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Flood Disaster Risk Analysis for the Community in Penjalin Village, Brangsong Sub-District, Kendal Regency

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Abstract

The aim of this research is to find out the impact of the flood that occurred in Penjalin Village, Brangsong Distric, Kendal Regency. This research uses a direct interview method with the people in Penjalin Villagofe based on the planned rainfall and the planned discharge obtained from the calculation results of a method. This research aims to analyze floods using two methods, namely using the Gumbel method calculation formula and the Type III Log Person method. The results obtained from calculations using the Gumbel method formula, the planned rainfall for the 2-year re-economy period is 195,422 mm while the 5 year repeat period is 255,547 mm and 10-year return period of 278,719 mm. The results obtained from calculations using the Log Person Type III formula are, The planned rainfall for the 2-year return period is 199,96 mm, while the 5-year return period is 219, 352 mm, and the 10-year return period is 262,63 mm. The distribution used in this calculation is Log Person Type III because it better meets the requirements, namely $Cs \neq 0$ compared to calculations using the Gumbel method. The calculation of the rain concentration time using the Kirpich method was 0,431 hours, and in determining the intensity of rain using the method, the results obtained were I2 = 121,482 mm/hour, I5 = 133,264 mm/hour, and I10 = 159,572 mm/hour. In determining the planned discharge using rational methods, the results obtained are, Q2 = 10,638 x 10-4m3/s, Q5 = 11,66 x 10-4m3/s, and Q10 = 13,97 x 10-4m3/s. From this research, it can be concluded that the planned rainfall and planned discharge from the 2-year return period, 5-year return period, and 10-year return period always increase.

Keywords: Rainfall, Return period.

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INTRODUCTION

Flood disasters are natural events that can occur at any time. A flood is a natural phenomenon in which water inundates an area that is normally dry, usually caused by high rainfall that exceeds the capacity of rivers or drainage systems. This phenomenon can be triggered by natural factors such as lowland topography and the lack of water infiltration areas due to development, as well as human factors, such as the habit of disposing garbage into rivers, land degradation caused by illegal mining, or deforestation that reduces rainwater absorption.

According to Law No. 24 of 2007, preparedness is a series of activities carried out by an individual or a group of people to anticipate disasters through comprehensive organization and through effective and efficient measures for the environment in which we live. Preparedness is one of the processes in disaster management, and its importance becomes a vital element in disaster risk reduction efforts. These activities serve as an effort to anticipate and reduce disaster risks, which may include the knowledge a person possesses and the actions taken. Knowledge about flood disasters is the most fundamental factor and becomes the key to preparedness attitudes. Knowledge possessed by an individual generally influences their attitude and awareness to be prepared in anticipating the occurrence of a disaster.

Kendal City is located in Central Java Province, Indonesia. The regency is bordered by the Java Sea to the north, Semarang Regency to the east, Temanggung Regency to the south, and Batang Regency to the west. When high rainfall occurs, inundation or flooding often affects areas around Kendal, including Penjalin Village. The inundation in the Aji River area in Penjalin Village disrupts the daily activities of local residents. The extent of inundation during periods of high rainfall commonly reaches 5 hectares. There are two possible causes of the flooding: first, the river's capacity is unable to accommodate the current flood discharge due to a lower downstream elevation that results in backwater. Efforts to address this flooding issue include planning an adequate drainage network in the Aji River watershed in Penjalin Village to accommodate the occurring flood discharge.

Based on the background above, the purpose of this thesis research is to analyze the causes and impacts of flooding and to evaluate vulnerability in Penjalin Village, Brangsong Sub-district, Kendal Regency. It is expected that this research can provide useful information, especially for the community and local government, in planning better mitigation and flood disaster management measures.

