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Flood Risk Analysis Due to High Astronomical Tides, And Tidal Effect in Low-Lying Areas Township

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Abstract: Low-lying coastal areas in Malaysia are exposed to rising sea levels influenced by topographical, climatological, oceanic currents, and weather factors. The increase in sea levels due to the highest astronomical tide and tidal fluctuations poses a flood risk to these low-lying urban coastal areas. However, the limited flood records resulting from the highest astronomical tide hinder reliable statistical predictions. Therefore, numerical analysis is necessary to simulate and forecast flood vulnerability in these non-tidal, low lying urban areas. This study aims to assess the flood vulnerability caused by the highest astronomical tide and rising sea levels by integrating numerical hydrodynamic modeling and flood vulnerability analysis. The MIKE21 numerical model is developed to simulate the highest astronomical tide with rising sea levels by integrating hydrodynamic processes, and the Global Mapper software is used for flood mapping. The model is calibrated and validated against the Highest Astronomical Tide (HAT) and Lowest Astronomical Tide (LAT). The validated model is then used to simulate for four different Return Period scenarios - 10 years, 20 years, 50 years, and 100 years. The maximum value of the increase is 86% for flood depth and 83% for flood area. The resulting flood inundation map shows the location of the flood risk according to the return period count and the highest high tide impact.

Keywords: Flood risk, High Astronomical Tide, Sea Level, MIKE21, Global Mapper

1. Introduction

Towards the end of 2021 and the beginning of 2022, several states in Malaysia experienced continuous heavy rain, in addition to the monsoon season and tidal effect. This led to unexpected floods in several states, especially in the Klang Valley area, Southern Malaysia, the East Coast, Sabah and Sarawak. The floods that hit the country at the end of 2021 and the beginning of 2022 caused damage to residential areas, vehicles, business premises, manufacturing and agriculture sectors, as well as public assets and infrastructure.

In Malaysia, several industrial areas in Selangor have been developed over the past few decades on land that was formerly part of the floodplain of the Klang River. Despite flood protection measures being in place around most of these industrial areas, some of them have experienced floods since 2004 up to the present in 2022. Improving flood management on a larger system scale is a challenging and time-consuming task. The Netherlands is often considered an example of the "best-protected delta in the world," with high safety standards and advanced organizational structures and financing for flood management. Investment in improving flood management infrastructure to an acceptable level is significant in all these areas. However, many countries are managing their budgets for flood mitigation (Jonkman & Dawson 2012)

The study area includes the industrial areas of Port Klang and Tanjung Harapan, which are developing as the largest trading hubs in Selangor State. Port Klang, located in the Klang district, is the 16th busiest container port and the 13th busiest trading port globally, as shown in Figure 1. The Port Klang Authority (PKA) oversees three ports in the Port Klang area: Northport, South Point, and West Point. Port Klang, Pulau Indah, and Pulau Indah Industrial Park are listed as major business and settlement centers in Selangor, while Armada Putra Town, Teluk Nipah Village, and Perigi Nenas Village are smaller settlement centers.

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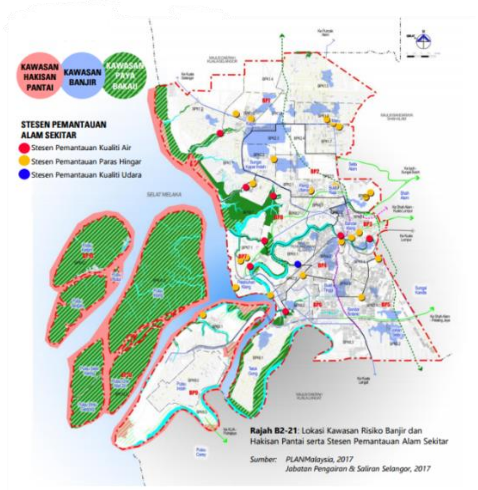

Fig. 1 - Location of Flood Risk and Erosion Area at Study Location
Source : PLANMalaysia 2017

Future climate scenarios are expected to play a significant role in urban coastal flood areas. Long-term sea level rise will impact the extent, frequency, and duration of coastal flood events. Figure 2 clearly shows the serious flooding situation in Westport, Port Klang, which nearly paralyzed the entire area. High-tide flood events that used to occur only a few times a year may now happen once a month or even once a week. In the future, the same changes in water levels can also raise groundwater levels, affecting rainwater storage capacity. Changes in rainfall patterns in many coastal areas are expected to result in heavier rain rates during storms, which could increase the frequency of rainwater runoff and river floods.

