

THE SIGNIFICANCE OF HYDRODYNAMIC MODELLING FOR MANGROVE GROWTH AND SURVIVAL IN MALAYSIA

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ABSTRACT

The hydrodynamic processes that exist in the nearshore region are generated by a number of different drivers such as force of gravity, pressure, velocity and density. Under the influence of these forces, the fluid motion of the water manifests itself as coastal currents, waves and tides. Upper intertidal shorelines that experience a complex hydrodynamic condition are inhabited by mangroves. The mangrove forest is a natural ecosystem that only survives in a certain environment because its growth is influenced by several factors such as sea level, water temperature, salinity, currents, waves, beach slope and type of sediment. The ability of mangroves to serve as natural buffer against the threat of big waves, strong winds and coastal erosion had increase the value of mangroves. In order to ensure the sustainability and the success of mangrove replanting activities, hydrodynamic conditions in the planting area need to be investigated. The right selection of the planting area is very crucial in determining the success of this project. Several studies have been conducted at Delta Kelantan, Kuala Teriang and Kudat to identify the optimum hydrodynamic conditions that will promote the growth and survival of mangrove in terms of wave action, currents and tides. Bathymetry and marine data have been measured and used as an input in the development of numerical models using MIKE 21 Hydrodynamic (HD) and Wave Spectrum (SW) modules. Model analysis and site verification reveals that in the muddy areas, current speed between 0.02 to 0.12 m/s is the most favorable condition for the growth of mangroves. In the area having a current speed exceeding 0.3 m/s, coastal erosion had taken place. Meanwhile, in sandy areas, currents' speed less than 0.2 m/s had caused sand precipitation on the roots of the seedlings resulting in death and stunted growth of the mangroves.

Keywords: Mangrove; currents; tides; waves; Malaysia.

1 INTRODUCTION

Mangroves are usually found in protected tropical and subtropical coastal environments. Their habitats are dependent on tidal influence and have complex hydrodynamic conditions. Mastaller (1997) and Walsh (1974) have suggested five basic requirements for extensive mangrove development, which are tropical temperature, fine grained alluvium, low wave and tidal action, salt water and large tidal range. These factors can influence the occurrence and size of mangroves, species composition and zonation, structural characteristics and the functions of the ecosystem itself (Mastaller, 1997).

The existence of mangrove forests can be said as a benchmark for approaching sea, river water, and land. Uniqueness of mangrove that grew in tidal influenced area plays an important role in the ecosystem. It became a refuge for flora and fauna in the mangrove swamps. The unique root becomes an ideal place for small fish to hide from predators and also acts as a natural breeding ground. It also acts as a natural buffer against the threat of big waves, strong winds and coastal erosion. Mangrove's ability to absorb wave energy helps to stabilize the beach (Rakotomavo and Fromard, 2010).

At present, mangrove populations worldwide are threatened by the dynamic forces of nature. Studies conducted by Valiela et al. (2001) estimated that the total area of mangrove forest in the world has dropped about 35 % in the last two decades. Giri et al. (2008) showed that the mangrove forests around the world are decreasing at an alarming rate, probably faster than other types of tropical forests. Hence, the Malaysian government has taken the initiative to protect and conserve the mangrove forests at the national level in collaboration with government agencies, NGOs and local communities.

After the 2004 tsunami disaster, mangrove replanting is actively conducted throughout the world with little success, particularly in areas with strong tidal and high currents. Similarly, in Malaysia, there is less successful mangrove replanting project, because most of the planted trees were swept away by waves and currents. Lack of studies and information on hydrodynamics governing the mangrove growth has becomes a constrained to ensure successful growth of the planted mangroves. Therefore, National Hydraulic Research Institute of Malaysia (NAHRIM) has conducted several studies at coastal areas along Delta Kelantan, Kuala Teriang and

Kudat in order to identify the optimum hydrodynamic conditions that promote the growth and survival of mangrove in the area. The hydrodynamic conditions emphasized in these studies are the behavior of waves, currents and tides. Results from this study can be used as a guide for future mangrove planting projects in Malaysia.

