Trans. Inst. Indian Geographers
Vol. 24 No. 1&2, 2002

Variations in the Location and Morphological Characteristics of the Ebb Delta at Aravi-Valvati Tidal Inlet

Anargha Wakhare

Abstract

Ebb tidal deltas are complex, highly dynamic morphological structures situated at the terminal portions of the tidal channels. These are considered to be significant components influencing the sediment budget of the tidal basins. Their dynamic nature if documented properly can throw light on the processes leading to their formations and alterations and hence they assume a core position in the study of beach-creek sediment transfer. In the present *paper an attempt has been made to document the varying locations as well as morphological characteristics of features at the mouth of Aravi-Valvati tidal channel. This documentation has been attempted through periodic surveys and* 'still and video photography' *of the delta proper as well as the locations of tidal channel across the beach.*

Introduction

Tidal inlets are one of the most dynamic features along a coastline. The complex temporal and spatial interactions of waves, tides and longshore currents create and constantly modify the morphology and sedimentary structures found along tidal inlets. One of such sedimentary structures, which play a crucial role in the total sediment budget of the tidal inlet and has a significant effect on the adjacent beach, are the ebb and flood deltas. These are actually large sand bodies that form as tidal shoals in the ocean and bay adjacent to the inlet opening respectively.

Ebb tidal deltas are complex, highly dynamic morphological structures situated at the seaward side of tidal inlets. They play an important role in the exchange of water and sediment between the tidal basin and the adjoining seaward parts of the coastal zone. The hydrodynamic conditions (that of waves, tides and currents etc.) determine the horizontal extent, shape and sand volume of the ebb delta. The interaction between the Ocean and the tidal basin (bay) results in the definition of channels and the ebb deltas. These migrate in the direction of the currents along the coasts with reference to the barriers. Consequently, the evolution of ebb tidal deltas exhibits a migratory behaviour. The ebb tidal deltas also act as a crucial link in the pathway for sediments moving along the shore, bypassing over ebb delta and between the shore and the tidal basins. Thus, it affects the stability of the inlet channel.

In many respects, ebb tidal delta found at tidal inlets are similar to deltas formed at river mouths. The comparison is particularly applicable at rivers where the flow temporarily, reverses during the flood stage of the river. The main difference between the two settings is that the river deltas grow over time fed by fluvially supplied sediments. The evolution and magnitude of the river delta is totally dependent on the catchment area, the gradient and the total discharges of the river as well as the load. Larger the catchment area and lower the gradient the larger will be the magnitude of the load that will be brought down by the river and dumped at its mouth. The heterogeneity of the material that is brought down by the river is considerable.

Moreover there is possibility of the material mixing and flocculating so as to settle down on to the bed at the mouth. The constant deposition of- such material leads to the formation of delta, which might grow beyond the high tide level as well, to form an island like feature.

The fact that the river mouth delta is made up of heterogeneous gives it more compactness and In contrast at many tidal inlets, only limited sediment is supplied from the back bay and the ebb deltas are largely composed of sand provided by longshore drift or reworked from the adjacent beach area. The evolution, magnitude as well as the dynamics (in terms of its migration) of an ebb delta highly depends upon the tidal range, tidal prism, over all surface area of the bay, shore currents and the total load that is deposited at the inlet mouth. With a considerably large surface area of the bay and a high tidal prism (total volume of water getting inside the bay) the net out-flux will also be high resulting in a larger ebb delta formation. However, the stability of these ebb deltas depends on the shore-current conditions.

The longshore currents, the shore normal currents as well as the tide currents constantly modify these deposits. The material which is being brought down from just the immediate vicinity of the shore (mostly reworked from the adjacent beach area) is generally homogeneous, mostly comprising of loose sand. The homogeneity of the material does not allow the material to flocculate or settle. Thus, it hampers any stabilization mechanism aiding the shore currents to modify the delta further. As against the river delta which is more stable, and has a lower order of morphological variations, the ebb delta are highly dynamic and exhibit lot of morphological variations as compared to the adjacent beaches and the bay area.

The ebb tidal deltas are found along the mixed-energy coasts as well as the purely wave dominated coasts. In case of many of the ebb tidal delta found along the mixed energy coasts, studies have revealed that the amount of sand in these deltas is comparable in volume to that of the adjacent barrier islands (Fitzgerald, 1988). Therefore on mixed energy coasts minor change in volume of an ebb delta can drastically affect the supply of sand to the adjacent beaches. In comparison, on wave dominated barrier coasts ebb tidal deltas are rare and therefore represent a much smaller per cent of the overall coastal sand budget. As a result volumetric changes in the ebb tidal deltas have primarily local effects along the nearby beaches. However, these effects are highly significant on the local scale.