Fig. 2 - Flood Incident in Westport Port Klang, Selangor State in Dec 2022
Source: Artikel Getaran 2022

The research objectives are to identify the impact of flood depth during high tide simultaneously with tidal fluctuations in the Westport, Port Klang area by producing flood inundation maps. The objectives of the detailed study are as follows:

a) Identifying the impact of high tides with sea level rise to low-lying areas townships

b) Evaluate the comparison of flood depth levels in the situation of the tide phenomenon

c) Creating a Flood Inundation Map based on the magnitude of the return period (10 years, 20 years, 50 years and 100 years) in low-lying areas townships

In the study conducted by Romali (2018), the HEC-HMS model was simulated to assess flood vulnerability for different return periods of 10, 25, 50, 100, 200, 500, and 1000 years. The HEC-HMS model is a hydrological model commonly used to study surface water flow and floods. Digital Elevation Model (DEM) data obtained from the Department of Irrigation and Drainage Malaysia (JPS) was used to process data within the HEC-HMS model.

According to Dano (2019), flood vulnerability maps were developed for Perlis State, Malaysia, with the aim of managing the impact of floods on humans and the surrounding environment. This study involved an integrated approach that combined Geographic Information System (GIS), Analytic Network Process (ANP), and Remote Sensing imagery for flood vulnerability assessment and mapping. In this study, variables obtained from Remote Sensing (RS) were used to assess factors related to flood vulnerability such as topography, land use, river networks, and others. These data were then utilized in GIS analysis and ANP processes to determine the importance of each factor's interrelationships and generate flood vulnerability maps.

Kadam & Sen (2012) studied flood simulations for the floodplain of the Ajoy River in West Bengal using the MIKE-FLOOD modeling approach, which integrates the 1-D MIKE-11 model with the 2-D MIKE-21 model. The river network layout, cross-sections, boundary conditions, and simulation parameters for hydrodynamics are inputs for the 1-D MIKE-11 model. On the other hand, for the 2-D MIKE-21 modeling, only bathymetry inputs are used. Both of these models are combined into MIKE-FLOOD for simulation modeling to generate flood vulnerability maps.

Flood vulnerability maps for the catchment area of Sungai Pinang were studied using the Frequency Ratio (FR) model and a combination of FR with Analytic Hierarchy Process (AHP) by Saleh (2022). The Frequency Ratio (FR) is a popular method in modeling forecasts due to its capability and ability to determine critical flash flood factors. The flood inventory for this catchment area was taken for the month of November 2017 when a major flood event occurred in Penang State. The study found that the prediction rate of the FR-AHP method had better accuracy compared to the FR method, with accuracies of 88.33% and 85.62%, respectively.

Zakaria (2017) employed a flood forecasting system approach based on geographic information and generated several series of flood maps. There were three types of flood maps in this study: Flood Hazard Map, Flood Risk Map and Flood Evacuation Map. However, the study only focused on simulating the Flood Hazard Map using Geographic Information System (GIS) for return periods ranging from 10 to 100 ARI.

On the other hand, Dottori (2016) utilized river flow data in the analysis using the Global Flood Awareness System (GloFAS) to generate flood vulnerability maps on a

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large flood scale. River flow data was generated on a high-resolution river network and processed to provide input for local flood simulations, which were conducted using a two-dimensional hydrodynamic model.

According to Bangkok & Goeysinsup (2022), flood risk management is crucial for the economic development of a country. In this study, the LISFLOOD-FP model was developed to simulate major floods in 2011 in Bangkok, Thailand, under scenarios of sea level rise for the years 2030, 2050, 2100, and 2150 with varying river flow rates. The impact of floods was analyzed to determine the level and danger of flooding with projections of sea level rise. The results showed that sea level rise has a significant impact on flood vulnerability. By 2050, it is projected that sea levels will rise by 0.39 meters, and 87% of the study area will be flooded.

Timbadiya & Krishnamraju (2023) used a 2D hydrodynamic model, the MIKE21 Flow Model (FM), to predict flood vulnerability levels after water release from the Sardar Sarovar Dam with a 100-year recurrence interval flood. The monitoring objective was to record the maximum flood levels under maximum rainfall conditions and simultaneously if there is water release from the dam. This 2D model was also used to analyze the river level rise in downstream areas severely affected by floods in 2019. However, the study did not consider the rate of sea level rise and river deviations after the dam implementation in the study area.