2 STUDY AREA

Delta Kelantan, Tumpat is located at the East Coast of Peninsular Malaysia and facing the South China Sea (Figure 1 (a)). The climate in this study area is characterized by the Northeast Monsoon occurring annually, normally, which starts in November and last until March. This dominant climate usually brings heavy rainfall and strong waves generated by wind (EPU, 1985).

The morphology of Kelantan Delta is characterized by an assemblage of parallel bars and spits due to numerous interrelated geomorphic and hydrological processes of erosion and deposition, both in the mainland and marine areas (Zakaria, 2005). The estuaries and lagoonal areas of Delta Kelantan are protected by the development of the sand spit at the outer part of the delta. Generally, the sand spits are developing towards the west at a rate of over 0.5 km/year (Kamal and Che, 1996). Koopmans (1972) had found that Kelantan River estuary experienced incremental process towards the west as a result of the waves and current generated by Northeast Monsoon. The movement of sediments to the west can be seen from the shifted position of sandbar in front of Tumpat Bay. Analysis on aerial photo data between year 1949 and 1966 have found that the spit of Pantai Laut has grown 1,240 m westward, whereas the sandbars of the Delta Kelantan gradually shifted 630 m landward at present (Koopmans, 1972).

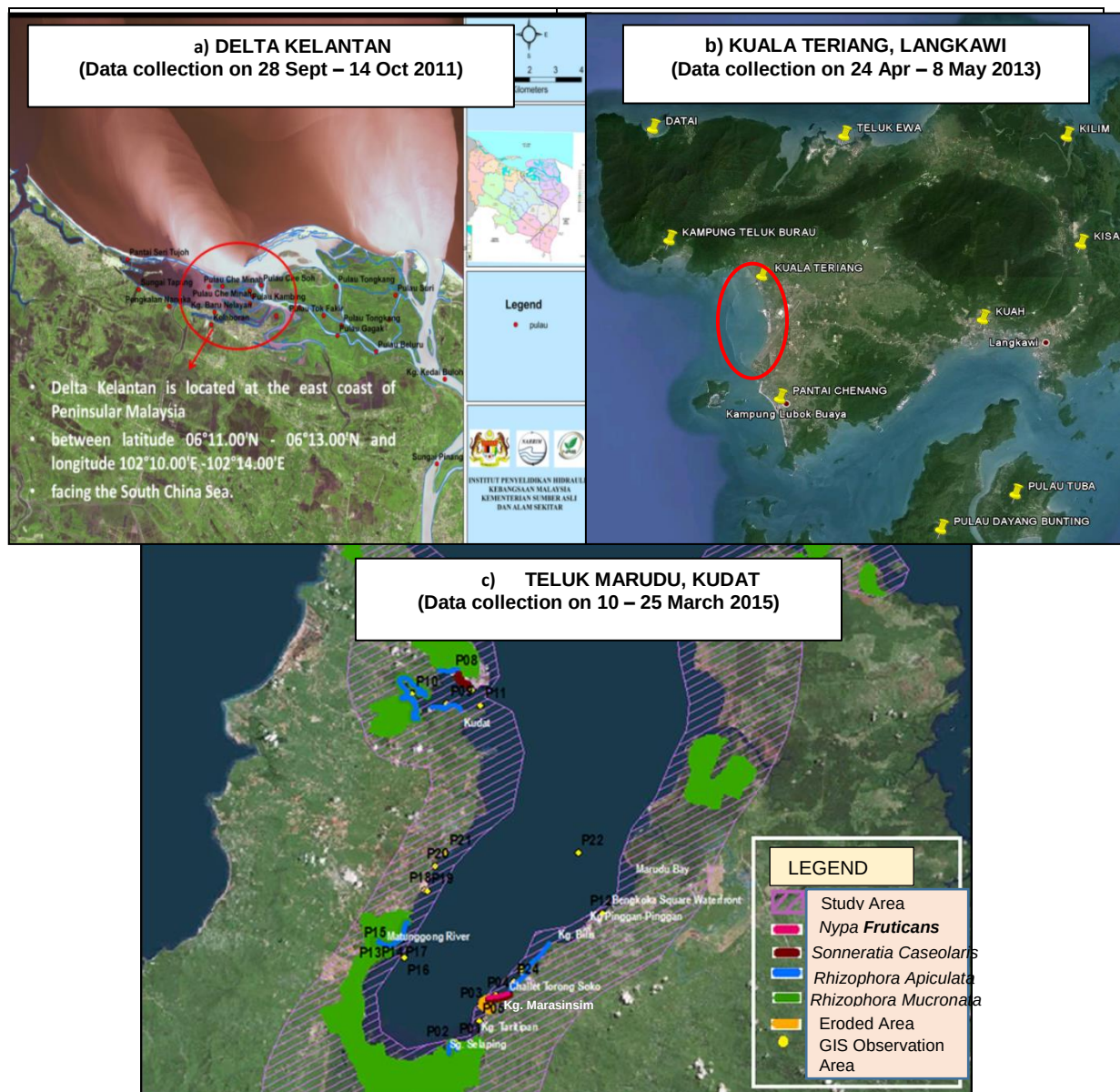


Figure 1. Study Area (a) Delta Kelantan (b) Kuala Teriang (c) Teluk Marudu

Figure 1 (b) shows another study area that located along the shoreline of Kuala Teriang, Langkawi, Kedah. Permanent mangroves reserve in Langkawi Island was gazetted in 1937 with an area of 3,126 hectares and managed by the North Kedah District Forest Office. Mangroves replanting were actively conducted to create a strong and stable natural buffer zone to reduce the need and cost of implementation for beach erosion control work in the future. A total of 29,500 numbers of *Rhizophora Apiculata* had been planted at Kuala Teriang on 5 hectares area in August 2010. However, during the audit visit on 21 September 2010, only 17,700 numbers of them were survived. It was reported that mangrove plantation using conventional and innovative techniques at this location were unsuccessful due to the coastal erosion and wave's impact.