Walton and Adams (1976) worked over the data from tidal inlets throughout US and showed that there is a direct correspondence between an inlets tidal prism and the size of the ebb delta, with some variability caused by changes in wave energy. This research underscores the importance of the role of coastal managers. It is necessary that the coastal managers thoroughly evaluate whether proposed structures at the throat of the inlet, or any local modification attempted (i.e. any kind of human intervention), or any natural mechanism that might change the tidal prism. The change in tidal prism will change the volume of the ebb tide shoal and in turn shall affect the sediment budget in nearby beaches.

The western coast of India, particularly that of Konkan, has large number of estuaries of varying size and provide an opportunity to study problem of estuarine stability in terms of transfer of beach materials. The author has been monitoring such changes in the morphological characteristics of a small tidal basin in North Konkan at Aravi-Valvati. The present paper attempts to describe the formation and morphodynamics of the ebb delta as observed through 1997-98 to 2001-2002.

Study Area

The study area (fig. 1) lies between 18° 3' N to 18° 6' N latitude and 72° 53' E to 73° 3' E longitude. The Aravi-Valvati beach and creek area lies just to the north of Shrivardhan. It is approximately 180 km from Pune. The entire catchment of Aravi-Valvati stream is approximately 56 sq km and the beach is around 4 km in length. It is flanked on the north by the Kondvil headland and towards the south by the Jeevan Bandar, Shrivardhan headland. A tidal inlet jets out at the extreme southern end of the beach at Aravi-Valvati. The average length of this inlet from its throat portion to the mouth is around 350 meters. The study area actually forms a small part of the tidal channel jetting out into the sea.

Methodology

The methodology adopted for the present work heavily depends upon the periodic field observations to understand the nature of morphodynamics. Besides this, the variations as observed were documented with the help of normal as well as video photography. In order to represent that in the form of a quantitative expression it was thought proper to carry out detailed survey with the help of transit theodolite using tacheometric method. However, due to various difficulties, particularly in terms of the constraint of the time for carrying out the surveys and high variability of the water line positions the major part of the work had to depend on the photographic records obtained in different periods. The information from these records was incorporated on the base map of the area prepared in 1998.

Morphological Conditions as observed at the Mouth of the Aravi-Valvati Tidal Inlet

The tidal inlet of Aravi-Valvati meanders through the dense mangrove swamp before terminating into the sea at the extreme southern end of the 4 km long beach. The inlet actually encircles the northern barrier (sand dune) to move across the beach and drain into the sea. The otherwise monotonous beach is interrupted at this location, which exhibits maximum dynamic conditions.

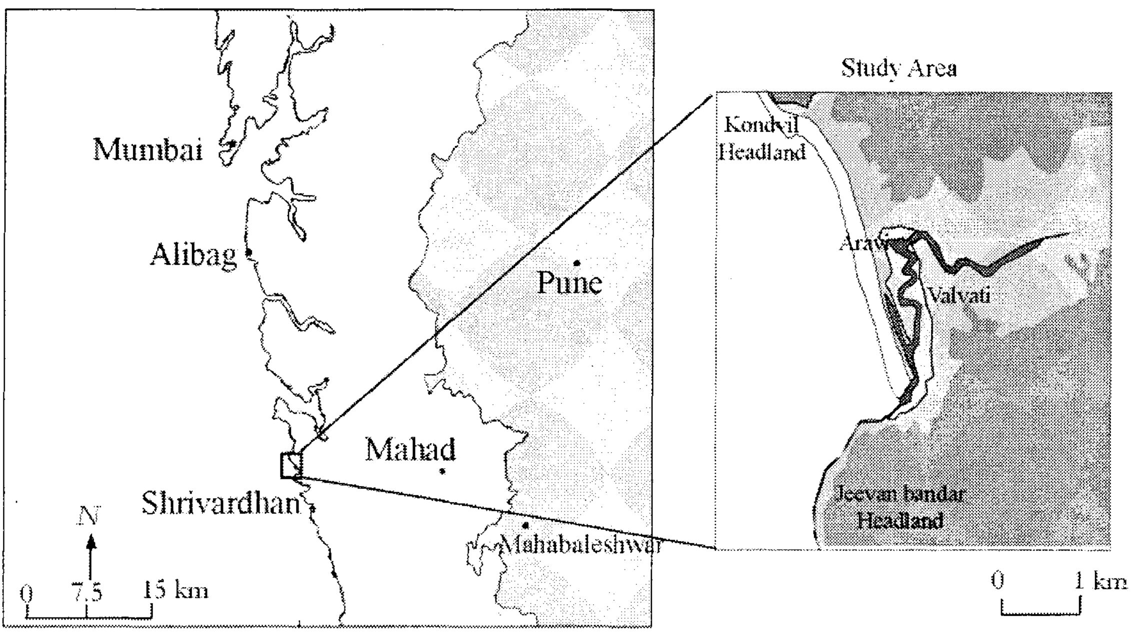

Fig. 1 : Location of the study area

A significant movement of the channel along the beach, instead of across the beach, is observed as the water moves out towards the sea through the throat. A throat is the segment of tidal inlet with minimum width and maximum velocity, which often acts as a gorge of channel influence of ebb current. Channel moves towards north before it takes a turn towards west. Instead of flowing across towards the sea it takes a southward turn before draining in to the sea. This northward movement of the channel can be attributed to the fact that a longitudinal bar parallel to the beach extending in south-north direction appears to be outgrowing. This bar however is visible only in low tide condition.