RESEARCH METHOD

The study was conducted in Penjalin Village, Brangsong Sub-district, Kendal Regency, Central Java, with the research area located along the Aji River, approximately 8.3 km or 15 minutes from the Pantura highway. Data collection employed interviews with local residents and village officials, documentation through field photographs, and direct on-site observations. Both primary data obtained firsthand through interviews, surveys, and field observations and secondary data from documents, literature, archives, and other existing sources were utilized. Data analysis involved examining hydrological cycles and rainfall characteristics, with Brangsong's annual rainfall recorded at approximately 2,987 mm and an average temperature of 32°C. The research variables focused on assessing flood disaster risk in Penjalin Village, including indicators of flood hazards and various dimensions of vulnerability, namely physical, social, economic, and environmental vulnerability.

RESULTS AND DISCUSSION

Planned Rainfall Analysis

This analysis was conducted to determine the annual rainfall in the 10th year, which will be used as source data for calculating planned flood discharge.

This study used data from the Kedung Pengilon Station of the Water and Environment Agency in Penjalin Village, Bransong Subdistrict, Kendal Regency.

Table 1. Rainfall Data from the Kedung Pengilon Station

Annual	**Maximum Daily Rainfall (mm)**
2014	171
2015	122
2016	217
2017	207
2018	199
2019	251
2020	171
2021	177
2022	249
2023	247
N=10	
Year	2011

(Source: Karangtengah Water and Environment Agency)

After obtaining the maximum average rainfall data, the distribution pattern was calculated using frequency analysis. The distribution used and analyzed in this study was the Gumbel distribution and the log-normal type III distribution.

Frequency Analysis

1. Calculation of Frequency Analysis of Gumbel Distribution

Table 2. Frequency analysis calculations for the Gumbel distribution

Year	Xi (mm)	$\bar{X}$ (mm)	Xi - $\bar{X}$	$(Xi-\bar{X})^2$	$(Xi-\bar{X})^3$	$(Xi-\bar{X})^4$
2014	171	201.1	-30.1	906.1	-27,270.901	820,854.1201
2015	122	201.1	-79.1	6,256.81	-494,913.671	39,147,671.3761
2016	217	201.1	15.9	252.81	4,019.679	63,912.8961
2017	207	201.1	5.9	34.81	205.379	1,211.7361
2018	199	201.1	-2.1	4.41	-9.261	19.4481
2019	251	201.1	49.9	2,490.01	124,251.499	620,014.8001
2020	171	201.1	-30.1	906.01	-27,270.901	820,854.1201
2021	177	201.1	-24.1	580.81	-13,997.521	337,340.2561
2022	249	201.1	47.9	2,294.41	109,902.239	526,431.72481
2023	247	201.1	45.9	2,106.81	96,702.579	4,438,648.3761
Total	2011			15,868.99	-228,380.88	57,094,979.3761

Description:
Xi = Maximum daily rainfall (mm)
$\bar{X}$ = Average rainfall (mm)
Statistical parameters:

1. Average rainfall $\bar{(X)}$ $\bar{X} = \frac{Xi}{n} = \frac{2011}{10}$ = 201.1 mm
2. Standard Deviation (Sd) $S_d = \sqrt{\frac{(Xi-\bar{X})^2}{n-1}} = \sqrt{\frac{15868,99}{9}}$ = 41.9907
3. Coefficient of Variation (Cv) Cv $= \frac{S_d}{\bar{X}} = \frac{41,9907}{201,1}$ = 0.2088
4. Skewness Coefficient (Cs)
$$C_s = \frac{\sum_{i=1}^{n}(X-\overline{X})^3}{(n-1)(n-2)\,S_d{}^3} = \frac{10.(-228380,88)}{(9)(8).(41,9907)^3} = -0.0102$$
5. Kurtosis Coefficient (Ck)

$$Ck = \frac{n^2 \sum_{i=1}^{n}(X-\overline{X})^4}{(n-1)(n-2)(n-3)S_{d^4}} = \frac{10^2(57094979{,}3761)}{(9)(8)(7).(41{,}9907)^4} = 0.0011$$

Table 3. Calculation of statistical parameters for the Gumbel distribution

Number of data	10
Mean	201.1 mm
Standard Deviation	41.9907
Coefficient of Variation	0.2088
Skewness Coefficient	0.0102
Coefficient of Kurtosis	0.0011

