

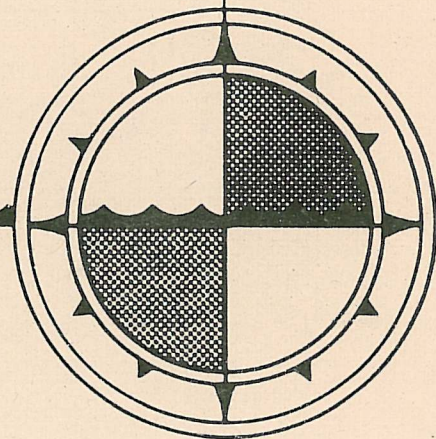
**TIDAL CURRENTS IN JOHNSTONE STRAIT**

by

**W. S. Huggett**

and

**M. J. Woodward**



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1981



## ABSTRACT

This report describes the tidal streams in the area of Johnstone Strait in British Columbia. Over a period of several years short-term current meter records were taken at 7 stations along the length of the strait and at 2 stations in Queen Charlotte Strait. It was found that, although tidal streams at locations where observations had been made were predictable, interpolation between stations is difficult due to the complexity of the currents. Generally the tidal streams in Johnstone Strait are semi-diurnal, with the streams at depth stronger than the surface streams and the times of turns earlier. In the passes at the western end of the strait, times of slack water are best referenced to slack water times at Seymour Narrows.

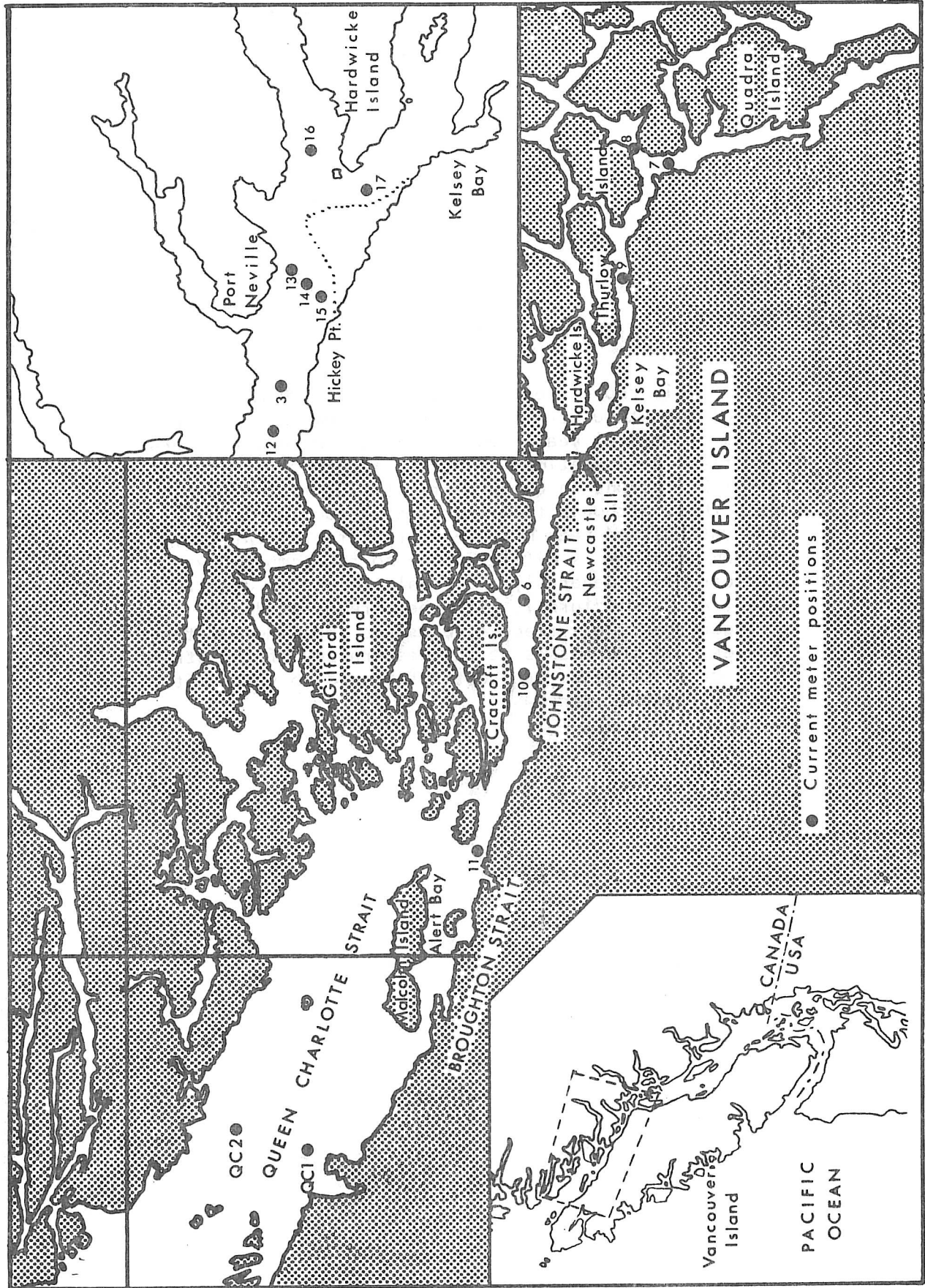


Figure 1. Current meter positions.

## Introduction

The purpose of this publication is to bring to the notice of ship and tug masters, fishermen and other seafarers, the vagaries of the tidal streams in Johnstone Strait. It is hoped that after reading this publication they will be able to make better use of the tidal streams in their work, and realize the difficulty of trying to present to the mariner predictions of times and speeds of the currents in Johnstone Strait and the adjoining passes.

These measurements in Johnstone Strait were taken in the years 1976, 1977 and 1978 to gain some knowledge of the propagation of the tidal wave and streams along the Strait, and to investigate the internal tide that is present in the area of Hickey Point. This latter investigation is a direct outcome from the data taken in 1973. Continuous current meter records were taken at seven stations along the length of the Strait and two in Queen Charlotte Strait, with continuous temperature and conductivity records also taken at most locations. During the course of these surveys ten oceanographic cruises were carried out with CTD (conductivity, temperature, depth) measurements taken at thirty stations stretching from south of Cape Mudge in the Strait of Georgia to Gordon and Goletas Channels in Queen Charlotte Strait. These measurements are necessary to determine the density structure of the water, to enable prediction of the baroclinic streams. At twenty of these stations dissolved oxygen, silicate, nitrate and phosphate samples were taken. Bottom grab samples were also taken along the Strait from Yorke Island west to Hanson Island. The above data is recorded in Data Record of Current Observations Volumes VII and VIII.

## Observations

The tidal streams in Johnstone Strait are predominantly semi-diurnal with a ratio of  $\frac{K_1+O_1}{M_2+S_2} = 0.22$  in contrast to the tidal components which have a ratio of 0.58. The actual amplitudes of  $M_2$  and  $K_1$  at Station 3, for example, are 28.0 cm/sec and 6.5 cm/sec respectively. Owing to their strong semi-diurnal characteristic the tidal streams follow very closely that of the  $M_2$  tide. Actual comparisons of the surface currents between Station 3 (Johnstone Strait Central) and other stations (Fig. 2) show that the time of the maximum current is practically the same as that for the  $M_2$  stream ( $29.98^\circ = 1$  hour), and the standard deviation of the comparisons is less than 25 minutes at all stations. The time of maximum surface streams (15 m depth) is delayed by 2h 36m from the outer Station QC2 off Masterman Island to Station 7 in Discovery Passage, and the bottom streams lag by 3h 10m (Fig. 3). Although the bottom streams lag the surface streams at both ends of the Strait, 52 min at Masterman Island and 18 min at Station 7, at Station 3 the bottom stream leads the surface stream by 16 min. Also at Station 3, the amplitudes of the diurnal and semi-diurnal constituents for the tidal streams at 225 metres depth are much larger than those of the surface streams, being a factor of 2.5 and 1.7 respectively higher (Fig. 4 & 6). These strong streams at depth are due to a baroclinic current generated by the tide at the sill just east of Station 3. The sill disturbs the equilibrium level of the uniform density surfaces to create temporary unbalanced horizontal density gradients and hence internal tidal motions (Thomson 1976, Thomson and Huggett 1980).

The times of slack water (on the surface and at the bottom) vary quite remarkably from station to station and from day to day because of (a) the large residual current present, and (b) the weather conditions. The winds in Johnstone Strait either advance or retard the surface current, which affects the times of slack water. A section across Johnstone Strait at Station 3 shows the distribution of the residual current (Fig. 8). At a mean depth of approximately 115 m there is no residual current; above this depth the current is outgoing and below this depth it is incoming. This general pattern is typical of tidal estuaries, and holds good for the remainder of Johnstone Strait as shown by Figure 9, except that the mean depth for no residual current is about 75 m when east of Kelsey Bay.

The surface current in Johnstone Strait between York Island and Alert Bay is quite straightforward with the turn to flood and maximum rates at Station 10 being 10 minutes earlier than Johnstone Strait Central, and with the turn to ebb occurring at the same time. This stretch is characterized by the two ebb currents per day having nearly the same amplitude of 75 cm/sec, and where, after the slack, the current quickly rises to 75% of the maximum current or better and maintains this speed for  $3\frac{1}{2}$  hours or more. This relationship however, does not hold when the tides are predominantly diurnal, in which case a marked difference between the two ebb currents is evident (Fig. 10). The larger tidal range produces the larger tidal current, which varies anywhere between 20 and 40 cm/sec, and on the smaller tide range of the day the current varies between 5 and 15 cm/sec. The flood current following the lower low water (LLW) of the day is the larger of the two flood currents and is about twice that of the other flood current, and when the lower high water (LHW) is less than 3.8 m (12.5 ft) there will be no flood current.

The bottom currents along this stretch have, conversely, a large flood bias, but, unlike the surface where the ebb currents have the same speed for both daily currents, a large diurnal inequality exists with a maximum difference of 40 cm/sec. The larger flood currents (85-110 cm/sec) have a duration of  $8\frac{1}{2}$  hours, but the smaller flood currents maintain their maximum speed for  $2\frac{1}{2}$  hours to 3 hours. The larger ebb currents (50-70 cm/sec) have an average duration of 5 hours with the diurnal inequality only half (20 cm/sec) that of the flood currents.

In the passes at the western end of the Strait, the times of maximum current are the same, or nearly so, as Johnstone Strait Central, but the times of slack water differ considerably and are best referenced to slack water times at Seymour Narrows. In Blackney Passage and Broughton Strait where the surface currents are affected by the bottom currents, the times of slack water in these narrow, shallow passes are a compromise between the two slack waters. This results in the times of slack water on the turn to flood and ebb being respectively two hours earlier and one hour later than the surface slacks in Johnstone Strait. The slack waters at Blackney Passage are 30 minutes earlier than off Alert Bay, but 20 minutes later than Pulteney Point. In the area between Blinkhorn Light and Alert Bay there are strong tide rips present on the flood current. At the eastern end in Sunderland Channel the current is only half that of Johnstone Strait Central, and both slack waters and the maximum ebb occur 1 hour 40 min earlier, and the maximum flood 1 hour 10 min earlier than in Johnstone Strait. During the times of maximum flood and ebb there are strong tide rips or fronts

present in the channel between Kelsey Bay and Port Neville.

In Johnstone Strait east of Yorke Island the times of maximum flood and ebb currents on the surface occur about 20 minutes later than those to the west of Yorke Island, but the times of slack water differ widely. Again the ebb bias is very prominent, and both daily ebb currents have the same velocity of 120 cm/sec. This appears to be the maximum velocity attained in that part of the channel, and the current maintains this speed for 2½-3 hours. When the range of the tide is less than 1 m, the maximum ebb velocity drops to about 70 cm/sec with some diurnal inequality in the two daily ebb currents. The flood currents, on the other hand, have a large diurnal inequality with the speed of the flood current following LLW being double that of the other flood current. The maximum floods have velocities up to 110 cm/sec, but when the range of the tide is less than 1 m, there is no flood current for that period. The maximum flood currents here and the maximum ebb currents west of Yorke Island are both dependent on the range of the tide as evidenced by the graphs in Figures 12-17. An appreciation of the current velocity to be expected from the range of the tide at Alert Bay can be had from these graphs.

The times of slack water are vastly different from those of Johnstone Strait Central, the turn to flood occurring 35 minutes earlier and the turn to ebb 90 minutes later. In Race Passage however the currents are the same as Johnstone Strait Central, but in Current Passage the turn to ebb occurs about 75 minutes earlier than the turn to ebb in Race Passage.

The bottom current along this part of the Strait east of Yorke Island also has a large flood bias with the flood current having a maximum speed of 120 cm/sec, but unlike the surface current, does vary with the tidal range. The maximum flood current also has two peaks roughly 2½ hours apart with a 20-40 cm/sec drop in speed between the two peaks (Fig. 11). This phenomenon was not apparent at any of the other stations in Johnstone Strait. The difference between the two daily flood currents is 30 cm/sec at times, the duration of the flood current is around 8½ hours and for at least half of the time the current is running at 80% or better of the maximum speed. The ebb current is generally less than 45 cm/sec, but when the tides are predominantly diurnal, rates up to 60 cm/sec are present. The duration of the ebb current is about 4 hours, with the diurnal inequality greater than that of the flood stream, attaining a difference of 50 cm/sec at times.

In Nodales Channel the bottom currents are more diurnal than at Station 9. The velocity of the bottom water entering and leaving Nodales Channel is only one-third of that at Station 9 (40 cm/sec as opposed to 120 cm/sec), and the times of maximum current vary anywhere from a half hour to five hours earlier. When the tidal range is large the current continues to flood (north going) on the bottom in Nodales Channel on the largest ebb of the day (a continuation of the ebb in Discovery Passage).

In Race and Current Passages, situated between Kelsey Bay and Station 9, the times of maximum flood and ebb are at the same time as those at Station 9, and the times of slack turn to flood are 15 minutes earlier than Station 9. The turn to ebb in Current Passage occurs 45 minutes earlier, and in Race Passage it occurs 30 minutes later than at Station 9. At the

north end of Discovery Passage the maximum flood occurs 10 min later and the maximum ebb 30 minutes later than at Station 9, with the times of slack water being very close to those of Seymour Narrows.

Looking at the Strait in cross-section in the vicinity of Station 3 over a 25 hour period during a time of average tide heights, large differences from one side to the other are evident on the surface in the speeds and time of the turn (Fig. 18). The flood current starts at depths around 200 m and builds up to speeds greater than 40 cm/sec while there is still an ebb current running on the surface. On the surface the flood current starts along the Vancouver Island shore at about the same time as it starts at depth, but takes over 2 hours to completely cover the Strait from one side to the other, with the current along the Vancouver Island shore far stronger than elsewhere across the Strait. However, as soon as the flood current covers the entire Strait, the speed drops off dramatically to about one-third of its maximum speed. In less than 2 hours after the flood current covers the entire surface, the ebb current is starting to run along the mainland shore, and within the hour the whole Strait on the surface is ebbing. The flood current still continues to run at depth for about 2 hours after the start of the ebb on the surface. At the time of maximum ebb, the current speed is the same across the Strait, then falls off quickly on the Vancouver Island shore prior to the start of the next flood current. The ebb current runs the strongest on the surface with the speed decreasing with depth.

On a cross-section 5.5 km (3 miles) to the east of Station 3, the start of the flood current exhibits the same characteristics as it did further to the west, but the ebb current appears to start in the centre of the channel rather than along the mainland shore, and when running at its maximum is much stronger along the mainland shore. On a large flood as shown in Fig. 19, the flood current runs for 6 hours on the surface, longer at depth, and the change to ebb on the surface is much quicker, within the hour, than on the change to flood.

A longitudinal look at the Strait between Stations 12 and 17, and on the same day as the cross-section at Station 14 was plotted, shows that at Station 17 on the bottom the ebb current runs for a very short duration, something less than four hours (Fig. 20). A prominent feature is again the wedge of strong flood current between 200 and 150 metres depth that persists long after the ebb current is running on the surface, and even after it is ebbing on the bottom. Another feature is the magnitude of the flood current at Station 3 at 235 m depth where it is much greater than that at Station 12 or 14 at maximum flood.

### Conclusions

Although the above features are regular in time, their complexity makes them difficult to describe and to present in one or two simple graphs. The tidal streams at any point can be predicted well, but their rapid change in behavior along the Strait, across the Strait, and with depth requires many reference and secondary stations in the tide tables, and defies simple explanations.

In 1982 current meter observations will be taken at Stubbs Island, east of Alert Bay, and from these observations it is hoped that better current predictions will result for the passes at the western end of Johnstone Strait.

### Acknowledgements

We would like to thank the many people who helped in the collection and analysis of the data, and in particular, A. Douglas, F. Hermiston, R. Thomson, J. Love and C. de Jong. C. Dale, B. Watt and K. Holman are thanked for their assistance in the preparation of the diagrams, and S. McKenzie in the typing of the manuscript. We also gratefully acknowledge the help and cooperation given to us by the officers and crews of the CSS *Parizeau*, CSS *Vector*, CSS *Richardson* and the CFAV *Endeavour*.

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Glossary of Terms

- Baroclinic current: is that current induced by two layers of water of different density having a sloping interface.
- Barotropic current: is that current induced by a sloping sea surface.
- cm/sec: 51.48 cm/sec = 1 knot
- Diurnal: having a period of, occurring in, or related to a day.
- Diurnal inequality: the difference between the heights of two successive high or low tides, or the difference in the speed between two successive flood or ebb tidal streams.
- Front: the vertical intersection of two masses of water of different density; often visible on the surface as tide lines or rips.
- $M_2$ : the principal lunar semi-diurnal constituent; that variation of the tide or current having 2 cycles per day and due to the gravitational attraction of the moon.
- $K_1$ : the principal diurnal constituent; that variation of the tide or current having 1 cycle per day and due to the combined gravitational attractions of the sun and moon.
- Residual current: non-tidal current due to causes other than tidal. It is that part of the total current that is left after the tidal component is removed.
- Semi-diurnal: having a period of, occurring in, or related to approximately half a day.
- Tidal stream: a current due to tidal action.  
Tidal stream + residual current = observed current.
- Tidal wave: a long period wave associated with the tide-producing forces of the moon and sun. Longest wave known in the ocean.

	Turn to Flood		Maximum Flood		Turn to Ebb		Maximum Ebb	
	h	m	h	m	h	m	h	m
Bear Point (J9)	-0	35	+0	30	+1	35	+0	20
Camp Point	-0	20	+0	30	+2	05	+0	20
Current Passage	-0	20	+0	30	+0	50	+0	20
Sunderland Channel (J16)	-1	40	-1	10	-1	40	-1	40
Forward Bay (J10)	-0	10	-0	10	0	00	-0	10
Masterman Island (Q02)	-3	45	-1	55	0	00	-1	55
Browning Islands (Q01)	-2	25	-1	50	-1	05	-1	55
Blackney Passage	-1	10*	0	00	-1	10*	0	00
Alert Bay	-0	40*	0	00	-0	40*	0	00
Pulteney Point	-1	30*	0	00	-1	30*	-1	00

\* Time difference for "Turn to Flood" and "Turn to Ebb" to be applied to the predictions for Seymour Narrows.

