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ESTUARINE CIRCULATION IN COCHIN HARBOUR

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ABSTRACT

The intensity of water current and the nature of mixing at the surface, middle and bottom of fifteen fixed stations in the Cochin Harbour are discussed with respect to the tide. Water circulation cells known as gyre which facilitates localised silting were identified at specific regimes of the channels. The maximum water flow is observed at the southern .tip of Cochin cut (during monsoon). The inter-relationship between depth and water current is studied by the regime approach and the characteristic scatter diagram of the above parameters are presented.

INTRODUCTION

WATER circulation is an important integral physical aspect to be investigated in the study of an estuary. In estuaries circulation is controlled by freshwater flow, friction and tidal mixing. The presence of tidally regulated sea water through the bottom and the constant freshwater flow along surface results a mechanical mixing of water between the two layers which necessitates, a net landward flow of shelf water to make good loss from the lower layers (Pond and Pickard, 1986). The result is a non-tidal circulation, typified by more vigorous and persistent flood tide currents within the intruding bottom layers. One direct result of it is the turbidity maxima located near the landward end of salt water and the increased flocculation and agglomeration of fine particles by increasing particle collisions and particle residence time. Consequently, the estuarine circulation pattern has a predominant role in determining the sediment movements (Bowden and Gilligam, 1971).

The Cochin Harbour situated (09°58'N and 76°14'E) at the southwest coast of Indian Peninsula (Fig. 1). There are many investigations pertaining to physical and ecological aspects of the Cochin Estuary (Rama

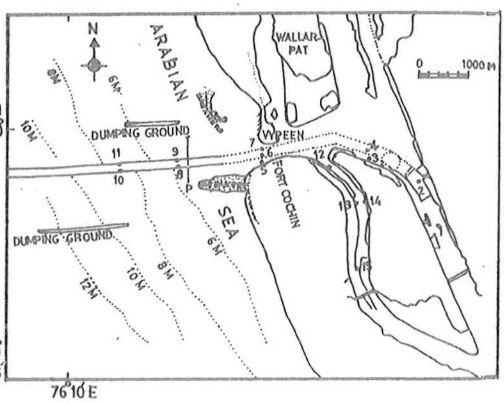

Fig. 1. Station locations at the study area.

Raju *et al.*, 1979; Qasim and Madhupratap, 1981; Udaya Varma *et al.*, 1981; Sankaranarayanan *et al.*, 1986). Practically no detailed study was conducted on the variation of the intensity of current with season in the harbour area. A close understanding of the estuarine circulation is essential to study the sediment behaviour and various estuarine processes. The present study attempts to elucidate the variations of water current at the surface and subsurface levels and the associated exchange and mixing of the estuarine water within the coastal waters.

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Materials and Methods

Data on water current were collected in Ernakulam Channel (Stations 1 to 4), Cochin cut (Stations 5 to 7), Approach Channel (Stations 8 to 11) and Mattancherry Channel (Stations 12 to 15) by direct reading digital current meter from October 1984 to September 1985. Climatologically three prominent seasons can be traced for this region as : Premonsoon (February - May), Monsoon (June - September) and Postmonsoon (October - January). Vertical variability of water current was recorded by sampling at 1 m below surface, mid depth and 1 m above the bottom at each station. The stage of tide at the time of observation is depicted in the Fig. 2.

