



UNIVERSITI PUTRA MALAYSIA

**GEOPHYSICAL STUDIES IN SETIU
LAGOON-ESTUARY SYSTEM**

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GEOPHYSICAL STUDIES IN SETIU
LAGOON-ESTUARY SYSTEM

by

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DEDICATION

To my parents
and
my son Ahmad Nizamuddin

Your sacrifices, spiritual support, and constant encouragement will
forever be remembered.



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'GEOPHYSICAL STUDIES IN SETIU LAGOON-ESTUARY SYSTEM'

oleh

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April, 1988

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Kawasan kajian adalah merupakan sebuah lagun muara cetek yang kitaran airnya adalah separa-campur dan dibentengi oleh benteng pasir. Corak pergerakan dan percampuran air berubah-ubah mengikut perubahan cuaca dan kadar curahan air sungai. Muara sungai Setiu ini mempunyai kepentingan oseanografi kerana ianya adalah salah satu muara sungai yang terbesar di perairan pantai Terengganu dan terdapat pula dua buah sungai besar yang mengalir ke dalamnya.

Kajian ke atas sistem ini telah dijalankan dalam tahun 1985 dan 1987. Ukuran parameter-parameter fizikal telah diambil pada tiap-tiap bulan dan juga setiap kali stesen pemerhatian dibuat. Lebih dari 30 sampel enapan diambil di sekitar stesen kajian.



Suhu menunjukkan perbezaan berlaku mengikut musim dan secara amnya suhu di mana-mana titik di dalam sistem ini adalah sekata. Keadaan perubahan kemasinan juga menunjukkan perubahan bermusim yang ada hubungan dengan kemasinan air sungai. Stratifikasi tegak terdapat di muara tetapi kekuatan stratifikasi berubah dengan masa dan kadar curahan air sungai yang masuk ke muara itu. Stratifikasi yang berlaku adalah disebabkan oleh perbezaan kemasinan dan tidak dari perbezaan suhu. Keadaan kemasinan di saluran masuk muara berubah dari hampir menjadi baji kemasinan hingga kepada keadaan stratifikasi yang lemah. Dua kumpulan besar air juga telah dikenalpasti di muara sungai ini. Arus yang terdapat di dalam muara adalah disebabkan oleh curahan masuk air sungai dan proses pasang-surut. Arus ketika air menyurut adalah lebih laju daripada arus ketika air memasang oleh kerana keadaan topografi dan geografi kawasan kajian. Keadaan ini juga merupakan faktor yang menentukan kitaran air di dalam sistem ini. Daya angin permukaan juga memainkan peranan di dalam menentukan kitaran pergerakan arus. Kebanyakan tiupan angin laju adalah semasa musim monsun timur laut. Ini juga mempengaruhi gelombang dan ombak laut. Arus bujukan pantai adalah penting di dalam pemindahan enapan ke dalam sistem ini.

Sampel-sampel enapan kebanyakannya adalah pasir halus ke-tersangat halus dengan nilai kepencongan yang kebanyakannya negatif. Kawasan muara sungai adalah dipengaruhi oleh daya pengangkut dan hakisan. Tiada terdapat kelodak dan tanah liat di muara sungai ini adalah kerana kurang terdapatnya faktor pemendapan yang dipengaruhi oleh arus kuat berbanding dengan kawasan lagun.



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The study area is a shallow, bar-built, partially mixed lagoon-estuary system, which undergoes changes in its pattern of movement and mixing due to meteorological and river run-off changes. The Setiu estuary is of primary oceanographic interest since it is one of the large estuaries of the Terengganu coast into which two major rivers empty.

A study of the system was conducted in 1985 and 1987. Measurements of the physical parameters were made monthly and during the anchored-stations period. More than 30 sediment samples were collected around the sampling stations.



