

TIDAL INFLUENCE ON THE SEASONAL VARIATION IN CURRENT AND SALINITY AROUND WILLINGDON ISLAND*

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ABSTRACT

The general distribution of current and salinity of Mattancherry and Ernakulam channels and the Cochin Harbour mouth is presented and discussed in relation to the tide.

During monsoon season stratification is observed. The salinity varies from 5‰ at the surface to 25‰ at the bottom during flood tide. The flood and ebb currents are comparatively high in the Ernakulam channel than in the Mattancherry channel. The ebb currents are strong in the surface layers and the flood currents at the bottom layers.

During premonsoon season no stratification is observed from surface to the bottom. The salinity varies from 32.0 to 36.5‰. The highest velocity of the ebb and flood currents is found at the surface layers. The velocity of the currents directly depends on the range of the tide. The highest velocities encountered in both the channels are found to be of the same order, around 70 cm/sec.

INTRODUCTION

The brackish water around Willingdon Island was made navigable in 1928 by dredging the two channels. The sand bar, which existed about 1.6 km off the coast and acted as a sill, was also dredged. The opening of the offshore bar and the annual dredging of the channels, to maintain a constant depth around 12 metres, had been changing the entire circulation pattern of the harbour region with subsequent changes in the sedimentation pattern. Recently many hydrographic studies of this region had been made (Sankaranarayanan and Qasim, 1969; Qasim and Gopinathan, 1969; Qasim, Wellershaus, Bhattathiri and Abidi, 1969; Gopinathan and Qasim, 1971; Haridas and Madhupratap, 1973; Rama Raju, Pylee, and Anto, 1975; Anto, 1977). These studies were focussed mainly on physical and biological aspects of the waters around Willingdon Island. Practically no detailed study on the variations of currents over a complete tidal cycle had been made. The present study attempts to discuss the current patterns in the channels around Willingdon Island with respect to the tidal rhythm and its effect on the salinity changes.

MATERIAL AND METHODS

The area studied (Fig. 1) included the Cochin Harbour in the middle of the Kerala coast and is a part of an estuarine system having approximately an area of about 320 sq. km. Two major rivers, Periyar and Pamba open into the estuary. The former

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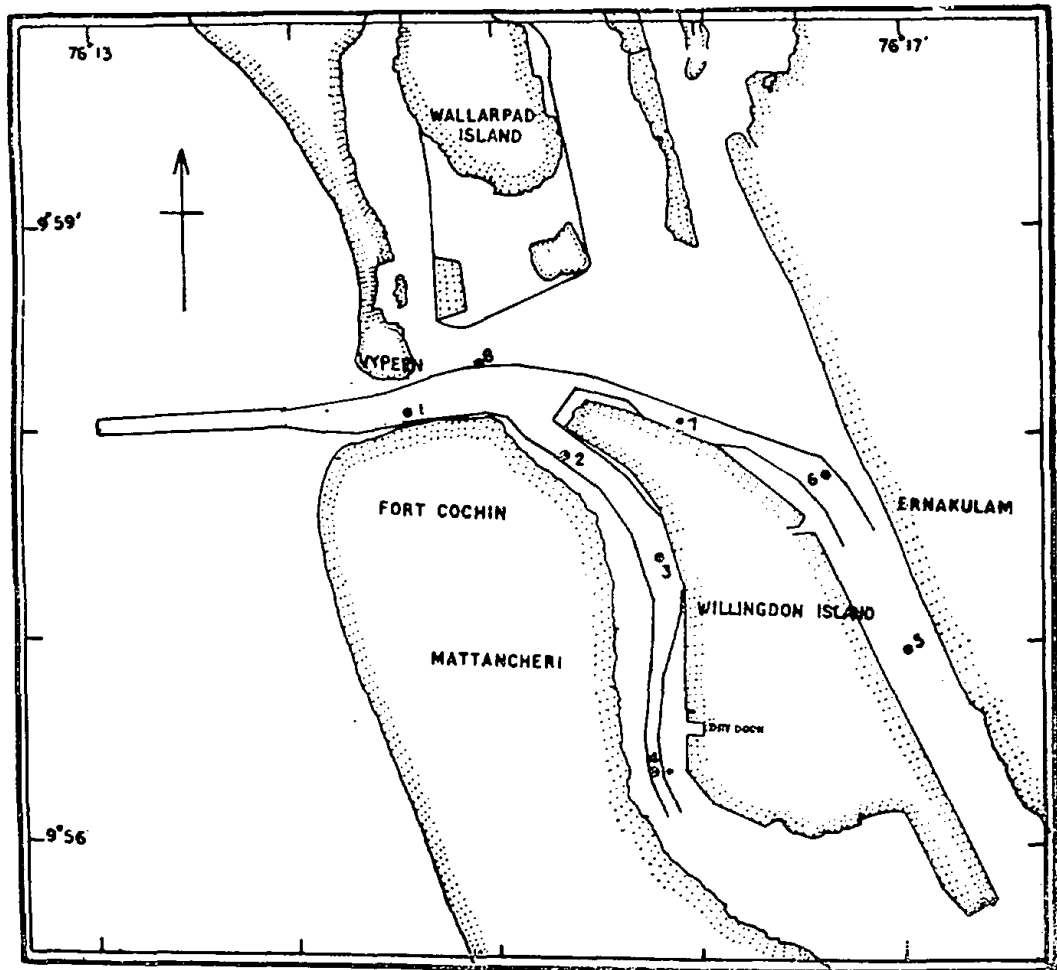


Fig. 1. Chart showing the location of stations.

north of Cochin and the latter at the southern extremity of the estuarine system. The Movattupuzha River and the Meenachil River join it around the middle. During the SW monsoon heavy discharge of fresh water occurs from these rivers into the estuary.

The eight stations occupied during the course of this study are shown in Fig 1. All these stations except Station 8, are located in the navigation channels. Station 8 is located on the edge of the navigation channel. Collection of salinity, temperature and current data were made for a continuous period of approximately two tidal cycles from all these stations once in every season—monsoon, postmonsoon and premonsoon. At shallow stations the samples were collected at 1 m intervals and at deeper stations with 2 m intervals.

The vertical variations of salinity and current in the different channels are studied in relation to the tide. For this the tide gauge data is made use of. The tide gauge is located in the Mattancherry channel and is close to the stations.

RESULTS AND DISCUSSION

Tidal characteristics

A study of the tidal characteristics of this region using the spring tide data, show that the tide is semidiurnal in character and has a maximum range of 1 m. The average

range of the tide for the monsoon, postmonsoon and premonsoon seasons is 47.3, 43.10 and 46.08 cm respectively. There is a marked difference in the mean sea level from season to season. Table I depicts the seasonal mean sea level values. The MSL is normally low during the monsoon season compared to post and premonsoon periods. These differences in the MSL are observed in the predicted tide data also.

