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Floodplain Modelling by Using HEC-RAS at Sungai Mersing, Johor Malaysia

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Abstract: Flood is a common natural problem that occur in Malaysia. This problem will lead to loss of life and property. Johor is one of the states in Malaysia that is frequently hit by floods. Therefore, flood mitigation methods can be applied in purpose of flood controlling. Flood mitigation should be constructed aimed at controlling flooding problems from recurrence. Floodplain modelling objective is to identify the floodplain area of the study area by it using a topography and geometric a rainfall data. This step begins with obtaining hydrological data of the study area to create rainfall-runoff modelling by using HEC-HMS and to obtain its peak value, the value obtained then are used in HEC-RAS along with topography and geometric data to produce floodplain map. The floodplain map produce will show which area that more vulnerable to flood. Result shown that most left of bank (LOB) of the upstream part re affected by flood, this is due to the lower depth of the river in range of 0.0 to 2.7 in height. The result obtained for flow velocity shown that right of bank (ROB) for river cross section for station 2318 to 1908 have the slightest range of velocity in between of 0 m/s to 1 m/s, this area located at Taman Pantai Timur, Mersing. The low range of velocity occur due to high range of river depth at the river cross section. Most of the right of bank for river cross section at river station 1618 to 222 remain unaffected by water flood velocity, thus making it not a flood prone area. For the right of bank (ROB) of river cross section at station 471 to 110 are recognized as a floodplain area as the flood are at the outer side of the right river bank, this due to the high range of velocity on that area. The high range of velocity occur due to low range of river depth. Floodplain problem arise should be controlled by an immediate action as it has more downsides compare to superiority as it leads to restrictions to develop new construction and high risk of flooding.

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Keywords: HEC-RAS, HEC-HMS, Floodplain

1. Introduction

Flood is a natural phenomenon that often occurs in Malaysia. This event leads to the loss of life and property. The risks have also increased in recent times due to climate change and human interference with river systems. Along with data collected by DID Malaysia in 2014, there are over 30,000 km^2flooded areas and 9 percent flooded area in Malaysia. 4.8 million live in a flood-prone area (DID,2014). The frequent flood problems in Malaysia occur due to climate changes. Climate change occurs due to rich rainfall catchments especially in the monsoon season from November to February (Md Zahri,2015). The worst flood ever happened in Johor was in December 2006 which had caused severe damage to the river basin. Flood problem again occurred the following year in January 2007 with a low magnitude nonetheless led to destruction and natural damage. In addition to the flood problems is unplanned development of private or public area without supervision from responsible parties dealing to control the development. Unplanned development took place to support the Mersing growing population in 2010 with a population of 70,894 (LIBUR.2017). For a long time, human beings have been fighting flood in various ways, but in reality, a flood is not fully controlled, but it can be reduced by floodplain management. A variety of computational simulations are available to predict the hydrodynamic properties of floodplain flows. The behavior analysis of river that correctly forecast the flow of the river through its simulation models leads to flood zoning maps that are among the valuable tools of floodplain management. The short and long-term well-being of human communities and their surrounding environments can be determined by effective management of the water and floodplain resources of a region. Mersing district is located in the Northeast of Johor, on the coast of South China Sea. Its border by Kluang District, Segamat to its west, Kota Tinggi to its south, and Pahang to its north. Mersing is the 3rd largest district in the State of Johor. HECRAS is a hydraulic model readily available and can conduct 1D and 2D hydraulic simulations for a network interface of natural and engineered waterways built by the US Army Corps of Engineers. HEC-RAS used to produce floodplain map. Floodplain modelling can be very useful solution as assessment and prediction can always be done with sufficient data. This flood hazard map helps the administrative parties in the area by giving them the ideas on determining which areas are affected by flood to avoid further flood event and as guideline in construction activity in purpose to avoid any construction failure by flood affect.

2. Study Area

The study was conducted in Sungai Mersing, Johor, Malaysia.Mersing district usually experience flood in the month of November to February due to rich rainfall catchment with 2713.7 mm a year (DID,2014). The district has an area of 2836.6 km^2 and a total population of 70,894 people (2010). The district is located 128 km from Johor Bahru City Center.

