International Conference on Hydroinformatics

2014

Simulation Of Shoreline Changes Along Muthalapozhy Harbour, India

Dhyan Singh Arya

Santosh Kori

A M. Vaidya

11th International Conference on Hydroinformatics
HIC 2014, New York City, USA

SIMULATION OF SHORELINE CHANGES ALONG MUTHALAPOZHY HARBOUR, INDIA

D.S. ARYA (1), SANTOSH KORI (2), A. M. VAIDYA (2)

(1): Department of Hydrology, IIT Roorkee, Roorkee 247 667, Uttarakhand, India

(2): Central Water and Power Research Station, Pune 411 024, Maharashtra, India

A study was conducted at Muthalapozhy fishing harbour, located in south India for simulating shoreline changes. The observed shoreline data were used for calibrating LITPACK modelling tool. The results show that initial advancement in shoreline will be of the order of 45 m/year however this rate will reduces to 25 m in later years. It is also found that the coastline advances more during the South West monsoon (June to September). To make channel operational until 2016 without dredging, it is proposed to increase the length of the south breakwater by 200 m and the length of the northern breakwater by 70 m from the point of bend parallel to south breakwater. Thereafter it is estimated that the major part of littoral drift may start bypassing littoral material which may then enter in the channel resulting choking of the mouth of navigational channel. The simulated shoreline will help the designer to decide the breakwater length and its orientation with respect to shoreline so that siltation in navigational channel could be minimised.

Keyword: LITPACK, Littoral Drift, Shoreline Changes, Wave Climate

INTRODUCTION

The coastline shows constantly varying nature due to seasonal changes in wave, wind and tidal effects. Development of major and minor ports and fishery harbours include activities like construction of coastal structures like breakwaters, jetties, and groynes etc. It also involves dredging and disposal activities to maintain the required depths of the channel for navigation. These coastal structures and the dredging activities interfere in the coastal processes and too modifications in the coastal processes have large impact on the coastline. Major impact is seen as the high rate of longshore littoral drift. Accumulation of sediments on the updrift side and erosion of the downdrift side is observed in these regions.

Muthalapozhy is a coastal outlet between towns Vizhinjam and Thangassery located at 8°38’ N latitude and 76° 50’ E longitude. In Muthalapozhy fishing harbour, located on west coast of India in Kerala state, the Vamanapuram River drains off the water into the sea (Figure 1). This is also the mouth of the navigational channel of the harbour. Usually, the river mouth is open for navigational purposes only from June to November in a year. The outlet gets gradually silted up during early summer (i.e. in February and/or March) and finally chocked with sediment carried by the Vamanapuram River and littoral current from the sea. During the south west monsoon, the backwaters along the coast are also flooded. To avoid floods in the area, the outlet of the river is artificially opened by dredging the littoral material. To make entrance channel operational throughout the year for navigational purposes, two rubble mound breakwaters were constructed. The length of the northern breakwater is 410 m and the south breakwater is 330 m.

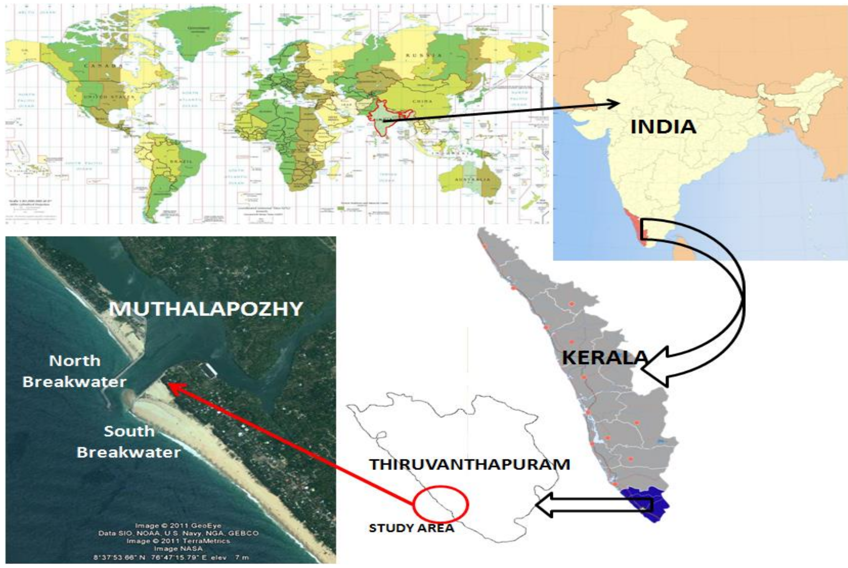


Figure 1. Location of Muthalapozhy harbour along with Google Earth image of the region.