Karl Banse (1968) has earlier reported lower mean sea levels during monsoon months for several stations on the west coast of India. He has attributed the same to the divergence of the surface layers of the sea and the consequent upward flow of the cool dense water from deeper layers which over-compensate the effect of the low density surface waters, due to fresh water influx during the SW monsoon, on the mean sea level. This lowering of mean sea level aids the quicker flushing of the estuarine water through the barmouth.

At the bar mouth there is an incursion of coastal water through the entire column of the estuary during the flood tide and outflow during the ebb tide. However, this general tidal flow pattern is disturbed during the SW monsoon season due to the heavy influx of fresh water. During this season, at certain phases of the high tide, the sea water that enters the estuary through the barmouth is restricted to the bottom layers of the channel and fresh water or low saline water is found at the surface layers flowing out into the sea. The occurrence of this two layer flow appears to depend mainly on the heavy fresh water influx.

Salinity distribution

Monsoon season: The salinity distribution during the monsoon are presented in Figs. 2-5. It is clear from these figures that except in the case of Station 8, the isohalines have more or less the same trend as the tidal curve and they run horizontal. This clearly shows that there is high stratification from top to bottom having salinity variations from less than 5‰ at the surface to more than 25‰ at the bottom. Higher salinity gradients occur during high tide than at low tides. At stations, which are farther away from the harbour mouth, low salinity gradients occur and so the waters appear to have relatively lower stratification. This is apparently due to the predominant influence of the fresh water inflow over the tidal flow.

Table I. Average mean sea level at Cochin during postmonsoon, monsoon and premonsoon seasons.

S. No.	Season	Average mean sea level	
		Observed	Predicted
1	Postmonsoon (Dec. to May)	70 cm	77 cm
2	Monsoon (May to Sept.)	59 cm	60 cm
3	Premonsoon (Sept. to Dec.)	75 cm	73 cm

At Station 8, the isohalines show more or less vertical distribution revealing the existence of a comparatively mixed layer during this season. The reason for this deviation is apparently due to the fact that at the time of occupation of this station the influence of the freshwater discharge or the monsoon has not been effective.

From the figures it can be seen that for the same phase of the tide, the vertical salinity distribution depends on the range of the tide. Thus at the harbour mouth, the high

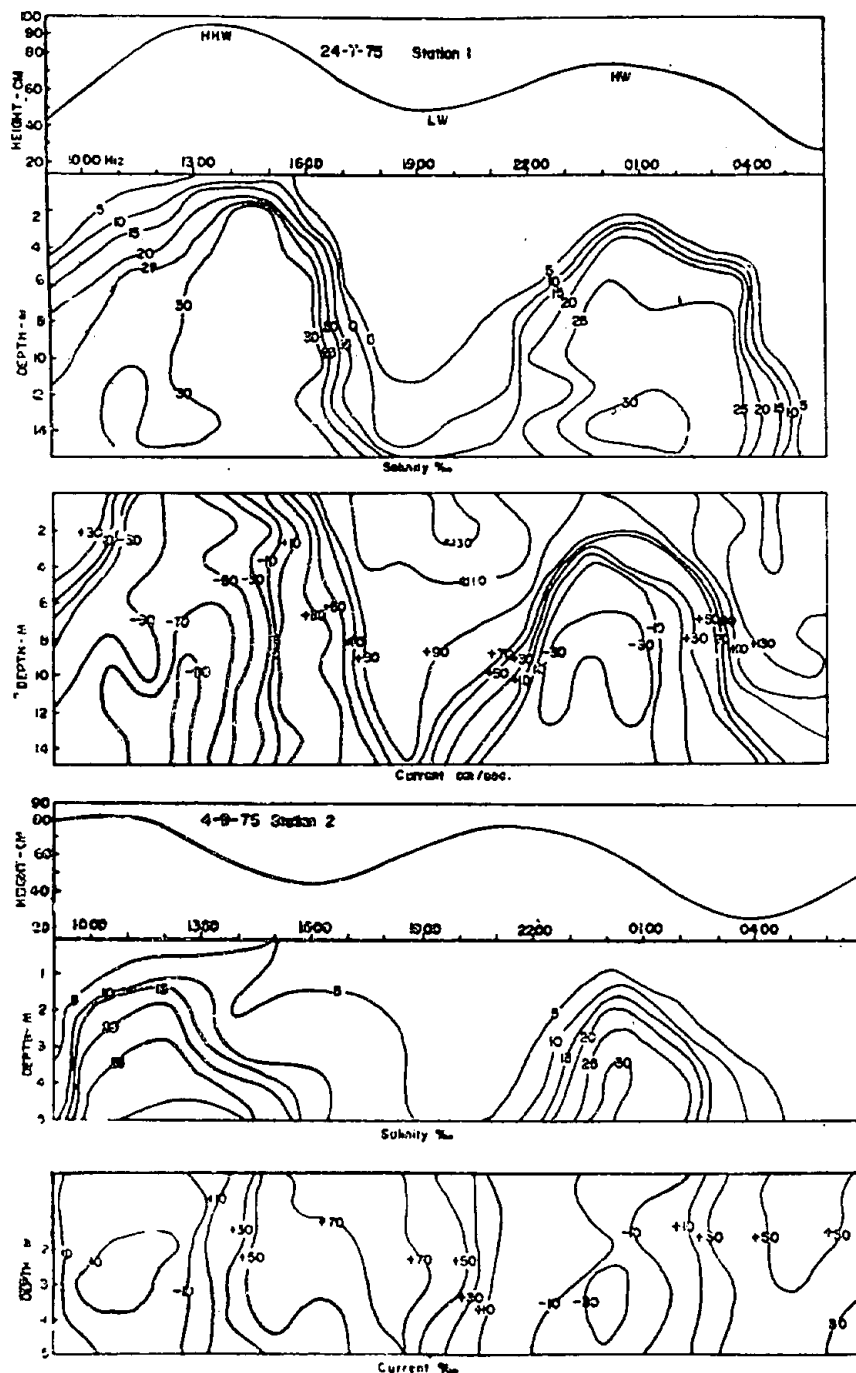


Fig. 2.

Figs. 2-5. Distribution of salinity and current at the stations studied in relation to the tide during the monsoon period.