Calculation of planned rainfall for 2-year, 5-year, and 10-year intervals as follows:

Yn (*Reduced mean*) = 0.4952

Sn (*Reduced standard deviation*) = 0.9496

$Y_{Tr}2$ (*Recuded Variatted*) = 0.3668

Y_{Tr} 5 = 1.5004

Y_{Tr}10 = 2.2504

1. Planned rainfall recurrence period: 2 years

   $K = 0\frac{Y_{Tr} - Y_n}{S_n} = 0\frac{0{,}36688-0{,}4952}{0{,}9496} = -0.1352$

   $X_T = X + K.\ Sd = 201.1 + ((-0.1352)\ (41.9907)) = 195.4228$ mm

2. 5-year return period design rainfall

   $K = \frac{Y_{Tr}-Y_n}{S_n} = \frac{1{,}5004-0{,}4952}{0{,}9496} = 1.0585$

   $X_T = X + K.\ Sd = 201.1 + ((1.0585)\ (41.9907)) = 245.5471$ mm

3. 10-year return period design rainfall

   $K = \frac{Y_{Tr}- Y_n}{S_n} = \frac{2{,}2504-0{,}495}{0{,}9496} = 1.8485$

   $X_T = X + K.\ Sd = 201.1 + ((1.8485)\ (41.9907)) = 278.7198$ mm

Table 4. Calculation of design rainfall with gumbel distribution

No	Period Repetition (T) Year	Y_{Tr}	Y_n	S_n	$\overline{X}$ (mm)	S_d	K	S_T (mm)
1	2	0.3668	0.4952	0.9496	201.1	41.9907	-0.1352	195.4228
2	5	1.5004	0.9452	0.9496	201.1	41.9907	1.0585	245.5471
3	10	2.2510	0.9452	0.9496	201.1	41.9907	1.8485	278.7198

(Source: Calculation)

2. Log Frequency Analysis Calculation for Person Type III

Table 5. Log-normal distribution frequency analysis calculations Type III

Year	X_i(mm)	Log X_i	$LogX_i\ \overline{X}$	$(\text{Log } X_i - \overline{X})^2$	$(\text{Log}X_i - \overline{X})^3$	$(\text{Log}X_i - \overline{X})^4$
2014	171	2.23299	-0.06101	0.00372	-4.43569	5.91426
2015	122	2.08635	-0.20765	0.04311	-5.69452	7.5927
2016	217	2.33645	0.04245	0.0018	3.60419	4.80558
2017	207	2.31597	0.02197	0.00048	2.31255	3.0834
2018	199	2.29885	0.00485	0.00002	-0.96665	1.28887
2019	251	2.39967	0.10567	0.01116	5.0943	6.7924
2020	171	2.23299	-0.06101	0.00372	-4.43569	5.91426
2021	177	2.24797	-0.04603	0.00211	-4.14605	5.528

2022	249	2.39619	0.10219	0.01044	5.041	6.72134
2023	247	2.39261	0.09861	0.00972	4.98543	6.64725
Total	2011	22.94		0.08646	1.35887	54.28806
‾X (mm)		2.294				

Description
Xi = Maximum daily rainfall (mm)
Log X = Logarithmic value of maximum daily rainfall
‾X = Average rainfall (mm)
Statistical parameters:

1. Average rainfall‾(X)‾X = $\sqrt{\frac{\sum_{i=1}^{n} \text{Log Xi}}{n}} = \frac{22,94}{10}$ = 2.294 mm
2. Standard Deviation (Sd) S_d
   Sd = $\sqrt{\frac{\sum_{i=1}^{n}(\text{LogX}_i - \bar{X})^2}{n-1}} = \sqrt{\frac{0,08646}{9}}$ = 0.09801
3. Coefficient of Variation (Cv) Cv
   Cv = $\frac{Sd}{\bar{X}} = \frac{0,09801}{2,294}$ = 0.03768
4. Skewness Coefficient (Cs)
   Cs = $\frac{\sum_{i=1}^{n}(\text{LogXi} - \text{logX})^3}{(n-1)(n-2)\,(S_{d})^3} = \frac{10x(1,35887)}{9x8x(1,73662)^3}$ = 0.036035
5. Kurtosis Coefficient (Ck)
   Ck = $\frac{n^2 \sum_{i=1}^{n}(\text{logX}_i - X)^4}{(n-1)(ni2)(n-3)S_d{}^4} = \frac{10^2 x\ 54,28806}{9x8x7x(1,73662)^4}$ 0.00157

