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The Flood Analysis with HEC-RAS a Case Study of Muarojambi River Basin

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Abstract. This study aims to determine how wide the catchment area is on the Melayu and Jambi rivers, how much the planned flood discharge is at a return period of 2, 5, 10, 25, and 50 years with the Nakayasu Synthetic Unit Hydrograph (**SUH)** Analyze the water level of these rivers downstream at the planned flood discharge conditions due to backwater from the Jambi river. This also plans the cross-sectional area and length of the Jambi River as a new channel to the Batanghari River using the HECRAS model.

The result shows that the Melayu River can still serve a water level of 10 for a 10-year return period and the Jambi River with a water level of 25 for a 25-year return period. However, there is a need for normalization of both rivers and disposal in a large basin located 2 km from the Melayu River. The length of the new channel section as a connection to the Batanghari River as a final water channel is 1,060 meters long, 5 meters wide at the top, 3 meters wide at the bottom of the river, with a depth of 5 m, with a channel embankment using an earthen wall.

Keywords*: *backwater, Jambi River, Melayu River, Channel, Sediment

INTRODUCTION

The Muara Jambi site has an area of about 3981 Ha. Until now, in the site area, there have been at least 33 brick buildings remaining. This site is an important tourist destination in the city of Jambi. Some of the main problems that cause the overflow of the Melayu and Jambi Rivers include this area having a relatively flat topography and high rainfall. On the east side is the Batanghari River, which overflows yearly [1-2]. In addition, in the south, outside the site area, there is a large plantation with poor drainage channels. The Melayu River is always used as the final water discharge (using sluice gates) during high rainfall. In both rivers, there is acute sedimentation on which water hyacinth plants grow, so the river discharge decreases [3]. The Melayu and the Jambi rivers meet downstream, and water is hoped to flow to the rice field embankments. However, sedimentation is getting higher over time in the channel leading to the rice field embankments, so backwater occurs downstream of the Jambi River. For this reason, flood control efforts need to be carried out to minimize the negative impacts. Based on the background, this study needs to be conducted to determine the effect of backwater on the increase in flood water levels in the Jambi River cross-section [4], and it is necessary to create a new drainage channel to connect the final disposal to the Batanghari river. The location previously did not have topographic data, so it was difficult to determine the water catchment area if a flood occurred due to the local government's blockage of the drainage channel, which always normalized the river without being based on hydrological and hydraulic analysis.

Floods are water that overflows from water bodies such as ditches, channels, drainage, rivers, lakesFloods are water that overflows from water bodies such as ditches, channels, drainage, rivers, lakes, or lakes and inundates the banks and surrounding areas [5]. Determining the flood design of hydraulic buildings can carried out in various ways depending on data availability [6]. The Ways of flood control in the structural method can be explained as follows: a) River network system [7-9]; b) Normalization of river channels and embankments; c) Making a flood control channel (floodway) [10]; d) Retention Pond; e) Making shortcuts; f) Groyne (defense embankment/flood embankment).

The backwater is a water flow that occurs at the confluence of large and small channels. This flow occurs because the water level in the large channel is higher than in the small channel [11-13]. In the case of the Muarajambi site, the confluence of the Melayu and the Jambi rivers, water will flow to the rice field area through the channel, but there is shallowing of the channel due to sedimentation. Backwater will occur at a specific water level elevation. Previously, there was an ancient canal for drainage to the Batanghari River. Still, there was shallowing of the river, which was almost level with the ground surface leading to the Batanghari River, and above the canal, there were already many houses.

MATERIAL AND METHOD

The research is located in Muarajambi Village, Muarajambi District, Muarajambi Regency, Jambi Province, which is the upstream and downstream watersheds of the Melayu River and Jambi River, Muarajambi District, which is the area of Muarojambi Regency ± 5,246 km^2, administratively has the following area boundaries :

- West Tanjung Jabung Regency borders the north side.
- South Sumatra Province borders the south side.
- Batang Hari Regency borders west side.
- In the east, it is bordered by East Tanjung Jabung Regency.

Geographically, Muarojambi Regency is located between 1°51' South Latitude to 2°01' South Latitude and between 103°15' East Longitude to 104° 30' East Longitude. Muarojambi Regency is a lowland area with an altitude above sea level, among others. The height of the sea level at the study site is 0-10 m at 11.80%, 11-100 m at 23.70%, and 101-300 m by 4.5%, including areas with a tropical climate with evenly distributed rainfall throughout the year an average of 186 mm per day with an average rainfall intensity of 16 rainy days in one month. The average temperature is 32ºC with relatively small variations in temperature between the rainy and dry seasons. Administratively, Muarojambi Regency consists of 11 Districts, 150 Villages and 5 Villages. Muarojambi District is an area that is almost always wet, with rainfall ranging from 1,000 - 6,000 mm/year. The rainfall intensity is higher in the south and the central regions than in the north.

The land cover in Muarojambi District consists of various types of cover, including forests, plantations, fields, paddy fields, shrubs, rivers, and built-up areas. However, most of the land cover of the Muarojambi District has been dominated by built-up areas, which account for nearly 50% of the total area of the Muarojambi District. The type of soil in the Muarojambi District is dominated by alluvial soil. The soil is relatively fertile and perfect for plantation areas and rice fields[14].

