CHAPTER 9

NUMERICAL MODELING STUDY

9.1 INTRODUCTION

Laboratory studies are generally termed as physical models because often they are miniature reproductions of a physical system. In parallel to the physical model is the numerical model, which is a mathematical representation of a physical system. Numerical models are mathematical models in which the governing equations are discretized and solved using a computer. Measurements and observations of hydrodynamic phenomena made at a specific site are often critical for understanding the hydrodynamic regime and its impact on existing or planned coastal projects. These measurements can be used to quantify the hydraulic flows, to specify hydrodynamics forcing conditions for numerical or physical model studies, or to verify the correct formulation and operation of numerical or physical model simulations.

Many flow conditions and problems in coastal engineering are not amenable to mathematical analysis because of the nonlinear character of the governing equations of motion, lack of information on wave breaking, turbulence or bottom friction or numerous connected water channels (Keulegan, 1966). In these cases it is often necessary to resort to physical models for predicting prototype behaviour or observing results not readily examined in nature.

Coastal Engineering practice is undergoing, and will continue to undergo, rapid changes. New technologies in coastal protection will be introduced and to a large extent, hard structures will be replaced by soft ones (beach nourishment) which are less harmful to nature and are aesthetically more pleasing. The field of coastal engineering involves providing reliable and economic design solutions to support men’s activities in the coastal zone. It involves study and attempt to understand diverse topics as wave mechanics and wave climate prediction, shoreline erosion and protection methods, harbour design and design of protective structures, geological and geotechnical aspects of foundation design, dredging technology, estuarine processes, hurricane and storm surge

effects and environmental impacts of coastal projects. Coastal engineering rely on three complementary techniques such as field measurements and observations, laboratory measurements and observations and mathematical calculations (Hughes, 1983).

9.2 NUMERICAL MODELLING

The interference with coastline becomes inevitable with the development of ports and harbours. In order to provide tranquil conditions inside the harbours, construction of breakwaters are essential. The waves generate longshore currents and produce sediment transport in the direction of current. The sediment transport along the coast manifest itself when arrested by the construction of breakwaters or groynes. Such construction also causes advancement of coastline on one side of structure and erosion on the other side. Accretion takes place in the direction of net littoral drift while the other side comes under the influence of erosion.

The first stage in the erosion during a storm generally involves the waves cutting away the upper part of the beach fronting the properties, a process which involves the cross-shore transport of sediment from the dry beach to the offshore. Research advances have led to a greatly improved understanding of the coastal processes important to erosion, and of the erosional responses of beaches and foredunes (Komar, 1995). The factors important to coastal erosion are deceptively simple. Large storm waves, perhaps aided by high tides, crash against the dunes or cliff and wash away anything that is in their path. However, research has established that coastal erosion is far more complex than this simplistic view.

The models are capable of predicting episodes of sea erosion during storms or the overwash and undercutting of foredunes and as such can serve as the basis for making coastal management decisions (Komar, 1995). Various models have developed for wave propagation across the surf zone and bore run-up on the beach face, leading to an improved capability to quantitatively evaluate run-up elevations as functions of the deep-

water wave conditions and beach slope. Those analyses in turn have led to the development of models for cross-shore sediment transport and beach profile responses to changing wave conditions and to models that attempt to predict rates of erosion. Although the models require testing and further refinement, they are important in having the potential for applications in evaluating the susceptibilities of coastal properties to erosion during extreme events where large storm waves combine with unusually high water levels.

Numerical modeling is a technique whereby the physical environment of the shoreline can be investigated using computer technology. In particular, it is suitable for studying the erosion process, shoreline changes, structure design and shoreline erosion prediction. Data needed for numerical modeling include shoreline, bathymetry, size of grain, waves and tides. The Danish Hydraulic Institute has developed a system of computer modules based on this approach namely MIKE 21 and LITPACK. In this models longshore current and distribution of sediment concentration in the vertical direction is determined to find sediment transport and morphological changes. In this study, this model has been applied to study the impact of breakwaters of Ennore Port on the coastline starting from south of Ennore Creek (near EID Parry factory) in the south to the bar mouth of Pulicat Lke in the north.