A couple of runnels running parallel to each other are also observed just towards the north of the channel. These runnels have their downstream opening at the right bank of the meander of the tidal channel. A shift in the position of the runnel is conspicuous. There is a constant periodic shift in the position of the runnels which is associated with the ebb channel. Eventually it leads to a change in the beach profile. It is observed that initially the ebb channel water moves northward. A part of this water might enter the runnel system. However the runnel has a general southward slope, which restricts the further advancement of the ebb channel flow. The southern barrier is highly prone to morphological variations. It is subject to erosion by wave action as well as the movement of spill over water at the time of full tide condition. This bar shows the presence of many micro as well as mega ripples in certain zones. Mega ripples are observed mostly in the pockets along the ebb channel and micro ripples in the marginal flood channels. A number of depressions and intermixed ripple types are also observed along with a few traces of the residual channels.

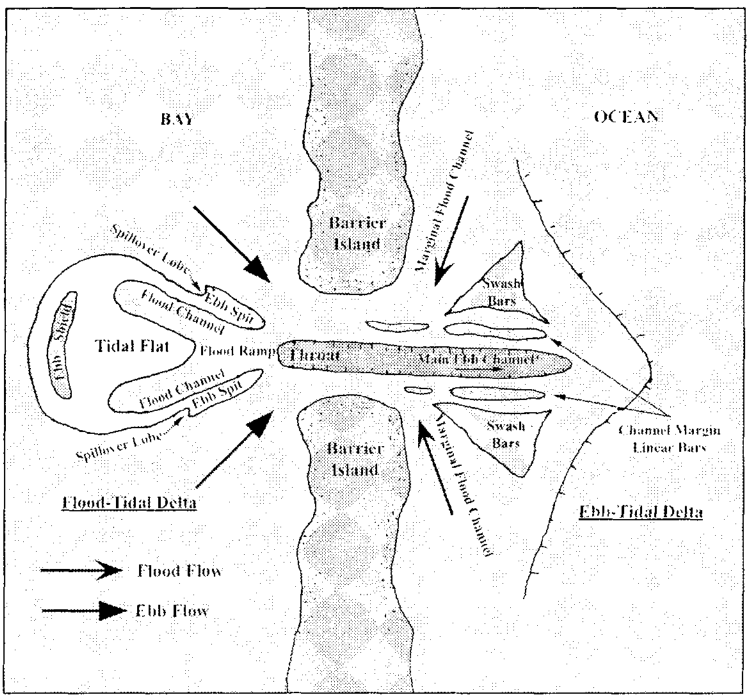

Fig. 2 Definition diagramof a tidal inlet with well-developed Flood and Ebb deltas
After Hayes (1980), Boothroyd (1985) and others

Ebb Tidal Delta: A Simplified Morphological Model (after Hayes (1980), and Boothroyd, (1985)

A simplified morphological model of a natural ebb tidal delta is shown in figure 2. The delta is formed from a combination of sand eroded from the gorge of the inlet and sand supplied by longshore currents.

This model (after Hayes, 1980 and Boothroyd, 1985) includes several components:

- A main ebb channel, scoured by the ebb jets
- Linear bars, that flank the main channel, are the result of wave and tidal current interaction.
- A terminal lobe, located at the seaward end of the ebb channel. This is the zone where the ebb jet velocity drops, resulting in sediment deposition.
- Swash platform, which are sand sheets located between the main ebb channel and the adjacent barriers.
- Swash bars, that form and migrate across the swash platforms because of the current (the swash) generated by breaking waves.
- Marginal flood channels, which flank both updrift and down drift barriers.

This is an ideal model proposed by Hayes, 1980 and modified by Boothroyd (1985). There can be number of variations observed in the real world condition due to the local relief and tide condition.

Ebb Tidal Delta at the Aravi-Valvati Inlet

The ebb delta is found to be occurring at the mouth of the Aravi- Valvati inlet. The existence of the delta all through the different period of the year and its quasi-permanent existence observed through the period of last six years indicate that the process of ebb delta formation is a well-established phenomenon in the study area. The formation of any such ebb delta basically would depend on the supply of the load from the bay area, dune and the adjacent beach zone.