Figure 2. Time differences between Johnstone Strait Central and secondary stations along Johnstone Strait for maximum currents and turns.

M2

Masterman Island Station #3 Station #9

Surface Currents 158° — 116min — 214° — 29min — 228°

Tide (Yorke Is.) 21° — 39min — 40° — 68min — 73°

Bottom Currents 135° — 178min — 221° — 6min — 224°

K1

Surface Currents 224° — 176min — 268° — 136min — 234°

Tide (Yorke Is.) 130° — 40min — 140° — 40min — 150°

Bottom Currents 200° — 28min — 207° — 168min — 249°

Figure 3. Diurnal and semi-diurnal times between Queen Charlotte Strait and Station 9, Johnstone Strait.

M<sub>2</sub> Amplitudes

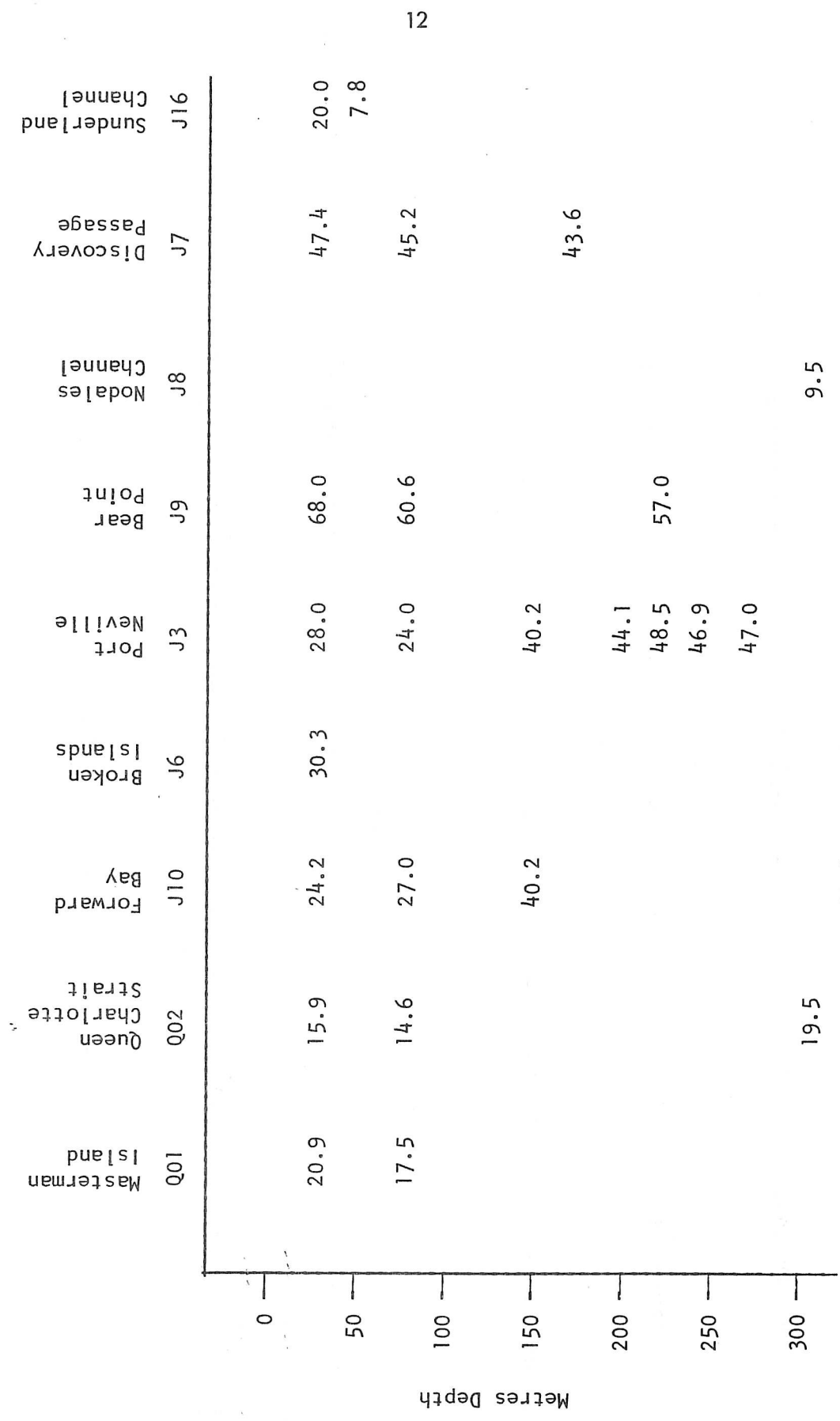


Figure 4. Semi-diurnal speeds of the tidal streams in cm/sec.

M<sub>2</sub> Phases

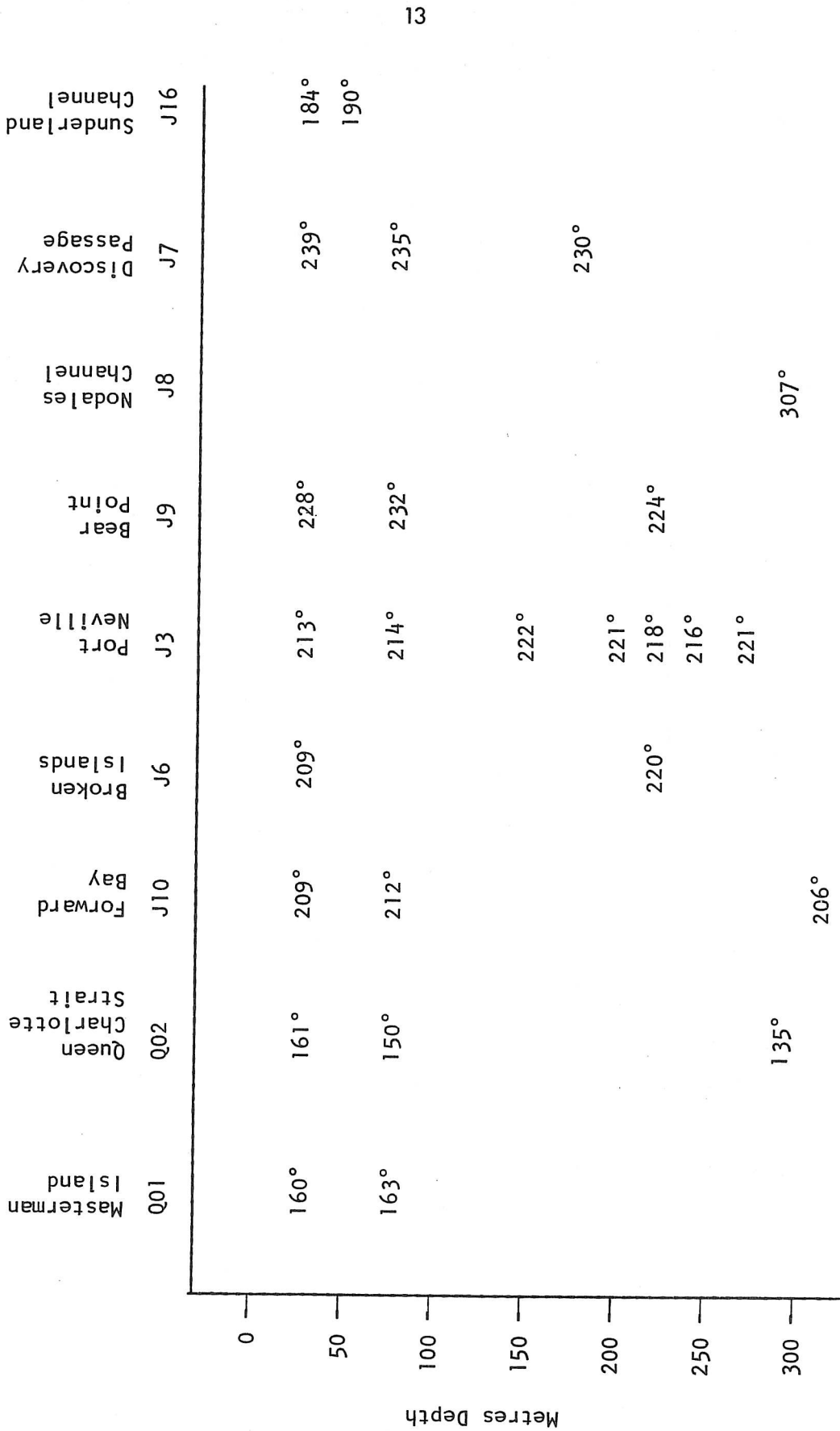
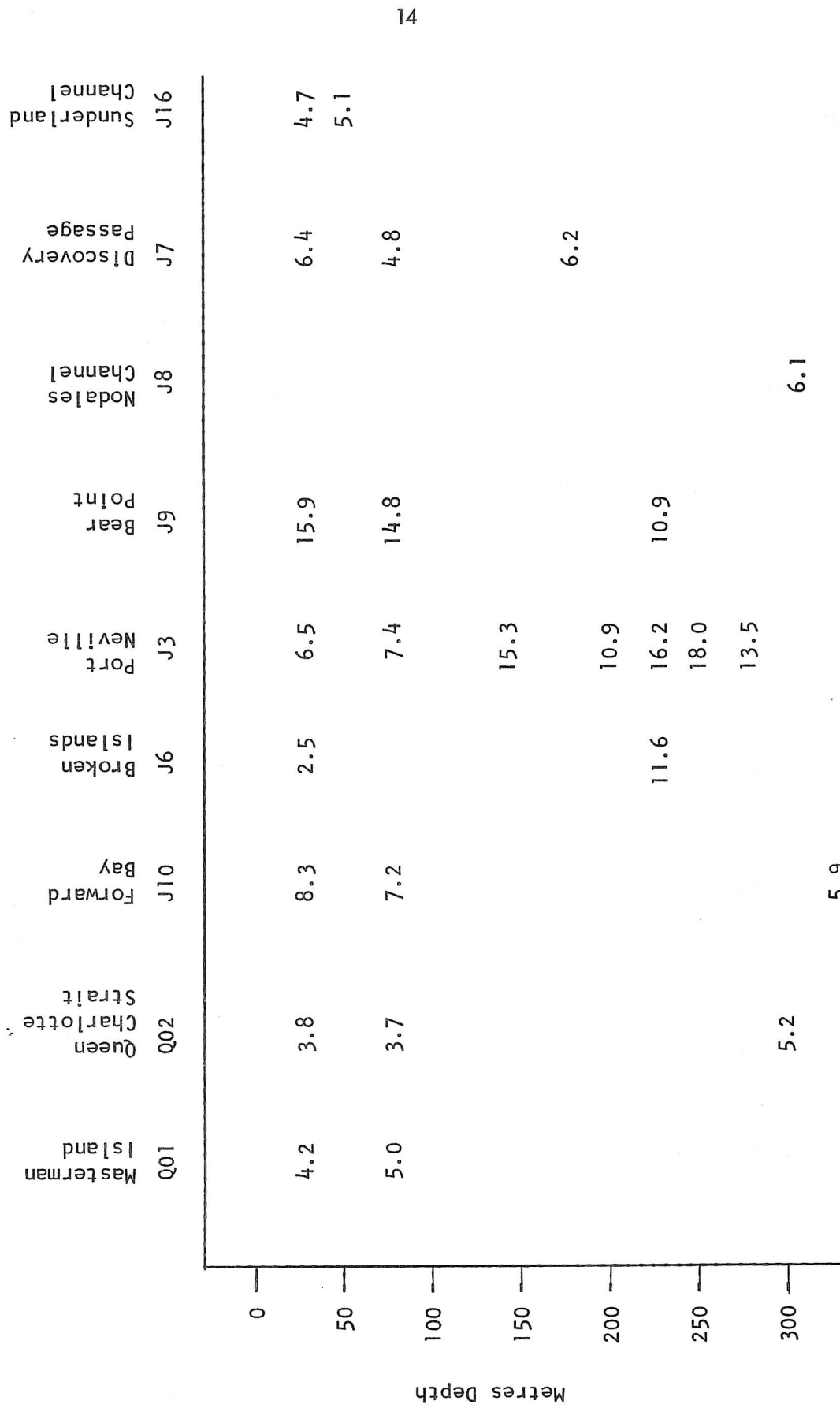


Figure 5. Phases of the semi-diurnal tidal streams. (28.98° = 1 hour)

Metres Depth

K<sub>1</sub> Amplitudes



5.9

Figure 6. Diurnal speeds of the tidal streams in cm/sec.

K<sub>1</sub> Phases

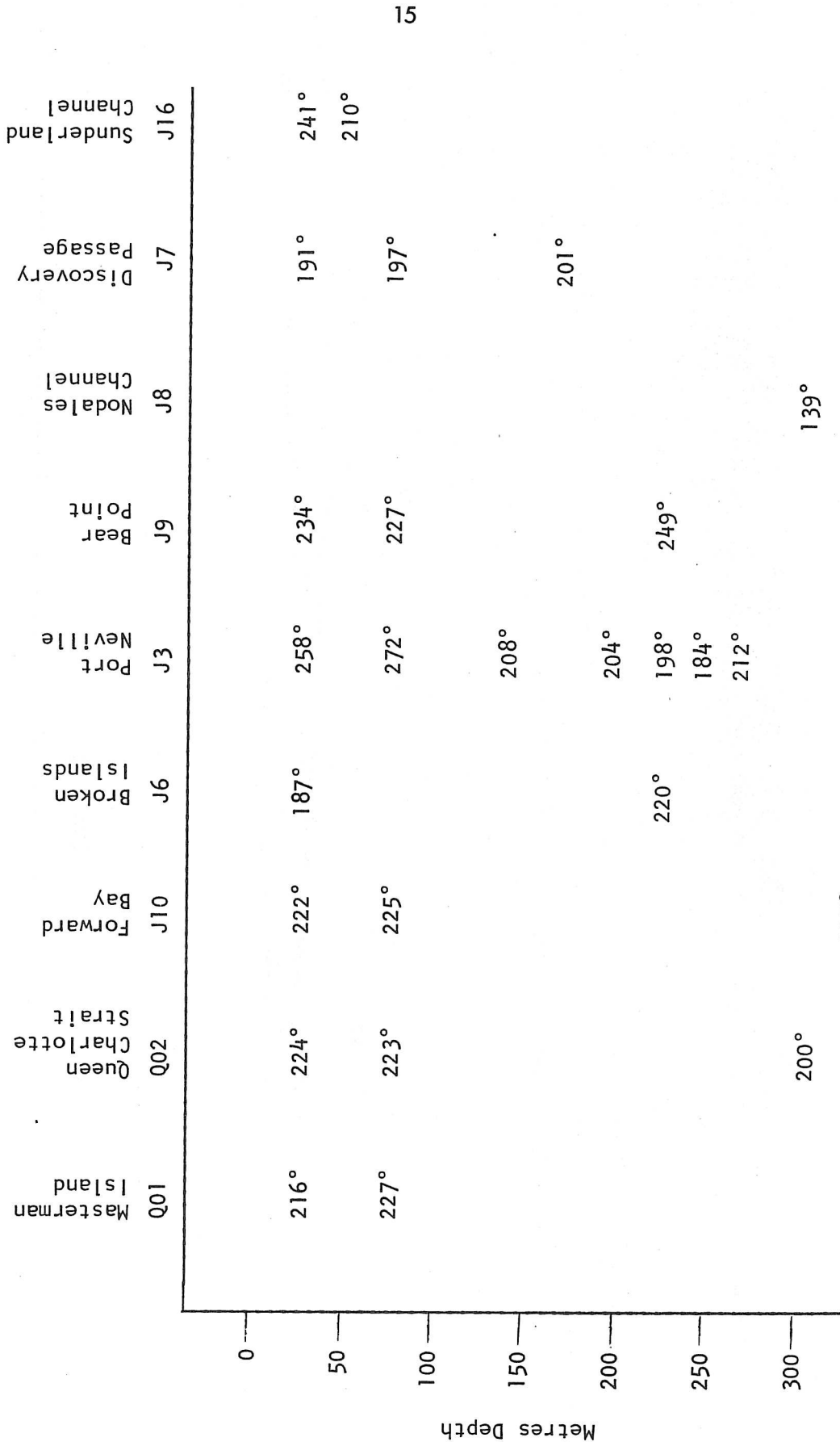


Figure 7. Phases of the diurnal tidal streams. ) (15.04° = 1 hour)

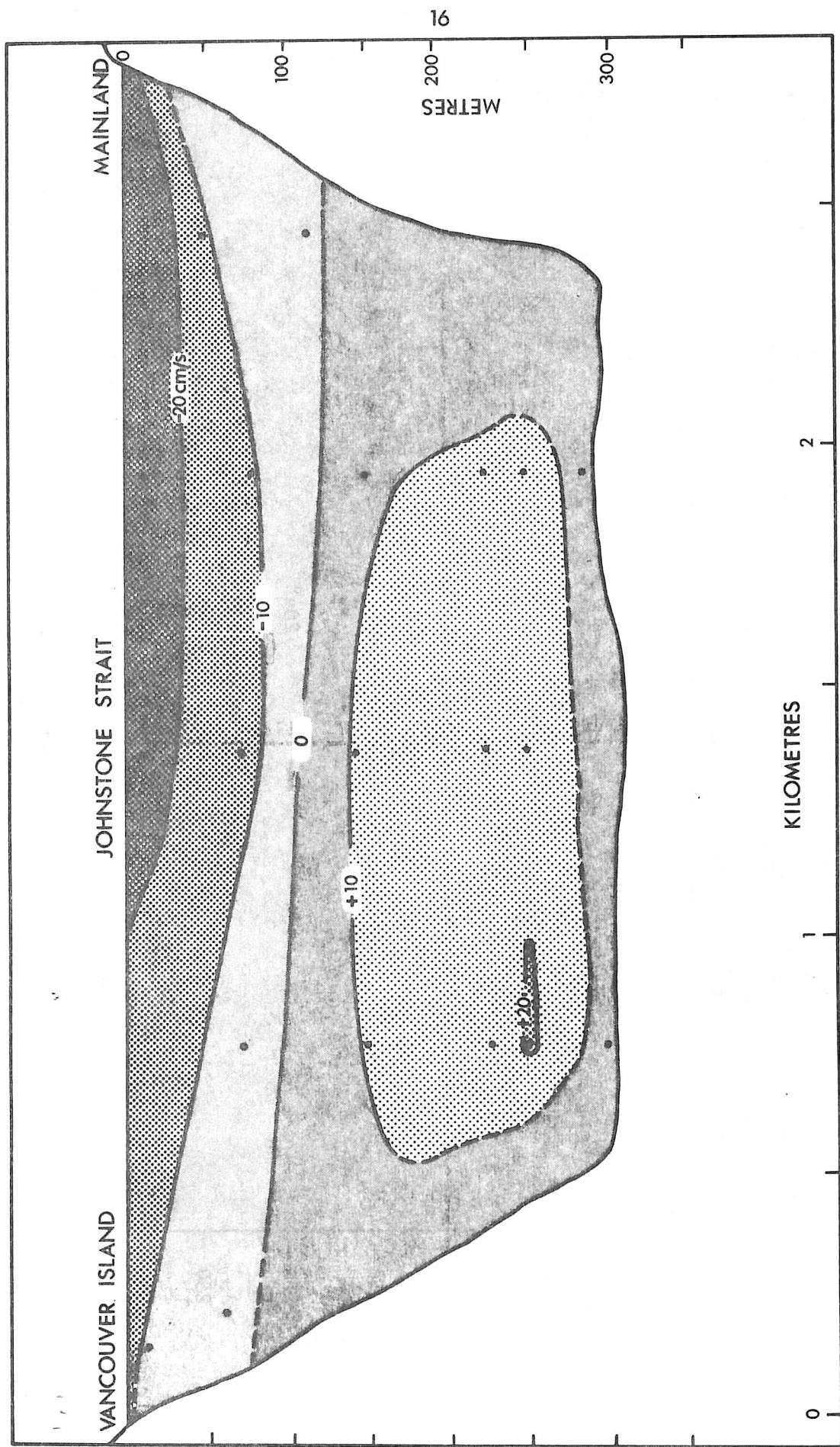


Figure 8. Distribution of the residual current across the Strait at Station 3.