9.3 SHORELINE CHANGE STUDIES

The LITPACK model has been applied to study the effect of construction of breakwaters of Ennore port on the adjoining coastline. A typical coastline of 13.5 km length has been selected of which 5 km is on the southern side of the south breakwater and 6 km on the northern side of the north breakwater. In between port length is of 2.5 km. The coastline is oriented 355º north. In the southern part at a distance of 2.3 km from the south breakwater an inlet called Ennore Creek with 200 m width is existing in the coastline. At the end of the study area about 20 km north of Ennore Port, an another inlet namely, Pulicat Bar Mouth is present. The shoreline change studies have been carried out by using LITLINE module available within the LITPACK model.

In this model calculations are carried out based on the input data such as annual wave climate, cross-shore profile, bathymetry, roughness, mean grain diameter, fall velocity, coastline description, height of active beach, etc. In this study, data collected during field measurements have been given as an input. The maximum wave height, maximum tidal range and peak currents were considered as 1.0 m, 0.5 m and 0.40 m/sec respectively.

9.3.1 RESULTS

The LITLINE module have been run for the coastline changes separately for the southern side of the south breakwater and northern side of the north breakwater. Apart from that separate runs were also made by introducing two groynes at the inlets of Ennore Creek and Pulicat lake as management options in order to have the ideal solution for eliminating the problem of frequent closing of mouths of the both the inlets. The impact of south breakwater on the coastline in the southern side for a length of 5 km from the breakwater has been considered. The simulation has been carried out for the period of 30 years in order to know the future trend of the coastline. Results are presented in the Figure 9.1. From the output it is evidenced that severe accretion is taking place in this entire region. In the second year the accretion rate is in the order of 218 m adjoining the breakwater from the original coastline and it is about 375 m, 581 m and 1006 m in the 5th, 10th and 30th years respectively. In this zone Ennore Creek inlet exists at a distance of 2.3 km south of south breakwater. Since accretion trend is showing upto a distance of 5 km, future of this inlet is in trouble. From the simulation, accretion at a rate of 36 m, 121 m, 182 m and 315 m have been obtained at the mouth of Ennore Creek during 10th, 15th, 20th and 30th years respectively.

As a management option in order to keep the mouth of the Ennore Creek open permanently, two numbers of jetties have been introduced in the coastline, one at the south and the another at the north of the inlet and the module has been run. The lengths of the jetties have been considered as 385 m length and the centre of the jetties have been

kept at the existing shoreline in the 0th year. Simulation has been run for the period of 10 years and the results are presented in the Figure 9.2. From the simulation, it is obtained that in the immediate north of northern jetty erosion is taking place at a rate of 150 m and 204 m during the 1st and 2nd years respectively and then decreasing trend of erosion has been obtained as 195 m, 173 m and 164 m for 5th, 8th and 10th years respectively. From the figure, it is understood that erosion is taking place with in a distance of 1000 km from the jetty, afterwards accretion is noticed. From the output it is seen that from the 10th year onwards the coastline is stabilized as it has reached a equilibrium state.

Likewise, in the immediate south of southern jetty accretion is being taking place at a rate of 127 m in the 1st year after the construction of jetty, whereas, from 2nd year to 10th year the accretion rate is stabilized at 177 m from the initial coastline. Therefore, it seems that after the construction of jetties on both sides of the mouth, the shoreline is stabilized from the 10th year onwards on both sides, i.e., after attained the equilibrium condition.

In order to identify the impact of the north breakwater the model has been run for the 30 years period. In this case, a coastal stretch of 6 km from the north breakwater has been considered for the study. Results of the simulation is presented in the Figure 9.3. From the results, it is seen that erosion is taking place for a distance of upto 114 m and 178 m during the 1st and 2nd years respectively. The same trend continues in the following years also as 400 m, 628 m, 928 and 1157 m during 5th , 10th, 20th and 30th years respectively. Erosion is taking place up to 4 km from the north breakwater but the erosion rate is gradually decreasing to a minimum of 50 m of erosion in the 30th year.