Despite of these structural measures used to keep the entrance of the channel open, the severity of the problem remained same. In order to protect the area and keep the channel open throughout the year, a case study of alongshore sediment transport was undertake. These days numerical models are widely used to study the longshore sediment transport and shoreline change. This paper also uses LITPACK modelling tool to study longshore sediment transport and shoreline changes along the coast and to find the optimum length of breakwaters.

DATA USED

Hydrographic survey was conducted in November 2004 near Muthalapozhy harbour. The Survey data was used for extracting bathymetry details of the region. Bathymetric map (Figure 2) of Muthalapozhy harbour shows uniform and parallel contours to the coastline. Cross shore profile of the area is also shown in Figure 3.The tidal range varies from 0.2 m (neap tide) to 1m (spring tide). The maximum currents velocity at the site is 0.5 m/s. Currents speeds and tidal levels are shown in Figure 4.

The bed sample analysis shows that the bed consists of 95.6% sand, and 4.4% silt and clay. The mean diameter of grain size (D50) is 0.16 mm. The wave data of past 30 years observed by ships plying in the offshore region of Muthalapozhy (between Latitude 50-10’N and Longitude 750-80’E) were collected from India Meteorological Department, Pune, India. The nearshore wave climate at Muthalapozhy was derived from the ship observed deepwater wave data.

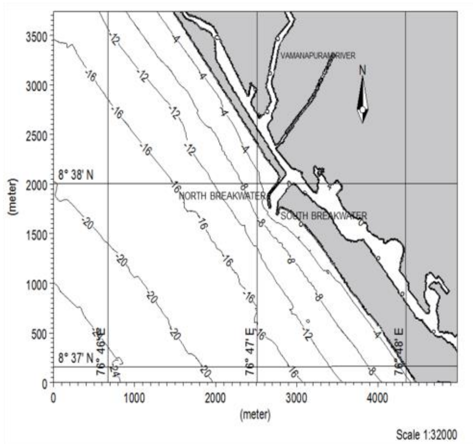


Figure 2. Bathymetry

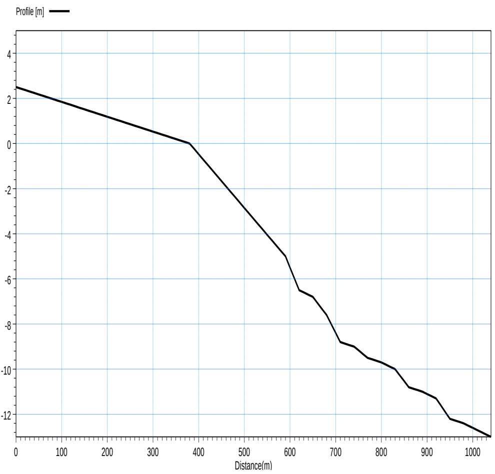


Figure 3. Cross Shore Profile

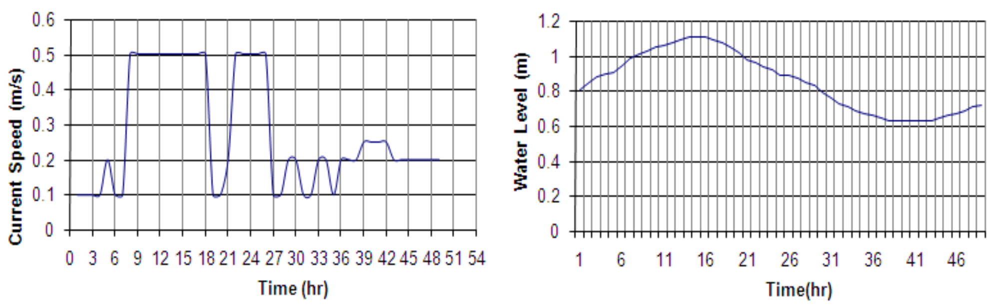


Figure 4. Currents and tidal levels

Longshore sediment transport rates for the Kerala coast were estimated by various researches. The net annual transport of 0.09 million m^3 towards north of Tiruvanantpuram which is located approximately 40km south of Muthalapozhy [1]. Estimated net transport 0.09 million m^3 towards north and gross as 0.12 million m^3 along Tiruvanantpuram coast [2]. Along Tiruvanantpuram coast net transport of 1.01 million m^3 of sand towards north occurs [3]. The general annual rate of northward and southward transport at Tiruvanantpuram are of the order of 0.3 million m^3 and 0.5 million m^3, respectively [2]. Hence these general values of transport rate were adopted in the calibration and validation of LITDRIFT. Shoreline changes charts of the period 2001 to 2010 were obtained from Harbour Engineering Department of Kerala the validation of the model (Figure 5).