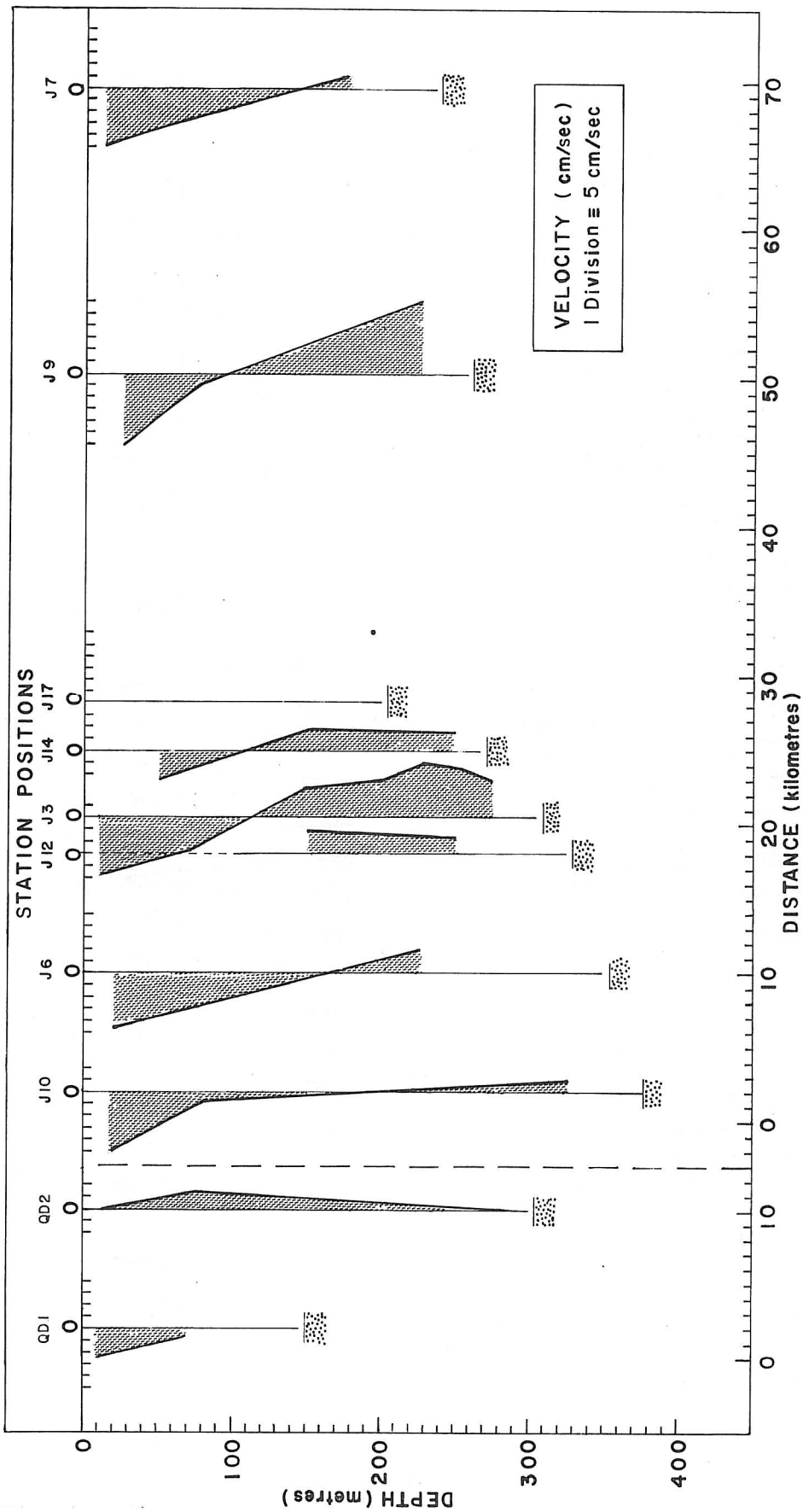


Figure 9. Distribution of the residual current along the Strait.

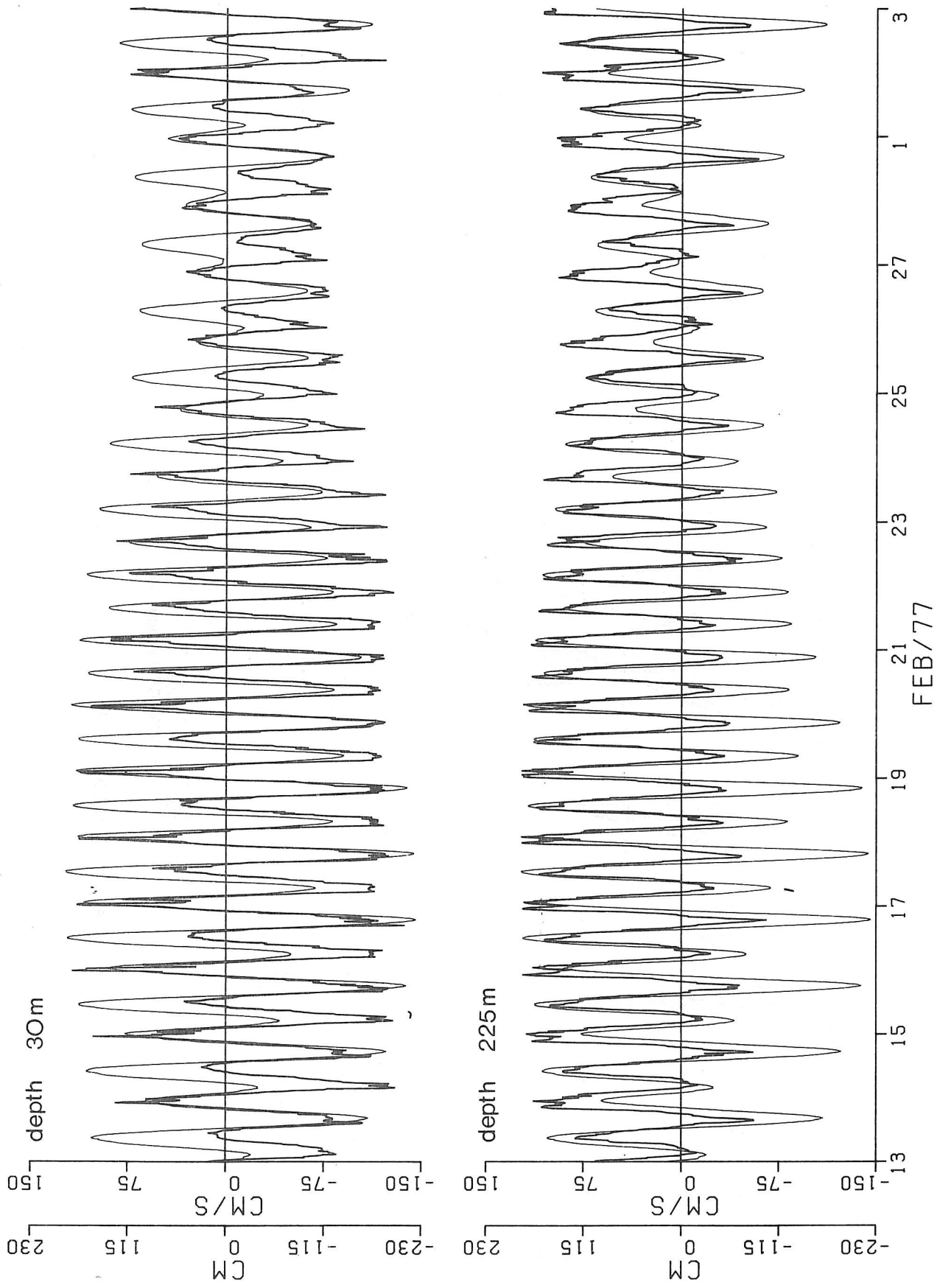


Figure 11. Plot of the surface and bottom currents at Station 9 with the tide (fine line) superimposed.

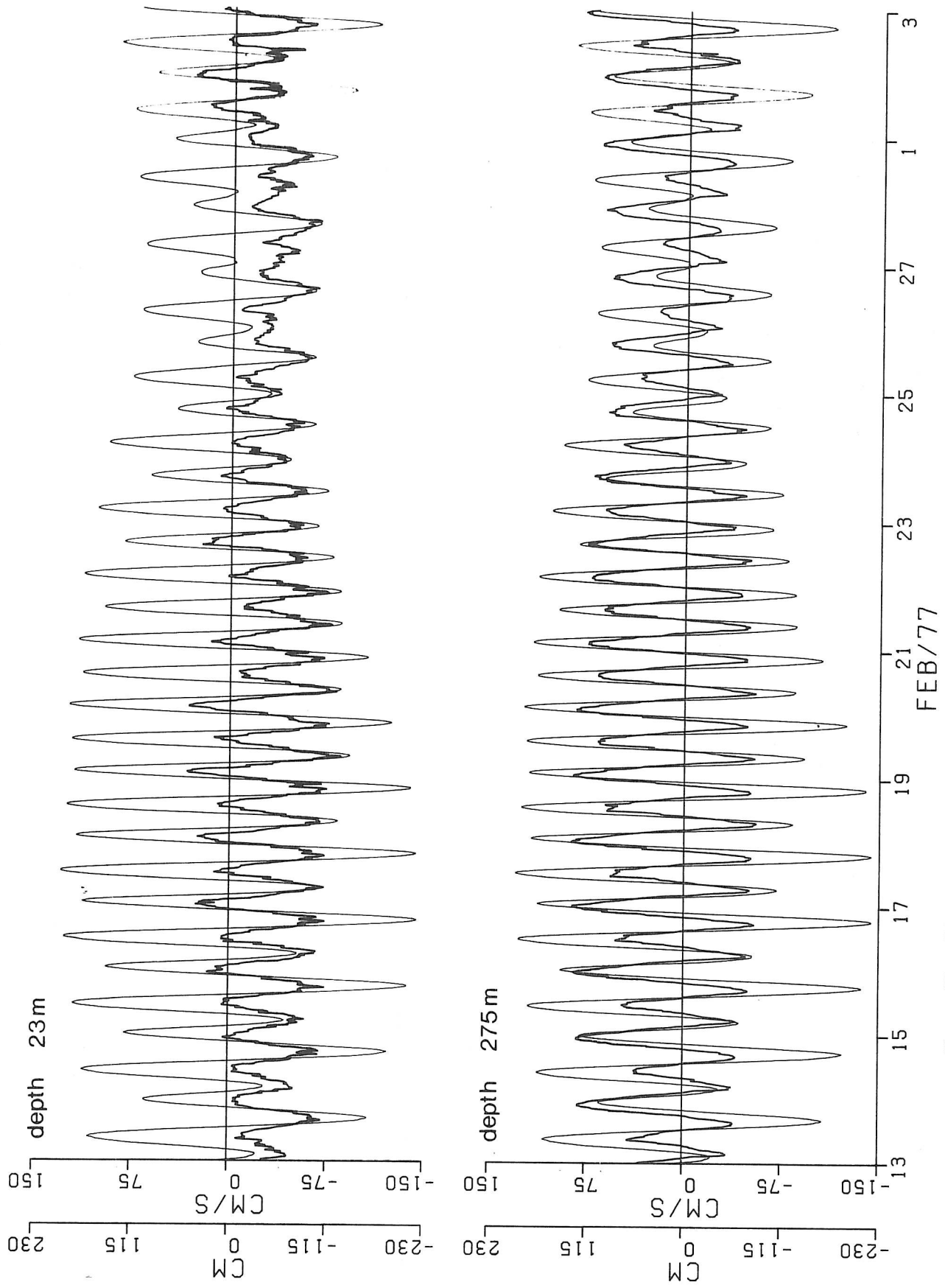


Figure 10. Plot of the surface and bottom currents at Station 3 with the tide (fine line) superimposed.

JOHNSTONE ST. 003  
FEB. 77, 27 PTS.  
MAX EBB CURRENT VS.  
TIDAL RANGE LOWER-  
HIGH TO LOW,  $R = .89$   
R = CORRELATION COEFFICIENT

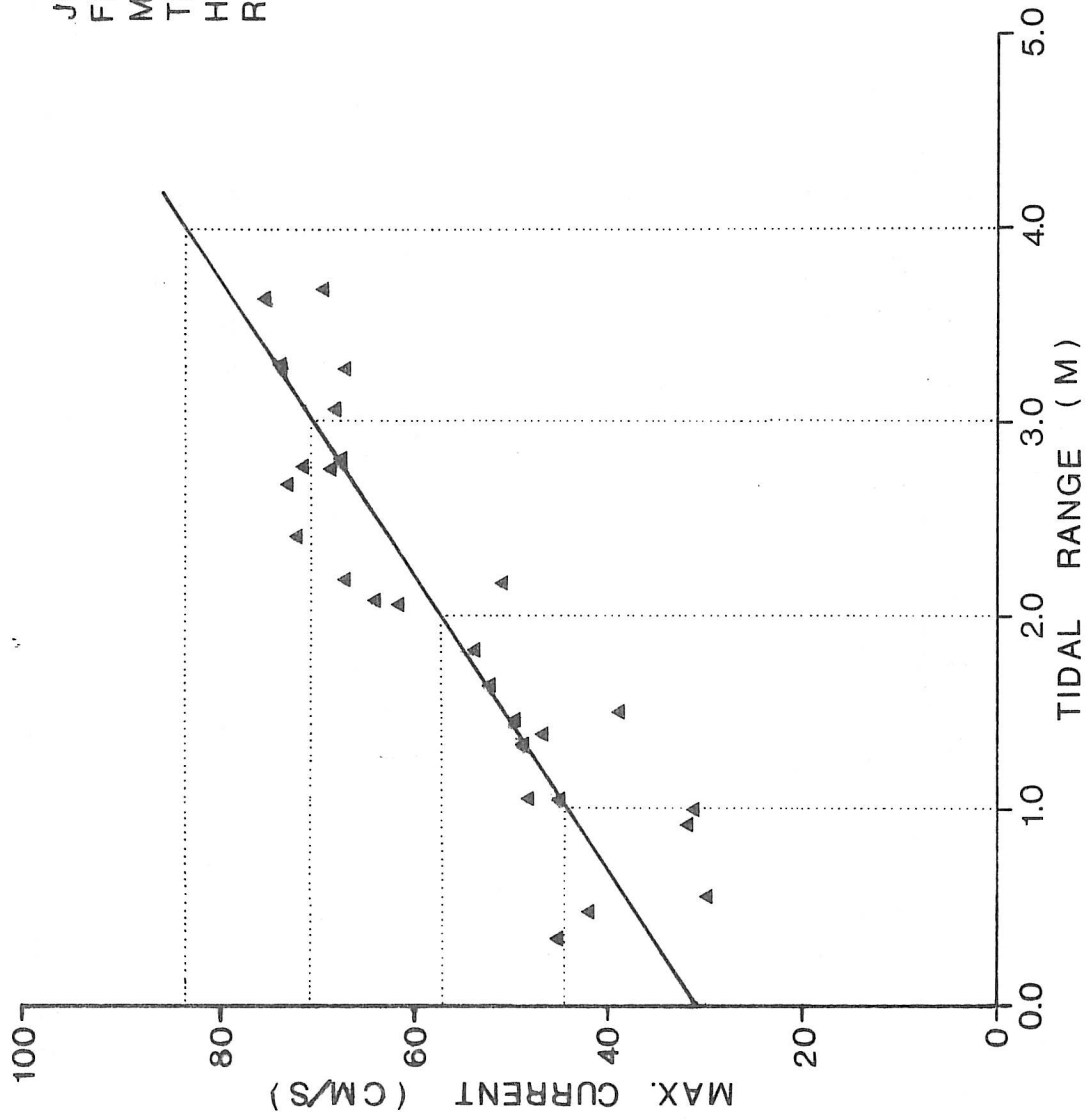


Figure 12. Station 3 Plot of maximum ebb current and the tidal range between lower high water and low water.

JOHNSTONE ST. 003  
MAR. 77, 42 PTS.  
MAX EBB CURRENT VS.  
TIDAL RANGE LOWER-  
HIGH TO LOW,  $R = .77$

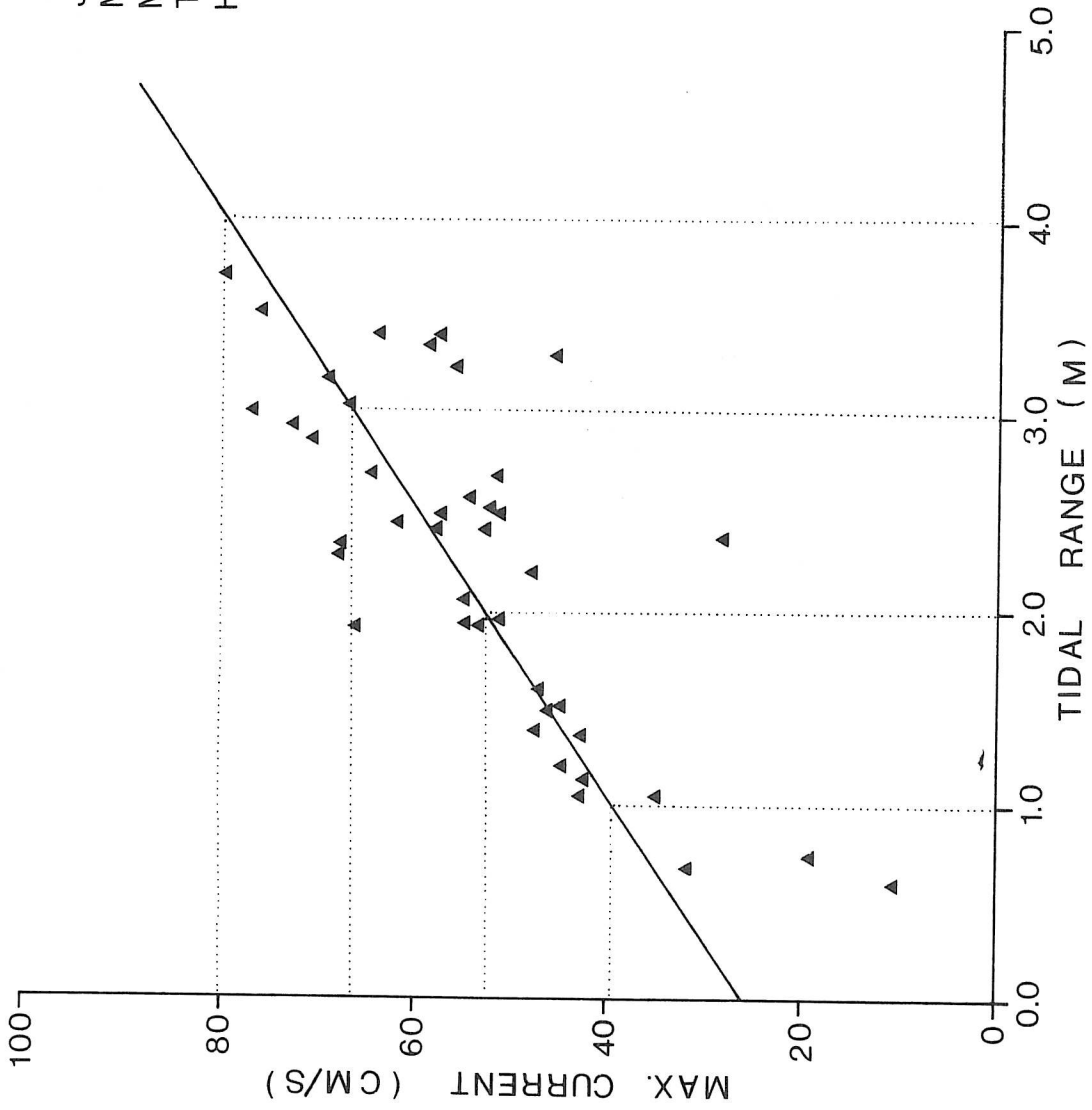


Figure 13. Station 3. Plot of maximum ebb current and the tidal range between lower high water and low water. Same as Figure 12. An indication of the current to be expected may be obtained from the above tidal range. See Figure 14.

