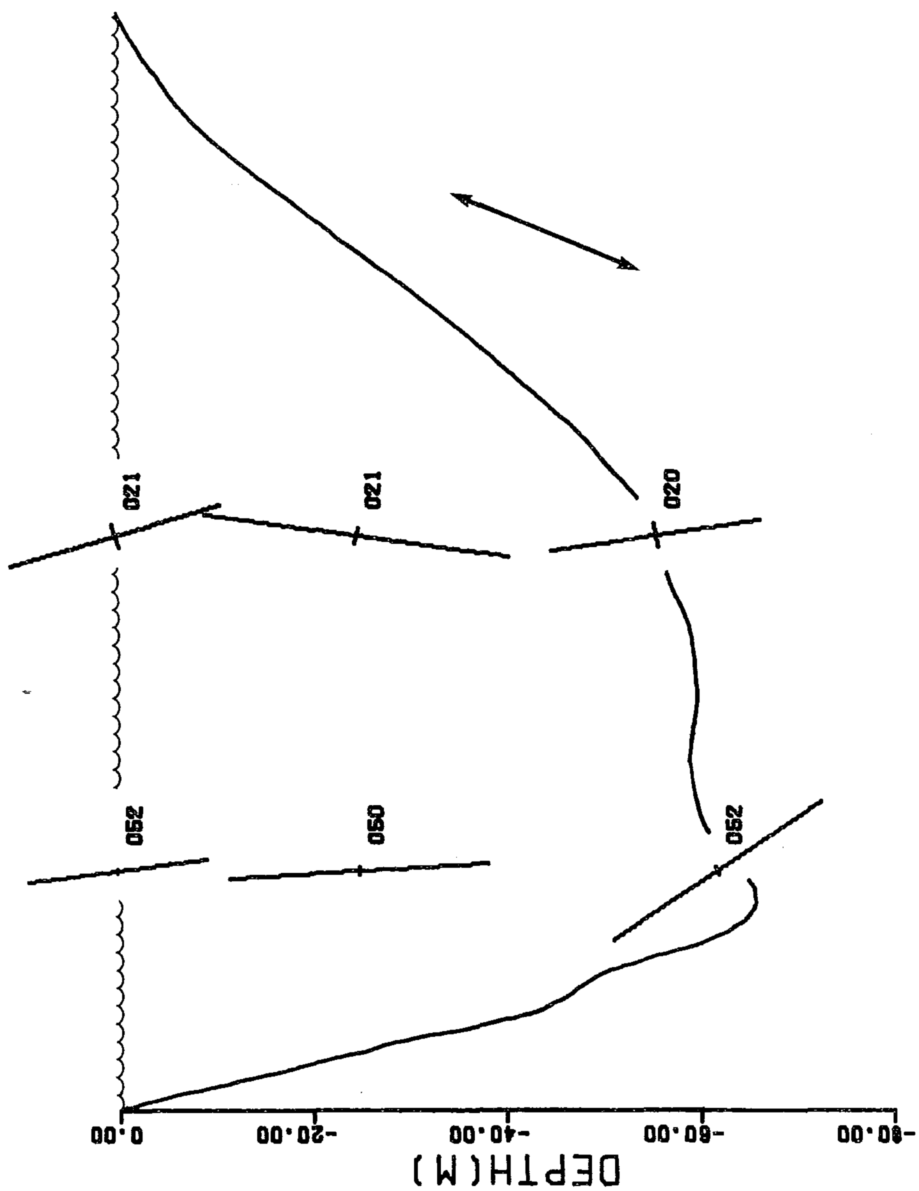
CROZIER STRAIT WEST K_1



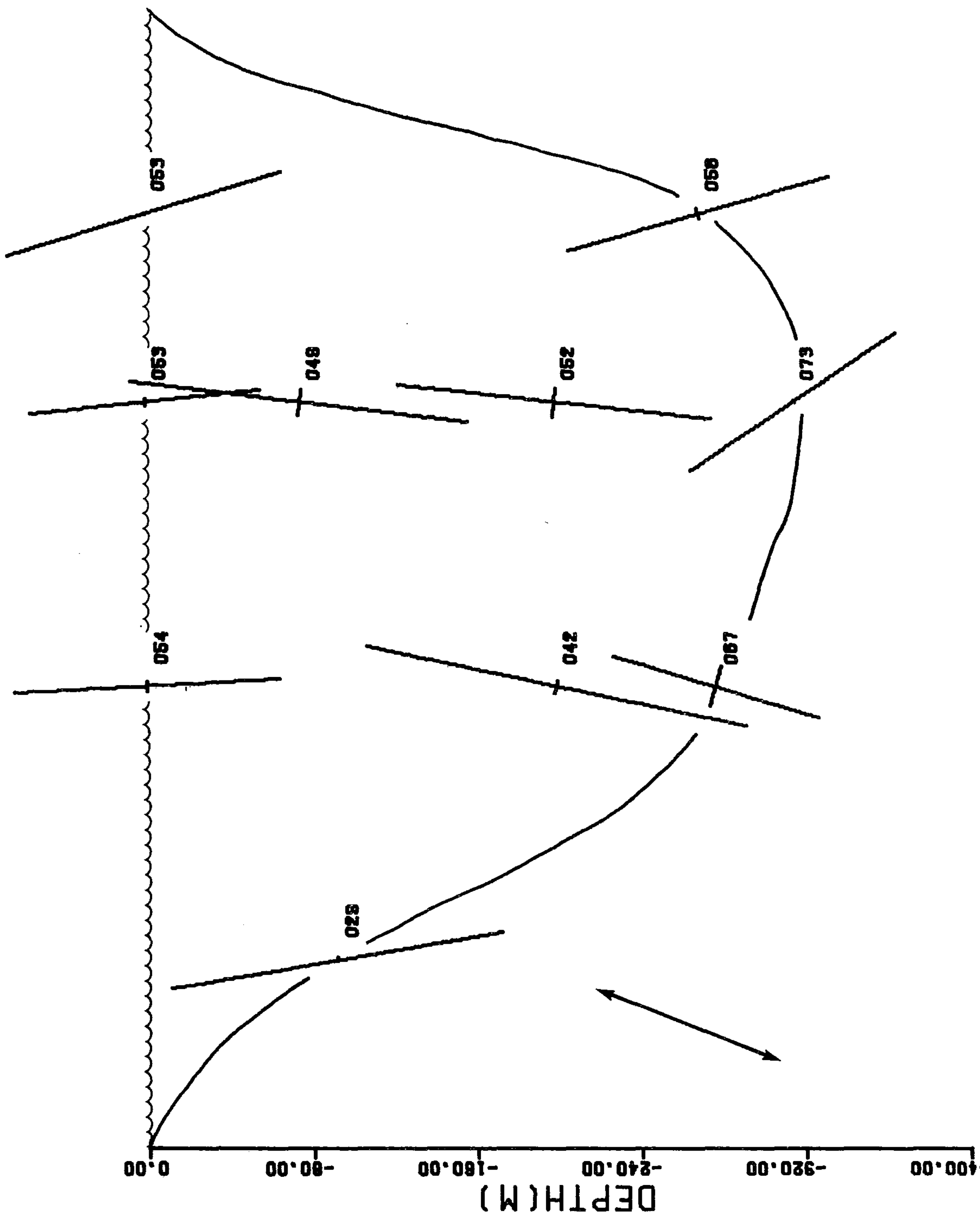
