CHAPTER 1
1. INTRODUCTION

The zone where land and sea meet is a complex environment. The coastal areas of the world are of extreme economic importance as approximately, two-thirds of the world's population live along the 4,48,000 km coastlines. In most of the highly developed countries, industrial, residential and recreational developments as well as large urban complexes occupy much of the coastal margin. The future expansion in many undeveloped maritime countries will also be concentrated on coastal areas. In order to utilize the coastal zone to the maximum of its capacity, and yet not plunder its resources, an extensive knowledge of this complex environment is necessary for geologists, engineers, oceanographers and coastal planners engaged in the coastal zone management. The general configuration of the beach (Fig. 1.1), changes continuously in response to the time varying forcing functions viz. winds, waves, currents, tides etc.

1.1. Coastal geomorphology of India

India has a long coastline of about 6500 km. The shelf has a gentle uniform gradient. Cliffs and offshore islands are comparatively scarce, while barriers and spits are common. The coastline of India is characterised by varieties of features like rocky headlands, coral reefs, reef-like structures, tidal inlets, estuaries, lagoons, barrier islands, bays, etc. The eastern coastline is essentially alluvial, gently indented and extensively
Fig. 1.1. Definition diagram for the Coastal Zone.
developed in contrast to the western coastline which has highly irregular, cliffed and wave eroded character. (Ahmad 1972). The backshore zone of the beach is commonly marked by the sand dunes or beach ridges. The foreshore is marked by tidal terraces. The plains of the west coast of India are confined to a narrow belt of about 10 to 25 km wide lying between the Arabian Sea and the western ghats extending from Gujarat to Kanya Kumari.

The shoreline of the west coast is one of the submergence attributed to rise in sea level against a stable coast. (Ahmad, 1972). According to him, about 55% of the Indian coastline is fringed by beaches receding in the past few decades. The most remarkable feature of the west coast is the widespread presence of estuaries and lagoons. (Nair, 1987). Almost the entire stretch of the west coast possess relatively similar geological and climatological characteristics.

1.2. Description of the Kerala coast

Kerala coast is a 560 km long narrow strip of land bordering the Arabian Sea at the south western part of the peninsular India extending from latitudes 8° 15' N to 12° 05' N and longitudes 74° 55'E to 77° 05' E and has a remarkable straight coastline oriented in NNW - SSE direction. It is believed to have originated as a result of faulting during the late Pliocene (Krishnan, 1968). Kerala plains are much
wider and less hilly than the rest of the west coast. Recent observations indicate that the shoreline as a whole is dynamic and neotectonically active leading to considerable erosion and loss of surface area. Narrow stretches of sandy beaches are present all along the coastline except in areas of cliffs.

The elevation of the shoreline on the western side bordering Arabian sea ranges from 0 - 5 m. Intervening the ghats and the shoreline are exposures of tertiary formations such as the Miocene Warkalli at Varkala in south and Tellicherry-Cannanore in the north. North of Varkala for about 100 km there are coastal Tertiaries occupying the zone between the extremely narrow alluvial bars towards the shore and the edges of the gneisses and granites interior on the east. This consists of marine fossiliferous coralline limestones and sands and clays with bands of lignite. They are frequently capped by laterite. The present shoreline is straight for over a great part of the length from Calicut to Quilon, but in Cannanore, Trivandrum and Quilon districts, indentations, cliffs and protuberances are present.

The width of the continental shelf along the Kerala coast varies widely from south to north. Major contributions for the shelf deposits are the west flowing rivers. There are 44 rivers flowing west into the Arabian sea which originate from the hills of the western ghats and drain into the backwaters. The major rivers are Pampa, Periyar, Bharathapuzha and Chaliyar (Fig. 1.2) which together drain
Fig. 1.2. Physiography and major rivers of Kerala
35% of the state's average discharge. The rivers of Kerala swell up during monsoon season into gushing torrents and shrinks into modest dimensions during summer months. They carry \(45060 \times 10^6 \text{ m}^3\) of water per year (Anonymous, 1974). The dams constructed across many of these rivers for power generation and irrigation have considerable influence on the sediment budget of the coastal zone.