Moreover the velocity of the tidal channel and the variations in the same as observed at different locations along the channel as well as in different tide period form major governing factors. From the throat point towards the seaward side, the channel is well defined and sufficiently deep so that the discharge passing through the same is confined to the channel bed. At the point where the channel circumvents the southern barrier and moves on to the open beach area the velocities are suddenly reduced. It is from this location onwards in the seaward direction the effect of deposition of load starts becoming apparent. The depth of the flow is greatly reduced though the width increases to some extent. It is in this area and further down stream the linear bars start appearing above the water line. Further in the downstream direction one can easily identify the bifurcation of the flow into different flow lines.

As regards the velocity variations over the time are concerned two distinct conditions can be observed such as:

(1) Velocities of withdrawing water from high tide level to the level of southern bar elevation.

(2) Velocity pattern after the entire flow gets confined to the tidal channel.

In the first condition the withdrawal of water from the beach area as well as one supplied from the bay portion is by and large controlled by receding tide levels and the movement is generally in the form of areal flows rather than linear flow. At this condition the velocity as well as the volume of water is considerably high. However, at the point when the depth of the flow decreases and the roughness of the surface across which the flow is maintained starts affecting the flow condition the erosional effect of the flow becomes apparent and the surface configuration leads to separation of flow into different lines. The gradient provided by receding tide levels as well as that of the ground both act in the same direction and this leads to formation of flow lines and their deepening. The flows in the channel then onwards are mostly controlled by the ground conditions. Huge volume of water which still remains arrested in the bay area, in the process of getting escaped leads increase in the velocities due to drop in width of the channel. At this time period maximum erosion is caused along the banks of the channel as the velocities are still sufficiently high to move this eroded material further downstream. However, with the passage of time, the flow reduces further and the effect of the barrier extensions starts becoming apparent. This leads to the deepening of throat point and the load brought at this point tends to get deposited as the within channel deposition at the barrier location. These velocity differentials in terms of temporal as well as spatial conditions contribute to the excessive deposition in downstream direction

As regards the availability of the material is concerned it appears that within the study area there are few well defined locations from which the material is getting supplied or redistributed leading to the formation of ebb delta. Of these, one of the most important is the bay area. The terrestrial input from the bay is too meagre and highly seasonal. Major part of the sediments which are moving under the ebb current are the one that are brought in and spread over the flood delta by the flood currents. The observations of the study area over a span of five years indicate that the areas of the flood delta are slowly but definitely advancing in upstream direction along the tidal channel. The existence of the ebb delta on one hand and advancement of the flood delta on the other indicates that the amount of materials being reworked at these locations is tremendous. The northern barrier has extended itself to a distance of about 60 meters in the last six years. Most of the material accretion of northern barrier is coming from the dune-beach interface partly by aeoline action and partly through the flow of the runnels. Most of the contribution from beach is in this form. This becomes quite evident from the fact that the runnels, particularly the one close to the dune face, gets totally filled up and tends to change its location.

The third location from which a major contribution of sand received is the southern barrier. It is in this area that huge quantities of sand are getting entrained and move in the seaward direction. Extensive swash bars are found to have been located in the area between the southern barrier and the ebb tidal channel.

The temporal observations of ebb delta at Aravi-Valvati clearly indicate that the geometry of delta as well as its locations are subject to change over a period of time. The details of the morphological characteristics of the delta observed in different periods are discussed in the following section.

Morphological Characteristics of Ebb Delta through 2000-2002

November 2000

Figure. 3a of the southern portion of the beach can help one to understand the salient features of the ebb delta as well as the orientation of the tidal channel. It may be observed that the channel after passing the throat moves northwards for a distance of about 250 to 300 m where its path becomes seaward. However, it does not move straight across the beach but moves southward to some extent. This southward turn is imposed on the channel by the low tide bar. The length of such flow component is not much significant and in a couple of tens of meters it appears to move seaward to reach the waterline.

It may be observed that there are not many bifurcations and distributary like channel flows. However, such separation becomes visible as the water recedes back. A number of spill over channels across the southern barrier can be seen in

