CHAPTER 132

Geomorphological Analysis of a Beach and Sandbar System

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Abstract

At Yunlin county a major development of over 10,000 ha of reclamation is being planned for port related industries. The development is taking place along a coast that bordered by Choshui river and the Wai-San-Ting sandbar. Detailed modeling using MIKE21 package with wave, flow and sediment transport modules were used to assess the morphological changes. Four such "relict" deltas were identified according to its ancient river courses. The decay of the sandbars was mostly independent due to the major discontinuities at sandbar headlands and tidal channels. The analysis of the complex morphological processes has provided an important insight into the probable impacts of coastal developments and guided the expensive and time-consuming model operations.

Introduction

At Yunlin county a major development of over 10,000 ha of reclamation is being planned for accommodating large scale port related industries and including a power plant and other developments. The reclamation, which covers shallow coastal areas along a 40 km length of coast, will be served by two new deep water ports.

The development is taking place along a stretch of coast that bordered in the North by Choshui river and in the South by the unique shoreline attached Wai-San-Ting sandbar. Wai-San-Ting, over 20 km long, is Taiwan's largest coast bar feature and morphologically is very active (Figure 1). Typhoons and a predominant NNE wind and wave climate approaching at very oblique angle to shore together with strong tidal currents are the main

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features shaping the existing coastline development.

During the six month winter period, the most frequently wave direction is NNE-N at offshore with 1.5-2 m in height, 5-6 second in period. In summer season, the most wave is coming from SSW direction with 0.5-1 m in height, 4.5-5.5 second in period. The tidal range is about 3-3.5 m in Yunlin coast with maximum current velocity of 1.5 m/s. Under these very rough sea conditions, a careful prediction is needed for the impacts' studies of the major reclamation project on the adjacent coast and sandbar systems for the Master plan study.

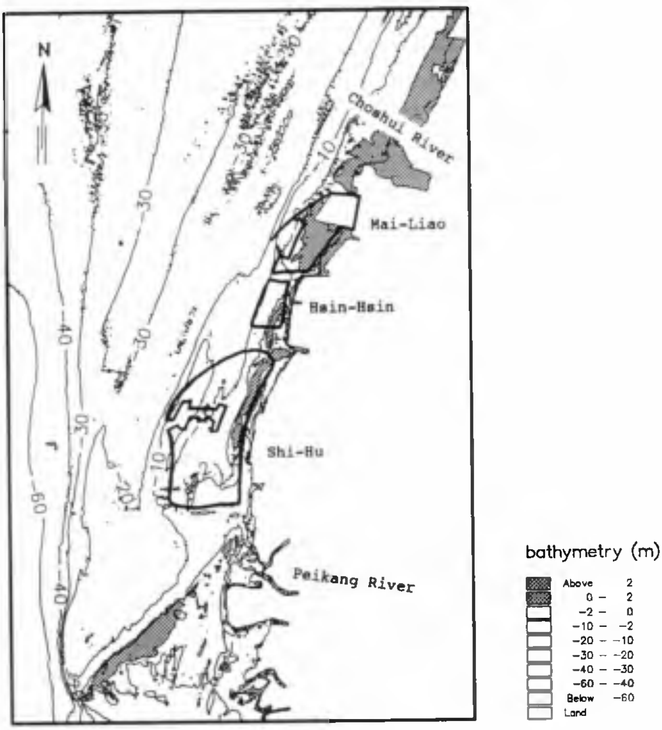

Figure 1 The Layout of Yunlin Offshore Industrial Estate in Yunlin Coast

<u>Historical Development of Yunlin Coast</u>

Most of the sediment between the shore and water depths of, say 20 to 30 m, originate from the various rivers and deposited in the last 100 to 300 years. At least four rivers have played an important role in the Yunlin coast, namely (from south to north) the Peikang river, the Old Huwei river, the New Huwei river and the Choshui river. In the last 300 years, these four rivers were the tributary of the Choshui river system, the old river channel traces of these rivers are shown in figure 2. The first three mentioned rivers transported much more sediment in the last century than nowadays when they were the main channel of the Choshui river during the flood season.