CROZIER STRAIT WEST O_1



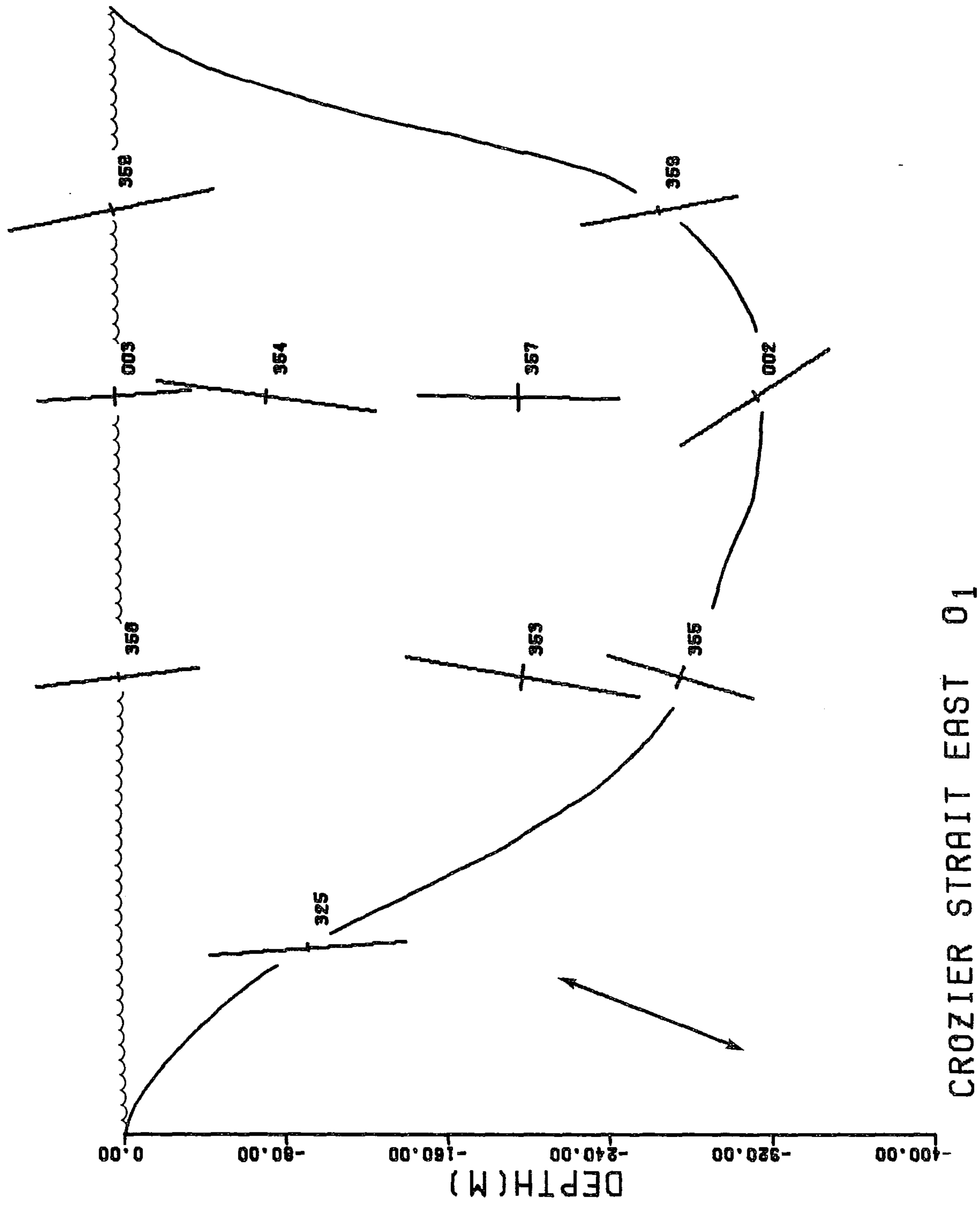
CROZIER STRAIT WEST M_2

