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Analysis of Design Flood Discharge and Water Level Case Study of the Batang Singkut River Section Sarolangun Regency

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Abstract

The Batang Singkut River section is a tributary of the Batang Asai River which passes through Pelawan District and Singkut District. This research was carried out by calculating the design flood discharge and modeling the water level using HEC-RAS. The starting point of the research is on the bridge around the Jambi University campus in Sarolangun Regency with the length of the river under review being 300 meters. The discharge data used is the maximum daily discharge for 10 years from 2011 to 2020. The method used to calculate the design flood discharge is the method of frequency analysis and distribution testing using the chi-square method. The analysis was carried out to find the design flood discharge frequency using the Pearson III log distribution type for return periods of 2 and 5 years. The calculated discharge is entered into the HEC-RAS to model the water level. The modeling results showthat at a 2-year return period for cross sections STA 0+00, STA 1+00, STA 1+50, STA 2+00, STA 2+50, and STA 3+00 are able to accommodate water with a discharge of 83.5026 m^3/s, but for the STA 0+50 cross section it is unable to accommodate the amount of discharge generated. Whereas for the return period of 5 years the cross section of STA 0+00 to STA 2+50 is unable to accommodate water with a discharge of 118.4132 m^3/s, while for STA 3+00 the cross section can hold water.

Keywords: Design Flood Discharge, Water Level, HEC-RAS.

1. Introduction

1. 1 Background

Jambi Province is a province that has a fairly wide watershed (DAS). The watershed in Jambi Province is the Batanghari Watershed which has an area of 4,550,338.98 Ha.The problem that often occurs in a sub-watershed is flooding, especially in the Batang Tembesi sub-watershed which has several river flows that are prone to flooding. The Batang Asai sub-watershed is one of the sub-watersheds that is often affected by flooding, because over the past few years the performance of the Batang Asai sub-watershed has decreased due to the increasing frequency of floods and extreme flow rates between the rainy and dry seasons. From the phenomena that occur, there is one river segment that is in the Batang Asai Sub-watershed which has always been affected by flooding in recent years. The Batang Singkut River section is a tributary of the Batang Asai River which is included in the list of villages that are always affected by floods every year. The factor that causes flooding in this river segment is the discharge that is too high which causes the river water level to rise. The purpose of this study is to determine the magnitude of the design flood discharge at return periods of 2 and 5 years and to model the water level using the help of the HEC-RAS program based on return periods of 2 and 5 years.

1. 2 Research Questions

Floods occur every year based on data from the Regional Disaster Management Agency (BPBD) of Sarolangun Regency, so it is necessary to analyze the flood discharge and the water level of the 300-meter section of the Batang Singkut River that crosses residential areas.

1. 3 Research Purposes

The purpose of this study is to determine the amount of flood discharge and water level based on HEC-RAS modeling with various return periods used.

1.4 The Significance of This Research

The benefits that are expected from this research are to become a source of information to the public about the potential for flooding that will occur and can be used as an effort to carry out flood prevention.

1. 5 The Limitation of This Research

This research is limited by the following matters:

1). The river section under review is 300 meters long which crosses Rantau Tenang Village, Sarolangun Regency.
2). The debit data used is the maximum daily discharge data for 10 years from 2011 to 2020.
3). The calculation of the design flood discharge uses the frequency analysis method.
4). Testing the type of distribution using the chi-square method.
5) Repeat is limited to only 2 and 5 years that have been selected based on the Minister of Public Works Regulation Number 12/PRT/M/2014.
6) Analysis hydraulics using the HEC-RAS program for modeling the water level.

2. Theoretical Basis

2.1 River

According to Junaidi (2014), the process of forming rivers comes from springs that flow over the earth's surface. The river has three parts with different characteristics, namely:

1). The upstream section is the base of the river which is located in a high place or with steep conditions and a fairly deep depth. In steep conditions it has a heavy flow rate, causing water to flow quickly to the lowest place and resulting in erosion where water can erode rivers.
2). The middle part is a continuation of the upstream of the river with conditions that are not too steep and normal discharge.
3). The downstream is the last part of the river that carries the flow from upstream to the sea.

2.2 Watershed (DAS)

According to Asdak (2010), a watershed is a land area that is topographically limited by mountain ridges that are able to accommodate and store rainwater and then channel it to the sea via the main river.

Watershed has four characteristics with different forms, namely:

1). Bird feathers/elongated, tributary paths are on the left and right of the main river and the flood discharge is small because the arrival time of the floods from the tributaries is different.
2). Radial, tributaries only go to a point radially so that if a flood occurs it will occur at the meeting point of the tributaries.
3). Parallel, two parallel river flow paths merge in the downstream so that flooding occurs at the meeting point of tributaries.
4). Complex, has several shapes with elongated, radial and parallel characteristics.

2.3 Flood

According to Hadisusanto (2010), floods originate from runoff flows that flow through rivers or become puddles. While runoff is the flow of water flowing on the surface of the land caused by rainfall after the water has infiltrated and evaporated, then flows into the river.