Table 6. Calculation of statistical parameters for Log Person Type III

Number of data	10
Mean	2.294 mm
Standard Deviation	0.09801
Coefficient of Variation	0.75707
Skewness Coefficient	-0.0102
Coefficient of Kurtosis	0.00157

(Source: Calculation)

Calculation of planned rainfall for 2-year, 5-year, and 10-year return periods as follows:

1. 2-year return period
   Log X_T= X + K.Sd
   Log X_T= 2.294 + (0.004 × 0.09801) = 2.30094
   X_T= 199.96 mm
2. 5-year return period
   Log X_T= X + K.Sd
   Log X_T= 2.294 + (0.481 × 0.09801) = 2.34114
   X_T= 219.352 mm
3. 10-year recurrence period
   Log $X_{(T)\,=}$X + K.Sd
   Log X_T= 2.294 + (1.279 × 0.09801) = 2.41935
   X_T= 262.63 mm

Table 7. Calculation of planned rainfall with Log Person Type III distribution.

Return Period (T)	$\bar{X}$ (mm)	Sd	K	Log X_T	X_T (mm)
2	2.294	0.09801	0.004	2.30094	199.96
5	2.294	0.09801	0.841	2.34114	219,352
10	2.294	0.09801	1.279	2.41935	262.63

(Source: Calculation)

3. Selection of Distribution Type

From the above calculations, several Cs and Ck values were identified as requirements for using the distribution method. The following table summarizes the conclusions from the above calculations:

Table 8. Rainfall distribution maintenance parameters

Distribution Frequency	Requirements	Result	Description
Gumbel Method	Ck ≤ 5.4002	Ck = 0.0011	No
	Cs ≤ 1.1396	Cs = -0.0102	Meets
Log Method		Ck = 0.00157	
Person Type III	Cs ≠ 0	Cs = 0.03603	Meets

Based on the above parameters, the distribution used in this calculation is Log Person Type III.

4. Goodness-of-Fit Test

This test is intended to determine the suitability of the frequency distribution of the data sample to the probability distribution function, which can be used as a reference to represent the frequency distribution.

To determine whether a sample meets the distribution requirements or not, a *Chi-Square* goodness-of-fit test of the Log Person Type III method calculation results is required, as follows:

$$K = 1 + 3.322 \log n$$
$$= 1 + 3.322 \log 10$$
$$= 4.322 = 5$$
$$Dk = K - (p + l)$$
$$= 5 - (2 + 1)$$
$$= 2$$
$$Ef = 0\frac{n}{K} = \frac{10}{5} = 2$$
$$\Delta X = \frac{(X\max) - (X\,min)}{K} = \frac{(2{,}39967 - 2{,}08635)}{5} = 0.062664$$
$$\frac{1}{2}\Delta X = 0.03133$$
$$\text{Initial X} = \text{X min} - \frac{1}{2}\text{X}$$
$$= 2.08635 - 0.03133$$
$$= 2.05502$$
$$\text{Distribution Class} = \frac{1}{5} \text{ x } 100\% = 20\%$$

Significance Level (∞) = 5%

This is because the confidence level used is 95%, so the error rate is 5% or 0.05. Then, using the critical value table, *Chi-Square*, the value X^2cr = 5.991, and the condition that must be met is X^2calculated < X^2cr.

Determining the interval limits is done using the following distribution class calculations.

Table 9. *Chi-Square* goodness-of-fit test calculation with Log Person Type III distribution.

