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Hydrological Analysis of The Cikapundung Watershed, Tamansari Balubur Areaof Bandung, West Java, Indonesia

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ABSTRACT

Cikapundung River is one of the rivers that divide Bandung City which functions as the city's main drainage, the general use of Cikapundung River water is for drinking water (PDAM Dago Pakar and PDAM Badak Singa), hydropower (Pakar and Cilengkung), and irrigation. The number of activities and utilization of the Cikapundung river in quantity is at risk of causing flooding which is influenced by various factors. Therefore, it is necessary to analyze the flood discharge to determine the value of the planned flood discharge in the Cikapundung River. The purpose of this study was to analyze flood discharge using empirical methods on the Cikapundung river in the Tamansari area in the context of flood control efforts. The analysis carried out is a hydrological analysis which includes an analysis of maximum rainfall using the frequency distribution method type Gumbel, Haspers, Weduwen, and Log Pearson, and a design flood discharge analysis using the Rational Method. Based on the results of the analysis of the highest discharge, Rational Gumbel with a return period of 2 years 5,076 m^3/s, a return period of 5 years 8,371 m^3/s, a return period of 10 years 10,553 m^3/s, a return period of 20 years 12,645 m^3/s, 25 year return period 13,097 m^3/s, 50 year return period 15,354 m^3/s, 100 year return period 17,384 m^3/s, 150 year return period 518,395 m^3/sec. Efforts that can be made in flood control efforts are restoration or rearrangement of the environment around the Cikapundung river border.

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1. INTRODUCTION

The Cikapundung watershed is a sub-watershed of the Citarum watershed with an area of approximately 434.43 km^2 covering West Bandung Regency, Bandung Regency, and Bandung City. The upstream area of the Cikapundung River is located in the Cigulung area and the Cikapundung area, Maribaya, (West Bandung Regency). The middle part includes Cikapundung Gandok and Cikapundung Pasir Luyu (Bandung City). The Cikapundung River is part of the 48 rivers that surround the city of Bandung and is the air supplier for the Citarum River from the 13 main tributaries (Akbardin, J., et al., 2018).

The level of urbanization in the city of Bandung is very high which causes problems, one of which is on the banks of the Cikapundung River Basin which passes right in the middle of the city. Along with the development of the city of Bandung, the change in the face of the Cikapundung river is a reflection of the changes in the city of Bandung (Akbardin, J., and Permana, 2020). The river that used to be a source of life for local people has turned cloudy and smelly, the banks are narrow, and a lot of trash can be seen (Akbardin, J., et al., 2020)(Maria, 2008).

Cikapundung River (Permana, A. Y., 2014a) has a very important function and role for the development of Bandung City, the use of Cikapundung River water (Permana, A. Y., 2014b), in general, is for drinking water purposes (PDAM Dago Pakar and PDAM Badak Singa), hydropower (Expert and Cilengkung), flushing and irrigation (Merinda, et al: 2018). Thus, there are more and more activities that arise related to the quantity and quality of the Cikapundung river water due to the use of the river. In terms of quantity, the Cikapundung river is dangerous to cause flooding for the surrounding area because it is caused by various factors, this causes especially in densely populated areas when the Cikapundung river water discharge exceeds its capacity, the river will overflow into residential areas (Akbardin, J., et al., 2020) (Permana, A. Y., et al., 2020).Therefore, there needs to be a more in-depth study to get an overview of the planning for the Cikapundung river flood discharge (Akbardin, J., et al., 2019).

The purpose of this study was to analyze flood discharge using empirical methods on the Cikapundung river in the Tamansari area in the context of flood control efforts. The analysis carried out is a hydrological analysis which includes an analysis of maximum rainfall using the frequency distribution method (Gumbel, Haspers, Weduwen, and Log Pearson) and a design flood discharge analysis using the Rational Method. By referring to various literature, it is expected to provide an overview of the flood discharge on the Cikapundung river (Permana and Wijaya, 2017).

