

Analysis of Flood Discharge in Muruk Rian District Tana Tidung Regency North Kalimantan Province Supporting Flood Management in the Simpang Seputuk Roadway

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Abstract

This study employs a quantitative descriptive method. The research process begins with a literature review, secondary data collection from relevant institutions or agencies, and data analysis. The results indicate that rainfall distribution analysis using the Log Pearson Type III method yielded planned rainfall values for return periods of 2, 5, 10, and 25 years, amounting to 116.69 mm/hour, 143.05 mm/hour, 161.62 mm/hour, and 186.32 mm/hour, respectively. The calculation of potential design flood discharge using the Nakayasu Synthetic Unit Hydrograph (SUH) method for return periods of 2, 5, 10, and 25 years in the Seputuk watershed resulted in 314.18 m³/s, 385.15 m³/s, 435.15 m³/s, and 501.80 m³/s, respectively, while for the Rian watershed, the results were 200.25 m³/s, 245.48 m³/s, 277.35 m³/s, and 319.83 m³/s, respectively. Additionally, the calculation of potential design flood discharge using the Rational Method for return periods of 2, 5, 10, and 25 years in the Seputuk watershed resulted in 75.75 m³/s, 92.83 m³/s, 104.92 m³/s, and 120.92 m³/s, respectively, while for the Rian watershed, the results were 57.33 m³/s, 70.28 m³/s, 79.41 m³/s, and 91.57 m³/s, respectively. The Nakayasu SUH method produced relatively higher planned flood discharges compared to the Rational Method, rendering the Rational Method less effective in this calculation.

Keywords: Planned Rainfall, Design Flood Discharge, Nakayasu SUH, Rational Method



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Introduction

Flood disasters have long been a persistent issue affecting human settlements worldwide, both in the past, present, and likely the future. These disasters can result from natural phenomena, human activities, or a combination of both (Kodoatie, 2021). Flooding is one of the most frequent natural disasters occurring in various regions of Indonesia, causing significant economic and social disruptions. One of the areas highly susceptible to flooding is Muruk Rian District, particularly the Simpang Seputuk roadway. The recurring floods in this area are primarily caused by high rainfall intensity and inadequate water management infrastructure.

The Simpang Seputuk roadway serves as a critical arterial route connecting several surrounding regions. However, frequent flooding in this area leads to traffic disruptions, road damage, and restricted access for local communities. Therefore, effective flood management along this roadway is an urgent necessity. To effectively mitigate floods, it is essential to obtain precise information on the flood discharge potential in Muruk Rian District, particularly in the Simpang Seputuk roadway area. Estimating flood discharge is a crucial step in understanding potential flood characteristics, including water height, flow velocity, and flood volume.

Flood mitigation plays a vital role in ensuring community safety and protecting infrastructure, especially arterial roads that serve as critical transportation routes. Hence, conducting a study focused on flood discharge estimation in Muruk Rian District, specifically in the Simpang Seputuk roadway, is of paramount importance. Understanding the potential flood discharge in this area will enable the development and implementation of appropriate and effective flood control measures tailored to the region's specific conditions. Currently, no studies have specifically focused on flood discharge estimation in Muruk Rian District, particularly in relation to flood mitigation efforts along the Simpang Seputuk roadway. Therefore, this research aims to fill this gap by providing crucial data and information necessary for designing and implementing effective flood mitigation strategies in the region.

Accurate flood discharge calculations will provide relevant stakeholders, including local governments, related agencies, and the community, with a solid foundation for designing and implementing targeted flood mitigation measures. Furthermore, the findings of this study can support the development of early flood warning systems, sustainable spatial planning, and the selection of effective flood management techniques in the Simpang Seputuk roadway area. These efforts can help reduce flood-induced damages and enhance regional resilience to flooding disasters.

Methods

This research was conducted in the village of Seputuk-Kapuak Rian, located in Muruk Rian District, Tana Tidung Regency, North Kalimantan Province. The study followed a structured research process, beginning with a literature review, collection of secondary data from relevant institutions, and comprehensive data analysis.