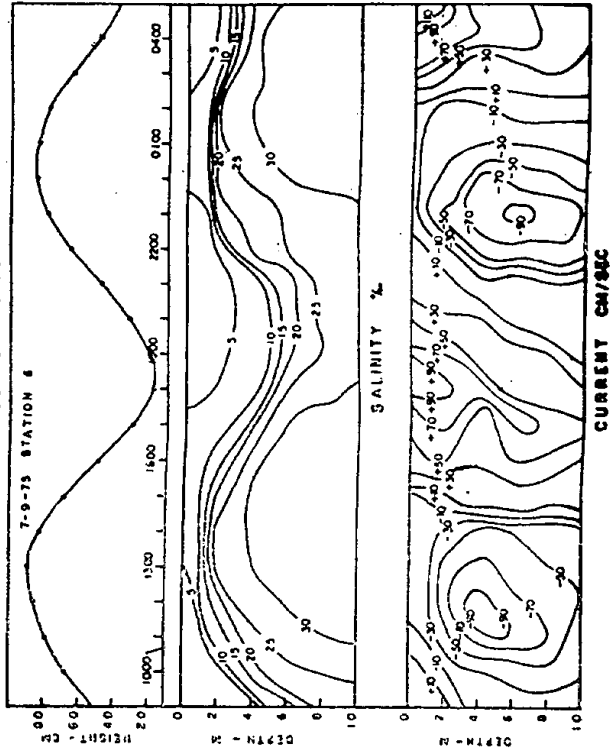
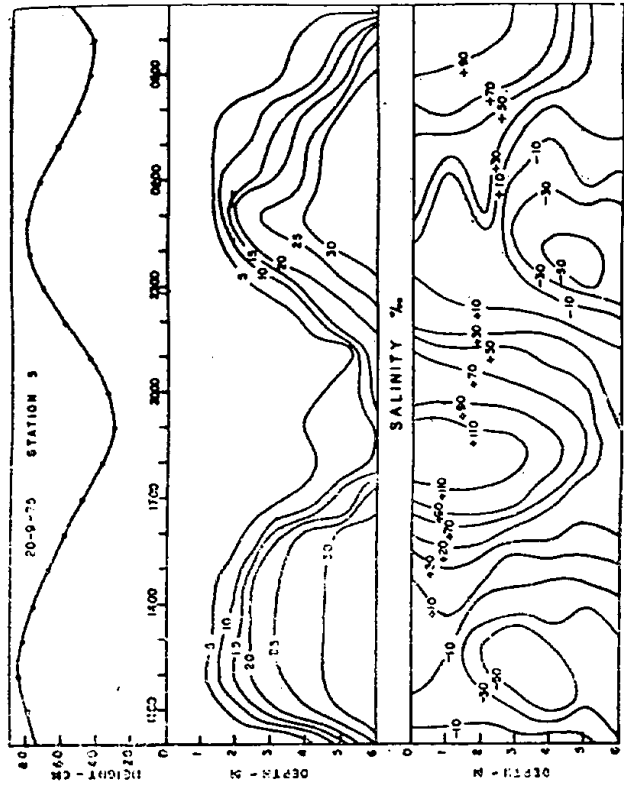


Fig. 4.

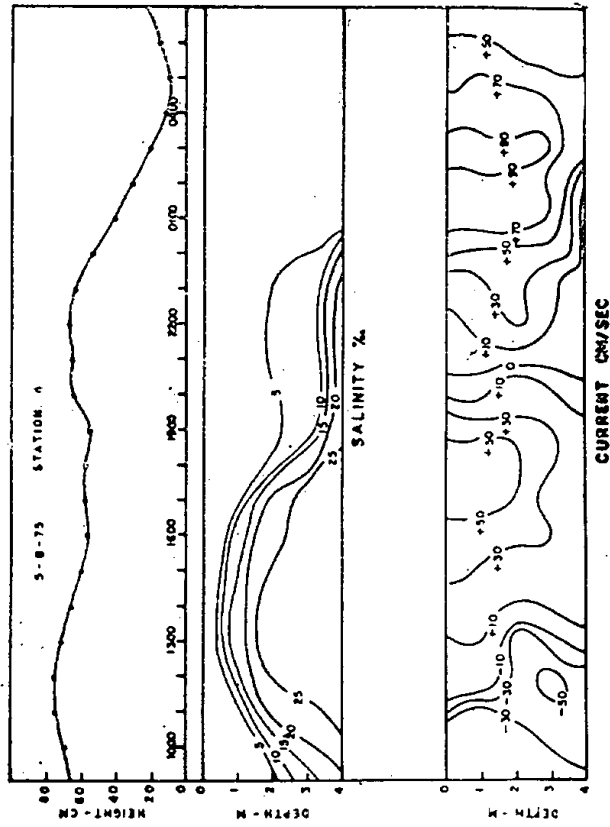
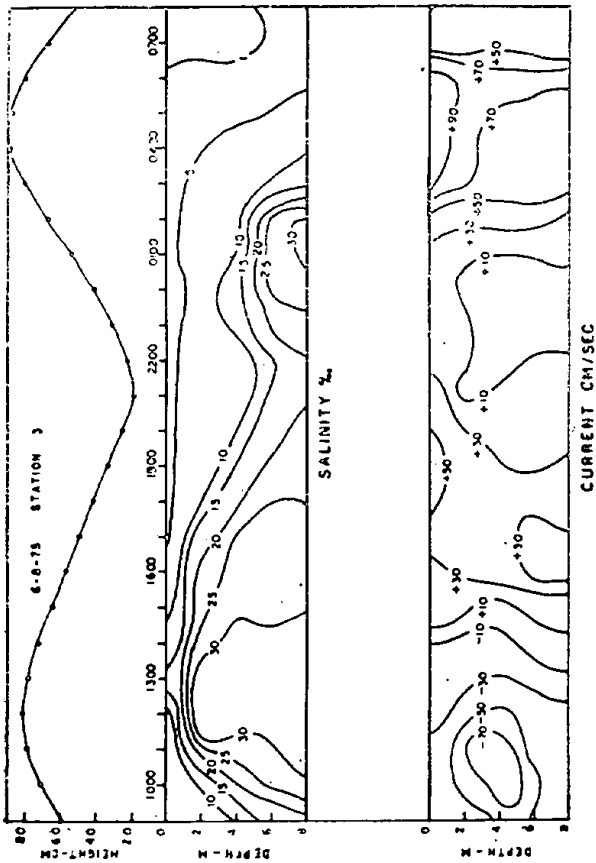


Fig. 3.

saline water is found to exist from near surface to the bottom at the peak of one of the high tides. But at stations away from the harbour mouth the influence of the high tide is not felt at the surface layers.

Postmonsoon: The salinity distribution during the postmonsoon conditions at the stations studied is depicted in Figs. 6-9. The distribution in relation to the tide, more or less conform to the monsoon conditions with reduced vertical salinity gradients. The isohalines do not show horizontal orientation as in the case of salinity distribution in monsoon. During low tide water of salinity 10‰ is present up to depth of about 6 m from the surface. But the thickness of this low saline surface layer depends on the freshwater discharge into the backwaters. During high tide, high saline waters having salinity up to even 34‰ is found to exist at the surface layers. As in the case of monsoon season, the range of the tide determine the salinity variations at all the depths with time during a tidal cycle.

