

ANNUAL FLOOD ANALYSIS OF CISANGGARUNG WATERSHED IN CIREBON REGENCY

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ABSTRACT

Cisanggarung River, a river in West Java Province, often experiences flooding. This study aims to discuss the magnitude of annual flood discharge that may occur in the Cisanggarung watershed. Rain data at each station in the Cisanggarung watershed from 2005 to 2017 were analyzed using descriptive-quantitative methods. Return period flood discharge 2, 5, 10, 20, and 50 years were compared to 2-yearly and monthly flood discharge. The results showed that the data followed the Log-Pearson Type III distribution. The return period flood discharge is: $Q_2 = 181.518 \text{ m}^3/\text{s}$, $Q_5 = 242.498 \text{ m}^3/\text{s}$, $Q_{10} = 283.109 \text{ m}^3/\text{s}$, $Q_{20} = 316.534 \text{ m}^3/\text{s}$, $Q_{50} = 373.369 \text{ m}^3/\text{s}$, $Q_{100} = 412.425 \text{ m}^3/\text{s}$, $Q_{200} = 452.013 \text{ m}^3/\text{s}$, dan $Q_{1000} = 546.683 \text{ m}^3/\text{s}$ by using the Nakayasu method. Based on the 2 annual maximum daily rains, 2005, 2007, 2009-2010, 2015, 2009-2017 has the potential to flood Q_2 , 2012 has the potential to flood Q_5 , and 2017 has the potential to flood Q_{10} . According to maximum 2-daily monthly rainfall, in 2005-2007, January-April and November have the potential to flood Q_2 . December has the potential to flood Q_{10} . These results are useful for flood control in the region to be more effective and accurate.

Keywords: Flood, Flood Discharge, Watershed, Re-Period, Cisanggarung River

INTRODUCTION

Flood is a condition where water is not accommodated in the drainage channel (river trough) or the flow of water is obstructed in the drainage channel, so that it overflows and inundates the surrounding area (floodplain). One of the flooding problems caused by natural factors is high rainfall and water flow in rivers that are hydrologically described as hydrographs with peak and volume of floods. Rainfall that falls above the watershed mostly becomes a direct runoff consisting of surface runoff and interflow. This kind of flow can produce high flood peaks. The event of maximum discharge or peak flooding is only a few moments, but can damage urban infrastructure facilities such as roads and bending, inundate settlements and rice fields, disrupt human activities and others.

Cisanggarung River is a river in West Java Province which is tipped south of the Darma Reservoir, Cageur Village, Darma District, Kuningan Regency and empties into the Java Sea. This river crosses Kuningan and Cirebon Regencies in West Java Province and Brebes Regency in Central Java Province. Every year, the Cisanggarung River will definitely experience flooding in several areas, one of which is Babakan Losari Lor Village, Pabedilan District, Cirebon Regency. Floods that hit the village had a height of 40-60 centimeters. This is because the location of the Village of Babakan Losari Lor is very close to the river. Even though there were no fatalities, this annual flood is of great concern and is certainly

detrimental to the community such as crop failures, access to waterlogged roads, houses becoming dirty, residents' activities disrupted and others.

As an action to control floods in the area around the Cisanggarung watershed, annual flood analysis is carried out. This research will record the magnitude of annual flood discharge that may occur in the Cisanggarung River Basin. Predictions of flood discharge figures can be calculated from rain data at each of the nearest rain recording stations. From the station rainfall data for 13 years, from 2005-2017, an annual flood analysis can be done which is caused by daily rains, daily rains and maximum annual rains. Flood discharges with a return period of 2, 5, 10, 20, 50 years will be compared with 2 yearly flood discharges and monthly flood discharges, so that it will be easier to socialize the risk of flooding for residents living in the Babakan Losari Lor region that are traversed by Cisanggarung river.

The results of this study can be useful as information in the field of civil engineering, especially regarding hydrology, namely annual flood analysis in a watershed. In addition, with this information, the local government can take consideration for maintenance and supervision of the Cisanggarung River Basin.

