Mar. Res. Indonesia Vol.20, 1977: 39-50

SOME WATER CHARACTERISTICS OF ESTUARIES IN INDONESIA

by

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ABSTRACT

This paper describes the results obtained during several hydro-oceanographical observations of some estuaries in Indonesia to provide environmental informations. It is also an attempt to make a general interpretation of the collected data, to explain or find out the physical processes acting in these regions.

INTRODUCTION

Within recent years several hydro-oceanographical surveys were carried out in some estuaries of Indonesia among others for Harbour Engineering, Dredging and the Safety of Navigation. Description of the results obtained from approximately monthly observation or more, was made to provide environmental information of these estuaries with special references to Belawan (North-East Coast of Sumatera), Jakarta Bay/Sunter River basin (North Coast of Java) and Cilacap (South Coast of Java). (Fig. 1).

The study was originally based on the results of the hydro-oceano-graphical surveys mentioned above and formed a "Preliminary study on the characteristics of estuaries".

It is already known that the main drawback in studying estuaries is that river flow, tidal range, and sediment distribution are continually changing. Consequently some estuaries may never really be steady-state systems. They may be trying to reach a balance which they never achieve.

Because of interaction of so many variables no two estuaries are alike and one never knows whether one is observing general principles or unique details. And therefore, it is also an attempt to make a general interpretation of the collected data to explain or find out the physical processes acting in these regions by comparing them to the general principles available in "Studies of Estuaries".