2. LITERATURE REVIEW

2.1 Regional Rainfall Analysis

The rainfall required to calculate flood discharge is the maximum daily rainfall data in the entire area concerned, not rainfall at a certain point (Christian et al., 2017). This rainfall is called regional/regional rainfall and is expressed in mm. Rainfall must be estimated from several rainfall observation points. The method of calculating regional rainfall from observations of rainfall at several points is as follows:

a. Arithmetic Average

This method is an algebraic calculation of rainfall in and around the area concerned (Chowdhury et al., 2019). Rainfall in the area can be calculated according to the following equation:

$$\bar{p} = \frac{p_1 + p_2 + p_3 + \cdots . + p_n}{n}$$

Where:
p = is the regional rainfall
n = is the number of observation points.

b. Thiessen Polygon Methodgon

This method is used in the rain stations are not evenly distributed. This method looks at the effect of the rain station on the watershed (Kurniawan et al., 2016). The area's rainfall can be calculated according to the following equation:

$$\bar{p} = \frac{A_1P_1 + A_2P_2 + \cdots .... + A_nP_n}{A_1 + A_2 + \cdots + A_n}$$

Where:
A = is the area representing the point of observation.

c. Isohyettic Line Method

This method uses an isohyet map depicted on a topographic map with a difference (interval) of 10 to 20 mm based on rainfall data at observation points in and around the area in question. The area's rainfallcan be calculated according to the following equation:

$$\bar{p} = \frac{A_{1.}\frac{I_1 + I_2}{2} + A_{1.}\frac{I_2 + I_3}{2} + \cdots . + A_{n.}\frac{I_n + I_{n+1}}{2}}{A_1 + A_2 + \cdots + A_n}$$

2.2 Frequency Distribution Analysis

In analyzing the frequency distribution of rainfall data, four methods are used, namely the normal distribution method, the normal log distribution method, the Gumbel distribution method, and the Pearsontype III log distribution method (Setiawan et al., 2021).

Normal Distribution

The equation of the Normal distribution method (Sri Harto Br, 1993) is:

$$X_{Tr} = \overline{X} + K_{Tr} \cdot S_X$$

Normal Log Distribution

The equation for the Log-Normal distribution method (Sri Harto Br, 1993) is:

$$\log X_{Tr} = \overline{\log X} + K_{Tr} \cdot S_{\log X}$$

Gumbel Distribution

The equation of the Gumbel method (Sri Harto Br, 1993) is:

$$X_{Tr} = \overline{X} + K \cdot S_X$$

Pearson Type III Log Distribution

The equation for the Log Pearson Type III method (Sri Harto Br, 1993) is:

$$\text{Log } X_{Tr} = \overline{Log\, X} + K_{Tr} . (S_{\log x})$$

2.3 Frequency Distribution Conformity Test

This suitability test is intended to determine the truth of a frequency distribution hypothesis. With this examination will be obtained:

a. The truth between the results of observations with the expected distribution method or theoreticallyobtained.

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b. The truth of the hypothesis is accepted or rejected for use in subsequent calculations. There are 2 ways to conduct a distribution suitability test, namely Chi-Square and Smirnov Kolmogorov test.

2.4 Planned Flood Discharge Analysis Rational Method

The most frequently used method for estimating discharge in a watershed where there is no discharge observation data is the Japanese Rational Method (Ghofur and Mahmud, 2016). In this case, the magnitude of the discharge is a function of the area of the watershed, the intensity of the rain, the condition of the ground surface which is expressed in the runoff coefficient, and the slope of the river (Joesron Loebis, 1992). Flood discharge is formulated generically as follows:

$$Q = C.\ I.\ A$$

or practical purposes in determining the unit, then:

$$Qp = 0.278\ .\ C\ .\ I.\ A$$

Where:
Qp = peak discharge (m3 /s)
C = runoff coefficient
I = Rain intensity with duration equal to flood concentration-time (mm/hour)
A = area of the watershed (km^2)