Pradhan & Youssef (2011) used hydrological and hydraulic analysis to generate flood vulnerability maps along the Kelantan River in Kelantan State. Geographic Information System (GIS) data in the form of RADARSAT was extracted to obtain historical flood data that occurred in 2007. Subsequently, digital elevation model and rainfall information were updated to enable flood-related calculations at the study site. The hydrological and hydraulic study found that the flood event occurred at a 100-year recurrence interval. The generated flood vulnerability map showed that the Kelantan River basin is at medium to high-risk levels.

Mohamad (2018) conducted a study on the impact of sea level rise in line with coastal zone planning and development, especially in the Klang and Kuala Langat districts. A comparison of results was made with the National Physical Plan – Coastal Zone (NPP-CZ) study provided by the Department of Town and Country Planning Peninsular Malaysia. Hydrodynamic numerical models for the Klang and Kuala Langat districts were simulated, and the impact study was forecasted due to sea level rise and climate change based on flood inundation maps for the year 2100. This study indicated that flood hotspots in the Klang and Kuala Langat districts would experience more frequent flooding due to sea level rise, including low-lying areas.

2. Methodology

The MIKE21 hydrodynamic model has been developed by the Danish Hydraulic Institute (IHP). It is part of a series of software programs that use two-dimensional planar mathematical models to simulate large-scale water flow features such as rivers, lakes, estuaries, coasts, and bays. MIKE21 has been widely used in hydrodynamic, water quality, and sediment studies in surface waters due to its high versatility. MIKE21 is based on an unstructured triangular mesh, which can be adapted to complex coastlines and topographies. Additionally, the model has methods to distinguish between wet and dry water depths. By setting minimum wet and dry water depths, the model can determine whether a grid is involved in the calculation and accurately simulate processes such as exposure and flooding that often occur in continental wetlands. The model can adapt to shallow and extensive earth surfaces and complex coastlines due to its comprehensive physical mechanisms and flexible triangular mesh profile (Long et al., 2023).

According to Bubeck et al. (2012), flood forecasting can reduce financial losses and economic impacts for a country. Identifying areas prone to flooding is crucial for flood damage control strategies. Efficient flood forecasting and mitigation can be achieved by combining the MIKE21 modeling method with remote sensing technology and Geographic Information System (GIS) such as Global Mapper. There are different techniques for mapping flood-prone areas. The four main categories of techniques that are most popular are hydrology-based learning techniques, quantitative techniques, qualitative techniques, and software-based techniques. Despite the existence of models for mapping flood vulnerability, a significant challenge with flood prediction maps is their reliability and accuracy. Each technique differs in its capabilities and is susceptible to various sources of uncertainty (Tella et al. 2023).

Measurement of models is typically done by comparing predicted river or sea water levels and velocities during tidal cycles with measured values and making necessary adjustments for various model parameters to match the two datasets. The following information is provided for modeling:

a) Values of all model parameters that have been adjusted.
b) Velocity difference (indicating the comparison of speed and direction for predicted and measured values).
c) Current direction difference (indicating the comparison of current direction for predicted and measured values).
d) Water level difference (indicating the comparison of water levels for predicted and measured values).

These measurements help assess the accuracy and reliability of the model by evaluating how well it reproduces the observed conditions.

Model validation is done by comparing predicted water levels and velocities with actual measured values. Validation stations should be located at different locations from the measurement stations. Validation stations should be near the study area (where the effects may occur) in this study. The number of measurement points should be sufficient to match the model size/project area.

Table 1.1 DID Guidelines for Tolerance Value (DID Manual)

No	Description	Tolerance Value
1	Water Level	10 %
2	Wave Speed	20 %
3	Wave Direction	20°

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According to the guidelines of the Department of Irrigation and Drainage Malaysia (JPS), the average tolerance values for velocity and direction should not exceed 20%, and the average difference in water levels should not exceed 10%. The general pattern of velocity and direction should be similar. The difference between predicted and measured values will be considered as absolute values, and these values should be averaged over the comparison period. The time interval between each consecutive value should be less than 60 minutes (Department of Irrigation and Drainage Malaysia 2015) as shown in Table 1.1 above.