Premonsoon: The salinity distribution at different stations during the premonsoon conditions are presented in Figs. 10-13. It can be seen from these figures that the isohalines are nearly vertical depicting a comparatively mixed layer from top to bottom. However, during the high tide the salinity slightly increases and then decreases during low tide. This fact brings out that the salinity of Cochin backwaters is always lower than that of the coastal waters thereby indicating that Cochin backwaters is a positive type of

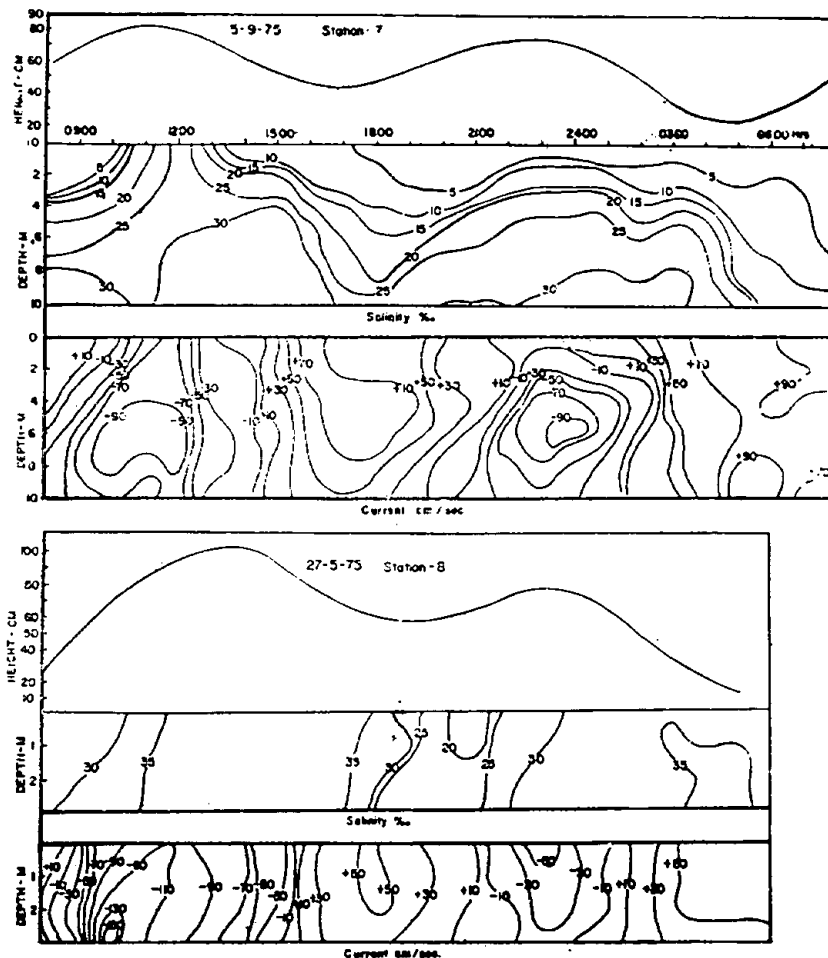


Fig. 5.

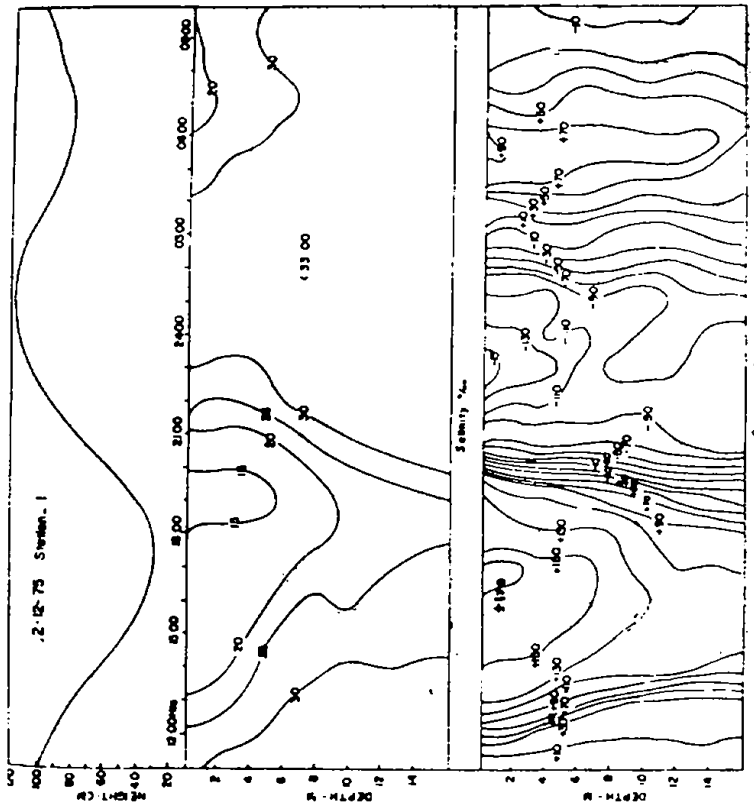
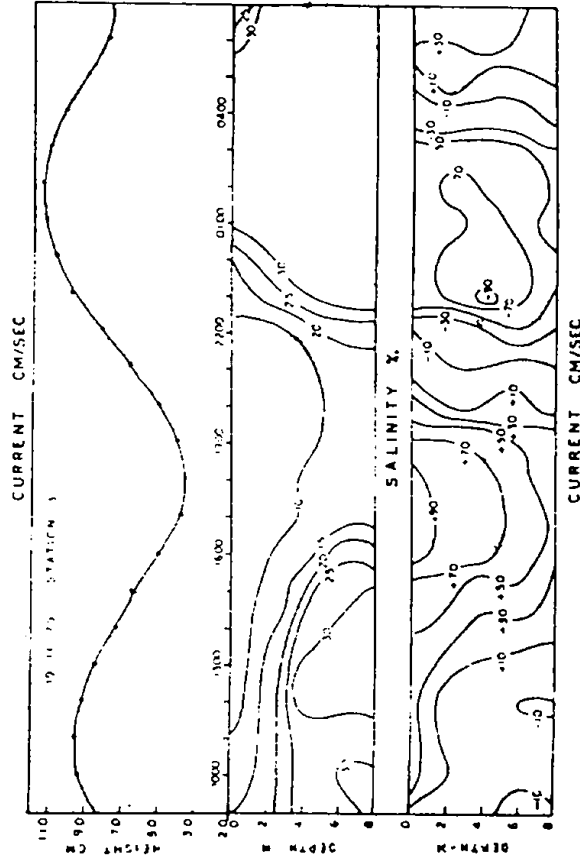
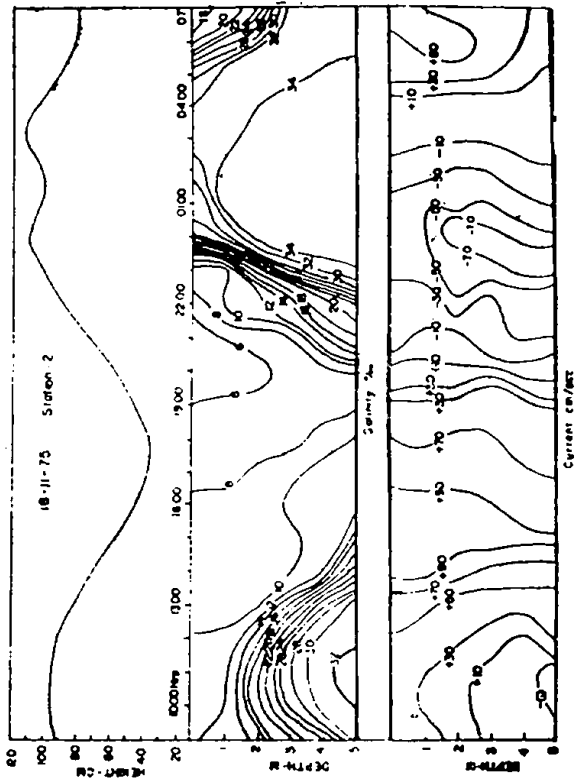
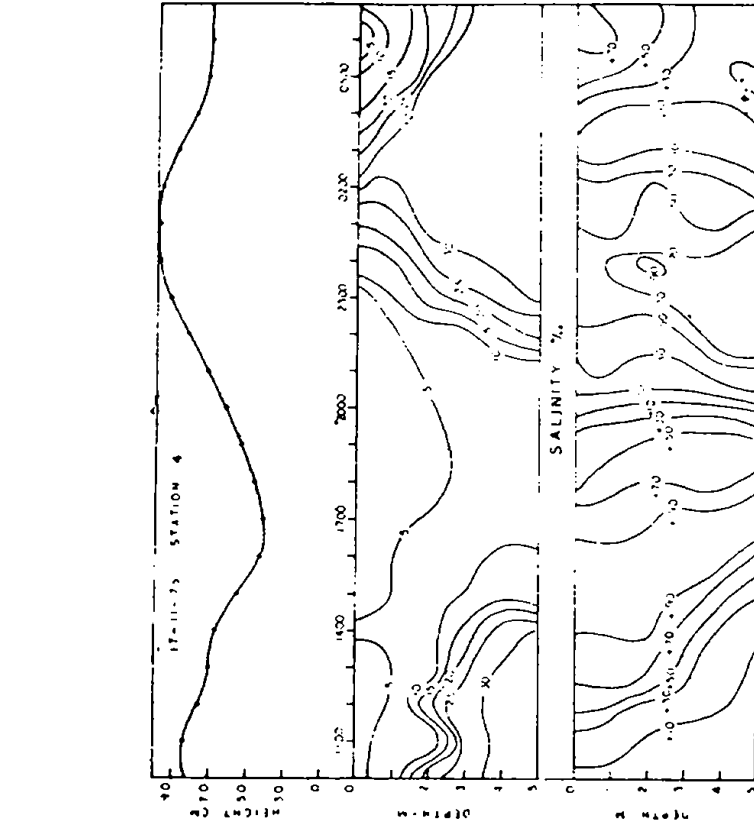