The primary dataset used in this study consisted of daily maximum rainfall data from 2008 to 2021, obtained from the Salap Rainfall Station. The regional average maximum daily rainfall was determined using the Arithmetic Mean Method. The frequency analysis of rainfall data was conducted using both the Gumbel and Log Pearson Type III probability distributions. To ensure the suitability of the selected distribution, the Chi-Square and Smirnov-Kolmogorov goodness-of-fit tests were applied.

Subsequently, the design flood discharge was analyzed using two hydrological methods: the Rational Method and the Nakayasu Synthetic Unit Hydrograph (SUH) Method. The Rational Method requires the calculation of rainfall intensity, concentration time, and the watershed runoff coefficient to estimate the peak discharge. Meanwhile, the Nakayasu SUH Method was employed to determine peak flood discharge over various return periods, allowing for a more detailed hydrological assessment.

The study area included two main watersheds, Seputuk and Rian, which were analyzed for their flood discharge characteristics. The Seputuk watershed spans an area of 170.59 km², while the Rian watershed covers 75.59 km². The hydrological and land-use characteristics of these watersheds were incorporated into the analysis to assess their impact on flood discharge levels.

The results of the rainfall analysis and subsequent hydrological modeling were used to determine design flood discharge values for return periods of 2, 5, 10, and 25 years. These values were then compared across the different methods to evaluate the effectiveness and applicability of each approach in predicting flood discharge in the study area.

Results and Discussions

1. Results

The study area is characterized by a low and flat topographical position, situated near the Sesayap River and forming the downstream section of two river basins, namely the Seputuk River and the Rian River, as illustrated in the figure below.

From a geological perspective, the study area is part of an alluvial deposit formation, which can be classified as clastic alluvial sedimentary rock. Clastic sediments are accumulations of particles derived from the fragments of pre-existing rocks and the skeletal remains of deceased

organisms. In contrast, chemical sedimentary rocks are transported in solution and subsequently precipitated chemically in a different location.

Alluvium consists of unconsolidated clay, silt, sand, or gravel that has been deposited by flowing water in riverbeds, floodplains, alluvial fans, beaches, or similar settings.

For a clearer representation, the location of the Simpang Seputuk Road and the surrounding villages can be observed in the figure below.

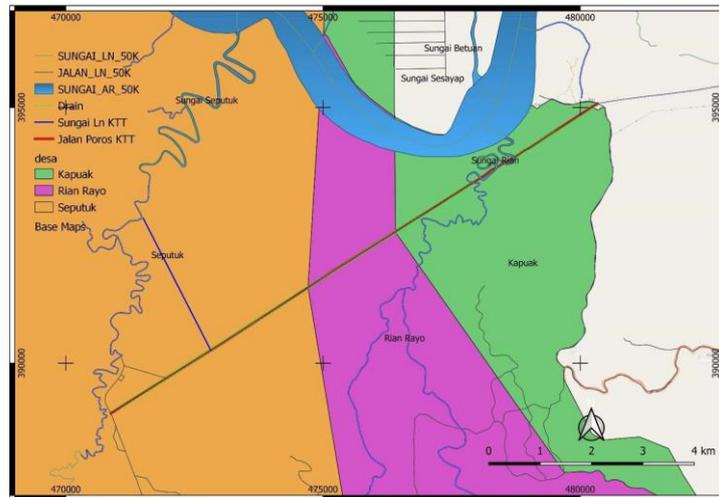


Figure 1. Study Area Location

The following are the characteristics of each river:

1. Seputuk River
 - River Length :41,20 Km
 - Watershed Area: 170,58 Km²
2. Rian River
 - River Length :19 Km
 - Watershed Area:75,59 Km²

The watersheds analyzed in this study are the Seputuk and Rian Watersheds. The spatial extent of these watersheds is illustrated in Figure 2.

