Investigation on the Impact of Boat Wakes to Mangrove Degradation

by

Nor Azimah Binti Abd Kadir

16684

Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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Approved by,

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(Assoc. Prof Ahmad Mustafa Bin Hashim)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NOR AZIMAH BINTI ABD KADIR

ABSTRACT

Mangrove ecosystem is one of the ecosystem that many people take it for granted due to lack of knowledge on the importance for having a healthier mangrove ecosystem. Several factors were identified to cause the mangrove degradation which not only because of nature activities but also factors induced by human activities. In recent days, human activities are seen the main factor leading to mangrove deterioration. Initially, boat wake was a negligible factor towards the mangrove erosion but since the increasing number of high speed craft, this issue became one of world's concern. Previous research indicated that, boat wake could contribute to the mangrove erosion. Matang Mangrove Reserve Forest is the largest mangrove reserve in Malaysia. Unfortunately, few areas was observed facing erosion and plants gradually collapses along the mangrove fringe. This research aimed to investigate the threshold limit of the maximum wave height generated by the travelling boats that could lead to mangrove riverbank erosion. Numerical simulation were employed using MIKE21 Boussinesq Waves module coupled with Ship Wake Generator. The findings were subsequently validated against the information from site measurement. Finally, guidelines were derived for acceptable boat speed especially in restricted waterway as part of the possible mitigation measures in protecting against further mangrove degradation.

ACKNOWLEDMENT

In the name of ALLAH S.W.T, the most merciful and compassionate, praise to ALLAH, He is the almighty, eternal blessing and peace upon the Glory of the Universe, our beloved Prophet Muhammad (S.A.W), and his family and companions.

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CHAPTER 1

INTRODUCTION

1.1 Background

Mangrove is growing at the interface between sea and land in subtropical and tropical latitudes whereas the condition is anaerobic soils, extreme tides, strong winds, high salinity, high temperature and muddy. Mangrove or sometimes known as Mangal is a forest with a unique characteristic of ecosystem which can be found in the environment where salt water, fresh water and land all meet together called as intertidal zone. Intertidal zone become an area where nearly 73 different species of mangrove trees live in over 123 countries around the world (Anderson & Chowdhury, 2014) exclusively within 30° of the equator.

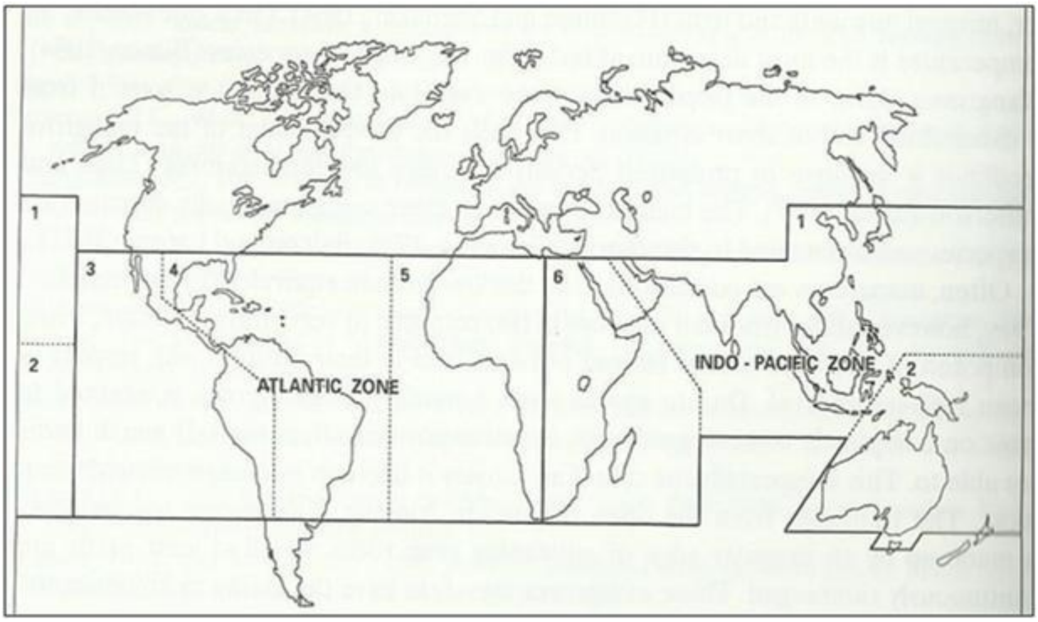


Figure 1: Mangroves distribution in the global scale

Mangroves area can be divided into two main zones (Indo-Pacific zone and Atlantic zone) and subdivided into six mangrove regions as in Figure 1. Mangrove forest is home to more than 60 species of plants. In Malaysia, there have four major types of vegetation that has the most significant:

1. Avicennia
2. Sonneratia
3. Rhizophora
4. Bruguiera

Mangrove forest is a valuable ecological and economical resources, securing life and as a residence. In 2005, International Union for Conservation of Nature (IUCN) reported that two villages in southern Sri Lanka which were hit by the 2004 tsunami, gave two different effect which proved that the presence of healthy mangrove could reduce the damages and fatalities. It was proved that mangrove forest act as a good protection system towards the storms, wave action and tsunamis as well. It is a natural barrier against coastal erosion and flooding. The roots act like a natural pollution treatment plant. Production of timber, charcoal, fuel, food medicine, building material and also breeding and nursing ground for fish and marine life made mangroves ecosystem importance to human society, as well as coastal and marine systems (Giri et al., 2011). Polidoro et al. (2010) was labelled the mangroves as foundation species because of their strong influence on biodiversity and species dynamics.

Kathiresan (n.d) has classified the mangrove threats into two types which are mangrove degradation and mangrove destruction. Mangrove degradation is caused by nature-induced changes meanwhile, mangrove destruction is caused by man-made activities which have seen as a great threats to mangrove.

According to Prasetya (2006), shoreline changes generated by accretion and erosion are natural processes that take place over a range of time scales. Erosion may occur in response to smaller-scale or short term events, such as normal wave action, storms, tides and winds. On the other hand, erosion also response to large-scale or long term events such as glaciation or orogenic cycles.

Soil erosion is a natural process but it becomes a problem when human activity causes the process faster than its normal natural process. It is interesting to aware that erosion will continuously occur even though all mitigating steps are employing for wake wash effect. It is because of unstoppable natural factors. Mangrove erosion gives serious effect to its flora and fauna and can cause mangrove deterioration in overall pictures.

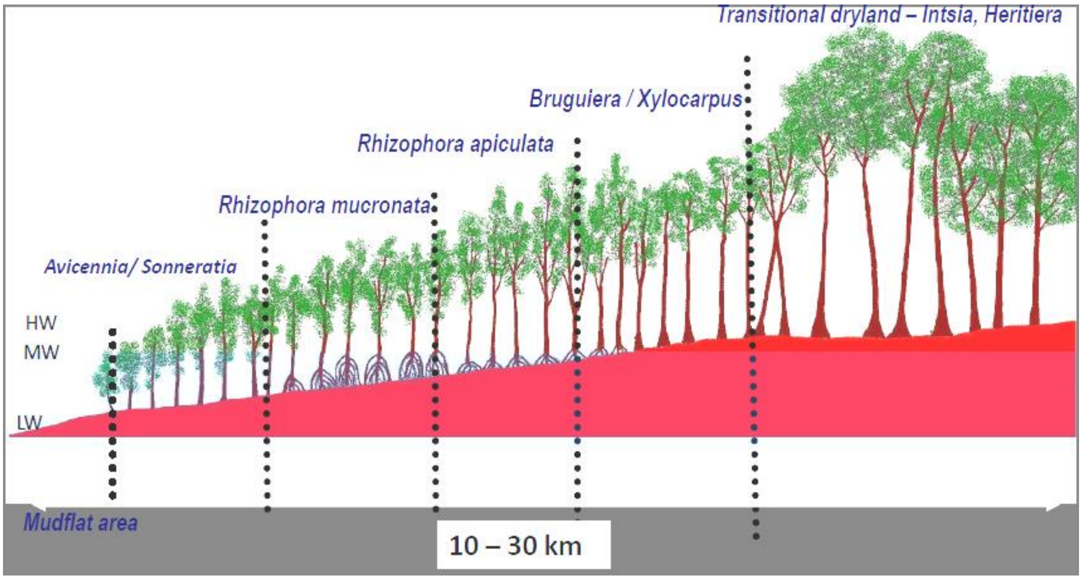


Figure 2: Vegetation zone for mangrove forest (Hwai & Rosli, 2012)

1.2 Feasibility of the Study

Healthy mangroves and sufficient thickness of mangrove belt is the key for mangrove to function well as a natural buffer zone against wave especially against tsunami which has been occurred in 2004. Protection of mangrove by attenuating the wave height lessen the fatality during the tsunami 2004. Based on this study case, people started to aware the importance of mangrove and it benefits to the human being and the ecosystem as well. Therefore, mitigation measures need to be done in order to preserving the mangrove especially due to human activities such as boat wakes created by the high speed vessel.

1.3 Study Area

Kuala Sepetang is located in Taiping, Perak and categorized as a coastal town. Kuala Sepetang is previously known as Port Weld. This town thriving as fishing village and at the river mouth is occupied by Chinese community which specializes in fish breeding in cages. Kuala Sepetang also well known for its mangrove swamp called Matang Mangrove Forest. (Pieter, 1995)

The Matang Mangrove Forest Reserve is one of the well-organized mangrove forests and world's best mangrove management system. Matang forest is $400km^2$ in coverage including estuaries at Kuala Larut, Sungai Sanggga Kecil, Sungai Sangga Besar and Sungai Sepetang. Topography around Matang Mangrove Forest is a broad river delta. Matang Mangrove Reserve Forest is claim to have well organized mangrove management, unfortunately it is not best protected in term of protection from erosion. Kuala Sepetang is having a mesotidal range (Chong, 2006) meaning the tidal range level is between 2 to 4 meter high.

Figure 3: Matang Mangrove Forest, Kuala Sepetang, Perak, Malaysia (Source: Google earth)

1.3.1 Matang Mangroves Forest, Perak.

Matang mangrove is located within the district of Larut & Matang, Manjung and Kerian in Perak. Matang mangrove forest itself covered 40,466ha area in Perak state. Meanwhile, Manjung, Pangkor & Lumut covered 3036ha. Matang mangrove consists 19 independently gazetted forest reserves and it is divided into 3 ranges: Kuala Sepetang, Sungai Kerang and Kuala Trong. Gazettement was fully applied in 1906 due to economic purposes such as demand for charcoals. Eight major types of forest in Matang mangrove is classified as (Forestry Department of Perak, n.d):

1. Accreting Avicennia Forest
2. Transitional New Forest
3. Berus Forest (Bruguiera cylindrica)
4. Rhizophora Forest
5. Transitional Dryland Forest
6. Dryland Forest
7. Nypa Forest

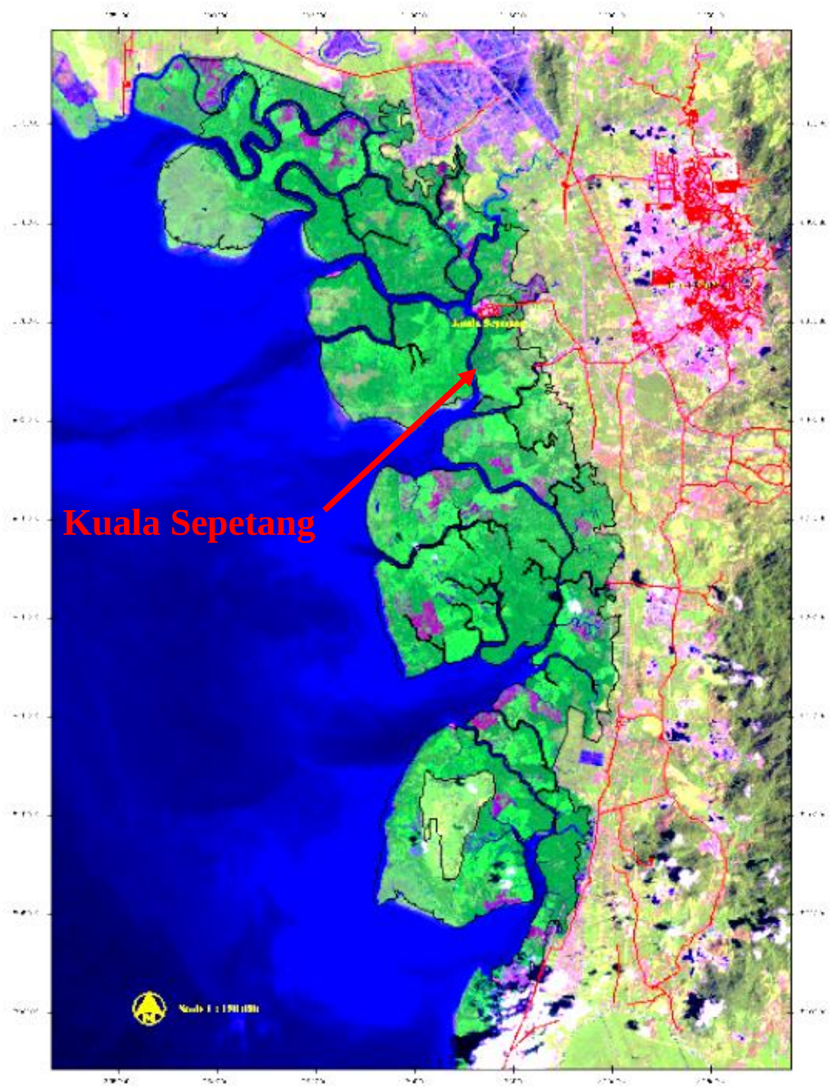


Figure 4: Matang Mangrove Forest Reserve.