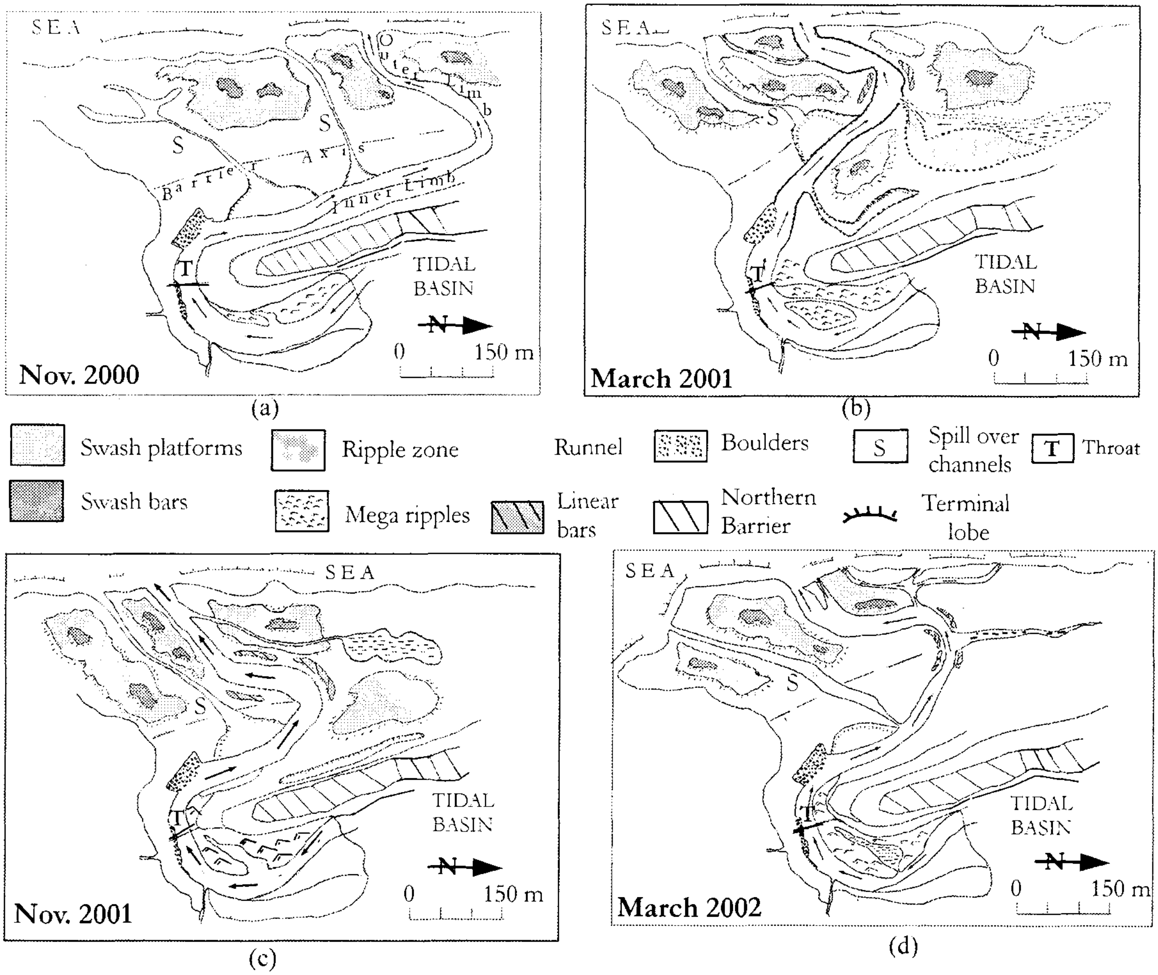

Fig. 3: **Morphodynamics of Ebb Delta**

the central part of the sketch. Actually it is a zone of spilling over of the water. The main spill over channel extending entire width of the barrier can be seen in the diagram. It may be considered as a major flow next only to the main ebb channel. The feeble flow lines particularly in extreme south, which possibly are following the edge of the buried platform, are the feeder for the residual portion of the water accumulation in the depression observed in the southwestern part of the fig. 3a.

Though, the characteristic features of ebb delta may not be observable in this particular figure a number of associated features are very well represented in the area.

May 2001

Figure 3b shows easily observable changes 'in the morphological characteristics and the channel location as well as the ebb delta region. The most conspicuous change noticed in this period (November 2000 to May 2001, fig 4a) is the shift of tidal channel towards south of its November 2000 position. The AND original location can be traced with the help of residual portions of previous channel. It is obvious that the spill over channels, which could be seen in figure 3a, have been responsible for the shift of the tidal channel. The 'beach-parallel' eastern limb of the tidal channel has now become fairly inclined toward the beach, though it is not exactly perpendicular at the point of throat position. The exposed portions of rocky platforms spotted with boulders are clearly seen in all the figures and it is these resistant portions that would always restrict the seaward flow of the tidal channel. The rough direction of this channel could be stated as ESE to WNW. The western limb of the channel, which was moving seaward for some distance circumventing the southern barrier, also can be traced through the residual water bodies on the beach finding their path towards sea. Though apparently weaker in this figure, this appears to be the previous principal outlet of the main tidal channel. The main outlet of the present channel does not have seaward limb in any form. It is quite obvious that the slope of the spill over channel across the barrier being fairly steep it has caused the tidal flow to move almost in straight direction without any breachihg or bifurcations. It is in extreme terminal areas a major bifurcation of the channel moves seaward and appears to be flowing parallel to the beach in southern portion. This bifurcation may be attributed to the fact that towards the south a slight rise in the form of low tide bar restricts the exit of the water coming from the bay and it tends to run parallel to beach for quite some distance.