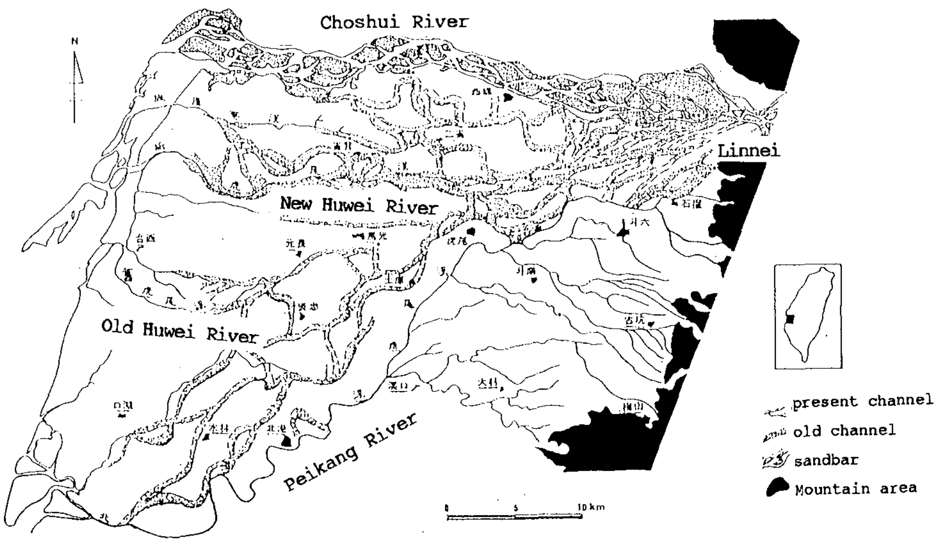

Figure 2 The old flow channel of Choshui river

In order to control the flood, several dikes and dams were constructed near the Linnei in 1911. The effect of these dikes was that the most of the drainage area of the Peikang river and the Old and New Huwei rivers were largely reduced. Their role as main sediment supplier to the coast stopped almost instantly. On the other hand, the Choshui rivers become the only sediment and water supplier to the coast. The consequence of this disturbance to the coast is the old river deltas are shrinking according to the reduction of the river sediment supply.

.Figure 3 shows the historical development of the Wai-San-Ting coast line based on old map and remote sensing images. This historical movement of the sandbar system reflects this disturbance of the old Yunlin coast. The present-day coastal morphology still reflects the importance of the Peikang river and the Old Huwei river. The Wai-San-Ting and Pao-Zi-Liao sandbar are most likely the remnants of the deltas of these rivers. The disturbance of the old balance between river discharge and marine forces has results in significant morphological changes of these "relict" deltas. This is the more true for the wave dominated areas above, say, MSL -10 m. Due to the long morphological time scale at the sea bed below MSL -20 m, it still reflected the "old" situation of several decades ago. Wai-San-Ting has steadily moved southwards with an average speed of 150 m/y. In the last two decades this southward movement took slowly rate of 75 m/y (Tsai and Huang, 1992). The orientation of depth contour of Wai-San-Ting has also undergone some changes. While the orientation of LW-line in 1932 was perpendicular to 305 degrees North, this is presently perpendicular to some 325 degrees North. This rotation took place mainly in the period among 1947 and 1972, the same period in which the largest southward movement occurred. The height of Wai-San-Ting has also undergone changes. In early time, Wai-San-Ting was a typical barrier coast, with heights above MSL along the entire coastline. Today, a lot of part of Wai-San-Ting is under the MSL.

