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Floodplain Modelling by Using HEC-RAS at Batu Pahat River, Johor

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Abstract: Malaysia is a country that is often hit by monsoonal and flash floods. Heavy seasonal monsoon rains bring extensive long-term floods to many riverine and coastal regions each year. People and property in the floodplain area are at risk of being destroyed when rivers overflow. It is essential to model the flood plain to enhance the necessary steps for future flood prevention. This study aims to create a floodplain modelling using Hydrologic Engineering Centers River Analysis System (HEC-RAS) at Batu Pahat river, Johor. This study applied one-dimensional steady flow analysis to the Batu Pahat River. To conduct the analysis, this study collects the necessary data, such as hydrological data, stream lengths, riverbank stations, and flow data for each river station. To meet the extra volume of water flowing into the river, a total of 3 flow rates were used to identify the increase of water level. The flow rates value obtain are the peak flow discharge in November 2020, 5-year return period and 10-year return period. From this study, water overflows into the floodplain from 6 out of 14 stations with a maximum flow rate of 768.50 m^3 /s. The results also show station 7429 was flooding at all flow rate used. Analysis from this study has demonstrated that HEC-RAS can easily identify the results of the affected area. This study can help future reference in flood management, development planning, flood control, and alert the community. It is also essential to show that HEC-RAS is reliable software to use for river analysis and modelling.

Keywords: Batu Pahat River, Floodplain, HEC-RAS,Flood

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1. Introduction

Over the last three decades, the number of flooding worldwide has risen drastically from some of the primary sources: climatic changes, land-use changes, and other anthropogenic interventions [1]. Malaysia is a country that lies in a geologically and climatically stable zone that almost free from disaster except for flood and human-made disaster [2]. In Malaysia, floods are classified into two categories: the Malaysian Drainage and Irrigation Department (DID): flash floods or tidal floods and monsoon floods. The December 2014 and January 2015 monsoon floods are known as one of the most destructive floods to hit Malaysia, and, officially, over 100,000 flood victims during these catastrophic incidents were evacuated from their homes [3]. Excessive rain can cause a problem to the riverbank's overflow to the riverbank, which leads to flooding in a floodplain area. As floodplains are quickly growing and being infringed upon, more people and property are facing flood risk. This paper uses non –structural approaches that include eliminating the destructive effects of the flood without constructing physical structure. As a nonstructural approach tool, floodplain modelling can gather important information for proper flood management.

The flood in early December 2006 and early January 2007 that strike Johor was considered as the worst flooding history of the state, and Batu Pahat district was affected [4]. The past flood event has grown concerned for reducing flooding impact. This study aims to provide floodplain modelling at Batu Pahat River, Johor, using Hydrologic Engineering Center's River Analysis System (HEC- RAS) software. This study also identifies the flood location with a different scenario of peak flow. The majority of community life in the riverine and coastal area are affected the most when flooding occurs. Past research has shown that floodplain modelling is a suitable tool for non – structural measures in flood management. Hydraulic software is necessary for floodplain modelling these days as it is less time consuming and effective. HEC-RAS is convenient tools to get helpful information for further action.

2. Literature Review

Floodplain is an area of low-lying land subject to inundation by the lateral overflow of water from river and lakes with which they are associated [5]. When a river overflows its banks, water will spill onto the floodplain area. Most likely, this situation occurs with the contribution of heavy rain, especially during the monsoonal season. The Department of Irrigation and Drainage (DID) recently emphasized nonstructural measures by providing more comprehensive solutions to manage to flood [6]. Floodplain modelling is one of the standard nonstructural measure tools used for flood and risk prevention. HEC-RAS is software for one-dimension or two-dimension simulations of a flood's evolution, which could have a stable or unstable flow rate, sediment transport, change of the riverbed, etc.[7] . HEC-RAS is an efficient but easy-to-use software package for determining water surface profiles in a wide variety of streams to develop information for floodplain modelling in the river. Marimin et al. [8] using HEC-RAS for designing a model for floodplain area in Sembrong River. It shows that HEC-RAS is a useful instrument for analysis and modelling. In their study, the different flow rate was used to determine the level of drainage capacity. Results from HEC-RAS are suitable for planning and design because an error from the analysis is typically suitable for watershed-level analysis.