Teluk Marudu is shared by three main districts in the north of Sabah named Kudat, Kota Marudu and Pitas. The accounted boundaries of the study area for hydrodynamic simulation run from The Tip of Borneo in Simpang Mengayau, Kudat to Kampung Mangkuban laut in Pitas. Analysis of observed data and secondary data shows that the mangrove swamp within the study area is about 178.81 km² (Figure 1 (c)).

During the site observation, it was found that mangroves cannot survive along the shoreline of Kampung Marasinsim. There is high probability that this area has been eroded by current and wave's impact. Meanwhile, the healthy mangrove area was spotted along Sungai Matunggong to Kampung Bilis and from Malubang Bay to Kampung Mangkuban Laut. It is inhabited by *Rhizophora Apiculata*, *Rhizophora Mucronata*, *Sonneratia Caseolaris* and *Nypa Fruticans*.

3 MATERIALS AND METHODS

Numerical modeling is the main method used in this study. In order to run the simulation, observation was carried out in order to investigate the existing condition at the study area. Incorporated with that, the marine data collection were undertaken for a few hydrodynamic parameters consisting of current, tide, wave and bathymetry data. The data collection was conducted for a period of 2 weeks for each study area. All these collected data were used for the purpose of hydrodynamic modeling by using MIKE 21 software developed by Denmark Hydraulics Institute (DHI). Two different models were used in this study which are Hydrodynamic (HD) Model and Spectral Wave (SW) Model. The simulation results were analyzed to identify the hydrodynamic patterns at Straits of Malacca, South China Sea and Sulu Sea.

3.1 Model Preparation

Preparation of the model involves digitizing the study area using satellite images, delineating model, analyze the model grid and develop the bathymetric profile of the study area. Bathymetric profiles were then generated by combining data extracted from the MIKE C-Map and bathymetry data measured in the field. Once the data interpolation completed, the boundary conditions for the study area were determined by using the Global Tide MIKE 21 model. Upon completion of model preparation and processing, models calibration was conducted to ensure that the results are in allowance of error, which are less than 10% of tidal, 20% of current speed and 20° of the direction of flow (DID, 2013).