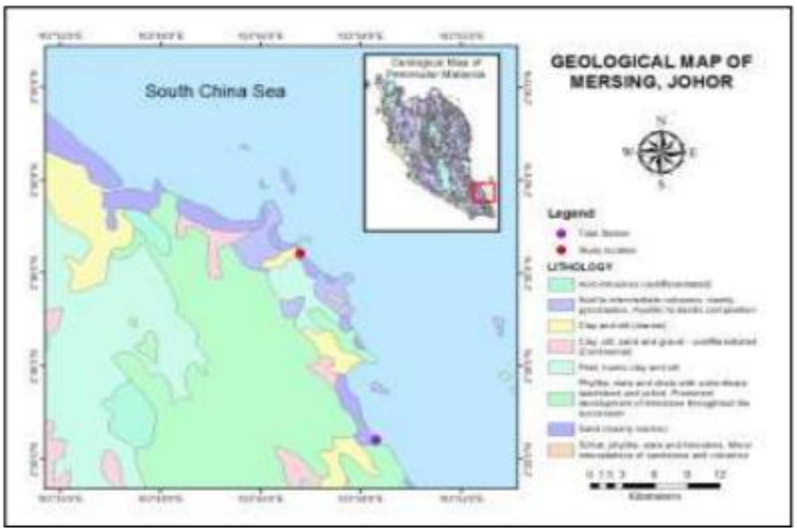


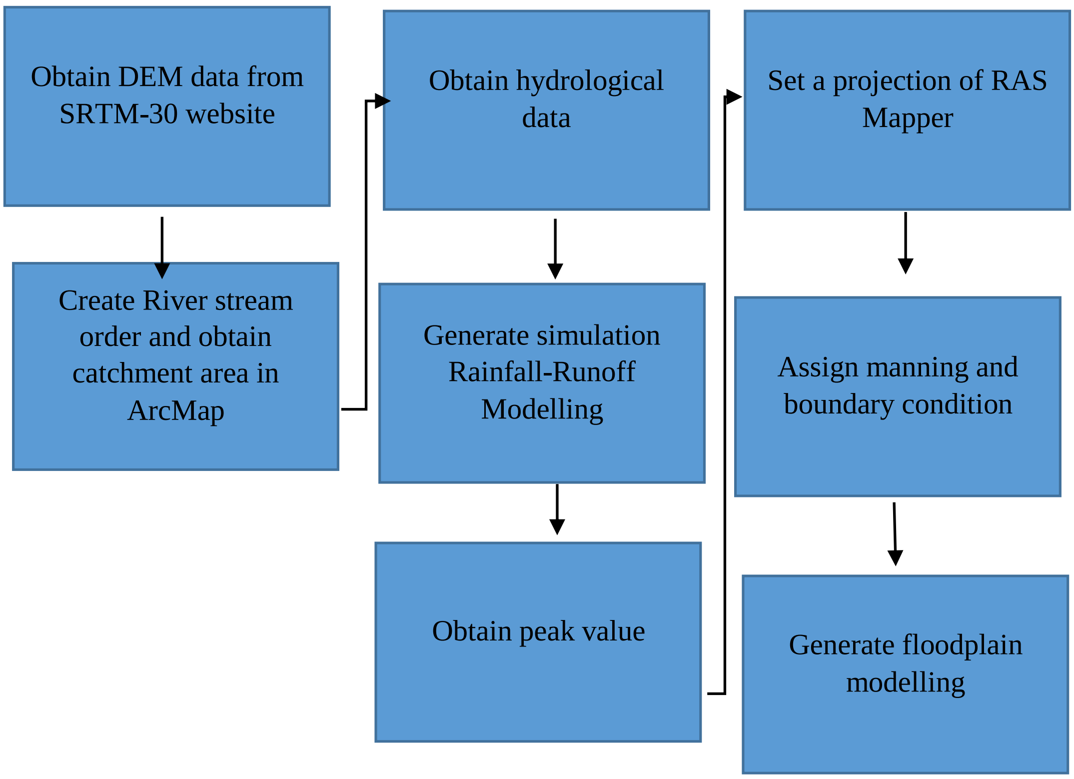
Figure 2.1: Study area geological map (Alel et al,2018)

3. Materials and Methods

To produce a floodplain modelling, the most important data needed is geometry data, topography data and hydrology data of the study area. The hydrology data are used I HEC-HMS to generate rainfall-runoff modelling and obtaining the peak value. The peak value describes which time of the precipitation occur lead to the most runoff value. The peak value then will be in in HEC-RAS along with geometry and topography data to generate floodplain map. Table 3.1 shows the flowchart of this study. Hydraulic data specifications, hydraulic computation, and HEC-RAS Hydraulic Model-Floodplain Modelling are a few phases that will be involved.