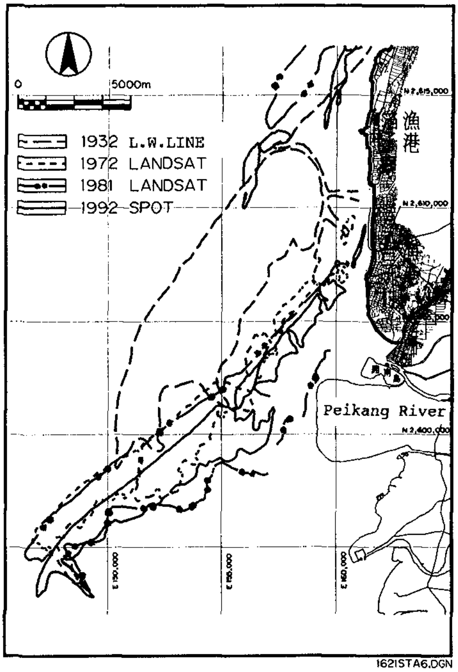

Figure 3 The historical changes of LW line of Wai-San-Ting

The Pao-Zi-Liao sandbar has undergone comparable changes in the last century like Wai-San-Ting: a steady southward movement (average above 100 m/y), its level being lowered in the last two decades, and a small westward rotation of 5 to 10 degrees. The general shape of the Pao-Zi-Liao has undergone significant changes. The sandbar has been broken up into separate bars that move southward and in a landward direction. The most southern sandbar has clearly become an isolated sand bar feature. The Pao-Zi-Liao sand bar system has degenerates more pronounced than Wai-San-Ting. Marine forces tend to disperse the sand bars and to smooth out the coast feature.

After the Linnei dike construction, the delta at Choshui river mouth becomes growing. The delta grows like a bow shape with strongly southward sediment transport. Due to the fish pond construction, the main stream of Choshui river changes toward to the north bank. The consequence of this disturbance is the sediment deposited at the north part of the delta during last two decades. After the construction of the Mailiao land reclamation (south of Choshui river mouth), the 10 meter's depth contour moved seawards. The MSL -20 m depth contour, on the other hand, did not follow this movement, which results in a steeping of the profile.

Conceptual Model of Morphological Change

The above considerations reflect for a part the complexity of the area. A mix of physical processes determines the morphodynamic behavior of the sea bed, each with their own time and space scale. The complexity makes it virtually impossible to simply calculate the future development and the impact of reclamation. Uncertainty will always be part of such prediction, even with today's most advanced modeling tools, such as MIKE 21 (DHI, 1992) coastal hydrodynamic simulation system. Although state-of-the-art knowledge on the various physical processes has been incorporated in this model, this does not guarantee that the large-scale morphological developments are represented well. In order to assess the long term morphological changes in the Yunlin coat, a conceptual model is need. This conceptual model is based on good interpretation of historical data and information from recent measuring data. The conceptual model will indicates which questions have to be answered by the numerical model and the numerical model will aim at quantifying the conceptual model.

At Yunlin coast, the balance between river sediment transport and the onshore sediment transport is to a certain extent the dimension of a river delta. After the dike construction at Linnei, the Peikang river and Old Huwei river is lost its drainage function. Consequently, the sand bars and relict deltas start erosion under very rough wave climate. Since most of the wave energy comes from north to north-east directions, the direction of littoral transport will be southward. Although the coastline of Yunlin is straight, relatively large local gradients in the depth orientation occur. These local gradients in the orientation of the depth contour are caused by the presence of the old deltas along the coastline. These give rise to relatively large gradients in alongshore sediment transport, which results in morphological changes. The net southward littoral transport contributes to the net southward movement of sand bars and other morphological features.

Since the littoral transport is a function of incoming wave angle, the river delta will reach its equilibrium condition according its wave condition. Due to the prevailing north wave condition, the northern part of Wai-San-Ting delta coastline tends to erode, and the seaward part tends to accrete. Due to this erosion and accretion processes, the coastline of delta will be re-shaped, which causes the point of maximum littoral transport to shift in downdrift direction. Hence, no limitation occurs to the seaward growth of the delta (Kung, 1993).

After the dike construction of Linnei, the erosion due to littoral transport is concentrated along the northern part of the coastline resulting in a steady rotating of Wai-San-Ting. Due to the sheltering effect of southward moving sand bars of Pao-Zi-Liao, the littoral transport at Wai-San-Ting as well as gradients in littoral transport, reduced and so the retreat of the coastline. Consequently, the rotation of Wai-San-Ting has remained more or less the same in the last two decades. The conceptual model of coast beach and sand bars morphological change in Yunlin coast is shown in figure 4.