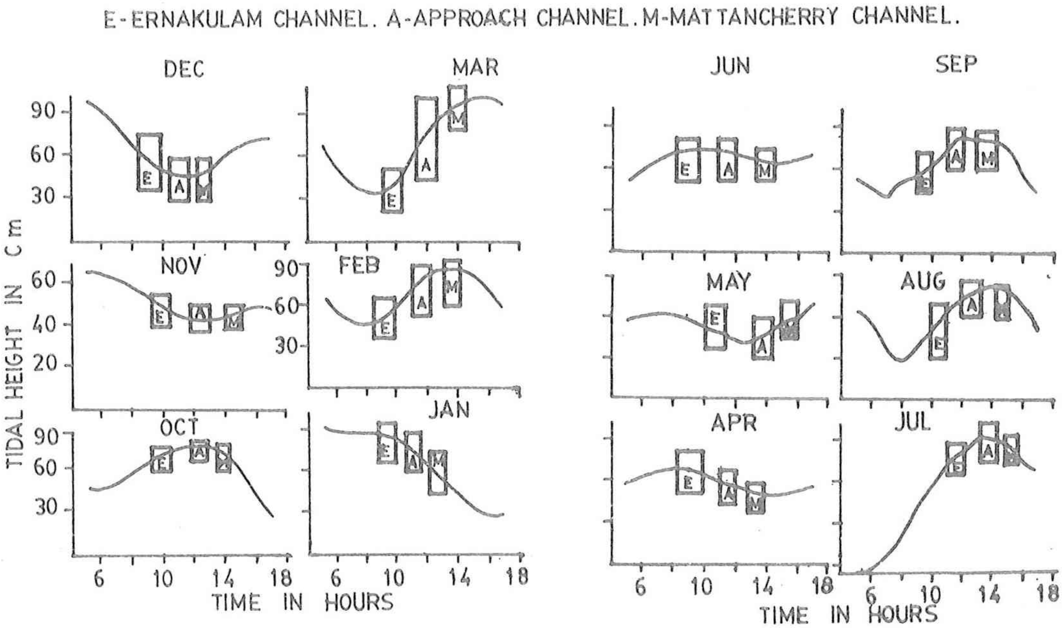

Fig. 2. Tidal height variations (at the time of observation) at Ernakulam, approach and Mattancherry Channels — October 1984 to September 1985.

Results and Discussion

Postmonsoon

During October 1984 the magnitude of flow decreased upstream in Ernakulam Channel and the velocity of bottom waters were slightly more than that of surface waters. In this channel the flood flow swept back the fluvial inflow further south, paving the formation of the tidal intrusion front in the transvers section at Station 2 (Fig. 3). The relatively low magnitude (6-26 cm Sec^{-1}) and translatory nature of currents in the ebb phase of tide in November reveals the effects of secondary currents arising from the interference of typical back and forth tidal movement by reduced the whole water column in the lower reaches of the channel even during the ebb tide phase revealed the incursion of coastal waters in this channel.