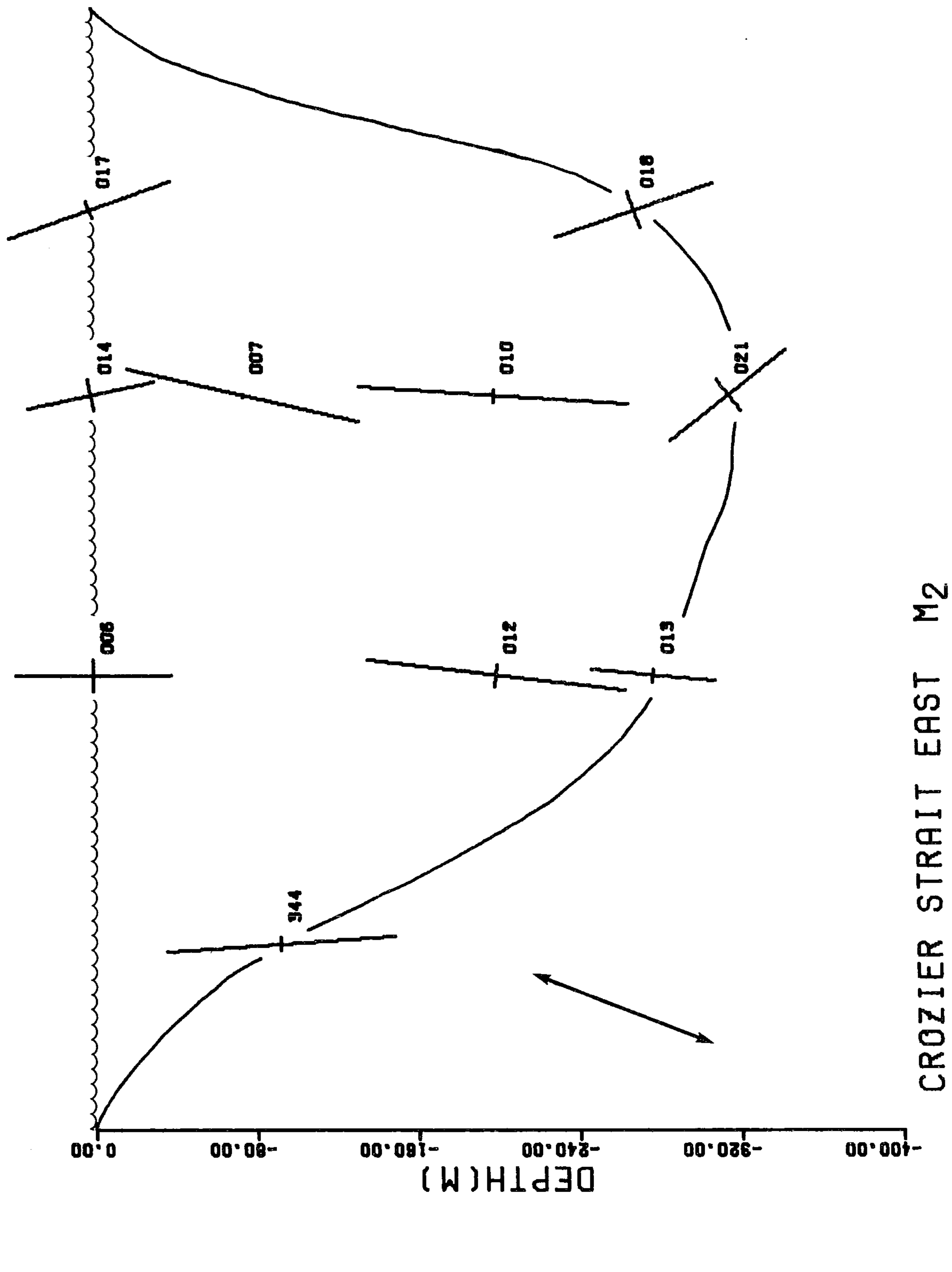


CROZIER STRAIT WEST S_2

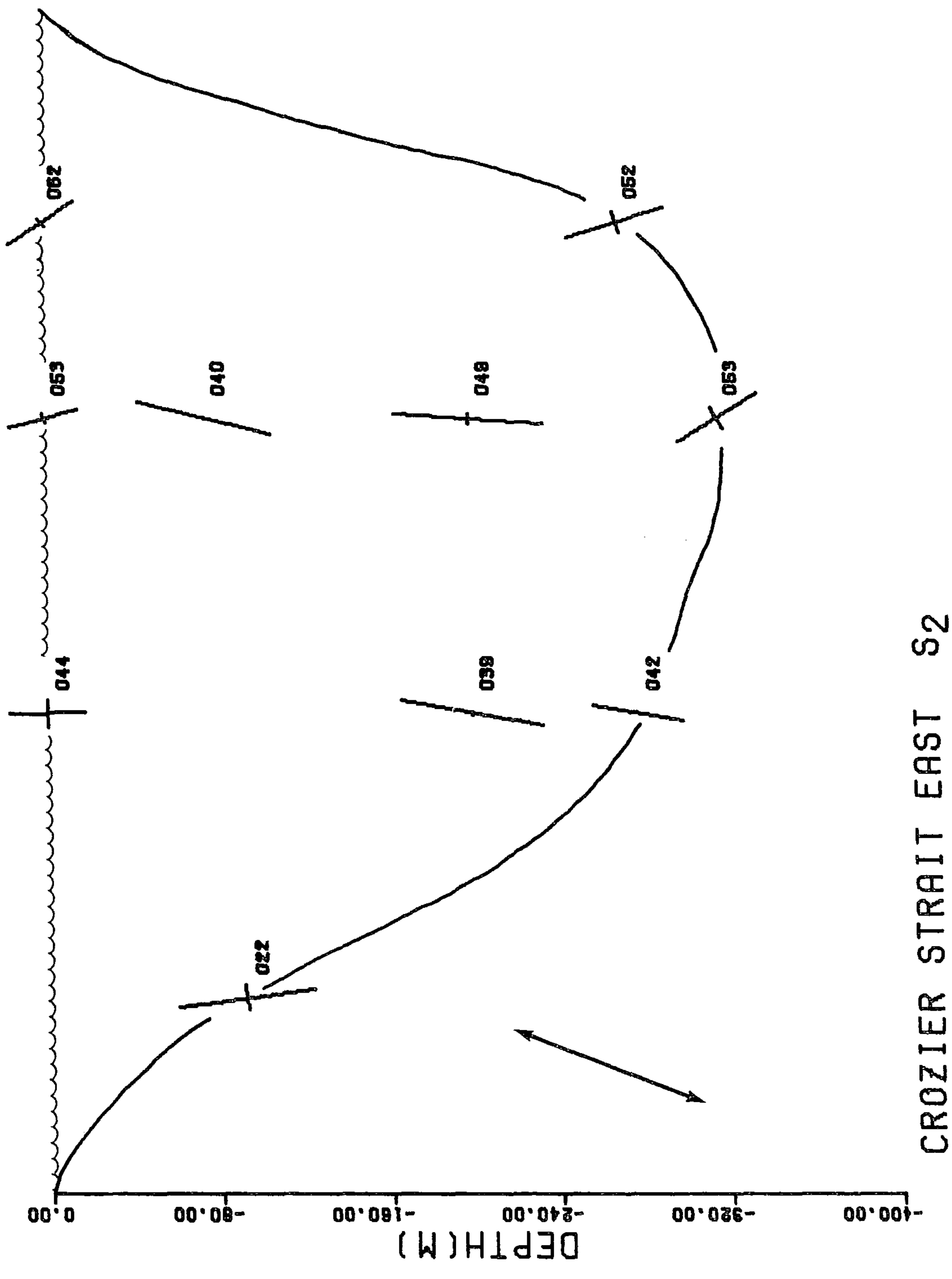


