Flood Water Level Simulation Bringin River, Semarang City by Using The HEC-RAS 6.3.1 Programming

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ABSTRACT

The Bringin River is a river in West Semarang, Semarang City, with the Tugu Region drainage subsystem. The Bringin watershed covers parts of the area in Tugu District, Ngaliyan District, and Mijen District. The overflow of water caused by high rainfall resulted in river flooding. The cross-section of the Bringin River cannot accommodate the magnitude of the flood discharge. The purpose of this study was to determine the cross-section of the Bringin River which was experiencing an overflow by carrying out a Hydrological Analysis-and using the HEC-RAS 6.3.1 Program as a 1-dimensional cross-sectional design. Calculation of the planned flood discharge with periods of 2, 5, 10, 25, and 50 years using the Nakayasu Synthetic Unit Hydrograph method with a peak discharge Q_2years : 52.45 m^3/second, Q_5years : 62.43 m^3/second, Q_{10}years: 68.44 m^3/second, Q_{25}years : 75.09 m^3/second, and Q_{50}years : 79.95 m^3/second. The results of the calculation of the design discharge will be used in the HEC-RAS 6.3.1 programming so that from these results it can be seen that several cross-sections of the river have flood overflows that exceed the capacity of the Bringin River under review.

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1. INTRODUCTION

Semarang City is the capital of Central Java Province which functions as central government, education, industry and a tourist city. Geographically, Semarang City is divided into 2 parts, namely low areas (lower city) and hilly areas (upper city) with an altitude of between 0.75 to 348,000 meters above the coastline. Semarang City has 16 sub-districts, namely 6 hilly areas and 10 land areas. With the characteristics of this area, the city of Semarang has the potential for natural disasters dominated by floods, tidal waves and landslides. Astronomically, it is located at 6°56'20" South Latitude - 7°4'19" South Latitude and 110°17'59" East Longitude - 110°20'51" East Longitude with an area of the Jratunseluna river of 9,896.01 km2. The Bringin watershed area is 33.90 km2 with the Bringin watershed length being 21.60 km. The Bringin watershed is in the West Semarang drainage area of Semarang City with the Tugu area drainage subsystem.

The Bringin watershed covers parts of the Tugu District, Ngaliyan District and Mijen District. The upstream of the Bringin watershed is in Mijen District, while the downstream is in Tugu District, northern part of Semarang City and will empty into the Java Sea [14]. The Bringin River is a river that frequently floods, resulting in river water overflowing onto the Pantura road. The Carryin River flood event occurred on October 13, 2022 and November 6, 2022.

The benefit of this research is to carry out hydrological analysis caused by rain to obtain a discharge plan. Can provide information regarding the flood discharge of the Bringin watershed to the community and Semarang City government agencies for flood management efforts.

2. LITERATURE REVIEW

2.1 Hydrological Analysis

Hydrological analysis was carried out by determining the research location from the nearest rain station and daily maximum rainfall data. The next stage is to test data consistency using the RAPS (Rescaled Adjusted Partial Sums) method [10][13][4]. If the rain data has been tested for consistency and the data results are consistent, then proceed with statistical parameter tests to determine the parameter values for the next stage. Furthermore, the calculation of the planned rainfall distribution is carried out to determine the distribution method using the Gumbel, Normal, Log Normal, and Log Person Type III distribution methods [3][11][16][18][21][22].

After calculating the distribution of rainfall, then a frequency distribution test was carried out using the Chi-Square and Smirnov-Kolmogorov methods[23][24]. The Chi-Square formula is

$$x^2 = \frac{(Oi - Ei)^2}{Ei} \quad (1)$$

$$DK = K - (\alpha + 1) \quad (2)$$

$$K = 1 + 3.3 \log n \quad (3)$$

Information:

x^2 = Chi-Square Value
DK = Degrees of Freedom
K = Class
n = Amount of data
Ei = Calculation Data

The Smirnov-Kolmogorov formula is

$$\Delta pmax < \Delta pkritis \quad (4)$$

Information :
Δpmax = Δpmax f rom calculations
Δpkritis = Δpkritis obtained from the table Δpkritis

2.2 Base Flow

Base flow is that part of the river flow that comes from the water below the ground surface. This occurs when the groundwater level is higher than the river bed elevation. Baseflow series are necessary to understand the variability over time and space of direct runoff processes in a DAS[12][15][15][16][25].

$$D = \frac{L}{A} \quad (5)$$

$$Q = 0.4751 \times A^{0.6444} \times D^{0.943} \quad (6)$$

Information:

D = Flow Density (km)

A = River Basin Area (km^2)

L = River Length (km)

Q = Base Flow (m3/second)

2.3 Rain Intensity

The intensity of rain is based on the time of concentration in the stream area under review, the formula used in calculating rain intensity is the mononobe formula[5][6][7].

$$I = \frac{R24}{Tc} \times \left(\frac{Tc}{t}\right)^{\frac{2}{3}} \quad (7)$$

Information:

I = Rain Intensity (mm/hours)

R24 = Maximum Rainfall (mm)

Tc = concentration time (hours)

2.4 Nakayasu Synthetic Unit Hydrograph

The Nakayasu synthetic unit hydrograph was developed in Japan and is very popular in Indonesia. The design flood discharge calculation for a water structure in Indonesia generally uses the Nakayasu method[1][8][19].