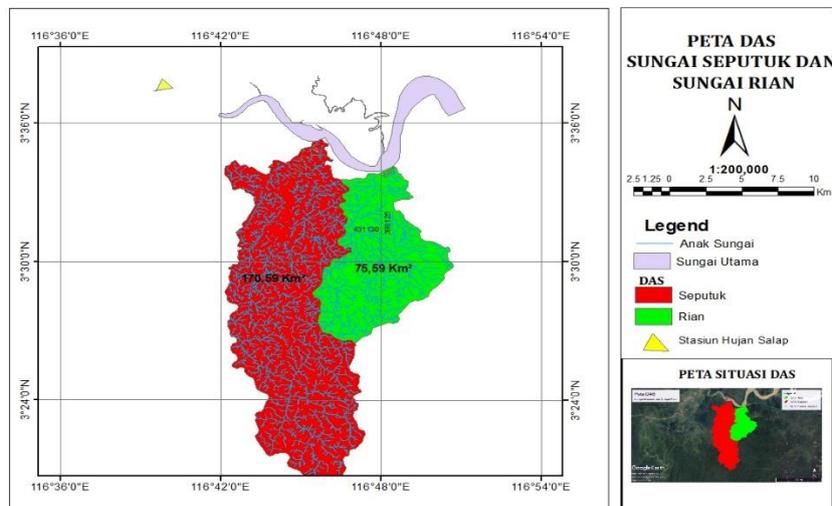


Figure 2. Seputuk and Rian Watersheds

a. Land Use

The land use area data for the Seputuk and Rian Watersheds in 2024 is presented in the following table.

Table 1. Land Use of the Seputuk Watershed

Number	Land Use	Area (km ²)
1	Residential Area	8,53
2	Suburban Area	63,97
3	Plantation	42,65
4	Parks and Cemeteries	6,40
	ROAD	
5	Paved Surface	6,40
6	Pathway/Trail	10,66
	SANDY LAND	
7	Flat Terrain (Slope up to 2%)	10,66
8	Vegetated Forest	10,66
	UNPRODUCTIVE LAND	
9	Flat, Impermeable Soil	10,66
	Total	170,59

Table 1. Land Use of the Rian Watershed

Number	Tata Guna Lahan	Area (km ²)
1	Residential Area	3,78
2	Suburban Area	28,35
3	Plantation	18,90
4	Parks and Cemeteries	2,83
	ROAD	
5	Paved Surface	2,83
6	Pathway/Trail	4,72
	SANDY LAND	
7	Flat Terrain (Slope up to 2%)	4,72
8	Vegetated Forest	4,72
	UNPRODUCTIVE LAND	
9	Flat, Impermeable Soil	4,72
	Total	75,59

The land use of the watershed in this study is illustrated in Figure 3.