Fig. 6.



Figs. 6-9. Distribution of salinity and current at the stations studied in relation to the tide during the postmoonson period.

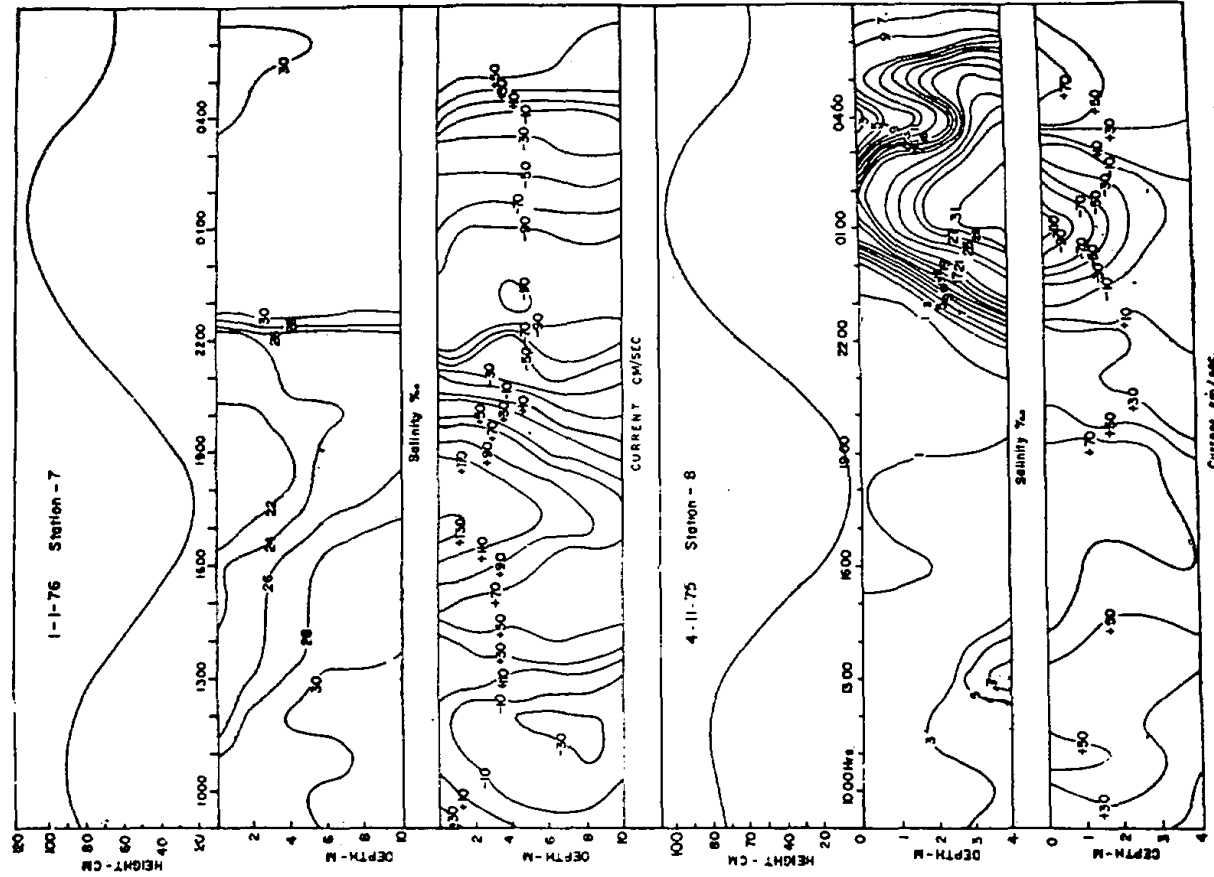
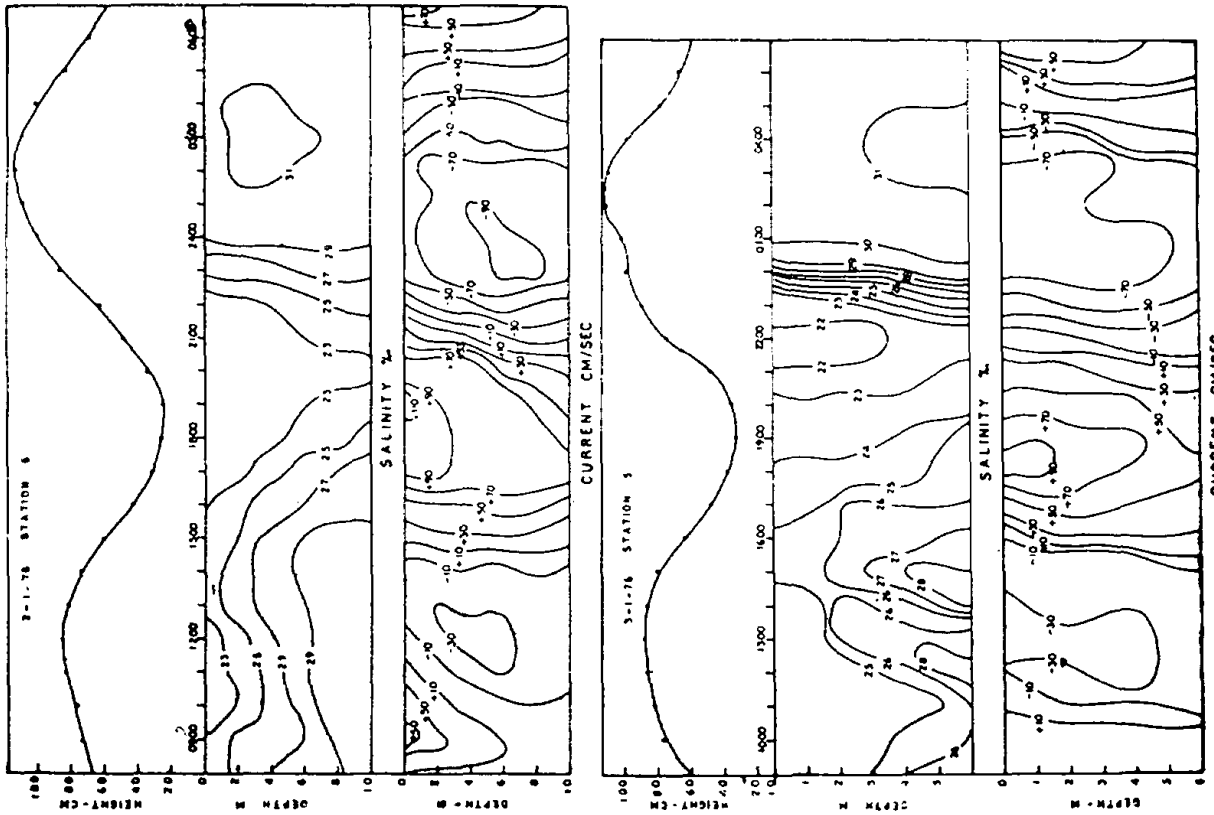


