Evaluation and verification of numerical modelling of nearshore changes due to waves and currents parameter in Carey Island, Malaysia

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Abstract. Coastal zones are one of the major significant areas for human activities and infrastructure growth. As known as dynamic area, thus the important to do study comprehensively in order to avoid damage due to climate change and more on. The main tool to assess these system is numerical modelling of the coast to predict the coastal environment characteristics. Thus, this study simulates the hydrodynamic characteristics at Selangor coast by applying a numerical modelling of MIKE 21 software based on flexible mesh grids. The objective of this study is to stimulate and verify the best estimation of Manning values around the Selangor coast. This study was carried out to evaluate the accuracy of the simulation results, statistical analysis method namely Root Mean Square Error (RMSE) is calculated to compare the observed and simulated results. The device of Acoustic Wave and Current Profiler (AWAC) was installed and used to record the water level, current direction and current speed at two stations near shore at Carey Island. Most of the hydrodynamic parameter in this study between observed and simulated were achieved requirement standard error for hydraulic study by Department of Irrigation and Drainage (DID) guidelines on year the 2013. The outcome of this study recommend that the bed resistant is significant factor in the hydrodynamic simulation using MIKE 21 Hydrodynamic FM.

1. Introduction
Coastal area is one of the most vital zones for human activities and infrastructure development [1] Nevertheless, coastal system is dynamic and must to be studied widely before any infrastructure is planned to avoid damage caused by natural processes such as erosion[2], [3]. The main natural
elements responsible for coastal hydrodynamics are waves, currents and tides [4]–[6]. As an important approach, the understanding of the processes in the coastal zone should be taken into consideration. Actually, the processes of the water column in the ocean environment are generally influenced by atmospheric flow, current, surface wave, tides and their mutual interactions as the information of the process is important in understanding of erosion and sediment transport [7]. As the area is located at the complex region of several large water bodies, understanding of the hydrodynamic behaviour in this particular system should be clearly explained. Also, this information is very important for various coastal engineering designs and applications for new modifications to coastal protection structures [8].

Numerical modelling is one of the reasonable approaches to investigate the hydrodynamic behaviours spatially or temporally. Several numerical hydrodynamic studies have been conducted within the same region and mostly discussed for regional model [2], [3], [8], [10]. Hence, this present study attempted to study the hydrodynamic parameters around the Selangor coastal zone, particularly in the coast of Carey Island. The hydrodynamic of water level, current speed and current direction was simulated in order to describe the physical characteristics within the study area. Therefore, in order to provide the best performances of the simulation results, the model was initially calibrated and validated against the measured conditions by adjusting the manning number in the computational domain.

2. Material And Methods

The hydrodynamic flow model was simulated by using MIKE 21 Hydrodynamic Module (HD) which was developed by Danish Hydraulic Institute (DHI). The Hydrodynamic module is one of the basic computational components of the entire MIKE 21 Flow Model modelling system [9], [10]. This module is applicable for the simulation of hydraulic and environmental phenomena in lakes, estuaries, bays, coastal areas and seas. By using MIKE 21 Hydrodynamic FM, the data required for the modelling consists of bathymetry data from the computational domain, wind speeds and wind directions, significant wave heights, mean wave directions and bed resistance. The model grid basically consist of mesh grid with size that varies from approximately 200m to 800m around Selangor coast and it can be up to over 1200m at the open boundaries.

The bathymetry was generated based on the data observation recorded includes depth from -0.01m to -19.77m from the Average Sea Level (MSL). In addition, bathymetry data of the ocean region was generated using C-MAP 2014. The model was simulated within the boundary covering large parts of the seas around the Malacca and Singapore Straits and the connection of Java and South China Sea. The water level for the three open boundaries consists of north boundary (bnd2), south boundary (bnd3) and east boundary (bnd4) were specified based on global tide model prediction provided in MIKE 21 as it was applied in varying time and along boundary format and basically generated the flow for the entire model domain [2], [3], [8], [9]. The model was run to simulate several parameters such as surface elevation, current speed and current direction. For the calibration and validation purposes, the data collected at Selangor Coast was used as it consists of water level, current speed and direction using AWAC devices on 23 December 2014 to 07 January 2015. This device was utilised to measure the water level, current speeds and current directions at 10-minute intervals. Table 1 and Figure 1 shows the location of the AWAC.

| No | Station | Latitude  | Longitude  | Depth (m) |
|----|---------|-----------|------------|-----------|
| 1  | AWAC 1  | 02° 48’ 40”N | 101° 20’ 11.18”E | 10.324 |
| 2  | AWAC 2  | 02° 49’ 26”N | 101° 18’ 58.14”E | 12.557 |
Figure 1. Locations of AWAC 1 and AWAC 2 at the Carey Island, Selangor

3. Results and Discussion

Figure 2 shows results the comparison of predicted and measured current speeds, current directions and water levels at the Coast of Carey Island during spring tide and neap tide between 23 December 2014 and 7 January 2015 at two locations of AWAC. In order to produce the best performance of the simulation results in hydrodynamic model of MIKE 21 Hydrodynamic FM model, the values of bed roughness indicated on Table 2 were used in the computation domain. The calibration and validation model was determined using a statistical method based on the standard error allowed for hydraulic study by DID guidelines on year the 2013 [5].