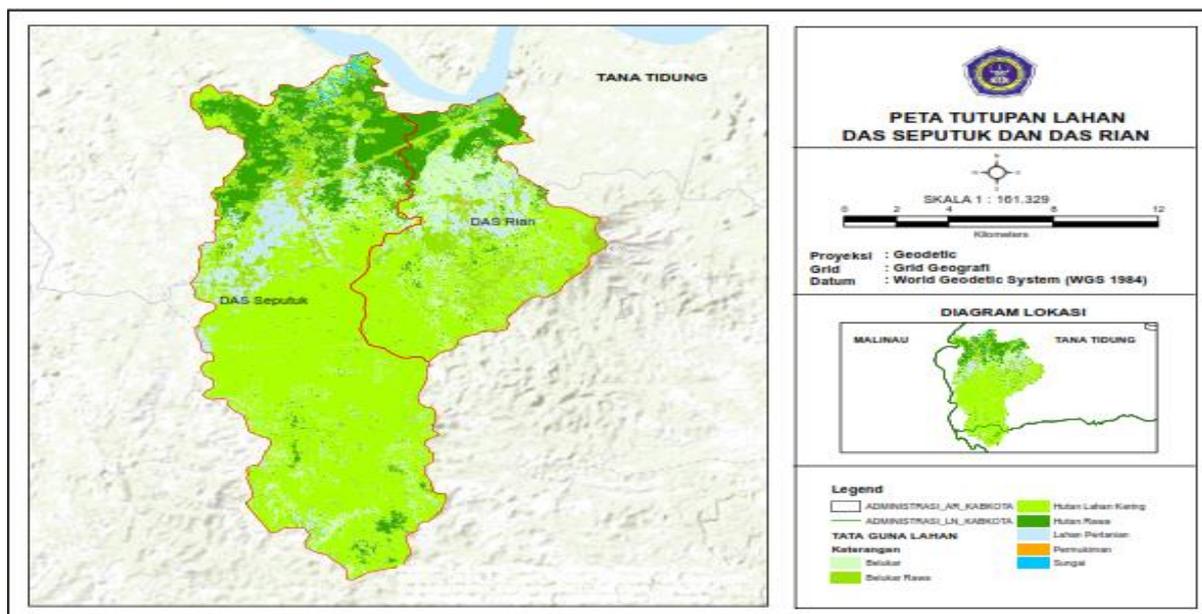


Figure 3. Land Use of the Seputuk and Rian Watersheds

b. Regional Rainfall Calculation

The rainfall data used in this analysis for the Seputuk Sub-watershed, located in North Kalimantan Province, was obtained from the Salap Rainfall Station. The dataset consists of maximum daily rainfall records over the past 14 years (2008–2021). The observation station utilized for this study is situated within the Seputuk region, North Kalimantan Province, with only one rainfall station being used for data collection.

The results of the maximum daily rainfall calculations for the Seputuk Watershed in North Kalimantan Province are presented in Table 3.

Table 3. Maximum Daily Rainfall

Maximum Rainfall at Salap Station			
Number	Year	Date	Maximum Daily Rainfall
1	2008	Okt 30	129,66
2	2009	Mar 08	106,13
3	2010	Apr 17	107,45
4	2011	Sep 08	134,17
5	2012	Mar 20	192,95
6	2013	Aug 07	169,80
7	2014	Jan 08	126,69
8	2015	Nov 03	93,36
9	2016	Apr 13	92,89
10	2017	Jul 16	105,89
11	2018	Jan 19	128,85
12	2019	Jan 26	102,73
13	2020	Mar 08	136,27
14	2021	Jan 20	91,66

Note: Salap Rainfall Station

c. Average Rainfall Frequency Analysis

Rainfall frequency analysis is a statistical method used to interpret rainfall data and determine the recurrence interval of rainfall over a specific period (Syofyan, 2018). The results of the statistical parameter calculations (dispersion) for each rainfall parameter are presented in the following table.

Table 4. Gumbel Distribution Method

Number	Year	RmAx	RI	RI - Rt	(RI - Rt) ²	(RI - Rt) ³	(RI - Rt) ⁴
1	2008	129,66	192,95	70,20	4927,72	345914,96	24282447,40
2	2009	106,13	169,80	47,05	2213,96	104172,96	4901623,89
3	2010	107,45	136,27	13,52	182,88	2473,17	33445,56
4	2011	134,17	134,17	11,42	130,51	1490,92	17032,34
5	2012	192,95	129,66	6,91	47,75	329,92	2279,66
6	2013	169,80	128,85	6,10	37,26	227,45	1388,40
7	2014	126,69	126,69	3,94	15,52	61,17	241,01
8	2015	93,36	107,45	-15,30	234,22	-3584,45	54856,68
9	2016	92,89	106,13	-16,63	276,40	-4595,17	76395,58
10	2017	105,89	105,89	-16,86	284,16	-4790,19	80748,87
11	2018	128,85	102,73	-20,02	400,97	-8028,98	160773,16
12	2019	102,73	93,36	-29,39	863,96	25394,39	746420,76
13	2020	136,27	92,89	-29,86	891,44	-26615,58	794659,93
14	2021	91,66	91,66	-31,09	966,67	-30055,20	934457,33
Total			1718,51	0,00	11473,41	351606,60	32086770,58
Average (Rt)			122,75				

Table 5. Log Pearson Type III Distribution Method

Number	Year	RmAx	Ri	Log Ri	Log (Ri - Rt)	Log (Ri - Rt) ²	Log (Ri - Rt) ³	Log (Ri - Rt) ⁴
1	2008	129,66	192,95	2,29	0,21	0,04	0,01	0,00
2	2009	106,13	169,80	2,23	0,15	0,02	0,00	0,00
3	2010	107,45	136,27	2,13	0,06	0,00	0,00	0,00
4	2011	134,17	134,17	2,13	0,05	0,00	0,00	0,00
5	2012	192,95	129,66	2,11	0,03	0,00	0,00	0,00
6	2013	169,80	128,85	2,11	0,03	0,00	0,00	0,00
7	2014	126,69	126,69	2,10	0,02	0,00	0,00	0,00
8	2015	93,36	107,45	2,03	-0,05	0,00	0,00	0,00
9	2016	92,89	106,13	2,03	-0,05	0,00	0,00	0,00
10	2017	105,89	105,89	2,02	-0,05	0,00	0,00	0,00
11	2018	128,85	102,73	2,01	-0,07	0,00	0,00	0,00
12	2019	102,73	93,36	1,97	-0,11	0,01	0,00	0,00
13	2020	136,27	92,89	1,97	-0,11	0,01	0,00	0,00
14	2021	91,66	91,66	1,96	-0,12	0,01	0,00	0,00
Total			1719	29,10	0,00	0,12	0,01	0,00
Average (Rt)			122,75	2,08				