Temperature shows a seasonal variation and is generally isothermal at any single point in the system. Salinity variation is also seasonal and related to periods of high river discharge. Vertical stratification is present in the estuary but its intensity varies overtime with river discharge. The stratification is the result of salinity difference rather than variations in temperature. Salinity condition varies from near salt wedge to weak stratification near the estuary's inlet. Two major 'water masses' are identified in the estuary area. Currents in the estuary area are due to river inflow and tides. The ebb flow is stronger than the flood due to the geographical and topographical nature of the system. These also control the circulation in the system. Surface wind stress also plays a role in setting up the flow pattern. Most of the stronger winds occur during the North-east monsoon. This also influence sea waves and swell. The long-shore current is important in transporting sediment to the system.

The sediment samples were mostly fine to very fine sands with mostly negative skewness. The estuary area is under the influence of transportative and erosive force. The lack of silt and clay in the estuary is attributable to less depositional factors under the influence of stronger current as compared to the lagoon area.



CHAPTER 1
INTRODUCTION

General Introduction

Man's interest in the use of estuaries and lagoons has been well-established in the past decades. Estuaries and lagoons are very important eventhough they cover only a small proportion of the total world's surface. They have been the main centers of man's development because of their sheltered anchorages and the navigational access they provide to a broad hinterland. Apart from that estuaries and lagoons are used for many other purposes. These include:

- 1) Recreation;
- 2) Commercial fishing;
- 3) Abstraction for industrial and agriculture use;
- 4) Tourism and amenity;
- 5) Nature conservation;
- 6) Tidal power;
- 7) Source of water supply for industry or for the cooling of power stations; and
- 8) Disposal of effluent.

Therefore, there are a number of scientific and practical reasons for the study of estuaries and lagoons. One of the main reasons for the study is to obtain background information to aid decision-makers in the uses and management of the estuaries and lagoons. The background information is needed by the engineers for the proper engineering design and maintenance in the estuaries and



lagoons. In addition, the background information is important in pollutant and sediment transport studies.

For future developments along the coast of Malaysia, a basic understanding of the physical and geological processes is necessary. In the past, especially in Malaysia, the major interest in estuaries and lagoons has been primarily biological, resulting in a notable lack of literature on specific coastal, physical and geological processes. Therefore, there is little background information to aid decision-makers and engineers in predicting the success of the developments. Lack of information on the coastal and nearshore processes may result in some undesirable situations. The study of the hydrodynamic, physical properties and sedimentation in estuaries and lagoons will help to provide baseline information and a better understanding of coastal processes.

It is of interest to note that concepts which have been applied with reasonable success to the deep oceans are found to have only a few applications to the lagoonal and estuarine problem. For instance, assumptions which held true in establishing boundary conditions for the deep oceans no longer held true for the smaller, shallow estuaries. Today, many basic questions concerning estuarine dynamics remain to be answered satisfactorily. Thus studies on the estuaries and lagoons should be considered as an important subject in order for us to progress.

Geophysical Studies in Estuaries and Lagoons

In the past, emphasis in the field of physical and geological oceanography has much been directed toward the study of the structure and circulation of the deep oceans. The study of lagoonal



and estuarine problems did not become a recognised phase of oceanography until the turn of the century, and then the major endeavor was centered in Europe. It was not until the last thirty years that any noteworthy efforts were made on this continent into the study of estuaries and lagoons. Sanitary engineers have had to deal with a problem of sewage disposal in small estuaries for sometime, but it was only after the end of World War II that an appreciable interest was displayed by the oceanographer in the study of the physical and geological problems associated with the shallow coastal regions of the oceans. Following World War II, the problems of industrial pollution of estuaries and lagoons precipitated on interest of an oceanographic nature in the dynamics, circulation and sedimentation of the estuaries. To the physical oceanographer, the water movement, circulation patterns, and flushing rates were among other things that present interesting and challenging problems in hydrodynamics. The physical features, moreover, largely control the transport of material in suspension and its erosion or deposition; topics with which the geological oceanographer is concerned about. Therefore the combination of the studies on the physical and geological processes of the estuaries and lagoons can be considered under a single subject; namely geophysical studies. Unfortunately, the study of the character of an estuary or lagoon is not a simple, clear-cut task. The work is complicated by the fact that the system is ever-changing. Each estuary proves to be entity unto itself, having its own unique characteristics. Differences in bathymetry, geomorphology, fresh water discharge, tidal ranges and numerous other parameters make it difficult to speak in generalities about estuaries as a group. A satisfactory explanation of the dynamics of