JOHNSTONE ST. 003  
FEB. 77, 26 PTS.  
MAX EBB CURRENT VS.  
TIDAL RANGE HIGHER-  
HIGH TO LOW,  $R = .47$

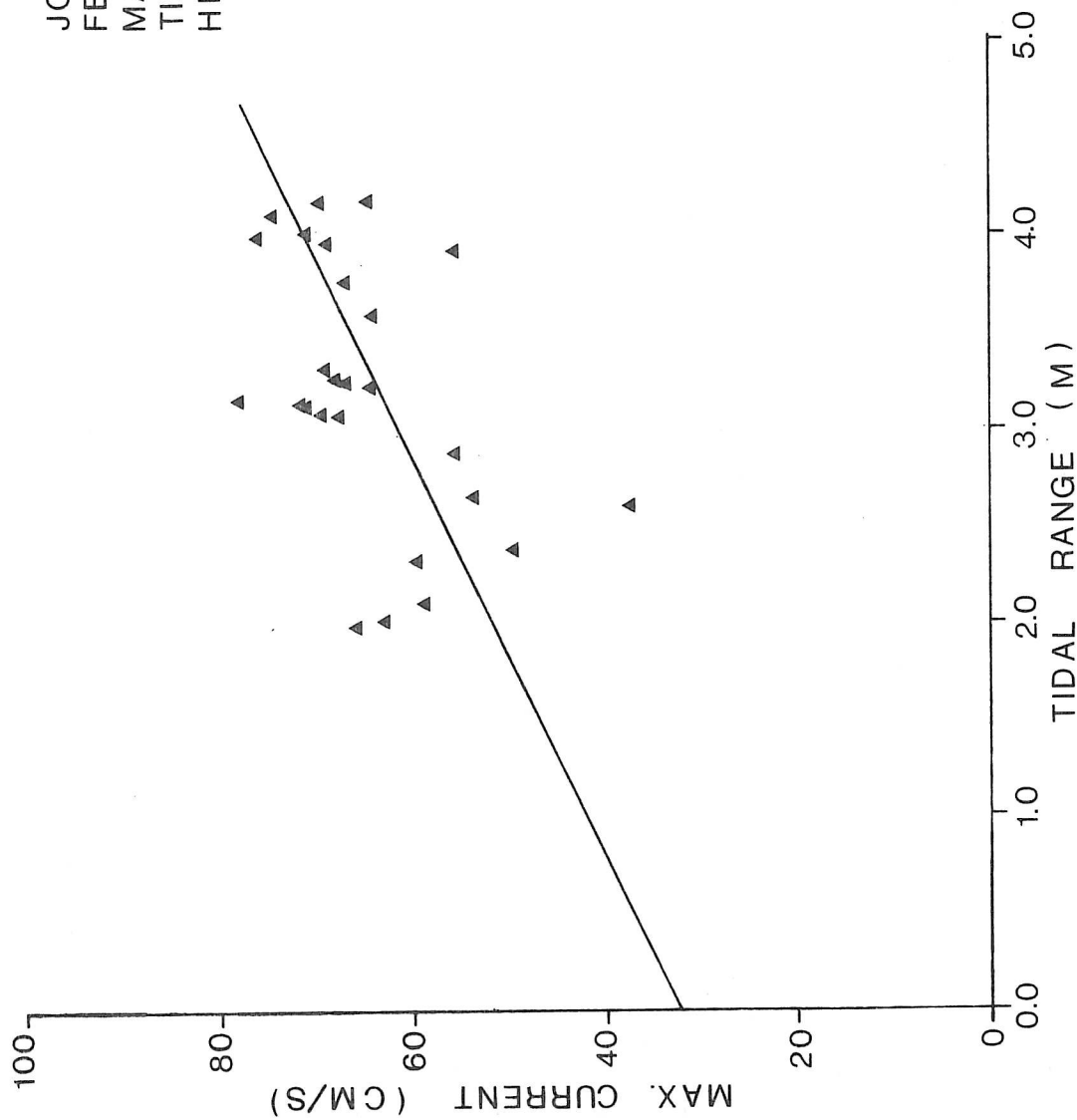


Figure 14. Station 3. Plot of maximum ebb current and the tidal range between higher high water and low water. This tidal range does not give a good indication of the currents to be expected.

JOHNSTONE ST. 003  
 MAR. 77, 41 PTS.  
 MAX EBB CURRENT VS  
 TIDAL RANGE HIGHER-  
 HIGH TO LOW,  $R = .76$

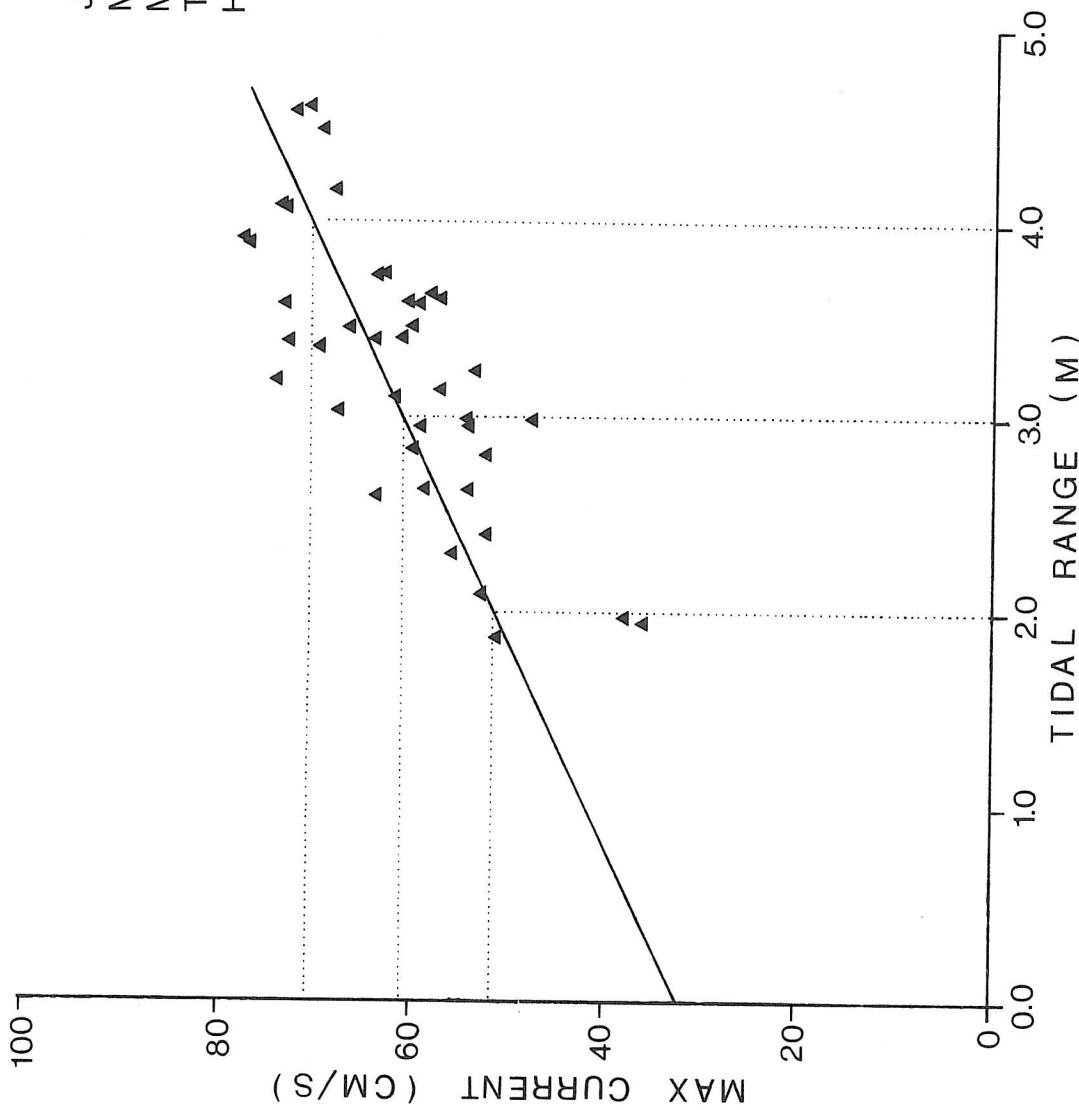


Figure 15. Station 3. Plot of maximum ebb current and the tidal range between higher high water and low water. This gives a very approximate indication of the currents to be expected.

JOHNSTONE ST. 009  
FEB. 77, 29 PTS.  
MAX FLOOD CURRENT VS  
TIDAL RANGE HIGHER -  
LOW TO HIGH. R = .86

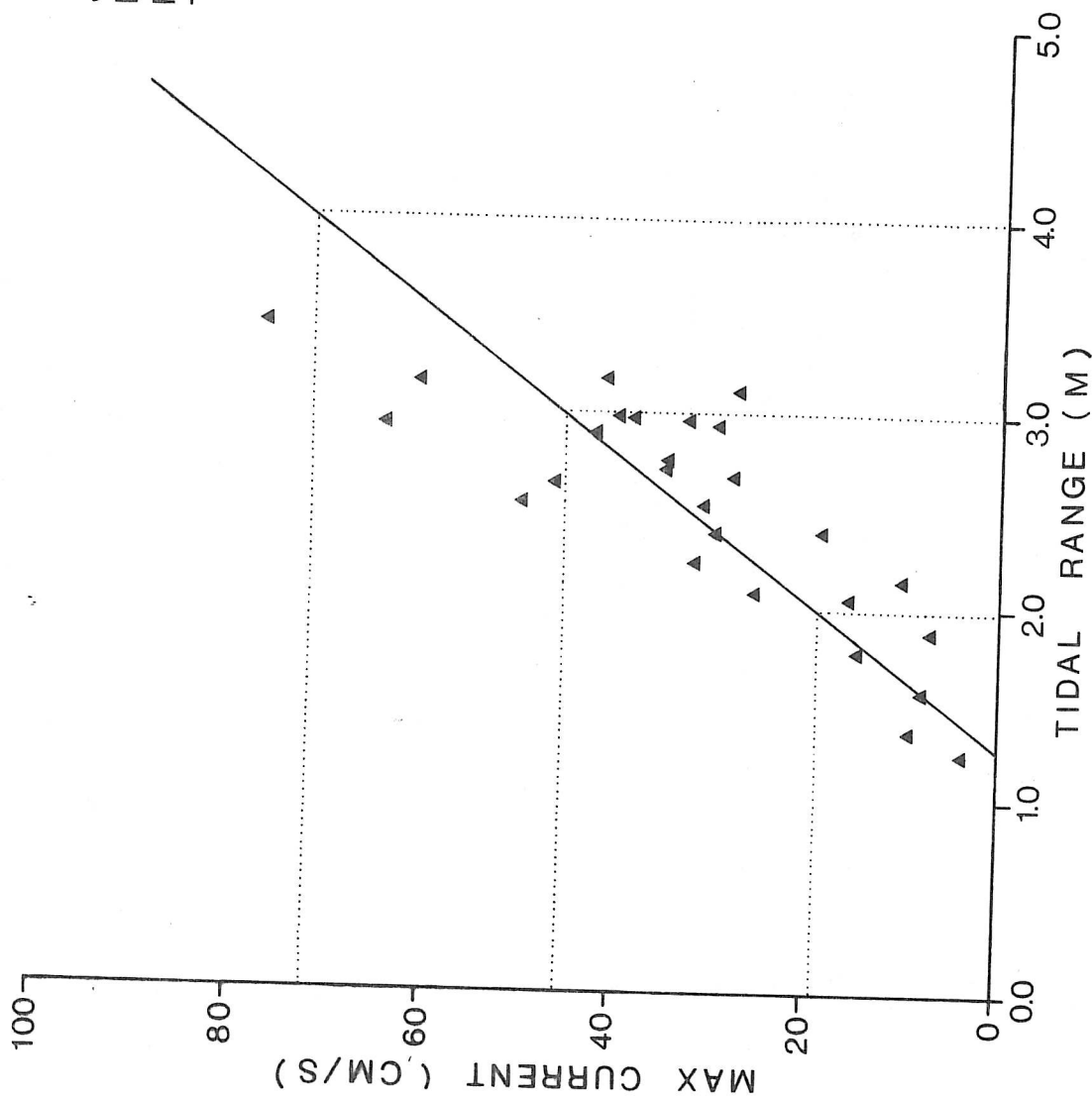


Figure 16. Station 9. Plot of maximum flood current and the tidal range between higher low water and high water.