d. Selection of Distribution Type

The Goodness of Fit Test is a statistical test conducted to determine the suitability of the selected distribution with empirical data. This test is performed using the Chi-Square Method and the Smirnov-Kolmogorov Method. Rainfall distribution has unique characteristics; therefore, the rainfall data must be validated using these methods to ensure proper distribution selection (Harto, 1993). An incorrect choice of distribution may result in significant estimation errors, leading to either overestimation or underestimation of rainfall values.

Table 6. Results of the Chi-Square and Smirnov-Kolmogorov Tests

Planned Rainfall		
Frequency Distribution Analysis		
Number	Year	Date
Tr (year)	Gumbel	Log Pearson Type III
25	202	186
10	174	162
5	152	143
2	119	117
Distribution Suitability Test		
Chi-Kuadrat Test		
X ² Calculated	2,43	5,29
X ² Critical	5,991	5,991
C	Representative	Representative
Smirnov-Kolmogorof Test		
D Calculated	0,18	0,17
D Critical	0,35	0,35
Conclusion	Representative	Representative

Based on the results of the frequency distribution suitability test, both the Gumbel Method and the Log Pearson Type III Method successfully passed the Chi-Square Test and the Smirnov-Kolmogorov Test. To determine the most appropriate distribution type, a statistical parameter matching process was conducted according to the required criteria for each distribution type. The distribution criteria are presented in the following table:

Table 7. Criteria for Distribution Type Selection

Number	Method Name	Requirements	Results	Remarks
1	Gumbel	Cs = 1,14	Cs = 1,20	Not Satisfied
		Ck = 5,4	Ck = 4,71	Not Satisfied
2	Log Person	Cs ≠ 0	Cs = 0,76	Satisfied

Based on the distribution calculations and suitability test results presented in the table, it is evident that the most appropriate distribution type for the maximum daily rainfall data in the Seputuk and Rian Watersheds is the Log Pearson Type III Distribution.

The calculated rainfall for a 2-year return period (Rtr) is determined using the following equation:

$$\begin{aligned}
 R_{tr} (2 \text{ years}) &= 10^{(\text{Log } \bar{R} + KTR \times S)} \\
 &= 10^{(2,078 + (-0,116 \times 0,10))}
 \end{aligned}$$

= 116,69 mm/hour

The results of the planned rainfall calculations are presented in the following table.

Table 8. Results of Planned Rainfall Calculation Using the Log Pearson Type III Method

Number	Return Period	Probability	Average Log X	KTr	S	Log Rx	Planned Rainfall (mm/hour)
1	2	50	2,078	-0,116	0,10	2,0670	116,69
2	5	20	2,078	0,79	0,10	2,1555	143,05
3	10	10	2,078	1,333	0,10	2,2085	161,62
4	25	4	2,078	1,967	0,10	2,2704	186,38
5	50	2	2,078	2,407	0,10	2,3133	205,75
6	100	1	2,078	2,824	0,10	2,3541	225,97

e. Runoff Coefficient (C)

The runoff coefficient values for the Seputuk and Rian Watersheds are presented in Table 9.