The data used in this study is secondary data obtained from related agencies and other collections of literature related to the research title. Secondary data used include (Figure 1).

1. Topographic map and land use in Muarojambi District, Muarojambi Regency.
2. Rainfall data for 2014-2023 and rain station coordinates from River Basin Management Bureau (RBMB) Sumatra IV in Jambi, Muarojambi Climatology Station.
3. Types of soil conditions from RBMB Sumatra IV.
4. Watershed characteristic data from RBMB Sumatra IV.

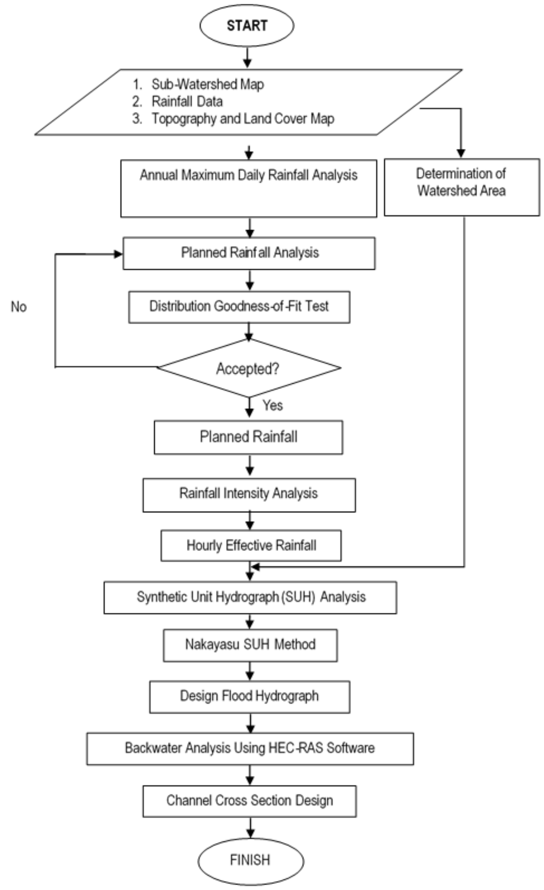


FIGURE 1. Research Framework Diagram

The study steps in this research are as follows [15-16] :

1. Analyzing the regional average rainfall using the Polygon-Thiesen method.
2. Determine the daily maximum rainfall.
3. Rain data consistency test.
4. Determine statistical parameters from data that has been sorted from small to large, namely standard deviation (Sd), coefficient of sloping (Cs), coefficient of kurtosis (Ck), and coefficient of variation (Cv).
5. Compute the average value of $\overline{X} = \frac{\sum_{i=1}^{n} Xi}{n}$ …………………………………… (1)
6. Calculate standard deviation s $Sd = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}}$ ………………………….... (2)
7. Calculate the slope coefficient $Cs = \frac{n\sum_{i=1}^{n}\{(X_i)-\overline{X}\}^2}{(n-1)(n-2)Sd^3}$ ………………………….... (3)
8. Calculate the kurtosis coefficient $Ck = \frac{\frac{1}{n}\sum_{i=1}^{n}\{(X_i)-\overline{X}\}^4}{Sd^4}$ ……………….……. (4)
9. Calculate the coefficient of variation $Cv = \frac{Sd}{\overline{X}}$
10. Analysis of planned rainfall was attempted using three distributions: the Gumbel distribution and Pearson Log Type III. The general formula used is $X_t = \overline{X} + Kt \times S$.
11. The distribution fit test uses Chi-Square, with the test criteria: if the value of f^2 Count $< F^2$ cr (accepted).
12. Analysis of the runoff coefficient by multiplying the area by the land cover type to get the total C value.
13. Rainfall intensity analysis is related to the occurrence and duration of rainfall; the formula used to calculate rain intensity is Dr. Mononobe $I_t = \frac{R_{24}}{t_c} \times \left[\frac{t_c}{t}\right]^{2/3}$ …………..…... (5)
14. Determine hourly adequate rainfall using the ABM method.
15. Unit Hydrograph Analysis with Nakayasu Method.

16. Analysis of the planned flood discharge using the SUH Nakayasu.
17. Determine the peak discharge (Qp) amount with return periods of 2, 5, 10, 25, and 50 years.
18. Hydraulic modeling of the Melayu and Jambi rivers using the HEC-RAS software.
19. Analysis of the effect of backwater or backwater on the Jambi River.
20. A new river channel cross-sectional design will be used to overcome the problem of the channel final [17].

FIGURE 2. The Conditions of the Melayu and Jambi River

RESULT AND DISCUSSION

The flood discharge analysis requires the availability of daily maximum rainfall data for at least the last 10 (ten) years so that the quality and quantity are sufficient to obtain accurate flood discharge results. The rainfall data used is daily data for the last ten years, from 2014 to 2023, taken from the nearest rain gauge station in the work area.