Similar to the inlet of Ennore Creek in southern part of the study area, another inlet of Pulicat Lake situated in the northern end of study area has also been studied. For this inlet as a management solution two jetties have been introduced on the coastline in order to maintain the inlet permanently open. In which the jetty in the southern side of the mouth has been considered as a lengthier one having length of 320 m and the northern jetty having a length of 260 m based on the coastline configuration. The centre of the

southern jetty has been kept at the existing shoreline and land side ends of both the jetties have been kept on the same baseline. Simulation has been run for the period of 10 years and the results are presented in the Figure 9.4. From the results, it is obtained that in the immediate south of the southern jetty accretion is taking place at a rate of 92 m during the first year itself and the coast has stabilized at the same level till the end of 10th year. But in the further south, at about a distance of 100 m erosion is taking place at a rate of 61 m, 107 m, 177 m and 254 m during 1st, 2nd, 5th and 10th years respectively and the trend is gradually reducing and stabilized at a distance of 3 km further south. Simulation results for the north shows that erosion is taking place in the immediate north of northern jetty at a rate of 38 m in the first to third years and at a rate of 46 m, 77 m and 100 m during 5th, 8th and 10th years respectively. This erosion trend has been gradually decreasing towards north up to a distance of 1 km and then accretion is being taking place. Maximum accretion is obtained at a place 2.5 km north of northern jetty at a rate of 31 m, 69 m, 92 m, 131 m and 154 m during 1st, 3rd, 5th, 8th and 10th years respectively. Afterwards the trend shows declining and naturally the shoreline will get stabilized in the further north after reaching equilibrium conditions.

9.4 STUDY ON LITTORAL DRIFT

Simulation for the annual littoral drift in the study region has been performed by running LITDRIFT module available within the LITPACK model. LITDRIFT is able to give a deterministic description of the cross-shore distribution of longshore sediment transport for an arbitrary, non-uniform, bathymetry and sediment profile as well as a detailed description of the sediment budget (DHI, 1998). In this simulation also all the inputs given to the LITLINE module has been taken for running the module.

9.4.1 RESULTS

The LITDRIFT module has been run for four different profiles namely, South of Ennore Creek, South of Ennore Port, North of Ennore Port and Pulicat Light House. At these locations beach profile data has been collected during 2000 and 2001. The same data has been given in addition to the data given to LITLINE module. Results obtained from the simulation as gross and net annual drift for each of the profiles have been presented in Figures 9.5 and 9.6 and in the Table 9.1.

From the output, it is observed that the gross transport of 1.095 million m^3/year and net annual transport in the direction of north at a rate of 0.628 million m^3/year for the profile in the south of Ennore Creek. For the profile in the south of Ennore port, it is about 1.113 million m^3/year and 0.657 million m^3/year as gross and net transport respectively. In the north of Ennore port, gross and net transport rate are 1.020 million m^3/year and 0.572 million m^3/year respectively. At the Pulicat light house, it is about 1.163 million m^3/year and 0.663 million m^3/year as gross and net transport respectively. From the results it is evidenced that for all the profiles the net transport is towards north only. The net annual transport of all the profiles, except north of port are more or less equal. In the north of port the amount of net transport is less compared to other profiles because considerable portion of the sediments are retained in the south by the south breakwater as accretion.

Table 9.1 Pattern of Littoral Drift in the North Chennai Coast

S.No.	Profile Location	Gross Littoral Drift (million m3/year)	Net Littoral Drift (million m3/year)
1	South of Ennore Creek (Transect 1)	1.095	0.628
2	South of Ennore port (Transec 3)	1.113	0.657
3	North of Ennore port (Transect 5)	1.021	0.572
4	Pulicat Lighthouse (Transect 6)	1.163	0.663

9.5 WAVE SIMULATION STUDY

The assessment of wave conditions and wave-induced currents are essential for the calculation of sediment transport and erosion/deposition patterns in the coastal zone. Therefore, wave transmission at nearshore and offshore regions of North Chennai coast from Ennore to Pulicat Lake inlet was studied using numerical modeling software MIKE 21. From the software, Parabolic Mild-Slope Module (PMS) was used for the wave simulation. It is a two-dimensional wind-wave model which describes propagation, growth and decay of short wave period and short crested waves. MIKE 21 PMS is a linear refraction-diffraction model based on a parabolic approximation to the elliptic mild slope equation. The model takes into account the effects of refraction and shoaling due to varying depth, diffraction along the perpendicular to the predominant wave direction and energy dissipation due to bottom friction and wave breaking. The model also takes into account the effect of reflection, wave blocking, frequency spreading and directional spreading using linear superposition, wave-current interaction and wave-wave interaction.