Flood modelling of river Godavari using HEC-RAS was conducted by Kute et al.[9]. The type of flow in this study is a steady flow. The essential data such as catchment area, maximum flood intensity, the cross-section of the river, alignment details of river and dam and contour of river cross-section at Ramkud was taken. The researchers concluded that HEC-RAS provide flood profile for the worst flood intensity. The flood profiles for different flood intensity with another return period can be plotted at any given cross-section. Therefore, mitigation measures are possible with flood modelling.

3. Materials and Methods

In general, the research methodology follows the flow chart shown in Figure 1. For the first phase, Sungai Batu Pahat is used for the study area, and the river geometry information of the selected location is developed from a digital elevation model (DEM). The DEM data were derived and projected from ArcGIS software. This study used the Hydrologic Modelling System (HEC-HMS) to obtain the peak flow discharges of the selected river. The average recurrence interval was obtained for different return period. All values that are ordered before used at the next step for evaluation.

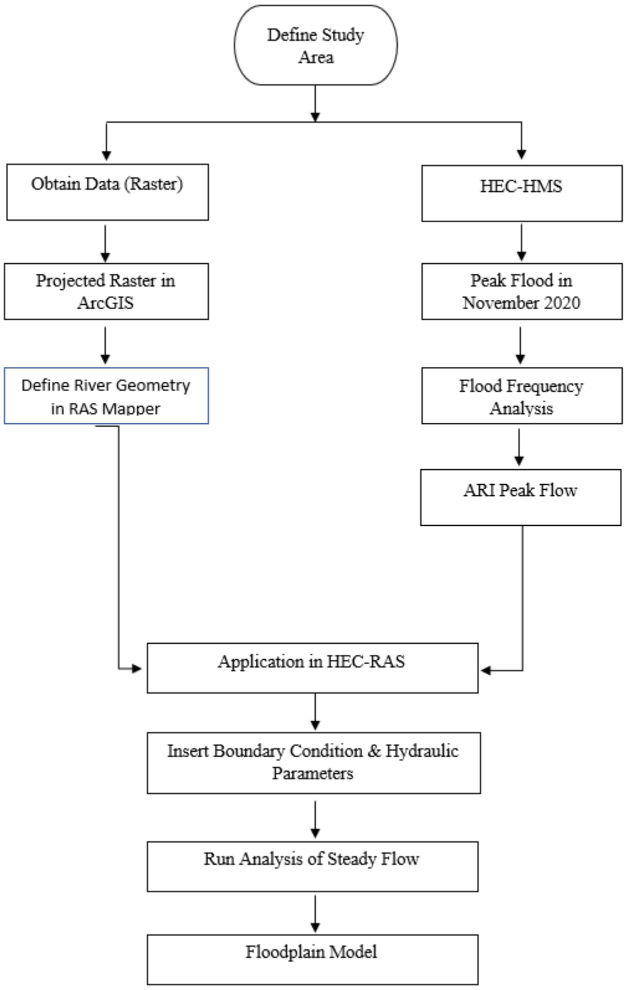

Figure 1: Methodology flowchart

3.1 Study area

The study area is Batu Pahat River, in Batu Pahat, Johor, in the southern part of Peninsular Malaysia. Batu Pahat is of average size with 1873 km^2 and a population of approximately more than 300,000 residents. Figure 2 shows the location of Batu Pahat River located in a 1°49.0258 N and 102°53.5001 E. Batu Pahat river drainage length is 12 km with sub-catchment area is 103.0 km^2. It originated from two rivers, Sungai Simpang Kanan and Sungai Simpang Kiri, and flows through Batu Pahat River until it reaches the waterway Pantai Minyak Beku on the coast of Johor. The focus is to produce the floodplain modelling for a regularly flooded area at Batu Pahat River.

A sequence of flooding has occurred in past years at the Batu Pahat River. Based on the historical record, the worst flooding hit Batu Pahat during 2006, 2007 and followed the most recent event in November 2020. The flood disaster has destroyed infrastructure, endangering human lives, and negatively affected the community.