There are several characteristic parameters of the flow area, such as:

1. Time period from the surface of the rain to the peak of the hydrograph (time of peak).
2. Time lag from the rainfall center to the hydrograph gravity point (time log).
3. Time base of hydrograph.
4. Water catchment area area.
5. Length of the longest main river channel.
6. Flow coefficient.

$$Qp = C \times \frac{1}{3.6} \times A \times \frac{Ro}{0.3Tp + T0.3} \quad (8)$$

Information :

Qp = Peak flood discharge (m^3/dt/mm).

A = The area of the drainage area (km^2).

Ro = Unit rainfall (mm).

Tp = Flood peak time (hours).

*T*0.3 = Time required on decrease in peak discharge to discharge of 30% of peak discharge (hours).

To determine *Tp* and *T0.3* the formula is used:

$$Tp = Tg + 0.8\ Tr \quad (9)$$

$$T0.3 = \alpha \times Tg \quad (10)$$

Tg calculated based on the formula:

$$Tg = 0.40 + 0.058L\text{ , for } L > 15\text{ km} \quad (11)$$

$$Tg = 0.21L0.70\text{ , for } L < 15\text{ km} \quad (12)$$

Information :
Tg = Time lag (hours).
L = River length (km).
Tr = Rain duration (hours).
A = Non-physical parameters.

Price α has the following criteria:
1. Prices are normal for drainage areas $\alpha = 2$.
2. For the slow rising part of the hydrograph and the rapidly falling price chart $\alpha = 1.5$.
3. For the fast rising part of the hydrograph and the slow falling part the value of α = 3.

To determine these parameters will be used with the following approach formula:

$$T0.3 = 0.47\ (A \times L)0.25 \quad (13)$$

$$T0.3 = \alpha \times Tg \quad (14)$$

From the two equations above, the value of α can be found by the following equation:

$$\alpha = \frac{0.47 \times (A \times L)^{0.25}}{Tg} \quad (15)$$

Information:
L = Longest main river channel length (km).
A = Area of flow (km^2).

However, it is possible to take varying α values in order to obtain a hydrograph that is in accordance with the observations. The unit hydrograph equation is as follows:

a. On an upward curve (*rising line*)

$$0 \leq t \leq Tp$$
$$Qt = Qp \times \left(\frac{t}{Tp}\right)^{2.4} \quad (16)$$

b. On the downward curve (*recession line*)

$$Tp \leq t \leq (Tp + T0.3)$$
$$Qt = Qp \times 0.30 \times (\frac{t-Tp}{T0.3}) \quad (17)$$

$$(Tp + T0.3) \leq t \leq (Tp + T0.3 + 1.5T0.3)$$
$$Qt = Qp \times 0.30\ (\frac{t-Tp+0.5T0.3}{1.5T0.3}) \quad (18)$$

$$t \geq (Tp + T0.3 + 1.5T0.3)$$
$$Qt = Qp \times 0.30\ (\frac{t-Tp+0.5T0.3}{2T0.3}) \quad (19)$$

2.5 HEC-RAS 6.3.1

This research analysis was carried out using the HECRAS 6.3.1 program. The HEC-RAS (Hydrologic Engineering Center – River Analysis System) program is a package from ASCE (American Society of Civil Engineers). HEC-RAS is designed to create one-dimensional flow simulations. This software provides convenience by displaying graphics. In this HEC-RAS software, it is possible to trace the condition of the river water under the influence of its hydrology and hydraulics, as well as further river handling as needed. This research will create a one-dimensional flow simulation with the HEC-RAS program which can evaluate the ability of the existing river condition to accommodate and carry out the planned flood discharge[2][4][17][20].

The data entered into the HEC-RAS program include:
1. River scheme.
2. Long section data, river cross section.
3. Manning/rudeness numbers
4. Planned flood discharge.

3. STUDY RESULT

3.1 Problem

The problem that occurs is in collecting rainfall data and river images, it is necessary to have approval from the relevant agencies.

