CHAPTER - 1

INTRODUCTION
1.1 Introduction

The coastal zone is characterized by variety of land forms like beaches, estuaries, islands, lagoons and promontories. The nearshore regions are usually the areas of high energy environs where waves and currents have sufficient strength to influence geomorphology. The beach and nearshore environs have been and are being studied from time to time along many coasts of the world by variously researcher — Geologists, Oceanographers, Coastal Engineers and Management personnel. Of late, the increased interest and the awareness to maintain this environment from problem of cyclones, tsunami, pollution, development of fishing, major harbour and recreational facilities by the coastal states lead to greater and detailed investigations on various environmental parameters of this zone as they are likely to provide a clue to understand better, the high energy dynamic zone controlling the movement of water and the sedimentary material (Nayak, 1993).

In any coastal geomorphic setting the beach and the shoreline which are thought to have permanent geomorphic forms at any moment are subject to constant changes. Such changes are understood from knowledge of various physical processes responsible. The most important physical processes governing the movement of sedimentary material are the turbulent diffusion and advection.

In the surf zone the breaking of the waves bring about the agitation of the sediments at the bottom and, at the point of wave breaking the concentration of the sediments in suspension increases (Mason, 1952). When the waves approach the shore at an angle, littoral currents are set up in the surf zone. These currents help in the transportation of the sediments brought in to suspension by the breaking waves along the shore. This movement or transport of sediments generally takes place between the upper limit of the swash on the landward side and the seaward margin of the breaker zone under moderate wave conditions (Shepard, 1950).
These shoreline processes are affected (i) by the natural process variables such as prevailing winds, waves and the associated longshore currents, and the permanent current systems, if any, in addition to the tides and tidal currents, (ii) indirectly by man-made structures such as groynes, jetties, seawalls and breakwaters, (iii) by natural offshore shoals, such as mud banks, bars, and small islands, (iv) by phenomena such as storm surges and tidal waves and (v) by beach slope and the material constituting the beaches. When these variables contribute to net movement of the beach material at any given locality, the beach profile undergoes deformations. If these physical agencies lead to a material balance, the beach profile remains in an equilibrium form in general (Fennemann, 1902). However, large scale irreversible transformations of the beaches induce reformation of the nearby shoreline.

Some of the most important features of a sandy coastline from a standpoint of littoral processes are those breaks in its continuity by river mouth such as estuaries and inlets, which are formed by the combination of the influence of current and wave action. Shorelines in the vicinity of river mouths are subject to considerable change, much more so than typical shorelines remote from river mouths.

Erosion, sedimentation and changes of the coastline in and around the river mouth are resulted from the interaction of hydro and morpho-dynamics. Rate of erosion, deposition and coastline changes vary with seasons. Large scale variations occur due to extreme condition such as cyclone. Sediment transport to or from the river, is responsible in changing morphology. The hydrodynamic parameters involved are waves and currents (tidal and river). These parameters are not only responsible for defining the erosion and deposition but also type and size of the sediments that erode or deposit.

Along the central coastal region of Vietnam, especially in and around the Thubon River mouth shoreline changes have been observed, and considered as serious problem by both Local and Central Government of Vietnam, as this is going to affect local population of Hoian Town. Considering the seriousness of
the coastal problem, it was proposed to undertake a detailed study on erosion, sedimentation and changes of shoreline in and around the Thubon River mouth.