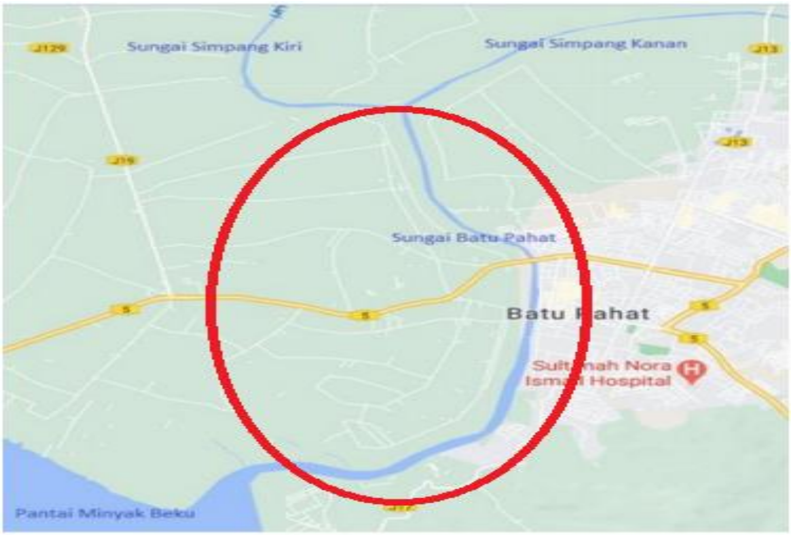

Figure 2: Study area

3.2 Data collection

All the data classified in the pre-processing stage before analyzing in HEC-RAS software. The data needed generate in ArcGIS and HEC-HMS software.

3.2.1 Raster data

The Shuttle Radar Topography Mission (SRTM) data were used to generate digital elevation data. A DEM is a raster representation of a continuous surface, most commonly the earth's surface. The DEM data was obtained from Derek Watkins with a resolution of 1-Arc Second Global, approximately 30 m resolution. The SRTM data was divided by tile based on the area we choose. The chosen SRTM tile from this study is N01E102. Then the raster data was projected to a different coordinate system from GCS_WGS_1984 to Kertau_UTM_Zone_48N using ArcGIS software. After the raster data was projected, the data exported to save the output as TIFF. Then the TIFF file transfer and opens in RAS Mapper in HEC-RAS.

3.2.2 Determination of flow data

In natural disaster management and flood mitigation structure design, determining peak flow is critical. Hence, this study used Hydrologic Modelling System (HEC-HMS) software as it is designed to stimulate the precipitation runoff process of a dendritic watershed system. To determine the peak flow discharge of the river, the data of daily rainfall were obtained from the Department of Irrigation and Drainage (DID). The peak flow data of 1st November 2020 until 30th November 2020 from HEC-HMS analysis is 768.5 m^3/s. The peak flow for 5 and 10 average recurrence intervals (ARI) were obtained by conducting flood frequency analysis. The estimated peak flows for 5 and 10-years return period are 57.89 m^3/s and 73.32 m^3/s respectively.

3.3 HEC-RAS application

For the hydraulic geometry of river channel flow and water movement analysis, the HEC-RAS program requires specific input parameters. The initial input needed in the HEC-RAS model set-up is the river cross-section profile. The river giver geometry can be created in RAS Mapper using terrain profile, as shown in Figure 3. Several parameters for running HEC-RAS are river station (cross-section) number, bank station locations, Manning's roughness coefficients, flow data, lateral and elevation coordinates for each terrain point, and any different cross-section properties. After setting the river cross-section profile, the Manning's roughness value was set up as 0.03 for the channel and 0.05 for the riverbanks. Flow data and the condition of the boundary river system are used to produce a steady stream of data that contains multiple profiles.