The beaches of Kerala are composed of fine to coarse grade sands (0.15 to 0.50 mm). The coastal area is mostly of sub-recent to recent sediments. The structure of the coast from Quilon to Quilandy have alluvial belt covered by laterite deposits. Placer deposits of considerable economic importance are present along the beaches of Kerala. The concentration of the heavy minerals like Ilmenite, Monozite, Rutile and Zircon in the coastal area from Neendakara to Kayamkulam is an important feature of the coast. Apart from various shades, the beach material comprises of shell fragments, magnetite, sillimanite and rare earths. The placer deposits of Kerala's coastal stretch occupies a pride place in India.

Muddy bottom shelf extends 50 to 60 kms from the coast to a depth of 100m. Beyond this, the shelf slopes down steeply to 1000m. The bathymetry of the inner continental shelf and nearshore of the south-west coast show considerable variability along its length. The slope of the continental shelf decreases towards north and increases north of Cannanore. (Baba, 1988).
The coastal zone of Kerala is well known for its rich fisheries, placer mineral deposits, water resources, transport facilities, excellent backwater systems and above all a well literate and hard working population. It is also rich with wetlands having mangroves, industries, ports and harbors, tourism and recreational facilities.

1.2.1. Morphological features

Lagoons and estuaries

Along the Kerala coast, between Quilon and Kasargod, long and irregular lagoons are present behind the impressive coastal barriers. Many of the lagoons, locally known as Kayals, are bestowed with numerous islands of different sizes. There are 34 Kayals in this area. Among these lagoons, Vembanad lake is the largest (205 sq.km) followed by Ashtamudi Kayal further south. The Vembanad lake opens into the Arabian Sea at Cochin. Six major rivers, Periyar, Pamba, Manimala, Achankovil, Meenachil and Muvattupuzha discharge into this lake. Lagoons and estuaries play an important role in beach dynamics along this coast.

Bars, spits, headlands and barriers

The south-west coast, as a whole, is well known for most well-developed bars and lagoons. Low cliffs alternating with pocket beaches, promontories, head-lands and bays are present along the coast of Kerala. North of Ponnani, the
shore consists of continuous formation of mainland beaches. North of Trivandrum, the coast is characterised by the presence of barrier beaches except at few places where rocky cliffs and headlands are present. Where the lagoons opens out into the sea across the bars, spits are present with or without submerged sand bars.

The principal influence of the lagoons in-so-far as beach studies are concerned is that they act as sediment traps. A well developed barrier is seen between Neeleswar and Cannanore. The Vypeen Island barrier, north of Cochin, is about 23 km long and 2 km wide. Several barriers are observed near Quilon. Remarkable features of the barriers are their elongated formation with small width.

1.2.2. Physical factors

Climatology of Kerala

Orographic influence on the monsoons plays an important role in the climate of Kerala. In the meteorological map of India, Kerala has a pre-eminent place. It is the gateway through which great rain-bearing south-west monsoon current gains access to the subcontinent year after year by the end of May or in early June and through which the monsoon make its lingering exit towards the end of the year after having dispersed its priceless bounty over the length and breadth of the country (Ananthakrishnan et al., 1979). Average annual rainfall in Kerala is nearly 300 cm, which is
Fig. 1.3. Distribution of average rainfall (Cms) over Kerala
about three times the average annual rainfall of India. The distribution of average rainfall over Kerala state during the south-west monsoon (June-September) and north-east monsoon (October-December) are shown in Fig. 1.3.

Wind

The basic feature of wind distribution over Arabian Sea is the reversal of the wind systems during an year known as the monsoon. The reversals take place predominantly from south-west direction during May-September to north-east direction during December-March. Between these reversals are the transition periods during which weak and variable winds prevail. The typical wind pattern for different seasons (south-west monsoon, north-east monsoon and non-monsoon seasons) are shown in Fig. 1.4. The wind set up caused by wind pushing surface water against the shoreline results in a change of the existing equilibrium profile of the beach. The wind is also significant on a wide sandy beach as large quantities of sand can be blown from the beach.

Tides

The tide is an important factor influencing the beach dynamics. Tidal currents which are oscillatory in nature are particularly important in transporting sand in shoals and in the formation of sand waves on submerged bars around entrances to bays and estuaries, but have virtually no effect on uninterrupted straight shorelines, except in areas with
Fig. 1-4. Seasonal Predominant wind pattern around Indian region.
very large tidal ranges. The tides of Kerala are mixed, semidiurnal in nature and occur within the microtidal range (<2m).