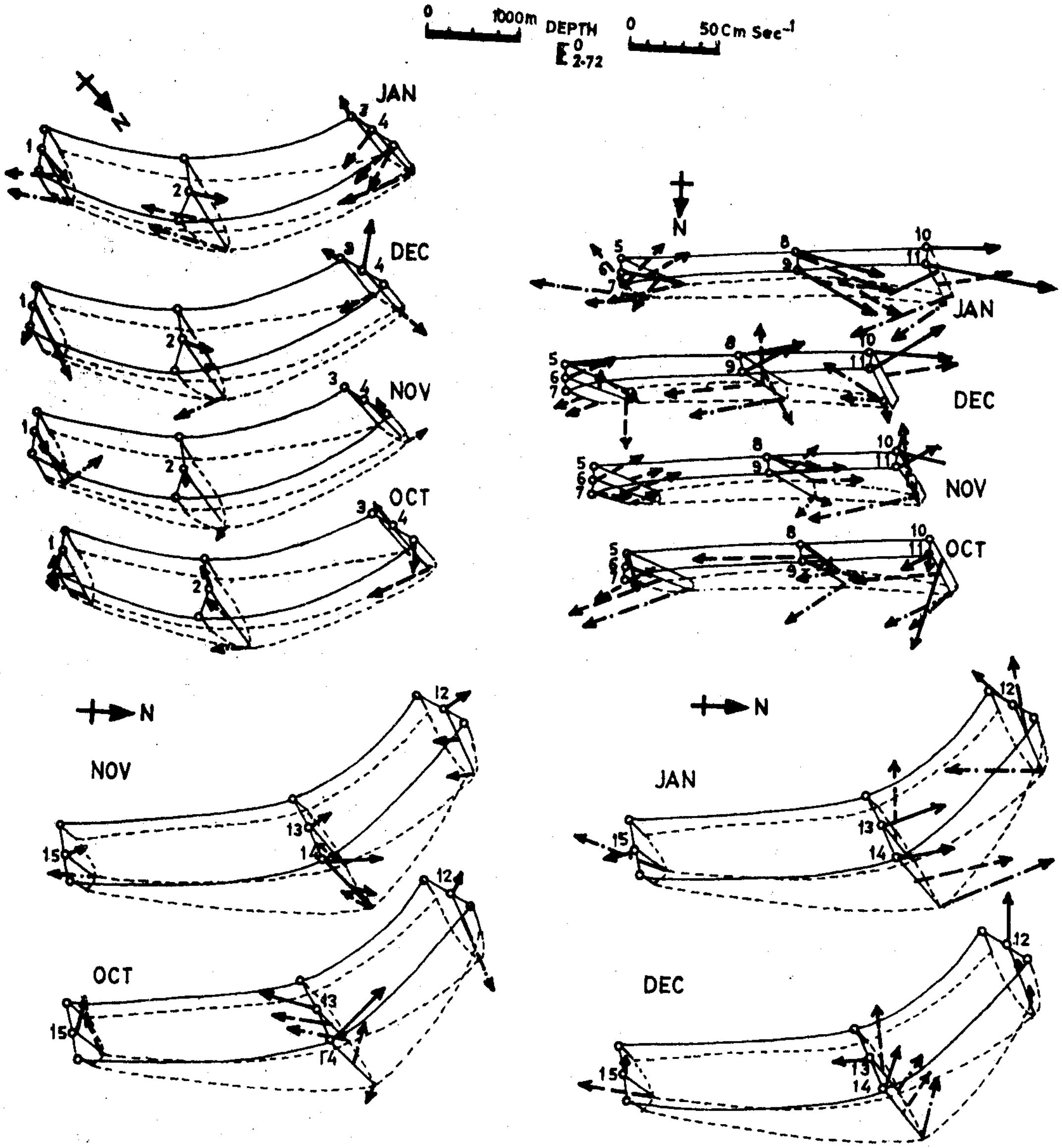

Fig. 3. Water currents in Ernakulam, approach and Mattancherry Channels at surface, middle and bottom during postmonsoon season.

fluvial supply. Two layer flow was present in January 1985 and the landward movement of

The direction of flow in the approach channel showed that ebbing persisted in the