TABLE 1. Terms of Use Distribution Type

No	Jenis Distribusi	Condition	Calculation	Results
1	Gumbel Method	Ck ≤ 5.4002	Ck = 2.768	satisfy
		Cs ≤ 1.14	Cs = 1.070	satisfy
2	Log Pearson Type 3 Method	Cs ≠ 0	Cs = 1.80	satisfy
		Cv ≠ 0	Cv = 0.27	satisfy

Judging from the results of Table 1 above, of the two methods, the one with the smallest error value is the distribution using the Log Pearson Type 3 rainfall distribution method with a Cs value = 1.80 approaching the requirements of Cs ≠ 0 and a Cv value = 0.27 approaching the criteria of Cv ≠ 0. From the types of distributions that have met these requirements, it is necessary to test the suitability of the distribution again using the Chi-Square method. The results of the distribution suitability test will later indicate whether the distribution is acceptable or not.

TABLE 2. Gumbel Method Chi-Square Goodness of Fit Test

No	Probability (%)					Amount of Data		$f^2=((Oi-Ei)^2)/Ei$
						Oi	Ei	
1	X		<		76.439	2.00	2.50	0.10
2	76.439	<	X	<	96.066	3.00	2.50	0.10
3	96.066	<	X	<	120.966	3.00	2.50	0.10

No	Probability (%)			Amount of Data		f^2=((Oi-Ei)^2)/Ei
				Oi	Ei	
4	X	>	120.966	2.00	2.50	0.10
	Total			10	10	0.40

TABLE 3. Chi-Square Goodness of Fit Test Type 3 Pearson Log Method

No	Probability (%)			Amount of Data		f^2=((Oi-Ei)^2)/Ei
				Oi	Ei	
1	X	<	71.805	1.00	2.50	0.90
2	71.805	< X <	89.918	4.00	2.50	0.90
3	89.918	< X <	114.055	2.00	2.50	0.10
4	X	>	114.055	3.00	2.50	0.10
	Total			10	10	2.00

degree of trust (α) = 5%, f^2 calculation results 0,40, and f^2 cr = 5,991. The f^2cr value is obtained in Table [17] by looking at the DK value and connecting it to the degree of confidence (α). The results of the comparison above show that f^2 Calculation (0.40) using the Gumbel method and the Pearson Type 3 log method < f^2cr (5.991), so the hypothesis being tested can be accepted.

The size of the catchment area affects the determination of the planned rainfall return period. The return period is a hypothetical time when the probability of a discharge or rainfall event with a certain magnitude will be equaled or exceeded once. According to PUPR No. 12/PRT/M/2014, determining the return period concerning urban drainage planning must meet the following provisions (Table 4).

TABLE 4. Period Based on City Typology

CITY TYPOLOGY	CATCHMENT AREA (HA)			
	<10	**10 - 100**	**101 - 500**	**> 500**
Small City	Two years	Two years	Two years	2 – 5 years
Metropolis	Two years	2 – 5 years	5 – 10 years	10 – 25 years
Big City	Two years	2 – 5 years	2 - 5 years	5 – 20 years
Medium City	Two years	2 – 5 years	2 - 5 years	5 – 10 years

Jambi River Flood Discharge. Calculation of flood discharge for the Jambi River uses the synthetic unit hydrograph (SUH) of the Nakayasu method using the equation described in the following calculation steps :

1) Calculation of SUH Nakayasu Jambi River using the following parameters :

a) Watershed area (A) = 5.45 km2
b) Main river length (L) = 5.33 km
c) Effective rain (Ro) = 1.0 mm
d) Hydrograph coefficient (α) = 3

α = 2 (ordinary streaming)
α = 1.5 (the ascending part of the hydrograph is slow, and the descending is fast)
α = 3 (the ascending hydrograph is fast, and the descending is slow)

1) Finding the time value of concentration (tg) (for L < 15 km).

$t_g = 0{,}21 \times L^{0{,}7}$
$= 0{,}21 \times 5{,}33^{0{,}7} = 0{,}6775$ hours

2) Find the time unit value of rainfall (tr).

$t_r = 0{,}75 \times tg$
$= 0{,}75 \times 0{,}6775 = 0{,}5081$ hours

3) Find the time from the beginning of the flood to the peak of the flood hydrograph (Tp).

$T_P = t_g + 0{,}8 \times t_r$

$= 0{,}6775 + 0{,}8 \times 0{,}5081 = 1{,}0840$ hours

4) looking for the peak flood time to be 0.3 times the peak flood ($T_{0.3}$).

$T_{0,3} = \alpha \times t_g$

$= 3 \times 0{,}6775 = 2{,}0326$ hours

6) Find the hydrograph value for each interval.

$$Q_p = \frac{A \times Ro}{3{,}6 \times (0{,}3 \times Tp + T_{0,3})}$$

$$= \frac{5{,}45 \times 1}{3{,}6 \times (0{,}3 \times 1{,}08 + 2{,}03)} = 0{,}642 \text{ m}^3\text{/sec}$$