2.5 Rain intensity

One of the data used in the calculation of flood discharge is rain forecast data. Rain intensity can be described by a curve which is usually called the intensity duration frequency (IDF). The IDF curve depicts therelationship between rain intensity, duration, and return period (Lestari, 2016). Rain intensity is the height of rainfall in a certain period expressed in mm/hour. To determine the amount of rain intensity, the Mononobe formula (Joesron Loebis, 1992) is used, namely:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3}$$

Where :
I = Rain intensity (mm/hour)
R = Maximum daily rainfall (mm)
T = Rainfall time (hours)

3. RESEARCH METHODS

The steps taken in this analysis are literature/literature studies, field surveys, secondary data collection, and data analysis. The stages of data analysis carried out were the maximum daily rainfall data for 10 years from the Bandung Geophysics station and then analyzed the average rainfall using the Thiessen method. The data is analyzed for the frequency distribution of rainfall using Gumbel distribution, Hasper distribution, Weduwen distribution, and log person type III distribution. Then tested the suitability of the frequency distribution with the Chi-Square Test and Smirnov Kolmogorov Test. Then proceed with analyzing the planned discharge from the rainfall data using the Rational Method. The planned flood discharge can later be used as a benchmark for planning water structures to overcome flood disasters.

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4. RESULT AND DISCUSSION

Table 1. Watershed characteristics

River	Cikapundung
Large (A= km^2)	90.4
River length	28
Upstream elevation	
Downstream elevation	
Height Difference	4
River slope	0,0001
Morphology	
C	0,6

The characteristics of the Cikapundung river according to the analysis results include river type G. Small river type G is a multilevel channel, ditch, narrow and deep with a high to moderate sinuosity. The slope of the channel is generally > 0.002 although the channel can have a gentler slope as the channel is cut down. Type G river has a very high rate of bank erosion, high sediment supply, moderate to steep channel slope, low channel width ratio, high sediment supply, high bottom load, and very high dissolved sediment rate.

4.1 Rainfall data

The rainfall data used in this analysis is sourced from the BMKG Geophysics Climatology Station in Bandung with a recording period of 2010 to 2019. The observation station used is the Mararena Meteorological Station.

Table 1. Rainfall Data

BMKG

ID WMO 97580
Station Name: Bandung Geophysics station
Latitude : -6.88356
Longitude : 107.59733
Elevation 791

No	Year	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des	Jumlah	Rata2	Maks
1	2010	86	82	94	27	92	27	61	22	55,5	123	88	78	836	70	123
2	2011	18	27	21	74	56	44	37	2	39	20	44	63	442	37	74
3	2012	12	47	37	65	66	50	22	0	11	18	83	79	491	41	83
4	2013	32	56	60	46	29	68	60	31	62	12	22	65	544	45	68
5	2014	55	16	58	28	62	37	37	42	1	50	44	41	471	39	62
6	2015	51	46	53	47	78	26	0	6	43	33	62	47	491	41	78
7	2016	17	8	15	19	12	7	8	8	11	14	15	3	136	11	19
8	2017	3	8	14	8	12	6	3	8	8	14	18	6	109	9	18
9	2018	7	10	12	13	8	2	0	6	5	7	21	15	106	9	21
10	2019	83	40	51	50	59	11	9	0	32	26	61	57	479	40	83
Jumlah		363	340	414	376	475	280	238	123	267	316	458	453			
Rata-rata		36	34	41	38	48	28	24	12	27	32	46	45			

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4.2 Analysis of Frequency Distribution of Rainfall Data

The method used to analyze the frequency distribution of rainfall data is the Gumbel distribution, the Hasper distribution, the Weduwen distribution, and the Log Pearson Type III distribution.