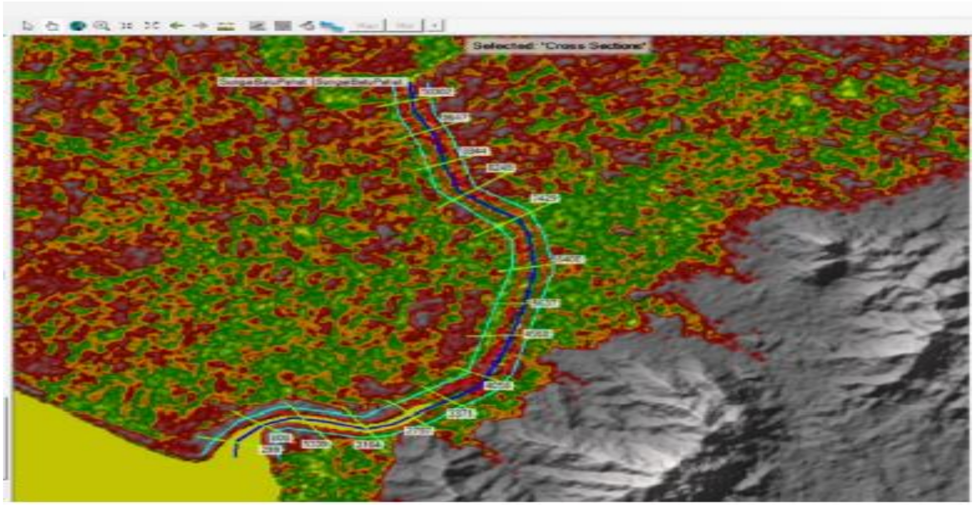

Figure 3: River geometry in RAS Mapper

4. Results and Discussion

An HEC-RAS hydraulic model was set up to generate water level based on several data such as river cross-section, boundary condition and various flow data. The hydraulic study of a steady flow simulation performed with multiple flow rate values reveals differences in the water surface elevation. The water level rose from the river's downstream to its upstream because most of the station upstream were flooding.

Some stations have been detected to be flooding due to water overflow into the riverbank. As shown in Table 1, six out of fourteen stations were flooding with different flow rates applied. The marked station specifies the flooding station. Station 7429 is the only station that started to flood with all-flow rate value, and other station was flooding with maximum flow rates, which is 768. 5m^3/s.

Table 1: Summary of flooding station

Flow rate, Q (m^3/s) / Station	PF 1(57.89)	PF 2(73.32)	PF 3(768.5)
299			
800			
1339			
2164			
2797			
3608			
4758			
5637			X
6400			X
7429	X	X	X

8245	X
8944	X
9647	
10302	X

4.1 River Cross-section

Figure 4 to Figure 7 show the results of the steady flow analysis of station 10302. It shows that the water overflows into the riverbank at the flow rate of 768.5 m^3/s. The greater flow rates show increasing in water surface elevation. At station 10302, with PF 1 and PF 2, water accommodates the surrounding area, even the water in the river not overflowing the riverbank. The land area is low; therefore, the large volume of water can cause the area to be fill.