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DOI: 10.14203/mri.v20i0.381

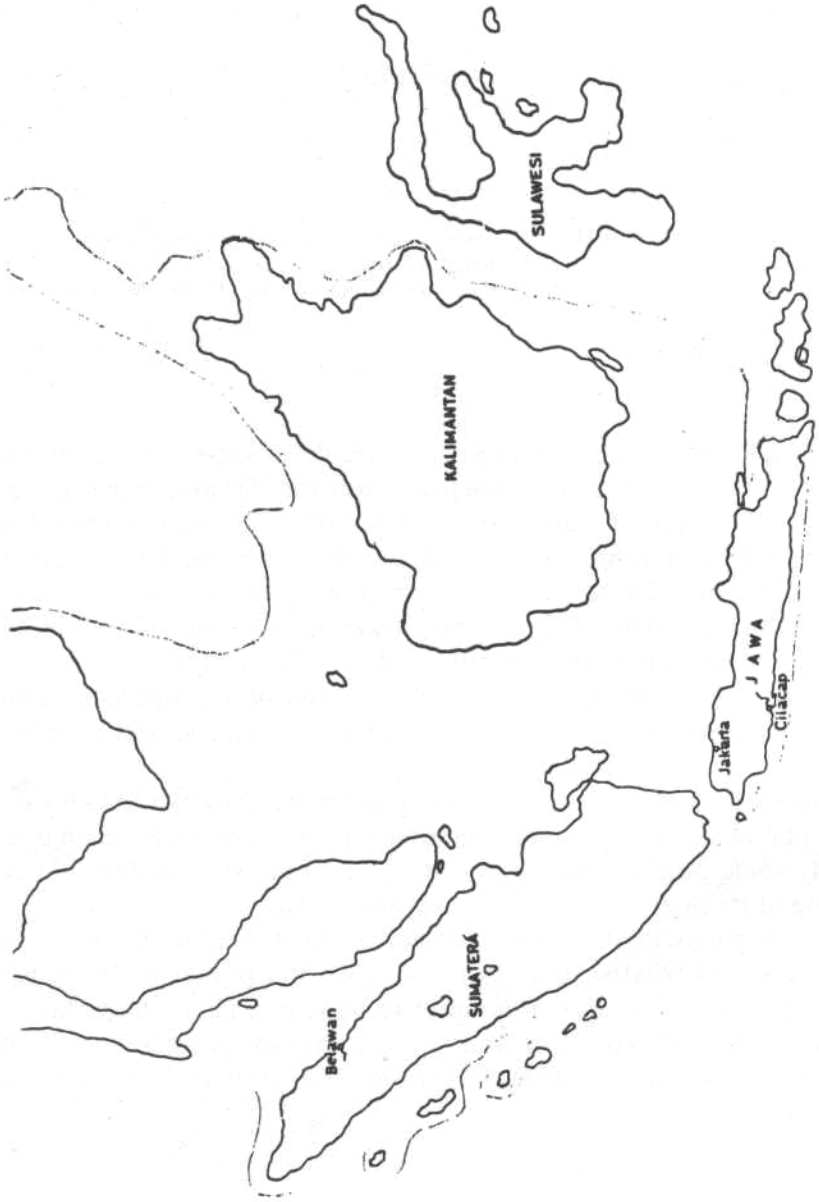

Figure 1. Situation of sites observed.

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MATERIAL AND METHODS

The investigations took place in the Western part of Indonesia, namely:

- in the Belawan Channel — during July — August 1969;
- in the Jakarta Bay (actually in the Sunter River mouth) covering
- several periods between November 1972 and March 1973; and
- in the approach to and in the Cilacap Channel itself up to the Donan River during April - June 1973.

Measurements were made on tides, currents, and other parameters in connection with the studies of the estuarine for certain purposes. Tidal observations in all these areas were done using automatic tide gauges (ASKANIA or NEGRETTI ZAMBRA) and were checked continuously by tide poles. The current measurements were carried out using automatic current meters (HYDROPRODUCT type 505) and were checked periodically using mechanical current meters (EKMAN MERZ) and driftpoles at certain periods. Studies of other water parameters were based on the results of water samplings using NANSKN bottles and other water and bottom samplers (RIGOSHA type).

RESULTS

1. In Belawan:
   a. From the tidal observations made from August 15th through August 29th 1969, tidal curves are drawn and after corrections the tidal components were calculated according to the Admiralty Method which gave the following harmonic constants for the position in the harbour channel :

Constants	:	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
Amplitude (cm)	:	271	60	35	14	15	7	0.4	0.6	8	7
Phase (^{o})	:	–	59	81	23	347	277	101	249	81	347
For positions at the River Mouth:											
Contansts	:	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
Amplitude (cm)	:	252	57	31	11	17	5	2	3	8	7
Phase (^{o})	:	–	37	81	30	8	291	8	2	81	8

Based on these constants we found that the type or character of the tide in this area is predominantly semidiurnal, namely usually two High Waters and two Low Waters in a lunar day; while the observed tidal range has a value up to 2.00 until 2.50 meters.

b. The current character in the area of Belawan River mouth is semidiurnal, but sometimes divergences can be noticed caused by the influence of the local current which is a non tidal current.
The outgoing current or ebb-current is up to 3.0 knot with a direction of north-north west and the ingoing or flood-current is up to 2.0 knot with a direction of south-south-east. The relationship between tides and currents for a certain period could be seen in Figure 2.

c. Belawan is situated between two river mouths, the Belawan and Deli River. Based on the bottom samples that were taken in the harbour the materials consists mostly of fine sand and muddy sand.

II. The Sunter River mouth (situated in Tanjung Priok Harbour):

a. Based on the tidal observations for a certain period between November 1972 and March 1973, the results are as follows:

Constants	:	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
Amplitude (cm)	:	81	5	5	–	26	14	–	–	–	8
Phase (^{O})	:	–	351	296	–	144	124	–	–	–	144

The type or character of the tide in this area is predominantly diurnal, namely usually one High Water and one Low Water in a lunar day, with a tidal range up to 1.00 meter.

b. From the current measurements made during the dry season (November 1972) and the wet season (February 1973) the results are as follows:
- during the dry season the river is strongly affected by tidal currents;
- in general the difference in velocity and direction between the currents at the surface, mid-depth, and bottom is caused by the influence of tidal currents, wind, and the configuration of the bottom.