Table 2. Bed Roughness in the computational domain

| No | Depth (m)       | Manning Number (m/s) |
|----|----------------|----------------------|
| 1  | Greater than 50 | 35                   |
| 2  | 15 to 50        | 38                   |
| 3  | Less than 15    | 45                   |
Based on Figure 2, the pattern of water levels obtained from hydrodynamic simulations for the Selangor coastal at the station 1 and 2 are show that these simulation have a good agreement with the field measurements. The water level range at both station are approximately – 2.0 to 1.6 meter.

![Water Level at Station 1 and 2](image)

**Figure 2.** Comparison between measured and predicted of water levels on 23th December 2014 to 7th January 2015 at two station of AWAC.

Based on Figure 3 and Figure 4, the current speeds for the Station 1 and Station 2 at the Carey Island, Selangor during spring tide and neap tide were indicated about 0 to 1.6 m/s respectively, while current directions for Station 1 and Station 2 represented value between 120°-125° and 115°-120°. Thus, Figure 2, Figure 3 and Figure 4 are show that the current speeds, current directions and water levels obtained from hydrodynamic simulations have a good agreement with the field measurement.

The minimum values of Root Mean Squared Error (RMSE) for current speeds and current direction at Station 1 and Station 2 are 13.5% & 11% and 12.1% & 10% respectively. The water level of Station 1 and Station 2 are show that the RMSE about 2.90% and 2.86 % which below the tolerance of JPS requirement. Therefore, the RMSE values prove that this numerical HD model is well calibrated and validated.

Generally, the simulation outcome shows that the current flow pattern in Selangor region and adjacent areas is dominated by tidal forcing. These findings is supported by the findings of Fitri [4] which reveal that direction of current which come from the northwest to southeast direction with 125°. Another study also by Fitri [11] found that the dominant wind direction and speed during the Southwest monsoon comes from almost about 120°–150° and 5–25m/s respectively. Thus, the finding indicates that the sediment transported to the shoreline of Carey Island is generally influenced by the cross shore and long shore transport caused by wave and tidal current.

Furthermore, Fitri [11] also explained that erosion and accretion patterns in study area are strongly influenced by the sediment characteristic and physical forces for instance waves and tidal current. Research finding by Tajul [12] also reveal that the entire Carey Island had 16,187 ha of mangrove before year 1900, however 88% (1,876 ha) of mangrove forest reserve in the present was
loss due to land opening and monsoon southwest waves which encourage coastal erosion at study area [13].

**Figure 3.** Comparison between measured and predicted of Current Direction (Degree) and Current Speed (m/s) on 23-December 2014 to 7-January 2015 at Station 1.

**Figure 4.** Comparison between measured and predicted of Current Direction (Degree) and Current Speed (m/s) on 23-December 2014 to 7-January 2015 at Station 2.
Moreover, Fitri [11] study also indicated lately the issues of erosion and mangroves degradation at Carey Island shoreline make attention of local decision makers. Thus, this problem of mangrove degradation is a more severe threat to Carey Island shoreline.

Table 3. The Statistical Method for hydrodynamic model performance

| No | Hydrodynamic Parameters | RMSE |
|----|-------------------------|------|
| 1  | Water Level (m)         |      |
|    | 1. Station 1            | 2.90 |
|    | 2. Station 2            | 2.86 |
| 2  | Current Speed (m/s)     |      |
|    | 1. Station 1            | 13.5 |
|    | 2. Station 2            | 12.1 |
| 3  | Current Direction (Degree,°) |    |
|    | 1. Station 1            | 11  |
|    | 2. Station 2            | 10  |

4. Conclusion
The statistical analysis applied in the numerical Hydrodynamic model for this study area gave a high significant between the model results and the measured data. Based on this study, the best estimation of Manning values around the Selangor coast are between 35 to 45 m/s with the water depths around 0 to 65 m. These findings provide useful information for further research in future especially for understanding in coastal environment for example water quality, sediment transport and coastal morphological processes.

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