9.5.1 SIMULATION BY PMS MODULE

The bathymetry data used in the wave simulation was based on the survey carried out in May 2001, which has been presented in the previous chapter. A constant grid spacing of 10 m in both x and y directions was used. Wave refraction analysis has been carried out for the study region of interest for the two monsoon conditions, southwest monsoon and northeast monsoon with typical wave parameters. The wave simulation runs were carried out to identify the wave pattern before and after the inception of the Ennore Port. For the run, the mean incident angle of 70º and 145º has been applied for the northeast monsoon waves and southwest monsoon waves respectively. The outputs of the wave simulation are presented in Figures9.7 and 9.8. It is observed from the figures that wave pattern has changed drastically after the construction of port. It is observed from the simulation that when the waves propagated towards the shore due to refraction, wave

orthogonals tended to become inclined to the shoreline. It is also found that the breaker line was not parallel to the shoreline. Therefore it is confirmed that the shore is not in eqillibrium state. This was observed for all the four conditions.

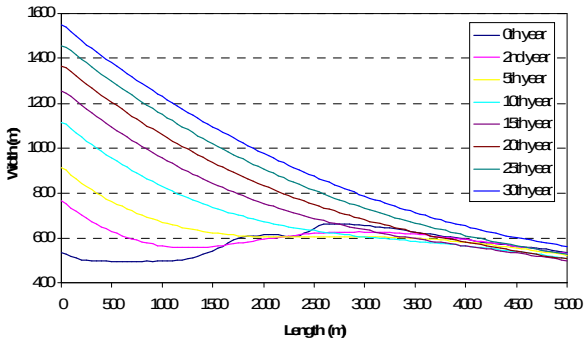

Figure 9.1 Predicted Coastline on south of south breakwater

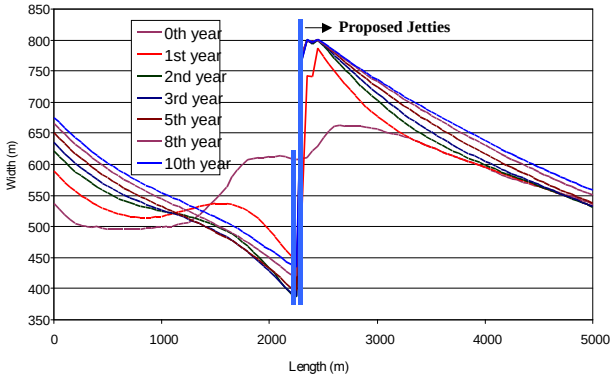

Figure 9.2 Predicted Coastline with proposed jetties at Ennore Creek

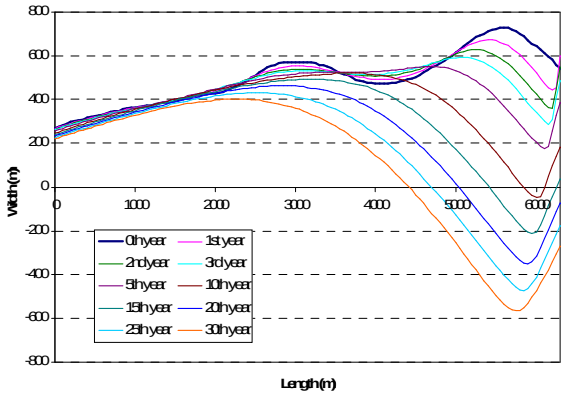

Figure 9.3 Predicted coastline on north of north breakwater

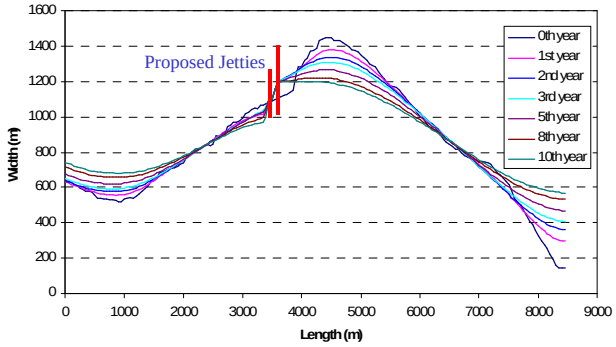

Figure 9.4 Predicted coastline with proposed jetties at Pulicat inlet

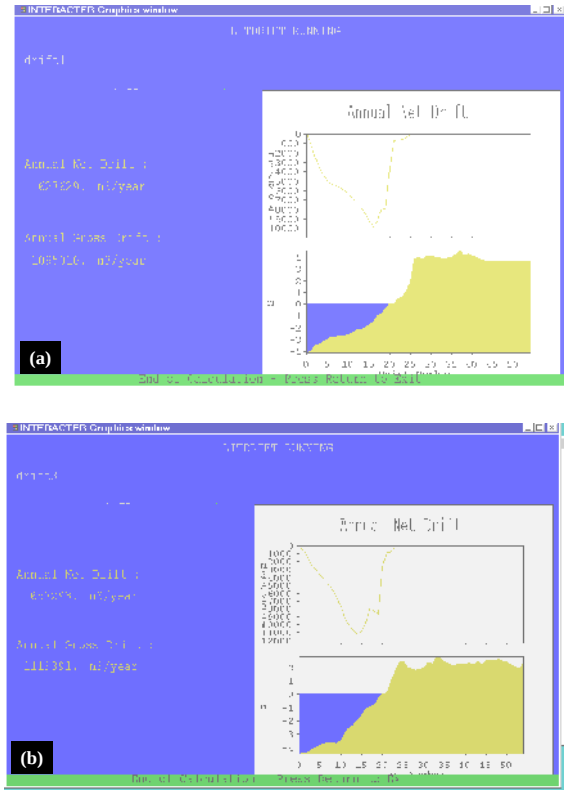

Figure 9.5 LITDRIFT output for profiles at (a) south of Ennore Creek and (b) south of Ennore Port

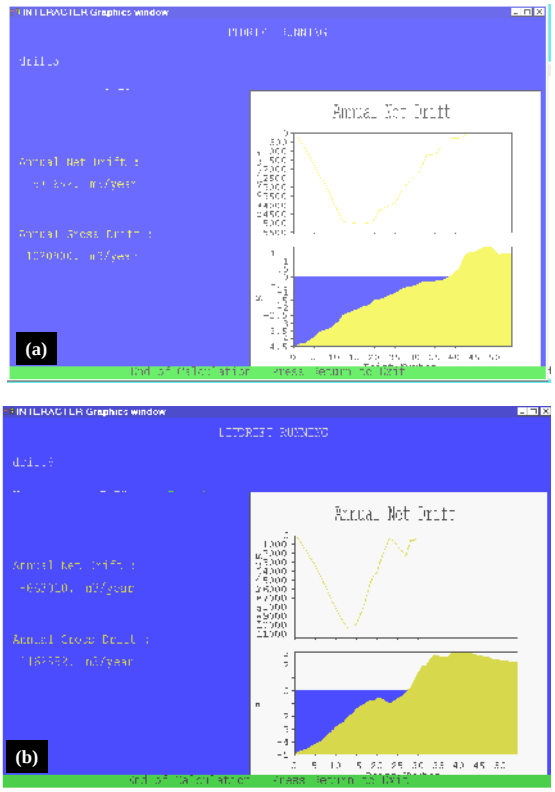

Figure 9.6 LITDRIFT output for profiles at (a) north of Ennore Port and (b) Pulicat Lighthouse