Nearshore waves

Most of the dynamic nature of the beach and nearshore zone is the direct or indirect result of wave action. Wave information is vital in design and construction of various coastal and offshore structures, ports, harbors and for various ocean engineering projects. For an understanding of long term variability of beaches, and for various developmental activities of the coastal region, wave data is very much essential. Energy mainly from wind, imparted to the water produces wave motion and are modified by the general configuration and contour of the near shelf. Waves are the most important cause of alteration and evolution of our coastlines. During south-west monsoon, due to the strong wind action, increase in wave activity with long swells and high breakers has been observed along the Kerala coast. Considering the orientation of the coastline (NNE - SSW), wave directions varying between 180° - 340° are more significant in the shore processes. In the south-west monsoon season the predominant direction of waves fall between WSW and WNW.

Longshore currents and rip currents

One of the major effects of wave action in the shallow water is the generation of longshore current, which plays an
important part in the longshore movement of material. As the waves arrive obliquely to a straight coastline and break at an angle to the beach, they generate longshore current flowing parallel to the shoreline. This wave induced current is confined to the nearshore, rapidly decreasing in velocity beyond the breaker zone. The nearshore currents varying in space and time are responsible for many of the beach processes.

Rip currents are the most noticeable of the exchange mechanisms between offshore and surfzone. Rip currents are strong and relatively narrow jets of seaward flowing currents. The rips are fed by a system of longshore currents. Bowen (1969) has shown that cell circulation with rip currents is produced by longshore variation in the wave breaker heights.

Littoral transport

The longshore current transports beach sediments for many kilometers in the longshore direction. Littoral transport of sand occurs in two modes. 1) parallel to the shoreline due mainly to the effect of longshore current, which is referred to as longshore transport and 2) perpendicular to the shoreline due to swash and backwash, referred to as the beach drift.

The direction of longshore transport varies from season to season, day to day or hour to hour depending upon
the location and direction of the storm winds which generate waves. It results from the stirring-up of the sediments by breaking waves and movement of sediment by the longshore component of wave induced current. The beach drift occurs as a result of the stirring up of the bottom sediments in breaker zone which tend to be carried up the beach to the limit of swash of the breaking wave and back with back wash. The volume of the beach drift is determined primarily by wave steepness, sediment size and beach slope. Determination of the amount of sand that can be moved in the onshore-offshore mode is difficult and entails detailed profile surveys.

Mud banks

Mud bank is a phenomenon peculiar to the south-west coast of India. The occurrence of mud banks provides safe and smooth anchorage even during the rough wave conditions of the south-west monsoon. As many as 27 locations are identified where mud banks had appeared along the Kerala coast. This has been classified into three regions, viz. the southern strip (Thrikkunnnapuzha - Alleppey), the central strip (Chellanum-Munambam) and the northern strip (Calicut pier-Muzhappilangadi) by Nair (1983). The mud banks are reported to be decisively affecting the equilibrium conditions thereby causing shoreline instability of the coast. They trap the littoral materials from either side thereby preventing it's downdrift, causing accretion within the mud banks and erosion on down drift sides.
1.2.3. Man made structures

Apart from natural phenomenon, the man-made structures along the coastline act as barriers to the material and energy balance, and produce adverse effects on the stability of the nearby coast. Kerala's maritime activity is mainly related to the major port at Cochin. There are 3 intermediate ports and 11 minor ports along this coast. Some of the man-made barriers are dredged channels, jetties, groins, sea walls and breakwaters. The structures constructed along these ports have triggered many environmental problems in addition to upsetting the sand balance in many locations of the coastal zone.

1.3. Scope of the present work

The sandy portion of the coastal zone is a complex and dynamic environment which is investigated in detail in this thesis. The general configuration of the beach changes continuously, in response to the variations in the forcing functions namely winds, waves, currents and tides on a similar time scale as these forcing mechanisms. The present work is aimed at a theoretical and field assessment of the physical processes involved in the shoreline development and beach stability along the entire stretch of the Kerala coast from Kasargod in the north to Trivandrum in the south.