Meanwhile, the forest was grouped into five zone as shown in Figure 5:

1. Seaward zone
2. Rhizophora zone
3. Bruguiera zone
4. Ceriops zone
5. Laneward zone

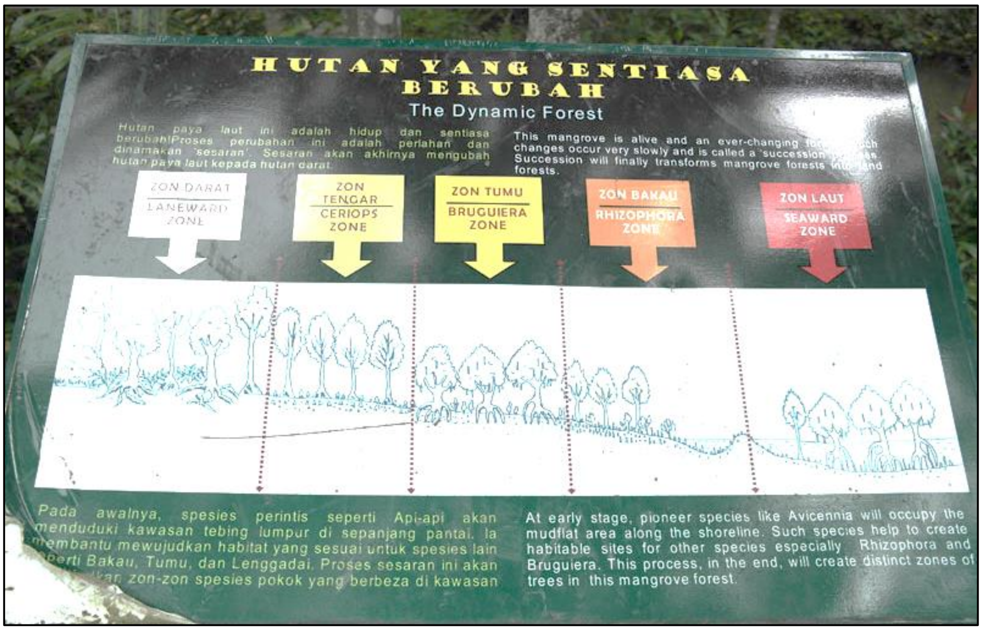


Figure 5: The dynamic forest of Matang Mangrove

Furthermore, Matang mangrove management was divided the area into 4 zones (productive zone, restrictive productive zone, unproductive zone and protective zone) for easiness of management. Each zone has its own function and covered different types of mangrove plantation. In addition, Matang management has taken protection and conservation steps for environmental protection. Guidelines for felling coupes has been produced to minimise its impact to wildlife and environment.

1.4 Problem Statements

Mangrove forests is gradually vanish. This is the truth that everyone around the world has to face even though people realize it or not. Mangrove forest seems not very important to some of the people, but believe or not, mangrove plays an important role to the environment. The importance of the mangrove forest to the environment and mankind cannot be underestimated. Terrible consequences will occurred because of rapid erosion of mangroves to the marine system and will create worst effect to atmospheric composition and climate (Giri et al., 2011).

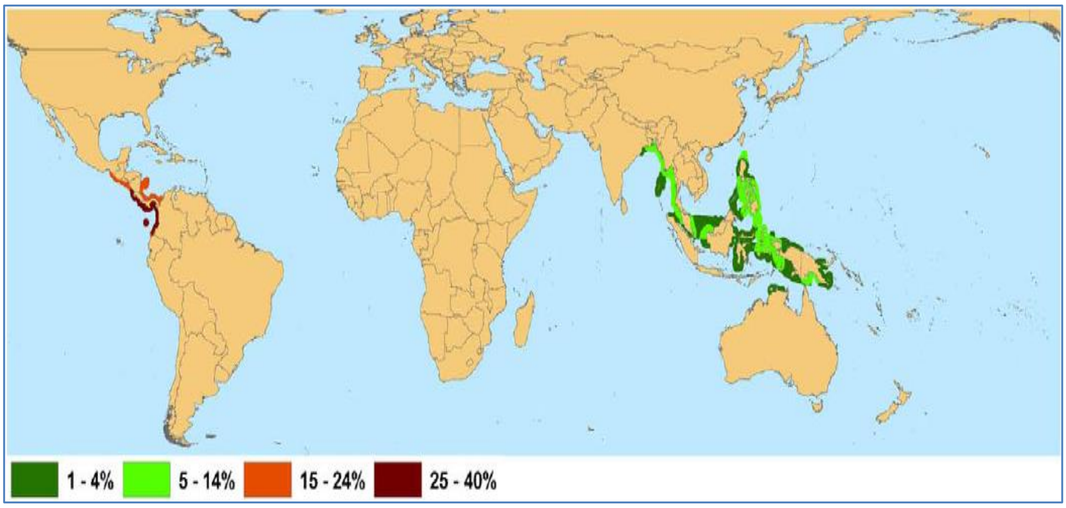


Figure 6: Proportion of threatened mangrove species (Critically Endangered, Endangered, and Vulnerable (Polidoro et al., 2010)

Most of the mangrove forests are growing in developing countries (Duke et al., 2007) which put the mangrove under the condition of critical endangered due to growing pressure of the urban as well as the industrial developments along the coast plus the climate change and sea level rise. Few reasons have been identified as a cause to mangroves loss. Flooding, sea level rise (Gilman, Ellison, Duke, & Field, 2008), storms, parasites and biological pests (Kathiresan, n.d) are natural causes meanwhile coastal development, shrimp aquaculture, water pollution, timber and fuel wood production are part of contributing factors created by people. Shrimp aquaculture has been introduced since 1970s taken place at the mangrove ecosystem as it was known as a good habitat to nursery for fish and invertebrate (Anderson & Chowdhury, 2014). As a consequence, mangrove forest need to deforestation for that purpose.

Nowadays, increasing number of boats, ferries and recreational vessels in many coastal, river and estuarine environment make the boat generated waves are seen as a major contributing factor to shoreline erosion in many parts of the world. As a result, bank erosion along river, canal and other navigable waterways become a major concern worldwide. For decades, this serious issue has been a point of disputation and controversy for management agencies and policy makers who interested in erosion cause by boat wakes (Nanson, Von Krusenstierna, Bryant, & Renilson, 1994).

According to Glamore (2008), there was a purposed wave management criteria created as a threshold, but then the management do not take into account the condition of bank and natural background of wave height.

Table 1: Previous wake wash management criteria

Wave Characteristic	Wave Management Criteria	Source
Maximum Wave Height (H_{max})	28 cm from peak to trough measured 300 m from sailing line in deep water.	Stumbo *et al.* (1999).
Maximum Wave Height (H_{max})	< 20 cm no action on bank stabilisation required. 20-30 cm requires monitoring. 30-40 cm requires bank engineering assessment and remediation.	Patterson Britton and Partners (2001).
Maximum Wave Height (H_{max})	Based on wave height criteria: $H_h \leq 0.5\sqrt{\frac{4.5}{T_h}}$ Where H_h is H_{max} and T_h is mean wave period. (Equates to 0.75m for 2.0 second wave period.)	Parnell and Kofoed-Hansen (2001)
Wave Energy	< 2450 joules/m (150 lb/ft) in the highest significant wave of the wave train as measured 300m from sailing line in deep water.	Stumbo *et al.* (1999).
Wave Energy, Wave Period and Speed	Energy: $1962H_m^2T_m^2$ <60 joules/m or <180 joules/m; Period: Comparison of boat length and energy in the from of $3.04\sqrt{L}$ Speed: Blanket Speed Limit of 5-6 knots	Australian Maritime College (2003)

1.5 Objectives and Scope of Study

This research is aimed to establish the threshold graph for the maximum that would cause erosion and to manage these potentially erosive boat wakes by developing criteria and guidelines for vessel speed at Sg Reba. To achieve these respective objectives, numerical modelling of MIKE 21 Boussinesq Waves was carried out and then it was validated with site measurement data.

Even though there are few factors that significantly affects the mangrove degradation, however, study will only focus on investigating the boat wake's impact to mangrove degradation. In this context, the main question is not to determined accurately whether the boat wakes cause an erosion because erosion will certainly happen in some extent anyway, but rather to investigate the limit of wave height that generated by boat wakes and which is suspected to triggered the erosion where concurrently give impact to mangrove degradation. Therefore, this study will concentrate on the wave characteristics especially the wave height generated by boats plying at Reba River where the erosion is significantly takes place.

CHAPTER 2

LITERATURE REVIEW

2.1 Mangrove Characteristics

Various mechanisms and phenomena of mangrove hydrodynamic have been studied and nowadays it is largely understood. According to Cardona and Botero (1998), soil salinity is the parameter that most correlated to the distribution and development of a mangrove vegetation and also related to biomass and mass mortality of mangrove trees. It was lead Botero (1990) to make a hypothesis on their study site that mangrove die-off is strongly related to soil hypersalinization and it was proven throughout the assessment that extreme salinity caused the deterioration. Few factors influenced the mortality, structure and productivity of mangrove including tidal range, intensity, climate, frequency of runoff and flushing as well as soil or substrate characteristics.

According to Glimore (2008), type of river and vegetation coverage are the key factors for riverbank's stability and Laderoute and Baeur (2013) also added the factors that influence the ability of riverbank to erode are grain sizes, stratification, height and slope of the bank.

The substrate of mangrove swamps are commonly consists of mud (cohesive sediment) and the soils are rich in humus and organic clay with respect to biotic action in the mangrove ecosystem. Sea wave current and tidal current periodically make the sediment resuspended and deposited in correlation with turbulence generated from the interaction between vegetation and current and thus created swamp topography.

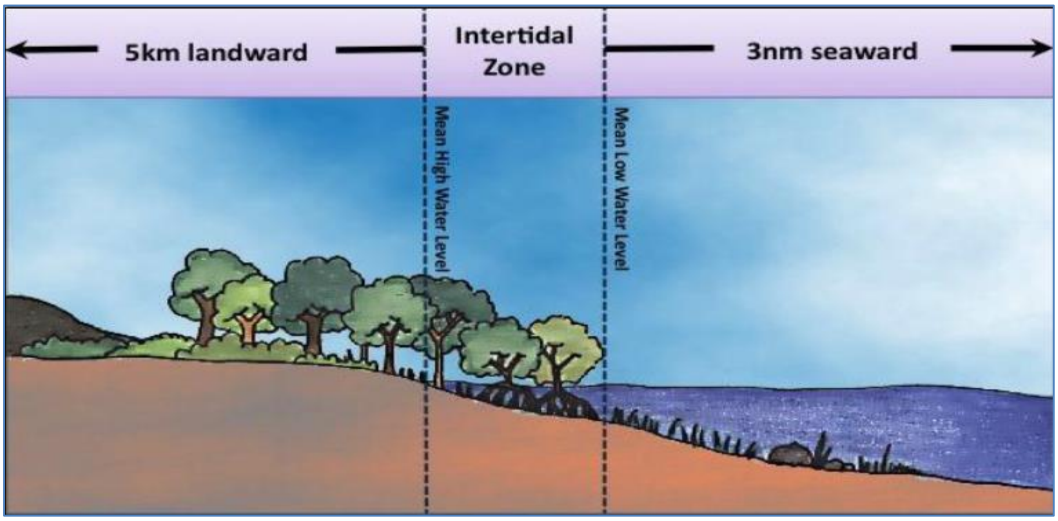


Figure 7: Water level at the mangrove shoreline (Hwai & Rosli, 2012)

2.1.1 Characteristics of Mangrove Forest

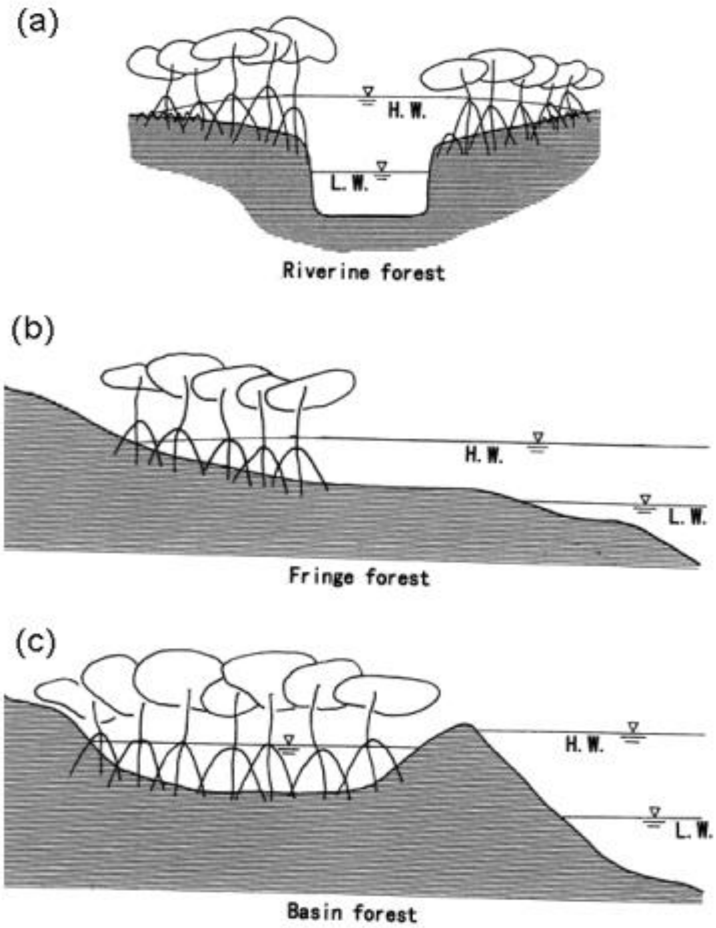


Figure 8: Classification of mangrove forest

Numerous researchers had come up with different ways of defining the mangrove's landform. Three types of mangrove topography features has been modified by Cintron and Novelli (as cited in Mazda, Wolanski & Ridd, 2007) which are fringe forest (F-type), riverine forest (R-type) and basin forest (B-type) (Figure 8).

Figure 9 shows the relationship between topographical characteristics, dynamic processes and environmental consequences for riverine forest type which is similar to the condition in study area.