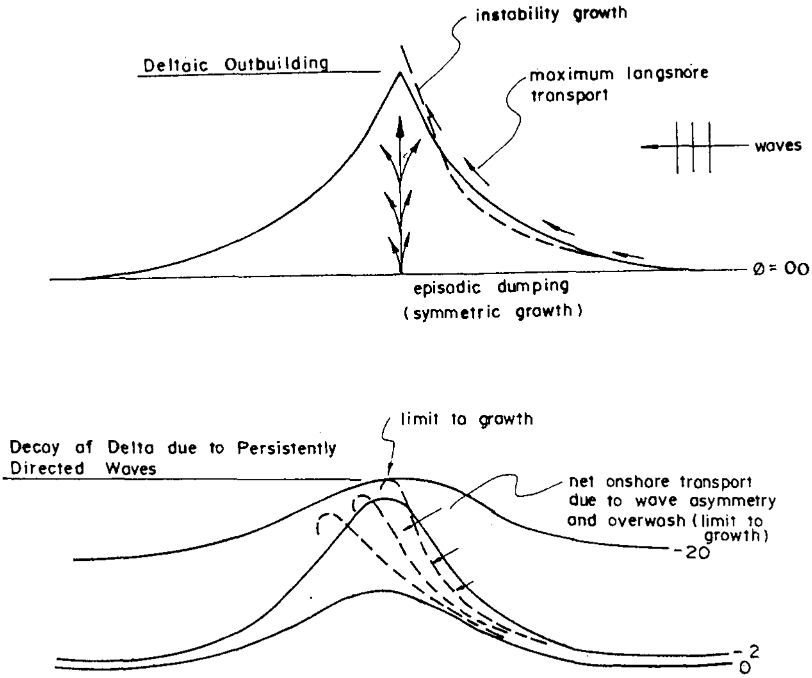

Figure 4 The conceptual model of morphological changes of "relict" deltas

Quantitative Analysis

The quantitatively analysis of morphological changes in Yunlin coast is initially concentrated on the geostatistical analysis. Natural variables such as grain size, shoreline change, land form, length of coast is all function of natural forces. Due to the stochastic nature of nature forces, the natural variables are also have stochastic characteristics in space and time domain. In a geostatistical model of shore line change or grain size distribution can represent its spatial structure of the natural forces and it's controlling physical processes.

A semi-variogram of shore line change among 1932 and 1992 based on Yunlin coast data is given in figure 5 as an example of the geostatistical analysis. The results show that the characteristic length is 7.5 km for the shore line changing rate. The characteristic lengths of the shore line change rates are similar to different periods - this reflects the similar processes within last century. The characteristic lengths also reflect the largest length scale of the coastline evolution process. The distance between Choshui river mouth and New Huwei river mouth is about 8 km and the distance between New Huwei river mouth and Old Huwei river mouth is 7 km. The length of the Santiaolun sand bar is 8 km. The length of north part of Wai-San-Ting is 7 km and the length of south part is 15 km. The geostatistic analysis shows that the shore line changes within the elic delta region are correlated and the shore lines' changes on different delta are more or less independent. The characteristic length of the grain size distribution is also 7.5 km along the main tidal direction. This length scale is very close to the tidal velocity length in Yunlin coast. The analysis shows that the morphological changes at deep water part, say MSL -20 m, is dominated by tidal movement.