RESEARCH METHODOLOGY

This research was conducted by descriptive-quantitative method. Through this method, it is expected to be able to describe the events and conditions of annual floods and infer them in the discharge rate. The location of the Watershed that was reviewed in this study was the Cisanggarung downstream watershed. This study uses Cisanggarung watershed data from Losari Lor rain station in Pabedilan sub-district, Jatiseeng station in Ciledug sub-district which includes data on rainfall depth and river flow discharge. This study uses secondary data that is data that is not taken directly from data collectors, but through documents or other people. The data obtained were processed using Microsoft Excel and Auto CAD programs.

In the hydrological aspect, what needs to be obtained first is the annual maximum daily rainfall data from the rain recording station. Rainfall data analysis can be done with the Normal, Log Normal, Pearson, Log Pearson Type III, and Gumbel distribution methods [3].

Normal distribution or normal curve is also called the Gauss distribution. This distribution has a probability density function as follows:

$$P(X) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right] \quad -\infty \leq x \leq \infty \quad (\text{Eq. 1})$$

where:

P (X) = normal probability density function (normal curve ordinate),

X = continuous random variable,

μ = average value of X,

σ = standard deviation of the value of X.

The formula commonly used for normal distribution is:

$$X_T = \bar{X} + K_T S \quad (\text{Eq. 2})$$

where:

X_T = the estimated value expected to occur with a T-annual return period,

\bar{X} = the average value of the counted sample,

S = standard deviation of the sample value,

K_T = frequency factor, is a function of the opportunity or return period and the type of mathematical model of the opportunity distribution used for opportunity analysis [11].

The properties of normal distribution are the skewness coefficient equal to zero and the value of the coefficient of kurtosis is close to three. In addition there are the following cumulative frequency distribution properties:

P X - S = 15.87 %

P X = 50 %

$P X + S = 84.14 \%$

Lognormal distribution is used if the values of the random variable do not follow the normal distribution, but the logarithmic value meets the normal distribution. The properties of the lognormal distribution are as follows:

Skewness Coefficient : $C_s = C_v^3 + 3C_v$

Kurtosis Coefficient : $C_k = C_v^8 + 6C_v^6 + 15C_v^4 + 16C_v^2 + 3$

The Gumbel distribution has the following formula:

$$X_T = \bar{X} + SK \tag{Eq. 3}$$

where:

X_T = rain plan (mm)

\bar{X} = average value of rain

S = Standard deviation of rain data

K = Gumbel frequency factor $\left(\frac{Y_t - Y_n}{S_n} \right)$

Gumbel distribution has the following characteristics:

Skewness Coefficient : $C_s = 1.1396$

Kurtosis Coefficient : $C_k = 5.4002$

One of the distributions of a series of distributions developed and that concerns water resources experts is the Log Pearson Type III. Three important parameters in distribution analysis are average prices, standard deviations and slope coefficients. If the slope coefficient is zero, the distribution returns to the Normal Log distribution.

Probability test distribution (distribution) is done by the chi-square method to find out whether the selected distribution equation can represent the probability distribution of the analysis data sample [7]. To obtain the magnitude of flood discharges caused by river overflows, it is done by processing annual flood data using the Nakayasu method. Flood discharge is analyzed based on annual maximum 2 daily rainfall data.

RESULTS AND DISCUSSION

This study uses rainfall data from 2005-2017 from two representative rain stations namely the Losari Lor and Jatiseeng rain stations. This data is used as preliminary data for determining flood discharge (Table 1). Cisanggarung watershed annual rainfall data is cumulative rainfall data in a year.

Table 1. Cisanggarung watershed annual rainfall data

Year	Annual Rainfall (l) (mm/year)	
	Losari Lor	Jatiseeng
2005	2159	2667
2006	1625	2477
2007	1437	2010
2008	430	647
2009	1042	347
2010	825	868
2011	671	1061
2012	1235	1867
2013	500	530
2014	927	1198
2015	845	2407
2016	2014	1911
2017	1600	3720

Source : Cirebon District Water Resources Management Agency

Determination of Annual Maximum Daily Regional Rainfall

Determination of the maximum annual daily rainfall amount is done by taking data of annual maximum daily rainfall from each station on the same event day in the same year. Using maximum daily rainfall data from both stations (Appendix 1). Using the Thiessen Polygon method and selecting the largest value from the two observer data, the maximum annual daily rainfall rate is obtained as in Table 2. The data in Table 2 afterwards performed a statistical parameter test.