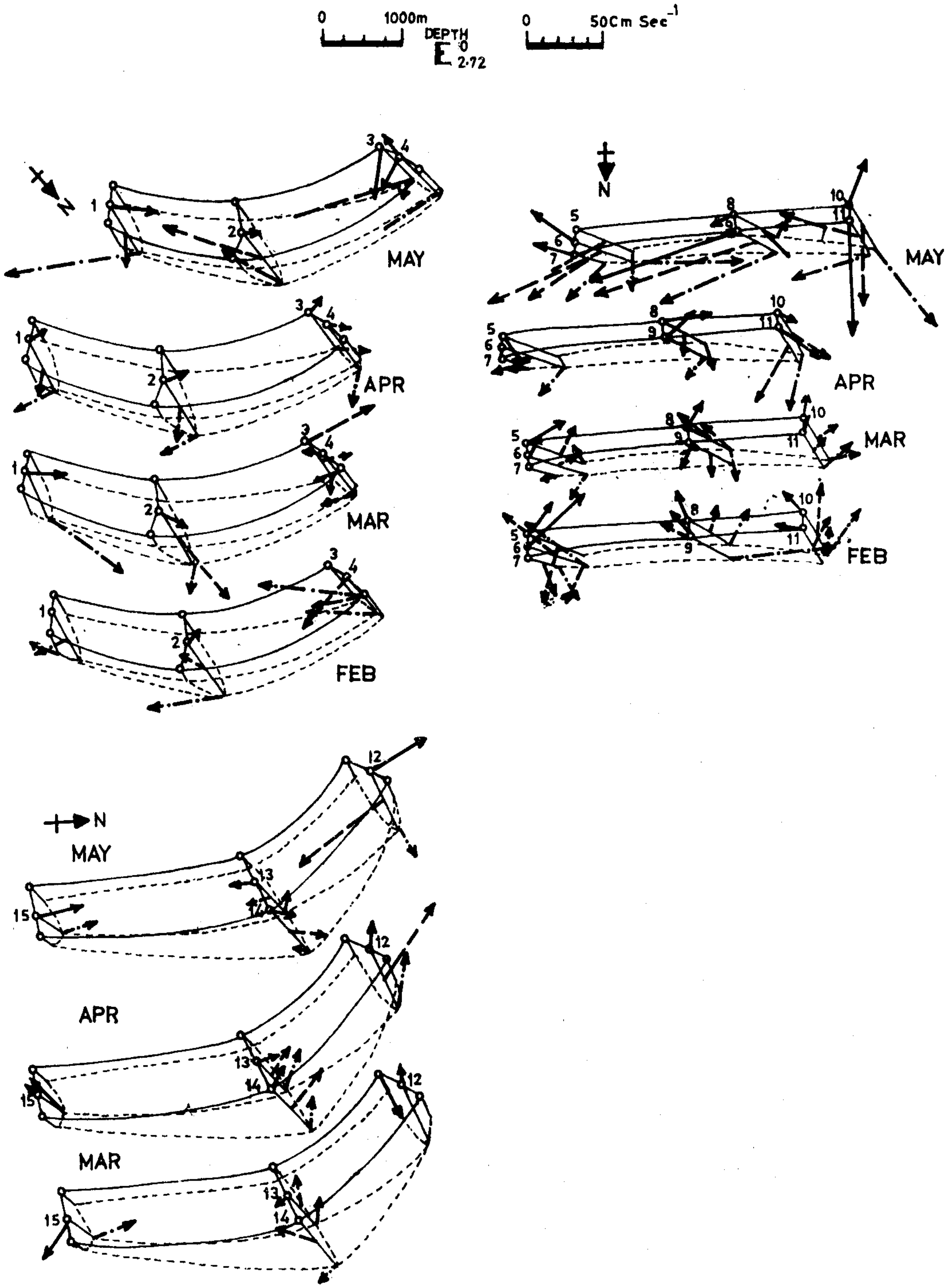

Fig. 4. Water currents in Ernakulam, approach and Mattancherry Channels at surface, middle and bottom during premonsoon season.

surface layers even at the commencement of hightide. Very evidently, two layer flows were observed throughout the approach channel during December with bottom waters mainly directed towards northeast. In January the water currents were directed towards the Seaward side from the turning point (Stations 8 and 9) while bottom currents flowed landward from the seaward end of the approach channel (Stations 10 and 11) which is likely to favour heavy sedimentation in this segment. It is observed that this channel was characterised by two distinct circulation patterns, one from the Cochin cut to the turning point (Stations 8 and 9) and beyond it, towards the seaward side.

Except in December two layer flow towards the lower reaches of the Mattancherry Channel is noticed (Fig. 3). The magnitude of water flow was less and was a minimum in November (9-34 cm Sec^{-1}). Low magnitude current may facilitate this channel to act as a sink causing the deposition of suspensate. Similar observations were made by Bartholdy (1984) during his studies on the transport of suspensate in a bar-built Danish Estuary. In October the surface and mid waters of the Stations 13 and 14 flow in opposite directions hence promotes the settling of suspensate and siltation processes in the Mattancherry Wharf. From Fig. 3 it is evident that gyre type circulation results at the Mattancherry Wharf in November (bottom water south-west, mid water north-northwest, and surface water north-northeast dirction). The circulation pattern in this channel during postmonsoon season reveals that the current lags considerably from the excepted tidal rhythms. The presence of secondary circulations that arises from the freshwater flow fluctuations, geographical orientation of the channel, the irregular depth variations due to dredging and topographical uneveness are reasons for the peculiar water flow variations observed in this channel. Such external influences on estuarine flow was also discussed in partially mixed estuaries (West and Shino, 1985).