JOHNSTONE ST. 009  
 FEB. 77, 30 PTS.  
 MAX FLOOD CURRENT VS  
 TIDAL RANGE LOWER -  
 LOW TO HIGH, R = .95

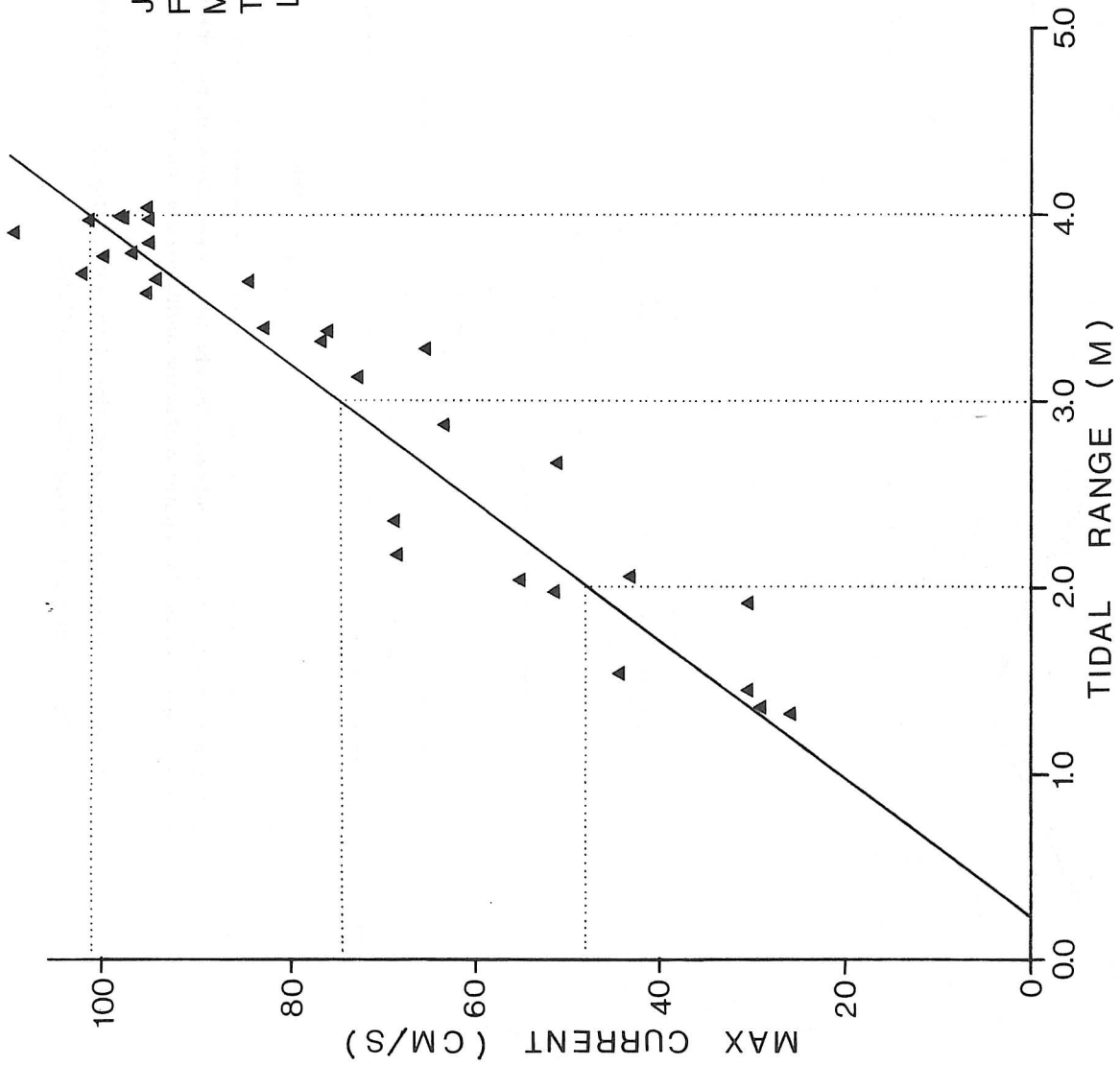
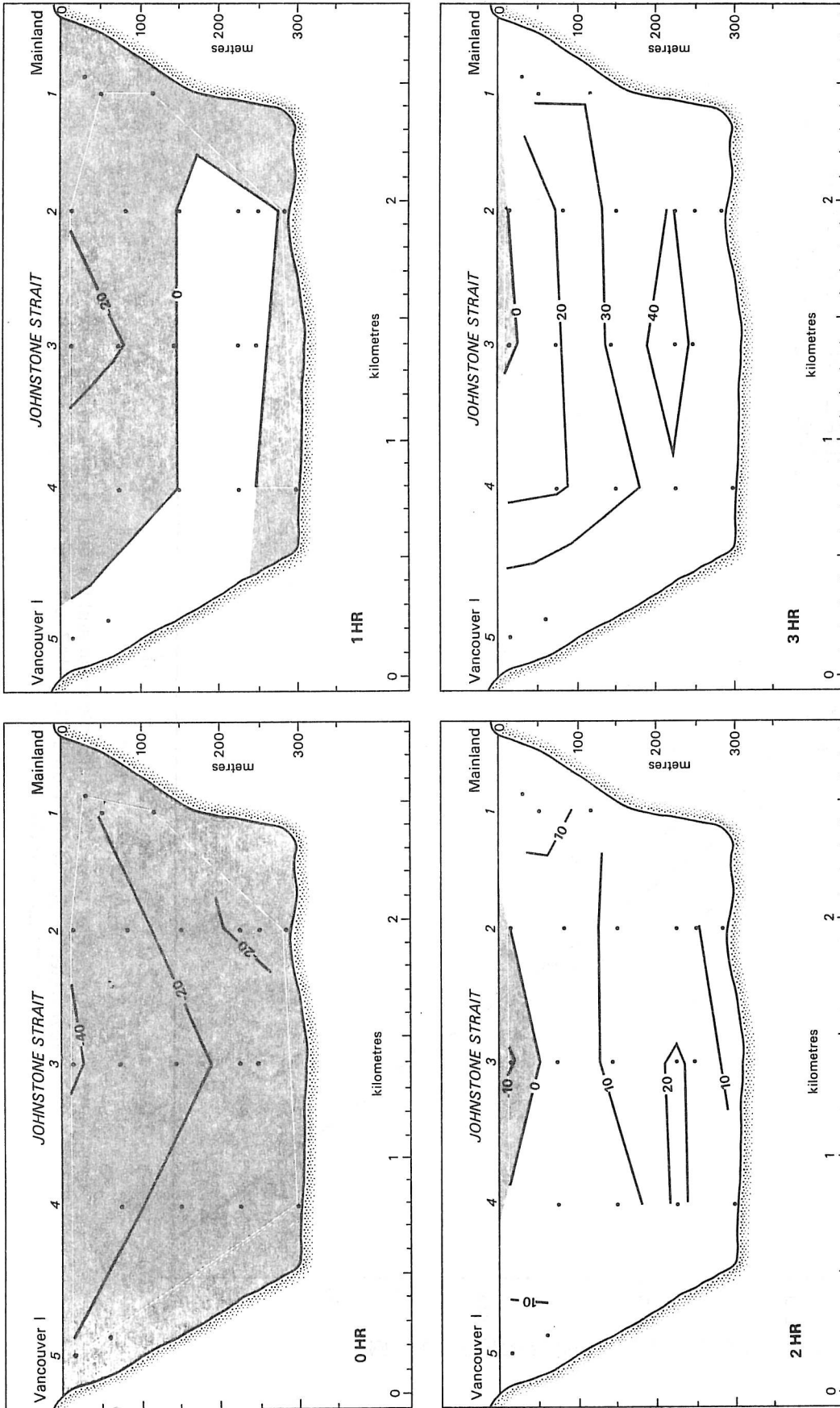
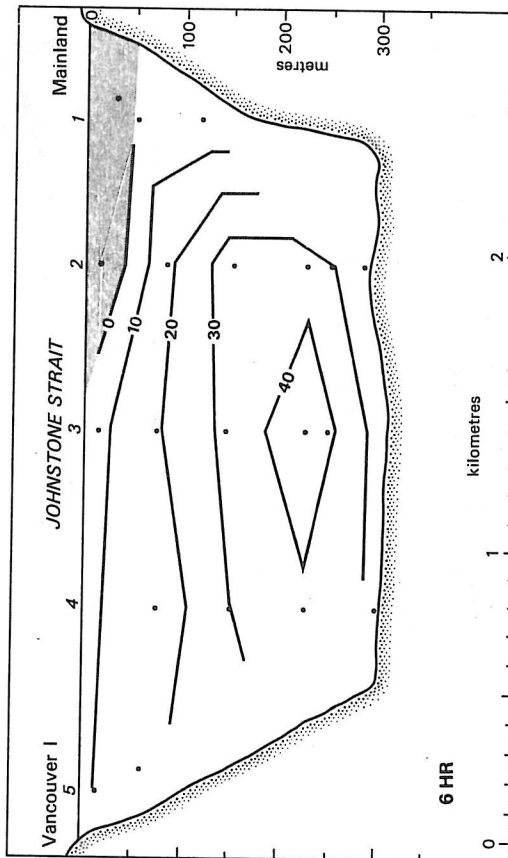
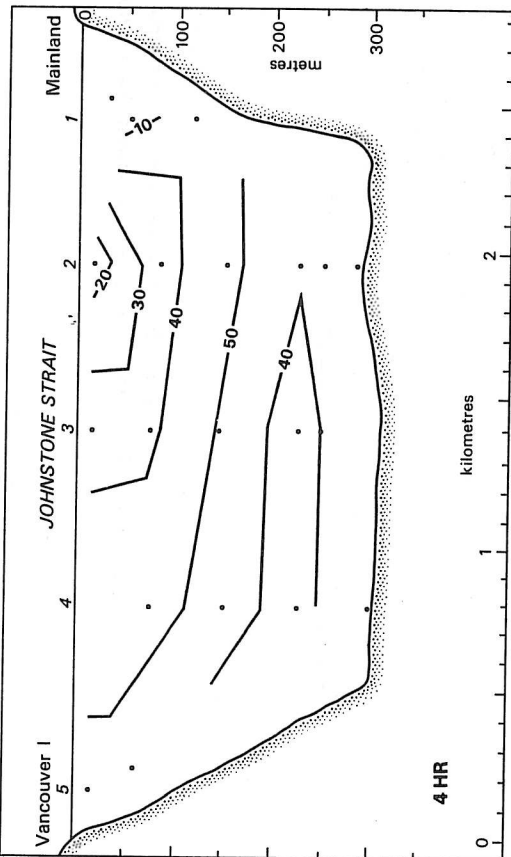
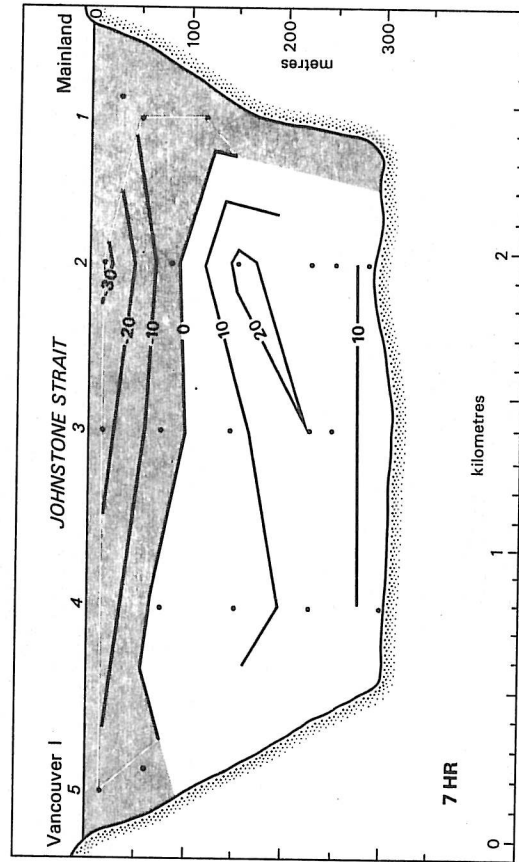
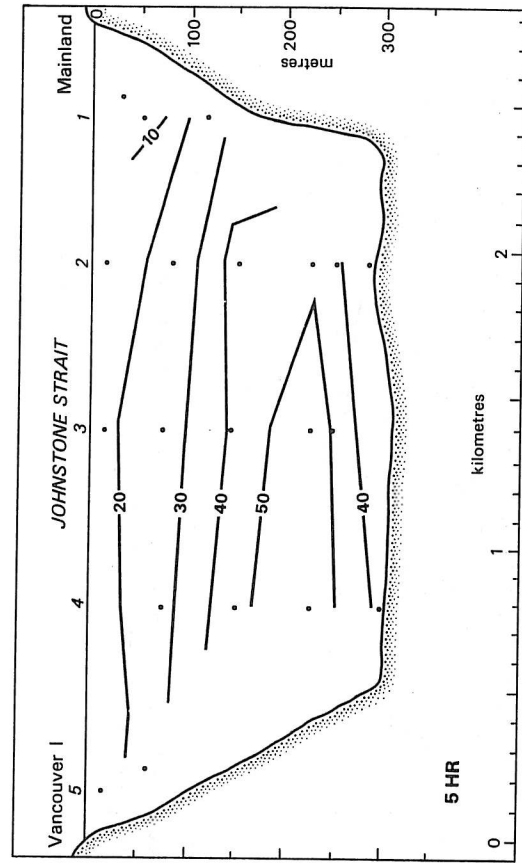


Figure 17. Station 9. Plot of maximum flood current and the tidal range between lower low water to high water. Figures 16 and 17 will give a fairly good indication of the currents to be expected.

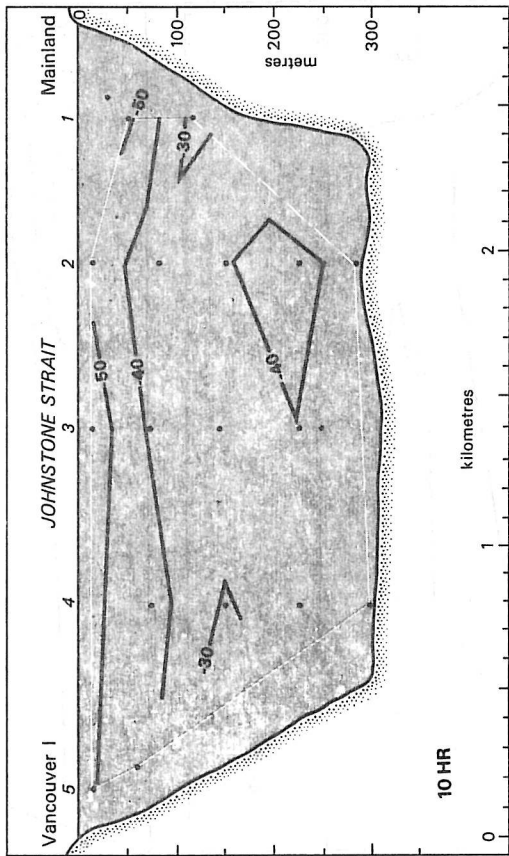
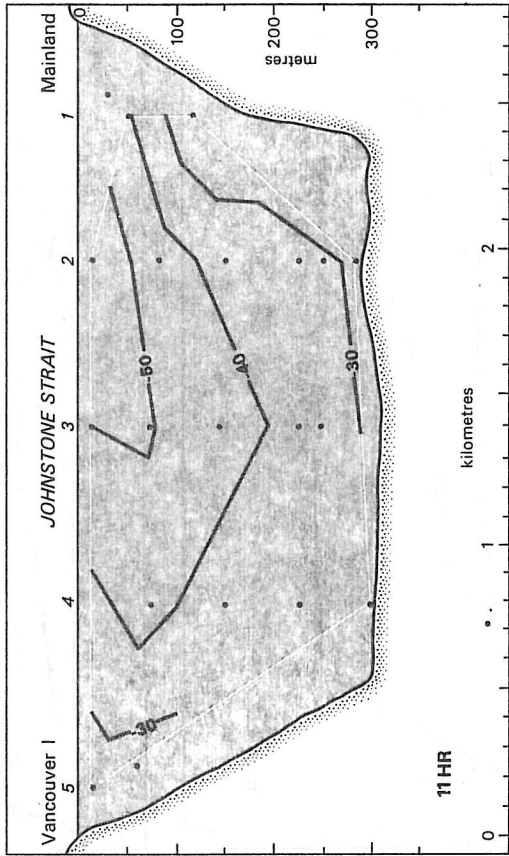
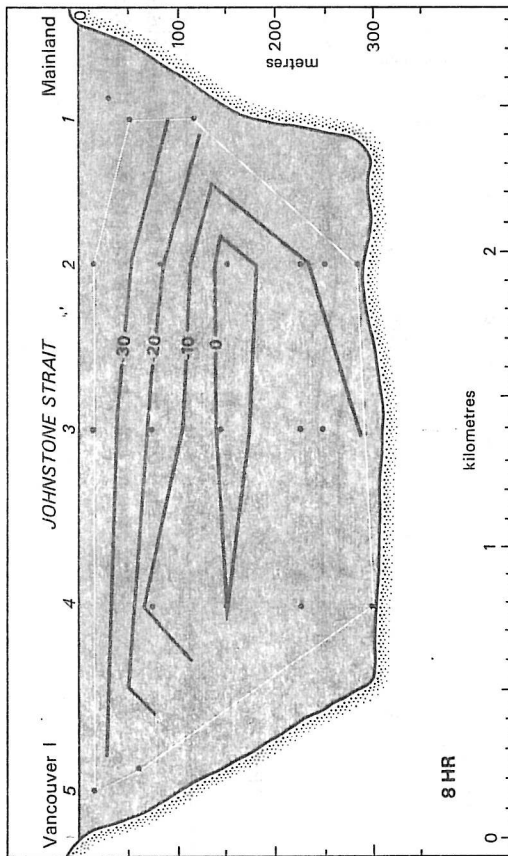
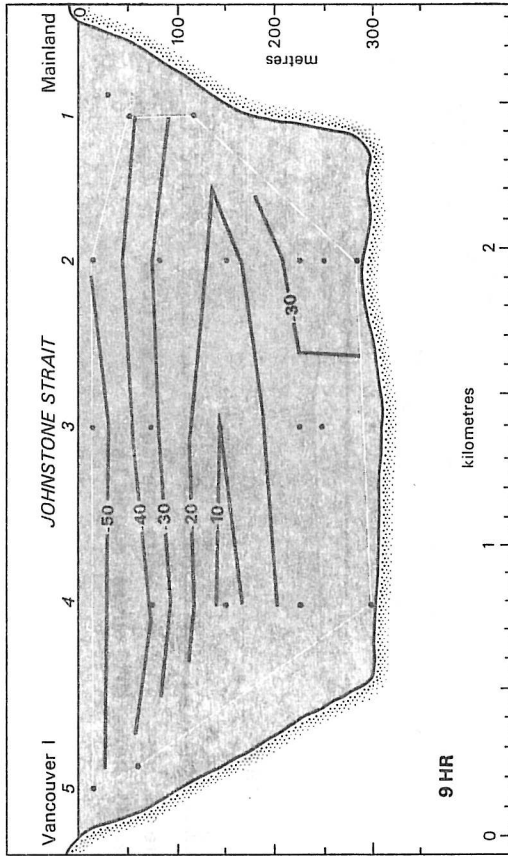


The shaded part of the diagram indicates the ebb tidal stream (west going); the white area indicates the flood tidal stream (east going). The figures within the profile denote cm/sec (51.5 cm/sec equals 1 kn).

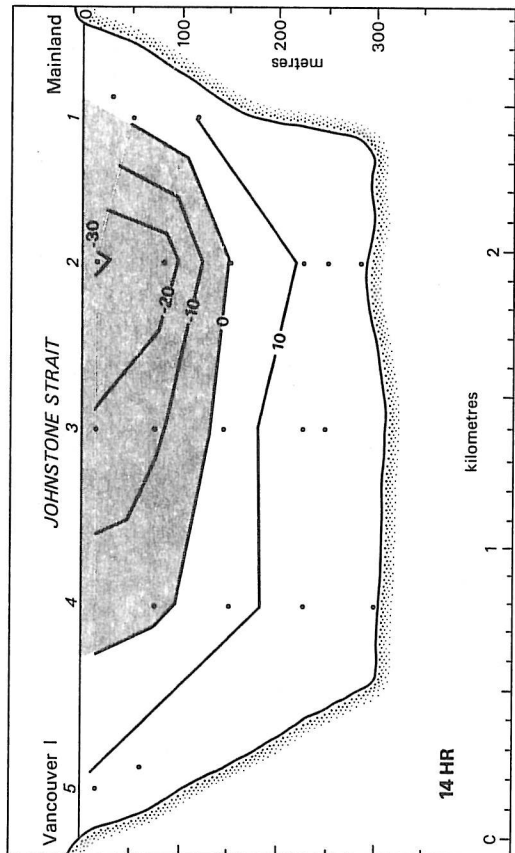
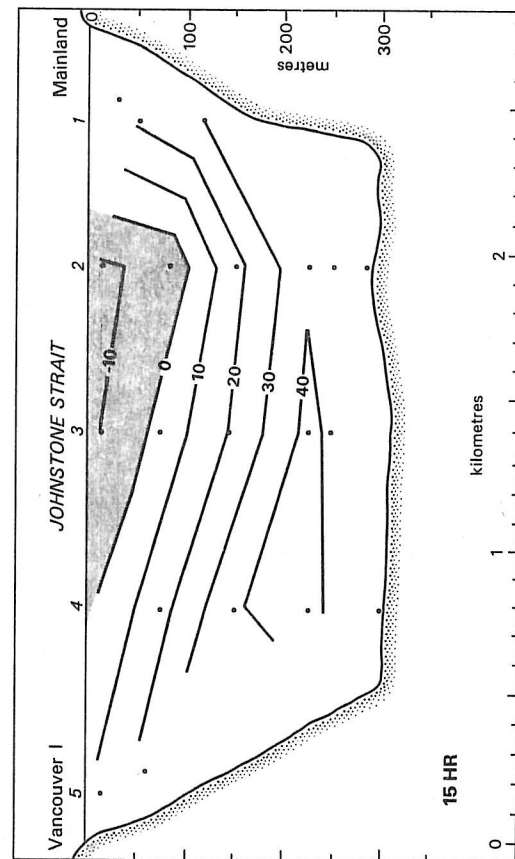
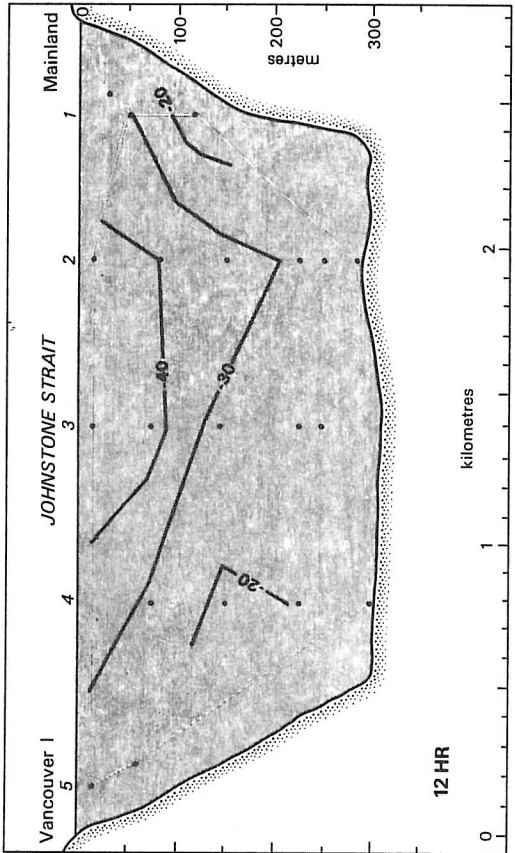
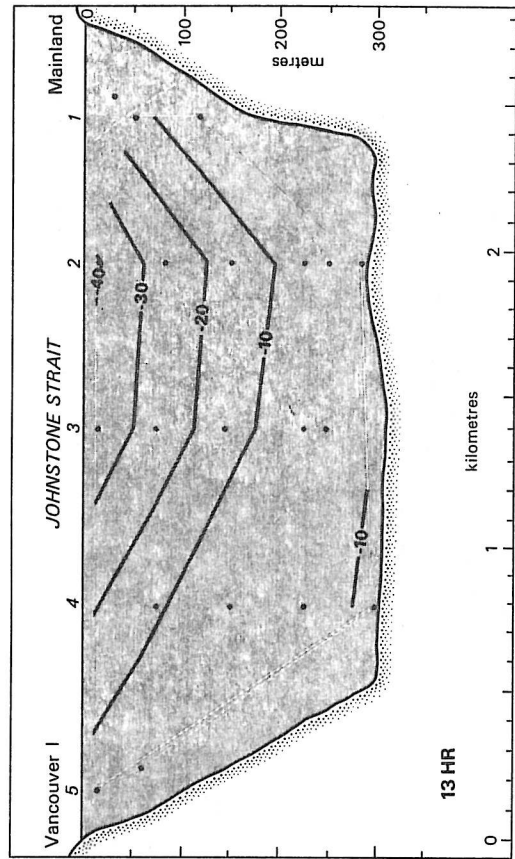
Figure 18. Hourly cross sections at Station 3 showing progress of tidal streams through a tidal cycle, (pages 26-31).  
The shaded portion denotes ebb currents.