Table 2. Annual maximum daily regional rainfall

Year	Maximum Rain Area (mm)
2005	67.540
2006	93.951
2007	64.263
2008	54.049
2009	82.340
2010	50.666
2011	39.185
2012	78.283
2013	127.964
2014	37.191
2015	60.553
2016	76.518
2017	62.390

Statistical Parameters

After calculating the annual maximum daily rainfall, the suitability of the distribution test is carried out through statistical parameters such as the average value (\bar{X}), standard deviation (S), coefficient of variation (Cv), skewness coefficient (Cs), and coefficient kurtosis (Ck). The determination of this statistical parameter is done to find the corresponding maximum daily rainfall probability distribution. From the calculation results, the data follows the distribution of the Log Pearson Type III because all conditions are not met (see Table 3).

Table 3. Results of the selection of distribution types

Distribution Type	Requirement	Value of coeff.	Conclusion
Normal	Cs = 0	Cs = 1.10	No
	Ck = 3	Ck = 5.46	No
Log Normal	$Cv^3 + 3Cv$ Cs(lnx)=0	Cs = 0.11	No
	$Ck = Cv^8 + 6Cv^6 + 15Cv^4 + 16Cv^2 + 3$ Ck(lnx)=3	Ck = 3.86	No
Pearson III	Cs > 0	Cs = 1.10	Yes
	$Ck = 1.5 Cs^2 + 3$	Ck = 5.46	No
Log Pearson III	If all requirements are not fulfilled	Cs = 0.11	Yes
		Ck = 3.86	Yes
Gumbell	Cs = 1.14	Cs = 1.10	No
	Ck = 5.4	Ck = 5.46	No

Testing of Distribution Type

The goodness of fittest test in Table 4 states that the type of Pearson Log Type III distribution from the annual maximum annual regional rainfall data is a good match. This can

be seen in the value of $\chi^2_{\text{count}} (9.40) > \chi^2_{\text{critical}} (5.991)$ which states that with a significance level of 5% chi-square test is accepted. That is, the maximum annual regional rainfall data available in Table 4 can represent other frequency data (distributing).

Table 4. Calculation of chi-square test of the log pearson III in cisanggarung watershed

No	Probability (P)	Expected Frequency (Ef)	Observed Frequency (Of)	Ef - Of	(Ef - Of) ²
1	0.00 < ≤ 20.00 P ≤	2.6	1	1.6	2.56
2	20.00 < ≤ 40.00 P ≤	2.6	2	0.6	0.36
3	40.00 < ≤ 60.00 P	2.6	4	-1.4	1.96
4	60.00 < 80.00 P	2.6	1	1.6	2.56
5	80.00 < 100.00 P	2.6	4	-1.4	1.96
Number			12		9.40

Calculation of Rainfall Periods

By using distribution equation of the log-Pearson Type III (Equation 4), the magnitude of the rain return period can be determined. Distribution coefficient of Log Pearson Type III (G) is determined from the calculation of the slope coefficient. The slope coefficient value is 0.110 so that the corresponding G value will be obtained.

$$\text{Log } X_n = L_n X_i + (GS) \tag{4}$$

Table 5. Results of effective rain calculation over time periods

Rain Time Period (T)	1	2	3	4
2	10.399	8.024	3.787	3.466
5	13.892	10.719	5.059	4.631
10	16.218	12.514	5.907	5.406
20	18.133	13.992	6.604	6.044
50	21.389	16.504	7.790	7.130
100	23.626	18.230	8.605	7.875
1000	31.317	24.165	11.406	10.439

The effective rain calculation is calculated by multiplying the return period rain rate by the value of the flow coefficient (0.396) [12]. The effective rain of the re-period period is generated by multiplying the value of the effective rain rate by the percentage distribution per hour within 4 hours [8]. The results have been tabulated (Table 5).