The reconstruction of the tidal channel of November 2000 can be attempted by joining the locations of residual depressions. However, the reconstruction of the portion of the channel across the beach and joining both the limbs mentioned above is rather difficult. This clearly shows the effect of redistribution of beach sediments brought towards south by the littoral drifts. Continuous filling in of the depression must have caused the seaward migration oi the channel.

November 2001

From March 2001 to Nov 2001 the area appears to have undergone definite changes of moderate magnitude (fig 3c, 4b). The locational shifts could be ascertained through the terrestrial surveys. What is more appealing is the fact that the shift of channel is towards the northern location than the previous condition, as well as it is showing the signs of becoming parallel to the dune face. This may be attributed to slow extension of the southern barrier in the northern direction probably caused by the marginal flood currents moving from south and causing an extension of the barrier as well as shallowing of the portion of the tidal channel in the seaward direction. An elongated depression at the base of the dune and its extension could be observed in the region with an increase in its length and shift in position more close to the dune base as compared to March 2001 condition. A runnel in the seaward direction also shows corresponding changes, but in different direction. The runnel length was observed to have been reduced and shifted more towards seaward direction than 'the previous condition. However, at this runnel, result of mixing of seawater and channel discharges in the form of development of megaripples could be easily noticed. This small depression representing the runnel location of previous survey was having a direct exit into the tidal channel in March 2001. However, as a result of migration of outer limb of tidal channel towards the dune, a small but well-defined flow from the seaward runnel flows for a distance of about 200 meters. This flow in the southward direction clearly indicates accretion of the material to its west, possibly as a result of wave action. The maximum amount of shift of the tidal channel at this location is of the order of 150 meters. A small spill over channel running almost parallel to the tidal channel over the southern barrier is also observed.

March 2002

In March 2002 some obvious changes which occurred in the region are as follows:

The runnel system, or the depressions representing the same, have been considerably weakened and reduced to only a shallow elongated depression, which now exists at a central location between the two previous runnel systems (fig 3d, 4c). Besides this. the spill over channel has become more active and sustains the flow for quite some time. The occurrence of mega ripples within the spill over channel indicate the fact that at the time when these ripples were getting formed the velocities of the channel flow as well as the wave water must have been comparable with each other and it represents a well defined zone of mixing of the two waters. It is in this case we find that the spread of the delta is at its maximum and it is as wide 550 meters.

A well defined swash platform between the distributaries and the swash bars over these platforms can be unmistakably observed. The effect of the flow bifurcations due to the within channel siltation as well as reworking of the inter-channel fills by the waves can also be observed to have caused the crenulations in the seaward side of the deposits. These deposits can be described as the terminal lobes, which are result of the interaction between the wave and the channel water.

In its upstream direction particularly at a location which can be identified as a segment where the channel appears to have circumvent the southern barrier, a system of linear bar has come into existence. This linear bar is unlikely to develop in the channel upstream this point for the simple reason that during the ebb tide period the effect of sea waves will become more prominent only after the depths in main channel are significantly reduced. Therefore, the zone between the maximum height of the barrier (generally at the centre of the barrier) towards the sea proper the deltaic torms such as linear bars, swash platforms, swash bars can be expected.

During this survey quite different deltaic features could be observed and mapped. It has facilitated the researcher to demarcate the possible migration zone of the ebb delta observed over a period of five years. Some discussions on this migration zone as well as the processes leading to migration are included in the conclusions.

Discussions and Conclusions

It is desirable to mentions certain facts related to the beach as well as to the tidal channel condition before entering the discussions on nature of migration and the variations of the locations of the ebb delta as well as the tidal channel. The facts that need to be taken into account are as follows:

1. The beach is considerably wide and the maximum width at lowest low condition on full moon or new moon day is as high as 400+ meters.
2. The length of the beach is around 4 km and the point at which the tidal channel crosses the barrier is confined to the southern portion of the beach. The length south of the channel upto the southern platform is about 600 m. Thus only 15 per cent of the beach length is to be found having been separated from rest of the beach by the tidal channel.
3. As a result of differentials in beach portions on the either side of the tidal channel the two drift current from south and north also have similar kind of differentiation in terms of sediment load they redistribute.
4. Due to the considerable width of the beach well-defined runnel systems get established towards the northern portion of the beach. At least two parallel runnel systems could be observed in almost all the visits to the area.