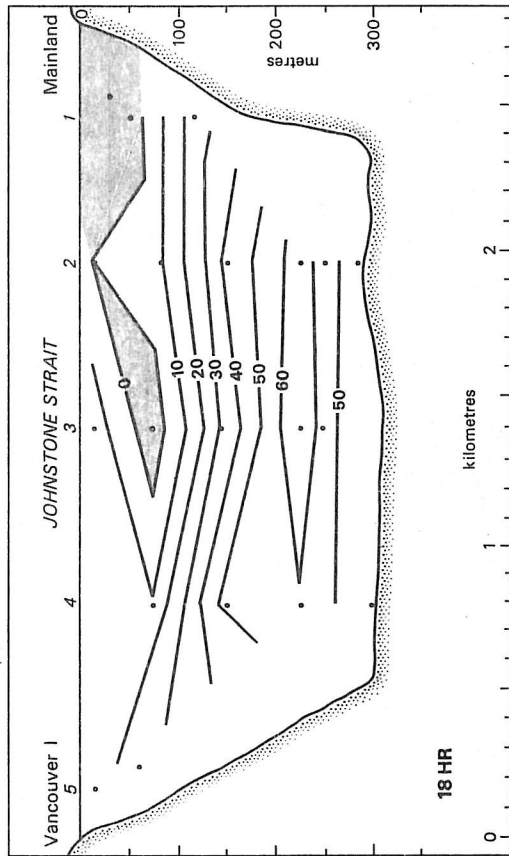
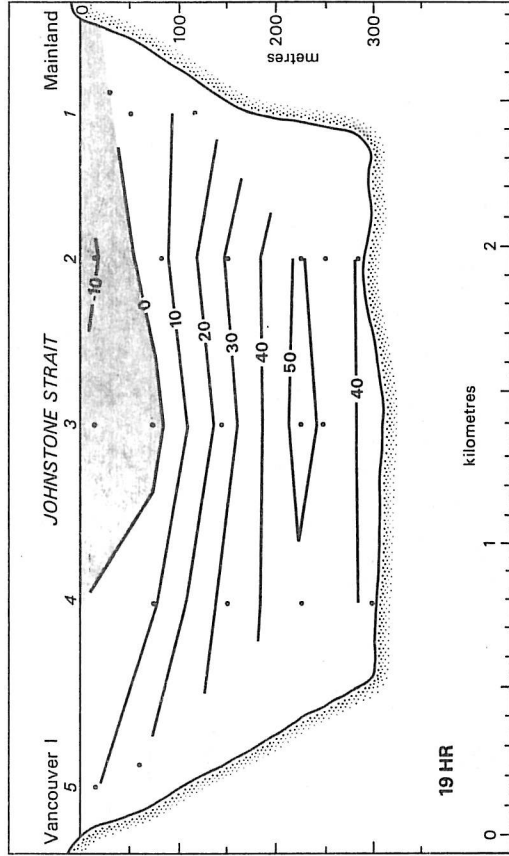
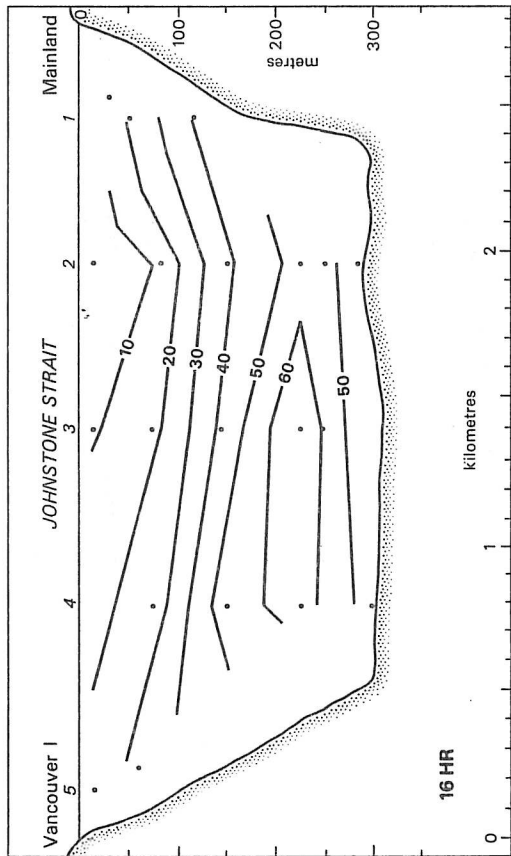
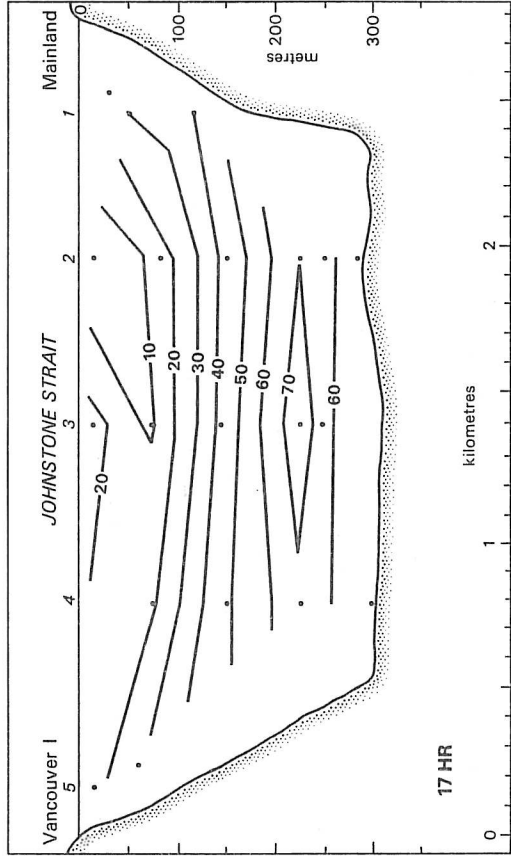
The shaded part of the diagram indicates the ebb tidal stream (west going); the white area indicates the flood tidal stream (east going). The figures within the profile denote cm/sec (51.5 cm/sec equals 1 kn).



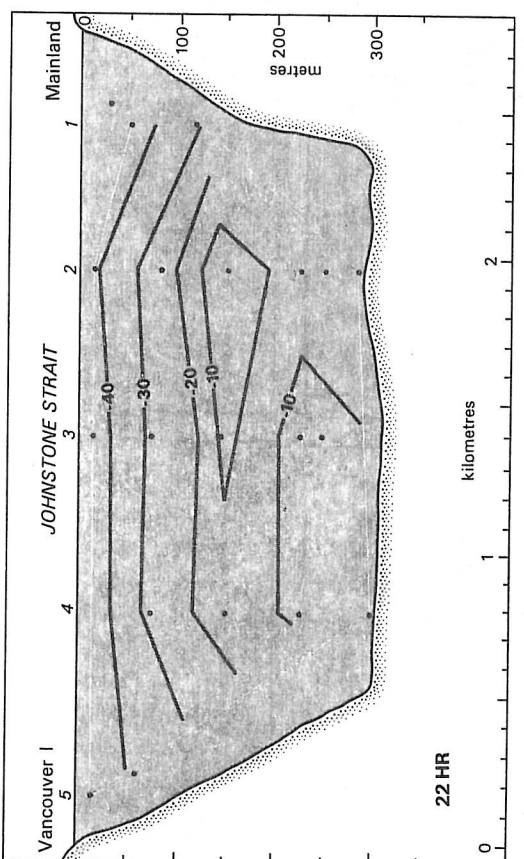
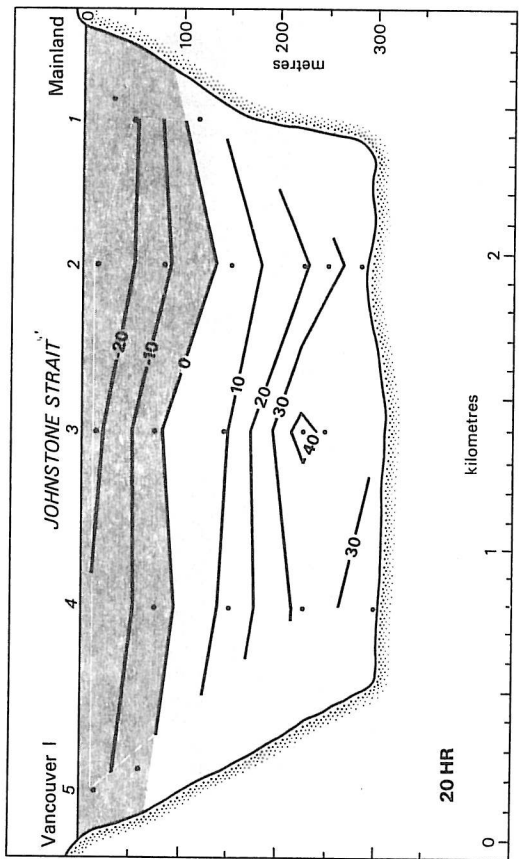
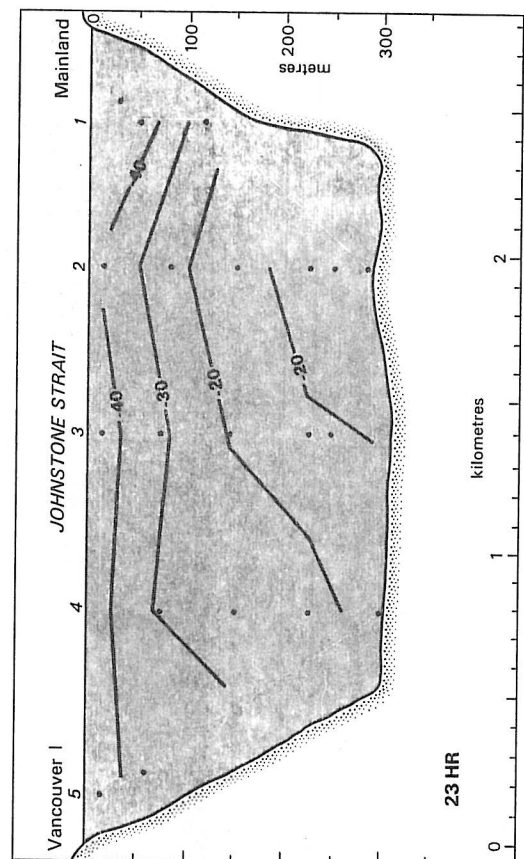
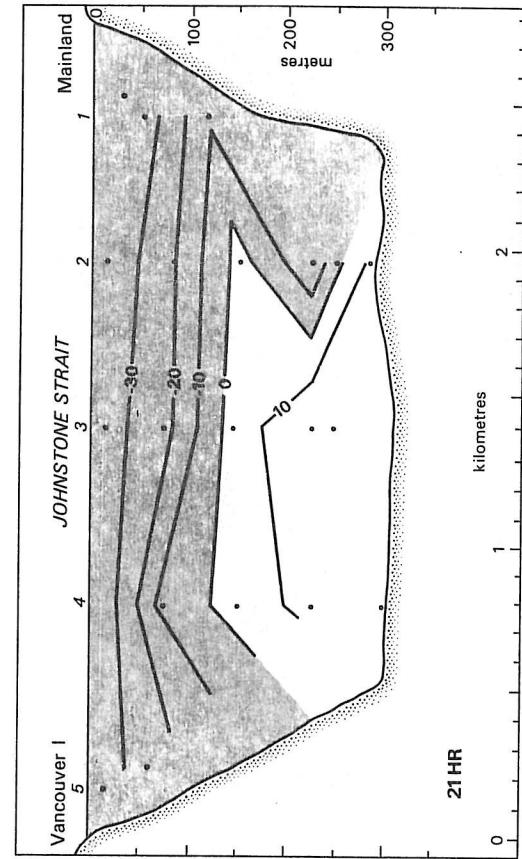
The shaded part of the diagram indicates the ebb tidal stream (west going); the white area indicates the flood tidal stream (east going). The figures within the profile denote cm/sec (51.5 cm/sec equals 1 kn).



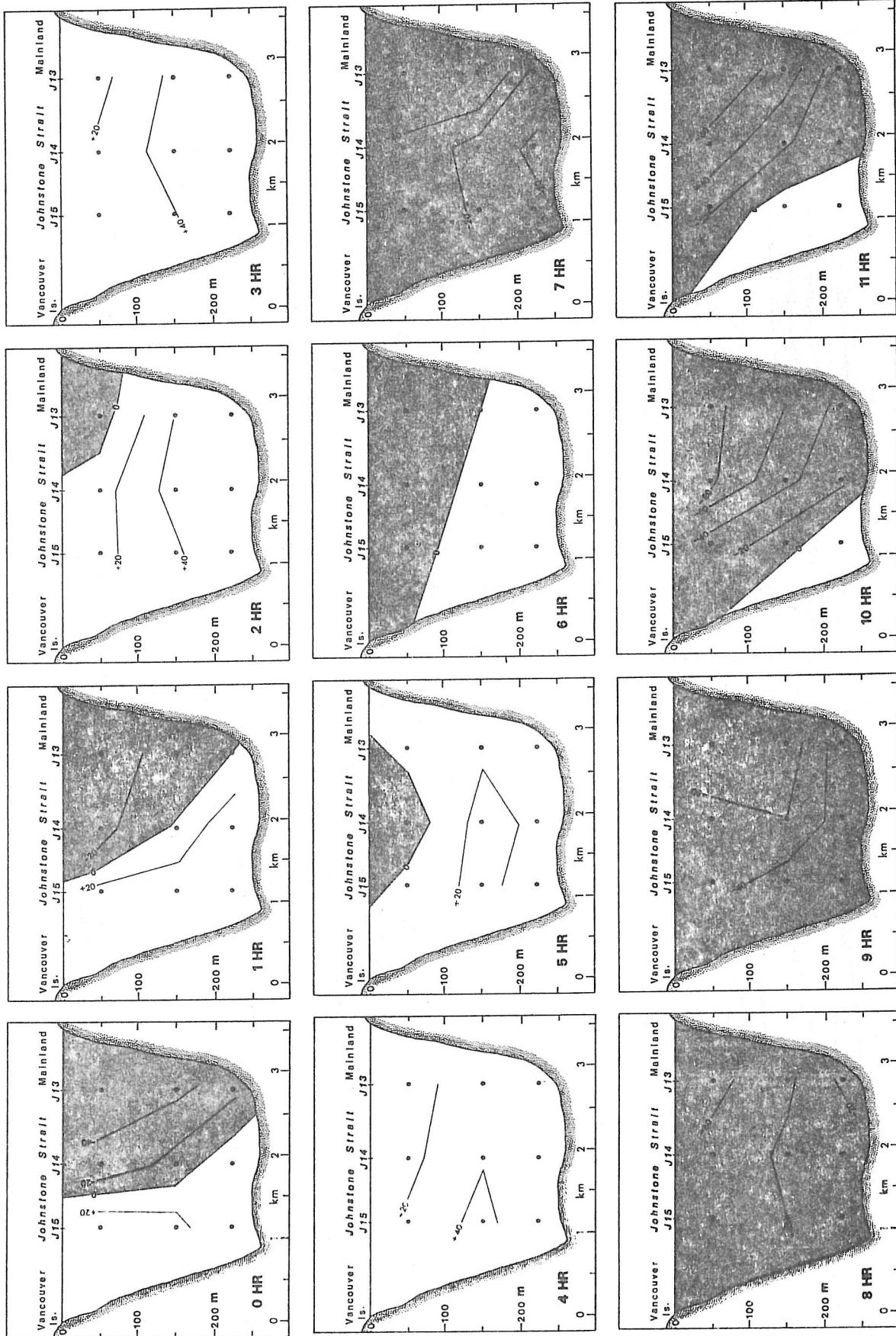
The shaded part of the diagram indicates the ebb tidal stream (west going); the white area indicates the flood tidal stream (east going). The figures within the profile denote cm/sec (51.5 cm/sec equals 1 kn).



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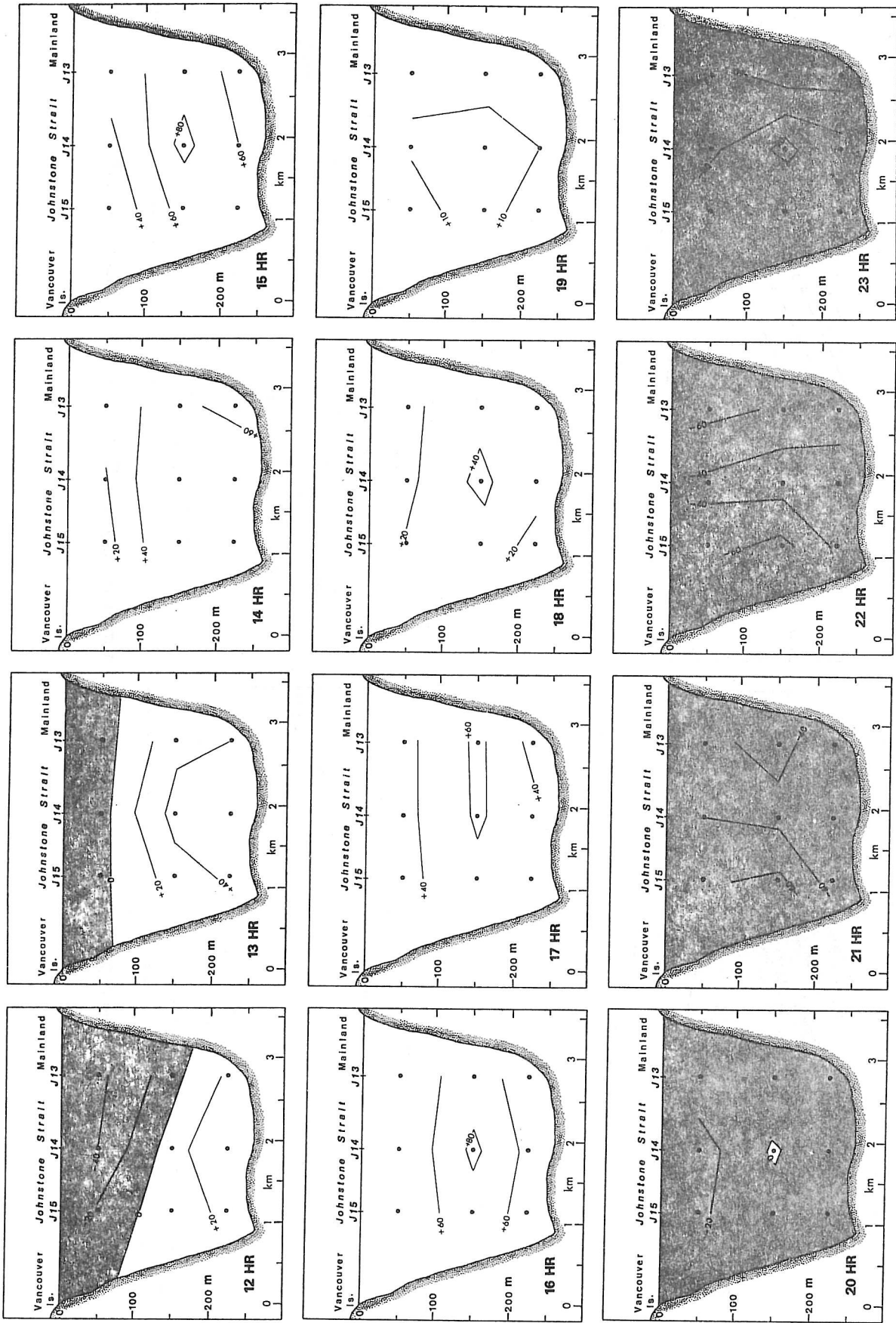


Figure 19. Hourly cross sections at Stations 13, 14 and 15. The shaded portion denotes ebb currents.