Premonsoon

The bottom water directed towards the upper reaches of Ernakulam Channel in premonsoon months (Fig. 4) (February and March) reveals the incursion of coastal water into this channel. The relatively stronger water flow (74 cm Sec^{-1}, midwater, 84 cm Sec^{-1} bottom) at the subsurface layer in May is persumed as the cumulative effects of upwelled water (as shown by the temperature and salinity observations) (Sundaresan, 1989) and the flooding effects. During March, the surface, middle and bottom waters at the Ernakulam Wharf (Station 3) flowed seawards while that at Station 4 of the same transverse section flow landwards, showing the presence of a circulation cell, may have a profound effect on the sediment transport mechanism.

In the approach channel the magnitude of bottom and mid water currents were higher than the surface currents. In April the surface flow was seawards at surface and the subsurface water flowed towards northeast and northwest directions; hence the presence of a two layer flow was detectable. Very high magnitude of current towards the northeast (landward direction) were present in the approach channel (though the observations was taken during the ebb tide) during April. This is due to the incursion of upwelled water as confirmed from the salinity and temperature date (Sundaresan, 1989).

The speed of water flow was marginally reduced in Mattancherry Channel (minimum in March, 8-29 cm Sec^{-1}) during premonsoon months (no data for the month of February 1985). The stations of the same transverse section in Mattancherry Wharf exhibits water flow in the opposite directions. In April the whole water column flowed seawards, much influenced by the ebb phase of the tide. Also noted here is the baroclinic adjustment of sea surface slope for a southerly flow that give rise to difference between the sealevel and the water level in the backwater system (Shenoi and Murthy, 1986). Two layer flows observed in May indicate the strong incursion of coastal waters.

Monsoon

The water flow in monsoon months in the Ernakulam Channel was measured during the flood tide phase. Relatively high water currents were observed in July (81-88 cm Sec^{-1}) and August (66-83 cm Sec^{-1}) (Fig. 5). The enhanced freshet from monsoonal rainfall and the high monsoon waves that influences the

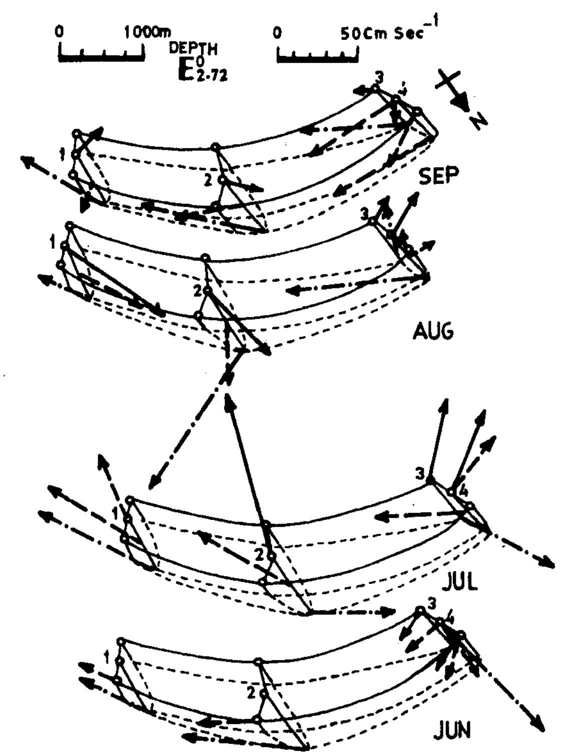

Fig. 5. Water currents in Ernakulam Channel at surface middle and bottom during monsoon season.