Calculation of the Nakayasu Unit Hydrograph

Due to the absence of hydrological data, to reduce the hydrographic unit, it is necessary to make a synthetic unit hydrograph based on the physical characteristics of the watershed. The width of the River Basin is 205.53 km² and the length of the River (L) is 27.30 km. The resulting hydrograph unit must be divided by the correction factor to make the hydrograph unit per one millimeter. The hydrographic unit correction factor is the ratio

between the volume and the watershed area. The Nakayasu unit hydrograph unit obtained is multiplied by the rain distribution factor.

Q_p is the peak flood discharge that occurs during peak time (T_p) at $3.47 \approx$ hours. Then the time from the peak flood drops to 0.3 times the peak flood discharge (see Figure 1).

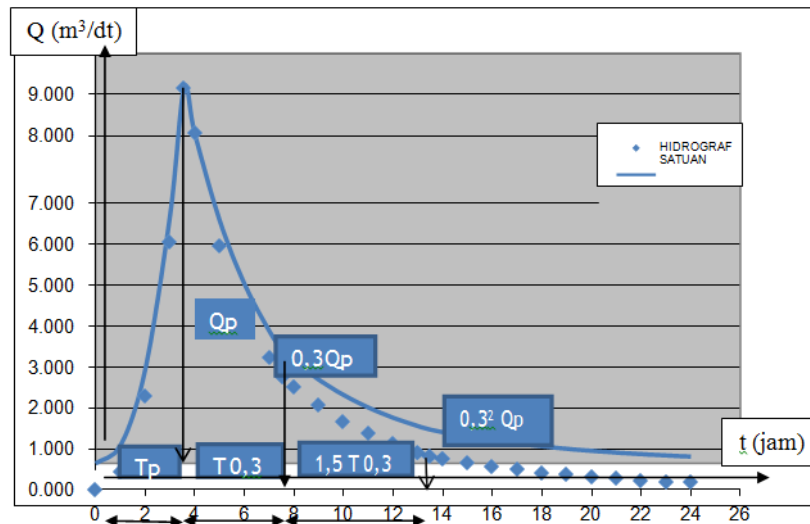


Figure 1. Nakayasu unit hydrograph

Calculation of Flood Discharge Period

Return period flood discharge is sought to anticipate the risk of flooding in the range of 2, 5, 10, 20, 50 and 100 years from the maximum daily rainfall data in the Cisanggarung watershed.

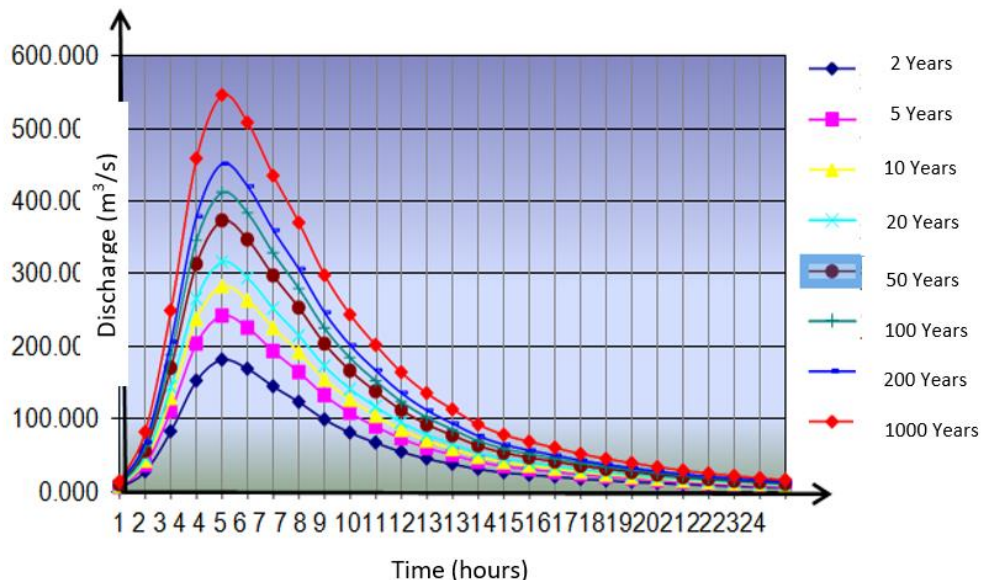


Figure 2. Return period flood discharge hydrograph

Figure 2 shows the relationship between the return period flood discharge and peak time. Of all the return periods, the largest flood discharge occurs at the 4th hour called the peak time. The amount of flood discharge each return period can be seen through the graph.