Fig. 8.



Current cm/sec.

Fig. 9.

estuary. At all the stations the salinity varies from 32 to 36.5‰. During the different phases of the tide the vertical salinity gradient is negligible showing the presence of a comparatively well mixed layer in the Cochin backwaters.

Currents

Monsoon: The variation of current velocity and direction with respect to the tide is depicted in Figs. 2-5. The positive sign before the current values denotes the ebb currents and the negative sign denotes flood currents. It can be seen that there is a negative or positive gradient in velocity from surface to bottom depending upon the nature of the tide. During high tide a positive gradient is noticed and at low tide a negative gradient. However at mid tide levels the gradient is comparatively small. The change of the + isolines to - isolines indicates that there is complete reversal in the direction of current in the entire water column as the tide reverses.

However, the flow pattern during the monsoon is the resultant of the tidal influence and the freshwater influx. During this season flood currents are first noticed at the bottom and gradually spreads to the surface layers. Also, the flood velocities are high in the layers 2-3 m above the bottom whereas the ebb velocities are more in the surface, i.e., up to 2 m depth. There is no persistent two layer opposite flow at any of the stations. But a two layer flow is noticed at the harbour mouth which exists only for a duration of 2-3 hrs during the changing phase of the tide.

It is also observed that the flood and ebb velocities are higher in the Ernakulam channel compared to that in the Mattancherry channel. While the highest flood velocity in the Mattancherry channel is 70 cm/sec it is 90 cm/sec in the Ernakulam channel. So also the highest ebb velocity in the Mattancherry channel is only 90 cm/sec while that in the Ernakulam channel is 110 cm/sec. The highest flood velocity (90 cm/sec) at the harbour mouth section is found to be low compared with the highest flood velocity in the Ernakulam channel. However, the highest ebb velocity at the harbour mouth (130 cm/sec) is high compared to the highest ebb velocities in both the channels.

Postmonsoon: The flow pattern (Figs. 6-9) more or less follow the salinity distribution pattern. The predominance of the tidal influence is evident. Mostly negative gradient exists from top to bottom. In certain cases, during high tide, there is a slight positive gradient from surface to midsurface levels and then a negative gradient. This shows that the intensity of the tidal incursion is at the mid depth levels. Also during flood tide there is not much difference in the highest recorded velocities in the two channels except at the harbour mouth. The highest velocities at the stations 2, 3 and 4 (Fig. 1) in the Mattancherry channel are 70, 90 and 90 cm/sec respectively as against those of 90, 70 and 110 cm/sec at the stations 5, 6 and 7 in the Ernakulam channel. Similarly the highest ebb velocity at the above three stations in the Mattancherry channel is 90 cm/sec. The stations 5, 6 and 7 in the Ernakulam channel have highest ebb velocities of 110, 90 and 130 cm/sec respectively. At the harbour mouth, comparatively high values of the order of 170 cm/sec at low tide and 150 cm/sec at high tide are recorded. There is a complete reversal in the direction of the current from surface to bottom with the change of the tide. However, there is a time lag of 1 to 1.5 hrs to have this reversal.

