Flood Analysis of the Kedung Ingas River and Pabean River the Cilegon City

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ABSTRACT

The Kedung Ingas River and Pabean River the Cilegon City often flood every year. It has an impact on losses and disruptions to public facilities and settlements such as highways, Cilegon Regional Hospital, Metro housing and residential areas located close to the river. The purpose of this study is to determine the amount of design discharge at 10, 25 and 50 years return period. The methods used to calculate the design flood discharge are Rational, Der Weduwen, and HSS Nakayasu. Based on the results of the study, the design flood discharge of the Kedung Ingas River and the Pabean River with Q_{10} = 121.25 m^3/s, Q25 = 131.01 m^3/s, and Q50 = 138.79 m^3/s. The design flood discharge value used is the calculation value using the selected method, namely Nakayasu Synthetic Unit Hydrograph.

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1. INTRODUCTION

Flooding is a form of natural phenomenon that occurs due to the high intensity of rainfall so that the water discharge is not accommodated by the channel and overflows out, inundating the surrounding area [1], [2]. The negative impact of floods often causes various losses in the form of materials such as damage to residents' houses and the contents of the house [3].

Cilegon City, which is an industrial city, often experiences various natural disaster problems, one of which is flooding [4], [5], almost every year from the last 10 years Cilegon City has always experienced flood problems, this is known based on news from various media and resident interviews, for example in 2023 the Cilegon City Regional Disaster Management Agency (BPBD) noted that there were as many as 10 points in the city of Cilegon that were flooded, one of which was Jombang District and in 2024 there was another flood in 3 sub-districts, one of which was Purwakata District [6], [7]. The worst flood that ever occurred in CilegonCilegon was in 2020, the impact of this flood also brought losses and damage to regional facilities such as Cilegon Hospital, a number of services that require electricity had to be stopped due to water overflowing from the Kedung Ingas River and inundating Cilegon Hospital [5], [8].

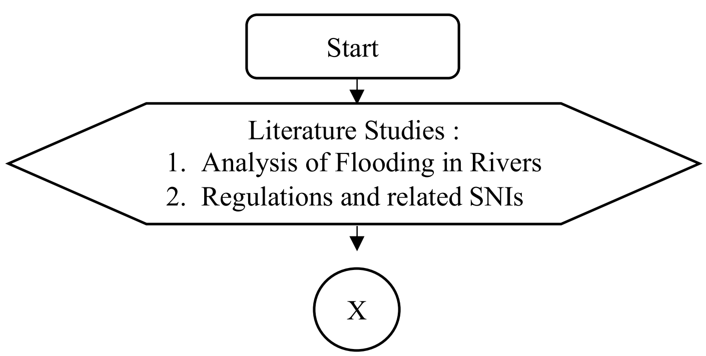
Based on the river map in Cilegon City, the location of the Customs River is on the north side of Cilegon, Purwakarta district while the Kedung Ingas River is in the center to the south of Cilegon, Jombang district, so it can be known that the flood problem in Cilegon City is due to the route of the two rivers passing through the administrative area of Cilegon City [5], In addition, clogging of waterways due to piles of garbage and narrowing of waterways[9], So that often water overflows and inundates the highway and the surrounding residents' housing [10].

Based on the factors that cause flooding in Cilegon City, there is a need for a flood analysis related to the ability of the river's cross-sectional capacity. In flood analysis, the value that needs to be known is the Design Flood Discharge (Q_S) [11]. Design flood discharge is a discharge that is calculated at a certain re-period to be a parameter of water building planning [12]. The flood discharge is design to use flood discharge for a 25 year return period because the channel under review is a river [13][14]. After getting the design flood discharge figures, the next comparison is with the Channel Discharge (Q_T) with the condition $Qs < Q_T$ [15].

The purpose of this study is to determine the magnitude of design flood discharge with a repeat period of 10, 25 and 50 years so that it can be compared with channel discharge to determine the capacity of the Kedung Ingas River and the Peban River. Research on flood analysis in rivers that has been carried out by previous researchers includes:, Nadia et al., (2019), Saudnya et al., (2017), Wahyuningtyas et al., (2017), Haryono et al., (2019), Azizah et al., (2013), Latif et al., (2022), Azizah et al., (2013). Based on previous research, no research has been conducted on the Flood Analysis of the Kedung Ingas River and the Pebean River in Cilegon City with the GIS Method.