1.2 Study area

1.2.1 The South China Sea

The South China Sea is the largest marginal sea in Southeast Asia, extends from the equator to 23°N and from 99°E to 121°E. It is a semi-enclosed, tropical sea located between the Asian land mass to the north and west, the Philippine Islands to the east, Malaysia and Indonesia to the south and southeast with a total area of 3.5 x 10^6 km^2 (Chu et al., 1999). It includes the shallow Gulf of Thailand and Tonkin, and connects to the East China Sea, through the Taiwan Strait; to the Pacific Ocean, through the Luzon Strait; to the Sulu Sea, through the Mindoro Strait; to the Java Sea, through the Gasper and Karimata Strait; and to the Indian Ocean, through the Strait of Malacca. Its complex topography includes the broad shallows of the Sunda Shelf in the south/southwest; the continental shelf of the Asian landmass in the north, extending from the Gulf of Tonkin to the Taiwan Strait; a deep, elliptical shaped basin in the center, and numerous reef islands and underwater plateaus scattered throughout. The shelf that extends from the Gulf of Tonkin to the Taiwan Strait is consistently near 70 m deep and averages 150 km in width; the central deep basin is 1900 km along its major axis (northeast-southwest) and approximately 1100 km along its minor axis and extends to over 4000 m deep (Figure 1.1).

Countries that have a major influence on and claims to the sea include China, Malaysia, Philippines and Vietnam, although Thailand, Indonesia and Taiwan have same too. The coastal fringes of the South China Sea are home to about 270 million people that have had some of the fastest developing and most vibrant economies on the globe (Morton and Blackmore, 2001).
The South China Sea is under the influence of the East Asia monsoon, the southwest monsoon in summer and the northeast monsoon in winter. The latter is a stronger and more constant by dry wind. The former is rain-bearing, deriving moisture from evaporation over the South China Sea. Furthermore, in summer there are often intense low pressure cells built up in the western Pacific that develop into severe tropical storm or, in extreme cases, into typhoons (or
hurricanes) which characteristically pass over the Philippines and either veer northeast towards Taiwan and Japan, or cross into the South China Sea and head towards Vietnam in the west or the coast of southern China in the north. In winter the northeast monsoon creates an anticlockwise pattern of circulation. The wind pushes cooler, coastal waters down through the Taiwan straits to circulate west and southwards along the coast of China and Vietnam and to either depart the South China Sea via the Karimata Straits or to be turned northeasterly and run along the coast of Borneo and Palawan and thus return to the northern rim of the sea. This creates an anticlockwise gyre in the central area. In summer, from May to September, under the influence of the southwest monsoon, current flow is reversed in the South China Sea and water enters from the Java Sea via the Karimata Straits to sweep up into the central area and exit through the Taiwan Straits. In the process, a clockwise gyre is established off the coast of Borneo, above the Spratlys (Truongsa Islands), and a smaller anticlockwise one off the coast of Vietnam.

In totality, therefore, the southern coasts of the South China Sea, i.e., Borneo and much of the western Philippines, are affected by a prevailing northeasterly flow while the coast of the northern rim, i.e., southern coast of China and most of Vietnam are influenced by a southeasterly flow.

According to Su (2004) the onset of the summer monsoon over South China Sea usually occur around the middle of May. The southwesterly winds are abruptly established in the southern and central part of the South China Sea and soon expand to the entire South China Sea by June. In the northern South China Sea, the summer monsoon winds are actually more southerly, reaching peak values in July. In September, the northeast winter monsoon begins to appear over the northern South China Sea, reaching the central South China Sea in October and covering the entire South China Sea by November. The winter monsoon gradually diminishes by April. In the northern South China Sea, the winter monsoon has a monthly average wind speed of 7 to 10 m/s, and generally < 6 m/s during the summer monsoon.
Shaw and Chao (1994) carried out a study by using a three dimensional, primitive equation model with a free surface to simulate the monthly circulation in the South China Sea. The results show that a strong coastal jet is present at the western boundary. The current is southward along the continental margin from China to southern Vietnam in winter. In summer, the current is northward and separates from the coast between 11°N and 14°N. The transition in September begins as a southward undercurrent, which is remotely forced by the northeast monsoon in the northern reaches of the South China Sea. The undercurrent extends to the surface in about a month.