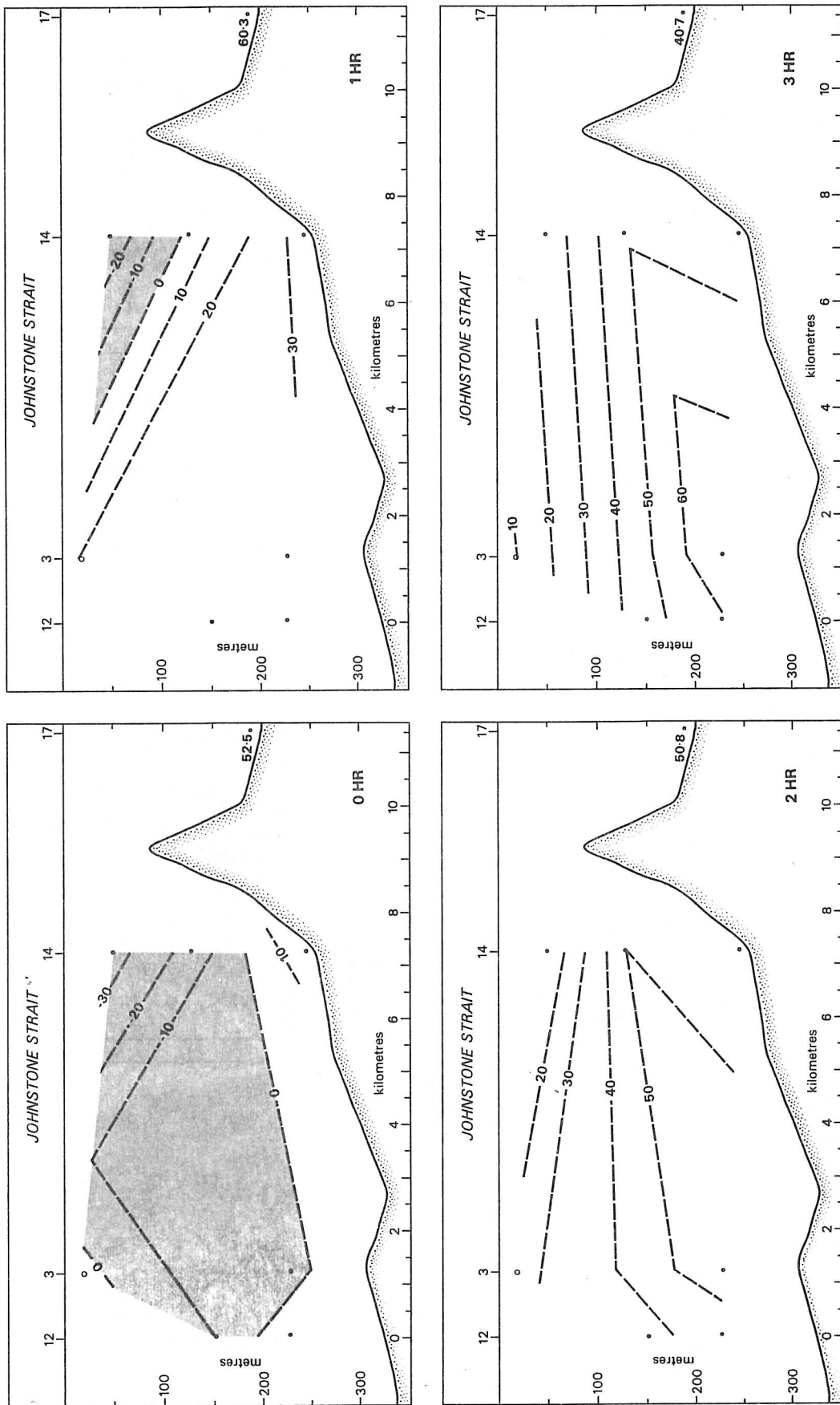
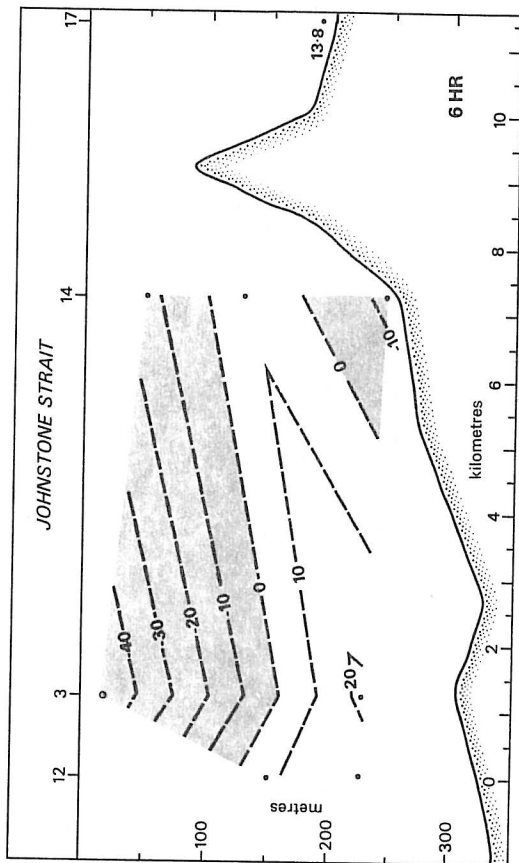
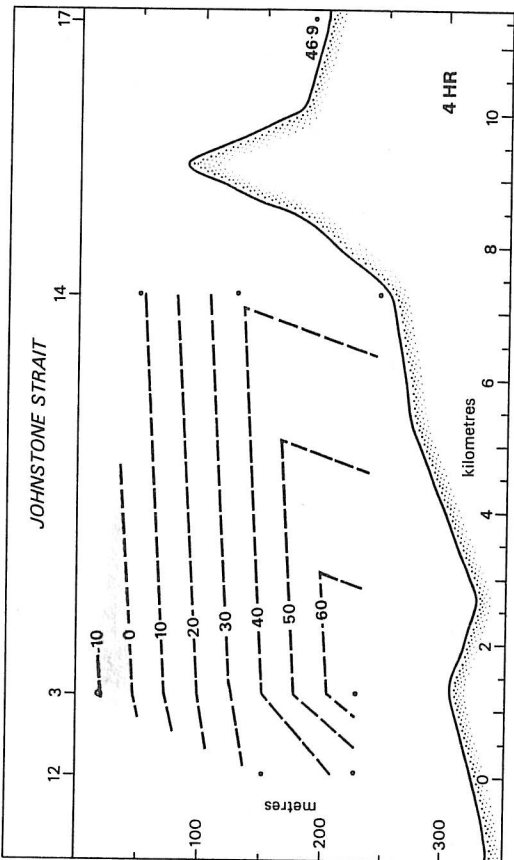
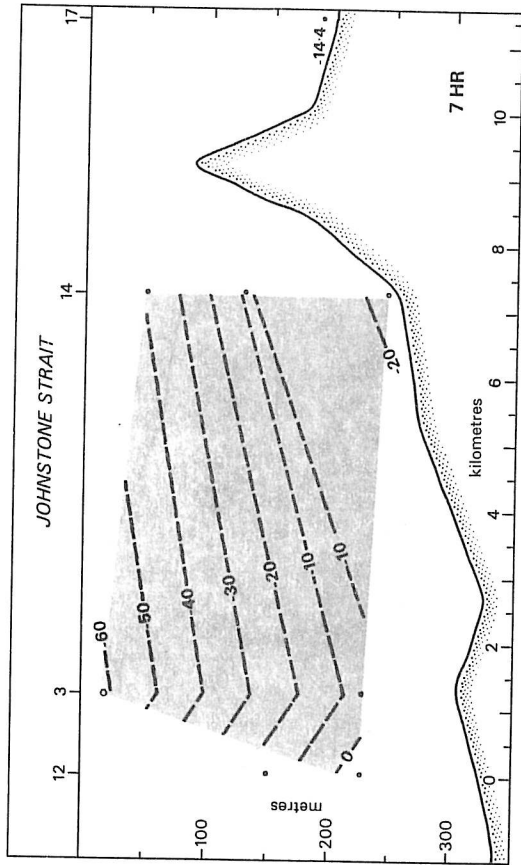
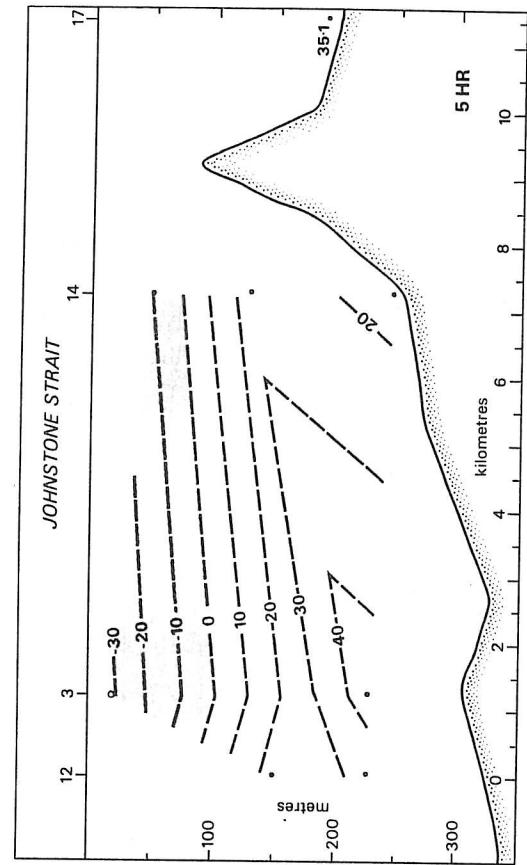
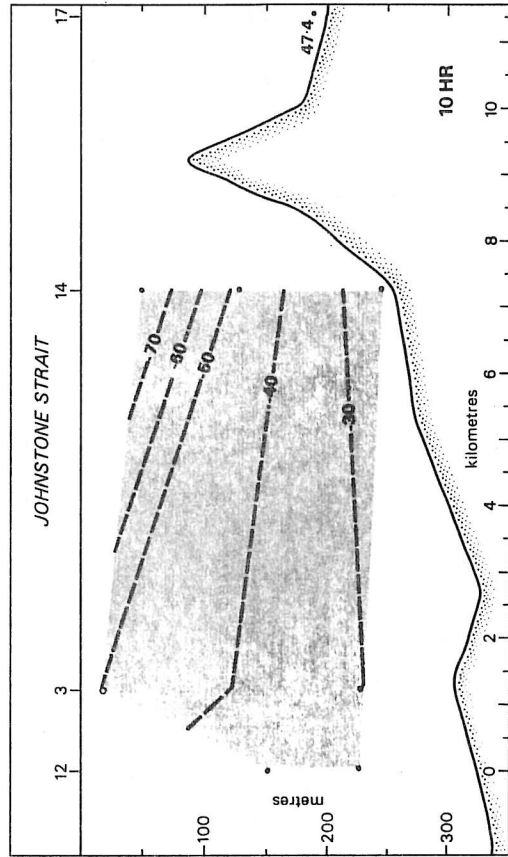
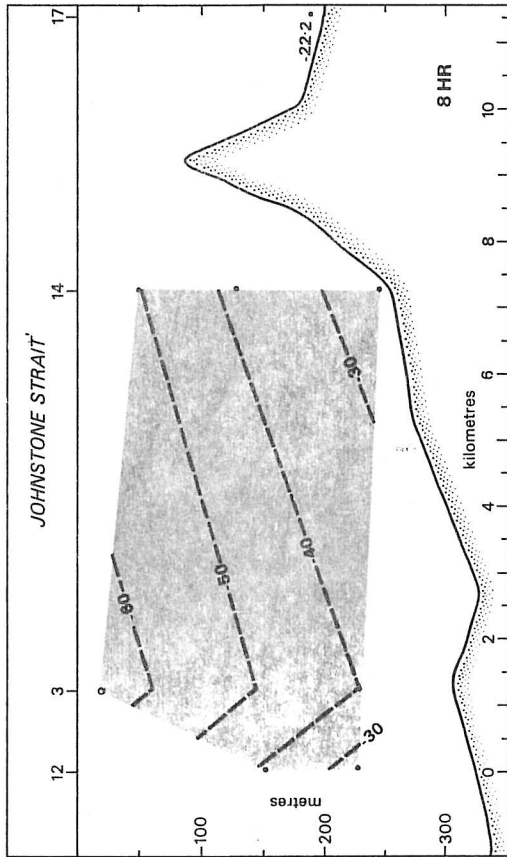
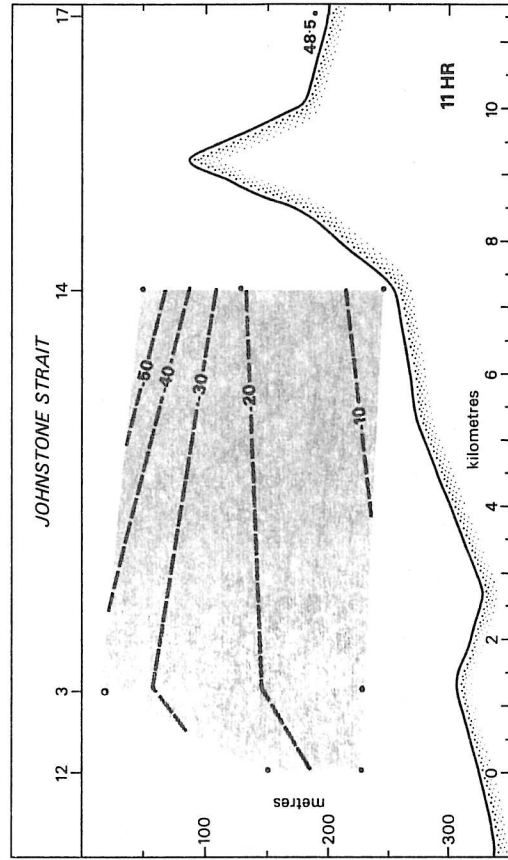
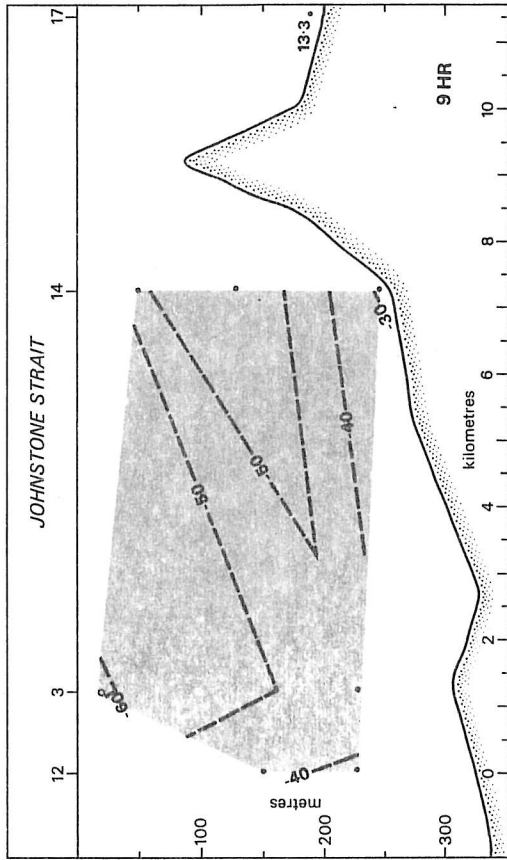
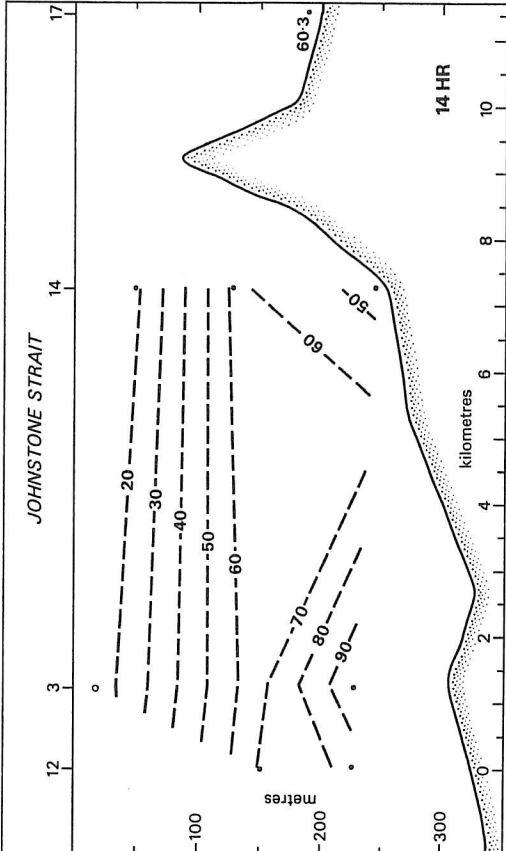
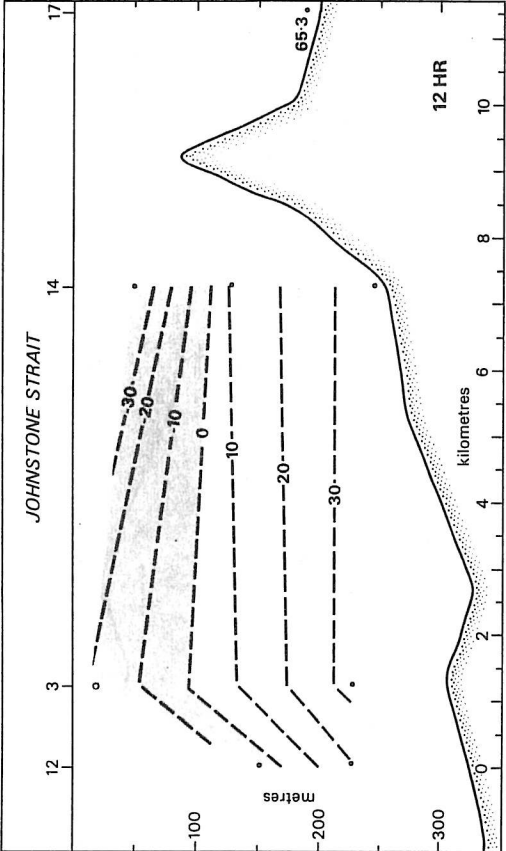
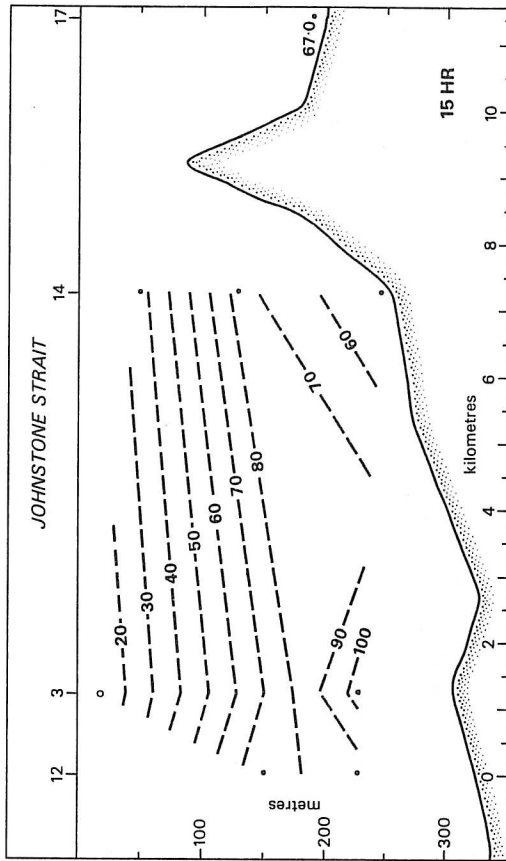
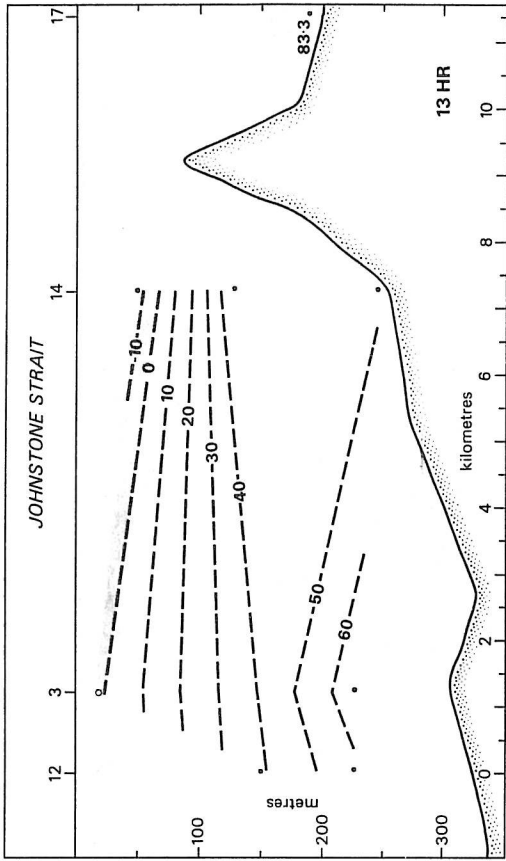
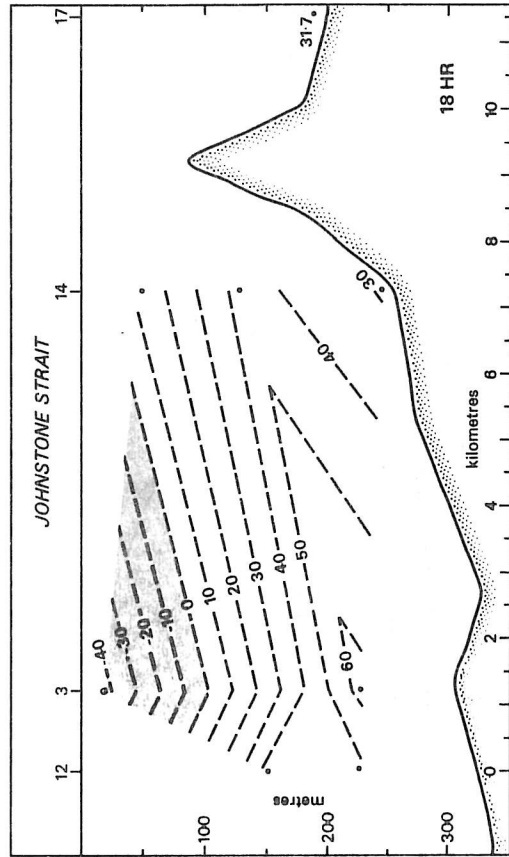
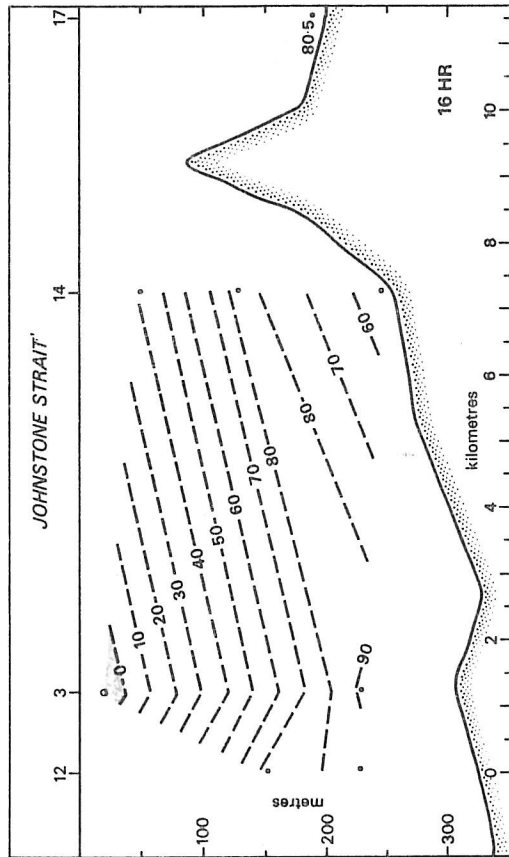
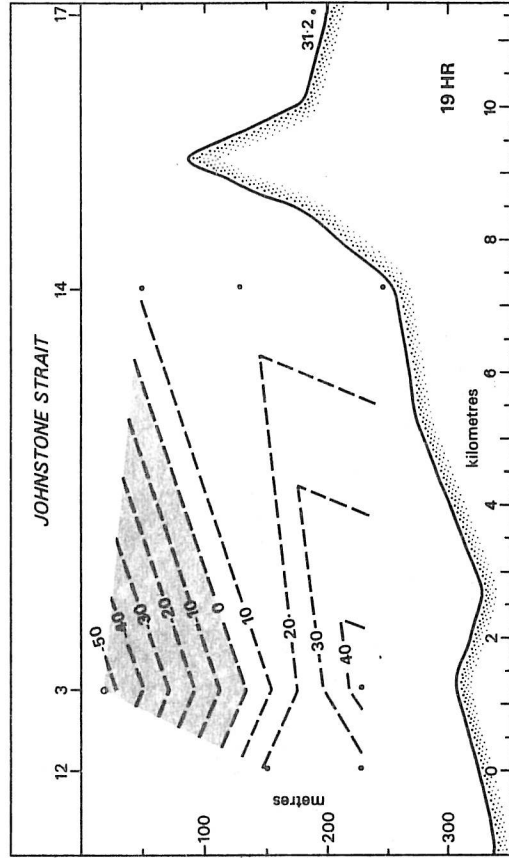
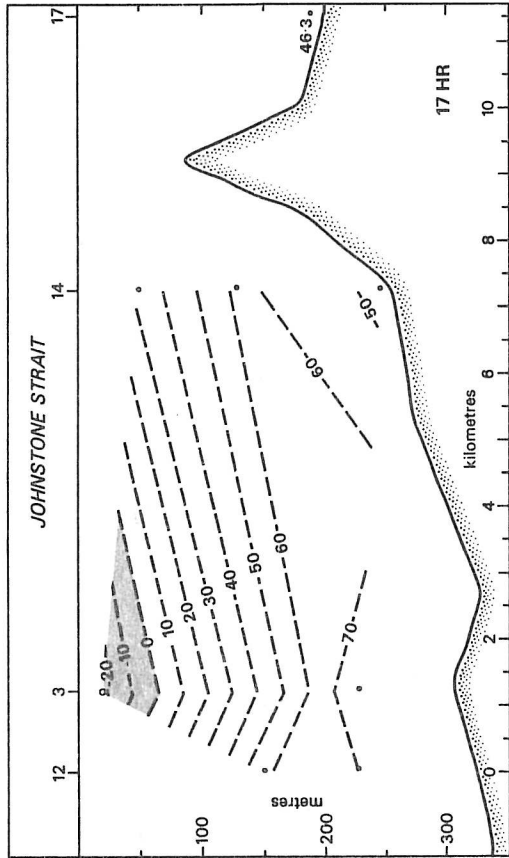