2. METHODS

The following flow chart is a series of stages carried out in the research. In this study, the rainfall data selected is the maximum daily rainfall data for each data series year. This maximum daily rainfall data is then used as regional rainfall through the algebraic method. Regional rain is then processed in frequency analysis by making statistical parameters based on distribution needs. Frequency analysis provides selected distribution results based on distribution testing. The selected distribution produces rainfall values which are then processed based on the calculation of mononobe hours of rainfall. After that, the rainfall value is used to calculate the estimated flow discharge. This flow discharge then becomes the basis for checking the hydraulic capacity of the existing channel.



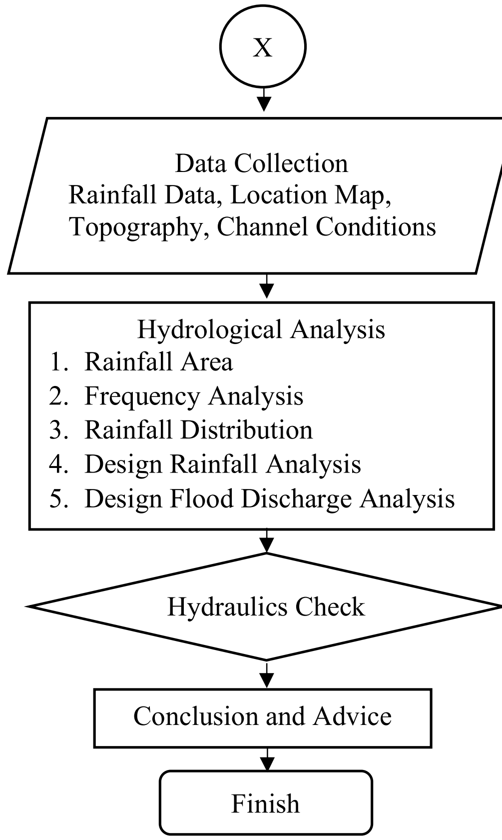


Figure 1. Research Flow Diagram

2.1 Data

The data in this study is in the form of secondary data consisting of rainfall data, topography, surface flow coefficient, and watershed characteristics.

2.2 Variables

This study has two variables, namely the independent variable and the dependent variable. Independent variables are variables that affect research, while dependent variables are variables that are influenced by independent variables. Rainfall, topography, surface flow coefficient, watershed characteristics and channel dimensions are independent variable. As for the dependent variables studied, namely flood discharge and channel capacity.

2.3 Hydrological Analysis

In this study, the hydrological analysis aims to obtain design flood discharge at 10, 25 and 50 year return period. The rainfall data owned is 10 years from 2014-2023, this data is then processed through hydrological analysis and produces rainfall values with selected distributions. The value of rainfall is then entered into the mononobe equation to obtain the value of the intensity of rainfall during the hours, the formula is as follows :

$$I = \frac{R_{24}}{24}\left[\frac{24}{tc}\right]^{2/3} \quad (1)$$

The value of t_c can be calculated using the Kirpich approach in minutes, i.e.;

$$tc = 0{,}0078L^{0{,}77}S^{-0{,}385} \quad (2)$$

The calculation of the design flood discharge is then calculated through several methods, including the rational method, the der weduwen method and the nakayasu synthetic unit hidograf method. These three methods were chosen in order to determine the selected debit from the average value of the three debits.

2.3.1 Rational Method

The rational method is to determine the design flood discharge produced only by the peak discharge (Qp), so it includes non-hydrographic design floods. The requirements of the rational method are that the watershed area is between 40-80 ha, according to the PU standard the watershed area < 5000ha, here is the calculations :

$$Q_T = 0{,}27778\ C\ I\ A \quad (3)$$

2.3.2 Der Weduwen Method

The Der Weduwen method is used for a watershed area of < 100 km^2, here are the calculations:

$$Q_T = \alpha\ \beta\ I\ A\ \frac{R_i}{240} \quad (4)$$

2.3.3 Nakayasu Synthetic Unit Hydrograph Method

This method aims to determine the design flood hydograph in a watershed, the following is the formula:

$$Q_P = \frac{A\ R_o}{3{,}6\ (0{,}3t\quad + T_{0{,}3})} \quad (5)$$

3. RESULTS AND DISCUSSION

3.1 Regional Rainfall Determination

The following is the determination of regional rainfall (watershed) using the algebraic method, by calculating the average of the rainfall values of the two stations. This method was chosen because this study only used 2 rain stations, namely Cinangka Station and Cilegon Station.