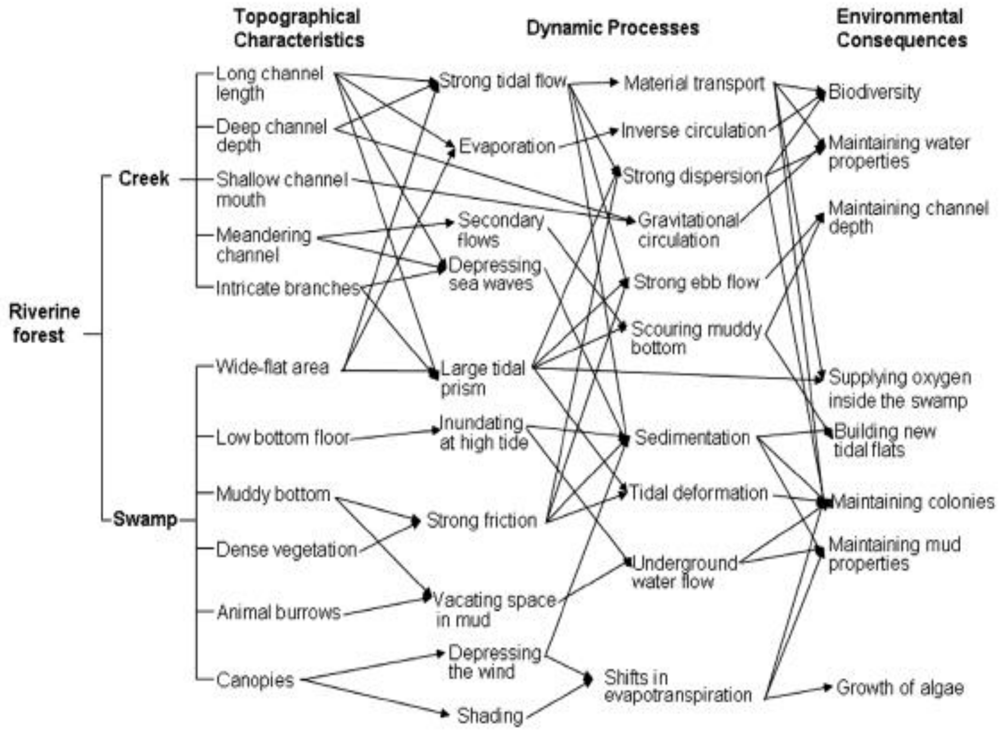


Figure 9: Links between topographical characteristic, dynamic processes and environmental consequences

Sg Reba can be classified as a creek. During flood tide, amount of water entering mangrove swamps influenced the tidal flow in creeks. Tidal flow in creeks is strongly dependent on the amount of water that enters the mangrove swamp during the flood tide. In tidal creeks, wakes generated by boats and ships can produce waves with a period of several seconds. These waves erode sediment from the creek bottom and the creek bank made of the fine and often unconsolidated nature of mangrove sediments. Mazda *et al*. (as cited in Mazda, Wolanski & Ridd, 2007) documented the effects of erosion caused by tourist boats, and found that the erosion exposed roots, causing trees to fall into the water.

2.3 Boat Wake

Boat wake also known as wake waves or wake wash, and it is a waves generated from the boat, ship or vessel. Normally, boat wake effect is negligible on shoreline stability especially at the coastal area subject to wind waves action or river system prone to frequent flooding. But, it will be as a main cause of shoreline erosion in tranquil coastal, estuarine and river environments (Gourlay, 2011). In addition, boat wakes also causes rubbing damage to boats berthed in marinas, creates nuisance, disturbance to personal watercraft, swimmers and water skiers (Yaakob et al., 2012).

In earlier decades, waves generated by big vessel were accepted and negligible. The wake wash turned into a world focus after the introduction of high-speed craft (HSC) that caused adverse erosion effect due to their speed and sizes. Numerous studies related to wake wash were conducted with the aim to identify its impact on bank erosion along river, estuaries and coastline. In spite of that, there is no solid fact or result's studies that able to come up with a specific amount of erosion caused by wakes relative to natural process engaged with current, wind waves and tidal fluctuations.

Boat wakes produce longer wave period compared to wind waves (Gourlay, 2011) and relevantly affected to banks erosion whereby it brings a new erosion mechanism to riverbank vegetation whereby it is naturally adapted to the short wave period of wind waves. (Macfarlane & Cox, 2004).

Referring to Figure 10, the first few wave commonly small height but long period, followed by larger waves and slowly decaying series of smaller waves.

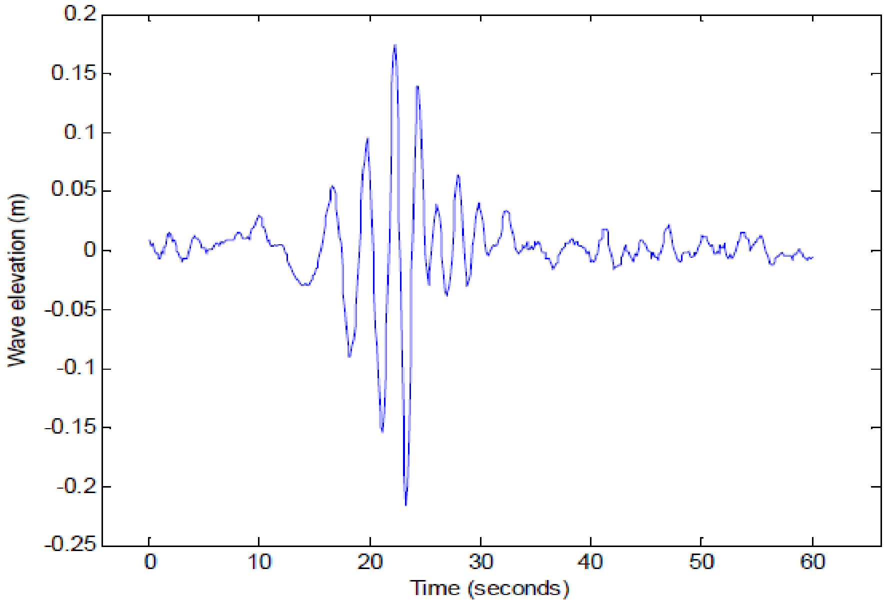


Figure 10: Example of boat wake profile

2.4 Wave Generation, Characteristics and Wave Transformation

As vessel moving through the water, it will generate wakes. The wave pattern generated by the vessel is affected by vessel speed and water depth (Macfarlane, 2012). In the uniform depth of water, characteristics of waves are dependent on two non-dimensionless parameters; depth based Froude number, F_{nh} and length based Froude number, F_{nl} (Kirkegaard, Kofoed-Hansen, & Elfrink, 1998). Depth Froude number is usually being applied for shallow water depth, meanwhile length Froude number is used for deep water depth. When water depth less than one-quarter of the vessel's waterline length, depth Froude number will get its greatest effect. Then, if water depth up to one-half waterline length, depth Froude number has moderate effect and will has less influence if the depth is greater.

$$F_{nl} = \frac{V}{\sqrt{gL}} \tag{1}$$

$$F_{nh} = \frac{V}{\sqrt{gd}} \tag{2}$$

Where,

V = Speed of the ship

g = gravitational acceleration

L = characteristics length of the ship

d = water depth

Figure 11 shows a typical wave pattern when the Froude number is less than 1 and it is called as Kelvin wave pattern. The wave pattern was named after the early pioneer of wave theory. This wave pattern consist of transverse waves and divergent waves.

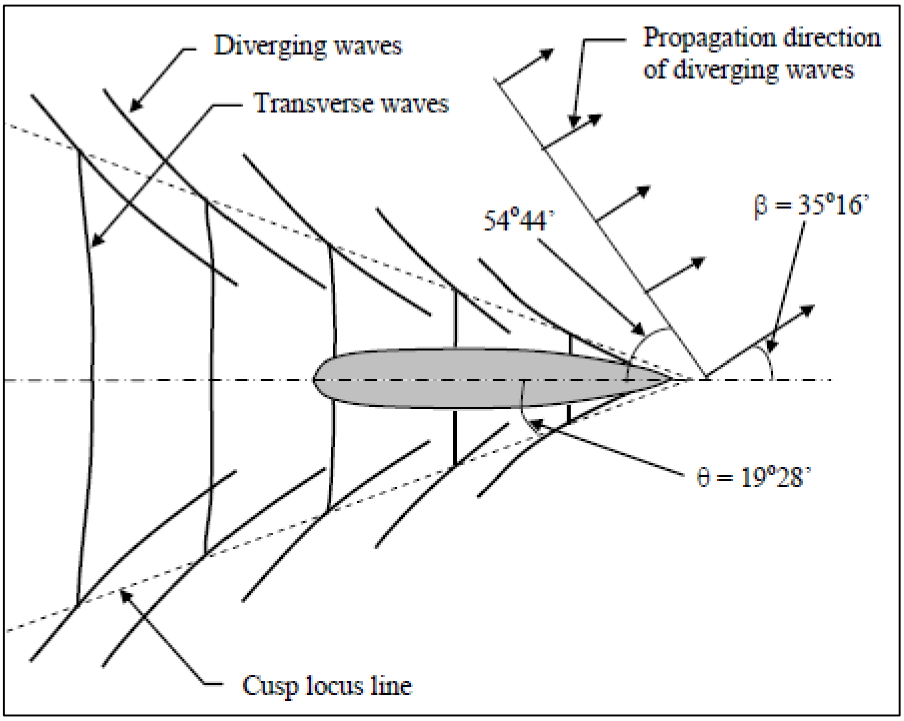


Figure 11: Kelvin wave pattern

Macfarlene (2012) has categorized the wakes pattern into 4 category as shown in Figure 12. The wave pattern was categorized with respect to depth Froude number.

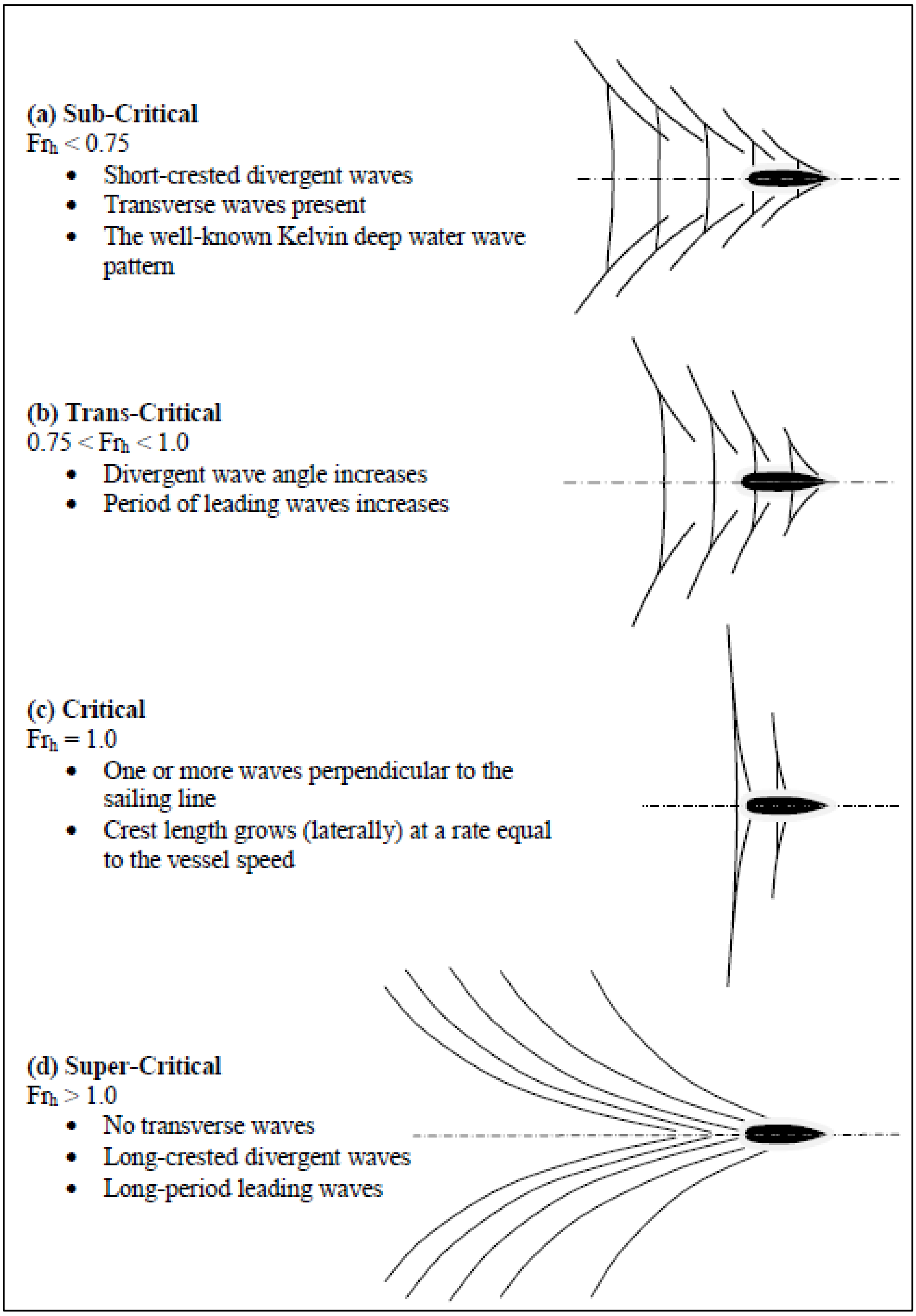


Figure 12: Wave wake patterns (Macfarlane, 2012)

Wave is a disturbance that travels through a fluid medium. Wave characteristics include wave energy, wave height, wave period, wave length and amplitude. Wave height and energy level generated by the boat wakes produced a great relationship. The total energy level is proportional to the wave height (Ahmad, Mohamad Yusoff, Husain, Wan Nik, & Muzathik, 2011). Meanwhile, wave height is proportional to the speed of boat and nonproportional to the wave length (Nasir, 2011). Speed and capacity carrying by the vessel will affect the wave heights (Nasir, 2011). Type of boat/ship, speed, length and distance of shipping lines from mangrove shoreline will be recorded for prediction of waves characteristic (Dam, Tanimoto, Nguyen, & Akagawa, 2006).