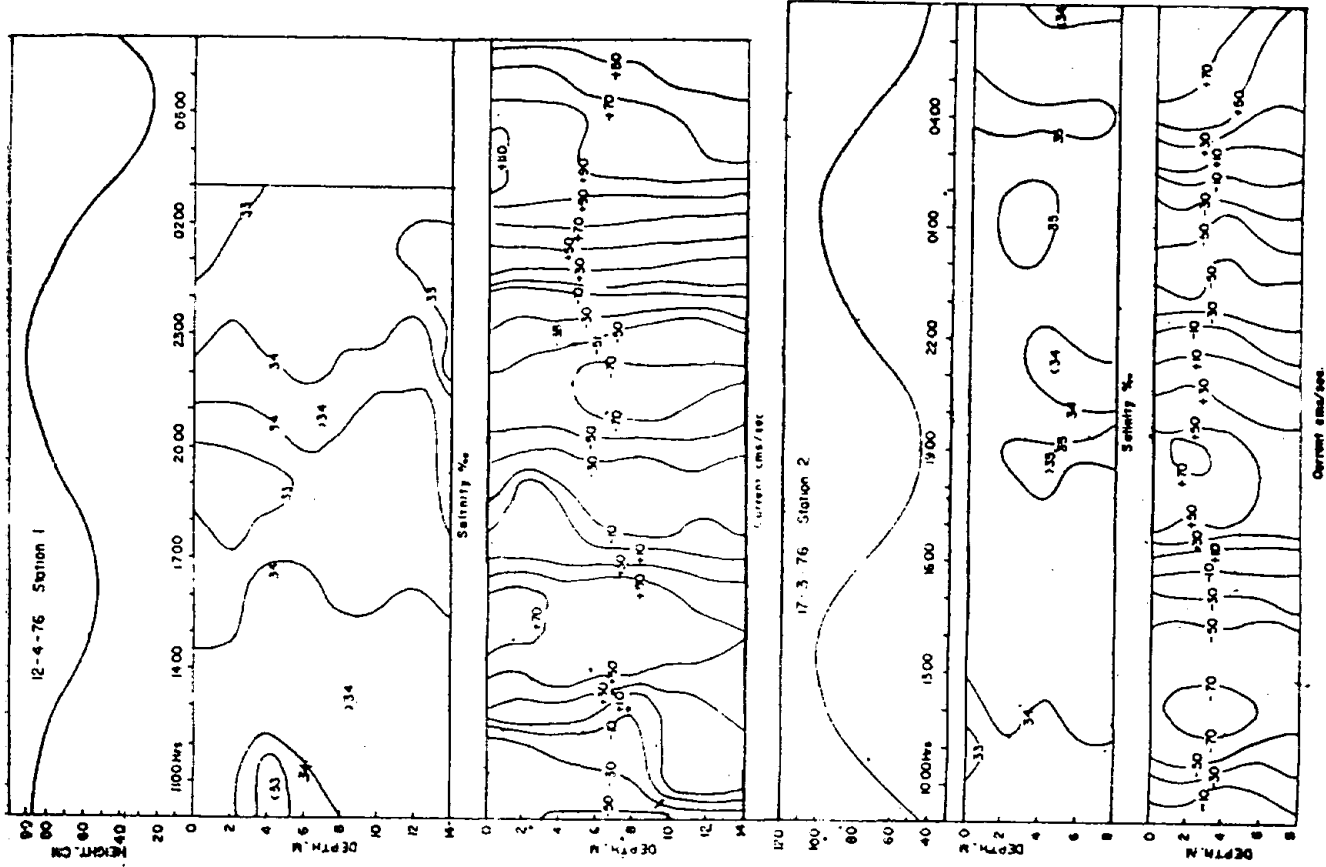


Fig. 10.

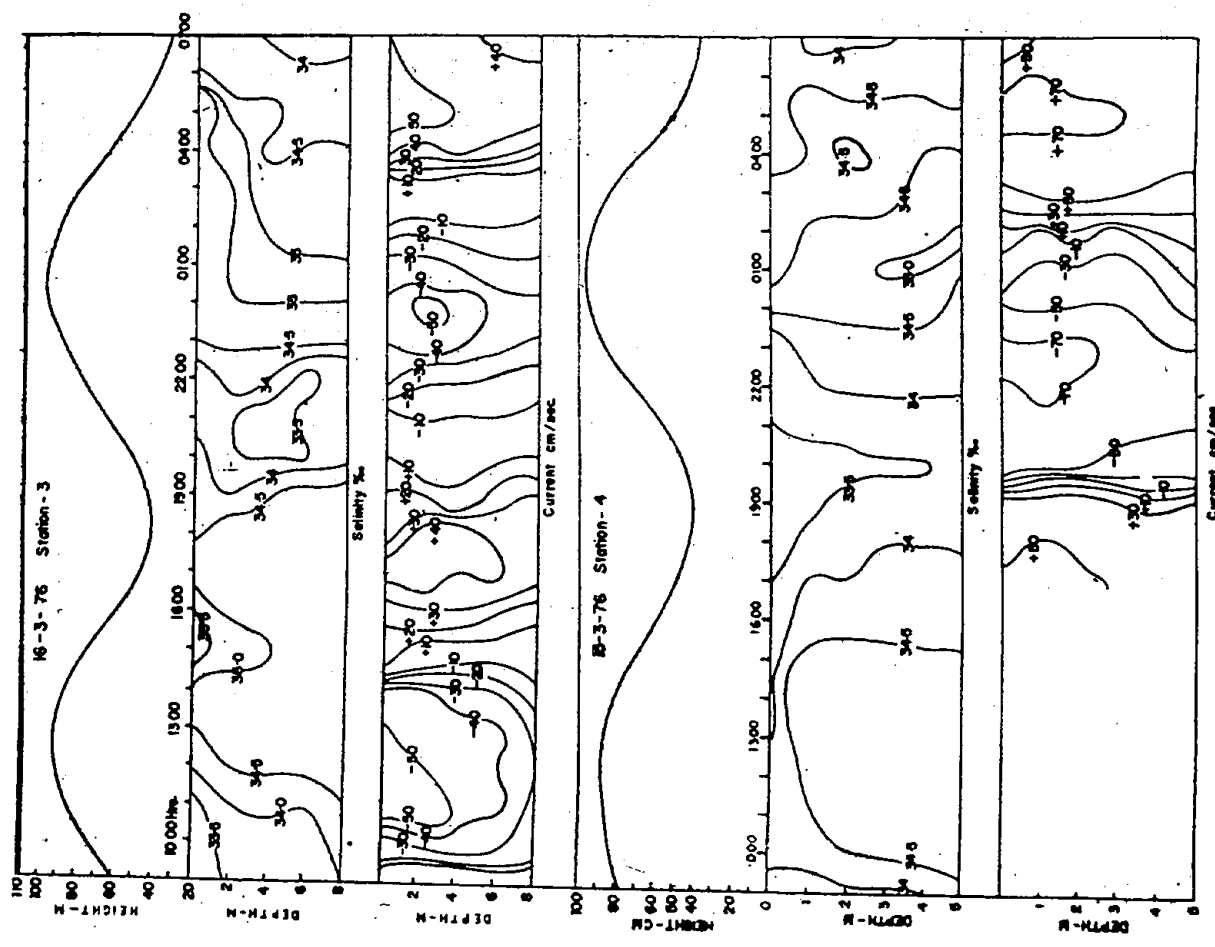


Fig. 11.

Figs. 10-13. Distribution of salinity and current at the stations studied in relation to the tide during the premoon period.

Premonsoon: During the premonsoon season (Figs.10-13) the flow pattern mainly depends on the tidal conditions. During high tide the flow is into the estuary from surface to the bottom with a velocity not exceeding 70 cm/sec. The velocities are more or less of the same order of magnitude near the harbour mouth and in both the channels. During low tide while the highest velocity observed in both the channels separately are 70 cm/sec each, the highest velocity recorded at the harbour mouth is 110 cm/sec.

From the figures it can be seen that the reversal in the direction of the current takes place from surface to bottom at about three hours after the occurrence of the high or low tides. Another characteristic feature of this season is that the highest velocities of both flood and ebb currents are observed in the surface layers.