During the wet season the river currents flow continuously northward, decreasing in velocity only because of the influence of the tidal current. The strongest current velocity (0.46 m Sec^{-1} or about 1.0 knot) was observed at a distance of about 0.8 km from the Sunter River itself. The strong current occurred when the influence of tidal current was weakest. The current velocity decreases from surface to bottom. The relationship between the tides and currents is shown in Figure 3.

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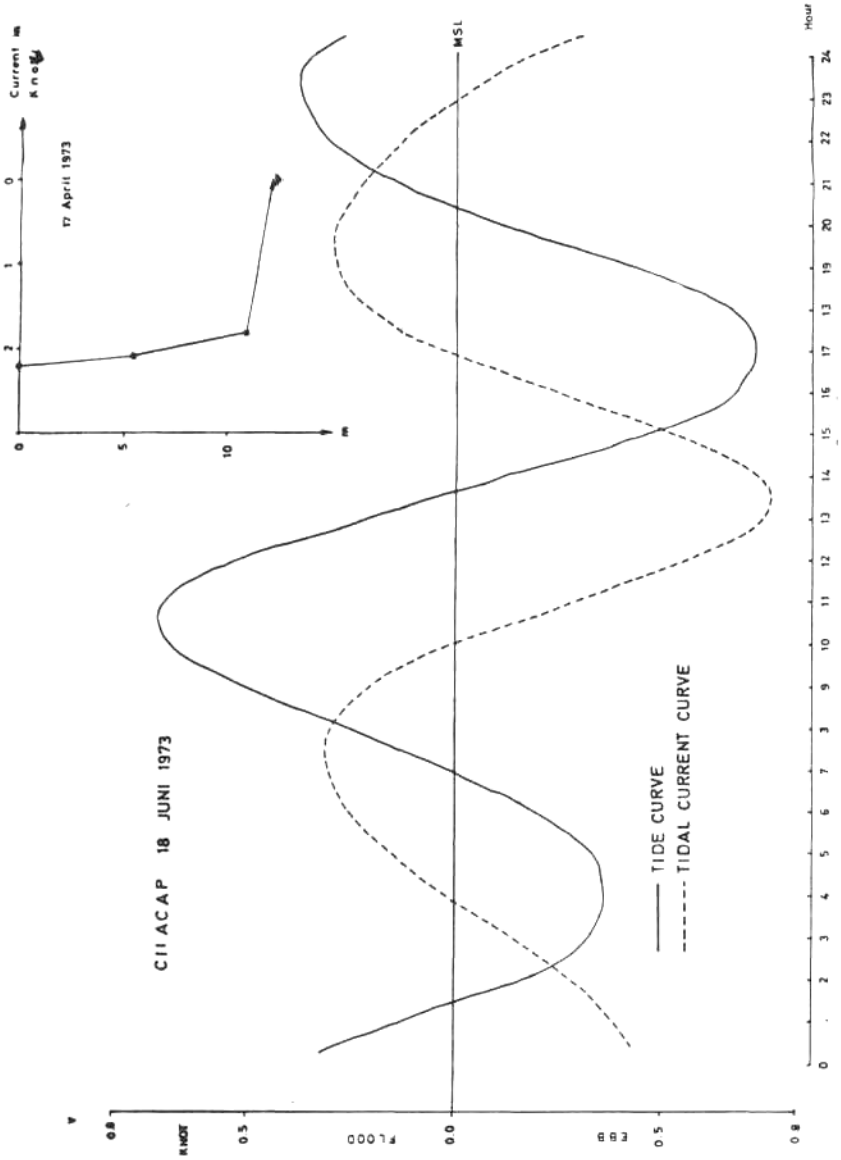

Figure 2. The relationship between tides and currents in Belawan.