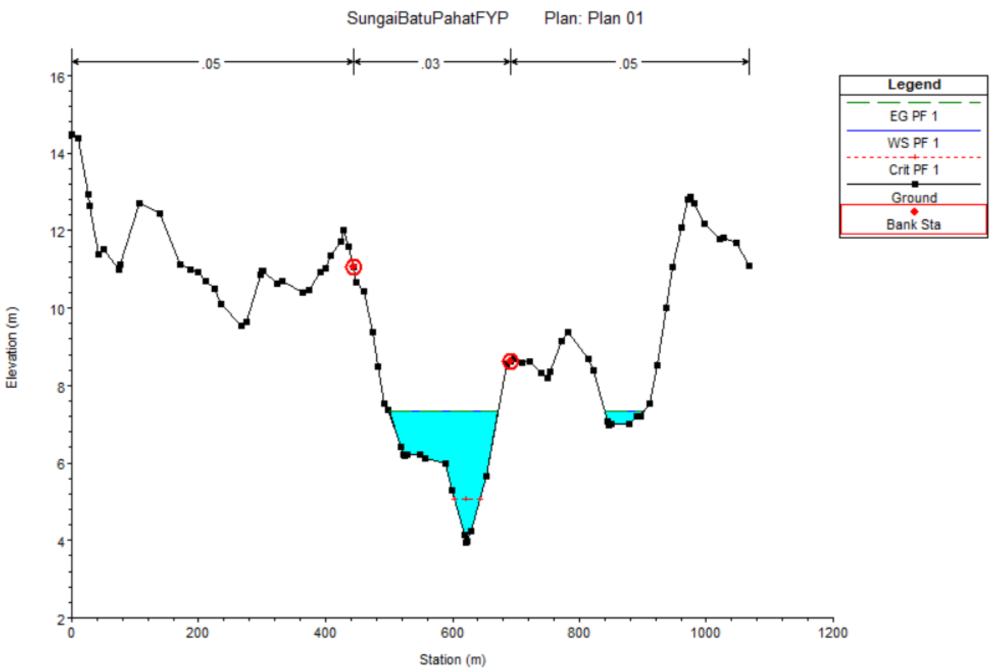

Figure 4: Cross section profile at station 10302 with PF 1

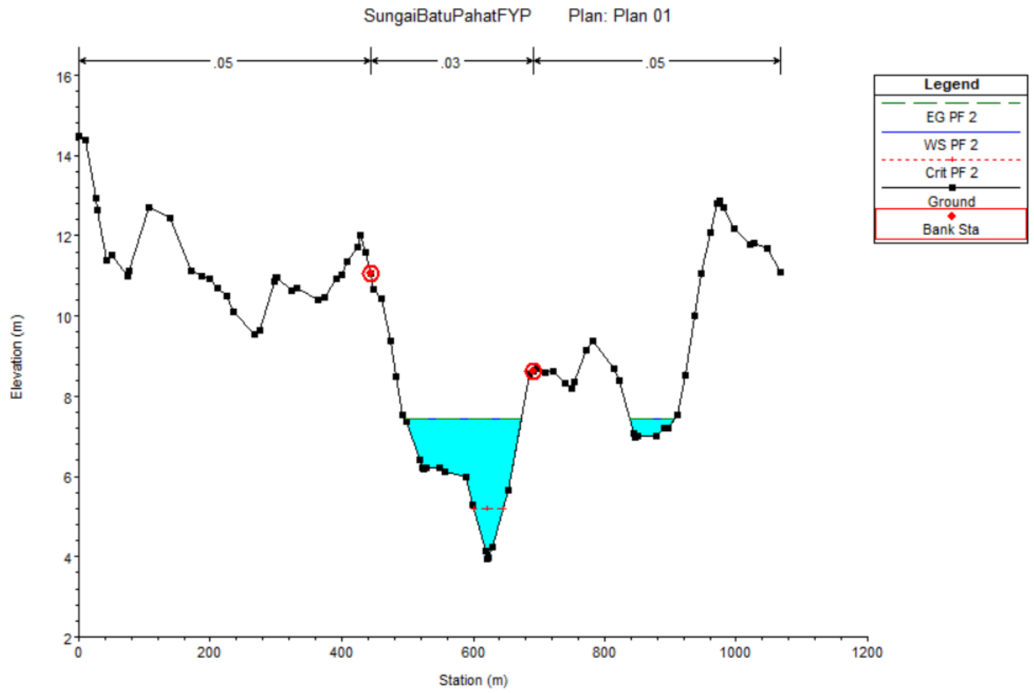

Figure 5: Cross section profile at station 10302 with PF 2

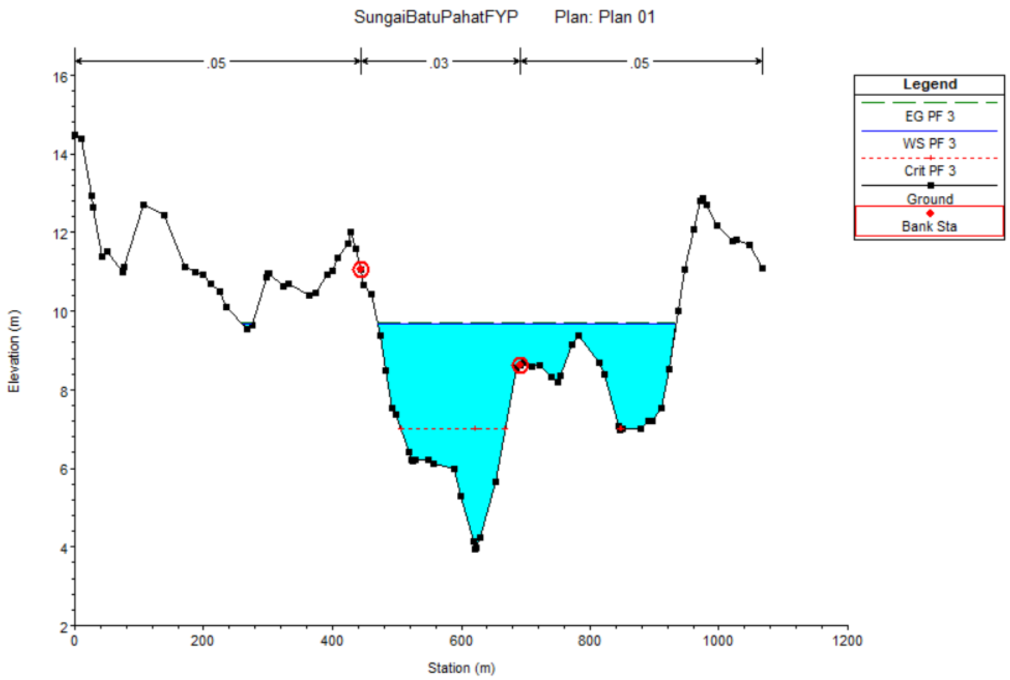

Figure 6: Cross section profile at station 10302 with PF 3

From this analysis, most of the station gets flooded with the maximum flow rates, especially at the river upstream. Figure 7 shows that station 2797 at the river downstream near