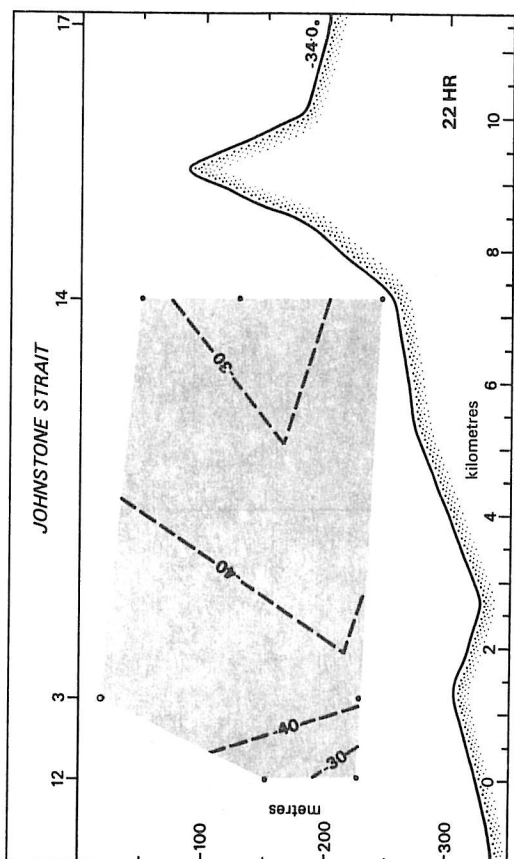
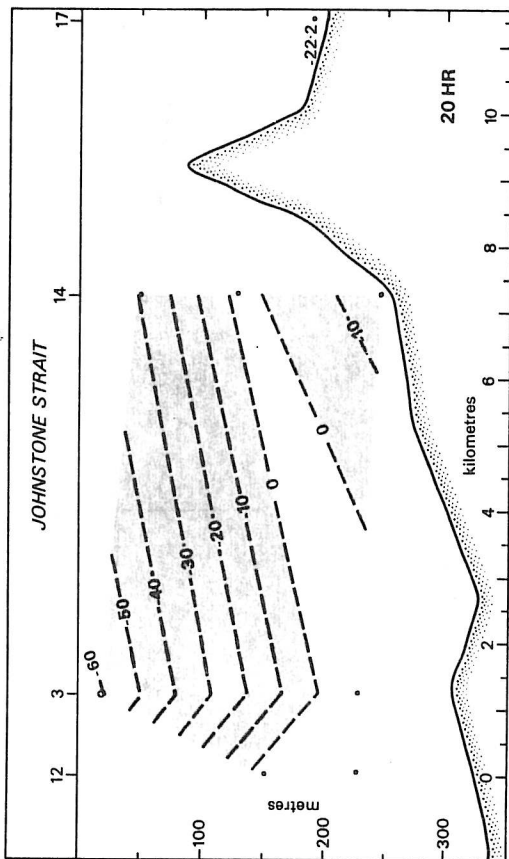
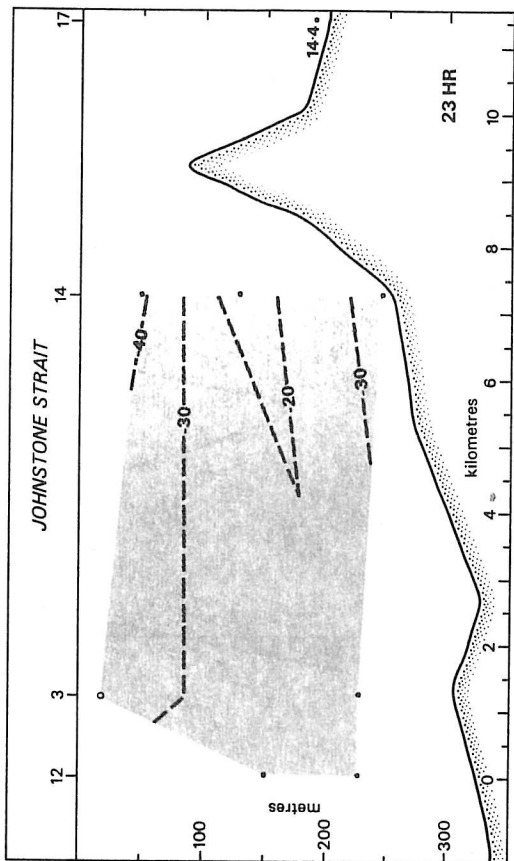
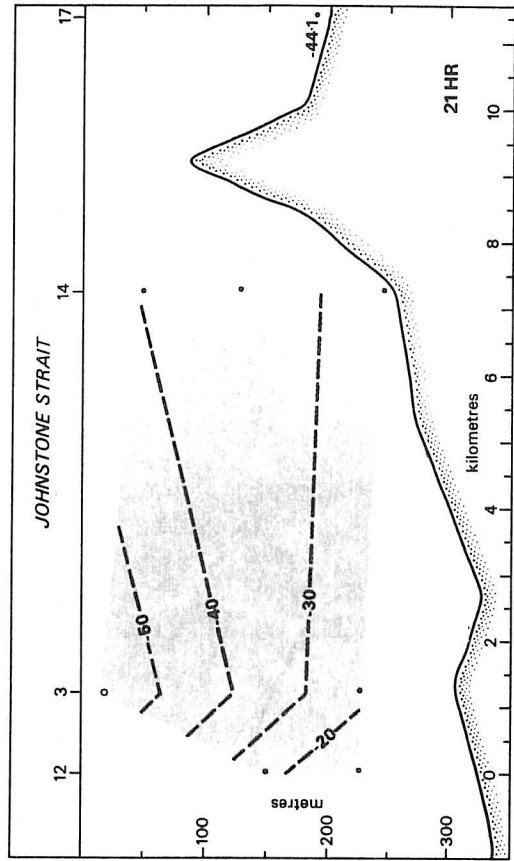
Figure 20. Hourly plots of the current in the centre of the strait between Stations 12 and 17, (pages 34-39).











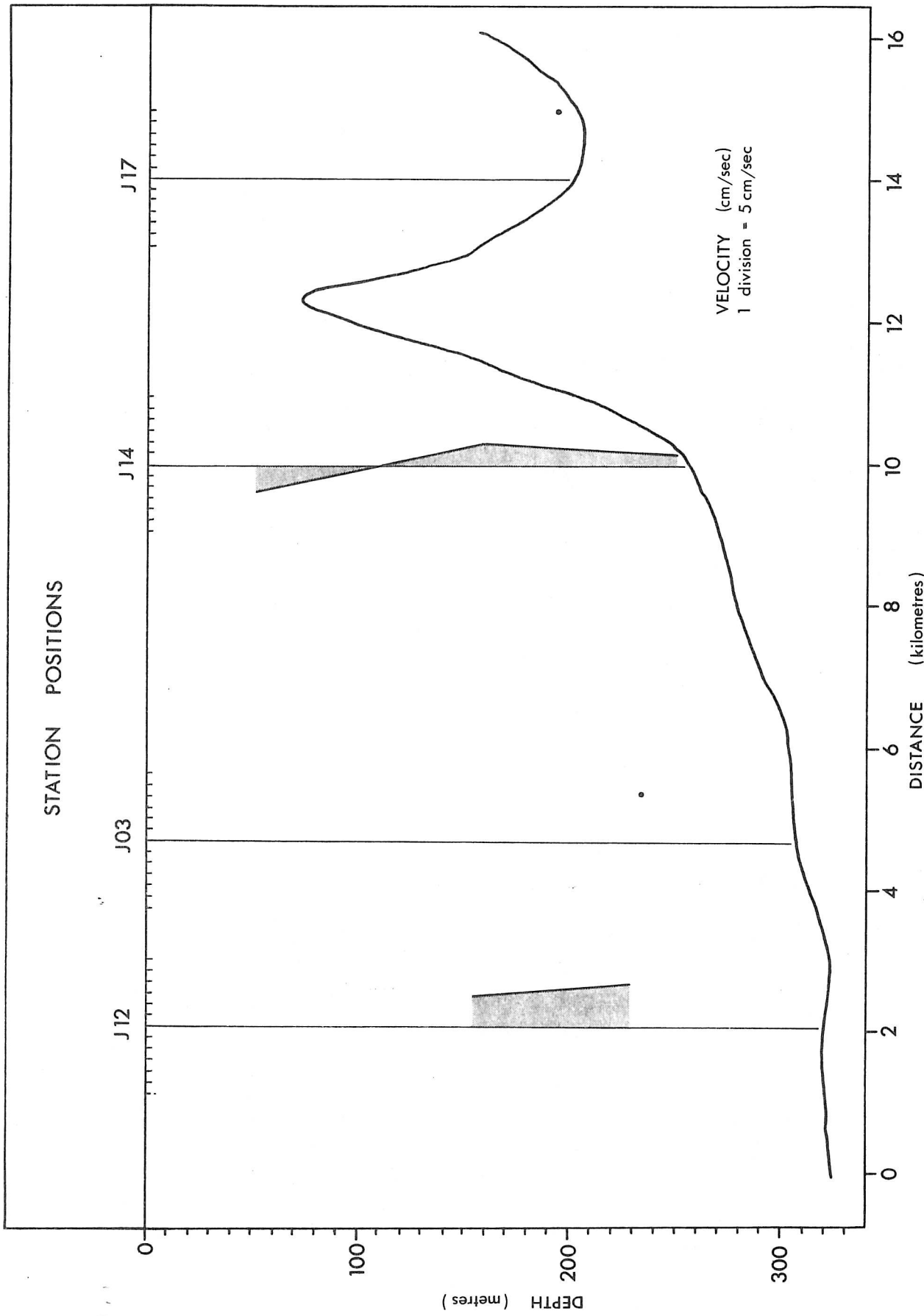


Figure 21. A plot of the residual current in the centre of the strait between Station 12 and 17.