estuarine currents may cause this high magnitude water flow. Earlier studies also revealed the presence of the wave induced currents in the Cochin Harbour (Central Water Power Research station, 1969). In July, the bottom water flow at Station 4 is in the landward direction, while the direction of flow at middle and surface layers of station 2 inclined slightly towards west of the channel hence the water column exhibits a gyre type circulation between stations 4, 2 and 3. A two layer flow was present in this channel during August and September 1985. The translatory nature of water flow during July and August is accounted by the interaction between floodtide flow and fluvial supply from Periyar on the northern side and Muvattupuzha and other rivers from the southern parts of the estuary. Similar type of estuarine circulation due to the interaction of different waterways and the tides have been observed in Chanjiang Estuary, China (Sujilan and Wangkanshan, 1986).

Relatively strong water flow during monsoon months in the approach channel (Fig. 5 i) with maximum speed at the southern tip of the cut (126 cm Sec^{-1}) in July. The water flow in the cut region during July is towards the inner channel lagging the ebb phase of tide. This was caused by the onshore component of strong winds increasing the sea surface slope along the shore and also due to the wave induced currents at the peak of the monsoon season. Srivastava and John (1977) highlights the role of wind speed in modifying the circulation pattern, while studying the current regime in the Gulf of Kutch. It is observed that the onshore component of strong winds would give rise to increased sea surface slopes along the shore in this season (Shenoi and Murthy, 1986). The narrow orifice of the cut at the barmouth may also cauuse jetting effects of water currents during the tide phases which in turn leads to two layer flow in the outer extension of the approach channel.

The water flow during monsoon months in the Mattancherry Channel exhibits considerable variation (30-103 cm Sec^{-1}). Two layer flow was present in June. Water flows in opposite directions near the Mattancherry Wharf. The maximum flow velocity recorded in September (103 cm Sec^{-1}) in the mid-water level at station 12. During September the surface and bottom waters at station 13 flowed towards