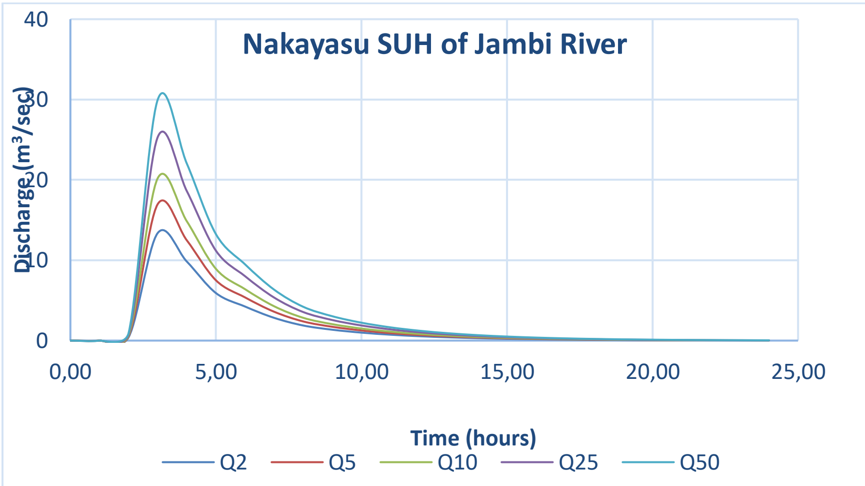


FIGURE 3. Nakayasu SUH Graph of Jambi River

Melayu River Flood Discharge. The calculation of flood discharge for the Melayu River uses the Nakayasu SUH method using the equation described in the following calculation steps :

1) Calculation of the SUH Nakayasu Melayu River using the following parameters: watershed area (A) = 3,08 km^2; main river length (L) = 4,48 km; adequate rain (Ro) = 1,0 mm; hydrograph coefficient (α) = 3 where: α = 2 (ordinary streaming); α = 1.5 (the ascending part of the hydrograph is slow, and the descending is fast); α = 3 (the ascending hydrograph is fast, and the descending is slow).
2) Finding the time value of concentration (tg) (for L < 15 km).

$t_g = 0{,}21 \times L^{0,7}$

$= 0{,}21 \times 4{,}48^{0,7} = 0{,}5999$ hours

3) Find the time unit value of rainfall (t_r).

$t_r = 0{,}75 \text{ x } tg$

$= 0{,}75 \text{ x } 0{,}5999 = 0{,}450$ hours

4) Find the time from the beginning of the flood to the peak of the flood hydrograph (Tp).

$T_P = t_g + 0{,}8 \times t_r$

$= 0{,}5999 + 0{,}8 \times 0{,}450$

$= 0{,}9599$ hours

5) looking for the peak flood time to be 0.3 times the peak flood ($T_{0.3}$).

$T_{0,3} = \alpha \times t_g$

$= 3 \times 0{,}5999 = 1{,}7998$ hours

6) Find the hydrograph value for each interval.

$$Q_p = \frac{A \times Ro}{3{,}6 \times (0{,}3 \times Tp + T_{0,3})}$$

$$= \frac{3{,}08 \times 1}{3{,}6 \times (0{,}3 \times 0{,}95 + 1{,}79)} = 0{,}410 \text{ m}^3/\text{sec}$$

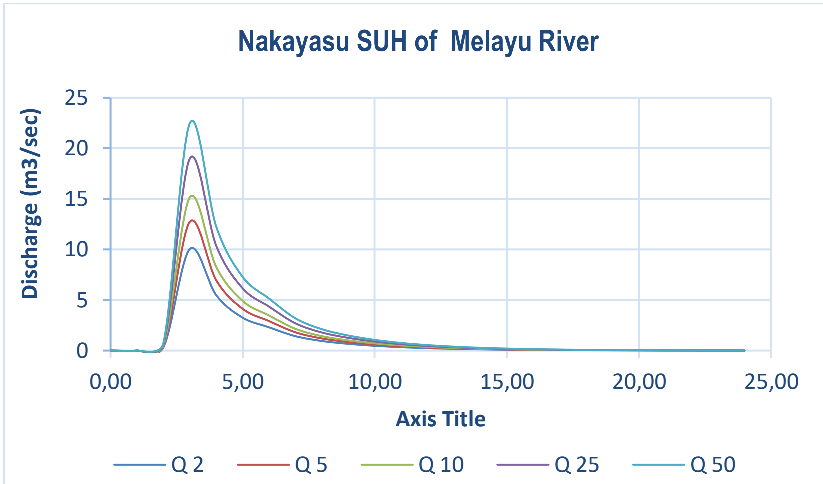


FIGURE 4. Nakayasu SUH Graph of Melayu River

River Hydraulics Modeling Using HEC-RAS Software. The Jambi River has a catchment area of 5.45 km^2 with a drainage length of 5.33 km. The Jambi River is in Muarojambi Regency. For the current conditions, the Jambi River can still accommodate the existing flood discharge; it's just that the downstream part is not directly connected to the final disposal, namely the Batang Hari River. Following are the results of hydraulic modeling of the Jambi river channel using the HEC-RAS software [18-19].

The picture above shows 11 cross-sections for the Jambi River, which are used as data for running modeling. The upstream part of the Jambi River starts from cross-section ten and ends at cross-section 0 with a length of 5.33 km. After entering the river geometry data, the next step is to input the flood discharge for running on the Jambi River cross-section using the HEC-RAS software. The flood discharge used for hydraulic modeling of the Jambi River flood discharge (JRFD) with a return period of 25 years and The Jambi River flood discharge (JMFD) with a return period of 10 years by the Public Work Ministry Regulation (PWMR) in 2014 as shown in Table 1 as below.