the river mouth is not flooding because of high elevation of riverbank.

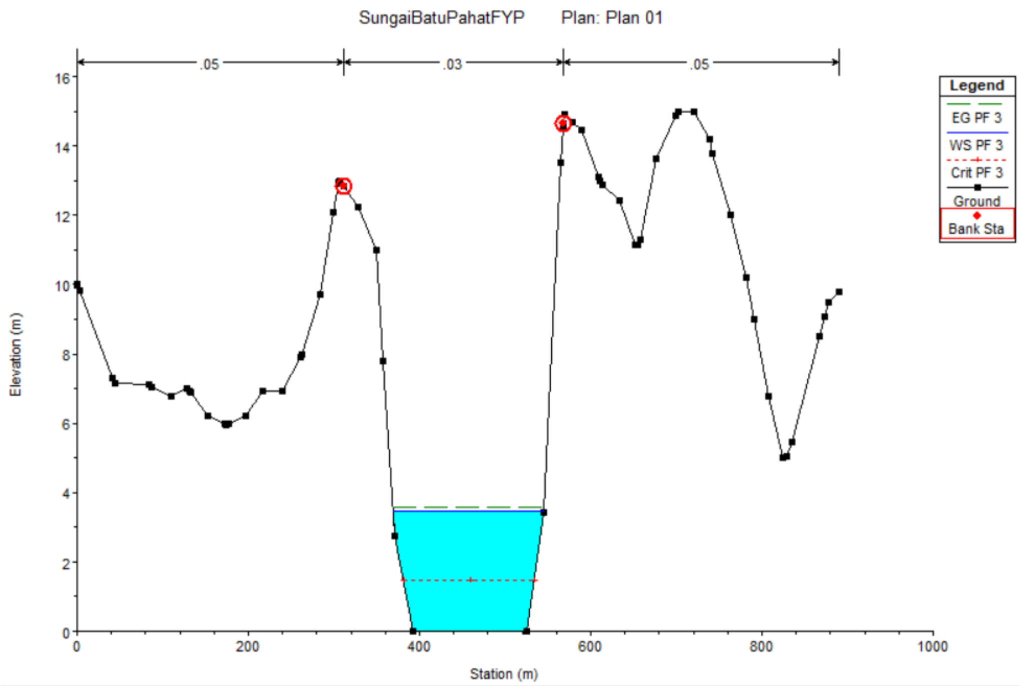

Figure 7: Cross section profile at 2797 with PF 4

4.2 Floodplain Mapping

Floodplain map was generated in HEC-RAS hydraulic modelling for peak flow of November 2020 and 5- and 10-year return period. The flood map between different flow rates is presented in Figure 8 to Figure 10. The blue color indicates the extent of flooding with darker color shows more depth.