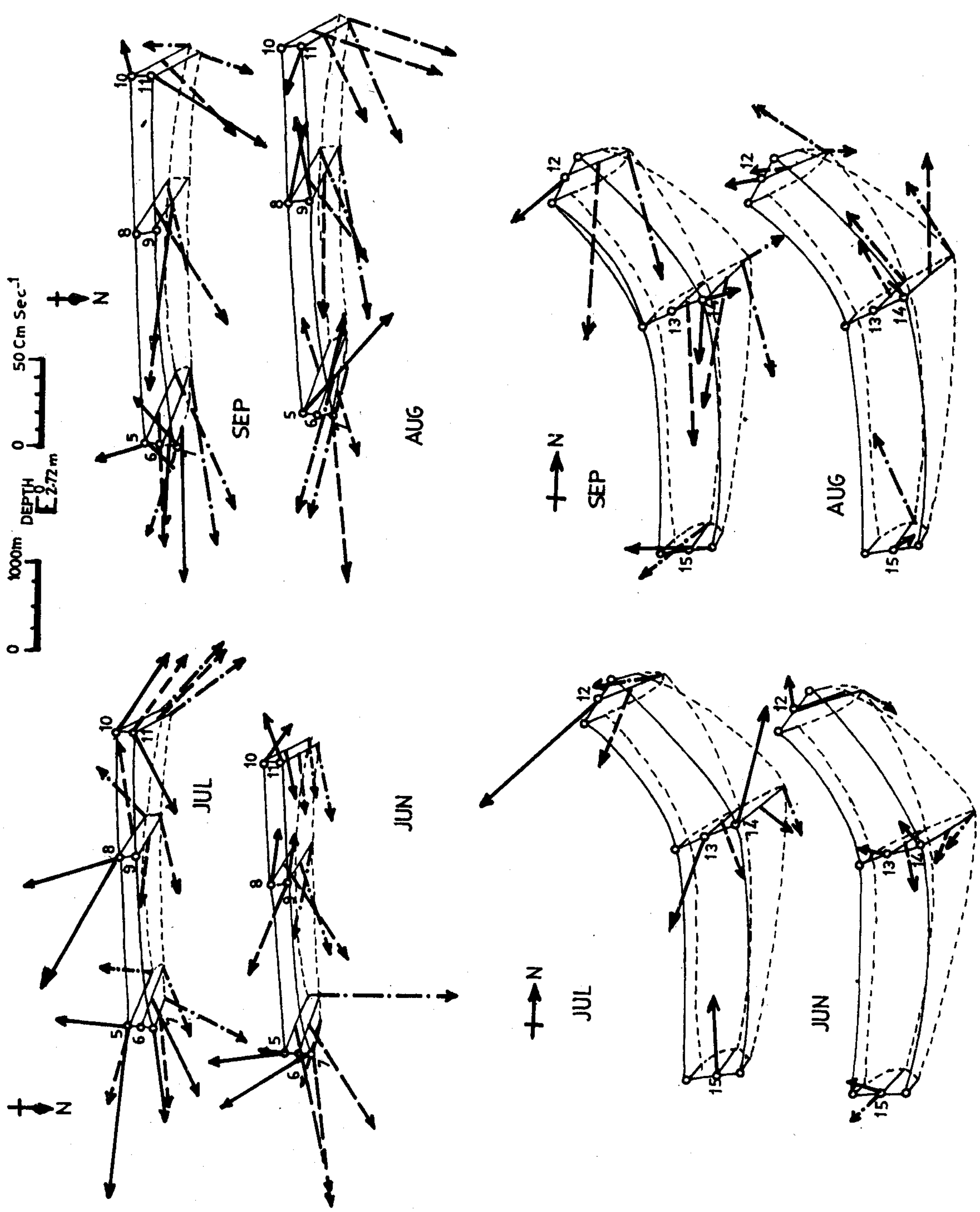

Fig. 5 i. Water currents in approach and Mattancherry Channels at surface, middle and bottom during monsoon season.

the Mattancherry Wharf which may promote the sedimentation at this regime. The study revealed that the effects of increased churning action of waves, intensified winds and orientation of the channel prominently influence the water circulation characteristics of the Mattancherry Channel.

Depth—Velocity diagram

From among a number of methods developed and applied to natural streams (Kennedy, 1977) the characteristic two dimensional diagram relating depth and water current can be plotted to describe the hydraulic system (Southard, 1971). The wide applicability