Maximum 2 Daily Floods Debit Discharge

Calculation of flood discharge is used to determine whether annual flooding from 2

daily rains has the potential to cause flooding in the annual return period. Calculation of flood period return based on annual 2 daily maximum regional rainfall using the Tadashi Tanimoto rain distribution. The Tadashi Tanimoto method is an analytical method that utilizes clock weather data in Java using 8 (eight) hours rain time.

The process of calculating regional rainfall from the 2 annual maximum daily rainfall is the same as the calculation of the annual maximum daily rainfall. The maximum rain area is chosen from both rain stations. Hydrograph analysis is the same, only using 48 hours of rain with 8 hours of rain. The resulting hydrograph unit must be divided by the correction factor to make the hydrograph unit per one millimeter. Hydrographic unit correction factor is the ratio between the volume and area of the watershed. The Nakayasu unit hydrograph unit obtained is multiplied by the rain distribution factor. After an annual flood discharge is obtained based on 2 annual maximum daily rains, the results are compared with Q2, Q5 and Q10 flood discharges (see Figure 3).

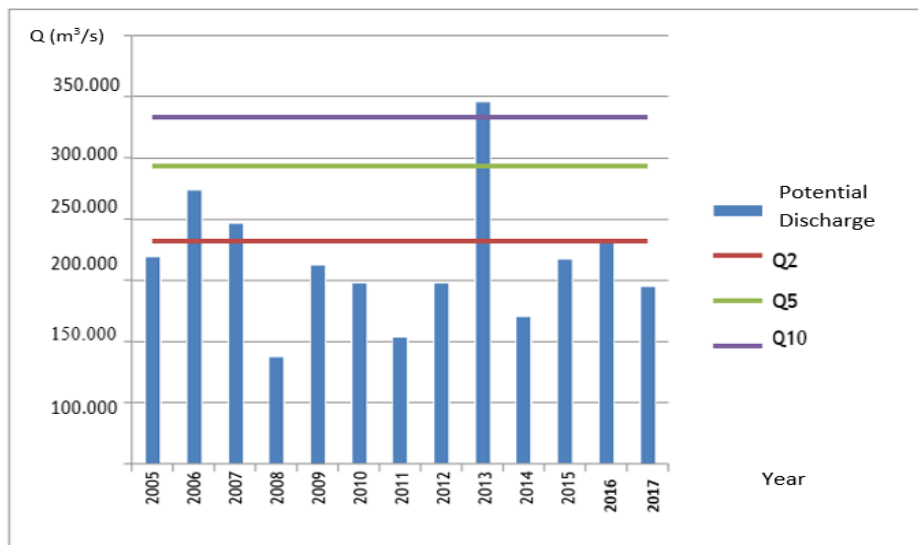


Figure 3. Comparison of annual 2-day flood discharge and return period flood

Figure 3 shows a comparison graph between the annual 2-day flood discharge and the return period flood. Annual data was taken from 2005-2017 (for 13 years). The results show that in 2005, 2007, 2009-2010, 2012 and 2014-2016 experienced the potential for Q2 flooding. In 2006, the area had the potential to flood Q5, while in 2013 it had the potential to flood Q10. The graph in Figure 3 can be concluded as in Table 6.