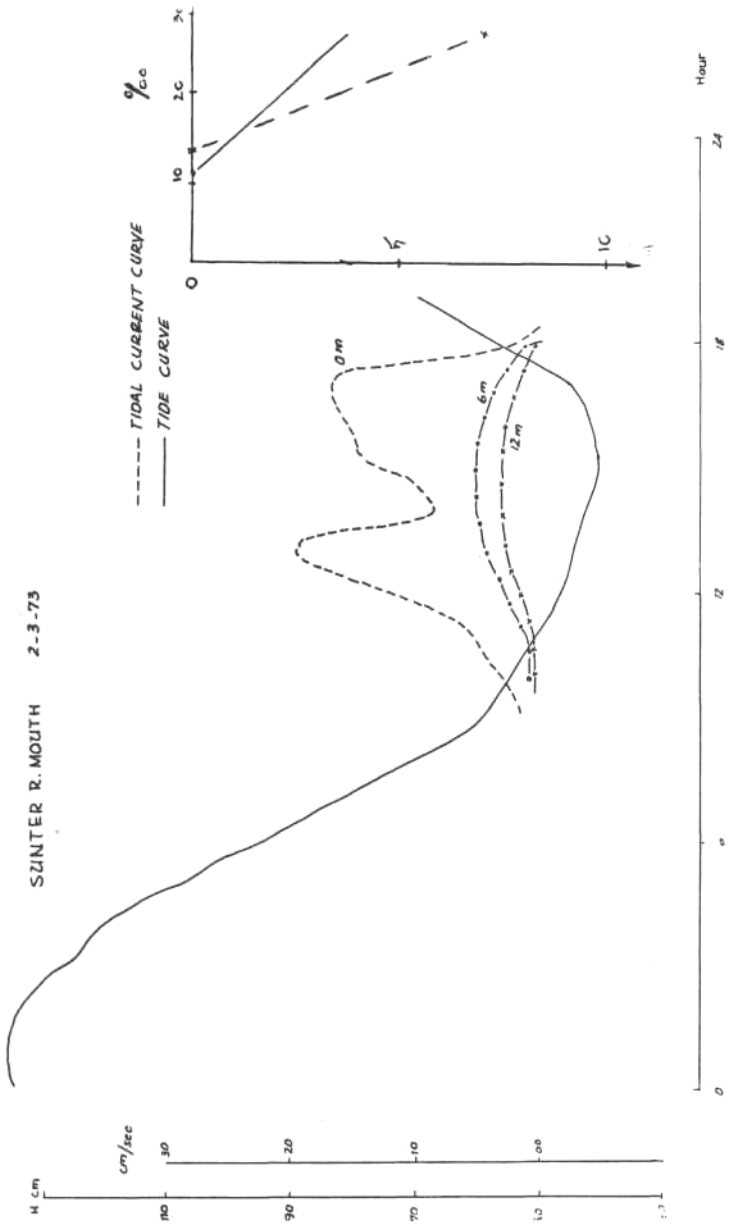

Figure 3. The relationship between tides and currents in the Sunter Rider Mouth.

c. Bottom samples were taken in the harbour of Tanjung Priok (in the vicinity of the Sunter River mouth) and analysed on their contents of organic material and the grainsize distribution. By weight 2.3% of the bottom consists of organic material. The rest consists of materials with grainsize that lies in the sand-silt-clay range, averaging:

6.2% by weight sand size material,

36.3% by weight silt size material, and

57.5% by weight clay size material.

d. Water samples showed the following results :
the salinity increases downward from top (10.15‰) to bottom (29.40 ‰) at high water and horizontally from south to the north;
—the salt water wedge reaches at high water into the river proper, even during flood;
—the mud content (calculated as solid material) increases from top (64.0 mg/1) to bottom (342.0 mg/1) at 4 m depth;
—the particle size of the material in suspension increases from top to bottom and lies in the silt-clay range (silt = 0.05 — 0.002 mm grainsize and clay = 0.002 - 0.0005 mm grainsize).