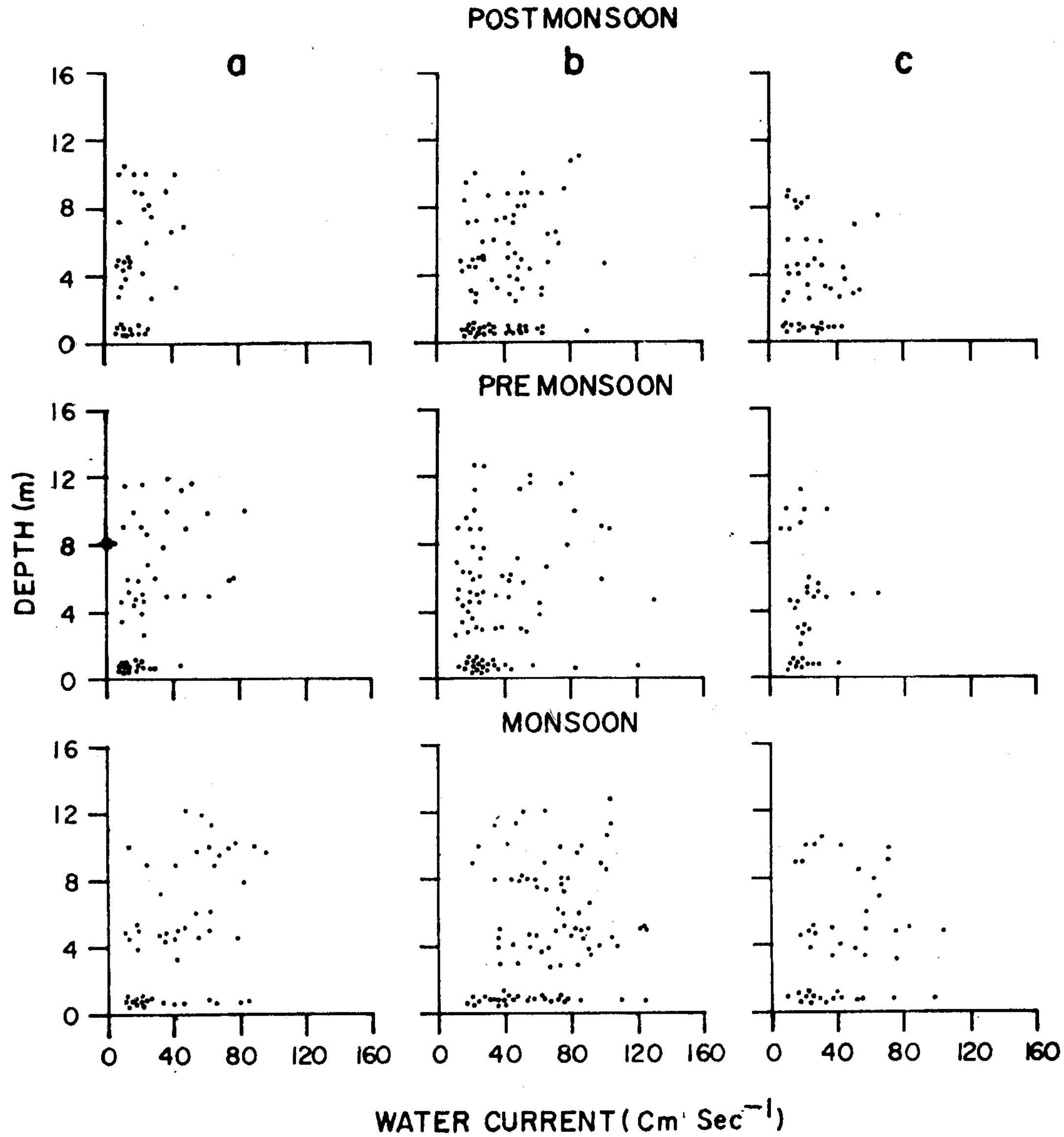

Fig. 6. Inter relationship between water current and depth in (a) Ernakulam Channel (b) approach channel and (c) Mattancherry Channel during postmonsoon, premonsoon and monsoon seasons.

of such plots had been demonstrated by Southard (1975) and Middleton and Southard (1978). The inter-relationship between water current and depth in the Ernakulam, Approach and Mattancherry Channels during postmonsoon, premonsoon and monsoon are shown in Fig. 6. The large scatter of values observed during monsoon related to the distribution of current vectors even at the deeper regions of the navigational channels. It can be inferred that the transport mechanism function effectively during this season. Among the inner channels, water current is sluggish during postmonsoon season in the Ernakulam Channel and during premonsoon season in Mattancherry Channel. As a rule the low magnitude of water current is present in Mattancherry Channel (Fig. 6). Most frequently observed water currents were in the range of 10-50 cm Sec^{-1} in the inner channels and 10-80 cm Sec^{-1} in the Approach Channel. The surface water current is much clustered (20-40 cm Sec^{-1}) in the Approach Channel during post and premonsoon seasons. The pattern of water current distribution with depth during pre-monsoon and postmonsoon in the inner channels may support to reason the prolonged persistence of suspensate in selected regions of the channels hence siltation.

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