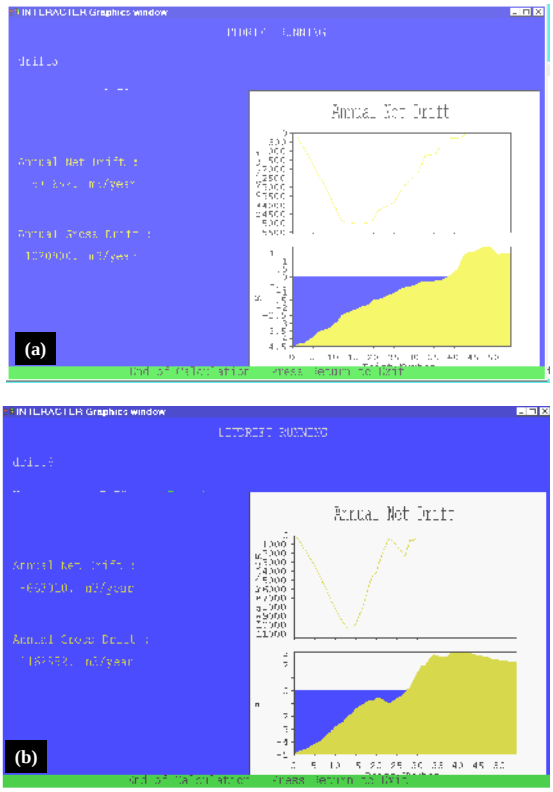

Figure 9.6 LITDRIFT output for profiles at (a) north of Ennore Port and (b) Pulicat Lighthouse

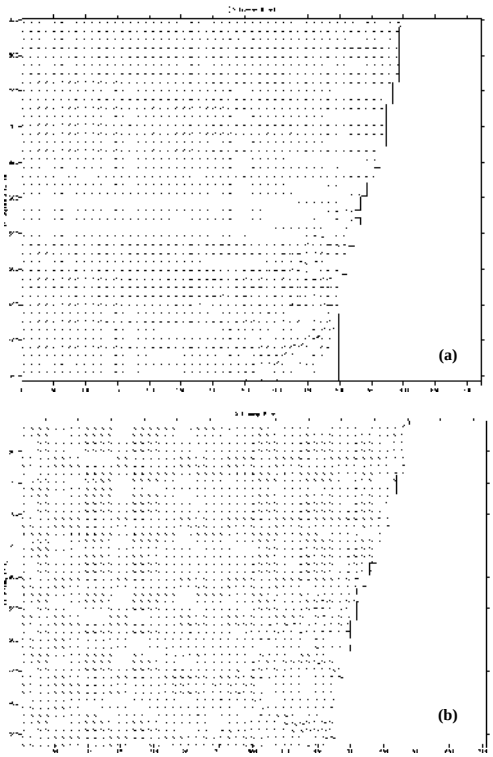

Figure 9.7 Wave simulation of before Ennore Port scenario, (a) 70 ° angle waves and (b) for 145 ° angle waves

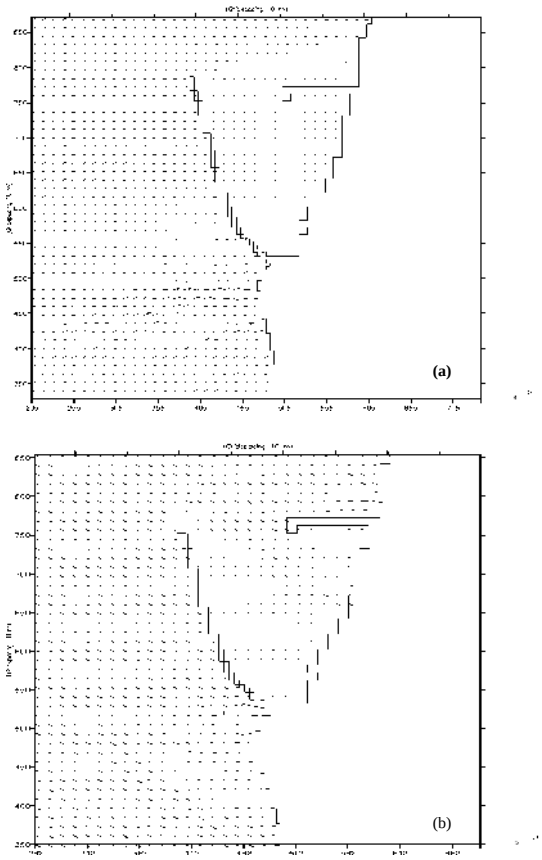

Figure 9.8 Wave simulation of after Ennore Port scenario, (a) for 70° angle waves and (b) for 145° angle waves