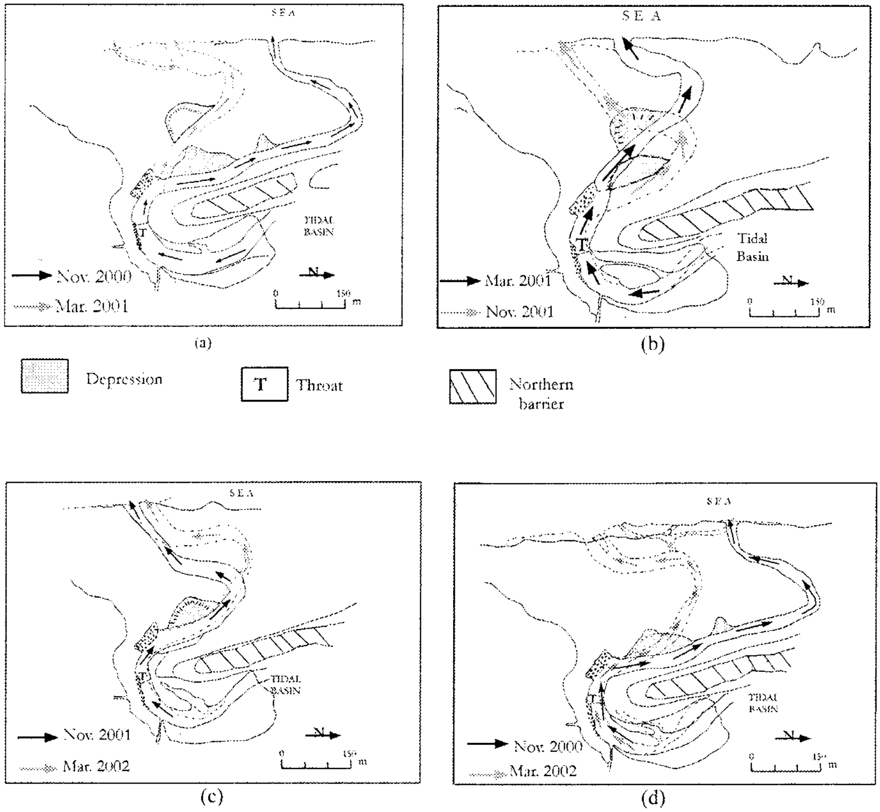

Fig. 4**:** Shift of Ebb Channel across the beach

5. The marginal flood current, though over a sshort distance, is efficient in terms of sediment transfer. This is evident from the fact that Ithe southern barrier not only extends to considerable distance but also attains sufficient height.

The observations over the last five years could be grouped into two categories:

i) Those related to the channel and its shifts

ii) Those related to the variations in the location and the morphological characteristics of the ebb delta.

The shifts of tidal channel

It may be noted from the preceding discussions that the maximum northward location of the tidal channel is about 500 m from the throat point. Whereas, it is 100 m from the throat in the southern direction. Thus the shifts or the migration of the channel are confined to a zone of about 600 m. The shift of the inner limb of the channel in the East-West direction is around 60 to 70 m. The outer limb (to be identified as the flow beyond the southern barrier) has a sizeable zone of migration in North-South direction, which could be as much as 550 to 600 m. almost comparable to the northward migration of the tidal channel.

Locational variations and morphology of Ebb Delta

The zone of migration of ebb delta corresponds to zone of migration of outer limb of tidal channel. It is observed that when the location of delta is more towards North it shows that the channel flow tends to confront with wave attack leading to bifurcation of channel at a higher angle and more at upstream locations. This leads to wider spread of the delta and better definition of deltaic features. As against this, if the terminal portion of the outer limb runs parallel to the wave front and escapes the direct confrontation with wave attack, it tends to redistribute material all along its length and the probability of the separation of channel becomes less. Wherever separation takes place of the flow is at an acute angle with main channel the spread is confined to a shorter distance. Due to the relatively straight channel course and redistribution of load along its margins parallel bar, are most common feature under this condition. Relatively swash platforms aer rare. This may be attributed to the fact that interfluent areas between main channel and the bifurcating flows are quite narrow.

From the preceding discussions it becomes clear that the tidal channel as well as the ebb delta have variable locations observed at different points of time. So far as the shift in channel is concerned there can be two possible interpretations.

i) The variations are seasonal.

ii) There exists a definite sequence of shift besides minor seasonal variations.