3.2 Hydrological Analysis Result

The result of the hydrological analysis was to collect daily rainfall data for 4 years at the research location and then obtain the maximum rainfall. Maximum rainfall data is obtained from BBWS Pemali-Juana. The following is the maximum rainfall data in table 1.

Table 1. Maximum Rainfall Data

Tanjung Emas Station			
Rainfall			
No	Year	Rmax (mm)	Ri (mm)
1	2013	135.00	155.00
2	2014	120.50	138.50
3	2015	119.40	135.00
4	2016	74.00	134.00
5	2017	99.50	120.50
6	2018	138.50	119.40
7	2019	92.70	105.60
8	2020	105.60	99.50
9	2021	155.00	92.70
10	2022	134.00	74.00

Source: BBWS Pemali-Juana

Calculating the planned rainfall, the planned rainfall with return periods of 2, 5, 10, 25 and 50 years can be seen in table 2.

Table 2. Calculation of Planned Rainfall

P	Distribution of Planned Rainfall			
	Gumbel	Normal	Log Normal	Log Person Type III
2	114.10	117.42	114.95	118.08
5	143.36	138.07	138.63	139.08
10	162.74	148.85	152.88	149.38
25	187.22	159.69	168.67	159.62
50	205.38	166.98	180.20	165.77

Source: Personal Calculation Results

Based on the Chi-Square and Smirnov-Kolmogorof tests, a Log Normal distribution test was obtained to be used in calculating the planned rainfall intensity. The results of the Chi-Square test and the Smirnov-Kolmogorov test can be seen in Tables 3 and 4.

Table 3. Chi-Square Calculation Results

Chi-Quadrate				
x-count	2	3	2	4
x-table	5.991	5.991	5.991	5.991
Information	Accepted	Accepted	Accepted	Accepted

Source: Personal Calculation Results

Table 4. Smirnov-Kolmogorov Calculation Results

Smirnov Kolmogorov				
Dmaks	1.26	1.26	0.18	0.18
D0	0.409	0.409	0.409	0.409
Information	Not accepted	Not accepted	Not accepted	Not accepted

Source: Personal Calculation Results

3.3 Nakayasu HSS calculations

Table 5. Nakayasu Peak Discharge Calculation Results

P (year)	Qp (m^3/second)
2	52.45
5	62.43
10	68.44
25	75.09
50	79.95

Source: Personal Calculation Results

3.4 HEC-RAS 6.3.1

In using Hec-Ras 6.3.1, it is necessary to generate geometric data. To make geometric data it is necessary to enter according to the data to be reviewed. Geometric data can be seen as shown in Figure 1.

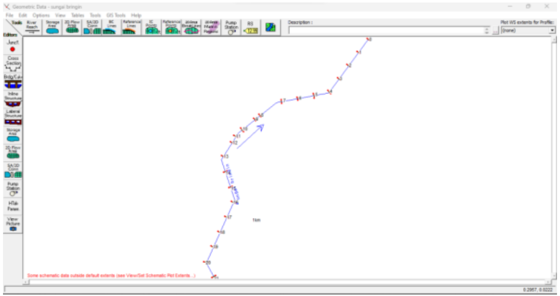

Figure 1. Geometric Data
Source: Personal Calculation Results

After geometric data, the next step is to enter cross section data. It can be seen in figure 2.

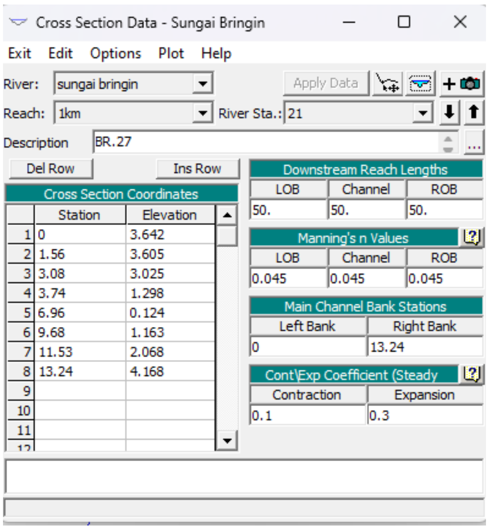

Figure 2. Cross Section BR.27
Source: Personal Calculation Results

Next, enter the discharge data input into HEC-RAS for steady flow which is the result of the peak discharge from the Nakayasu synthetic unit hydrograph for return periods of 2, 5, 10, 25 and 50 years. For Steady Flow Boundary Conditions use critical depth flow conditions. Below are the results of inputting flood discharge data for planned return periods of 2, 5, 10, 25 and 50 years as shown in Figures 4.3 and 4.4.