Table 9. Runoff Coefficient Values for the Seputuk Watershed

Number	Land Use Type	Area (km ²)	Runoff Coefficient (C)	C × A Value
1	Residential Area	8,53	0,50	4,26
2	Suburban Area	63,97	0,40	25,59
3	Plantation	42,65	0,40	17,06
4	Parks and Cemeteries	6,40	0,25	1,60
ROAD				
5	Paved Surface	6,40	0,95	6,08
6	Pathway/Trail	10,66	0,85	9,06
SANDY LAND				
7	Flat Terrain (Slope up to 2%)	10,66	0,10	1,07
8	Vegetated Forest	10,66	0,25	2,67
UNPRODUCTIVE LAND				
9	Flat, Impermeable Soil	10,66	0,90	9,60
Total		170,59		76,98
Average				0,45

Table 10. Runoff Coefficient Values for the Rian Watershed

Number	Land Use Type	Area (km ²)	Runoff Coefficient (C)	C × A Value
1	Residential Area	3,78	0,50	1,89
2	Suburban Area	28,35	0,40	11,34
3	Plantation	18,90	0,40	7,56
4	Parks and Cemeteries	2,83	0,25	0,71
ROAD				
5	Paved Surface	2,83	0,95	2,69
6	Pathway/Trail	4,72	0,85	4,02
SANDY LAND				

7	Flat Terrain (Slope up to 2%)	4,72	0,10	0,47
8	Vegetated Forest	4,72	0,25	1,18
UNPRODUCTIVE LAND				
9	Flat, Impermeable Soil	4,72	0,90	4,25
Total		75,59		34,11
Average				0,45

f. Rainfall Intensity

In this study, the Mononobe Method was used for hourly rainfall analysis, with a rainfall duration of 6 hours.

⊙ Mononobe Method Formula:

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

Explanation:

I : Rainfall intensity (mm/hour)

R₂₄ : Maximum daily rainfall over 24 hours (mm/hour)

t : Rainfall duration (hours), which is 6 hours in this study

Applying the formula:

$$I = \frac{R_{24}}{t} \left(\frac{t}{T} \right)^{2/3} = I = \frac{1}{6} \left(\frac{6}{1} \right)^{2/3} = 0,550$$

Table 11. Hourly Rainfall Distribution

Hour (T)	Rainfall Distribution (R _T)		Rainfall Amount		Ratio (%)	Cumulative (%)
	Every 1 st Hour	R ₂₄	Hour	R ₂₄		
1	0,550	R ₂₄	0,550	R ₂₄	55,03	55,03
2	0,347	R ₂₄	0,143	R ₂₄	14,30	69,34
3	0,265	R ₂₄	0,100	R ₂₄	10,03	79,37
4	0,218	R ₂₄	0,080	R ₂₄	7,99	87,36
5	0,188	R ₂₄	0,067	R ₂₄	6,75	94,10
6	0,167	R ₂₄	0,059	R ₂₄	5,90	100,00

In the calculation of effective rainfall intensity for the Seputuk and Rian Watersheds, a 6-hour duration was used. The 6-hour period is commonly applied in effective rainfall calculations in Indonesia and is often suitable for the watershed response time, which represents the time required for rainfall to travel from its point of impact to the watershed outlet.

Table 12. Hourly Effective Rainfall

Hour (T)	Percentage of Hourly Rainfall (T)	Net Hourly Rainfall (mm/hour)			
		2 Year	5 Year	10 Year	25 Year
1	55,03%	64,22	78,72	88,94	102,57
2	14,30%	16,69	20,46	23,12	26,66
3	10,03%	11,71	14,35	16,22	18,70

4	7,99%	9,32	11,43	12,91	14,89
5	6,75%	7,87	9,65	10,90	12,57
6	5,90%	6,88	8,43	9,53	10,99
100%					
Net Rainfall (Effective Rainfall)	(mm/hari)	116,69	143,05	161,62	186,38

g. Design Flood Discharge Using the Nakayasu Synthetic Unit Hydrograph (HSS) Method