3.2 Hydrodynamic Modeling (HD)

Hydrodynamic (HD) Model is the basic computational hydrodynamic module in MIKE 21 numerical modeling application. This module was simulated in order to provide the hydrodynamic condition mainly current speed, current direction and surface elevation. The calibrated hydrodynamic model can be used with other modules such as spectral wave module (SW), sediment transport (ST) and mud transport (MT). MIKE 21 HD simulates the difference in water level and flow in response to a variety of reactions in the ocean, lakes, estuaries, bays and coastal areas. It can be used for a variety of hydraulic related phenomena such as, tidal, wind and wave generated currents, storm and flood wave.

3.3 Spectral Wave Model (SW)

Spectral wave model simulation was developed to identify the significant wave heights along the study areas. Wave model simulations were conducted for the Southwest Monsoon that usually occurs in May through October for Delta Kelantan, and Northeast Monsoon for Kuala Teriang that usually occurs in November through April. During the Northeast Monsoon, waves usually approach the coast from the 30° to 60°. Wave heights less than 1.8 meters in less than 6 seconds. According to EPU (1985), the west coast of Peninsular Malaysia may have poor wave magnitude compared to the east coast as protected by the islands of Sumatra and limit the length of about 40-130 km in the Strait of Malacca. During the Southwest Monsoon, the waves approaching the coast with the highest waves may reach about 2.0 to 3.0 meters.

4 RESULTS AND DISCUSSION

4.1 Delta Kelantan

Analysis from the simulation results shows that most of the islands in Delta Kelantan experienced current speed of less than 0.3 m/s due to the existence of sand bar that sheltered most area from the direct impact of wind and current. The mean current speed for Delta Kelantan is in the range of 0 – 0.4 m/s, while the maximum current speed is from 0.4 – 1.2 m/s (Figure 2).