III. In Cilacap:

a. Based on the tidal observations from May 10th through June 7th 1973, the results are as follows:

Constants	:	S_0	M_2	S_2	N_2	K_1	O_1	M_4	MS_4	K_2	P_1
Amplitude (cm)	:	205	50	22	9	15	8	1	1	6	5
Phase (^{o})	:	–	218	307	201	50	240	355	6	307	50

The type or character of the tide calculated based on these harmonic constants in this area is mixed, mainly semidiurnal, with usually two High Water and two Low Water in a lunar day with irregularities. The tidal range is considered larger than that on the North Coast of Java with a value up to 1.50 till 2.00 meters.

b. Maximum current velocity was 2.00 m Sec^{-1} (about 4.0 knots) at the surface which was observed with the "driftpole run" method; 1.81 m Sec^{-1} (about 3.62 knots) for mid-depth observed with the automatic "Hydro-product" type 505 currentmeter and 1.05 m Sec^{-1} (about 2.1 knots) near the bottom observed with the "Ekman Merz" current meter. All values were obtained during ebb-tide as outgoing stream.

A comparison between the current condition and the tide is given, in order to examine the connection between these two proceses (Fig.4). The current velocities mentioned above may increase due to the influence of the river flow during rainy season.

The type of the current in Cilacap Channel is semidiurnal, while the duration of the outgoing stream is rather longer compared with the duration of the incoming stream which is caused by the permanent or non-tidal stream of the river flow. The non-tidal current could be found based on the following equation:

V non-tidal current = V observed current V tidal current,

c. It could be seen from the results of turbidity that the sea water covered the Cilacap Channel up to the Donan River proper during High Water, while during Low Water the river water played a great role in covering the channel and downward to the sea.

DISCUSSION

In order to compare different estuaries and to set up a framework of general principles, within which it may be possible to attempt prediction of the characteristics of estuaries, a scheme of classification is required. Many different schemes are possible, depending on which criteria are used.

Topography, river flow, and tidal action must be important factors that influence the rate and extend of the mixing of salt and fresh water (DYER 1972). It would be sufficient (for this moment) just to draw the attention at the classification of these subjects, as it is mentioned before, that this study will be a "Preliminary Study on the Characteristics of Estuaries". It would also be interesting in the future to know the influence of wind in these regions, because locally and for short periods, wind also may become significant. Furthermore, the resultant mixing will be reflected in the density structure and presence of stratification may cause modification of the circulation of water. Obviously all of these causes and effects are interlinked and it would be difficult to take account of them all in one classification system.

Classification based on topography presented by DYER 1972, divides estuaries into three groups: coastal plain estuaries, fjords, and bar-built estuaries. All these three estuaries have the same characteristics as those in the bar-built estuaries, namely:

— they have a characteristic bar accross their mouths;