As can be seen in the results of the hydraulic modeling of the canal above, along the Jambi River, it can still withstand flood discharges with a return period of 25 years. The flooding that has been occurring so far is likely due to the water being held back and the flood discharge not being channeled to its final disposal, namely the Batang Hari River. The long cross-section of the Jambi and Melayu rivers can be seen in Figure 6 - 13.

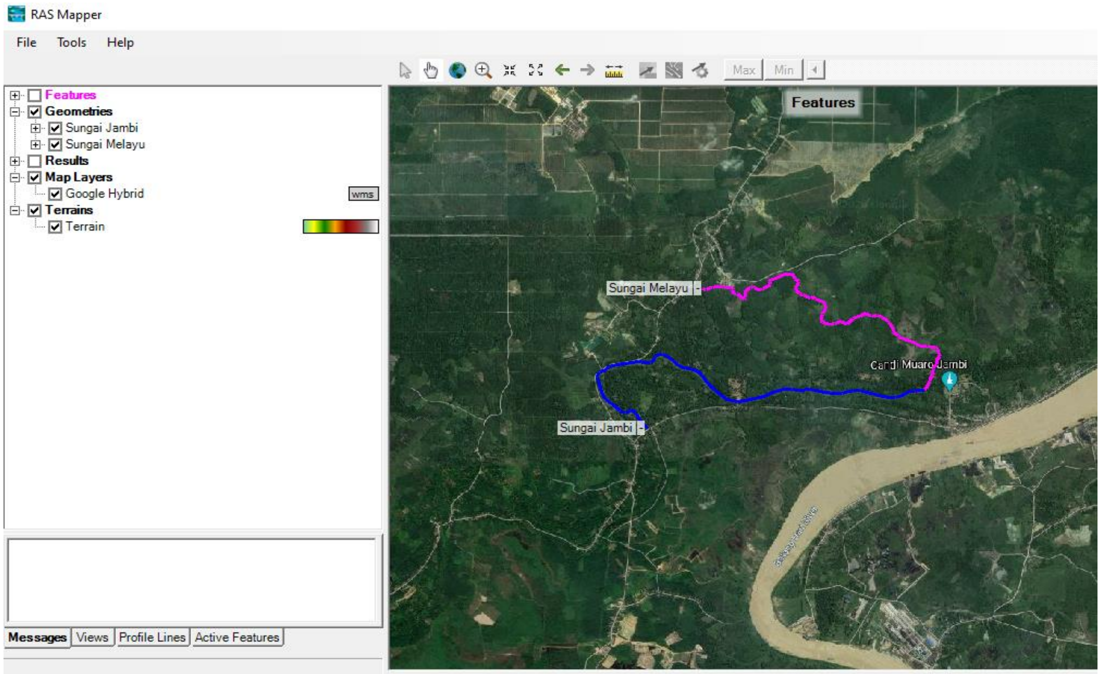


FIGURE 5. The Jambi River Network Schematic

TABLE 5. Catchment Area and Return Period of Jambi and Melayu River

District Name	Name of River	Catchment Area (Ha)	Period
Muarojambi	Jambi	545	25 Years
	Melayu	308	10 Years

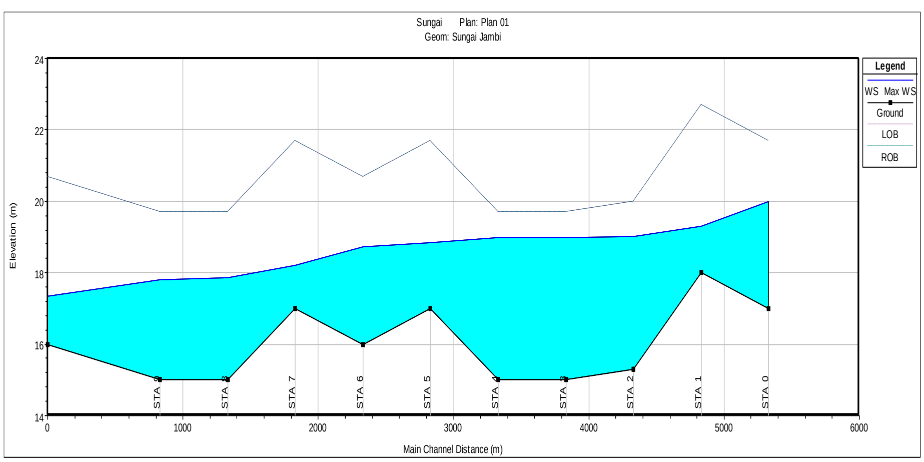
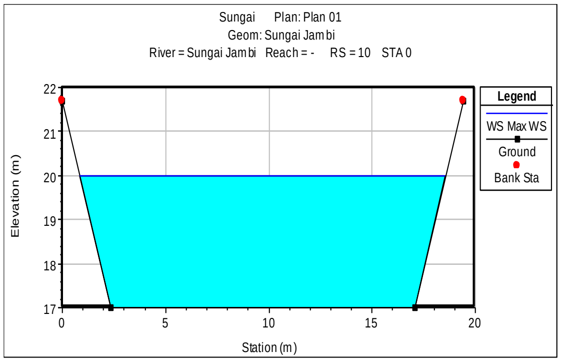
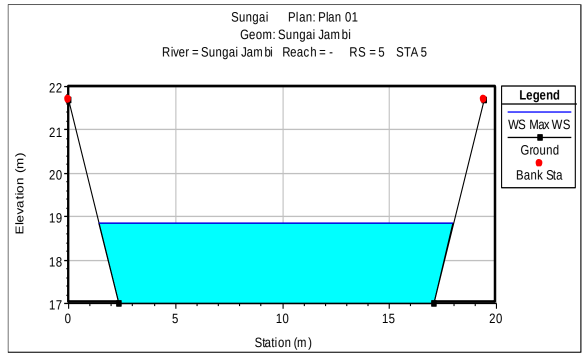