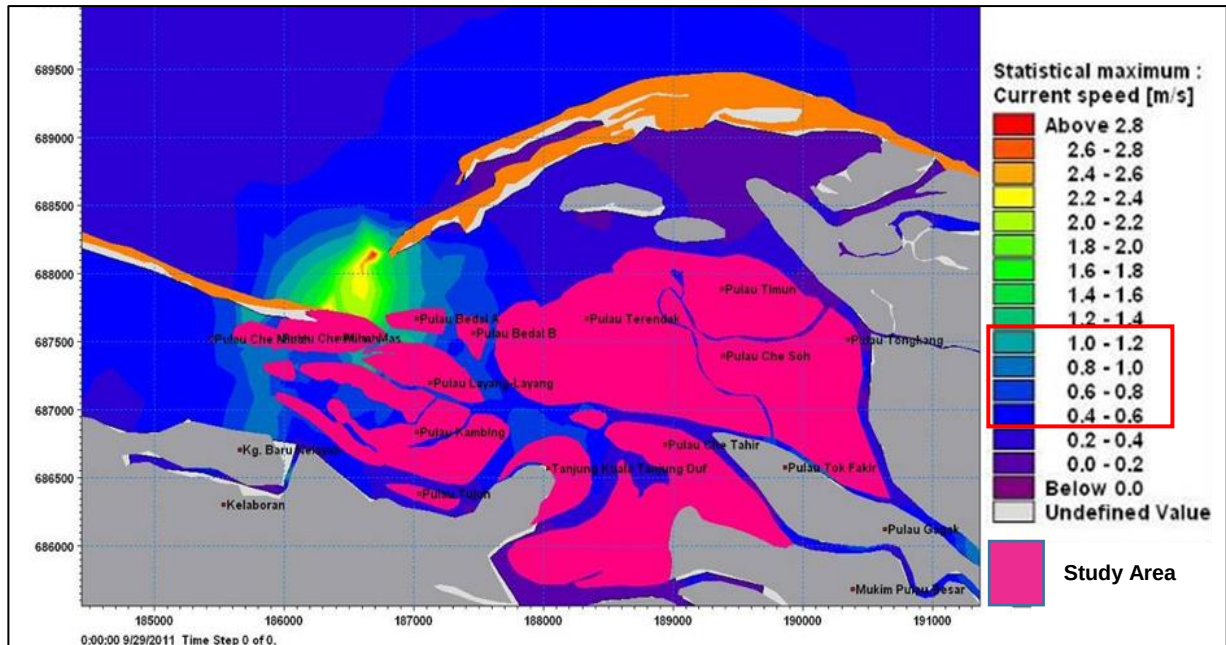


Figure 2. Maximum current speed at Delta Kelantan, Tumpat, Kelantan

Results from the wave models show that waves did not give any significant impact since it was blocked by a sand bar. Waves with a height of 0.5 m from offshore has been breaking and approaching the mangroves area with a height of almost 0 m. Waves coming from the direction 0 - 100° was refracted by a sand bar and left the mangroves behind unaffected. Delta Kelantan were dominated by *Rhizophora Apiculata*, *Rhizophora Mucronata*, *Sonneratia Caseolaris*, *Avicennia Marina* and *Nypa Fruticans*. Site observation and model output show that mangroves can grow healthily in areas where current speeds are below than 0.3 m/s. In areas having more than 0.3 m/s current speed, the mangrove growths were stunted due to erosions. The presence of sand bars and boat navigation had caused some areas having higher current speeds, hence the impact are much bigger. In sandy areas such as Pulau Che Minah, model output shows that when current speed is less than 0.2 m/s, sand precipitation occurs on the roots of mangrove trees and can lead to death/stunted trees (Figure 3). Whereas, in muddy areas such as Pulau kambing and Pulau Tujuh, the results show that the current speed between 0.02 - 0.12 m/s is the most favorable condition for the mangrove growth. Healthy mangrove stretches were spotted in both islands.



Figure 3. Sandy beach with current speed less than 0.2 m/s lead to death/stunted mangrove trees (Pulau Che Minah)

4.2 Kuala Teriang, Langkawi

Model simulations show that the maximum current speed at Kuala Teriang is in the range of 0.06 - 0.36 m/s (Figure 4). The current flows are lower inside the area protected by the breakwater, while the shoreline opposite of it experiences higher current speed.