Along the Kerala coast, the beaches are subjected to changes of varying degrees in response to seasonally varying
monsoonal forcing. At times, the beach sand containing valuable minerals is lost due to erosion which may be local or seasonal. It is from this viewpoint that studies on problems of the coastal and nearshore areas along the coast of Kerala received considerable impetus in recent years. There had been many studies in the past, concerning various aspects of beach/coastal dynamics along the different stretches of the coast of Kerala. However, studies along the entire stretch of the coast of Kerala combining both the theoretical model and field observations are practically lacking. It is in this background that the problem "Beach dynamics of Kerala coast in relation to land-sea interaction" has been taken up in this study. The present study aims at examining 1) the dynamic response and stability of different types of the beaches along the coast of Kerala, 2) the predictability of the beach changes along the entire stretch of the Kerala coast, both theoretically and empirically. The result of this study could provide the basic information required for various developmental as well as recreational purposes.

The objectives of the present study are achieved through following:

1) The application of a numerical wave transformation model for the Kerala coast to study the distribution of nearshore wave energy for the predominant deep water wave directions and periods.
2) The application of the Empirical Orthogonal Function (E.O.F) analysis to the beach morphology and grain size data to separate the temporal and spatial variations and thereby relate the E.O.F mode of beach morphology and grain size to the waves.

3) The study of the variations in grain size of beach sediments from Kasargod to Trivandrum and to bring out the physical factors controlling different environments of the beach.

4) The estimation of the longshore sediment transport based on the field observation. (LEO data - Littoral Environmental Observation data).

1.4. Area of Investigation

The field observations consist of a detailed survey on waves, littoral currents, beach sediment size and beach morphology for a period of one year along the Kerala coast from Kasargod (Lat. 12° 13'N and Long. 74° 58' 24''E) to Trivandrum (Lat. 08° 29' 11''N and Long. 76° 54' 12''E), consisting beaches of different morphologic types.

Due to the geographical variations of the nature and type of beaches constituting the Kerala coast, the responses of the individual type of beaches is different, though the monsoonal forcing is more or less same. Inview of this, 8 sites were selected along the entire stretch of the kerala coast (Fig. 1.5) for the field observation by taking into
Fig. 1.5: Region under study showing the bathymetry and location of stations.
account the morphological settings. They have been chosen to represent headland beaches, barrier beaches, open coast beaches, beaches exposed to low and high energy environment and beaches in the vicinity of mud bank formation.

1.5. Previous Studies

Much work has been done in India and elsewhere on various types of coastal process phenomena.

A good deal of literature have been generated in regard to the general principles, beach set up, various processes and structure of the beaches (Bascom, 1954, 1980; Inman and Fratuschy, 1966; Ippen, 1966; Komar and Inman, 1970; King, 1972; Shepard, 1973; Komar, 1976; Goldsmith et al., 1977; Curt, 1990; Wiel, 1991). They have conducted various experimental as well as model studies on this subject. The Coastal Erosion Board (CEB), Army Crops and the CERC (Coastal Engineering Research Centre) of United States have made substantial contributions on beach processes and configuration. The stability of beaches in California and north Carolina have been extensively described by Dingler (1981) and Dolan (1965) respectively. Beach processes and erosion in various beaches of United states have been studied by Brunn (1954), Caldwell (1956), Giles and Pilkey (1965) and Ingle (1966).

The first attempt to quantify the longshore sediment transport of sand has been made by Scripp's Institution of
Oceanography. Many theories have been developed using the relationship between the wave forces and the transport of sediment (Krumbien, 1944; Savelle, 1950; Johnson, 1956; Galvin, 1972; Komar and Inman, 1970; Komar, 1976; Walton and Bruno, 1989). Extensive studies on nearshore currents have been made over the last several years. Several investigations have been made both in the field and laboratory to obtain a quantitative measure of the field of motion in relation to the breaker characteristics utilizing the concept of radiation stress (Longuet-Higgins and Stewart, 1962). Many theories have been initiated to derive the nature of circulation in the surf zone (Bowen, 1969; Inman and Bagnold, 1963; Sonu, 1972; Noda, 1974). All these studies have shown the occurrence of discrete circulation cells for normal incidence of wave rays. Sediment drift estimations based on empirical relationship developed from quantitative estimates of littoral flows through wave refraction studies and field experiments have been made along various coastlines of the world. Pyokari and Lehtovaara (1993) have studied the beach material and its transport in accordance with the predominant wave directions on some shores in Northern Greece. Bagnold (1963) and Horikowa (1978) have conducted model experiments and explained the formation of beaches. Friedman (1967) has given a detailed picture of dynamic processes and statistical parameters and compared the size frequency distribution of beach and river sands. These studies, both experimental and theoretical, have brought out the importance of topography
and radiation stress in the realistic derivation of the complicated field of motion within the surfzone.