However, from the observations in last five years the shift due to seasonal variation cannot be favoured for the following reasons:

If it were a result of seasonal variation one would expect the location of the channel to be generally same in a given season. However, the observations do not support this possibility. The locations of channel in two successive post monsoon or pre monsoon period do show considerable variations. Moreover the ebb delta locations do not show perfect correspondence with seasonal cycles. Seasonal fluctuations could normally be within a restricted zone than the one observed in the region. The range of shift of the order of 500 to 600 meters makes it hard to believe that it is just the effect of seasonably. The researcher would like to "make a case for the second interpretation mentioned above. The wide range of migration zone of the tidal channel, the shifts observed over a period of time, observations related to the role of runnel systems as well as that of the longshore drifts, all indicate a possibility that the shift is not seasonal; though it could be fluctuating over a period of few years. It is clear that within five years of survey and observations the channel has been definitely migrating towards south, though the amount of shift is not necessarily the same in the successive years.

The tidal channel within the basin, east of the dune zone, has itself shifted towards the south over a period of forty years. This can be clearly seen from the topographical maps of 1925 and 1965. This shift has been caused due to a steady but definite extension of the dune zone in the southward direction. During the last fifteen years or so, number of scholars have been working in this area and the photographic records obtained by them also shows that the process of southward extension of dune is in progress during recent past. As a result of this, tidal channel is progressing itself in seaward direction.

As mentioned, the length of the beach towards the north of channel throat is much greater than its southern component. The .two runnel systems have been observed a number of times in this portion of the beach. A longshore drift current from the north, which brings considerable amount of sediment, fills the runnel depressions and restricts the migration of channel towards the north. As and when the runnels are active and bring sufficient discharges into the tidal channel, the tidal channel tends to enter into the runnel close to the dune and finds its exit through the seaward runnel system after breaching the runnel bar separating the two runnel systems. These two runnels being described here are observed to have maximum lengths of 700 to 800 m. In the During period when the two runnel systems are active, the tidal channel tends to move into the runnel. It is during the same period the marginal flood current from south to north tends to extend the southern barrier. This also contributes to northward movement or the tidal channel across the beach. The inner limb of channel tends to become straight and moves northward at the base of the dune complex parallel to the beach. Due to high discharges and constricted nature of the channel, the velocities increase and this causes considerable erosion along the sides of the channel, on the beach are Well defined cross sections the result of this process.

During the flood tide, water tends to submerge greater part of the southern barrier. While the tidal channel is having much northward location, the seaward slope of the southern channel starts becoming steeper and allows the ebb water to move across with greater velocities leading to initiation of spillover channels. This process gets repeated over a period of time and the spill-over channels get firmly established. Parallel to this, the filling in of the runnel system in the north progresses. This causes piling up of the water to a certain distance from the throat point. This water, thus momentarily stagnated, is forced to move across the southern barrier following the spill over channels. This removes considerable amount of water from the tidal basin area and the discharge passing through the channel get reduced considerably resulting in further filling in of the tidal channel in down stream direction. The location of spill-over channels causing the diversion of discharge, observed over a period of last six years, indicates that they themselves are migrating towards the south. This indicates a progressive unidirectional change in the location of the tidal channel across the beach. However, this does not rule out the possibility of minor shiftsin the location during successive years towards the north.

Acknowledgement

The author is grateful to Prof. S.R. Jog, Department of Geography, University of Pune. for his valuable guidance and timely suggestions throughout the present work.

References:

Boothroyd J. C. (1985): Tidal inlets and tidal delta. *Coastal sedimentary environments*, 2nd ed. Springer-Verlag, New York. NY. pp.445-532.

Bruun Per, (1968): Sediment transport-Fluvial and marine, *The Encyclopaedia of Geomorphology*, Encyclopaedia of Earth sciences series, Vol III. ed. Rhodes WFairbridge, pp.982 - 984.

Fitzerald. (1988): Shoreline erosional - depositional processes associated with tidal inlets. *Hydrodynamics and sediment dynamics of tidal inlets*, ed ®.D. G.Aubrey and L. Weishar, Springer Berlin. 186-225.

Hayes. M. 0. (1980); General Morphology and sediment patterns in tidal inlets, *Sedimentary Geology*, Vol. 26. pp. 139-156.

Price Armstrong W, 1968): Tidal inlet. *The Encyclopaedia of Geomorphology*, Encyclopaedia of Earth sciences series. Vol III. ed. Rhodes W Fairbridge. pp. 1152 - 1155.

SeaburghWilliam. (2001): Hydrodynamics of tidal inlets, in *Coastal hydrodynamics part II*, ed. Demirbiick Zeki. Coastal Engineering Manual. Department of Army. U. S. Army Corps of Engineers, Washington D.C.

WaltonT. L.Jr. and Adams W. D, (1976): Capacity of inlet outer bar to store sand. *Proceedings of the fifteenth coastal engineering conference*, July 11-17, Honolulu, H I. American Soc. of civil engineering, N.Y. pp 1919-1937.

Ms. Anargha Wakhare
Department of Geography,
University of Pune, Pune - 411 007