No	Class Boundary Values	Ef	Of	$(Ff-Of)^2$	$(Ef-Of)^2/Ef$
1	2.0550 < Xi < 2.1176	2	2	0	0
2	2.1176 < Xi < 2.1802	2	1	1	0.5
<	2.1802 < Xi < 2.242 8	2	2	0	0
4	2.2428 < Xi < 2.3054	2	2	0	0
5	2.3054 < Xi 2.368	2	3	1	0.5
2428	Total	10	10	10	1

(Calculation Source)

Calculation result X^2 = 1 and value X^2 cr = 5.991X^2

The result of the *Chi-Square* test calculation above shows that $X^2 < X^2$cr, so the tested hypothesis can be accepted and the Log Person Type III method can represent the analyzed statistical distribution.

5. Calculation of Planned Rainfall

The calculation of planned rainfall using the Log Pearson Type III distribution method can be seen in the table below:

Table 10. Calculation of Planned Rainfall Distribution Using Log Pearson Type III

Return Period (T)	$\bar{X}$ (mm)	Sd	K	Log X_T	X_T(mm)
2	2.294	0.09801	0.004	2.30094	199.965
5	2.294	0.09801	0.481	2.34114	219,352
10	2.294	0.09801	1.279	2.41935	262,635

(Source: Calculation)

Xt = Log Xi = Log Xi + K + S

Where:

Xt = Planned rainfall

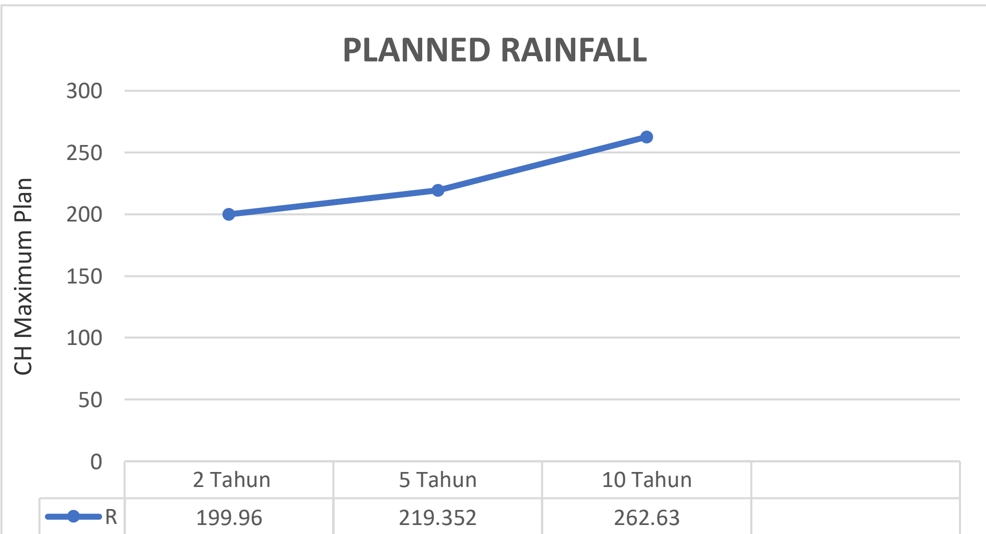
$\bar{x}$t = Average rainfall

K = Coefficient for Log Person Type III distribution

Sd = Standard deviation

Graph of Planned Rainfall using Log-Pearson Type III

Figure 1. Planned Rainfall Graph using the Log Person Type III method



6. Rainfall Intensity Analysis

Rainfall intensity calculations using the Monobe Method. The Monobe Method is a formula for calculating rainfall intensity at any time based on daily rainfall data.