Bathymetric data refers to hydrographic data that maps the depth and shape of the underwater terrain. It is used to create seabed or water body base maps. It commonly employs sonar, echo sounding, or Doppler systems to generate sound waves and measure the distance to the seafloor. It can also collect data about coastlines, tides, currents, and waves or identify structures and anomalies underwater. River bathymetry studies are also necessary as part of field measurements to meet the study's requirements. It provides an initial scale of physical characterization of the riverbed and river slope in the area. Survey routes were generated at intervals of every 100 m along the river's centerline. Profile surveys were conducted using a single beam at the project site. Water level measurement data were obtained from JPS Malaysia, captured at two (2) locations namely ADCP 1 (Longitude 101.297680, Latitude 3.101020) and ADCP 2 (Longitude 101.12525, Latitude 2.8346) from December 14, 2022, to January 5, 2023, for a period of 23 consecutive days including neap and spring tides. All water level readings are relative to Mean Sea Level Datum. Data were logged at 10-minute intervals with a resolution of 0.01 m. MIKE 21 Flow Model FM is a new modeling system based on a flexible network approach. Figure 3 is the modeling system developed for applications in oceanography, coastal, and estuarine environments for this study.

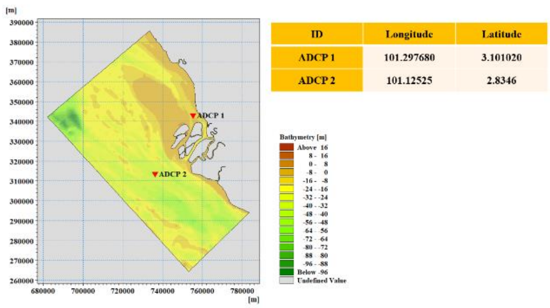

Fig. 3 - MIKE21 Modeling System developed using Bathymetry Data

The 2D MIKE 21 FM model is based on a network or flexible framework system. The model domain is represented by a network of triangular elements that form a connected network as shown in Figure 4. The network is generated automatically by the software, and the model resolution is controlled by specifying the maximum planar shape area that any individual element can occupy in the network. The network resolution can be adjusted in different parts of the model domain. When the network cell size is reduced, both the number of elements in the model and the computation time for the simulation model increase.

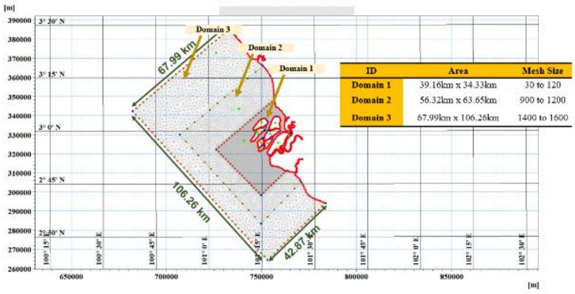

Fig. 4 - Study Area Basin Model distributed to 3 domains

Coastline modeling in Figure 5 involves modeling and analyzing the physical structure of the coastline, including landforms, shorelines, and other coastal features. In MIKE 21, bathymetric data and coastal geometry information are used to build an accurate boundary model. This enables better simulations of the interaction between the sea, river flow, and land around coastal areas. Boundary modeling can assist in understanding changes in the coastline over a study period, erosion and sedimentation, changes in river flow patterns, and significant impacts on coastal areas due to sea level rise.

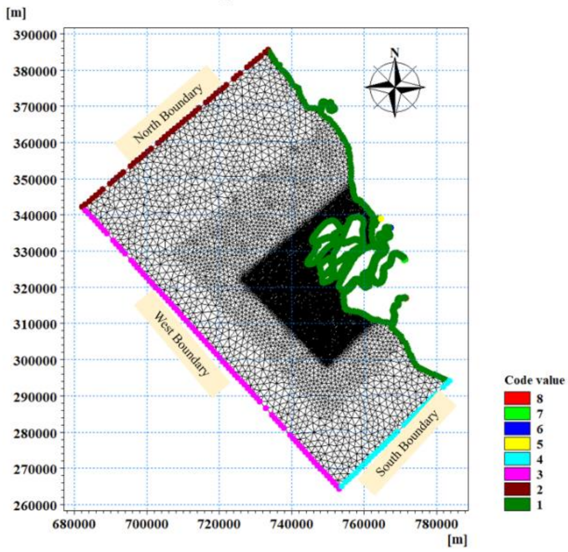

Fig. 5 - Delineation Model

In MIKE 21, bathymetry is combined with NGVD data to model and analyze the effects of sea level rise on coastal areas. Figure 6 shows the simulated sea level rise and its significant impact on the coastline, water level rise, and hydrodynamic changes in the water bodies can be predicted. Through bathymetry and NGVD modeling, better decision-making can be achieved in planning adaptation to climate change and sea level rise.