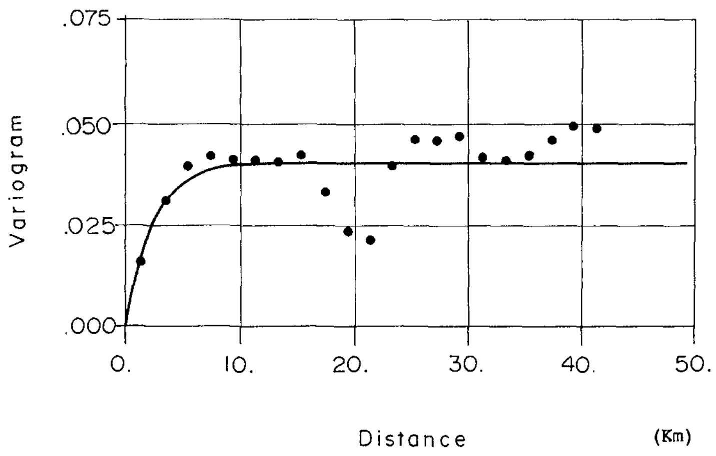

Figure 5 The semi-variogram of shoreline changing rate along Yunlin coast

The UNIBEST model (DH, 1991) was used for evaluating the longshore sediment transport rate along the Yunlin coast. The offshore wave climate was simulated by using MIKE21 NSW package based on the local wave measurement data. The typical tidal motion was simulated by using MIKE21 HD model. The current velocity and wave information are used in the long shore sediment transport by using UNIBEST model. The result of the longshore sediment transport calculation is shown in figure 6. Due to the large ground water subtraction along the coast, the possible land subsidence rate along the Yunlin coast is also shown in figure 6.

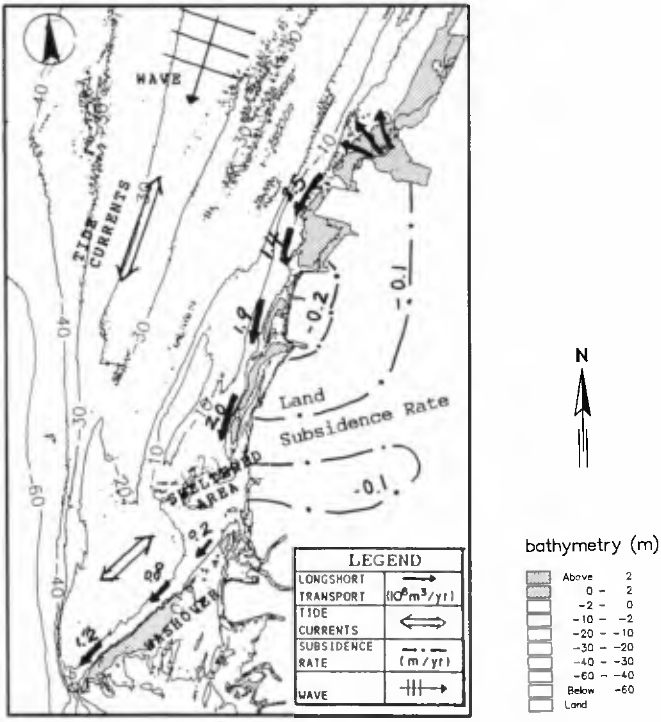

Figure 6 The longshore sediment transport rate of Yunlin coast

The longshore transport rate calculation shows that the local gradients of sediment transport exist at the tip of sand bar and along the Wai-San-Ting. The coast segment at south of Choshui river will be accretion due to the huge sediment supply from the river and south going littoral transport. The littoral transport rate is increased along the Santiaolun sand bar which imply the erosion of the sand bar. The littoral transport rate of the Wai-San-Ting is also gradually increasing along the southward direction. This local gradient implies the erosion of the Wai-San-Ting. The littoral transport rate is very minor at the north part of Wai-San-Ting due to the sheltering effect of shelter by the Pao-Zi-Liao sand bar. The Pao-Zi-Liao sand bar its self has very huge littoral transport rate and gradient that means the significant morphological changes.

Does the Pao-Zi-Liao sand bar provide sediment transport to the Wai-San-Ting that is the main question on the impact assessment of the reclamation. If the Pao-Zi-Liao sand bar is the sediment supplier to the Wai-San-Ting, the reclamation will stop the sediment to the downstream area and causing more serious erosion. In order to answer this question, the more details two dimensional sediment transport simulation is need due to the complicated coast geometry and flow conditions. The well-known MIKE21 coastal hydrodynamic modeling system was used for analyzing the sediment transport capacity and initial movement of the coast sand near the Wai-San-Ting area. The 75 meter grid was used for balancing the computation time and the resolution. This gives around 4 grid point in the surf zone that provides reasonable accuracy for alongshore current simulation. Three different wave conditions was simulated by using NSW module which represents the wave climate of the area. The radiation stress field was used in the hydrodynamic simulation for calculation the velocity field under the tide and wave combination situation. The Engelund-Fredsor formula (Engelund and Fredsoe, 1976) was used to calculated the sediment transport capacity at each grid point. The result of sediment transport capacity of Wai-San-Ting region is shown in figure 7.