Table 1. Rainfall Determination in the Kedung Ingas and Pabean Watersheds

Year	Name of Rain Station		Regional Rainfall (mm)
	Cilegon	Cinangka	
2014	58,70	184	121,35
2015	69,50	138	103,75
2016	80,10	146	113,05
2017	155,10	105	130,05
2018	103,20	180	141,60
2019	101,60	188	144,80
2020	52,07	163	107,54
2021	77,80	166	121,90
2022	92,96	281	186,98
2023	74,00	66	70,00
Sum			1.241,02
Average value (mm)			124,1

3.1 Testing of Goodnes of Fit

To ensure that the empirical approach in the form of data polation can be represented by a theoretical curve, it is necessary to test the suitability of the distribution. In this study, there are 2 tests carried out, namely the Chi Squared Test and the Smirnov Kolmogorof Test, using a Dk value = 2 and a degree of confidence of

3.1.1 Chi Kuadrat Test

In the chi squared test, the value of Dk = 2 and the degree of confidence is 0.05 so that the value of X^2_{cr} = 5,99. Based on the table of critical squared chi values so that this value is compared to the chi squared test value (X^2). In conditions $X^2 < X^2_{cr}$.

Table 2. Recapitulation of Chi Squared Test for Each Distribution

Distribution Type	X^2	X^2_{cr}	Information
Gumbel	2	5,99	ACCEPTED
Normal	2	5,99	ACCEPTED
Log Normal	2	5,99	ACCEPTED
Log Pearson III	3	5,99	ACCEPTED

Based on Table 2 all probability distributions have a value of $X^2 < X^2_{cr}$ then it can be concluded that all of these distributions are acceptable in determining rainfall.

3.1.2 Smirnov Kolmogorof Test

In the Smirnov Kolmogorof test, the number of data (n) = 10 and the degree of confidence (α = 0.05) so that a critical ΔP value = 0.41 was obtained. The critical ΔP value is further compared to the maximum ΔP value of each distribution. The eligibility requirements are a maximum ΔP < Δ critical P.

Table 3. Recapitulation of Smirnov Kolmogorof Test on Each Distribution

Distribution Type	ΔP_{max}	$\Delta P_{Cririal}$	Information
Gumbel	0,1388	0,41	ACCEPTED
Normal	0,0728	0,41	ACCEPTED
Log Normal	0,0958	0,41	ACCEPTED
Log Pearson III	0,0900	0,41	ACCEPTED

Based on Table 3 all probability distributions have acceptable because the value of ΔP max < ΔP is critical. Based on the two tests above t, the selected distribution is Normal Distribution because it produces the smallest deviation value from the other distributions, which is 0.0728 and passes the Chi Squares test.

3.2 Rainfall Analysis Design

The distribution used is the Normal Distribution based on the results of the Chi-Quadratic and Smirnov-Kolmogorof tests, so the following are the steps to calculate the rain of this Normal Distribution plan:

Average value ($\overline{X}$) = 124,1
Standard deviation (Sd) = 30,69
Deviation (Sn) = 0,9487
Reduced Mean (Yn) = 0,4952

Design rain is calculated using the normal distribution formula $X_T = \overline{X} + KT \times Sd$. The following are the results of the calculation of the rain design for the 10, 25 and 50 year re-period.

Table 4. Results of Design Rainfall Calculation

Return Period (Year)	K_T	X_T (mm)
10	1,28	163,38
25	1,708	176,52
50	2,05	187,01

3.3 Design Flood Discharge

The design flood discharge is calculated using 3 methods, namely rational, der weduwn and HSS Nakayasu, along with the calculation of each method for a re-period of 10, 25 and 50 years.

3.3.1 Rational Method

The calculation of design flood discharge using the rational method requires the results of the calculation of rainfall intensity (I), run off coefficient (C) and watershed area (A). The following is a summary of the calculation of the design flood discharge for each re-period.

Table 5. Results of Calculation of Rational Method Design Flood Discharge

Return Period (Year)	I (mm/h)	C	A (km^2)	Q_T (m^3/s)
10	27,7136	0,44	32,07	108,54
25	29,9431	0,44	32,07	117,28
50	31,7215	0,44	32,07	124,24

3.3.2 Der Weduwen Method

The calculation of design flood discharge using the der weduwen method requires the results of the calculation of β price, rainfall intensity (I), irrigation coefficient (α), watershed area (A) and re-period rainfall (Ri). The following is a summary of the calculation of the design flood discharge for each re-period.