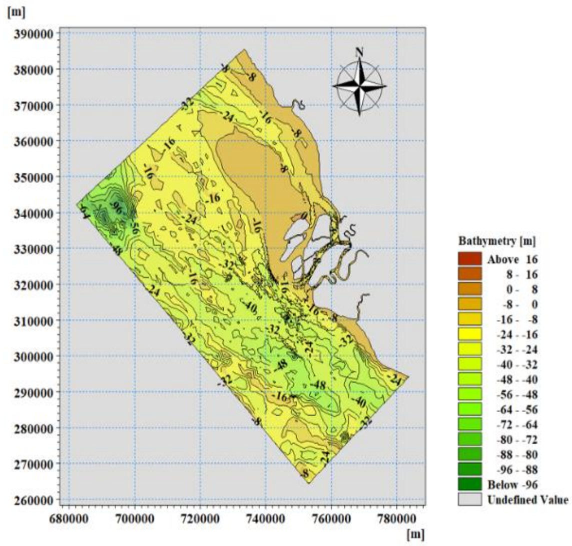

Fig. 6 - Bathymetry Boundary Model

1. **Results and Discussion**

Table 1.2 shows the results of measurement analysis in the study area at station 1 (ADCP 1). The maximum current velocity recorded was 1.614 m/s, and the minimum was recorded at 0.00 m/s. Observations indicate that the dominant current direction is around 110º - 150º during high tide and 350º - 70º during low tide. The average tidal range varied by 2.225m, with the highest water level recorded at 2.26m and the lowest level recorded at 2.19m.

Table 1.2 Results of measurement analysis in ADCP 1

Station	**Current Speed (m/s)**		**Water Level (m)**	
ADCP 1	Max	Min	Highest	Lowest
	1.614	0.00	2.26	2.19
Average Observation Value	**1.614**		**2.225**	

Table 1.3 shows the results of measurement analysis in the study area at station 2 (ADCP 2). The maximum current velocity recorded was 1.313 m/s, and the minimum was recorded at 0.00 m/s. The dominant current direction varies during high tide and low tide. Observations indicate that the dominant current direction is around 310º - 350º during high tide and 140º - 170º during low tide. The average tidal range at station 2 is 2.30m, with the highest water level recorded at 2.37m and the lowest level recorded at -2.23m.

Table 1.3 Results of measurement analysis in ADCP 2

Station	**Current Speed (m/s)**		**Water Level (m)**	
ADCP 2	Max	Min	Highest	Lowest
	1.313	0.00	2.37	2.23
Average Observation Value	**1.313**		**2.30**	

The average values obtained in Tables 1.2 and 1.3 are referred to as the basis of the tidal datum water levels for the purpose of numerical simulation modeling. The simulation period for this study, as shown in Figure 7, was conducted for 17 days, with the first 2 days considered as the model stabilization period to achieve accuracy during the measurement period of this study.

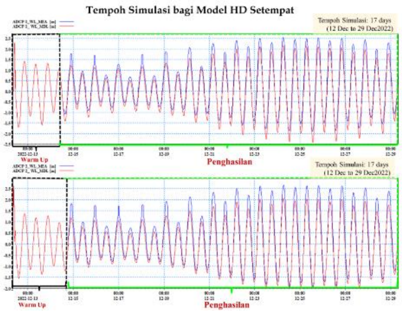

Fig. 7 - Simulation of Local Hydrodynamic Models

Table 1.4 Datum relationship between tidal level at WL station, Port Klang

TIDAL LEVEL at WESTPORT KLANG		
(Based on tidal data from 14/12/2022 until 15/01/2023)		
LEVEL	**LAT/CD (m)**	**NGVD (m)**
HAT	5.20	**2.974**
MHWS	4.428	2.202
MHWN	3.414	1.188
MSL	2.512	0.286
NGVD	2.226	0.00
MLWN	1.683	-0.543
MLWS	0.654	-1.72
(LAT)/ Chart Datum (CD)	0.00	-2.226

The tidal analysis of Port Klang was conducted using Geotide software. The results of this analysis are presented in Table 1.4 above. The Highest Astronomical Tide (HAT) level is at 2.974m above the NGVD vertical datum, and the Lowest Astronomical Tide (LAT) level is at -2.226m below the NGVD datum.