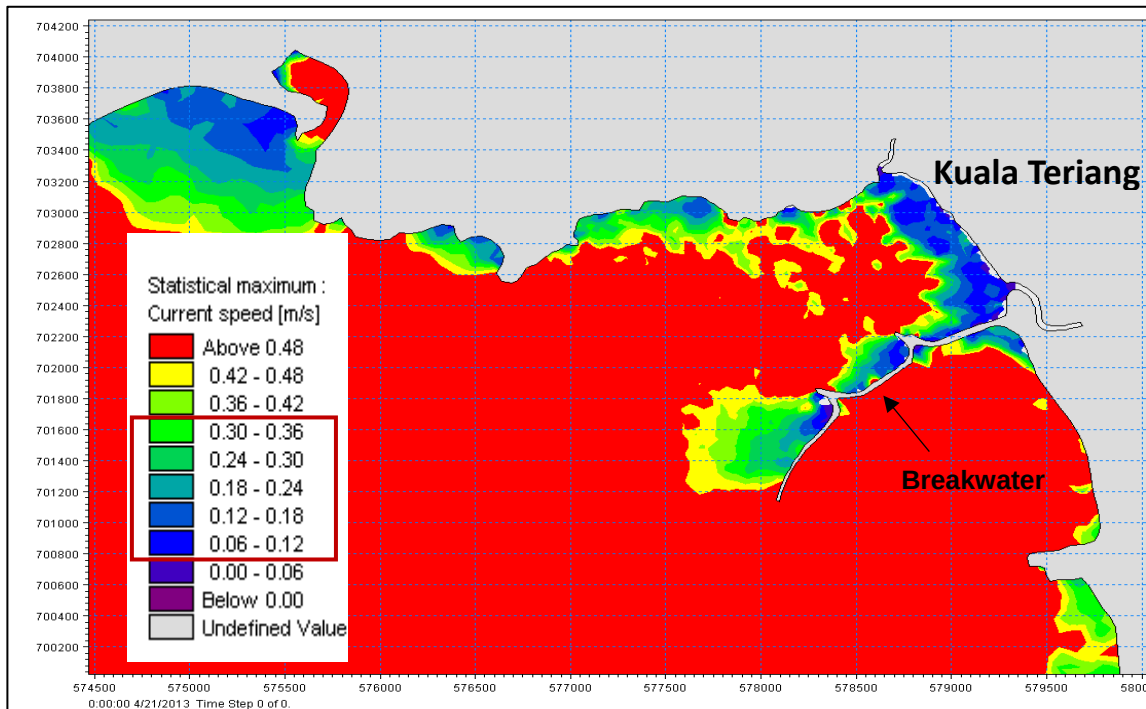


Figure 4. Maximum current speed at Kuala Teriang, Langkawi, Kedah

Kuala Teriang has been planted with *Rhizophora Apiculata*. However, the mangrove replanting in this area was reported unsuccessful. Site observation revealed that erosion has taken place in mangrove areas experiencing current speed of more than 0.3 m/s (Figure 5). The calibrated hydrodynamic model shows that the hydrodynamic factor is not a big issue in this area.



Figure 5. The area with current speed more than 0.3 m/s experienced erosion problem

Spectral Wave Model shows that the study area has affected by a mean significant wave height of 0 to 0.04 m and maximum wave height of 0.7 to 1.0 m. Based on wave characteristics derived by World Meteorological Organization, the wave at the study area falls within the smooth to slight characteristics (>0.1 m). Therefore, the study area hasn't calm conditions within the two months of data collection period (April - May).

Nevertheless, further study should be conducted on sediment, soil stability, wave and current through different monsoons as well as other factor, such as the existence of breakwater and other structure that may alter the hydrodynamic condition along the Kuala Teriang coastline.

4.3 Teluk Marudu, Kudat

Simulation results for maximum current speed in Figure 6 show that there are three main areas in Teluk Marudu coastline, which are at high risk of the occurrence of erosion. The areas are in front of the coast of Kota Marudu where the current speed can reach up to 0.48 m/s, around the coast of Tip of Borneo with a maximum

current speed of 0.60 m/s and also around the coast of Tiga Tarok and Kampung Dundulit, where the current speed is approaching to 0.78 m/s. The mean current speed in the coastal area of Kota Marudu and Sg. Bengkoka is in the range of 0.075 m/s to 0.2 m/s. This value indicates a good condition for the growth of mangrove trees in the vicinity.