During winter monsoon period in the southern South China Sea an anticyclonic eddy is formed periodically over the Nansha (Truongsa) Trough, which grows and spreads westward, then dissipates in the western boundary, with around a 50 day period (Cai et al., 2002). According to McGregor (1995) an assessment of the spatial dimension of tropical cyclone hazard potential in the South China Sea is based on an analysis of girded tropical cyclone frequency data, covering the period 1970-1989. Data was taken from six-hourly tropical cyclone position obtained from the Hongkong Royal Observatory using a 2 x 2° grid. Analysis reveals that percentage probability that any tropical cyclone entering the South China Sea is relatively high in the northern sector than that in the southern sector of the South China Sea. Kuo et al. (2003) shows that during southwest monsoon period along the central and southern Vietnamese coast, upwelling is the most intensive one when compared with California coastal upwelling and mid-Atlantic Bight coastal upwelling.

1.2.2 Hoian area

Vietnam is located in the South–East Asia with South China Sea on the east. It has a long coastline of 3,200 km and many islands, most of the provinces of Vietnam are located along the coastline and therefore large population lives along the coast or adjacent coastal low land areas.

Thubon River joins the South China Sea at Dai mouth, Hoian Town, Quangnam Province (Central Vietnam). The continental shelf off the study area is relatively
narrow with 20 m depth contour occurring at 2 km, 30 m at 10 km and 50 m at 12 km away from the coast, except in the area of Thubon River mouth, where shoals are present. At about 12 km distance from the Thubon River mouth in the northeast direction, Cham Island of 8 km width is present. Coastline consists of long sandy beaches, with medium to fine sand and with median size approximately ranging from 0.15 to 0.2 mm. The location and general geomorphological features of the study area are shown in Figures 1.1, 1.2 and Plate 1.1.
Statistical wind data from 1978 to 1997 from Danang Station shows that, during normal condition the major wind direction was E and N and during maximum wind condition (>14 m/s) the major wind direction was N and NNW.

The measured current data in the nearshore region (Tuong, 1995) shows that during NE monsoon (November 1993), the major direction of current was NNW and SSE, which is almost parallel to the shoreline. The maximum current speed was 1 m/s and the average current speed was 0.2 m/s. During pre SW monsoon (May 1998) at Stations O4 and O5 the maximum speed was 0.4 m/s and the average speed was 0.2 m/s. The major direction was NNW and SSE, which is almost parallel to the shoreline. At breaking zone in general during NE monsoon the alongshore current was towards the south and vice versa during SW monsoon.

A study on wave refraction and sediment transport in the Hoian area was carried out by Mau (2002a, b). The wave refraction patterns estimated based on
TARANGAM wave model (Chandramohan, 1988) shows that the shoreline of Hoian is subjected to concentration of wave energy and Cham Island has important role in the distribution of wave energy along Hoian coast. Long-shore sediment transport rate estimated based on the CERC equations (SPM, 1984) for Station S1 (northern shoreline) shows that the annual gross sediment transport \( (Q_g = 880,799 \, m^3) \) and also the annual net transport rate \( (Q_n = 604,308 \, m^3) \) are relatively high with the net sediment transport towards south.

Oceanographic conditions of the nearshore waters along this region are subjected to seasonal variability with the reversing southwest (June to August) and northeast monsoon (October to April) with the transitional period (May and September). The data on tides of this region were taken from Danang Station, which have average tidal height of 0.77 m, the mean spring tidal range was 1.36 m and the neap tidal range was 0.37 m (Hung, 1995).

Study by Mau et al. (2004) shows that hurricane occurred in the vicinity of Hoian coastline during 1945 to 2003 with an average of 1.2 times a year, mostly in September (26.1%), October (30.4%) and November (13%).

In the recent years two oceanographic expeditions were carried out in this region, they are:

- Cooperation Project between Local Government and Center for Marine Meteorology-Hydrology (1993-1995): “Surveying, studying, planning and protecting the land tenure, environment and exploitation on the agri-maricultural potential in the Cuadai (Hoian) area” (Tuong, 1995). They concentrated on the area of hydrodynamic processes such as: tides, nearshore circulation, hurricanes, wave transformation. This study gave the patterns of hydrodynamic processes for some typical situations.