3.1 Analysis of Water Level Results, Current Direction and Current Speed

Based on the simulation model from MIKE21 software, the selected model type is Hydrodynamics (HD). According to the guidelines from the Department of Irrigation and Drainage (JPS), the acceptance criteria for simulation model accuracy regarding water levels should not exceed 10%, current speeds should not exceed 20%, and current directions should not deviate more than 20 degrees as shown in Table 1.1. In conducting hydrodynamic studies in this area, ADCP instruments were deployed in the sea to record current speed and direction, while a tide gauge instrument was installed near Pulau Indah, Port Klang, to collect tidal data. The data collection period for tidal data, current speed, and current direction in the study area should range from 15 days to 17 days, covering both spring tides and neap tides. Overall, calibration and verification indicate that the model produced is at a satisfactory level of accuracy.

3.2 Flood Inundation Map

The first objective of this study is to identify the impact of the highest spring tide water level increase on different return periods. For a return period of 10 years, the increase in water level in the study area is only 0.11 meters. Significant increases are observed in scenarios of 50 and 100 years, ranging from 0.40 meters to 0.70 meters. The results of the highest spring tide water level impact for the four different scenarios are shown in Table 1.5. This increase in water level will elevate the flood risk in areas such as Westport, Bandar Armada Putra, Pulau Indah Industrial Park, Kampung Teluk Nipah, including Carey Island.

Table 1.5 High Astronomical Tide Impact Results

Scenario	High Astronomical Tide (HAT)	Water Level Simulation (m)	Water Level Rise (m)
10	2.250	2.13	0.11
20	2.350	2.10	0.25
50	2.500	2.10	0.40
100	**2.850**	**2.17**	**0.68**

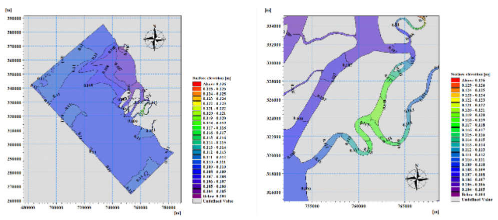

Fig. 8 - Flood Inundation Map for the HAT for 10 years return period

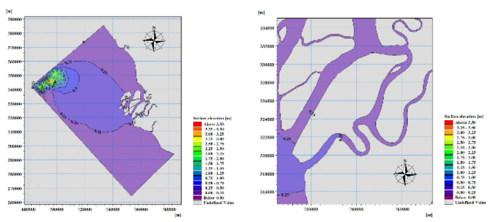

Fig. 9 - Flood Inundation Map for the HAT for 20 years return period

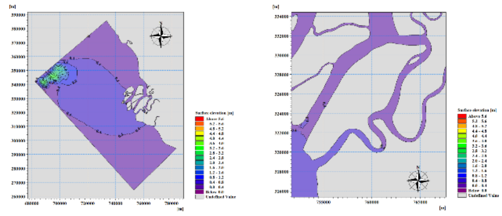

Fig. 10 - Flood Inundation Map for the HAT for 50 years return period

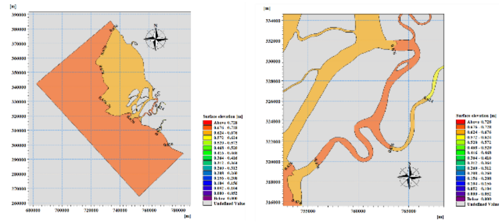

Fig. 11 - Flood Inundation Map for the HAT for 50 years return period

The second objective of this study is to estimate the depth of floodwater over the study area based on changes in the magnitude of different return period calculations (10, 20, 50, and 100 years) regarding the response of the highest spring tide water level. Referring to Table 1.6, the flood inundation area increases in different magnitudes. For example, the simulation results for the 10-year scenario show a water depth of 0.11 meters, while for the 20-year scenario, it is 0.25 meters. This increasing trend is significant for the ARI magnitudes of 50 and 100 years. An increase in water depth of up to 0.68 meters will have serious flood implications, with up to 11.91% of the area in Port Klang being inundated.