Shoaling happens when the waves moving from deep to shallower water or when the waves approaching shoreline. Changing in depth causes shoaling effect whereas the waves increase in height and getting steeper but maintaining their wave period. The waves will loss the energy through bottom friction before wave breaking takes place. Wave breaking occurs when the waves become depth-limited which is meaning the depth of the water is about half the wavelength of wave. Dissipation due to wave breaking and interaction of the flow with the mangrove vegetation has been identified as a basic energy mechanisms dominated in mangrove forest (Vo-Luong & Massel, 2008). Nasir (2011) has proved in that large shear stress is not dependent on energy level but rather influenced by water depth and she also added that the nearest sailing distance to the riverbank will produce highest energy. Thus, wave height is one of the determination factors for the level of erosion. There are two types of wave, longitudinal waves and transverse waves. The transverse wave causes the particles vibrate in the right angles of wave direction.

2.5 Erosion

Mangrove fringe riverbank has been eroded in several places such as in Kuala Kedah, Sangga Besar River and Merbok River where boat traffic is heavy. Erosion also happened along the channel of Klang Island cause by the passenger ferries activities (Chong, 2006). As a consequences in Kuala Kedah, erosion has caused severe damage to settlement properties. In addition, shipping activities in Tajung Piai is increased progressively especially since the opening of Tanjung Pelepas port eventually give serious impact to mangrove forest. Wakes from large ship has undercut the fringing Rhizophora trees and topple it down. Rhizophora have a stilt root, once it is collapse, it will leave big hole to the soil and thus it has been eroded at least 15m over the period of time (Chong, 2006)

Wave breaking may trigger the erosion, wash away the sediments and thus erode the mangrove banks. The concept of erosion caused from boat wakes occurred when the boat generates wave motion and energy produces is initiating the sediment transport. Erosion of the shoreline may be caused from the effect of single wave and cumulative of several wave trains from boats as it travels through the water the it is critically determined by shape of hull, speed and length of the watercraft (Glamore, 2008; Laderoute & Bauer, 2013). According to Ahmad et al. (2011), relationship between total wave energy and energy from maximum wave height give an information data in order to control the level of erosion at study site.

River bank erosion is driven by the energy exerted by the flow of the banks. Erosion may not occurs if the river bank materials capable to resist the shear stress and not exceeding the threshold for entrainment of the bank materials (Laderoute & Bauer, 2013). Natural factors contributing to erosion process such as wind waves, currents and bank characteristics. Sediment produced from erosion could create a big damage to agriculture land whereby it will reduce the productivity and fertility of soil plus (Nasir, 2011). Multiple criteria such as wave height, wave period, wave energy per unit wave height and total wake trace energy, provide a better indicator of erosion potential due to boat wakes compare to the traditional single criteria such as wave height (Ahmad et al., 2011; Laderoute & Bauer, 2013; Macfarlane & Cox, 2004).

2.6 Tide and Current

Degradation is giving serious impact to the mangrove sustainability ecosystem and adversely affected the human populations. Factors such as strong tidal flow and dramatic changes in the environment has influenced the colonization of mangroves. Since 1983 in Asian countries, interdisciplinary research on mangrove ecosystem has been carried out with the aim of ecosystem conservation due to high percentage of mangrove forest degraded and even completely destroyed. Mangrove ecosystem is being supported by physical environment whereby it was formed by tidal motion of seawater with a semi-diurnal or diurnal period, even though the tides does deform significantly the mangrove forest due to high density of mangrove roots and trees (Mazda & Kiyama, 2007).

Sediment dynamics at mangrove area is dominated by tide. Tide is the main factor for causes an erosion, transportation and deposition of sediment (Mahmood, Misri, Sidik, & Saberi, 2005). Tidal driven currents are highly imperative among the several types of water movement within mangrove areas (Mazda, Wolanski, & Ridd, 2007). Water currents are forced by the tides. The peak ebb tidal currents velocity are recorded higher by 20 to 50% than the peak flood tidal current velocity in many tidal creeks fringed with wide mangrove swamps. Tidal characteristics, wind, current and rainfall are the elements that important in the exchange of sediment erosion and accretion in mangrove vicinity.

2.7 Boussinesq Waves Module Coupled With Ship Wake Generator

MIKE 21 BW is software that has been developed and maintained by DHI company and also have been applied for thousands of application worldwide. This model can be used to predict and analysis the waves generated from ship/boat also known as wake wash (DHI, 2011). Dam et al. (2006) concluded in their research, model with improved Boussinesq type equation and the slender-ship theory approximation for the near field flow provided satisfactory result to predict the characteristics of waves induced by vessel.

CHAPTER 3

METHODOLOGY

Methodology is a set of ideas on how to proceed in gathering and validating knowledge at particular research study. To ensure this study achieves its objective, methodology plays a great role to convert the information based on paper to the real condition for a better understanding and to get a realistic end results.

3.1 Project Flow

Theoretically, project flow illustrate on how the project will be done. Flow process clearly outlined for better understanding and seen to be more structured. For this project, field measurement and numerical modelling are the main component to ensure this project executed accordingly. Field measurement was carried out at Kuala Sepetang specifically at Sg. Reba as shown in Figure 3.

3.1.1 Field Measurement

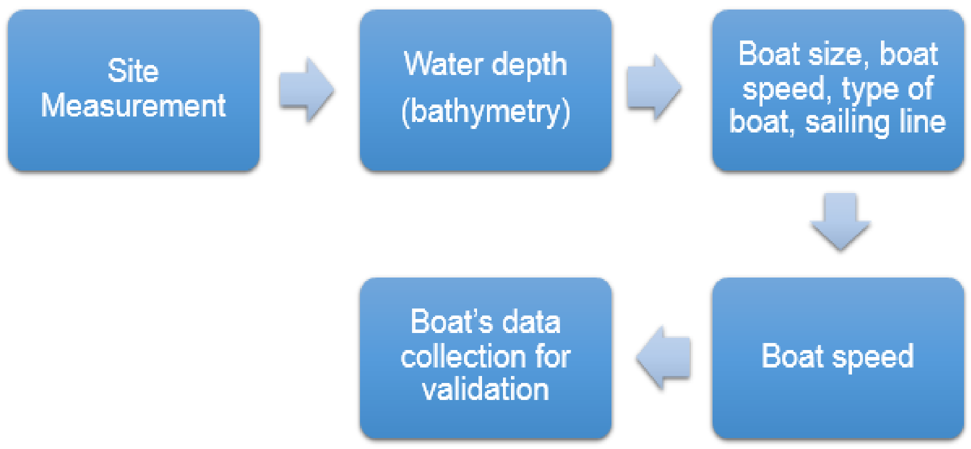


Figure 13: Flowchart for site data collection

3.1.2 Numerical Modelling

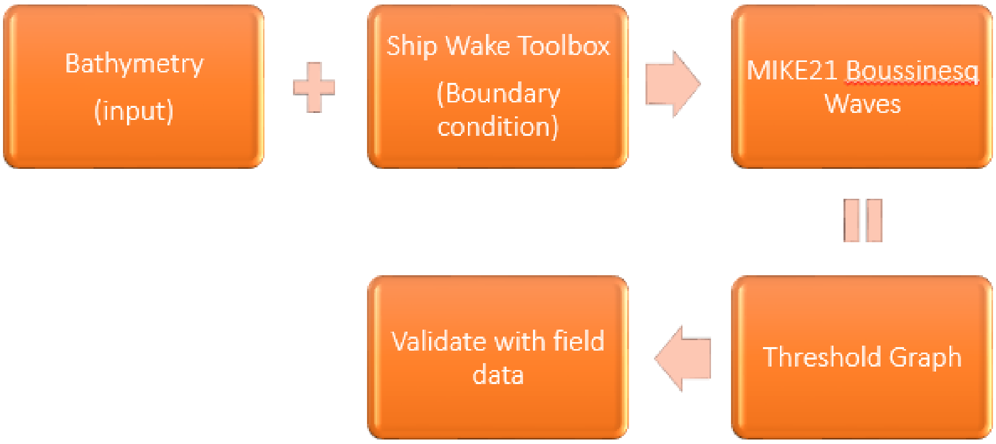


Figure 14: Flowchart for numerical modelling

3.2 Data Acquisition

Selection of the study area was based on the site observation. Site observation was done to evaluate which area significantly affected by the boat waves as a study area. Furthermore, due to the limitation of measuring tool, Sg Reba with approximately 40meter width has been selected.

3.2.1 Bathymetric Survey

Levelling staff has been used to measure the water depth at Sg. Reba to create model bathymetry. Measurement has been done during neap tide. During field measurement, due to low tide, riverbank of mangrove was exposed and erosion can be observed. Five transects was identified along the stretch. Measurement was taken at four point in each transects (Figure 15).

Measurement was done manually by putting the levelling staff until it touched the river bed as shown in Figure 16. The height were recorded and it was adjusted with respect to Mean Sea Level (MSL).

Figure 15: Red lines indicate transect for bathymetric measurement

Figure 16: Water depth measurement using level staff

3.2.2 Boat Wakes Measurement

Figure 17: Measurement of boat wakes

Surface elevation of boat waves were taken by using levelling staff. The staff attached to the tree sheet pile at the pontoon jetty. Waves were recorded when the boats passes the jetty. Speed of the boats were recorded manually by selecting two points which then calculated as distance divide by time.

3.3 Model Setup (Boussinesq Waves)

In order to investigate the effect of the boat wakes on the mangrove degradation, MIKE 21 BW (Boussinesq Waves) model coupled with Ship Wake Generator were used to simulate the boat wakes at the study area. The set-up of this modelling tools and its use are briefly described in subsequent sections.

3.3.2 Simulation period

Based on MIKE 21 BW Model Setup Planner at Appendix 2, the maximum time steps interval can be used is 0.01sec.