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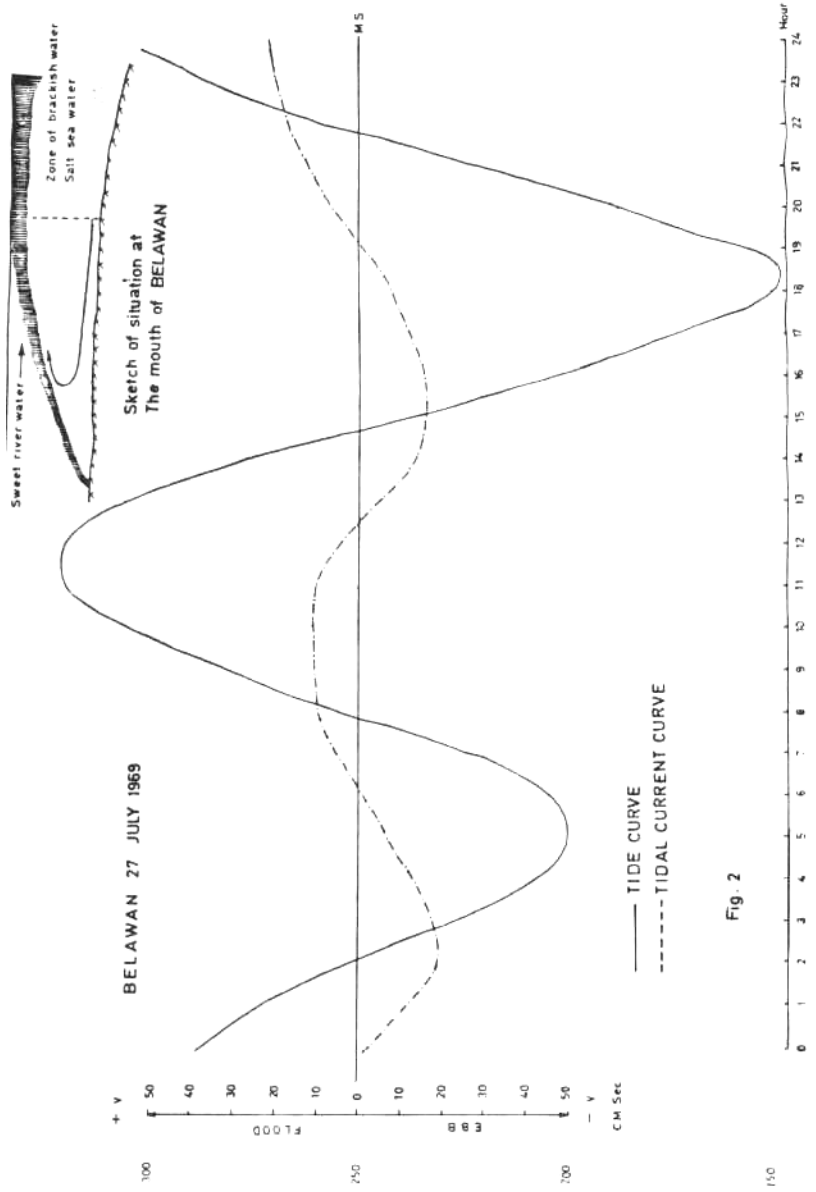

Figure 4. The relationship between tides and currents in Cilacap.

— the tidal range must not be so large, but they have active coastal deposition of sediments, this could be seen from dredging activities in these areas;
— the estuary form is governed by the river regime at the flood stage and may show a basin-bar structure caused by meander scouring;
— during the floods the bar may be swept away completely, but it will re-establish itself quickly when the river flow diminishes or decreases. This was also observed during the surveys.

Consequently, it could be classified that all these three estuaries are bar-built estuaries (and perhaps also the others).

It also agrees with the characteristics given by LAUFF (1967) which mentioned that: "one feature common to all estuaries of the Indian Ocean coastal zone is the formation of sand bars at the river mouths".

These bars generally are horse-shoe shaped. The open side facing the river is steep and that facing the sea has a very gentle slope. In spite of heavy tidal action, these bars maintain their slope and size. These bars and heavy siltation in some of the estuaries often render them unnavigable. The same case happens at Belawan and Cilacap. (Fig. 5).

Looking at the tidal response in these estuaries (Figs 2, 3, 4, and 5) it can clearly be noticed that the strongest current is located at the slopes of the tidal curves, while the time of slack water or decreasing current is located around the top and trough of the curve. From the curves it can also be seen that the maximum tidal current occurs during low water.

Almost in all of these three estuaries the duration of the outgoing current are somewhat longer than those of the ingoing, consequently, High Water and Low Water and the Time of turning of the current are slightly not so simultaneous throughout the estuary (DYER 1972).

As there is some dissipation of the tidal energy before and after reflexion, the tidal response in most estuaries (as seen here) is a mixture of a standing wave with a progressive contribution of variable magnitude. Depending on the relative magnitudes of the two influences so the tidal amplitude and the timing of events vary along the estuary. Consequently, it can be said that based on these events mentioned above these estuaries could be classified to the partially mixed estuary.

As it was always mentioned before that the type of currents are similar to that of the tides but to know the exact value of tidal current it is needed to do a separation between the tidal current and non-tidal current (river flow, etc.). It could than be concluded that in these estuaries the river flow played also a great role in influencing the currents within the estuaries although they have always the same character or type as the tides.