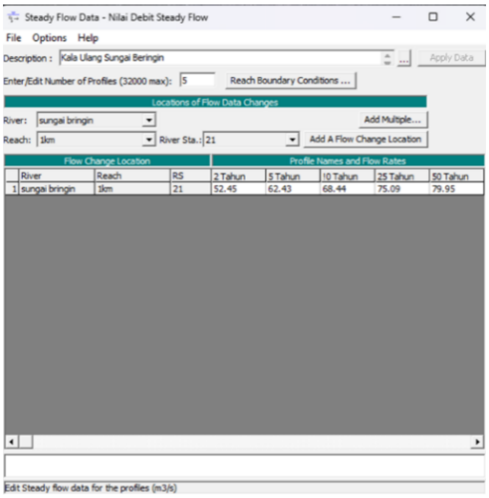

Figure 3. Steady Flow
Source: Personal Calculation Results

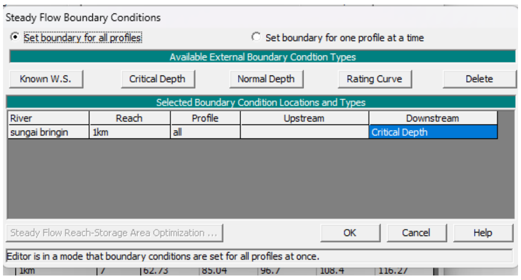

Figure 4. Steady Flow Boundary Conditions
Source: Personal Calculation Results

Below are the results of rivers that have been run by HEC-RAS using the example BR.27 to BR.26.

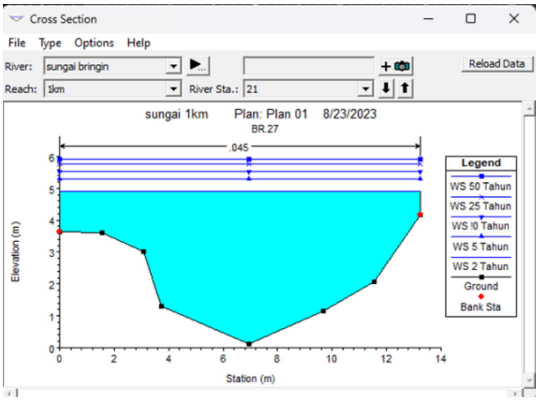

Figure 5. Cross Section BR.27
Source: Personal Calculation Results

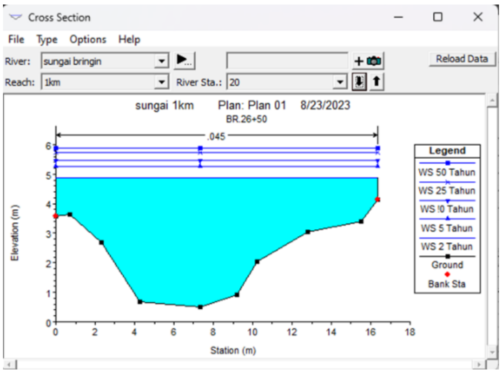

Figure 6. Cross Section BR.26+50
Source: Personal Calculation Results

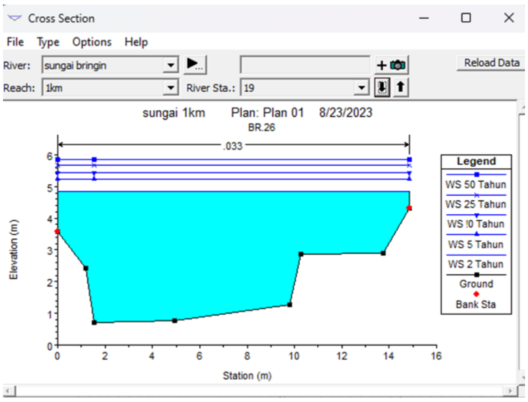

Figure 7. Cross Section BR.26
Source: Personal Calculation Results

4. CONCLUSION

The conclusion of this research is that high rainfall causes the Bringin River in Semarang City to flood.

1. The results of the analysis and study on the Bringin River in Semarang City show that the design flood discharge using the Nakayasu Synthetic Unit Hydrograph with flood discharge at a year return period = 52.45 m^3/second, 5 year return period = 62.43 m^3/second Return period 10 years = 68.44 m^3/second, 25 year return period = 75.09 m^3/second, and 50 year return period = 79.95 m^3/second.
2. The Bringin River overflowed during periods of 2 years, 5 years, 10 years, 25 years and 50 years which resulted in the river flooding. However, in section BR.17 the return period is 2 years and the return period is 5 years, the left bank and right bank do not overflow and the river does not overflow, and in section BR.17 the return period is 10 years, the return period is 25 years, and the return period is 50 years the left bank does not overflow and the right bank overflows so the river overflows.

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