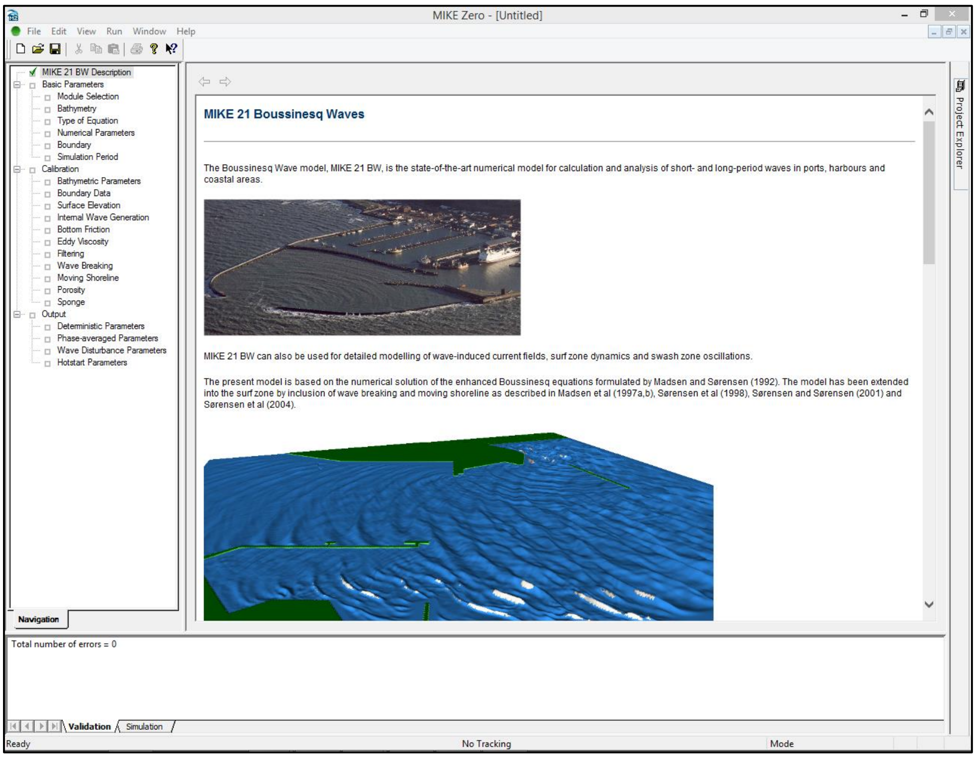


Figure 18: Interface of MIKE21 BW model

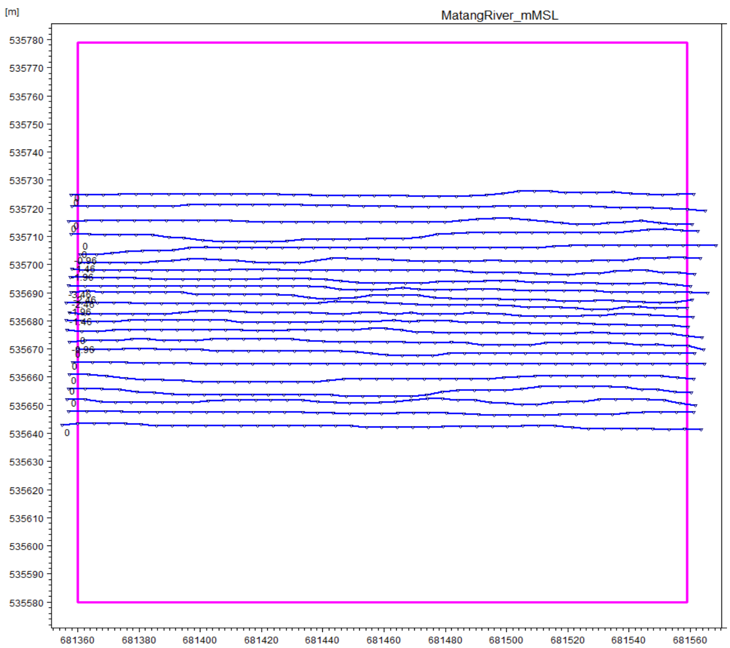


Figure 19: Model area. Blue lines indicate the added contour line

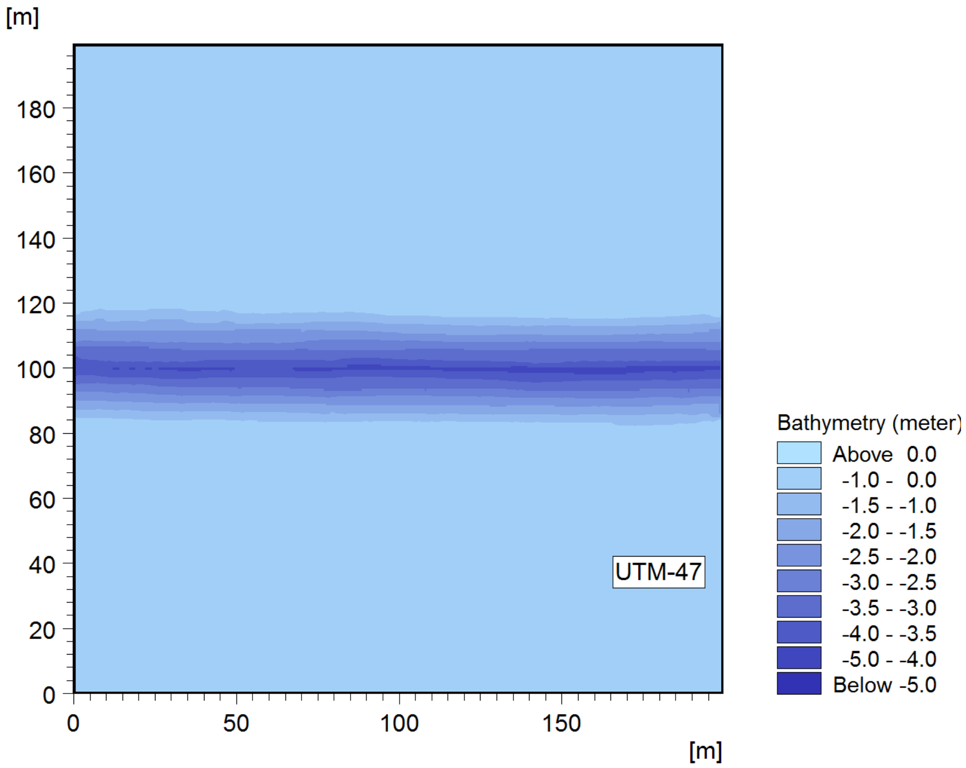


Figure 20: Model bathymetry. Model is projected to UTM47

3.3.3 Internal Wave Generation

MIKE 21 BW Ship Wake Generator toolbox was developed based on the slender-ship theory. The MIKE 21 BW numerical model coupled with the toolbox has produced a satisfactory result (Dabbi, Mortensen, Jakobsen, & Hashim, 2011). The program is employed for the setting up of the internal wave generation. The output file is in profile series data type. Figure 21 shows the user interface toolbox.

Internal generation of waves is performed by adding the discharge of the incident wave field along the specified generation line and generated using MIKE21 Toolbox. Advantage of using internal generation is that sponge layers can be placed behind the generation line, to absorb waves leaving the model area.

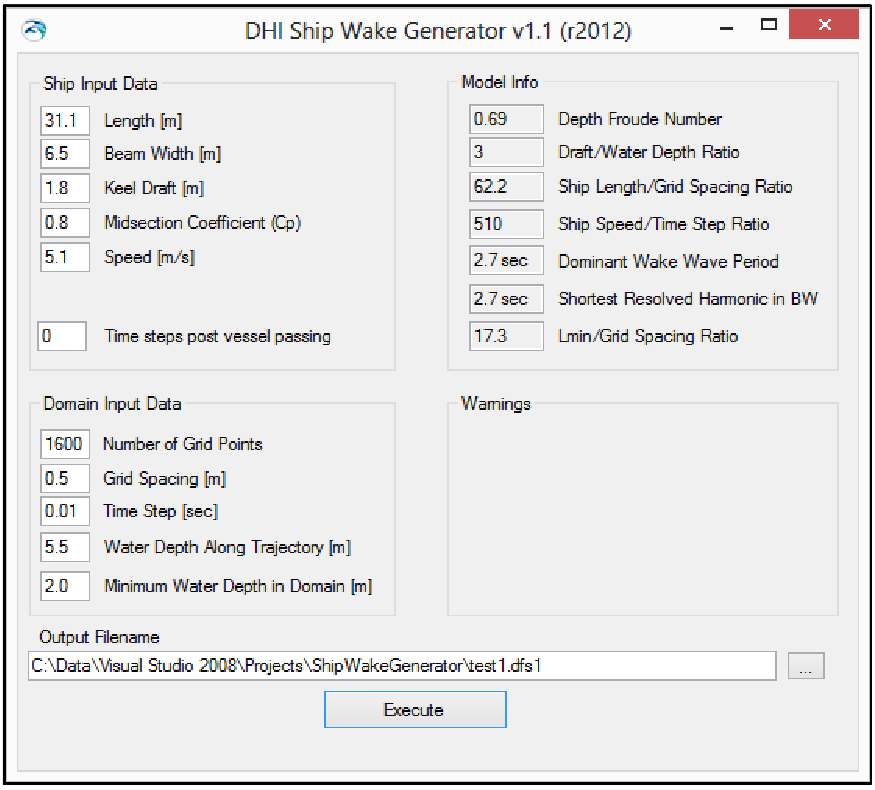


Figure 21: User interface of Ship Wake Generator toolbox

3.3.4 Wave Breaking

The wave breaking is initiated if the slope of the local water surface exceeds a certain angle, in which case the geometry of the surface roller is determined. The characteristics of the wave breaking are Type 3 roller celerity with factor 1.3 and roller form factor of 1.5. Breaking is predicted to occur at angle 20° and assumed to change gradually to a smaller terminal angle at 10°.

3.3.5 Sponge Layer

Sponge (or absorbing) layers are used as numerical wave absorbers in Boussinesq wave simulations. These may e.g. be set up along model boundaries to provide radiation boundary conditions, which absorb wave energy propagating out of the model area. A 10 points wide sponge layer is applied along model boundaries and it is recommended to use a = 5, and r = 0.5 based on method for sponge layer technique introduced by Larsen and Dancy (as stated in DHI, 2011).

3.4 Project Timeline and Key Milestone

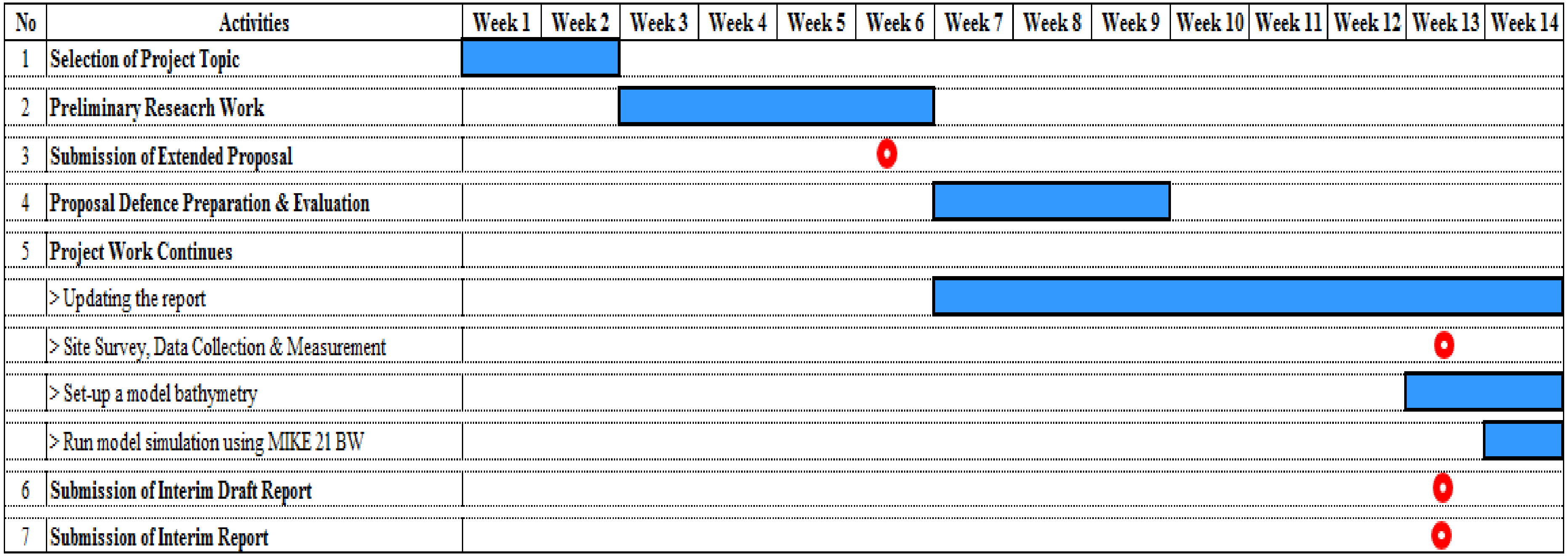
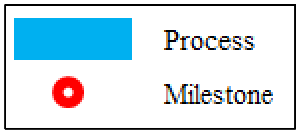


Figure 22: Project Timeline & Key Milestones (FYP 1)



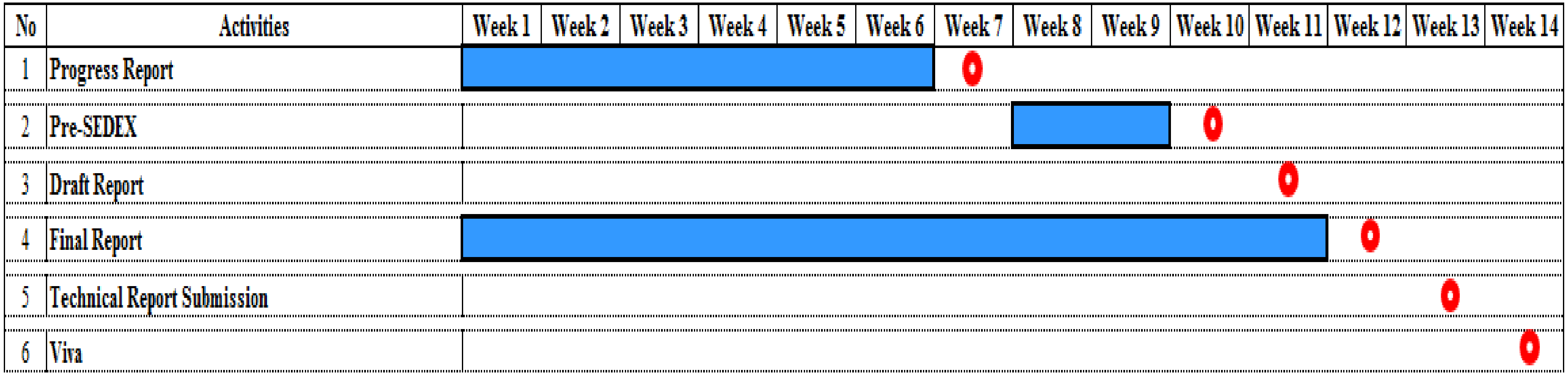
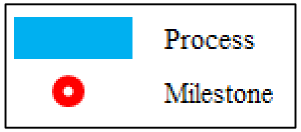


Figure 23: Project Timeline & Key Milestones (FYP 2)



3.5 HSE Aspect

Health Safety and Environment aspect is a vital aspect especially task involving site survey. Implementation HSE guidelines is to ensure safety and unwanted accidents during outdoor task. Safety shall not take for granted in any situations. Listed are some of the HSE applications when conducting site survey:-

1. Use of safety boots when going to the site to protect against broken glasses, nails and any object that could cut the foot.
2. Use of safety helmet when going for the survey for head protections if needed.
3. Use the trolley when lifting heavy objects
4. When taking samples of water, rubber gloves are used.
5. When going out to the sea for marine sampling, use of life jacket is compulsory.
6. When entering areas such as mangroves, forest or the side of a pond, make sure to check the surrounding for possible risk.
7. No survey is to be done if the weather conditions do not allow i.e. storms.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Field Data Collection

Field measurement or site visit is the primary source of information. Secondary data should always be collected but cannot fully substitute primary data. The site visit always be more valuable than any data collected.

First of all, rough observation has been made to understand the local conditions at the surrounding area. Some information that have been collected including type of mangrove plant, condition of the riverbank, boat activities, etc.

4.1.1 Type of Mangrove at Study Area

Matang mangrove is an estuaries type of coastal formation. It is comprises with rivers (refer to Figure 3). Along the rivers, different types of mangrove plants were identified such as Bruguiera and Rhizophora.

In the vicinity of Sg. Reba, vegetation is dominated by Rhizophora trees. Specifically, the trees were identified as Rhizophora Mucronata (Bakau Minyak) by its colour of leaves, it is yellowish in colour. Rhizophora have stilt root and new roots will grow downward, thus makes the root lifted then it is called as prop root. It grows well in mud soil. Its typical height is 15-25 meter tall. Rhizophora Mucronata can survived well in complete daily inundation. This type of plant can be easily found in Malaysia.

Figure 24: Rhizophora Mucronata

4.1.2 Vessel Information

Majority of the population in Kuala Sepetang is a fisherman. Thus, boats are used as their transportation to do their daily work. It was recorded by Fisheries Department in year 2013, 611 nos of boats were registered under Kuala Sepetang area. There are four types of boat has been classified by Fisheries Department. Boat dimensions will determine the zone that they can operating and based on this, their boats was labelled according to their respective zone.