Monobe Formula*:* $I = \frac{R_{24}}{24} \left(\frac{24}{t}\right)^{\frac{2}{3}}$

Explanation:

I = Rainfall intensity for rainfall duration t (mm/hour)

t = Rain duration (hours)

R_{24} = Maximum rainfall over 24 hours (mm)

Table 10. Rainfall Intensity Calculation

Duration (Hours)	R 2 Years	R 5 Years	R 10 Years
0.25	174,683	187,545	224,552
0.5	109,810	120,460	144,230
1	69,318	76,042	91,046
2	43,965	48,230	57,746
3	33,326	36,558	43,772
4	27,494	30,160	36,112
5	24,136	26,477	31,702
6	20,995	23,031	27,576
7	18,079	19,833	23,746
8	17,329	19,010	22,761
9	15,980	17,091	20,463
10	14,663	16,085	19,336
11	13,830	15,171	18,165
12	13,163	14,440	17,290
13	12,414	13,618	16,305
14	11,830	12,978	15,539
15	11,630	12,758	15,276
16	10,914	11,972	14,335
17	10,331	11,333	13,569
18	10,122	11,104	13,295
19	9,831	10,784	12,912
20	9,573	10,501	12,573
21	9,081	9,962	11,928
22	8,573	9,904	11,260
23	8,548	9,377	11,227
24	8,331	9,139	10,943

(Source: Calculation)

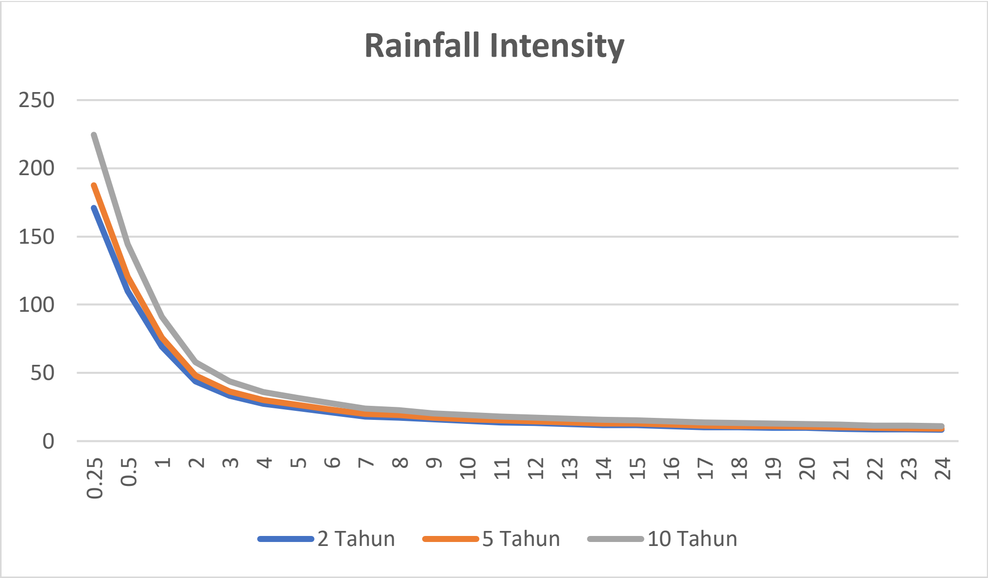


Figure 4.2 Rainfall Intensity

Flood Hazard Parameters

1. Planned Flow Rate

Before calculating the discharge, the concentration time and rainfall intensity during the concentration time are first calculated to obtain the I value in determining the discharge using the rational method.

2. Determination of Concentration Time (Tc)

The concentration time (Tc) is determined using the Kirpich (1940) formula as follows:

$$Tc = \left(\frac{0{,}87\ x\ L^2}{1000\ x\ S}\right)^{0{,}385}$$

$$S = \frac{H}{0{,}9\ x\ L} = \frac{0{,}0004}{0{,}9\ x\ 0{,}36} = 0.001$$

$$Tc = \left(\frac{0{,}87\ x\ 0{,}36^2}{1000\ x\ 0{,}001}\right)^{0{,}385} = 0.431 \text{ hours}$$

Where:

L = River length

S = River slope

H = Height between the farthest point and the point under review

3. Determining Rainfall Intensity During Concentration Time

The determination of rainfall intensity during the concentration period uses the Mononobe Formula as follows:

$$I_2 = \left(\frac{199{,}959}{24}\right) x \left(\frac{24}{0{,}431}\right)^{\frac{2}{3}} = 121.482 \text{ mm/hour}$$

$$I_{(5)} = \left(\frac{219{,}352}{24}\right) x \left(\frac{24}{0{,}431}\right)^{\frac{2}{3}} = 133.264 \text{ mm/hour}$$

$$I_{10} = \left(\frac{262{,}635}{24}\right) x \left(\frac{24}{0{,}431}\right)^{\frac{2}{3}} = 159.572 \text{ mm/hour}$$

Flow coefficient for dense settlements (family/mixed settlements) 0.75

4. Design Flow Calculation

Design flow calculation for 2-year, 5-year, and 10-year recurrence periods

Q_2= 0.278 x C x l x A
= 0.278 x 0.75 x 121.482 x (42 x 010^{-6})
= 0.001063817
= 10.638 x10^{-4} m³/dt

Q_5= 0.278 x 0.75 x 133.264 x (42 x$^{10^{-6}}$)
= 0.001166992848
= 11.66 × 10^{-4}m³/dt

Q_{10}= 0.278 × 0.75 × 159.572 × (42 $^{\times 10^{-6}}$)
= 0.001397
= 13.97 × $10^{-4 m3}$/dt

Based on the calculation of planned rainfall data for a 2-year recurrence period of 199.96 mm, while the 5-year return period is 219.352 mm, it can be concluded that the 5-year return period has increased by 19.392 mm compared to the previous 2-year return period, and the 10-year return period is 262.63 mm, an increase of 43.278 mm compared to the previous 5-year return period. Therefore, as there is an increase in rainfall in each period, to reduce the risk of future flooding, there must be better drainage construction or management, such as the construction of culverts or ditches in areas that are often affected by flooding to reduce water accumulation when it rains.

From the results of the planned discharge calculations for a 2-year recurrence interval, it is 10.638 x10^{-4} m³/dt, and for a 5-year recurrence interval, it is 11.66 x10^{-4} m³/dt, an increase of 1.022 x10^{-4} m³/dt. and the 10-year recurrence period is 13.97 x10^{-4} m³/dt, which also shows an increase of 2.31 x10^{-4} m³/dt from the 5-year recurrence period. Due to the increase in planned discharge, measures to address this increase must be implemented by adding height to the embankments on both sides of the river and maximizing river normalization.

CONCLUSION

From the research conducted, the following conclusions can be drawn:

1. Rainfall calculations were performed using rainfall data from a single station, namely the Kedung Pucung station.
2. The planned rainfall calculation uses the *Log Person Type III* method. The planned rainfall results for a 2-year return period is 199.96 mm, a 5-year return period is 219.352 mm, and a 10-year return period is 262.63 mm.
3. Calculation of rainfall concentration time (tc) using the Kirpich method yielded a result of 0.431 hours.
4. Rainfall intensity was determined using the Mononobe method, with the results of the calculation being I_2 121.482 mm/hour, I_5 133.264 mm/hour, and I_{10} 159.572 mm/hour.
5. The rational discharge method was used to determine the planned discharge. The results obtained using the rational method were Q_2= 10.638 x 10^{-4}m^3/dt, Q_5= 11.66 x 10^{-4}m$^{3/dt}$, and Q_{10}= 13.97 x 10^{-4}m^3/dt.
6. From this study, it can be concluded that planned rainfall, rainfall intensity, and planned discharge for periods of 2 years, 5 years, and 10 years have always increased.

Based on the above conclusions, with high rainfall intensity and large runoff discharge, it is recommended that

1. River normalization
   Immediately carry out normalization along the river to help increase the river's capacity to accommodate and drain rainwater properly. With this, the risk of flooding can be significantly reduced.
2. Increasing the height of river embankments
   Increasing the height of river embankments can increase water retention capacity, thereby preventing flooding and protecting surrounding areas from overflowing water. With higher embankments, the river system can withstand greater water discharge during floods, keep the flow within the river channel, and protect infrastructure and settlements from damage.

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