MODELLING USING LITPACK

LITPACK is a professional engineering software package developed by Danish Hydraulic Institute (DHI) for the modelling of non cohesive sediment transport in waves and currents, littoral drift, coastline evolution and profile development along quasi-uniform beaches. All modules of LITPACK use a fully deterministic approach. This allows consideration of many and sometimes dominating factors that are not available to semi-empirical formulations. LITPACK contains various modules like LITSTP, LITDRIFT, LITLINE, LITPROF, LITTREN [4]. In this study, LITDRIFT and LITLINE modules were used to compute longshore drift and shoreline evolution. Module LITDRIFT is based on the mathematical model [5] and LITLINE is based on one-line model [6]. The governing equations are solved using finite difference approach and the software computes wave, shoaling, refraction, diffraction and the resulting sediment transport at each time step for each grid point.

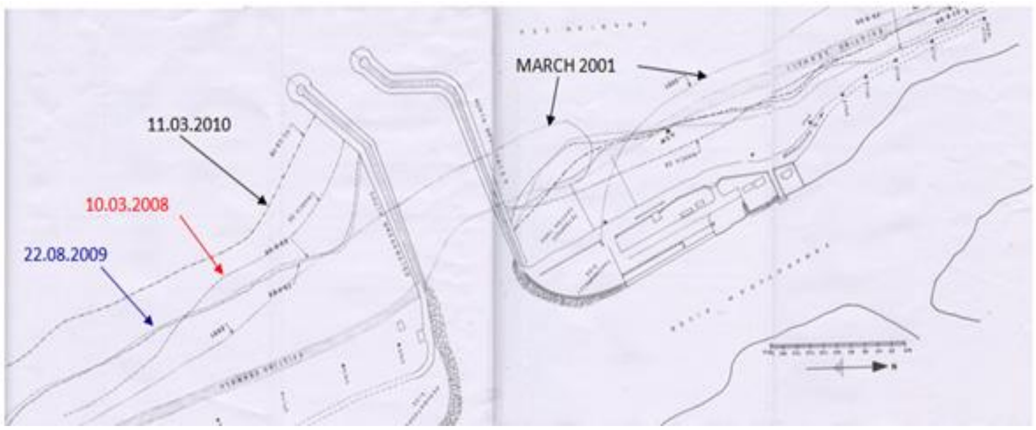


Figure 5. Shoreline Changes From 2001 to 2010

LITDRIFT Model Setup

LITDRIFT is a comprehensive deterministic numerical model, which consists of two major parts: a hydrodynamic model and a. sediment transport model. The hydrodynamic model includes a description of propagation, shoaling and breaking of waves, calculation of the driving forces due to radiation stress gradients, momentum balance for the cross-shore and longshore direction giving the wave setup and the longshore current velocities. Sediment transport model forms the basic sediment transport description from combined wave and current action. In combined waves and current the turbulent interaction in the near bed boundary layer is of importance for the bed shear stresses as well as for the eddy viscosity distribution. The basis for the sediment transport description is the model for turbulent wave-current boundary layers [7].

LITDRIFT was used to estimate seasonal and annual littoral drift rates. The profile normal to the shoreline was computed as 2330 N. The cross shore profile covers a distance of 1.5 km extending up to about -13m depth contour from mean sea level. The profile was descretized with 10 m grid size. Based on nearby site transport rate ($0.12x10^6$ m^3/year), the model was calibrated by varying the bed roughness.