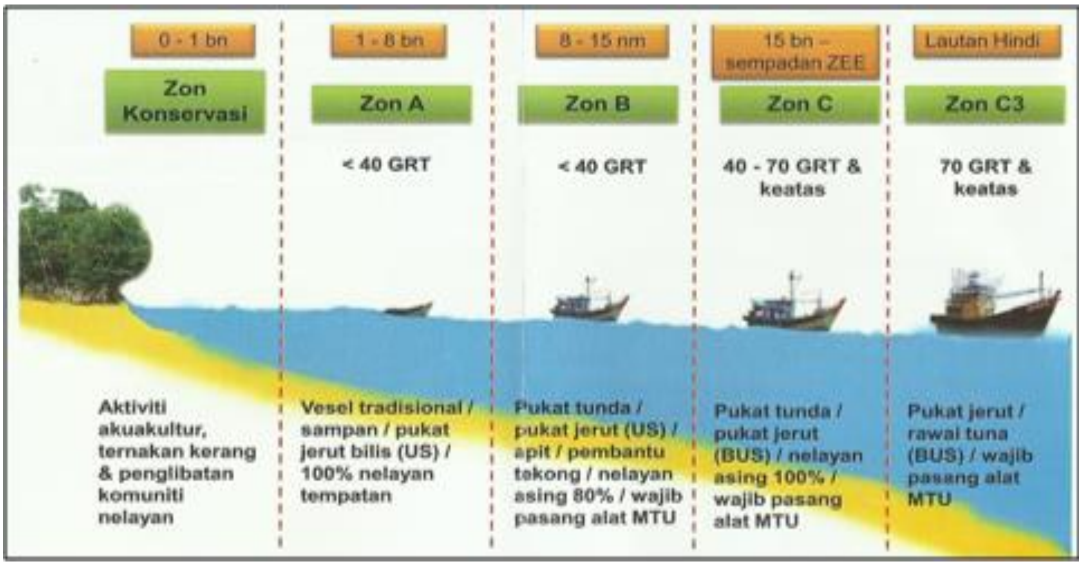


Figure 25: Boat classification based on GRT

Gross Register Tonnage (GRT) is a volume of vessel using its total permanently enclosed capacity. Calculation of GRT needs length, width and depth of haul of vessel.

Example of GRT calculation:

Length	**= 18.15 meter**
Width	**= 5.75 meter**
Depth of haul	**= 1.95 meter**
GRT	**= (18.15 x 5.75 x 1.95 x 0.8)/2.83**
	= 57.53 (Zone C)

Notes: Calculation based on Fuad (2015).

Figure 26: Boat Zone A(left) and boat Zone B(right)

Figure 27: Boat Zone C (left) and passenger boat (right)

Kuala Sepetang also attracted outsiders with its fireflies, eagles sight-seeing, dolphin and etc. Therefore, demand for passenger boat also higher to bring the visitors around. 22 nos of passenger boats were recorded by Marine Department. These make Kuala Sepetang busy with plying boats every day.

4.1.3 Riverbank Condition

Based on site observation, erosion was observed along the mangrove riverbank. It was clearly seen during low water level. Figure 28 shows the trees in certain area along Sg. Reba showing signs of uprooted. It can be seen that the soils are eroded causes the roots to have a very loose grip on it and eventually makes the trees unstable and going to fall down shortly. This study area is categorized as sheltered area and thus waves is not affected by wind waves.

Figure 28: The mangrove trees showing signs to fall down.

Meanwhile, at certain part along Sg. Sepetang, mangrove fringe shows unpleasant condition whereby many trees fell down (Figure 29). According to the interview with forest ranger Razalee (2015), this problem occurred due to designated buffer zone inside the mangrove forest for felling purpose. Mangrove trees need sufficient thickness of area to make it act as a stronger forest. Unfortunately, leaving the outer part of Rhizophora forest as a buffer zone without felling causes unstable trees.

Rhizophora trees getting bigger and eventually the soils cannot hold it anymore. In addition, boat wakes is one of the factor that speed up the process for trees to fall down.

Figure 29: Degradation of Rhizophora trees

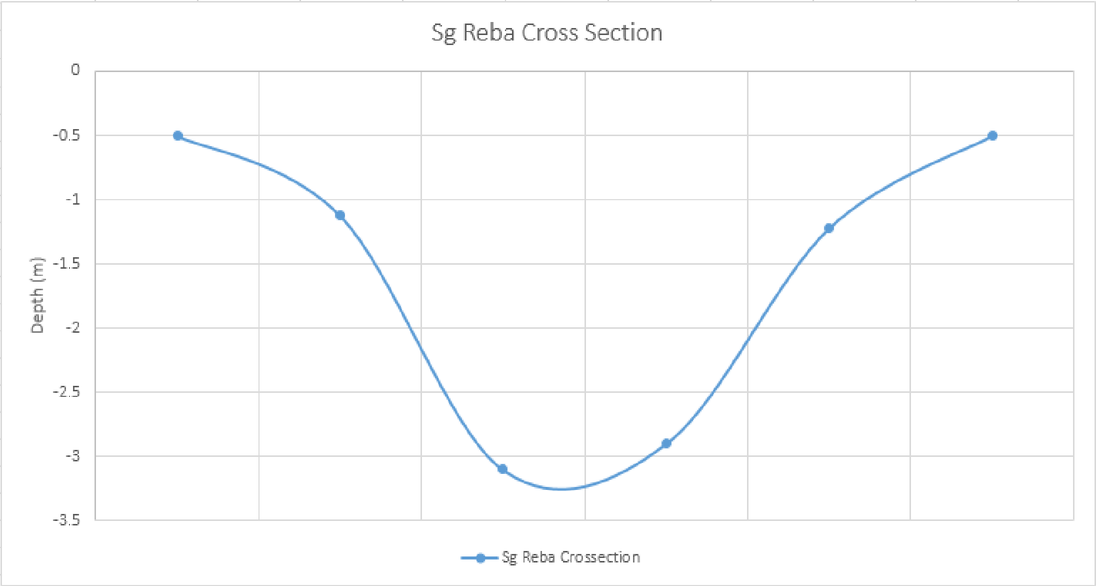


Figure 30: Sg Reba cross section

Figure 30 shows a Sg Reba cross section which has been identified from the site measurement. With slope of 1:4.5, it can affect the potential erosion level. In addition, suitable slope also affect the smoothness of MIKE21 BW simulation. This module cannot perform well when the bathymetry having a steep slope.

4.2 Result and Discussion

Six value of waves were successfully recorded and from these scatter data, graph was created. Wave heights were recorded when the boat passes the jetty with certain level of speed. Sailing distance was around 20 meters from the riverbank, meanwhile measurement was done approximately 15 meters from the sailing line. Graph of wave height versus boat speed was created to get a threshold for wave height.

Table 2: Boat speed collected from site measurement

Speed		Wave Height (m)
knots	m/s	
5.4	2.8	0.24
9.2	4.7	0.4
11.9	6.1	0.5
3.89	2.0	0.14
4.28	2.2	0.2
2.72	1.4	0.12

For the simulation, the boat has a waterline length of 10m, beam of 3.6m and draft of 1.3m. Dimension of boat is based on passenger boat which has high frequency along this river. Basically, these are parameter used as a boundary condition of the model. Boundary condition was set to create a boat wakes by using Ship Wake Generator tool. In this study, only speed of the vessel is manipulated, in order to achieve the objective stated earlier. Data of maximum wave height were extracted from the simulation to be compared with maximum wave height on site measurement.

Result that has been produced by MIKE21 BW was in grid series (.dfs2) and converted to times series (.dfs0) as shown in Figure 31. Therefore, zero-up crossing analysis was performed to extract the wave height and wave period. Table 2 is the result of wave height extracted from the simulation result. The point of extraction was approximately 15 meter from the sailing line.

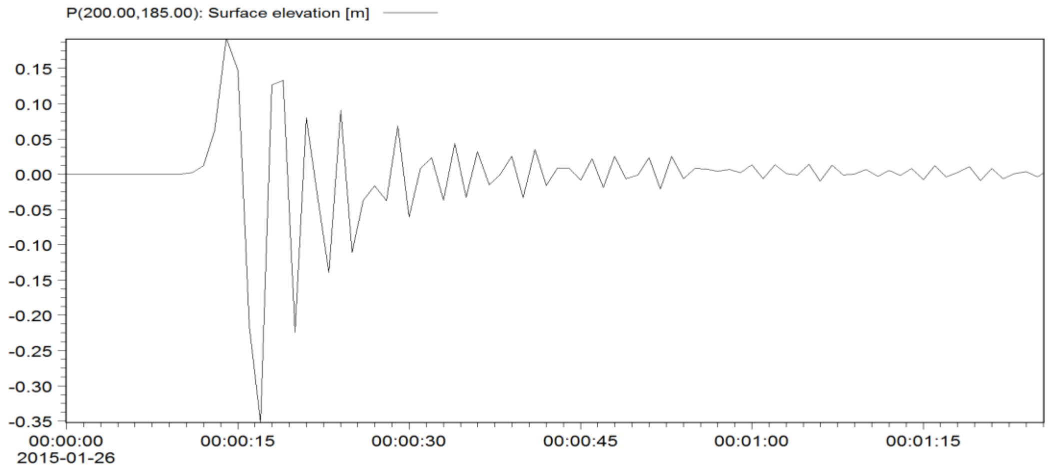


Figure 31: Time series of surface elevation extracted at point (200,185)

Table 3: MIKE21 BW Result

Knots	Speed (m/s)	Depth Froude Number	Wave Height (m)
10	5.1	0.81	0.547
11	5.66	0.9	0.723
12	6.17	0.99	0.357
13	6.69	1.07	0.350
15	7.72	1.23	0.294
20	10.29	1.64	0.244
23	11.83	1.89	0.210
25	12.86	2.05	0.236

Figure 32 shows linear graph of wave height versus boat speed. Based on the graph, wave height extracted from the MIKE21 BW modul not in good relation with site measurement data. Boat speed below 6 m/s is higher than the linear line meanwhile, speed greater than 6 m/s below the linear line. Speed of 6 m/s and above seems have undereatimated values, meanwhile below than 6 m/s speed is having overestimated wave height. Initially, based on literature review which reported by numerous researchers, wave height is propotional to the wave speed. As indicated in

Figure 32, this was however true until cetain limit . As boat travelling faster than 6 m/s apparently producing reducing wave height.

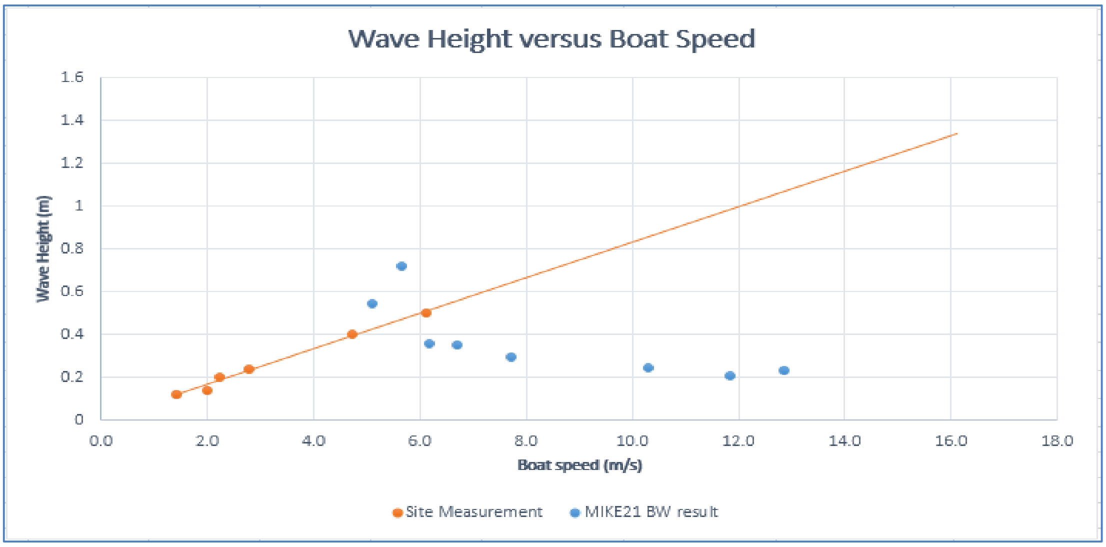


Figure 32: Wave height versus wave speed

According to Laderoute & Bauer (2013), it is rather counter-intuitive that vessel travel at high speed is actually produce relatively small wakes, whereas boats travel below the planning speed create largest wakes. This result also supported by Glamore (2008), when he did the field test, boat with high velocity produced low wave height, contrary when the boat operating at low velocity.

Based on BW model results, for the wave height less than 6.5 m/s it produced Froude number less than 1.0. Meanwhile Froude number greater than 1, the maximum wave height reduces. One of the elements influencing the wave height that stated earlier is the shape of hull. Shape of hull gave significant impact to the wakes that has been produced. Planning hull and displacement hull gave two different impacts to the wakes. Planning hull is used for a vessel designed for speed, which normally creates smaller wave height. On the other hand, passenger boat or the fishing boat were not designed for speed and thus the hull is called as displacement hull. This type of hull, the wave height generated by the travelling boats is proportional to the boat speed.

Boat wakes on the shoreline from one boat maybe not significantly give an impact, but the compounding waves will do. Cumulative wave height or called as wave train would give significantly impact to the bank. In addition, high frequency of boats at Kuala Sepetang would definitely give impact in term of accelerate the level of erosion. Table 4 shows the previous threshold recorded by few researches.

Table 4: Previous threshold based on wave height

Threshold	Criteria	Documented by
A	Limiting the boat speed, 12km/hr	Jaakson (1988)
B	Maximum Wave Height, 0.3m	Gourlay (2011)
C	Maximum Wave Height, 0.4m	Glamore (2008)

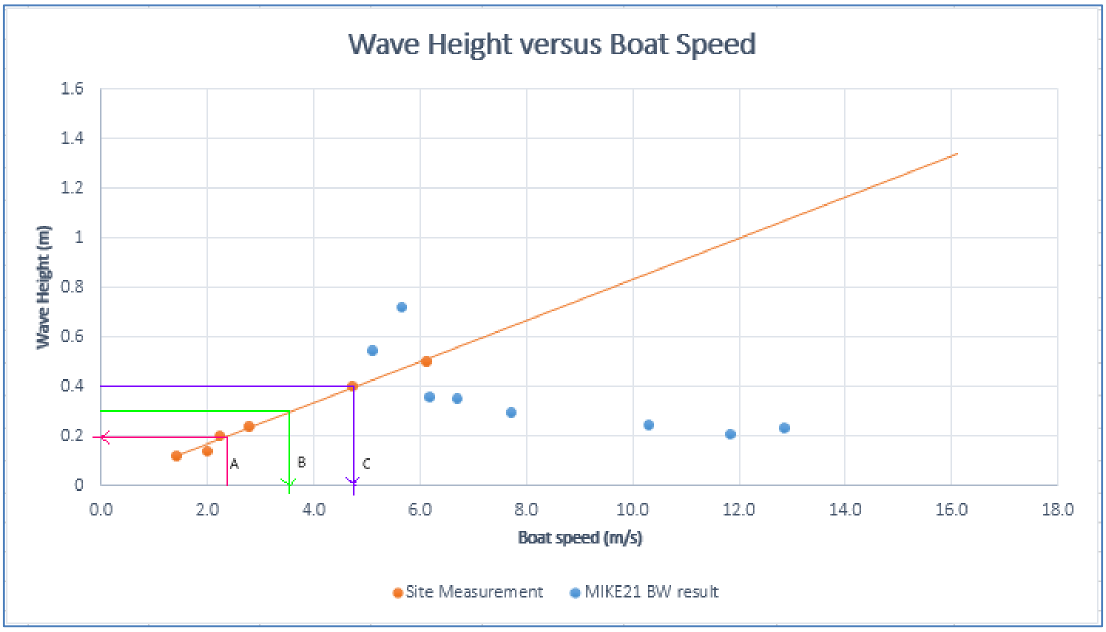


Figure 33: Threshold graph of boat speed

Riverbank soil normally is a non-cohesive soil, meanwhile in the mangrove area is dominated by cohesive soil. Therefore, the level of erosion maybe slightly different. Cohesive soil erosion is a complex phenomenon because there are few factors affect it such as flow hydraulics and as well the chemical interaction. Cohesive soils is erode as an aggregate, meanwhile noncohesive soils is erode as a single grain. That is why, noncohesive soil level of erosion can be easily determined. After all, creek is having high rate of river current especially during ebb tide. It could easily wash away the suspended sediment generated by boats wakes initially and this could lead to erosion. Suspended sediment is proportional to the energy and energy proportional to the wave height.