Earlier studies of the morphology of sandy beaches, for example those reported by Eliot (1974), Wright et al. (1978, 1979), Chappel and Eliot (1979), Short (1979), Short and Wright (1981) and Frew et al. (1983) have described a variety of morphologic patterns and highlighted their susceptibility to changes. Previous statistical analyses of beach profile data have been stochastic in nature or have treated the changes in profile configuration as Markov processes (Sonu and Young, 1970; Sonu and Van Beek, 1971; Sonu and James, 1973). The E.O.F method has been applied for morphological studies of the beaches at Torrey Pines in United States (Winant et al., 1975; Aubrey, 1979; Aubrey et al., 1976), at Gorlestone and Great Yarmouth (Aranuvachapun and Johnson, 1979) and at Coledale (Clarke et al., 1984) and for prediction of beach changes at Torrey Pines (Aubrey, 1978).

Studies on different coastal processes relating to the east and west coasts of India are briefly reviewed in the following sections.

East coast of India:

Detailed coastal geomorphological studies have been carried out first by Andhra University (1954 and 1958), along the east coast of India. In addition, littoral processes
along the east coast have been investigated by La Fond and Prasada Rao (1956), Sastry (1958), Subba Rao and Madhusudhana Rao (1970), Varadarajulu (1972), Reddy et al. (1979), Chandramohan et al. (1981), Vasudev (1982), Chandramohan and Narasimha Rao (1984), Chandramohan and Rao (1985) and Sundar and Sarma (1992). Wave refraction studies using graphical method has been carried out by Prasad et al. (1981) and Dhanalakshmi (1982). Sediment dynamics along the east coast has been studied at Kakinada Bay by Subba Rao (1967) and at Madras and Puri by Kanth (1984). Grain size trends in the Kakinada beach have been studied by Sathyaprasad et al. (1987). Other studies relate to analysis and hindcasting of wave data along the coast. (Sathe et al., 1979; Reddy et al., 1980; Mukherji and Sivaramakrishnan, 1982a, 1982b). Chandramohan et al. (1991) compared reported wave data with instrumentally measured waves at Kakinada coast.

West coast of India:

Since coastal processes along the west coast have been investigated by many researchers in relation to various aspects of the beach problems, they have been broadly classified subjectwise herein.

Geomorphology: Formation of the Kerala coast with its network of lagoons and estuaries and rich and heavy mineral sands has been studied by Prabhakara Rao (1968). Studies on the origin and distribution of black sand concentration on the southern coast of India have been carried out by
Aswathanarayana (1964). Later, Jacob (1976) described the general geology of south Kerala including the structure, tectonics and erosion. Soman (1980), Thiagarajan (1980) have reviewed the earlier studies on geology and geomorphology of Kerala.

Studies on morphological changes at selected places along the west coast of India in relation to wave energy have been made by Veerayya (1972), Veerayya and Varadachari (1975) and Murty (1977). The coastal evolution of Kerala with special reference to coastal instability and erosion has been reviewed by Varadarajan and Balakrishnan (1980). Coastal geomorphology of Kerala has been described by Nair (1985). Report by Kerala Engineering Research Institute, KERI (1971) shows that 600 m wide belt of land has been lost during a period of 120 years from 1850 to 1970. Shoreline changes based on historical records have been investigated by Ravindran et al. (1971). A comprehensive report of the coastal geomorphology of this area is available in the text book by Ahmed (1972).

Comparative study of the maps of 1850 to 1966 by John and George (1980) suggested that a major part of Kerala coast has receded during this time. Shoreline changes on Kerala coast between Ponnani and Quilon for a period of 120 years have been studied by John and Verghese (1976) based on authentic maps and charts. However shoreline fluctuation studies over a time gap of 55 years (1910-1965) by Thrivikramji et al. (1983) using Survey of India toposheets
have shown that the Kerala coast has gained 41 km$^2$ by accretion and lost 22 km$^2$ by erosion.