LITLINE Model Setup

The module LITLINE was used to simulate the evolution of the coastline of the study area. For validating the model, shoreline of the year 2009 was considered as the base line (Figure 6). The length of the shoreline considered for the study was 2.4 km, extending about 1.30 km towards north and about 0.90 km on south of the breakwaters (Figure 1). The grid size considered for shoreline change study was 20 m. The effective blocking lengths (normal to shoreline) of the south and north breakwaters are considered to be about 500 m and 480 m to avoid siltation in the channel. Average shoreline difference between simulated and measured/observed coastline from the initial coastline is about 7.6 m. Correlation between simulated and measured/observed coastline is 0.995. Percentage relative error between simulated and observed coastline was found to be 3.2%.The validation results of the model are shown in Figure 6. The figure clearly shows a match in the 2010 coastline at the Muthalpozhy coast.

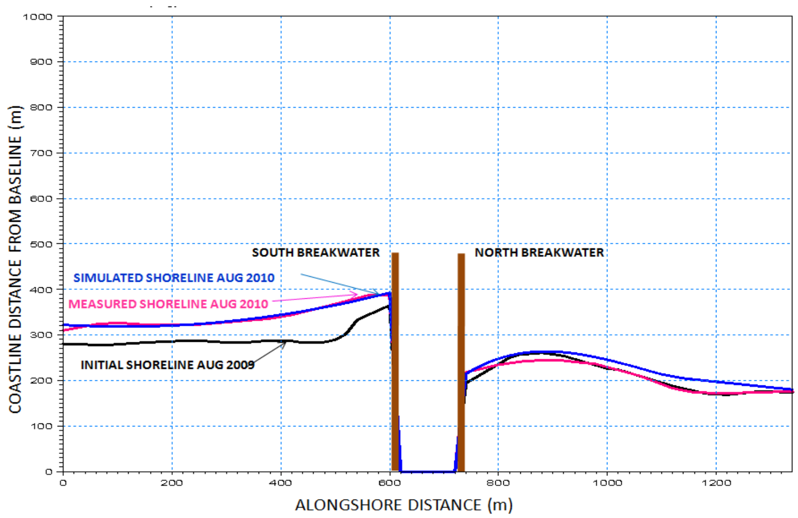


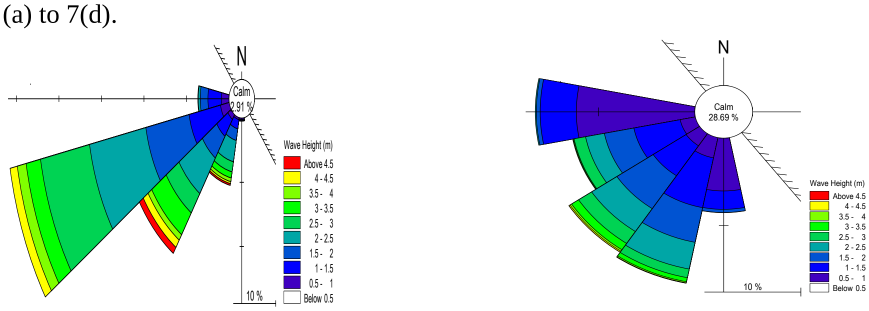
Figure 6. Validation results of coastline using LITLINE model

RESULTS AND DISCUSSION

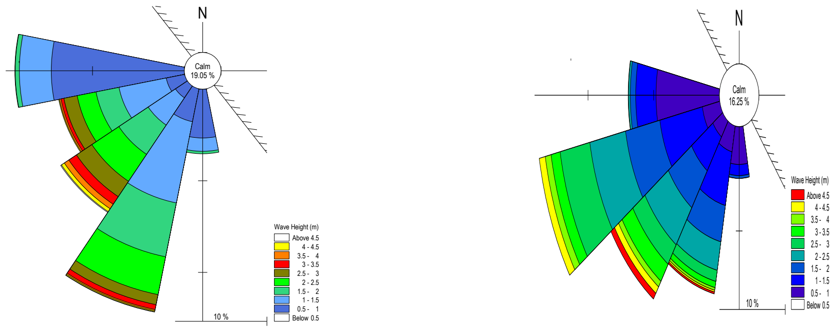
Sensitivity Analysis

Sensitivity analysis was also performed with various parameters like wave height, angle of wave incidence, wave period, mean water level and shoreline angle. The results of the analysis show that sediment transport increases with the wave periods; it also increases exponentially with the increase in wave height. With the increase in mean water level, sediment transport rate decreases exponentially. The littoral drift was found highly sensitive to the alignment of the shoreline with predominant wave direction which plays an important role in deciding the drift direction.