Table 2. Gumbel distribution

NO	Years	Rainfall (Xi)	(Xi - X)	$(Xi - X)^2$
1	2010	123	60,021	3602,481
2	2011	74	10,621	112,799
3	2012	83	20,121	404,842
4	2013	68	5,521	30,478
5	2014	62	-0,879	0,773
6	2015	78	14,821	219,652
7	2016	19	-43,583	1899,458
8	2017	18	-45,191	2042,256
9	2018	21	-41,871	1753,150
10	2019	83	20,421	417,004
Σ		628,793	0,000	10482,893
X		62,879		
Sx		32,377		
Rmax		122,900		

Source: Calculation Results

Table 3. Rainfall Plan

Repeat period	Yt	Reduction factor		RT
		Yn	Sn	
2	0,367	0,500	0,968	58,426
5	1,500			96,352
10	2,250			121,463
20	2,970			145,549
25	3,125			150,745
50	3,902			176,726
100	4,600			200,090
150	4,948			211,729

Source: Calculation Results

Table 4. Hasper distribution

No	Year	Rainfall (Xi)
1	2010	123
2	2011	74
3	2012	83
4	2013	68
5	2014	62
6	2015	78
7	2016	19
8	2017	18
9	2018	21
10	2019	83
Σ		628,793
X		62,879

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Sx	-3,381

Source: Calculation Results

Table 5. Rainfall Plan

Repeat period	μ	RT
2	-0,22	63,623
5	0,64	60,715
10	1,26	58,619
20	1,89	56,489
25	2,10	55,779
50	2,75	53,582
100	3,43	51,283
150	3,84	49,896

Source: Calculation Results

Table 6. Distribution of Weduwen

No	Year	Rainfall
1	2010	123
2	2011	74
3	2012	83
4	2013	68
5	2014	62
6	2015	78
7	2016	19
8	2017	18
9	2018	21
10	2019	83

Source: Calculation Results

Table 7. Rainfall Plan

Repeat period	Mn	R70	RT
2	0,492	115,728	56,938
5	0,602		69,668
10	0,705		81,588
20	0,811		93,855
25	0,845		97,790
50	0,948		109,710
100	1,05		121,514
150	0,000		0,000

Source: Calculation Results

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Table 8. Distribution of Log Person III

NO	Year	Rainfall (Xi)	LOG xi	log xi - log x	(log xi - log x)^2	(log xi - log x)^3
1	2010	123	2.090	0.373	0.139	0.052
2	2011	74	1.866	0.149	0.022	0.003
3	2012	83	1.919	0.202	0.041	0.008
4	2013	68	1.835	0.118	0.014	0.002
5	2014	62	1.792	0.075	0.006	0.000
6	2015	78	1.890	0.174	0.030	0.005
7	2016	19	1.285	-0.431	0.186	-0.080
8	2017	18	1.248	-0.469	0.220	-0.103
9	2018	21	1.322	-0.394	0.156	-0.061
10	2019	83	1.921	0.204	0.042	0.008
Σ			17.169	0.000	0.855	-0.166
X			1.717			
SX			-0.855			
CX			-0.113			

Source: Calculation Results

Table 9. Rainfall Plan

Repeat period	PROBABILITAS	G	LOG RT	RT
2	50.0	0.050	1.674	47.221
5	20.0	0.853	0.987	9.713
10	10.0	1.245	0.652	4.488
20	5.0	1.510	0.425	2.662
25	4.0	1.643	0.312	2.050
50	2.0	1.890	0.100	1.260
100	1.0	2.104	-0.083	0.827
150	0.7	2.199	-0.164	0.686

Source: Calculation Results

4.3 Thiessen Method Average Rainfall

The analysis used to find the average rainfall using the Thiessen method can be seen in the table below (Table 10).

Table 10. Average Rainfall Gumbel

NO	STATION	RAINFALL								LARGE (A)	KOEF	AVERAGE							
		R2	R5	R10	R15	R30	R60	R100	R150			R2	R5	R10	R15	R30	R60	R100	R150
1	Mararena Meteorological Station	58.4260	96.3521	121.4625	145.5490	150.7453	176.7265	200.0896	211.7286	15.6720	1.0000	58.4260	96.3521	121.4625	145.5490	150.7453	176.7265	200.0896	211.7286
Σ										15.6720	1.0000	58.4260	96.3521	121.4625	145.5490	150.7453	176.7265	200.0896	211.7286