**Nearshore waves:** Studies to understand the wave climate were initiated in the fiftees mainly for understanding coastal processes (Varadachari, 1958; Sastry, 1958). The need for an in-depth study of the waves in the seas surrounding India was felt in the late sixties and early seventies. Some information on wave groupness along the south-west coast is available for Mangalore (Dattatri, 1973) and for Vizhinjam (Namboothiriri, 1985). Non dimensional time series data on waves measured by wave rider buoys are available for limited locations and duration. (Dattatri, 1973; Baba, 1985; Nayak et al., 1990, Baba et al., 1991). The wave studies along the south-west coast have been conducted by many researchers (Swamy et al., 1979; Gopinathan et al., 1979; Murty and Varadachari, 1980; Varma et al., 1981; Baba et al., 1987; Joseph et al., 1984; Baba and Harish, 1986; Harish and Baba, 1986; Baba, 1987; Muraleedharan, 1991). Ship observed data, reported by I.M.D have been analysed by Srivastava and George (1976) and Thiruvengadathan (1984). Hindcasting studies also have been taken up for this period by Srivastava (1964), Dattatri and Renukaradhya (1971), Rao and Prasad (1982) and Joseph (1984). The ship reported waves around the Indian coasts have been compiled for the wave statistics of different regions and prepared in the form of atlases and charts. (Srivastava et al., 1968; NPOL, 1978; Varkey et al., 1982; Chandramohan et al., 1990).
The analysis of the wave data (Baba et al., 1985; Thomas and Baba, 1983) collected by CESS for five years have helped in understanding the wave climate and its year-wise variations at different locations of the Kerala coast. They have reported that the wave climate along the coast showed considerable variation, with highest wave activity at Trivandrum as compared to the northern beaches. The wave climate is evidently controlled by the meteorological conditions in the neighboring Arabian Sea and Indian Ocean. The highest wave activity has been observed with the occurrence of Southwest and Northeast monsoon winds. It has also been revealed that the wave power potential varied from place to place along the beaches of Kerala and Valiyathura (Trivandrum) recorded the highest wave power (4 - 25 Kw/m) throughout the year. (Baba et al., 1987).

Wave transformation and Refraction: Areas of erosion and accretion have been identified by the construction of refraction diagrams along the west coast of India by Das et al. (1966), Reddy (1970), Sastry and D' Souza (1973), Gouveia et al. (1976), Antony (1976), Varma and Varadachari (1977), Veerayya et al. (1981), Shenoi and Prasannakumar (1982) and Prasannakumar et al. (1983). The sediment characteristics, beach volume changes and the wave transformations have been studied by Reddy and Varadachari (1972), Murty and Varadachari (1980), Hameed et al. (1984), Prakash et al. (1984), Baba (1988a), Ramamurthy et al. (1986) and Mallik et al. (1987). Only limited studies have been reported on wave
transformation using numerical models (Mahadevan and Renukaradhya, 1983; Kurian et al., 1985a). Kurian (1987) and Chandramohan (1988) have studied the wave transformation of deep water wave in shallow water using refraction models.

Beach erosion and stability: The impact of erosion on the socio-economic sphere has inspired the researchers to account for the processes that impart instability to the coast. Studies on various beach processes, stability and structure of the Kerala coast have been made by Narayanaswamy (1967), Nayak (1970), Dattatri and Ramesh (1972), Ahmed (1972), Kurup (1977), Shenoi and Prasannakumar (1982), Shenoi (1984), Prasannakumar (1985), Murty and Veerayya (1985), Suchindan et al. (1987) and Samusuddin and Suchindan (1987).

Beach erosion and geomorphology of the Kerala coast have been studied by Das et al. (1966), Varma and Varadachari (1977), Moni (1980), Sreenivasan et al. (1980) and Baba (1979b, 1981a & 1986). Chavadi and Bannur (1992) have studied the relationship between the changes in volume of the foreshore and its slope. A review of erosion and shore protection works along the Kerala coast has been provided by Achuthapanickar (1971).

Some insight into the management problems related to coastal erosion in Kerala has been provided by Kurup (1974), Baba (1979b) and Moni (1981). A critical appraisal of coastal erosion of Kerala has been done by Raju and Raju (1980).
Monsoon-induced seasonal variability of the beaches has been studied by Shenoi et al. (1987) and Kurian et al. (1985). Studies on beach profile conducted by Thrivikramji et al. (1983) during the pre-and post-monsoon showed that all along the coast from Cape Comorin to Mangalore, 30 million tons of sand were removed by waves from the shore face of Kerala while 11 million tons were added in different sectors. The effects of seawall constructed along the beach were discussed by Murty et al. (1980). Reddy et al. (1982) have made valuable contribution to the study of formation of beaches, its set up and the different processes responsible for causing drastic changes on the beach face. The beach cycles and the seasonal changes at Valiyathura, Trivandrum were recorded by Murty and Varadachari (1980) and along the Quilon beaches by Prakash and Aby Verghese (1985).