In order to find the predominant wave angle and percentage of occurrence the ship observed deepwater wave data were transformed using a spectral wave model. In this area estimated highest wave height is 4.5 m. The rose plots of the wave climate are shown in Figure 7 during various seasons. The predominant directions of waves are found from SSW, SW and WSW with percentages of occurrence as 11%, 26% and 52% respectively as seen in the Figures 7 (a) to 7(d).



(a) **(b)**



(c) **(d)**

Figure 7. Nearshore wave rose plots for (a) SW Monsoon (b) NE Monsoon (c) Non Monsoon (d) Annual

As reported by many researchers the general trend of drift is towards southern side along the west coast of India, and towards northern side along the east coast of India [8]. At the Muthalapozhy coast, littoral drift is found towards northern side which is not in agreement of the general trend of the drift in the region.

Estimation of Littoral Drift

The calibrated model was applied in the Muthalapozhy harbor area. The estimated net transport rates for three seasons are presented in Figure 8 (the negative sign is used for southerly drift whereas the positive for northerly drift). It is found that the net littoral drift is towards northern side having a rate of 0.12 x10^6 m^3/year. It is also found that the transport rate is southerly during Southwest monsoon season (i.e. June to September) and northerly during rest of the year.

These results justify the choking of the entrance of the channel during month of March because the alongshore drift is more during the non-monsoon season (February to May) as compared to the other seasons. Hence blocking the sediment from southern side during this period would minimize siltation in the channel. It means that the length of southern breakwater needs further extension.

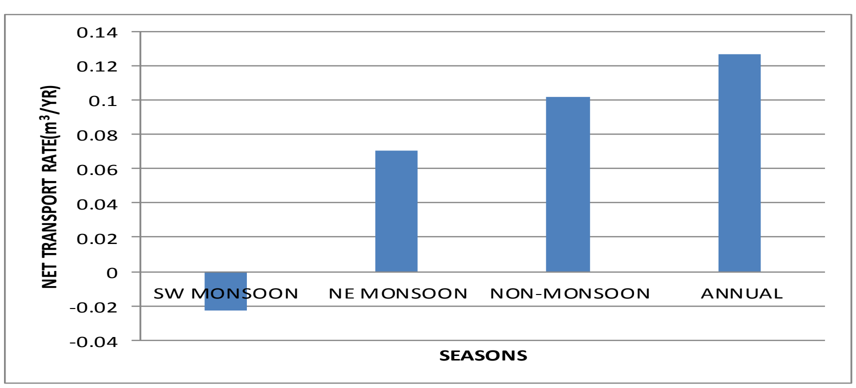


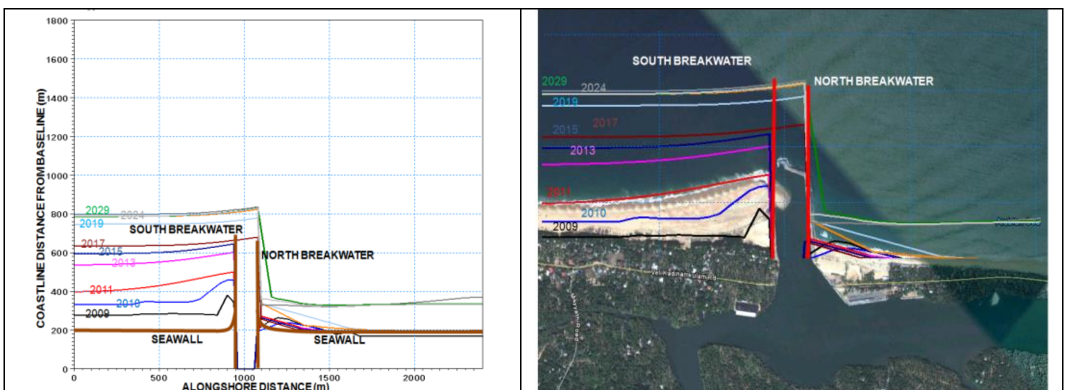
Figure 8. Bar graph of simulated net sediment transport in various seasons at Muthalapozhy harbour.