Source: Calculation Results

Table 11. Average Rainfall Hasper

NO	STATION	RAINFALL								LARGE (A)	KOEF	AVERAGE							
		R2	R5	R10	R15	R30	R60	R100	R150			R2	R5	R10	R15	R30	R60	R100	R150
1	Mararena Meteorological Station	63.6231	60.7155	58.6193	56.4892	55.7792	53.5816	51.2825	49.8963	15.6720	1.0000	63.6231	60.7155	58.6193	56.4892	55.7792	53.5816	51.2825	49.8963
Σ										15.6720	1.0000	63.6231	60.7155	58.6193	56.4892	55.7792	53.5816	51.2825	49.8963

Source: Calculation Results

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Table 12. Average Rainfall Weduwen

NO	STATION	RAINFALL								LARGE (A)	KOEF	AVERAGE							
		R2	R5	R10	R15	R30	R60	R100	R150			R2	R5	R10	R15	R30	R60	R100	R150
1	Mararena Meteorological Station	56.9381	69.6682	81.5881	93.8553	97.7900	109.7100	121.5142	0.0000	15.6720	1.0000	56.9381	69.6682	81.5881	93.8553	97.7900	109.7100	121.5142	0.0000
Σ										15.6720	1.0000	56.9381	69.6682	81.5881	93.8553	97.7900	109.7100	121.5142	0.0000

Source: Calculation Results

Table 13. Average Rainfall Log Person III

NO	STATION	RAINFALL								LARGE (A)	KOEF	AVERAGE							
		R2	R5	R10	R15	R30	R60	R100	R150			R2	R5	R10	R15	R30	R60	R100	R150
1	Mararena Meteorological Station	47.2210	9.7131	4.4884	2.6617	2.0497	1.2602	0.8268	0.6858	15.6720	1.0000	47.2210	9.7131	4.4884	2.6617	2.0497	1.2602	0.8268	0.6858
Σ										15.6720	1.0000	47.2210	9.7131	4.4884	2.6617	2.0497	1.2602	0.8268	0.6858

Source: Calculation Results

From the results of the calculation of the planned rainfall with various return periods, the planned discharge is obtained using the empirical method with a return period of 2 years, 5 years, 10 years, 20 years, 25 years, 50 years, 100 years, and 150 years. The average maximum rainfall data can be seen in the table.

Table 14. Average Maximum Rainfall

NO	Repeat period	GUMBEL	HASPER	LOG PERSON	WEDUWEN
1	R2	58.426	63.623	47.221	56.938
2	R5	96.352	60.715	9.713	69.668
3	R10	121.463	58.619	4.488	81.588
4	R20	145.549	56.489	2.662	93.855
5	R25	150.745	55.779	2.050	97.790
6	R50	176.726	53.582	1.260	109.710
7	R100	200.090	51.283	0.827	121.514
8	R150	211.729	49.896	0.686	0.000

Source: Calculation Results

4.4 Rational Flood Discharge

The analysis used in calculating the flood discharge is using the Rational method with various return periods. The parameters used in the calculation of the flood discharge rational method are runoff coefficient, watershed area, and planned rainfall intensity. The results of the flood discharge analysis using the RationalGumbel method can be seen in table 15.

Table 15. Gumbel's Rational Flood Discharge

Repeat Period	RT	V	t	I	Q
R2	58.426	1.513	1.652	14.491	5.076
R5	96.352			23.898	8.371
R10	121.463			30.126	10.553
R20	145.549			36.101	12.645
R25	150.745			37.389	13.097
R50	176.726			43.834	15.354
R100	200.090			49.628	17.384
R150	211.729			52.515	18.395

Source: Calculation Results

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The results of the flood discharge analysis using the Rational Haspers method can be seen in table 17.

Table 17. Haspers Rational Flood Discharge

Repeat Period	RT	V	t	I	Q
R2	63.623	1.513	1.652	15.781	5.528
R5	60.715			15.059	5.275
R10	58.619			14.539	5.093
R20	56.489			14.011	4.908
R25	55.779			13.835	4.846
R50	53.582			13.290	4.655
R100	51.283			12.720	4.455
R150	49.896			12.376	4.335

Source: Calculation Results

The results of the flood discharge analysis using the Rational Weduwen method can be seen in table 17.