Table 6. The 2-Day recapitulation of flood discharge

Year	Discharge (m³/s)	Conclusion
2005	168.756	Approaching the 2 yearly flood
2006	223.204	Approaching the 5th annual flood
2007	195.823	Approaching the 2 yearly flood
2008	86.789	Does not cause flooding
2009	162.344	Approaching the 2 yearly flood
2010	147.130	Approaching the 2 yearly flood
2011	103.182	Does not cause flooding
2012	147.619	Approaching the 2 yearly flood
2013	295.085	Approaching the 10th annual flood
2014	119.576	Does not cause flooding

Year	Discharge (m ³ /s)	Conclusion
2015	166.504	Approaching the 2 yearly flood
2016	183.221	Approaching the 2 yearly flood
2017	144.648	Approaching the 2 yearly flood

Monthly 2-Day Flood Discharge

Rain distribution for monthly 2-day plan discharge was analyzed using the Tadashi Tanimoto distribution. Average rain is calculated using the sum of 2 consecutive days each month (for 13 years) and the region's average rainfall is taken. The maximum 2 days monthly rainfall is shown in Table 7.

Analysis of monthly 2-day regional rainfall uses the Tadashi Tanimoto rain distribution by utilizing hourly rain data in Java using 8 (eight) hours rain time. As for knowing the effective rain hourly times, the multiplication between effective rain and the Tadashi Tanimoto distribution percentage is used.

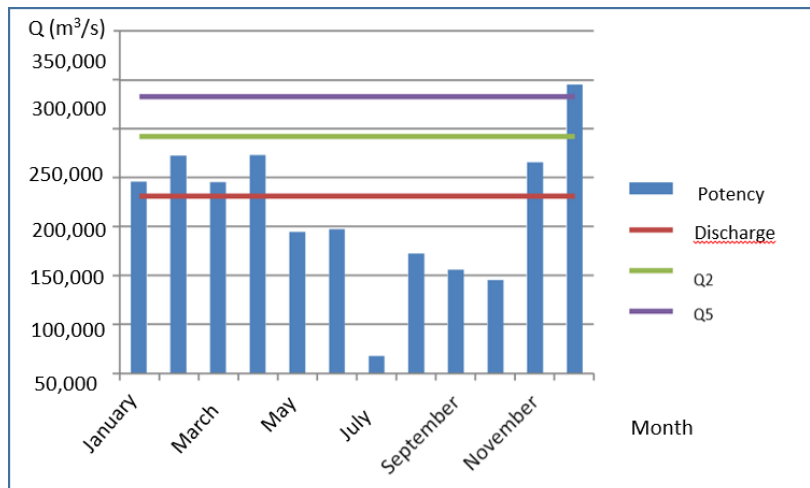


Figure 4. Comparison graph of annual maximum monthly flood and return period floods

Table 7. Monthly 2-day flood discharge recapitulation

Month	Discharge (m ³ /s)
January	195.823
February	222.489
March	195.260
April	223.204
May	144.648
June	147.619
July	18.030
August	122.469
September	105.925
October	95.468
November	215.608
December	295.085

Next, calculate the hydrograph unit by dividing it by the correction factor to make the hydrograph unit per one millimeter. Hydrographic unit correction factor is the ratio between the volume and area of the watershed. The Nakayasu unit hydrograph unit obtained is multiplied by the 8-day rain distribution factor which has been multiplied by the runoff

coefficient.

After obtaining the annual maximum flood discharge, the data was compared to the flood discharge Q2, Q5 and Q10. The chart above shows that in January-April and November there is a potential for Q2 flooding. Whereas December could potentially flood Q10 (see Figure 4).

CONCLUSIONS

From the results of the analysis and calculation, the rain distribution in the Cisanggarung River Basin follows the Log Pearson Type III rain distribution pattern. The results of the calculation of flood return period using the Nakayasu method are Q2 = 181.518 m³/s, Q5 = 242.498 m³/s, Q10 = 283.109 m³/s, Q20 = 316.534 m³/s, Q50 = 373.369 m³/s, Q100 = 412.425 m³/s, Q200 = 452.013 m³/s, Q1000 = 546.683 m³/s. Annual flood data based on 2 annual maximum rainfall states that 2005, 2007, 2009-2010, 2015, 2009-2017 has the potential to flood Q2, 2012 has the potential to flood Q5, and 2017 has the potential to flood Q10. Meanwhile, monthly flood data based on 2 daily maximum rainfall states that 2005-2007, January-April and November have the potential to flood Q2, and December has the potential to flood Q10. The magnitude of the plan discharge and the potential flood that have been obtained can predict future floods, so that it can urge the public to anticipate the existence of floods in the following years.

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