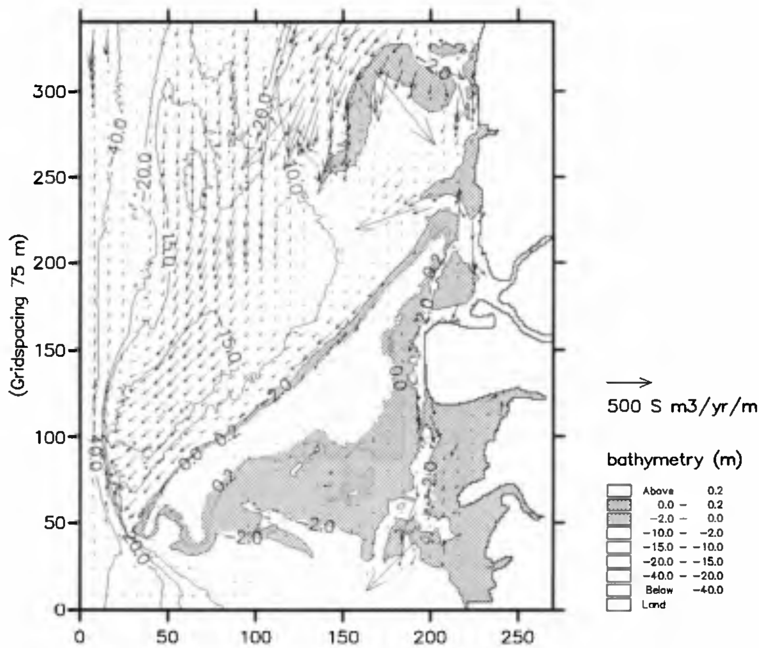

Figure 7 The sediment transport capacity near the Wai-San-Ting area

Results show that the sediment transport capacity is very small in the area between two sand bars due to the deeper water depth, stronger tidal current and the sheltering effect of Pao-Zi-Liao sand bar. Along the sand bars, the sediment transport capacity is much stronger that represent significant morphological changes along the sand bars. The sea bed initial movement of the sand bars is shown in figure 8. The result of simulation shows that two sand bars are evolution by itself. The migration of the Pao-Zi-Liao sand bar is toward to south-west and south. The sand bar does not provide sediment to the Wai-San-Ting that give quantitative explanation to the conceptual model.

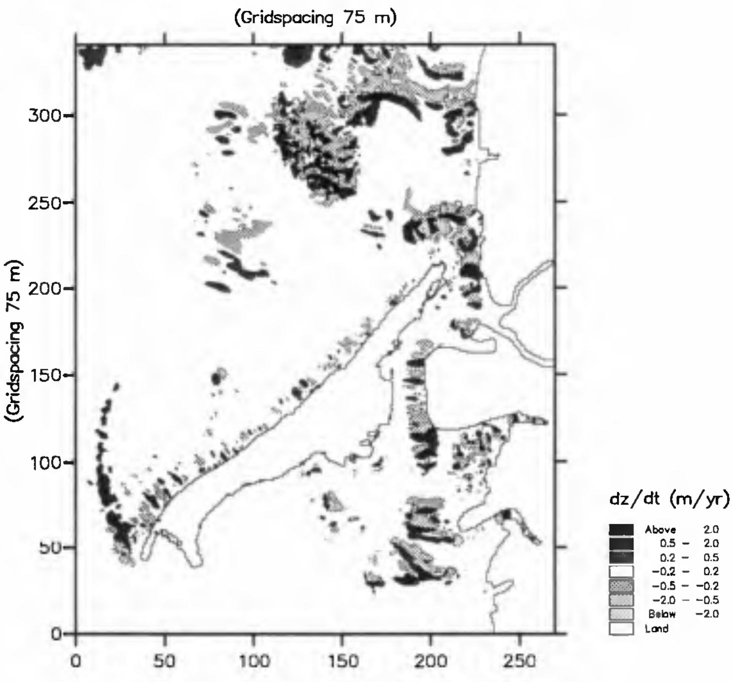

Figure 8 The sea bed initial moveemnt rate distribution of Wai-San-Ting area

Figure 9 shows the erosion and accretion area between the survey 1993 and 1994. The measurment bathymetry show similar erosion and accretion pattern among Pao-Zi-Liao and Wai-San-Ting sand bars. The maximum erosion rate is around 2m/year near the tips of the sand bars. The conceptual model and numerical model very well agree with the measurement data.