Table 1.6 Flood Depth Level Comparison

Scenario (ARI)	Depth of Water Level (m)
10	0.11
20	0.25
50	0.40
100	0.68

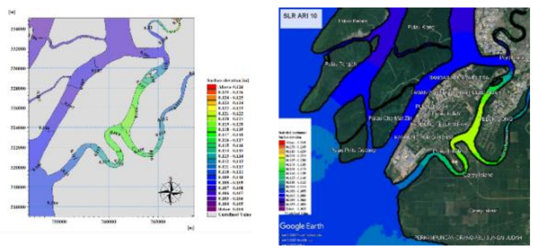

Fig. 12 - Flood Depth Level Comparison for 10 years return period

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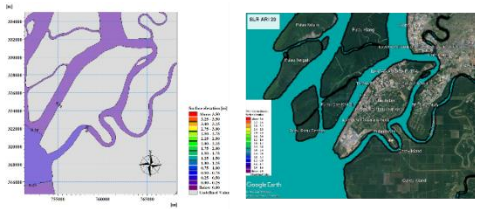

Fig. 13 - Flood Depth Level Comparison for 20 years return period

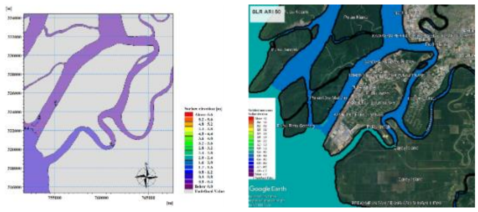

Fig. 14 - Flood Depth Level Comparison for 50 years return period

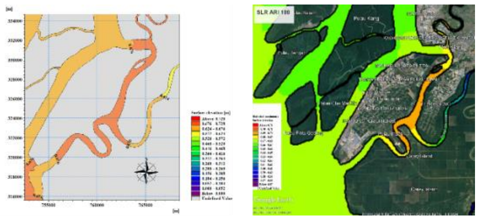

Fig. 15 - Flood Depth Level Comparison for 100 years return period

The third objective of this study is to create flood inundation maps based on different return period calculations (10 years, 20 years, 50 years, and 100 years) in the study area. For the 10-year magnitude, the flood area extent and percentage of area affected are 0.953 km² and 1.59%, respectively, as shown in Table 1.7 below.

Table 1.7 Flood Inundation Map Results based on Return Period Magnitude

Scenario (Years)	Water Level Rise (m)	Flood Inundated Area (km^2)	Percentage (%) Flooding Area
10	0.11	0.953	1.59
20	0.22	1.179	1.97
50	0.38	1.918	3.20
100	0.68	7.138	11.91

For the 20-year magnitude simulation, the flood area extent is 1.179 km² with a percentage of 1.97% of the area affected. This trend indicates an increase in the 50 and 100-year magnitudes. The flood area extent for the 20-year magnitude is 1.918 km², and for the 100-year magnitude, it is 7.138 km². The percentage increase in flood area extent is almost 86% from the 10-year to the 100-year magnitude. This increasing trend aligns with studies conducted by Dottori et al. (2016), where the impact of sea level rise will affect nearly 87% of non-tidal urban areas bordering the sea.