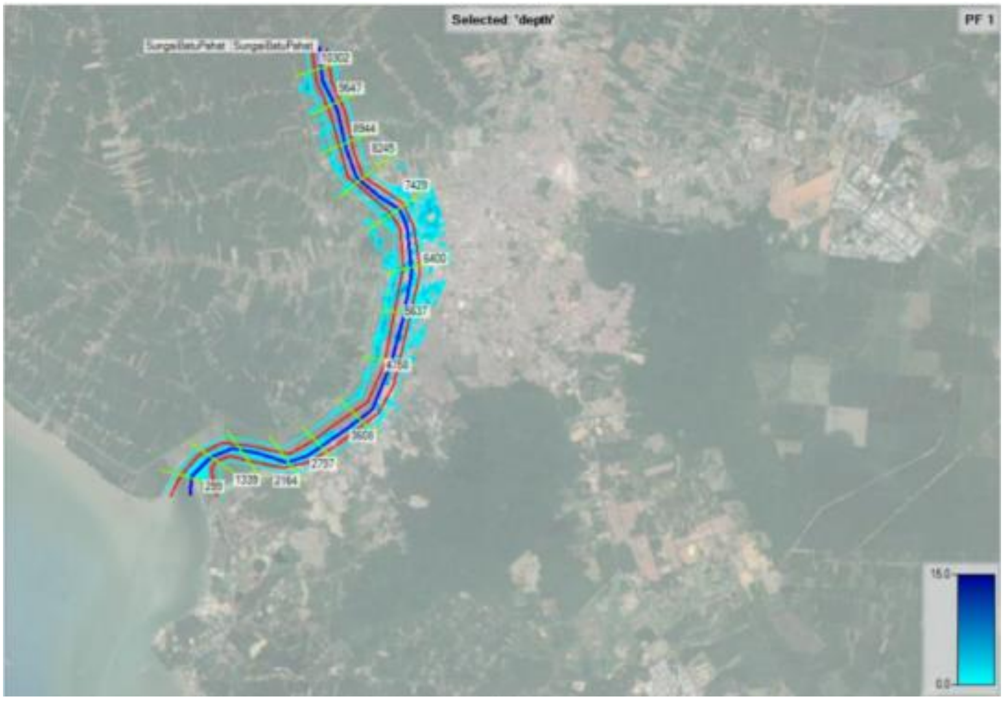

Figure 8: Floodplain Map for PF 1

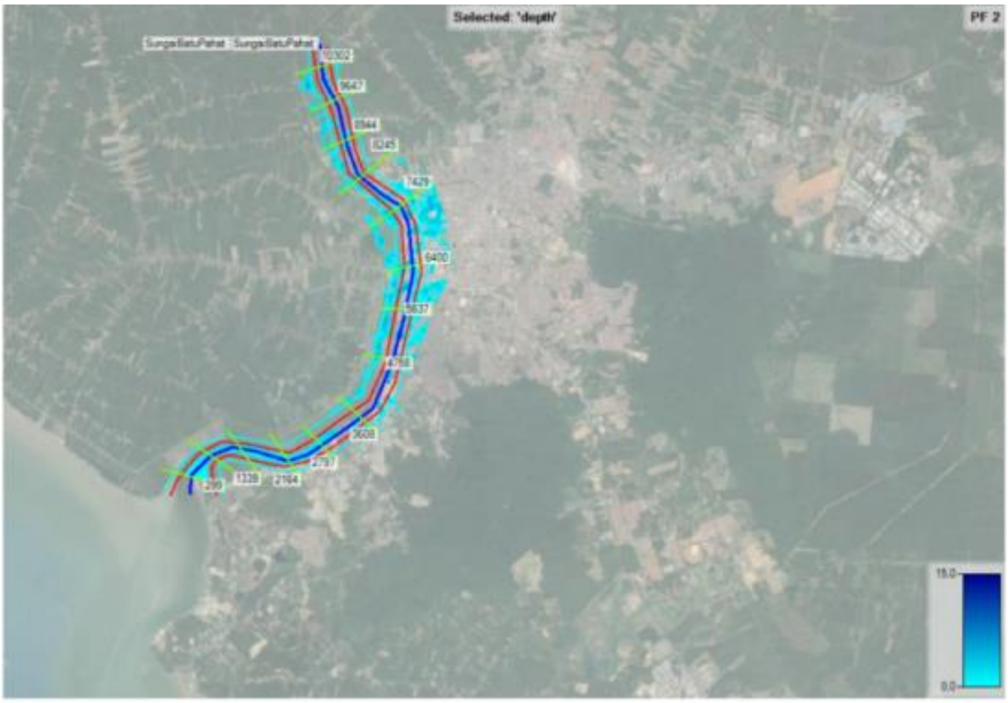

Figure 9: Floodplain Map for PF 2

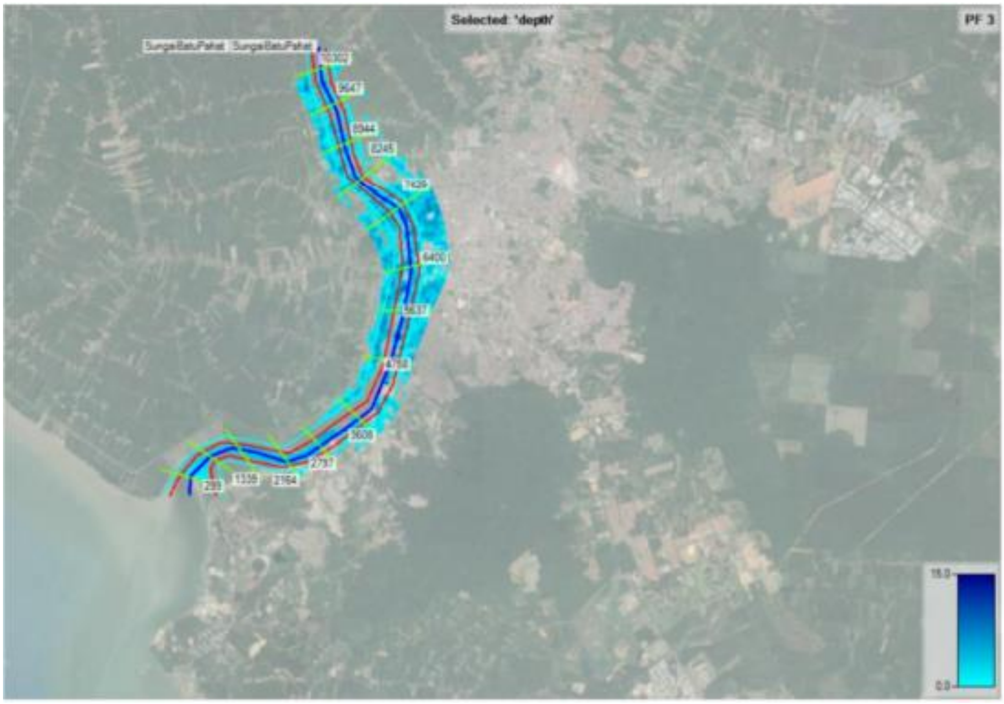

Figure 10: Floodplain Map for PF 3

In Figure 8, the maximum depth of water overflows the riverbank is 2.450 meters. The area affected is a residential area which is Kampung Pegawai. As shown in Figure 10, the inundation of floodplain area becomes more extensive. Most stations at the river upstream have water overflowing the riverbank. The surrounding area at the river upstream is plantation from station 10302 to station 8245. PF 3 also has an enormously affected residential area which Taman Nira, Kampung Pegawai and Taman Sejahtera, with the largest depth is 4.882 meters.

5. Conclusion and Recommendation

By referring to the objectives, it can be concluded this study has achieved it aims. The result from steady flow analysis in HEC-RAS has been analyzed and shown in the figure and table. The overall results allowed for the identification of flood zones, water velocity and heights. A more extensive floodplain area could be inundated if the number of peak flows is more than the maximum flow used in this study at the study area. Most of non-inundated station located at river downstream where the river debouches into the sea called Pantai Minyak Beku. Station 299 has the highest elevation up to 20 meters which able to accommodate maximum flow rates. From RAS Mapper results, Kampung Pegawai, Taman Nira and Taman Sejahtera were at risk of flooding with maximum depth more than 4 meters. It shows populated areas close to floodplain area will create various concerns and losses, and lives. The simulation indicate that flooding area of November 2020 is larger than 5- and 10-year return period. The results from this study can provide helpful information to plan better flood management for prevention from damages. The application of HEC-RAS can be a functional tool to analyze the hydraulic model.

Some recommendations to improve this study in the future are essential and professional studies, regular field trips, paying close attention to the necessary interactions in the river, software simulations, and engineering experiences to produce good quality results. River geometry is an essential parameter in hydraulic modelling. Therefore, information on the elevation of the river should be accurate to carry out a good analysis. In the future, it is better to use a high resolution of SRTM data to get a better view of the raster data set. The findings of this study should be improved in the future as the data will keep changing in the future.

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