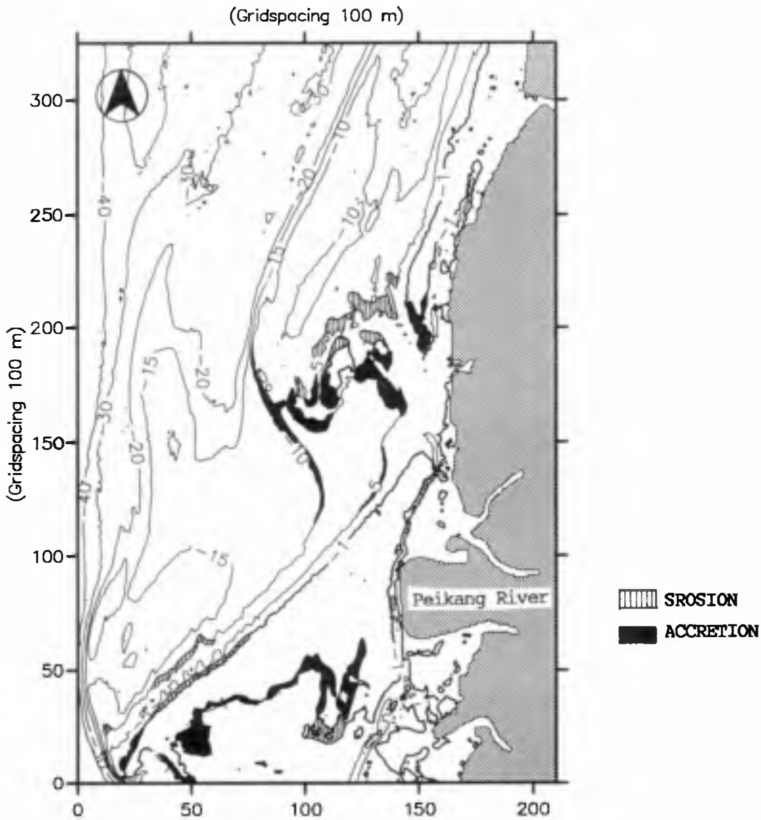

Figure 9 The erosion and accretion area among 1993 and 1994 bathymetry

Discussion and Conclusion

A hypothesis concerning the historical morphological development of the coast and its present state in the ongoing coastal development process was formulated. Explanations to the questions concerning the origin and persistence of the main shoreline features were found in deeper water than the present surf zones. The -20 m contour marked the outer edge of very distinct historical features. The features were linked to the pathways of ancient river courses which deposited deltas over thousands of years. At the persistent and very oblique wave attack cut the original deltas to form the present day sandbars. Four such "relict" deltas were identified according to its river courses. Below -10 m the time scales of development and change were far larger than those above -5 m, marking the difference between tide and wave dominated Zones. In the zone -5 to -10 m combined wave and tide effects dominate the processes.

Detailed modeling using MIKE21 package with wave, flow and sediment transport modules together with geostatistical analysis were used to assess key elements of the morphological hypothesis. Critical findings for the Yunlin coast morphological processes were:
(1) that the decay of the sandbars was mostly independent from the upstream coastal sediment supply due to the major discontinuities at sandbar headlands and tidal channels.
(2) That the deep water transport due to currents and waves outside the surf zone was not playing an important role in the development of the shoreline feature.

The analysis of the complex morphological processes has provided an important insight into the probable impacts of coastal developments and guided the expensive and time-consuming model operations. Many of the processes and investigations are common to other complex sandbar coasts worldwide.

Reference

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