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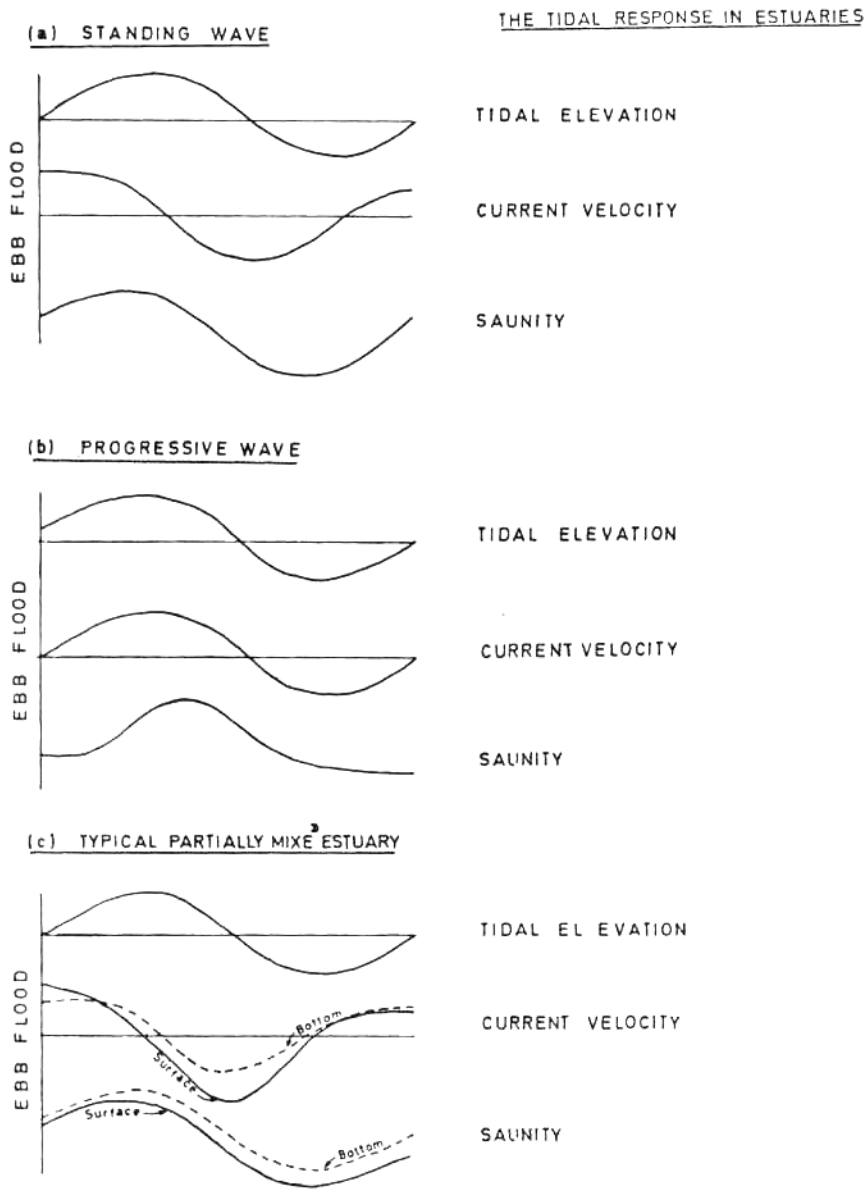

Figure 5. The tidal response in Estuaries.

CONCLUSIONS

It could be concluded from the foregoing that:

1. All these three estuaries (and perhaps the others) are "bar-built estuaries" based on the classification by DYER (1972).
2. From the other point of classification by PRITCHARD (DYER 1972) the estuaries studied are partially mixed estuaries with some specifications according to their local geographical features.
3. The type or character of the currents in these estuaries have the same type or character as that of the tides; while on the other hand the river flow has also a great influence depending on their limitations of activity in the River Basin itself up to the Estuarine Zone.

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