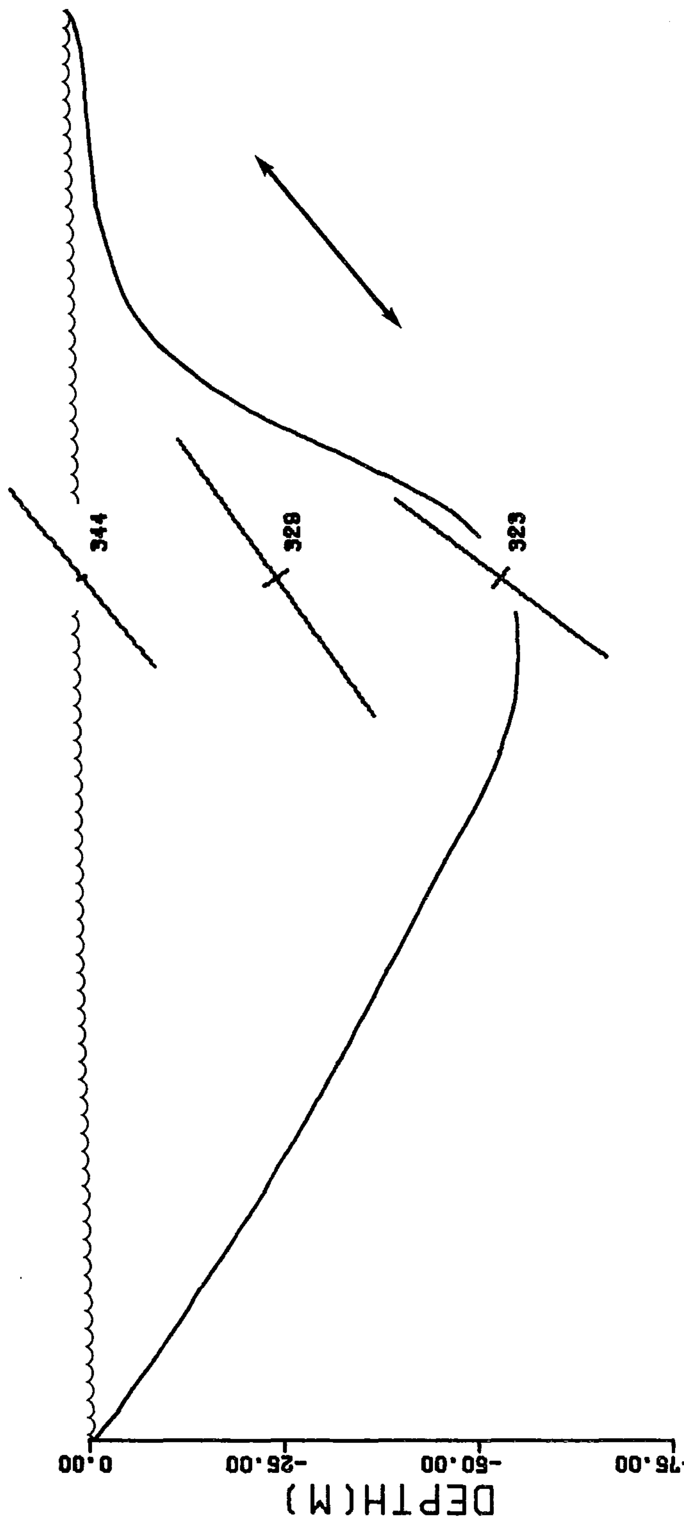
CROZIER STRAIT EAST K_1


CROZIER STRAIT EAST O_1
DEPTH(M)
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
358
003
354
357
002
359
353
355
325