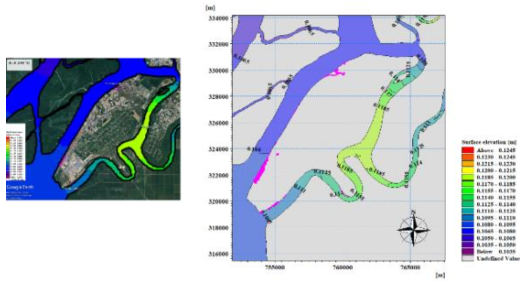

Fig. 16 - Flood Inundation Map for 10 years return period

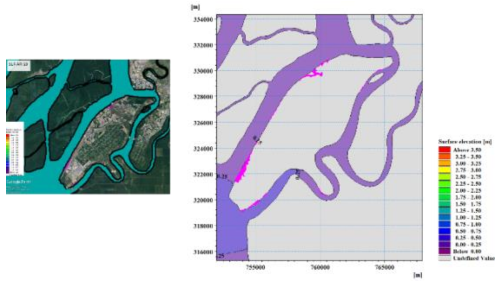

Fig. 17 - Flood Inundation Map for 20 years return period

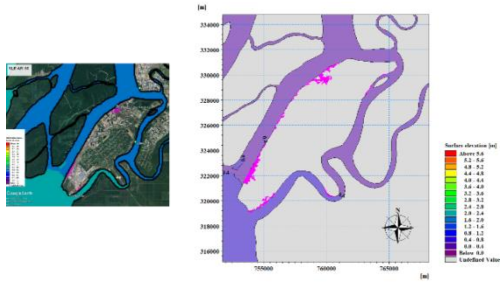

Fig. 18 - Flood Inundation Map for 50 years return period

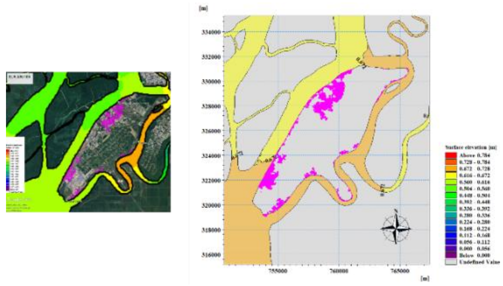

Fig. 19 - Flood Inundation Map for 100 years return period

4. Conclusion

This study found that sea level rise is expected to impact infrastructure located within the 2 km coastal zone along Port Klang, especially Westport. The study area will experience varying rates of sea level rise and is predicted to increase by up to 0.7m by the 21st century. The MIKE 21 software was used to forecast flood-prone areas from 2030 to 2100 due to sea level rise. The simulations of the highest high tide impacts and flood inundation maps predict that between 2% to 12% of the Westport area in Port Klang will be affected by the highest high tide impacts. Furthermore, several urban

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areas such as the Port Klang Shipping Terminal, Bandar Armada Putra, Taman Perindustrian Pulau Indah, Pulau Indah, Kampung Teluk Nipah, and Kampung Perigi Nanas will also be affected by these highest high tide impacts. These findings provide valuable information for future research in identifying flood-affected areas. Therefore, the results from hydrodynamic simulations for predicting the highest high tide impacts and flood inundation maps can be used to protect areas that may be affected in the future.

Referring to the Sea Level Rise Projections for Malaysia 2017 Report, the impact values of sea level rise according to the 10-year, 20-year, 50-year, and 100-year magnitudes are shown in Figure 20.

Year	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
2020	0.06 [0.02 - 0.10]	0.06 [0.02 - 0.10]	0.06 [0.02 - 0.10]	0.07 [0.04 - 0.10]
2030	0.10 [0.05 - 0.15]	0.10 [0.05 - 0.15]	0.10 [0.05 - 0.15]	0.11 [0.07 - 0.15]
2040	0.14 [0.08 - 0.21]	0.15 [0.09 - 0.21]	0.14 [0.08 - 0.21]	0.16 [0.10 - 0.23]
2050	0.19 [0.11 - 0.27]	0.20 [0.12 - 0.28]	0.19 [0.11 - 0.27]	0.22 [0.14 - 0.31]
2060	0.23 [0.13 - 0.33]	0.25 [0.15 - 0.36]	0.24 [0.14 - 0.34]	0.30 [0.19 - 0.41]
2070	0.27 [0.16 - 0.40]	0.31 [0.19 - 0.43]	0.30 [0.18 - 0.42]	0.38 [0.24 - 0.52]
2080	0.31 [0.17 - 0.46]	0.37 [0.22 - 0.52]	0.36 [0.22 - 0.51]	0.47 [0.30 - 0.65]
2090	0.35 [0.19 - 0.52]	0.42 [0.25 - 0.61]	0.43 [0.26 - 0.61]	0.57 [0.37 - 0.80]
2100	0.39 [0.20 - 0.58]	0.48 [0.28 - 0.69]	0.50 [0.30 - 0.71]	0.68 [0.44 - 0.95]
2081 - 2100	3.7 [1.2-6.3]	5.7 [2.9-8.6]	7.0 [4.2-10.0]	10.5 [6.7-15.3]

Fig. 20 - Impact value of HAT on impermeable urban low-lying areas

Source : NAHRIM Report 2017 (Sea Level Rise Projections for Malaysia 2017)

The RCP8.5 value was chosen as a reference because the Representative Concentration Pathways (RCP) represent climate change scenarios regarding sea level rise and their effects on phenomena such as high tides that can cause flooding. The RCP8.5 value represents the highest-risk scenario for sea level rise.

In explaining the scenario in this study, the RCP8.5 value is compared with the simulation results from this study. The simulations of the highest high tide impacts and flood inundation maps predict that between 2% to 12% of the Westport area in Port Klang will be affected by the highest high tide impacts. Furthermore, several urban areas such as the Port Klang Shipping Terminal, Bandar Armada Putra, Taman Perindustrian Pulau Indah, Pulau Indah, Kampung Teluk Nipah, and Kampung Perigi Nanas will also be affected by these highest high tide impacts. When this projection is compared with the simulation results, it is expected that the study area will experience serious flooding issues by 2100. The increase in flood depth of up to 0.68m with a flood vulnerability of up to 11.91% is expected to have a significant impact on the largest business hub in the state of Selangor.

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