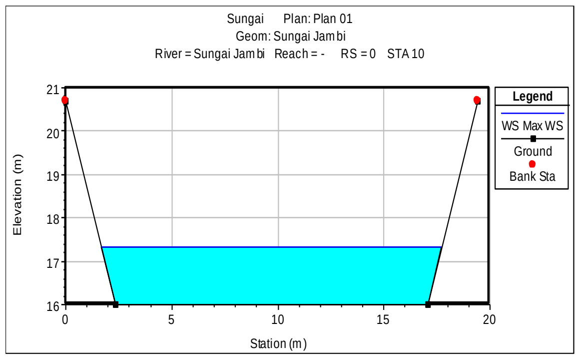
FIGURE 6. Longitudinal Section of Jambi River



(a)



(b)



(c)

FIGURE 7. (a) Crosssection 10, (b) Crosssection 5, and (c) Crosssection 0 Jambi River Flood Discharge

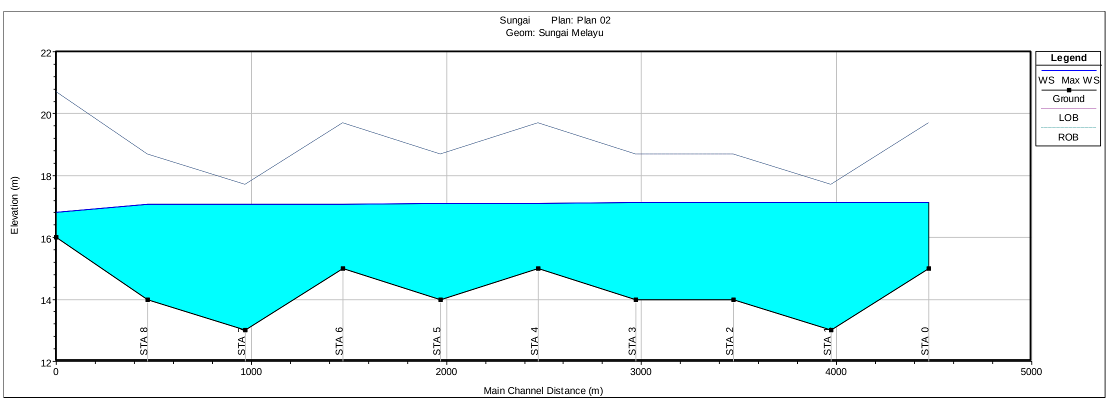
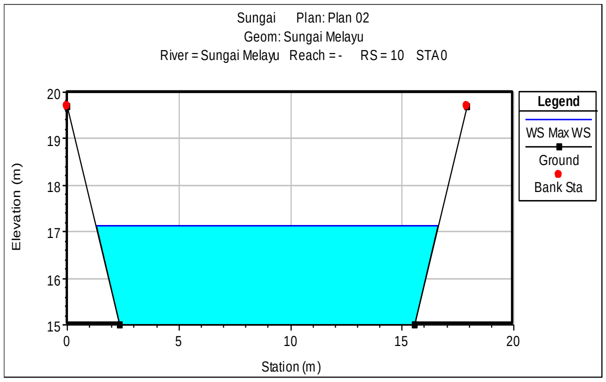
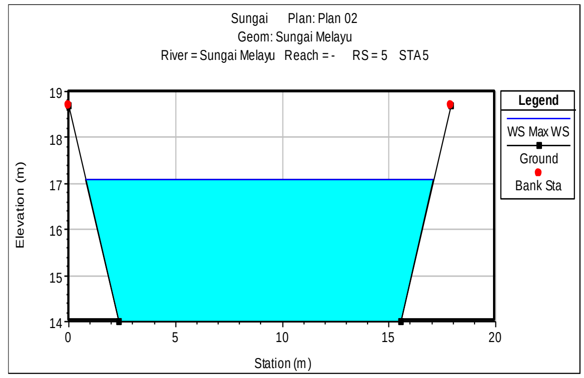