The variation of salinity with time and space is the result of the interaction of the tidal flux and the freshwater discharge. In the monsoon months when the fresh water discharge is more a salinity gradient develops from surface to bottom and the entire water column remains stratified. This happens more prominently during the high tide period. At the bottom layers, high saline water having a maximum salinity of 33.0‰ is found to exist. As the tide starts rising the incursion of this high saline water is first noticed at the bottom and it spreads to the mid layers, with the progress of the tide. As the tide falls gradually this high saline water completely disappears and the backwater region is dominated by water having salinity not exceeding 25‰ at the bottom. Thus a permanent two layer flow and the presence of a permanent saline wedge during the monsoon or other seasons is not observed as reported earlier by other workers. The presence of a two layer flow is transitory in nature and lasts for a brief period of the tidal cycle.

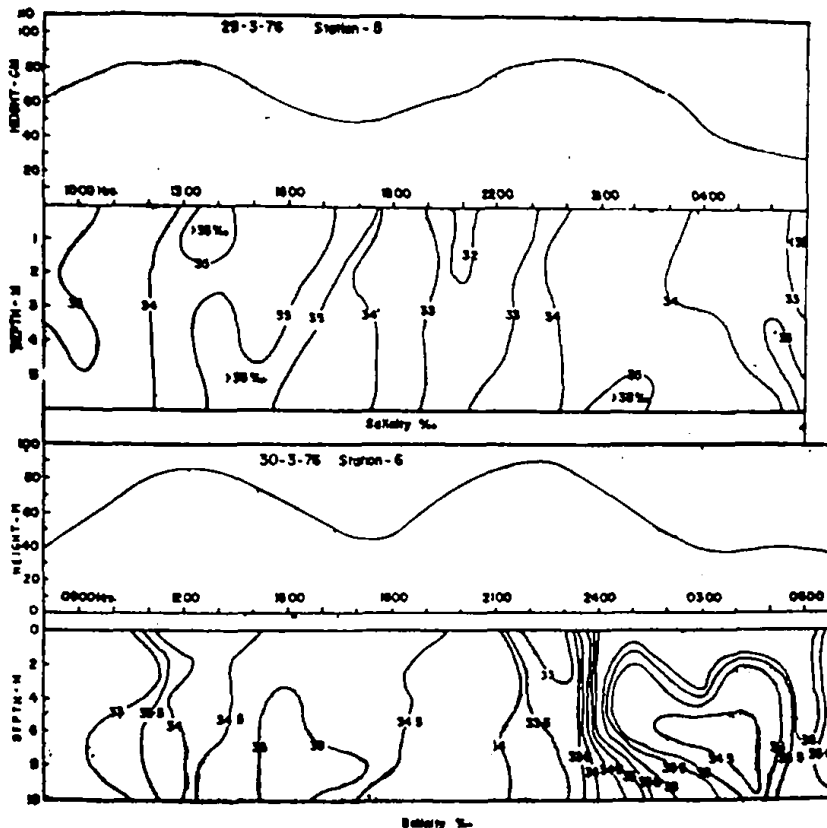


Fig. 12.

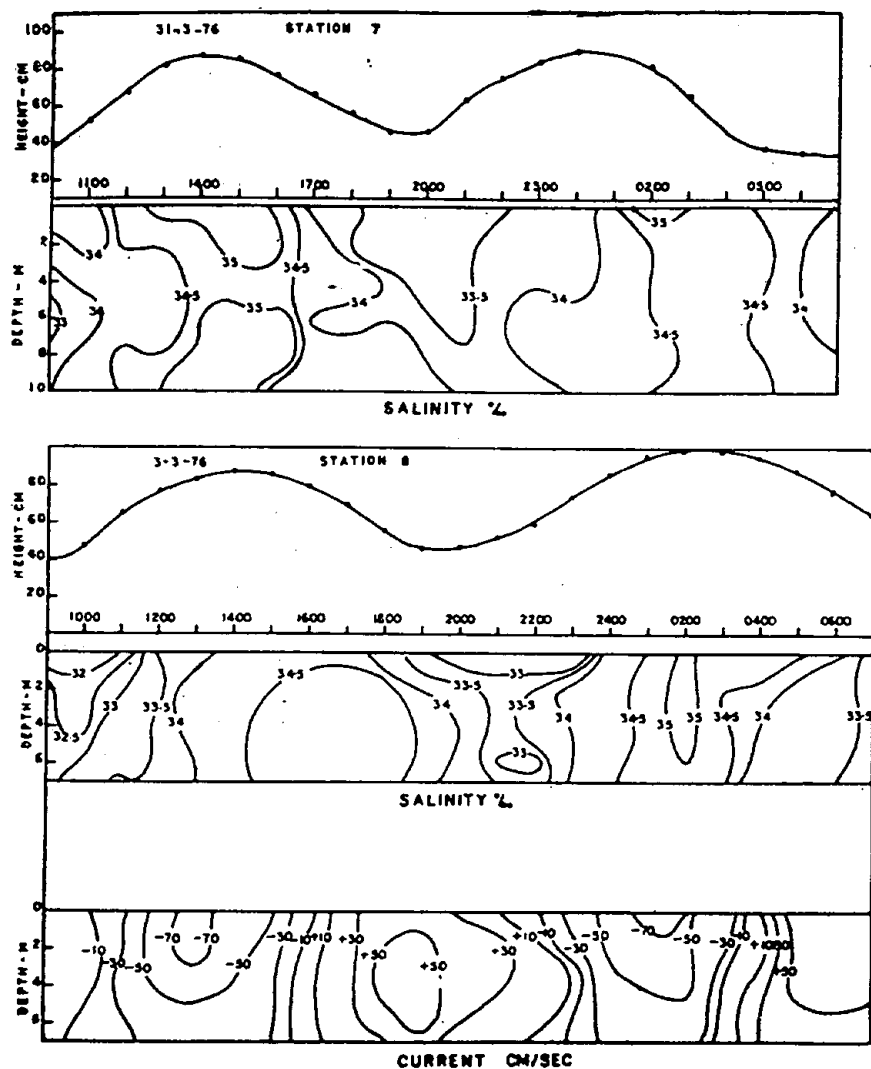


Fig. 13.

When the fresh water influx is less, a comparatively well mixed column of water from surface to bottom exist in this region. There is not much salinity variations from surface to bottom and the salinity varies from 33 to 35‰.

The flow pattern and the salinity distribution of this region of the estuary is more related to the tidal rhythm. It has been observed from these studies that the general pattern of circulation in this region can be described as the incursion of sea water into the estuary during high tide and the draining of this water during the ebb. The direction of the flow from top to bottom during the two phases of the tide gets completely reversed conforming to the flooding and flushing of the estuary from top to bottom which is very important from the point of view of pollution and siltation. However, during the monsoon months this system of flow gets disturbed and the saline water intrusion takes place only through the bottom layers. Also then the velocity of the current is more at the bottom than at the surface in contrast to the non-monsoon months, when the velocity is more at the surface layers both for ebb and flood currents. This is due to the effect of the freshwater discharge which shows a tendency to oppose the surface flood currents.

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