Table 6. Results of Calculation of Der Weduwen Method Design Flood Discharge

Return Period (Year)	I (mm/h)	α	β	A (km^2)	R_i (mm/h)	Q_T (m^3/s)
10	10,49	0,44	0,8795	32,07	163,38	179,03
25	10,49	0,44	0,8795	32,07	206,05	225,8
50	10,49	0,44	0,8795	32,07	231,66	253,85

3.3.3 Nakayasu Synthetic Unit Hidograf Method

The calculation of design flood discharge using the Nakayasu HSS Method requires the results of calculations from the delay time (T_g), rain duration (T_r), the time of discharge equal to 0.3 times the peak discharge ($T_{0.3}$), the peak time (T_p) and the peak discharge (Q_p).

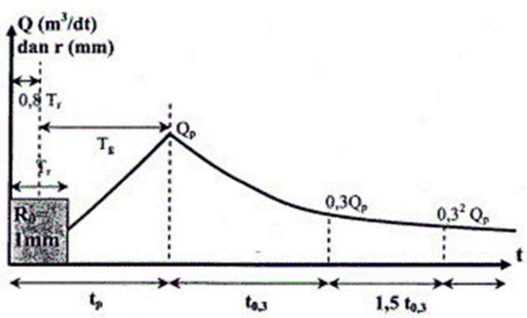


Figure 2. Nakayasu HSS Chart

The graph above shows the calculation of the discharge from the upward curve to the downward curve. After calculating the upward curve ($0 < t < t_p$), according to the graph above, it is necessary to determine the value of the downward curve, namely ($t_p < t < t_{0.3}$), ($t_{0.3} < t < 1.5\ t_{0.3}$) and ($t > 1.5\ t_{0.3}$) so that the values of Q_p, $0.3Q_p$ and 0.3^2Q_p are obtained. The following is the calculation of the Nakayasu HSS Method to find the design flood discharge of the 10, 25 and 50 years return period. The results of the calculation will be described through the tables and charts below:

Table 7. Results of Flood Discharge Calculation for the Return Period of 10 Year

No	t (h)	Unit Hydrograph m³/s/mm	Hydrograph (m³/s) Consequences of Rain					Total (m³/det)
			11,7113	17,4205	95,5443	24,8340	13,8684	
1	0,00	0,00	0,00					0,00
2	1,00	0,07	0,85	0,00				0,85
3	2,00	0,38	4,46	1,26	0,00			5,72
4	2,83	0,87	10,25	6,64	6,90	0,00		23,79
5	3,00	0,83	9,68	15,24	36,43	1,79	0,00	63,14
6	4,00	0,59	6,94	14,39	83,60	9,47	1,00	115,40
7	5,00	0,43	4,98	10,32	78,93	21,73	5,29	121,25
8	6,00	0,30	3,57	7,41	56,62	20,52	12,13	100,25
9	7,00	0,23	2,72	5,31	40,62	14,72	11,46	74,83
10	8,00	0,19	2,18	4,05	29,14	10,56	8,22	54,15
11	9,00	0,15	1,75	3,25	22,21	7,57	5,90	40,68
12	10,00	0,12	1,40	2,60	17,80	5,77	4,23	31,81
13	11,00	0,10	1,12	2,08	14,26	4,63	3,22	25,32
14	12,00	0,08	0,90	1,67	11,43	3,71	2,58	20,29
15	13,00	0,07	0,77	1,34	9,16	2,97	2,07	16,31
16	14,00	0,06	0,65	1,14	7,34	2,38	1,66	13,17
17	15,00		0,00	0,97	6,26	1,91	1,33	10,46
18	16,00			0,00	5,30	1,63	1,07	7,99
19	17,00				0,00	1,38	0,91	2,29
20	18,00					0,00	0,77	0,77
20	19,00						0,00	0,00
MAX			10,25	15,24	83,60	21,73	12,13	**121,25**