Table 3.1: Floodplain modeling flowchart

Pre-processing (ArcMap)	Processing (HEC-HMS)	Post Processing (HEC-RAS)



3.1 Materials

- Topography data

  In this study, DEM was taken from the SRTM 30 website. DEM is the most basic type of digital topographic representation. In carrying out this study, SRTM data N02E103 as in Figure 3.1 was selected as DEM data because it covers the area in Sungai Mersing.

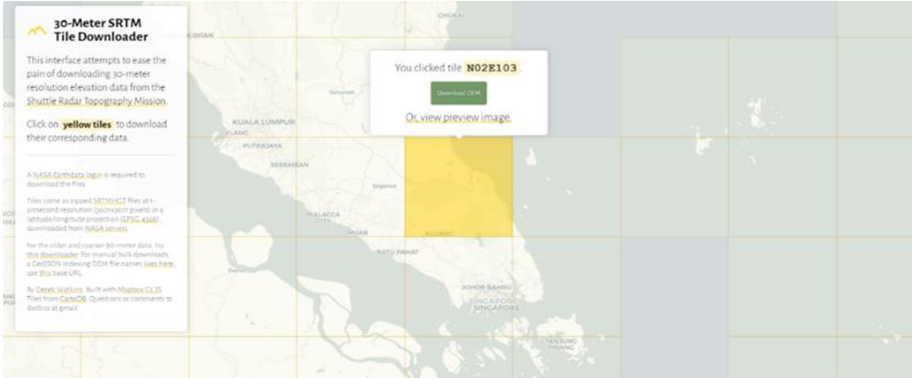


Figure 3.1: DEM from SRTM 30

- Geometric data

The procedure of hydraulic geometry of river channel flow and water movement analysis requires various input factors. These settings are used to generate a sequence of river cross-sections. Each position along the flow, as well as the location where variations in discharge flow rate, pitch, shape, and roughness occur, need a cross section. HEC-RAS employs various factors at each cross-section to characterize shape, elevation, and relative placement, including:

i. Number of river station (cross-section)

ii. Locations of the left and right bank stations

iii. River flow paths

iv. Manning's Roughness coefficient

- Rainfall data

Historical flood event reports, flood maps for surrounding areas, newspaper stories or articles relating to earlier flood events in a specific area, water level records, stream flow records, and evaporation records are all to be included.

3.2 Method

- Preprocessing: ArcMap

A topography data of the study area is obtained online on SRTM website in raster format. The raster coordinate system is adjusted to match the location of Sungai Mersing. In ArcMap, the raster data used as to find the catchment value of the study area. This are done by delineating the watershed of the location selected on the study area. Watershed are created in ArcMap by extracting all the river study area information such as sink, fill, flow direction, flow accumulation, conditional, stream to order, stream to feature and basin, then proceed to find the catchment value of the study area.

- Processing: HEC-HMS

Both catchment value and hydrological data of Sungai Mersing are used to create rainfall- runoff modeling that shows the peak value both in table and graph form (runoff vs time). The hydrological data are obtained from Department of Irrigation and Drainage Ministry (DID) website.Empangan Labong hydrological data has been chosen as it the nearest location to Sungai Mersing .The rainfall data collected are from 1 October 2019 to 1 December 2019.The peak value on the graph which time with the highest runoff value, based on the graph the peak value is 304.5 $\frac{m^3}{s}$.

- Post processing: HEC-RAS

Peak flows obtain from Rainfall-Runoff modelling in HEC-HMS are used as data to perform steady flow analysis in HEC-RAS.HECRAS are used to generate a cross section based on the input parameters entered. The river was the first layer to be digitized, and it has been drawn on the line that goes through its center. The Flow Path Centerline, which specifies the river center flow direction, is then dynamically constructed, and the flood land boundaries are digitized in the same layer. Cross sections are the line created along the river drainage channel to designate the transversal sections of the river, with the goal of obtaining elevation values from the terrain model and creating a terrain profile, Manning's value use in this study is in range 0.035 to 0.040.