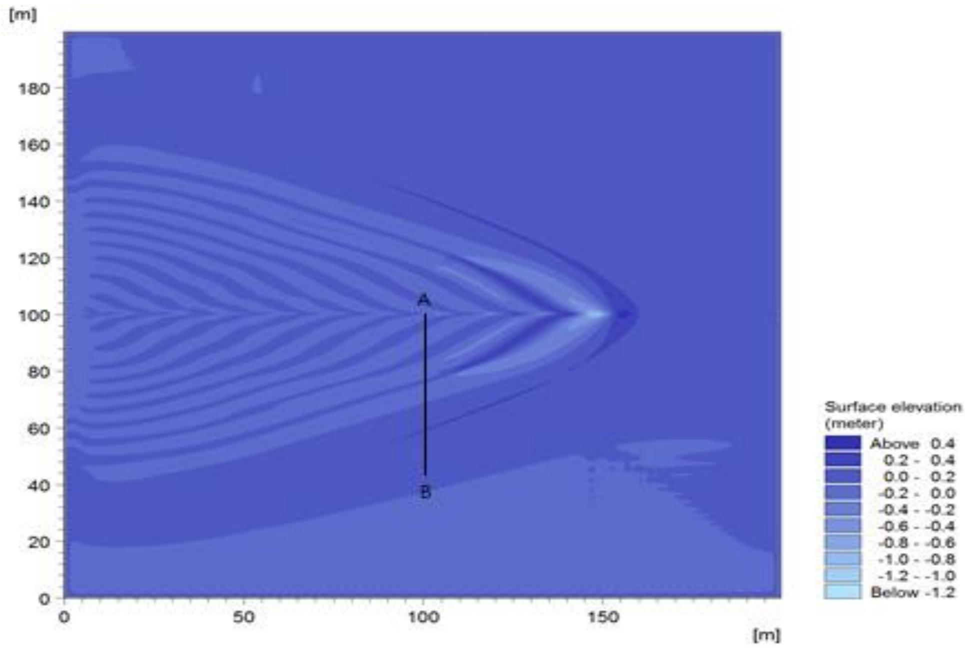


Figure 34: Surface elevation on the MIKE21 BW model for vessel speed of 6.17 m/s (Fr=0.99)

Figure 35 shows an example of simulation result. Next, time series along line A-B were extracted for further analysis on the relationship of wave height against the distance of propagation from sailing line.

Table 5: Wave height at certain distance from the sailing line

	Wave Height (m)							
Distance (m)	**Fr0.81**	**Fr0.90**	**Fr0.99**	**Fr1.07**	**Fr1.23**	**Fr1.64**	**Fr1.89**	**Fr2.05**
2.5	0.657	0.545	0.296	0.310	0.273	0.243	0.223	0.202
7.5	0.547	0.723	0.357	0.350	0.294	0.244	0.210	0.236
21	0.000	0.273	0.337	0.348	0.149	0.123	0.101	0.273
25	0.214	0.170	0.307	0.278	0.261	0.124	0.158	0.140

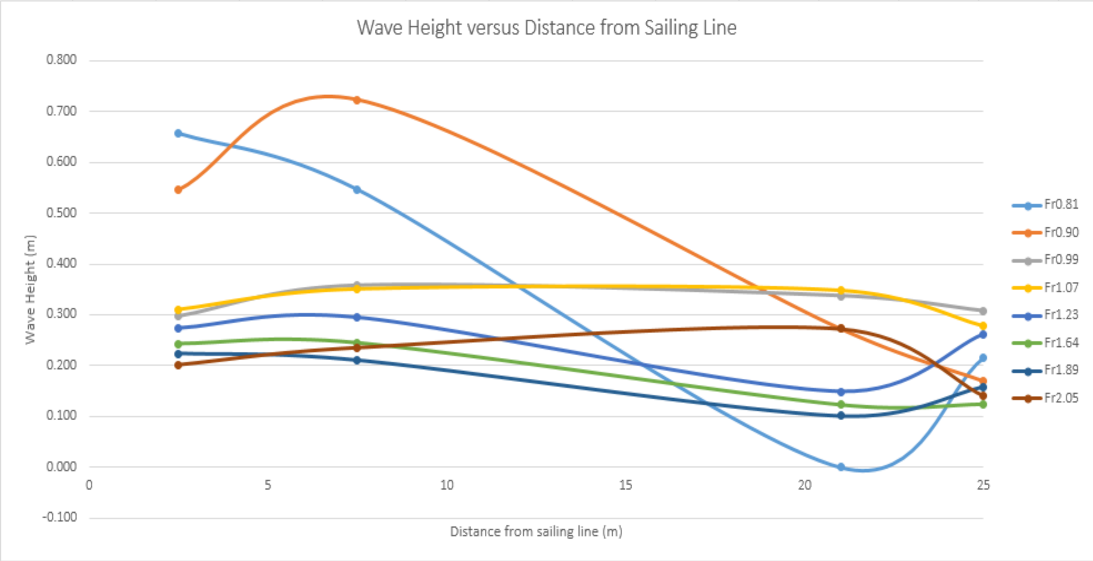


Figure 35: Wave height versus distance from the sailing line

Wave height propagation is reduces with respect to distance from sailing line. Wave height is decaying gradually except for Fr0.81 and Fr0.90. The wave heights are decline significantly in 15 meter distance. Boat generated waves is different with wind generated waves in term of duration of wave. Boat generated wave occurs and propagate only when the boat moving on the water and occur within short range of time around couple of minutes. Compare to wind waves, the waves can propagate in a long duration as long as there is a wind blows over the fetch.

Figure 36: Boat generated waves

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Development is not a ticket or excuse that allow people to take over the mangrove area blindly for their own benefits. Mangrove is deteriorated day to day. Deforestation not only cause the extinction of mangrove ecosystem but the worst case is many people will directly affected because they depending on mangrove sources. Maintaining the mangrove ecosystem especially the shoreline area by preventing erosion is critically important. Realize the importance and benefits of mangrove forest, numerous efforts have been carried out in some countries to rehabilitate the mangrove plants. Individual studies and group researches are required and vital to be carried out to determine the most effective remedial to maintain mangrove ecosystem. Moreover, it is also imperative as to give broad understanding about the mangrove forest ecosystem and to highlight the level of mangroves deterioration.

Mangrove and mangroves ecosystems have been recently studied extensively but still remain poorly understood. Thus, wide knowledge is needed in order to develop effective strategies for rehabilitation programme. Based on this study at Kuala Sepetang, authority should take a serious thought regarding the erosion problem. All parties must collaborate to produce mitigation steps and establish guidelines in order to preserve our mangrove. Mangrove erosion cannot take for granted for betterment of society and environment as well as to ensure next generations know what mangrove forest is. A well-known quote says, we are not inherit this environment from our ancestor, but indeed we are borrowing it from our children.

As a conclusion, even though boat wake is not proven in large extent causes significant erosion, but it is undeniably play a role in accelerate erosion and one of cause towards the mangrove degradation.

5.2 Recommendation

Creating a good bathymetry is a main element to produce a good result using MIKE21 Boussinesq Wave. Due to limited of measuring tools, it is restricts the selection of study area. Kuala Sepetang is having a wide and deep river to be measured and explored. Therefore, it is recommended in future to make an improvised in term of the study area selection and the usage of appropriate tools. Using a suitable tools for measurement will lead to better selection of study area and hence, produce a better bathymetry model.

In addition, validation using site data should be done extensively to get wave height by using an advance tools to validate the MIKE21 BW result. Hence, accurate result could be achieved. Next recommendation is to study the properties of cohesive soil, as it would give more accurate result in term of erosion level.

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APPENDICES

Appendix A

(A1: Water Depth with respect to MSL)

On 26 January 2015 at 11.30am, water level was -0.46342 m MSL

Point 1	-0.960	-3.460	-2.660	-1.160
Point 2	-1.060	-2.660	-2.960	-1.260
Point 3	-1.260	-3.360	-2.760	-1.160
Point 4	-1.060	-3.360	-2.760	-1.260
Point 5	-1.260	-2.660	-3.360	-1.260

Tidal level at Kuala Sepetang's port

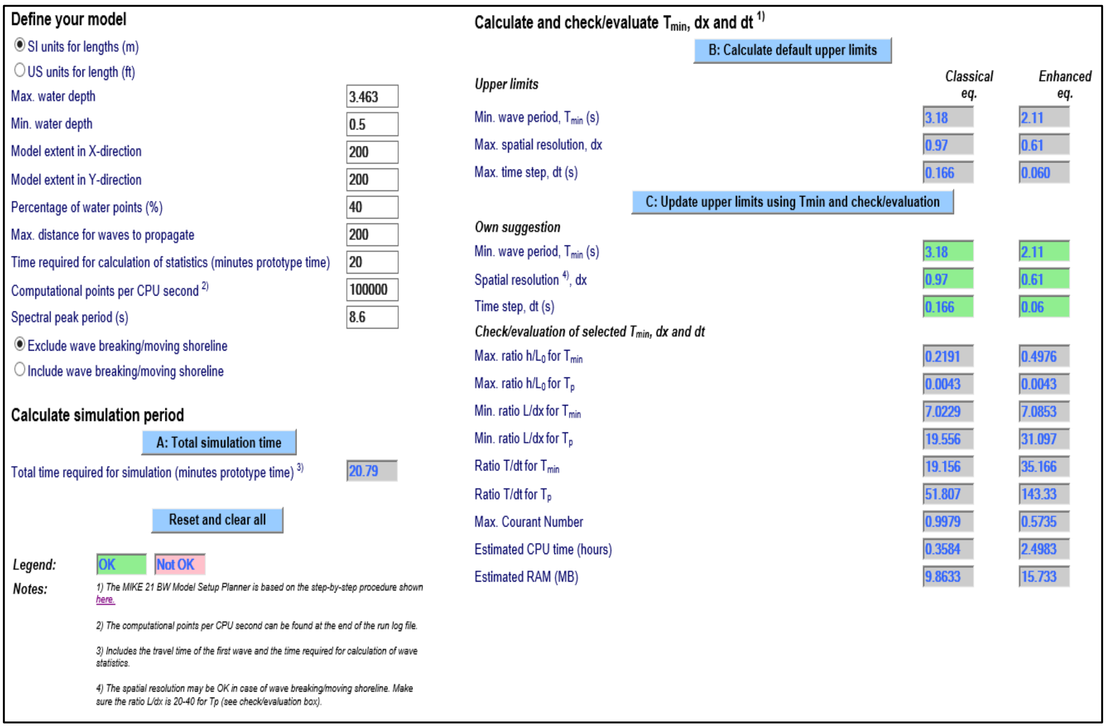
LAT	0.00
MLWS	0.82
MLWN	1.45
MSL	1.76
MHWN	2.06
MHWS	2.69
HAT	2.96

(A2: Boat/Vessel Statistics)

	Kuala Sepetang
Vessel*(Enjin Dalam)*	560
Vessel*(Enjin Sangkut)*	51
Total of vessel (nos)	611
Total number of fisherman	1647

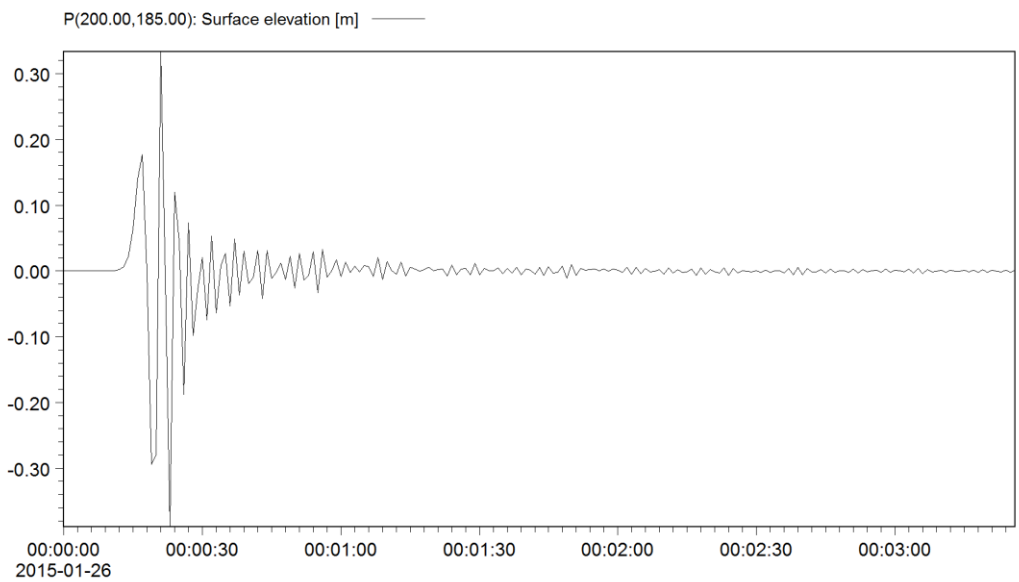
Appendix B

(B1: BW Setup Planner)