Table 17. Weduwen's Rational Flood Discharge

Repeat Period	RT	V	t	I	Q
R2	56.938	1.513	1.652	14.122	4.947
R5	69.668			17.280	6.053
R10	81.588			20.236	7.088
R20	93.855			23.279	8.154
R25	97.790			24.255	8.496
R50	109.710			27.211	9.532
R100	121.514			30.139	10.557
R150	0.000			0.000	0.000

Source: Calculation Results

The results of the flood discharge analysis using the Rational Log Person method can be seen in table 19.

Table 19. Rational Flood Discharge Log Person

Repeat Period	RT	V	t	I	Q
R2	47.221	1.513	1.652	11.712	4.103
R5	9.713			2.409	0.844
R10	4.488			1.113	0.390
R20	2.662			0.660	0.231
R25	2.050			0.508	0.178
R50	1.260			0.313	0.109
R100	0.827			0.205	0.072
R150	0.686			0.170	0.060

Source: Calculation Results

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4.5 Rain Intensity

Rain intensity is one of the inputs that will be used in the design discharge analysis. The available rainfall data is in the form of daily rainfall data so that in this analysis using the mononobe method

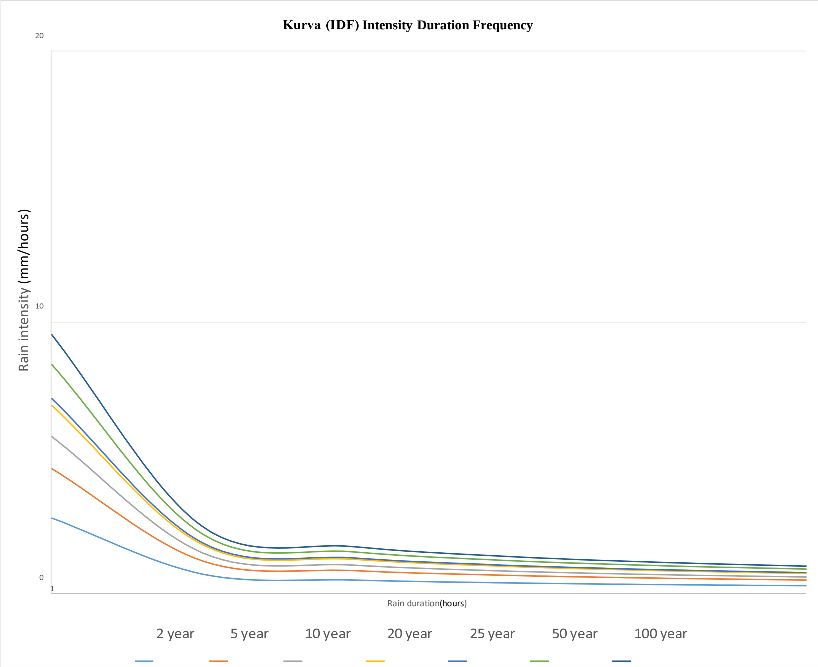

Figure 1. Mononobe curve
Source: Calculation Results

The results of the analysis are intensity duration frequency or better known as the IDF curve for 24 hours with return periods of 2 years, 5 years, 10 years, 20 years, 25 years, 50 years, and 100 years.

5. CONCLUSION

Based on the results of the analysis of the highest discharge, Rational Gumbel with a return period of 2 years 5,076 m^3/s, a return period of 5 years 8,371 m^3/s, a return period of 10 years 10,553 m^3/s, a return period of 20 years 12,645 m^3/s, 25 years return period 13,097 m^3/s, 50 years return period 15,354 m^3/s, 100year return period 17,384 m^3/s, 150 year return period 518,395 m^3/sec. The Cikapundung River belongs to the G river type which has a very high rate of edge erosion, high sediment supply, simple to steep channel slopes, low channel width ratio, high sediment supply, high baseload, and very high dissolved sediment rate. so that efforts that can be made in flood control efforts are restoration or rearrangement of the environment around the Cikapundung river border.

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