one estuary may not satisfies to an explanation of the dynamic of any other estuary. However, once an estuary can be classified as a particular dynamic and geologic type, theories and techniques that have been proven successful in estuaries which are then known to be similar can often prove useful in further understanding the estuary of concern.

Ketchum (1950) published the first of several papers associated with the circulation of tidal estuaries (Raritan Bay). Other studies undertaken in estuarine and coastal areas (Prictchard, 1952; Bowden, 1967; Drinkwater and Osborn, 1975; Allen, 1971; Costa 1983, Beer 1983; Moore and Slinn, 1984, Phillips, 1985 and Dyer, 1986) led to the selection of six basic parameters for measurement in this study.

These are:

- (1) Current velocity and direction;
- (2) Tidal height;
- (3) Salinity;
- (4) Temperature;
- (5) Wind velocity and direction; and
- (6) Wave characteristics.

The measurement of these parameters, and subsequent deductions have led to a better understanding of a very complex system, the lagoonal-estuary system. The physical parameters, moreover, largely control the transport mechanism of sediments. Analysis of the textural parameter to delineate transport mechanisms and depositional environment of sediments is widely employed in studying modern sedimentary provinces. Several approaches have been used to interpret depositional environment from grain-size distribution such

as plotting skewness versus sorting (Friedman 1961) and analysing cumulative curve shape (Visher, 1969).

Definitions of the Estuary and Lagoon

Classically, a lagoon is a shallow body of water extending along inside of a barrier (Shepard, 1973). The most commonly accepted definition of an estuary from an oceanographer has been expressed by Pritchard (1967);

"An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with freshwater derived from land drainage".

It should be noted that this definition limits the estuary to the landward limit of salinity intrusion, thus possibly not including the entire body of water under consideration. There are further definitions based on geomorphology and biological consideration, which give rise to the question of the difference between a lagoon and an estuary. For instance, Webster's Dictionary defines a lagoon as a shallow sound, channel, pond or lake near or communicating with the open sea. Caspers (1967), has distinguished between these two types of water bodies on biological considerations. He states that a stable body of brackish water is a lagoon, whereas a basin that shows periodic changes in the mixing of fresh and marine water is an estuary.

Johnson (1919) has gone as far as differentiating estuaries from lagoons by the influences of geological coastline development. Emery (1967) states that lagoons are typical of areas where



continental and coastal plains are wide and nearly flat because lagoons have been long-conceived as being caused by the marine deposition of offshore bars in areas of low relief. Estuaries, on the other hand, are related to continental shelves and coastal plains that are narrow and of high relief, mainly because they are formed by drowned river valleys, glaciers and other tectonic processes. In geomorphic terms, an estuary is an inlet of the sea reaching into a river valley as far as the upper limit of tidal rise (Fairbridge, 1980). Furthermore, estuaries can be modified by the regional history of sea level, morpho-tectonic factors, climatic factors, freshwater, and sediment supply.

Thus from the definitions described above, it seems that the water body at Setiu not only fits the description of a coastal lagoon, but also agrees with Pritchard's definition of an estuary. Furthermore, due to its geography and freshwater inputs, the water body exhibits both lagoonal and estuarine characteristics. The water body under consideration can therefore be conveniently divided into two regions which will hereafter be referred to as the estuary area and the lagoon area.

Formation and Evolution of Estuaries and Lagoons

Shubel and Hirschberg (1978) state that the origin of estuaries is an event strongly influenced by the climatic processes of glaciation and de-glaciation that control sea-level changes. Estuarine formation may be due to other phenomena, such as tectonic activity. Faulting may have markedly influenced the formation of estuaries along the coastline.