- National Project (1997-2000) was carried out by National Institute of Oceanography: “Study on laws and prediction erosion – deposition habitude in the coastal zone and river mouth of Vietnam” (Trinh, 2000). They carried out the investigation on hydrodynamic processes such as: tides, nearshore circulation,
wave transformation, river discharge. Especially, they concentrated on the area of sediment dynamics, morphological and shoreline changes. This study gave the features of change and general trend of development of the shoreline in and around the Thubon River mouth.

These expeditions have applied some models to describe the hydro-lithodynamic processes for typical situations in the study area. These studies have shown that the Thubon River mouth was drifting towards south with an average rate of about 20 to 25 meters per year during the period from 1965 to 2000 (Hieu et al., 2000). This may need further study and confirmation. No effort has been made to quantify the extent of erosion, deposition and changes of coastline with reference to annual and seasonal, till date by any individuals or institutions.

1.3 Objectives

The objectives of the present study are:

(a) To assess the extent of erosion, deposition in the Thubon River mouth.

(b) To assess the seasonal and the annual changes in the coastline in and around the Thubon River mouth.

1.4 Selection of models

Based on the capabilities of the available models in the related areas such as, hurricane waves, offshore wave, nearshore wave, sediment transport, and shoreline change, the following models have been selected for the present study.

1.4.1 Young’s model

Estimation of extreme wave height during a hurricane has considerable importance in planning and operation of coastal and offshore activities. Various wave prediction models were developed and presented by many scholars
based on different approaches. SWAMP (1985) gives a comparison of various wave prediction models and also the merits and demerits of each model. The complicated wave generating processes within hurricanes make estimation of the wave conditions associated with a given storm difficult. A more realistic estimation of wave height during hurricane can be done using the Young’s model. The Young’s model is a second generation spectral wave model which was developed based on the concept of the equivalent fetch and the standard JONSWAP fetch-limited growth relationships (Hasselmann et al., 1973). The model was used to generate a synthetic data base covering a wide range of hurricane parameters. The three wind field parameters varied was: velocity of forward movement, maximum wind velocity in the storm, and radius to maximum winds. The model results give both the magnitude of the waves generated and the spatial distribution of these waves, and provide a simple means for estimating wave conditions within hurricanes (Young, 1988).

1.4.2 WAM model

WAM (acronym for WAve Modeling) model is a third generation wave model which solves the wave transport equation explicitly without any presumptions on the shape of the wave spectrum (Guenther et al., 1992). It represents the physics of the wave evolution in accordance with our knowledge today for the full set of degrees of freedom of a 2d wave spectrum. The model runs for any given regional or global grid with a prescribed topographic dataset. The grid resolution can be arbitrary in space and time. The propagation can be done on a latitudinal-longitudinal or on a carthesian grid. The model outputs the significant wave height, mean wave direction and frequency, the swell wave height and mean direction, wind stress fields corrected by the wave induced stress and the drag coefficient at each grid point at chosen output times, and also the 2d wave spectrum at chosen grid points and output times.

The model runs for deep and shallow water and includes depth and current refraction. The integration can be interrupted and restarted at arbitrary times. The source terms and the propagation are computed with different methods and time steps. The wind time step can be chosen arbitrarily.
Sub-grid squares can be run in a nested mode. In a course grid run the spectra can be outputted at the boundaries of a sub grid. They can then be interpolated in space and time to the boundary points of the fine sub grid and the model can be rerun on the fine mesh grid.

The cpu time and memory usage depend on the region of interest and the grid resolution. For a global run 20 minutes cpu time (CRAY unicos computer) is needed for a ten day forecast for a 3° by 3° lat-lon grid, 26 frequencies, 12 directions and 512 grid points in a block.

The model has been installed at world-wide institutions and is used for research and also operational application. It is also being applied for interpreting and assimilating satellite wave data.