2.4 Design Flood Discharge

The design flood discharge is the maximum discharge in a stream such as a river with a certain return period. According to Jeffry (2013) states that the planned flood discharge is usually obtained by several methods, including:

1). Discharge data available
Availability of debit data for a minimum of 10 years by entering maximum instantaneous discharge data. The method that can be used is the frequency analysis method of the available discharge data. The analysis can use the most appropriate distribution function, such as normal, normal log, gumbel, or Pearson III log.
2). Debit data not available
If the discharge data is not available, then the analysis is carried out by calculating the design rainfall first by entering rainfall data for at least 10 years, after the design rainfall is obtained, the design rainfall results are converted to design discharge by using the synthesis unit hydrograph method and the rational method.

2.5 Frequency Analysis

According to Triatmodjo (cited in Sondak et al, 2019), frequency analysis aims to determine the magnitude of an event and the frequency or return period of the event by using a probability distribution.

The selection of distribution type is done by calculatingmean value ($\bar{x}$), standard deviation (S)$\bar{x}$,coefficient of variation (Cv), Slope coefficient (Cs), andKurtosis coefficient (Ck).

1). Average value ($\bar{x}$) =$\bar{x}\,\frac{\sum_{i=1}^{n} x_i}{n}$

2). Standard deviation (S) = $\sqrt{\frac{\sum(x_i-\bar{x})^2}{(n-1)}}$

3) Coefficient of variation (Cv) =$\frac{S}{\bar{x}}$

4) Slope coefficient (Cs) =$\frac{n\sum_{i=1}^{i}(x_i-\bar{x})^3}{(n-1)(n-2)(S)^3}$

5) Kurtosis coefficient (Ck) =$\frac{n\sum_{i=1}^{i}(x_i-\bar{x})^4}{(n-1)(n-2)(n-3)(S)^4}$

Statistical parameter requirements for a distribution can be seen in Table 1.

Table 1. Statistical parameter requirements for a distribution

No	Distribution	Requirements
1	*Gumbel*	Cs ≤ 1.1396 Ck ≤ 5.4
2	Normal	Cs ≈ 0

		ck = 0
3	Log Normal	Cs ≈ Cv2 + 3Cv = 0.3
4	Log Pearson III	Cs ≠ 0

After selecting the distribution type, then testing the distribution type using the chi-square test method with the equation:

$$\chi^2 = \frac{\sum_{i=1}^{n}\left(O_{fi} - E_{fi}\right)^2}{E_{fi}}$$

The selected distribution that has been tested using the chi-square test method to calculate the design discharge is a distribution that has a calculated chi-square parameter value that is smaller than the critical chi-square parameter value, or you can see the equation as follows:

$$\chi^2 < {\chi^2}_{cr}$$

The calculation procedure using the chi-square method is as follows:

1). Sort data from largest to smallest
2). Count the number of classes
3). Calculate the degrees of freedom (Dk) and the critical chi-square parameter (${\chi^2}_{cr}$)
4). Calculating the distribution class
5). Calculate class intervals
6). Calculating the value of the calculated chi-squared parameter ()χ^2
7). Calculates the chi-squared parameter value calculated () againstχ^2critical chi-square parameter (${\chi^2}_{cr}$)

3. Research Methodology

This research is located around the campus of the University of Jambi which is in Rantau Tenang Village, Pelawan District, Sarolangun Regency. The analytical method used in this research is the frequency analysis method which is carried out by finding distributions that meet the requirements for the type of distribution, then the selected distributions are tested using the chi-square test method. For the frequency analysis method, maximum daily discharge data for 10 years were used, taken from 2011 to 2020. The following are the stages of conducting the research:

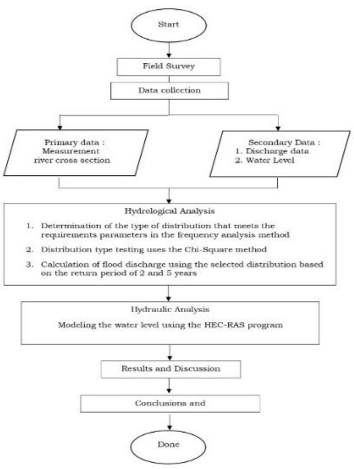

Figure 1. Stages of conducting the research

4. Results and Discussion

Analysis of the Design flood discharge on the Batang Singkut River segment uses maximum daily discharge data for 10 years. Maximum daily discharge data can be seen in Table 2.

Table 2. Maximum Daily Discharge Data

No	Year	Daily Maximum Discharge (m3/s)
1	2011	98.27
2	2012	64.02
3	2013	89.99
4	2014	84.97
5	2015	71.56
6	2016	98.27
7	2017	87,91
8	2018	66.05
9	2019	56,18
10	2020	319.07

4.1 Distribution Type Determination

Calculation of the type of distribution is done to find out the right distribution. The results of determining the type of distribution can be seen in Table 3.