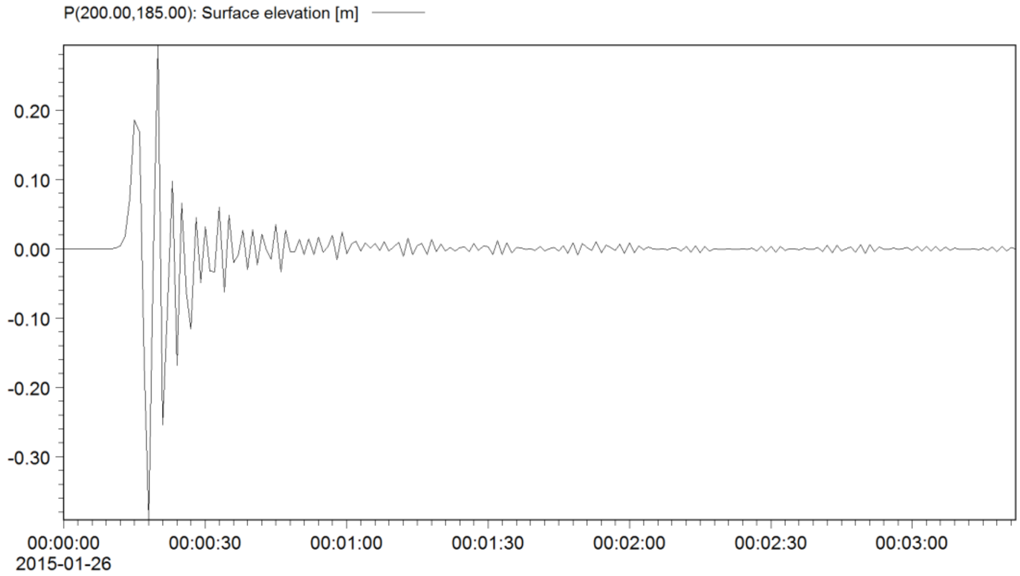


(B2: Time Series at point (200,185) for every Froude number)

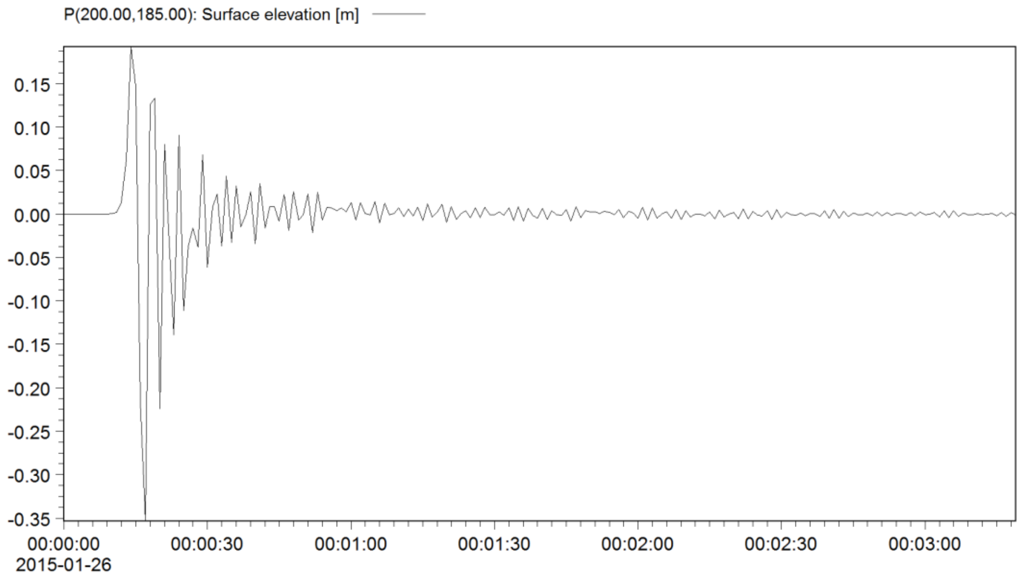
$F_{nh} = 0.81$



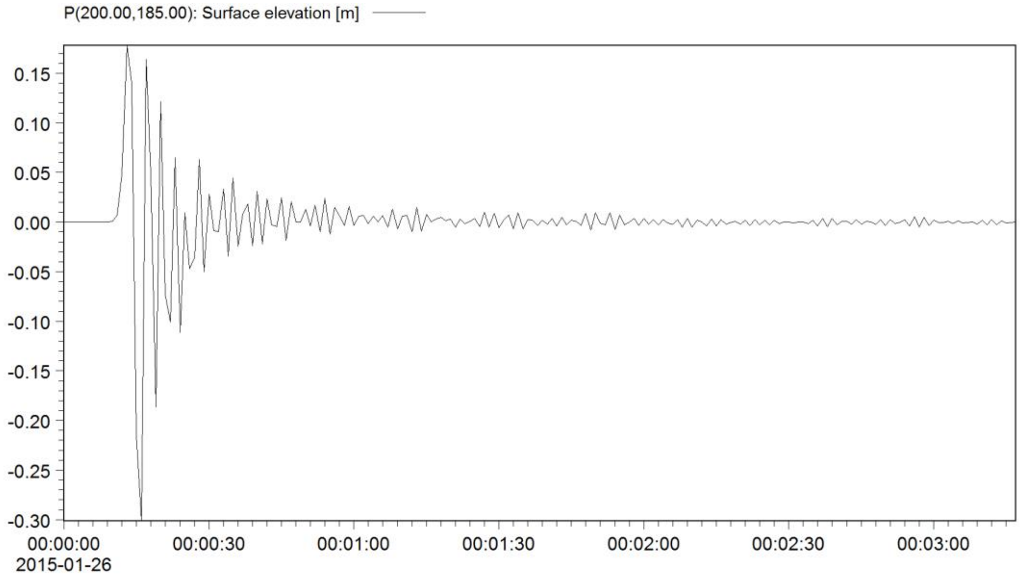
$F_{nh} = 0.90$



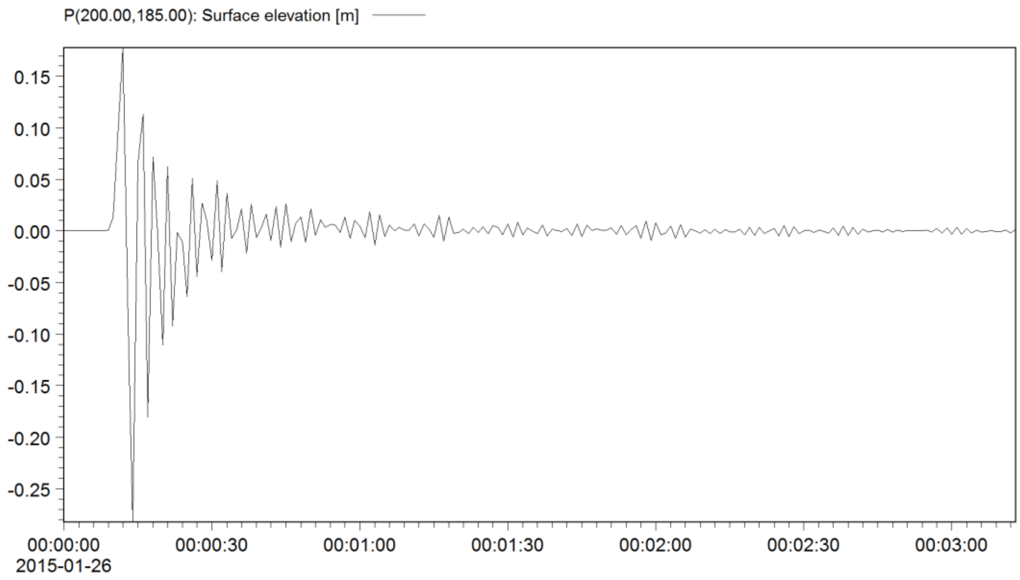
$F_{nh} = 0.99$



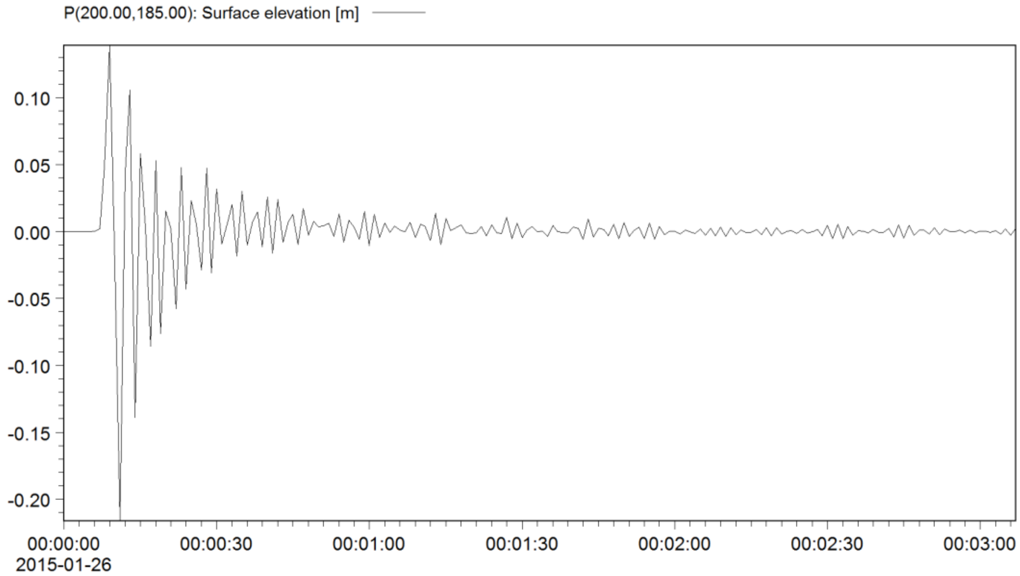
F_{nh} = 1.07



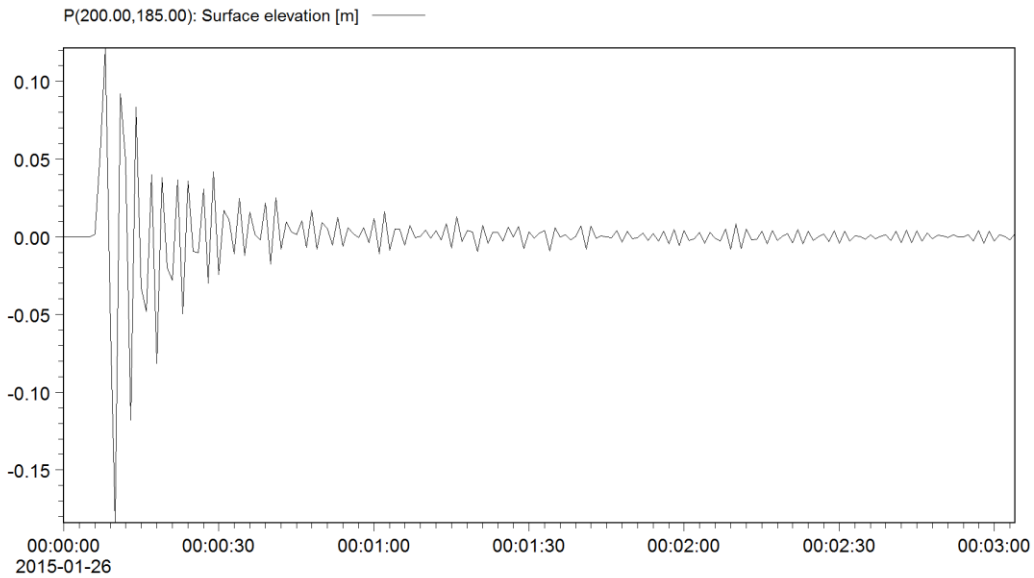
F_{nh} = 1.23



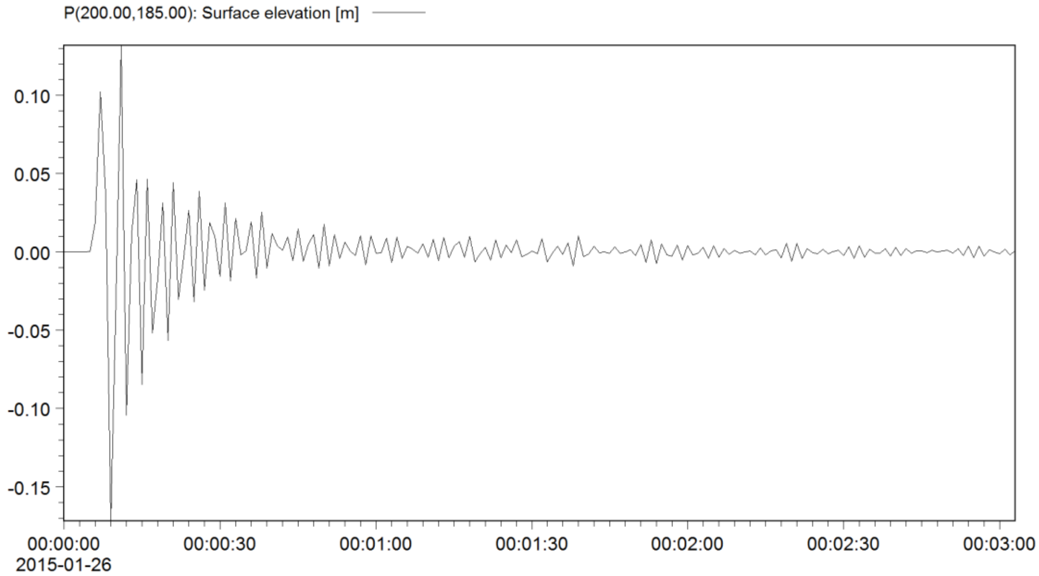
F_{nh} = 1.64



F_{nh} = 1.88



$F_{nh} = 2.05$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2015-01-26
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