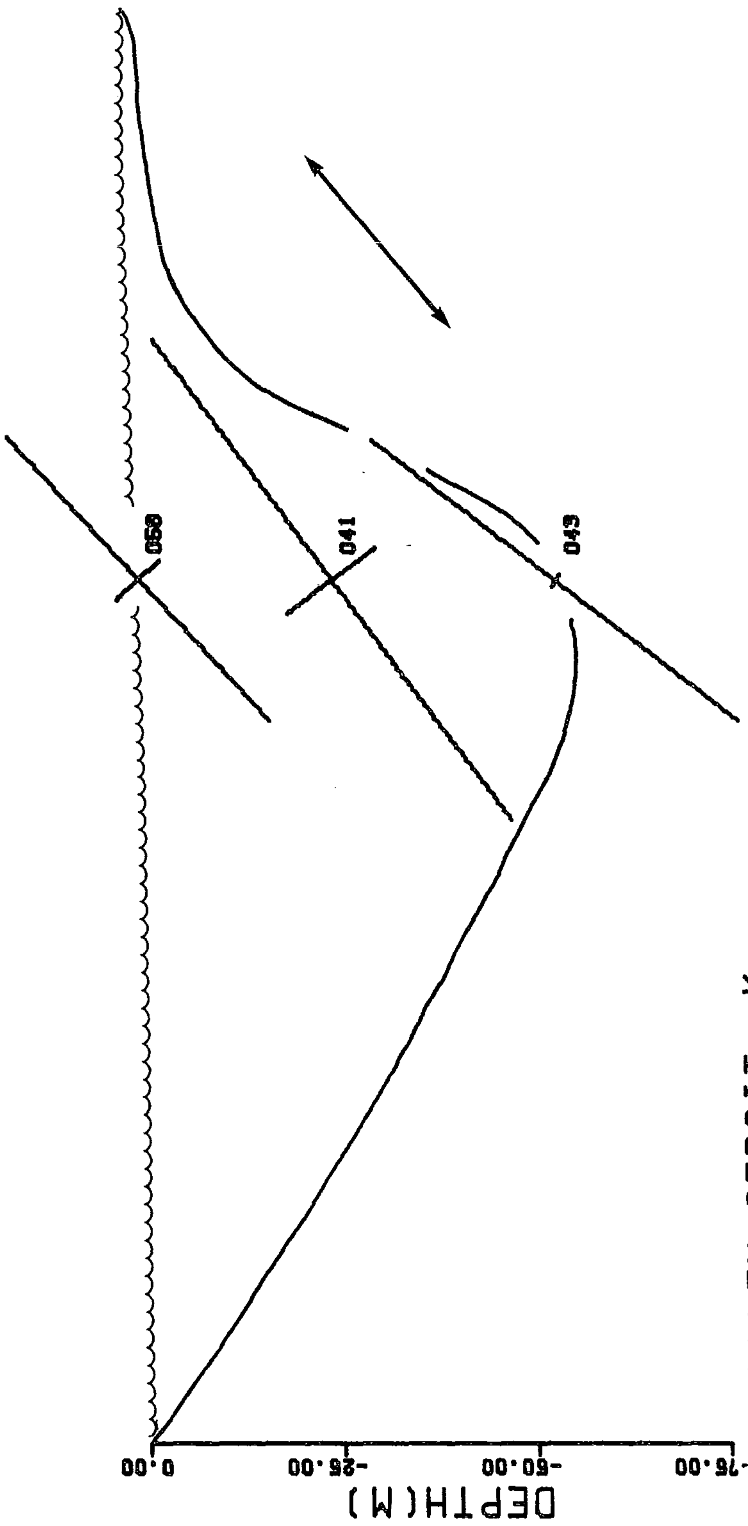


017
014
007
010
018
021
008
012
013
344
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
DEPTH(M)
CROZIER STRAIT EAST M2