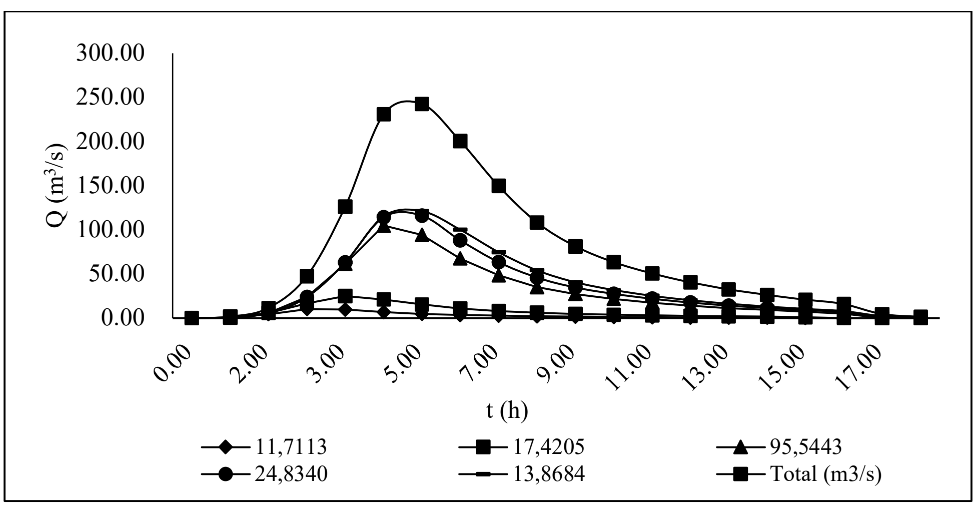


Figure 3. Flood Discharge Chart for Return Period of 10 Year

Table 8. Results of Flood Discharge Calculation for the Return Period of 25 Year

No	t (h)	Unit Hydrograph $m^3/s/mm$	Hydrograph (m^3/s) Consequences of Rain					Total (m^3/s)
			12,6535	18,8219	103,2306	26,8318	14,9841	
1	0,00	0,00	0,00					0,00
2	1,00	0,07	0,91	0,00				0,91
3	2,00	0,38	4,82	1,36	0,00			6,18
4	2,83	0,87	11,07	7,18	7,46	0,00		25,70
5	3,00	0,83	10,45	16,47	39,36	1,94	0,00	68,22
6	4,00	0,59	7,50	15,55	90,32	10,23	1,08	124,68
7	5,00	0,43	5,38	11,15	85,28	23,48	5,71	131,01
8	6,00	0,30	3,86	8,00	61,18	22,17	13,11	108,32
9	7,00	0,23	2,94	5,74	43,89	15,90	12,38	80,85
10	8,00	0,19	2,36	4,38	31,48	11,41	8,88	58,51
11	9,00	0,15	1,89	3,51	24,00	8,18	6,37	43,95
12	10,00	0,12	1,51	2,81	19,23	6,24	4,57	34,36
13	11,00	0,10	1,21	2,25	15,41	5,00	3,48	27,36
14	12,00	0,08	0,97	1,80	12,35	4,01	2,79	21,92
15	13,00	0,07	0,83	1,45	9,90	3,21	2,24	17,62
16	14,00	0,06	0,70	1,23	7,93	2,57	1,79	14,23
17	15,00		0,00	1,04	6,76	2,06	1,44	11,30
18	16,00			0,00	5,72	1,76	1,15	8,63
19	17,00				0,00	1,49	0,98	2,47
20	18,00					0,00	0,83	0,83
20	19,00						0,00	0,00
MAX			11,07	16,47	90,32	23,48	13,11	**131,01**