Simulation of Shoreline Changes

The shoreline changes were simulated in two years intervals time. The results are shown in Figure. 9 (a). The simulated shorelines were then superimposed on the Google Earth image of the area for better visualization which is shown in Figure 9 (b). These figures show that due to the south breakwater and north breakwater, further accretion on the south of the south breakwater and erosion on the north of the north breakwater will take place because the net transport is directed towards the north. Since natural bypass of sand shall be minimum toward the north of the north breakwater, the affected length of the northern coastline due to erosion will increase further. It is also estimated the initial advancement in shoreline will be of the order of 45 m/year which will reduce to 25 m/year in later years. In 2016, it is estimated that the cross-shore accretion on the south side of the south breakwater would be approximately 260 m from the shoreline which will later start bypassing the sand into the channel towards north side.

To make channel operational until 2016 without dredging, the required length of the southern breakwater would be 530 m. Hence it is proposed to increase the length of the south breakwater by 200 m. Accordingly, the length of the northern breakwater should be of around 400 m that to parallel to southern breakwater not as the existing one as seen in figure 9b. It means that the north breakwater needs an extension of 70 m from the point of bend. After 2016, major part of littoral drift might start bypassing and it might enter in the channel resulting choking the channel mouth.

Further extension of the length breakwaters to make the channel navigational upto 2029 may not be an economically viable solution for minimizing siltation in the channel. Hence regular sand bypassing from south to north is essential to prevent erosion of the northern coastline and accretion on the south through dredging of the channel.



(a) (b)

Figure 9. (a) Shoreline evolution from 2009 to 2029. (b) is superimposed on Google Earth image of year 2011 showing a match of the simulated results.

CONCLUSIONS

A study of a navigational channel was undertaken for studying the shoreline changes using mathematical modelling tool LITPACK to estimate the littoral drift and evolution of shoreline due to the construction of breakwaters at the outlet of the Vamanapuram River at Muthalapozhy harbour in South India. The results show that the annual littoral drift is towards northern side. The estimated net littoral drift rate of 0.12 x 10^6 m^3/year. It is also found that the transport rate is southerly during Southwest monsoon season (i.e. June to September) and northerly during rest of the year. In 2016, it is estimated that the cross-shore accretion on the south side of the south breakwater would be approximately 260 m from the shoreline. To make channel operational until 2016 without dredging, it is proposed to increase the length of the south breakwater by 200 m and the length of the northern breakwater by 70 m from the point of bend parallel to south breakwater.

Since LITPACK model is 1D model, coastal structures are added either perpendicular or parallel to the coastline which is one of the limitations. Yet, LITPACK allows consideration of many dominating factors giving better results than the semi-empirical formulations. The results of the analysis of the case study shows that LITPACK modelling tool is reliable and helpful in making decisions about the structural measures to be adopted for protecting navigational channels.

Acknowledgement

The authors wish to acknowledge the support extending by Dr. I.D. Gupta, Director and Shri M.D, Kudale, Joint Director, Central water & power Research Station, Pune. Thanks are also due to Shri V. B. Sharma, Assistant Research Officer for providing valuable support during the study.

REFERENCES

[8] Chandramohan P., Jena B. K. and Kumar V. S., "Littoral Drift Sources and Sinks along the Indian Coast". *Current Science*, 81, (2001), pp 292–297.

[6] Dabees M. A. and Kamphuis J. W., "A Numerical model for shoreline change". *Proc 26th international conference on coastal engineering* , ASCE , Copenhagen (1980), pp 2668-2681.

[4] Danish Hydraulic Institute (DHI), "An integrated modelling system for littoral processes and coastline kinetics, short introduction and tutorial", DHI Software, Copenhagen, 2005.

[5] Fredsoe, D. R. J. and Hedegaard I. B., "Mathematical Model for Littoral Drift". *J waterway port coastal and ocean eng*, ASCE, 112(3), (1986) pp 351-369,

[2] Kumar V Sanil., Pathak K. C., Pednekar P., Raju N. S. N. and Gowthaman R., "Coastal Processes Along The Indian Coastline". *Current Science*, Vol. 91, No. 4, (2006), pp 25.

[3] Kunte P. D. and Wagle B. G. "Littoral transport studies along west coast of India". *A review Indian Journal of Marine Sciences* Vol. 30, (2001), pp. 57-64.

[1] Sanjeev R., Chandramohan P. and Sankaranarayanan V. N., "Studies on Sediment Transport Along Kerala Coast, South West Coast Of India", *Indian Journal Of Marine Sciences*, Vol 26, (1997), pp 11-15.

[7] Fredose, J. and Deigaard R. "Mechanics of Coastal Sediment Transport". *Advanced Series on Ocean Engineering*, vol. 3. World Scientific Publishing, Singapore, (1992).