4. Results and Discussion

4.1 Water surface profile

Referring to Table 4.1, there are overall 12 cross sections produced that range from strata 2318 to 37 in Reach 1. The water surface elevation (WSE) along the river and the flood extent at peak discharges were investigated in this study. The flow characteristics at two locations, RS 1384 and RS 37, upstream and downstream of the main river respectively. For RS 37 the top width of the flow has a least value which is 182.32. The velocity of the channel shown range from 0.16 m/s to 2.46 m/s, this is influenced by the flows of the channel section. Meanwhile the value for water surface elevation shown are gradually declination due to the constant value of flow. Critical water surface is recorded at river strata 609, river1 471 and river strata 37 with corresponding value of 6.66, 6.35 and 5.79 respectively this due to the minimum value of total energy head. The ability to see the flow for any sketched cross-section is one of the key benefits of utilizing HEC-RAS. Figure 4.1 shown X-Y-Z plot cross section. In steady flow analysis, hydraulic simulation was carried out using geometric data, flow data, and boundary conditions.

Table 4.1: Flow characteristic at station RS 2318 to 37

Reach (m3/s)	River Sta (m)	Q Total (m)	W.S. Elev (m)	E.G. Elev (m/m)	Crit W.S. (m/s)	E.G. Slope (m2)	Vel Chnl (m)	Flow Area	Top Width
Reach 1	2318	304.5	7.42	7.43	0.000047	0.26	1253.17	812.45	
Reach 1	2209	304.5	7.42	7.42	0.000062	0.27	1149.02	826.06	
Reach 1	2083	304.5	7.41	7.42	0.000021	0.2	1600.82	795.87	
Reach 1	1908	304.5	7.4	7.41	0.000068	0.28	951.66	540.82	
Reach 1	1618	304.5	7.4	7.4	0.000013	0.17	1791.59	697.39	
Reach 1	1384	304.5	7.4	7.4	0.000017	0.16	1834.04	934.95	
Reach 1	1220	304.5	7.39	7.39	0.000065	0.3	1002.98	539.25	
Reach 1	609	304.5	7.2	7.27	6.66	0.001918	0.61	282.28	411.21
Reach 1	471	304.5	6.35	6.64	6.35	0.01936	2.39	127.23	222.84
Reach 1	222	304.5	6.27	6.28	0.000157	0.38	834.86	745.31	
Reach 1	110	304.5	6.23	6.25	0.000429	0.51	485.25	434.28	
Reach 1	37	304.5	5.79	6.13	5.79	0.016803	2.46	119.76	182.3