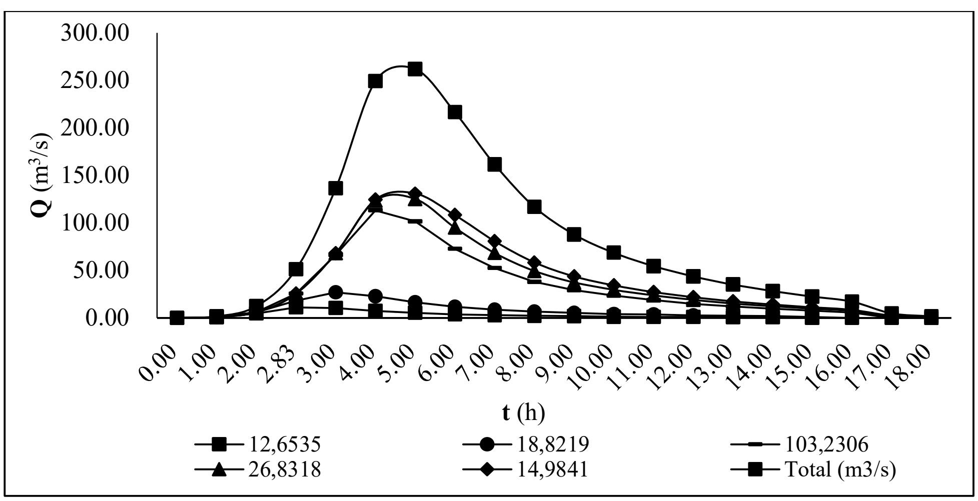


Figure 4. Flood Discharge Chart for Return Period of 25 Year

Table 7. Results of Flood Discharge Calculation for the Return Period of 50 Year

No	t (h)	Unit Hydrograph m³/s/mm	Hydrograph (m³/s) Consequences of Rain					Total (m³/s)
			13,4050	19,9398	109,3617	28,4254	15,8740	
1	0,00	0,00	0,00					0,00
2	1,00	0,07	0,97	0,00				0,97
3	2,00	0,38	5,11	1,44	0,00			6,55
4	2,83	0,87	11,73	7,60	7,90	0,00		27,23
5	3,00	0,83	11,07	17,45	41,69	2,05	0,00	72,27
6	4,00	0,59	7,94	16,47	95,69	10,84	1,15	132,09
7	5,00	0,43	5,70	11,82	90,35	24,87	6,05	138,79
8	6,00	0,30	4,09	8,48	64,81	23,48	13,89	114,75
9	7,00	0,23	3,12	6,08	46,50	16,85	13,11	85,65
10	8,00	0,19	2,50	4,64	33,35	12,09	9,41	61,98
11	9,00	0,15	2,00	3,71	25,42	8,67	6,75	46,56
12	10,00	0,12	1,60	2,98	20,37	6,61	4,84	36,40
13	11,00	0,10	1,29	2,39	16,33	5,30	3,69	28,98
14	12,00	0,08	1,03	1,91	13,08	4,24	2,96	23,23
15	13,00	0,07	0,88	1,53	10,48	3,40	2,37	18,67
16	14,00	0,06	0,74	1,31	8,40	2,73	1,90	15,08
17	15,00		0,00	1,11	7,16	2,18	1,52	11,97
18	16,00			0,00	6,06	1,86	1,22	9,15
19	17,00				0,00	1,58	1,04	2,62
20	18,00					0,00	0,88	0,88
20	19,00						0,00	0,00
MAX			11,73	17,45	95,69	24,87	13,89	**138,79**

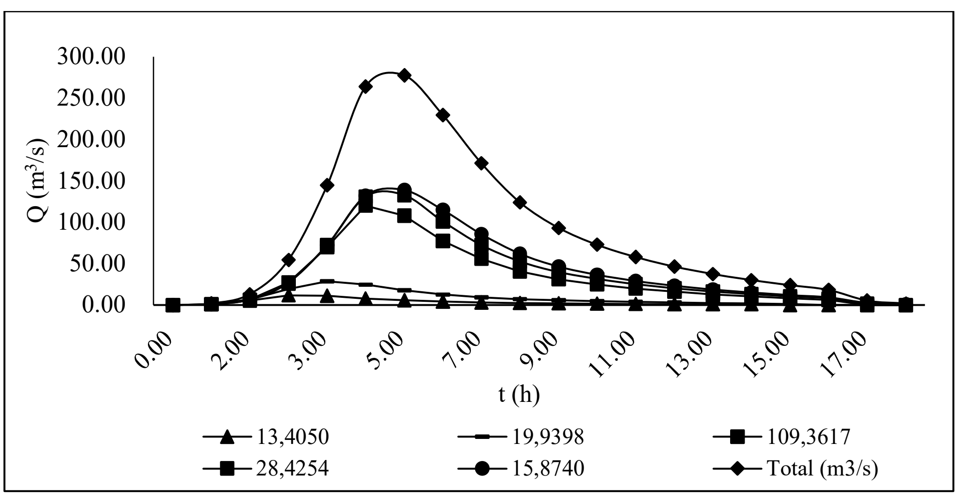


Figure 5. Flood Discharge Chart for Return Period of 50 Year

The table and figure above show the design flood discharge value for the 10, 25, 50 year re-period. It can be seen that the design of the flood discharge values obtained are Q_{10} = 121,25 m^3/s, Q_{25} = 131,01 m^3/s, Q_{50} = 138,79 m^3/s. This value is taken from the total maximum value of the sum of the consequences of the rain hydograph.

4. CONCLUSION

Based on the description of the results and discussion, it is concluded that the design flood discharge of the Kedung Ingas River and the Pabean River were Q_{10} = 121,25 m^3/s, Q_{25} = 131,01 m^3/s, and Q_{50} = 138,79 m^3/s, respectively. The design flood discharge value used is the calculation value using the selected method, namely Nakayasu Synthetic Unit Hydrograph.

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