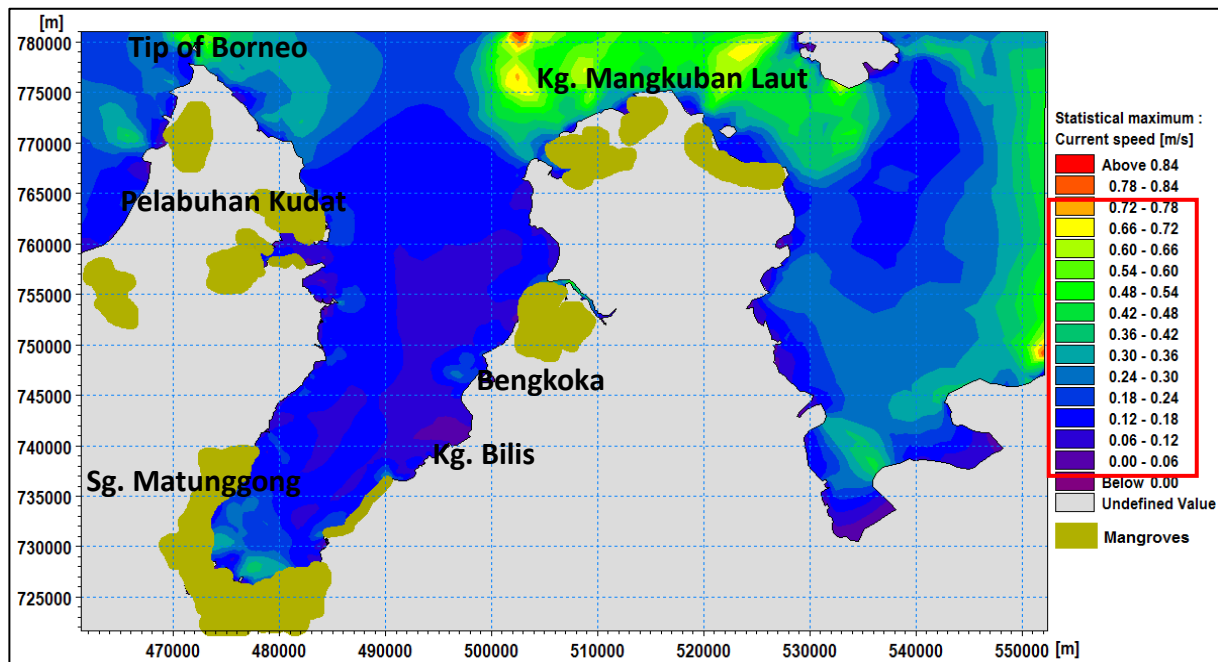


Figure 6. Maximum current speed at Teluk Marudu, Kudat, Sabah

Result analysis also shows that Sungai Matunggong is situated in a sheltered area with a maximum current speed of 0.18 m/s – 0.24 m/s. Sungai Matunggong that is located in Kota Marudu district is covered by healthy mangrove stretches (Figure 7). It has been gazetted as a mangrove forest reserve of Matunggong by the Forestry Department of Kudat. Its location in estuaries and sheltered environment makes it an ideal environment for the growth of mangrove trees.

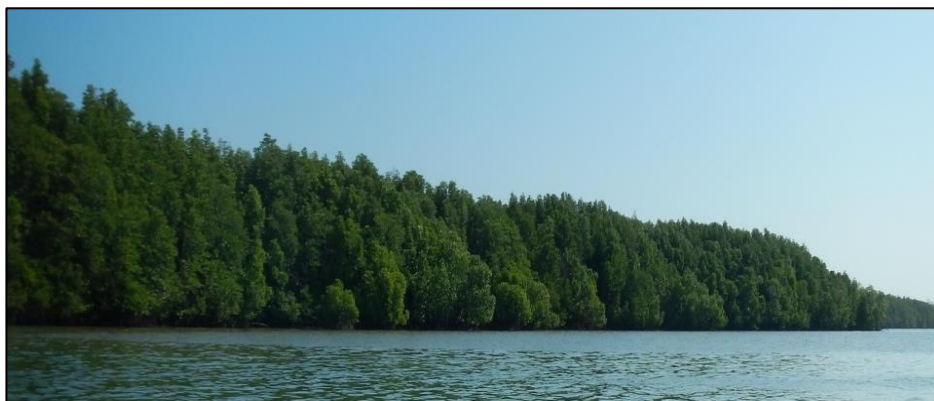


Figure 7. Mangrove forest reserve along Sungai Matunggong, Teluk Marudu

5 CONCLUSIONS

Based on hydrodynamic modeling studies of current and waves in Delta Kelantan, Kuala Teriang and Teluk Marudu, it was found that the current speed between 0 - 0.3 m/s are the most favorable condition for the mangrove growth. In areas that experience current speed more than 0.3 m/s, the growth of mangroves were disrupted due to coastal erosion. The study also showed that at the sandy area with current speed less than 0.2 m/s, sand accumulation has occurred on the roots of mangrove that may cause death/stunted of mangroves trees. Whereas in muddy areas, the current speed between 0.02 to 0.12 m/s provides a good condition for the growth of mangroves.

By understanding the hydrodynamic conditions in a given area, the selection of potential planting sites or new cultivation areas for mangrove trees can be done wisely. A suitable site condition is very important in determining the success of mangrove replanting project. In addition, the technique of mangrove trees planting

should also be emphasized, particularly in the area adjacent to the structure of breakwater. The wave energy and currents resulting from the reflection and diffraction of rock structures are capable of washing away newly planted mangrove seedlings.

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