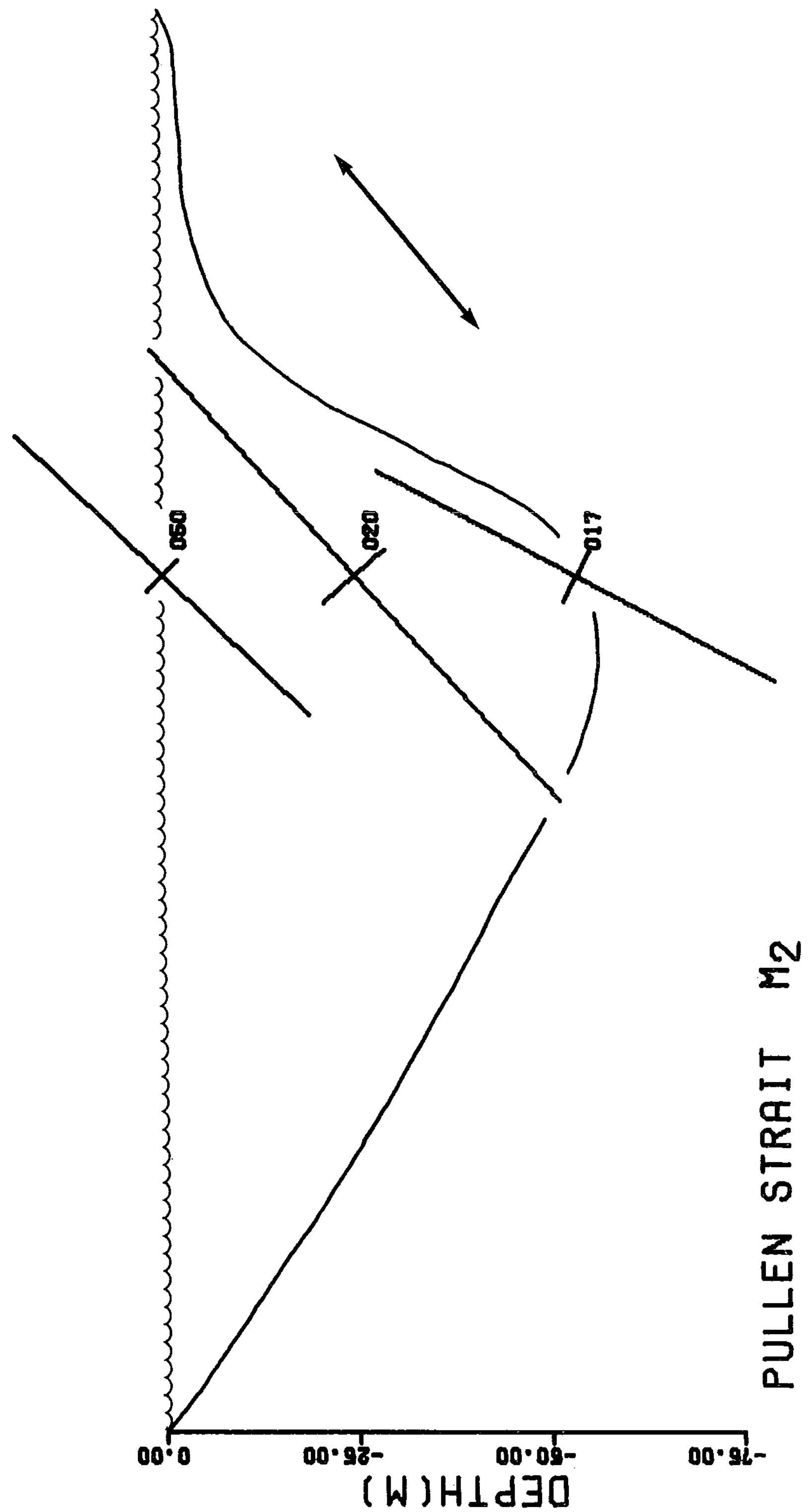

CROZIER STRAIT EAST S_2
DEPTH(M)
0.00
-80.00
-160.00
-240.00
-320.00
-400.00

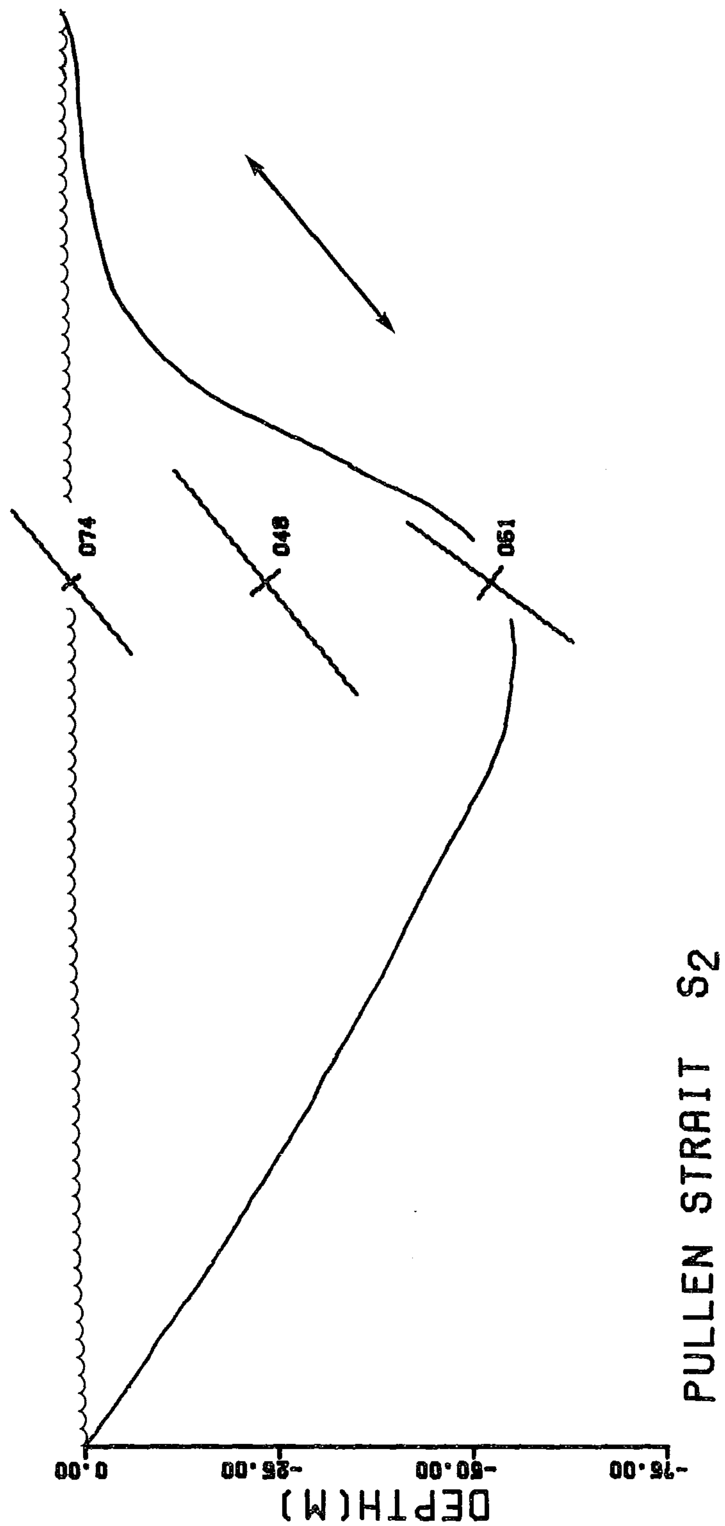


PULLEN STRAIT O_1



PULLEN STRAIT K_1


050
020
017
PULLEN STRAIT M2
0.00
-25.00
-50.00
-75.00
DEPTH(M)



074
048
061
DEPTH(M)
0.00
-25.00
-50.00
-75.00
PULLEN STRAIT S2