Only a very few studies have been made using E.O.F method for the Indian beaches. The responses of the barrier beaches of the south-west coast of India due to the monsoonal forcing have been studied using E.O.F analysis by Prasannakumar (1985) and Prasannakumar and Murty (1987) and the changes in profile configuration of the beaches along the
west coast of India have been compared by means of E.O.F analysis by Shenoi et al. (1987) and Harish (1988).

**Sediments and Grain sizes**: Viswanathan (1949) has studied the physical and chemical characteristics of the beach sands of south Kerala coast for the first time. Nair and Pylee (1965) have given the grain size characteristics and Calcium carbonate content of the shelf sediments of the west coast of India. Studies on beach sediments have been carried out by Murty et al. (1966) and Nair et al. (1973).

Murty et al. (1966) have investigated the nature of the beach sand level changes during a tidal cycle on the beaches along the south-west coast of India. Varadachari and Murty (1966) studied the sedimentation pattern of the beaches along the south-west coast. A detailed study of geochemistry of sediments of the west coast of India has been made by Murty et al. (1970). Studies on movement of sediment using radioactive/fluorescent tracers have been carried out by Nair et al. (1973). A comprehensive report on coastal geomorphology of recent shelf sediments has been given by Siddique and Mallik (1972).

Physical aspects of shoreline dynamics and the textural characteristics have been given in some detail by Murty (1977). The grain size characteristics have been utilized mainly to distinguish major depositional environments (Veerayya, 1972; Veerayya and Varadachari, 1975; Chaudhri et al., 1981; Prakash et al., 1984; Ramamurthy et
A study on the graphic measures of the beach sand size distributions in the foreshore and breaker zone has been carried out by Samsuddin (1986). Textural and mineralogical variations of beach sands along the Kerala coast have been studied by Purandara et al. (1987) and Unnikrishnan and Dora (1987). Previous studies pertaining to the inter-relationship between wave-refraction, shoaling and ultimate effects on the transportation of sediments are numerous (Nair et al., 1973; Reddy and Varadachari, 1972; Varma, 1971; Murty and Varadachari, 1980; Shenoi et al., 1987). The seasonal variations in textural characteristics of the beach sediments in relation to beach profiles of northern Kerala, between Mahi and Talapadi have been studied by Suchindan et al. (1987). Sediment characteristics, processes and stability of the northern Kerala coast beaches have been presented by Samsuddin et al. (1991).

**Longshore current**: A number of studies have been conducted on longshore currents along the west coast (Chandramohan and Rao, 1984; Hameed et al., 1986; Krishnakumar et al., 1989). Structural aspects of the surfzone currents have been presented by Murty et al. (1975) and Murty and Veerayya (1985). The erosion/accretion pattern and the related longshore current variations have been studied in detail along the coastal stretch of the northern Kerala by Samsuddin and Suchindan (1987), Suchindan et al. (1987) and Samsuddin et al. (1991). Wave induced nearshore flow pattern has been studied by Prasannakumar et al. (1990).
Littoral transport: Many authors have summarised the littoral transport of beach sediments (Sastry, 1958; Nambiar and Moni, 1966). Along the west coast of India, quantitative determination of littoral flows have been made only at few localities. (Sastry and D'Souza, 1973; Antony, 1976; Lalithananda Prasad et al., 1981; Shenoi and Prasannakumar, 1982; Prasannakumar et al., 1983, 1990). Sediment transport along the west coast of India has been studied by Chandramohan et al. (1989) and Chandramohan and Nayak (1991). Sediment movement in relation to the wave refraction and beach erosion and accretion has been studied by Varma (1971), Nair et al. (1973), Reddy and Varadachari (1972), Murty and Varadachari (1980) and Baba (1985). The sediment movement on Aligagga beach has been studied by Hanamgond and Chavadi (1993) using E.O.F analysis and volume changes have been compared to better understand the on-offshore sediment movement.