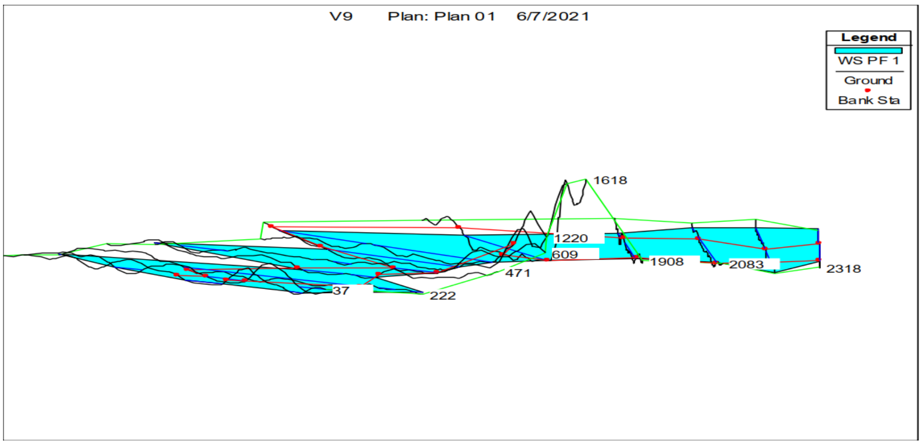


Figure 4.1: X-Y-Z cross section

4.2 Floodplain modelling

Maps are effective tools for displaying the geographical extent of flood risk. Floodplain for the river were created in this study based on peak discharges estimated in hydrological models using the study area TIN. RAS Mapper was used to visualize the results. The flood area covers the 36418.207538 ha catchment area along the river as shown in Figure 4.2. Based on the figure shown below, it can be analyzed that the most vulnerable area to flood is at the left of bank of the river at the cross section 2318 to 1908 and river cross section 1618 being the most affected while for right bank of river cross section of 2318 to 1918 are not affected by flood. Most of the affected area are located near the upstream of the river. This is due to the water depth at that area seem to be higher compared to the other location. The higher water depth will influence the risk of flood exposure. At cross section 609 to cross section 110 seems to have the slightest area that vulnerable to flood for both of its left and right bank of the river.

Figure 4.2: Floodplain map along the river

4.2 Water flow velocity

Regardless of the fact that water level (maximum) is the most important parameter when analyzing flood hazard, other characteristics such as velocity are also relevant since water flows at a specific rate during flood events, water flow velocity which can cause significant damage. As shown in Figure 4.3, from the result obtained right of bank (ROB) for river cross section for station 2318 to 1908 have the slightest range of velocity in between of 0 m/s to 1 m/s, this area located at Taman Pantai Timur, Mersing. The low range of velocity occur due to high range of river depth at the river cross section. Meanwhile for the river cross section of station 609 to 222, it has the highest flow velocity that range from 0.71m/s to 1.34 m/s, this is influenced by the low range of the river depth. Most of the right of bank for river cross section at river station 1618 to 222 remain unaffected by water flood velocity, thus making it not a flood prone area. For the right of bank (ROB) of river cross section at station 471 to 110 are recognized as a floodplain area as the flood are at the outer side of the right river bank, this due to the high range of velocity on that area. The high range of velocity occur due to low range of river depth.

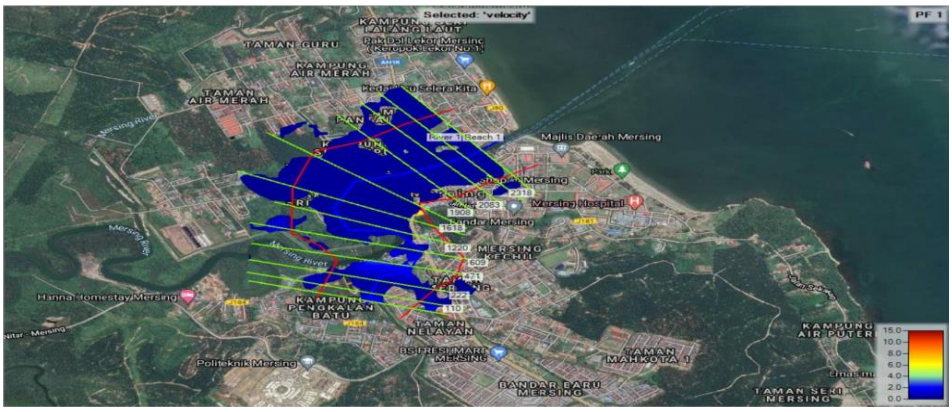


Figure 4.3: Water flow velocity

5. Conclusion and recommendation

Most of the area in the upstream are affected by flood, this cover at the area of Taman Pantai Timur ,Mersing. most vulnerable area to flood is at the left of bank of the river at the cross section 2318 to 1908 and river cross section 1618 being the most affected while for right bank of river cross section of 2318 to 1918 are not affected by flood. Most of the affected area are located near the upstream of the river. This is due to the water depth at that area seem to be higher compared to the other location. The higher water depth will influence the risk of flood exposure. At cross section 609 to cross section 110 seems to have the slightest area that vulnerable to flood for both of its left and right bank of the river.

As no model is perfect, there is then a need to always refined the model. The current model can be refined by using a long series of discharge data to improve the quality of the calibration of the model parameters. Also, the need of using DEM 90 as a raster maybe can be considered as it has a clear resolution of topographic image. The rainfall data collected in this study are not the exact location of the study area as it doesn’t have an available discharge station, thus for future modelling, data should be collected at study area location that have its own discharge stations in a purpose to reduce results error.

Acknowledgement

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