FIGURE 8. Longitudinal Section of the Melayu River

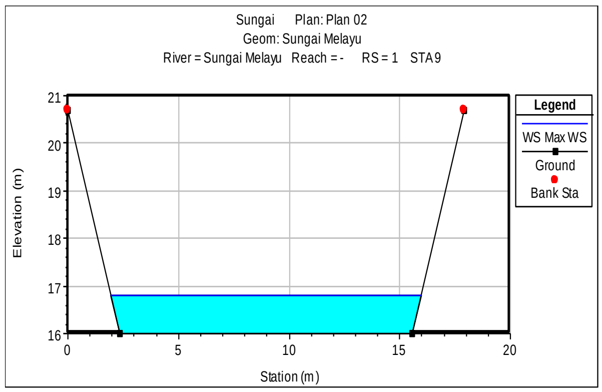
The image above shows ten cross sections for the Melayu (4.48 km) and Jambi river (5.33 km), used as data for running the modeling. The upstream part of both rivers starts from cross-section ten and ends at cross-section 1 with a channel length. After entering the river geometry data, the next step is to input the flood discharge to be run on the Melayu River cross-section using the HEC-RAS software (Figure 11-13).



(a)

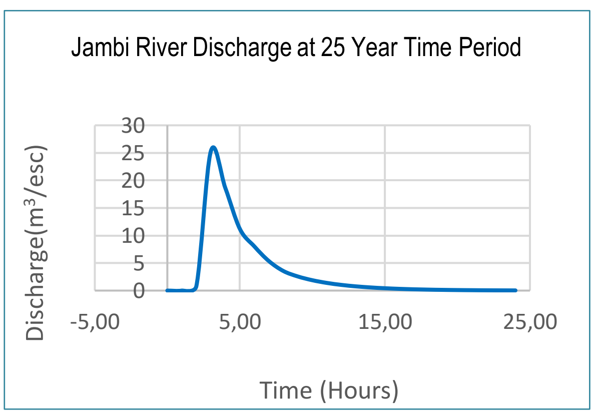


(b)



(c)

FIGURE 9. (a) Crosssection 10, (b) Crosssection 5, and (c) Crosssection 0 Melayu River Flood Discharge



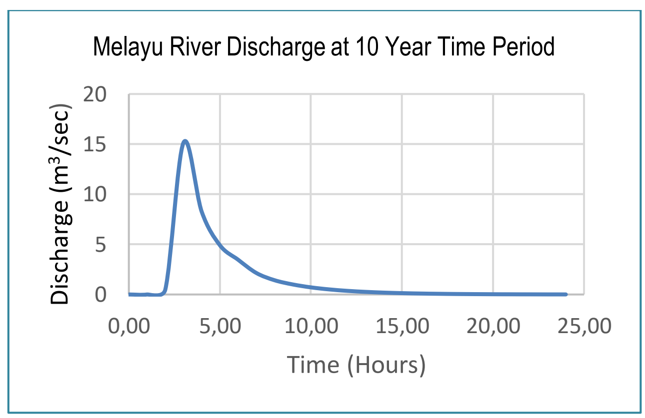


FIGURE 10. The JRFD Graph of the 25 years is in Figure **11.** The MRFD Graph at 10 Years Time Period

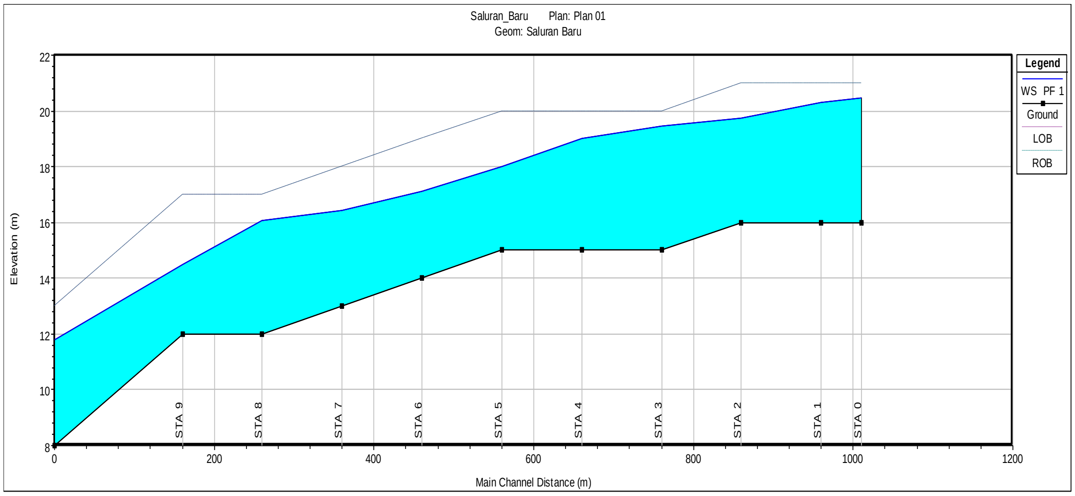


FIGURE 12. Longitudinal Section of New Channel

As seen in the image of the results of the hydraulic modeling of the new channel (connector) above, along the channel, it is still able to withstand the existing flood discharge with a trapezoidal cross-section shape with an upper width of 5 m and a lower width of 3 m with a channel height of 5 m. The cross-section shape and water level at each cross-section of the new channel can be seen in Figure 17-19 below :