1.4.3 SWAN model

SWAN (acronym for Simulating WAves Nearshore) is a third-generation spectral wave model from which one can obtain realistic estimates of wave parameters in coastal areas, lakes and estuaries from given wind, bottom, and current conditions. The model is based on the wave action balance equation with sources and sinks (Holthuijsen et al., 2003).

Wave propagation processes are represented in SWAN:
- Propagation through geographic space
- Refraction due to spatial variations in bottom and current
- Shoaling due to spatial variations in bottom and current
- Blocking and reflections by opposing currents
- Transmission through, blockage by or reflection against sub-grid obstacles

Wave generation and dissipation processes are represented in SWAN:
- Generation by wind
- Dissipation by white capping
- Dissipation by depth-induced wave breaking and bottom friction
- Wave-wave interactions (quadruplets and triads)
- Obstacles and wave induced set-up

SWAN is stationary and optionally non-stationary and formulated in Cartesian or spherical coordinates and SWAN can be nested in the WAM model which is formulated in terms of spherical coordinates. SWAN can be also run in a nested condition.

1.4.4 Van Rijn formula

The capabilities of Van Rijn formula (Van Rijn, 1990) are as follows
- The formula can be applied for a movable fine sand bed (50 to 500 μm), i.e. for the plane bed (sheet flow) in the coastal, river or estuary areas.
- The formula can be calculated separately for bed load, suspended load, or total load transport rate in current or wave directions.
- Compute time-average concentration profiles and depth-integrated transport rates in combined currents and wave action.

1.4.5 GENESIS model

GENESIS (acronym for GENEralized Model for Simulating Shoreline Change) is a coastal engineering tool simulates shoreline change produced by spatial and temporal differences in alongshore sand transport (Hanson, 1989). The major capabilities of GENESIS are as follows:

- The alongshore extent of a typical modeled reach can be in the range of 1 to 100 km, and the time frame of a simulation can be in the range of 1 to 100 months.
- Almost arbitrary numbers and combinations of groins, jetties, detached breakwaters, beach fills, and seawalls.
- Compound structures such as T-shaped, Y-shaped, and spur groins
- Bypassing of sand around and transmission through groins and jetties
Diffraction at detached breakwaters, jetties, and groins.
- Offshore input waves of arbitrary height, periods, and direction.
- Multiple wave trains (as from independent wave generation sources).
- Sand transport due to oblique wave incidences and alongshore gradient in height.
- Wave transmission at detached breakwaters.

The main data required for GENESIS is shown in Table 1.1

<table>
<thead>
<tr>
<th>Type of data</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Shoreline position</td>
<td>Shoreline position at regularly spaced intervals alongshore by which the historic trend of beach change can be determined</td>
</tr>
<tr>
<td>Offshore waves</td>
<td>Time series or, at a minimum, statistical summaries of offshore wave height, period, and direction</td>
</tr>
<tr>
<td>Beach profiles and offshore bathymetry</td>
<td>Profiles to determine the average shape of the beach. Bathymetry for transforming offshore wave characteristics to values in the nearshore</td>
</tr>
<tr>
<td>Structures and other engineering activities</td>
<td>Location, configuration, and construction schedule of engineering structures (groins, jetties, detached breakwaters, harbor and port breakwaters, seawalls, etc.). Structure porosity, reflection, and transmission. Location, volume, and schedule of beach fills, dredging, and sand mining. Sand bypassing rates around jetties and breakwaters.</td>
</tr>
<tr>
<td>Regional transport</td>
<td>Identification of littoral cells and transport paths. Sediment budget. Locations of inlets. Wind-blown sand transport</td>
</tr>
<tr>
<td>Water level</td>
<td>Tidal range. Tidal and other datum</td>
</tr>
<tr>
<td>Extreme events</td>
<td>Large storms (waves, surge, failure of structures, etc.). Inlet opening or closing. Earthquakes.</td>
</tr>
<tr>
<td>Other</td>
<td>Wave shadowing by large land masses. Strong coastal currents. Ice. Water runoff.</td>
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