Table 3. The results of selecting the distribution type

Type	Requirements	Calculation	Conclusion
Gumbel	Cs ≤ 1.1396 Ck ≤ 5.4	2.9478 1.2151	Not Fulfill
Normal	Cs ≈ 0 ck = 0	2.9478 1.2151	Not Fulfill
Log Normal	Cs ≈ Cv2 + 3Cv = 0.3	0.3341	Not Fulfill
Log Pearson III	Cs ≠ 0	2.2491	Fulfill

4.2 Distribution Type Testing

After obtaining the type of distribution that meets the requirements then testing the type of distribution using the chi-square method. The test results can be seen in Table 4.

Table 4. Value recapitulation (χ^2) and (${\chi^2}_{cr}$)

Distribution Probability	χ^2	${\chi^2}_{cr}$	Information
Gumbel	13.0	5,991	Not received
Normal	11.0	5,991	Not received
Normal Logs	8.0	5,991	Not received
Pearson Type III logs	3.0	5,991	Received

4.3 Design Flood Discharge

Analysis of design flood discharge with pearson type III log distribution. The calculation is done as follows:

Q : 2 year

KT : -0.157

$log\bar{x}$: 1.9547

$S_{log\bar{x}}$: 0.2102

Then, flood discharge with a return period of 2 years:

$$log x_2 = log\bar{x} + K_T \times S_{logx}$$

$$log x_2 = 1{,}9547 + (-0{,}157) \times 0{,}2102$$

$$log x_2 = 1{,}9217$$

$$x_2 = 83{,}5026 \ \ m^3/s$$

Table 5. Design flood discharge

Repeat	Flood Discharge $()m^3/s$
2	83,5026
5	118,4132

4.4 Water Level

The water level uses the HEC-RAS program by entering cross-sectional data based on the 300 meter measurement results and the amount of discharge obtained based on the return period.

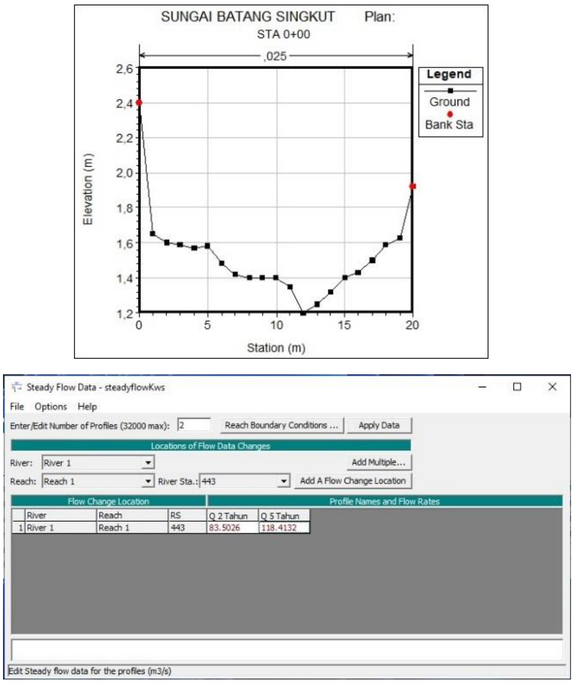

Figure 2. Cross section of STA 0+00 and filling in discharge data

The modeling results show that the cross section of the Batang Singkut River Section for a 2 year return period at STA 0+00, STA 1+00, STA 1+50, STA 2+00, STA 2+50, and STA 300 is still able to hold water, while at the STA 0+50 cross section it cannot hold water because at STA 0+50 there is siltation in the western part of the cross section. For the 5 year return period at STA 0+00, STA 0+50, STA 1+00, STA 1+50, STA 2+00, and STA 2+50 are unable to accommodate water because there is some siltation in the western and eastern parts of the cross section , while the STA 3+00 cross section is still able to accommodate water because this point is the downstream part of the cross section.

For inundation caused by the amount of discharge according to the calculation, it can be seen in Figure 3.

Figure 3. Flood inundation at 2 year return

In the results of the flood inundation modeling with a 2-year return period, water overflows in the eastern part of the river cross section, causing inundation in the residents' plantation areas which are in the eastern part of the river cross section.

5. Conclusion

Based on the analysis of the design flood discharge, the amount of discharge with a return period of 2 years is 83.5026 m^3/s and the amount of discharge with a return period of 5 years is 118.4132 m^3/s. Where there was an increase in discharge of 41.8%.

The modeling results show that the cross sectionThe Batang Singkut River section for a 2 year return period at STA 0+00, STA 1+00, STA 1+50, STA 2+00, STA 2+50, and STA 300 is still able to hold water, while at STA 0+50 unable to hold river water. For the 5 year return period at STA 0+00, STA 0+50, STA 1+00, STA 1+50, STA 2+00, and STA 2+50 are unable to accommodate river water, while at STA 3+00 it is still able to accommodate water because this point is the downstream part of the cross section.

Based on the results of calculations, discussion, analysis and conclusions, it can be suggested to build embankments around community settlements, this is intended to prevent erosion on river banks which can cause siltation of rivers.

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