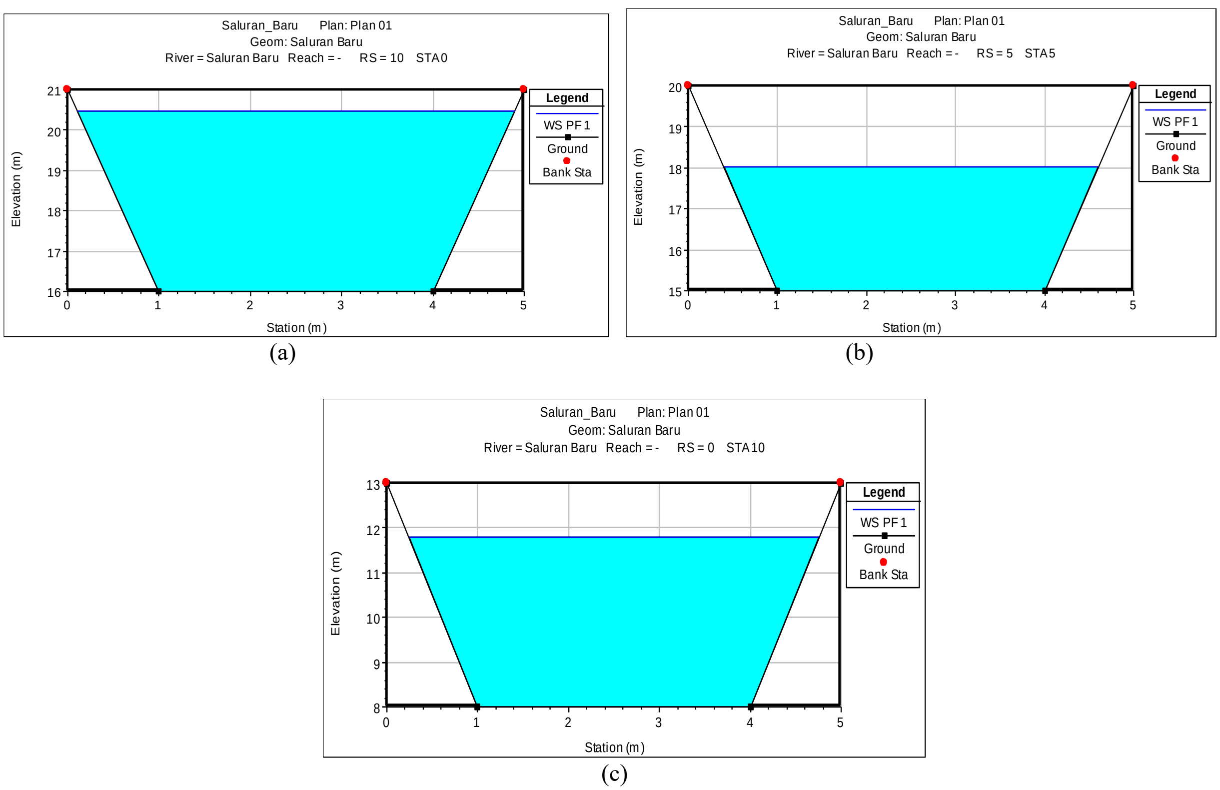


FIGURE 13. (a) Crosssection 10, (b) Crosssection 5, and (c) Crosssection 0 New Channel Flood Discharge

The Channel widening describes a situation where bank erosion occurs on both sides of a river channel. Unlike superficial river bank erosion, which naturally occurs in limited areas such as along bends or contractions, widening the channel at the top is to anticipate significant flooding from the Batang Hari River. Channel widening can occur naturally due to large floods or can be driven by an increase in peak flood flow rate caused by watershed changes [21-23]. During the rainy season, the Batanghari River often overflows; at certain times, there is even flooding in the temple site area.

The new channel is hoped to speed up water receding when floods occur.

CONCLUSION

Based on the results of the analysis of calculations and modeling, the authors can conclude that the results of the rain distribution analysis obtained the flood discharge value of the Melayu River for Q 2nd = 10.034 m^3/sec, Q 5th = 12.727 m^3/sec, Q 10th = 15.144 m^3/sec, Q 25th = 18.976 m^3/sec, and Q 50th = 22.468 m^3/sec. The Jambi River also obtained the discharge value result for Q 2nd = 13.387 m^3/sec, Q 5th = 16.980 m^3/sec, Q 10th = 20.204 m^3/sec, Q 25th = 25.317 m^3/sec, and Q 50th = 29.977 m^3/sec.

The catchment area of the Jambi River is 545 Ha with a return period of 25 years, and the Melayu River is 308 Ha with a return period of 10 years.

Hydraulic modeling on a 1.06 km long canal along the canal can withstand the existing flood discharge with a trapezoidal cross-section with a width of 5 m at the top and 3 m at the bottom with a channel height of 5 meters.

In the downstream part, the new channel meets directly with the main river, the Batanghari River, which becomes an obstacle during the rainy season. The Batanghari River produces large flood discharges, which can cause backwater in the new channel. To anticipate the occurrence of backwater in the new channel, sluice gates are provided on the downstream side, and embankments are built along the banks of the Batanghari River.

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