1. Seputuk Watershed

Watershed Area (DAS Seputuk) : 170,59 Km²

River Length : 41,2 Km

Watershed Runoff Coefficient : 0,45

Unit Rainfall (Ro) : 1

Lag Time Parameter (Tg): For a river length L > 15 km, the calculation is as follows:

$$\begin{aligned} T_g &= 0,4 + 0,058 \times L \\ &= 0,4 + 0,058 \times 41,20 \\ &= 2,79 \text{ Hour} \end{aligned}$$

$$T_r = 0,75 \times T_g = 0,8 \times 2,79 = 2,092 \text{ Hour}$$

$$\begin{aligned} T_p &= T_g + (0,8 \times T_r) \\ &= 2,79 + (0,8 \times 2,092) \\ &= 4,46 \text{ Hour} \end{aligned}$$

$$\begin{aligned} \alpha &= (0,47 \times ((A \times L)^{0,25})) / T_g \\ &= (0,47 \times ((170,59 \times 41,2)^{0,25})) / 2,79 \\ &= 1,543 \end{aligned}$$

$$T_{0.3} = \alpha \times T_g = 1,543 \times 2,79 = 4,30 \text{ Hour}$$

$$\begin{aligned} Q_p &= C \times A \times R_o / 3.6 \times (0.3 T_p + T_{0.3}) \\ &= (170,59 \times 0,45 \times 1) / (3.6 \times ((0.3 \times 4,46) + 4,30)) \\ &= 3,779 \text{ m}^3/\text{second} \end{aligned}$$

- On the rising curve before reaching peak discharge (Qp)

Interval $0 < t < T_p$

$$Q_n = Q_p \times (t/T_p)^{2.4}$$

- On the falling curve (Qt)

Interval $T_p < t < T_p + T_{0.3}$

$$Q_n = Q_p \times (0.3 \wedge ((t - T_p) / T_{0.3}))$$

- On the falling curve (Qt)

Interval $T_p + T_{0.3} < t < T_p + T_{0.3} + 1.5 \times T_{0.3}$

$$Q_n = Q_p \times (0.3 \wedge (((t - T_p) + (0.5 \times T_{0.3})) / (1.5 \times T_{0.3})))$$

- On the falling curve (Qt)

Interval $t > T_p + T_{0.3} + (1.5 \times T_{0.3})$

$$Q_n = Q_p \times (0.3 \wedge (((t - T_p) + (1.5 \times T_{0.3})) / (2 \times T_{0.3})))$$

Table 13. Qn Values on the Rising and Falling Curves

Interval	t	Qn
0	0	0
	1,00	0,104
	2,00	0,550
	3,00	1,456
	4,00	2,905
Tp	4,46	3,779
	5,00	3,252
	6,00	2,459
	7,00	1,859
	8,00	1,405
Tp+To3	8,77	1,134
	9,00	1,085
	10,00	0,901
	11,00	0,748
	12,00	0,620
	13,00	0,515
	14,00	0,427
	15,00	0,354
Tp+To3+1,5*T0,3	15,22	0,340
	16,00	0,305
	17,00	0,265
	18,00	0,231
	19,00	0,200
	20,00	0,174
	21,00	0,152
	22,00	0,132
	23,00	0,115
	24,00	0,100

Based on the table above, it can be observed that the peak time calculated using the Nakayasu Synthetic Unit Hydrograph (HSS) Method for the Seputuk Watershed occurs at 4.46 hours, with a peak discharge of 3.779 m³/s.

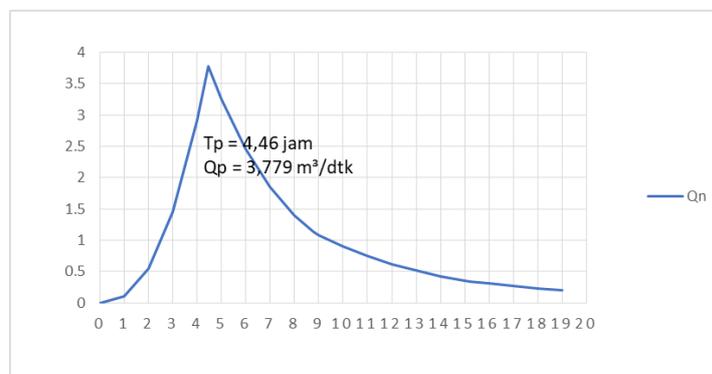


Figure 4. Peak Time of Nakayasu HSS

Example Calculation for Hourly Rainfall with a 2-Year Return Period:

$$\begin{aligned}
 Q_1 &= R_{n1} \times Qn_1 \\
 Q_2 &= R_{n1} \times Qn_2 + R_{n2} \times Qn_1 \\
 Q_3 &= R_{n1} \times Qn_3 + R_{n2} \times Qn_2 + R_{n3} \times Qn_1 \\
 Q_n &= R_{n1} \times Qn_n + R_{n2} \times Qn_{(n-1)} + R_{n3} \times Qn_{(n-1)} + \dots + R_n \times Qn_1 \\
 Q_1 &= R_{n1} \times Qn_1 \\
 &= 64,22 \times 0,10 \\
 &= 6,70 \text{m}^3/\text{det} \\
 Q_2 &= R_{n1} \times Qn_2 + R_{n2} \times Qn_1 \\
 &= 64,22 \times 0,55 + 16,69 \times 0,10 \\
 &= 37,09 \text{ m}^3/\text{det}
 \end{aligned}$$

The subsequent calculations can be observed in the table below.

Table 14. Design Flood Unit Hydrograph for a 2-Year Return Period

t hour	Qn (m ³ /s)	Resulting Rainfall (mm)						Total (m ³ /s)	Remarks
		64.22	16.69	11.71	9.32	7.87	6.88		
0.00	0.00	0.00						0.00	Qa
1.00	0.10	6.70	0.00					6.70	Qa
2.00	0.55	35.34	1.74	0.00				37.09	Qa
3.00	1.46	93.53	9.19	1.22	0.00			103.94	Qa
4.00	2.91	186.5 5	24.31	6.44	0.97	0.00		218.28	Qa
4.46	3.78	242.6 8	48.49	17.05	5.13	0.82	0.00	314.18	Qa
5.46	2.86	183.4 6	63.08	34.01	13.58	4.33	0.72	299.18	Qd1
6.00	2.46	157.8 8	47.68	44.25	27.08	11.46	3.79	292.14	Qd1
7.00	1.86	119.3 5	41.04	33.45	35.23	22.87	10.02	261.95	Qd1
8.00	1.40	90.22	31.02	28.79	26.63	29.75	19.99	226.40	Qd2
8.77	1.13	72.81	23.45	21.76	22.92	22.49	26.00	189.42	Qd2
9.00	1.09	69.71	18.92	16.45	17.32	19.35	19.66	161.41	Qd2
10.00	0.90	57.84	18.12	13.27	13.10	14.63	16.92	133.88	Qd2
11.00	0.75	48.00	15.04	12.71	10.57	11.06	12.79	110.16	Qd2
12.00	0.62	39.83	12.48	10.55	10.12	8.92	9.67	91.57	Qd2

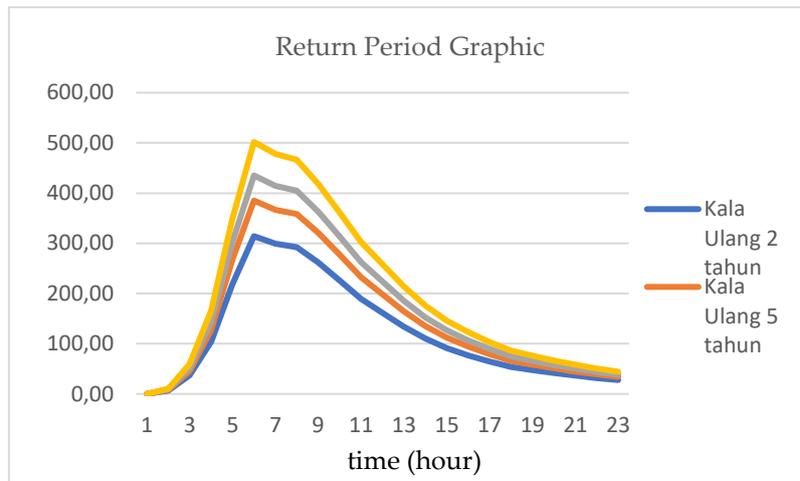
13.00	0.51	33.06	10.35	8.75	8.40	8.54	7.80	76.90	Qd3
14.00	0.43	27.43	8.59	7.26	6.97	7.09	7.47	64.81	Qd3
15.00	0.35	22.76	7.13	6.03	5.78	5.88	6.20	53.78	Qd3
15.22	0.34	21.84	5.92	5.00	4.80	4.88	5.14	47.58	Qd3
16.00	0.31	19.59	5.68	4.15	3.98	4.05	4.27	41.72	Qd3
17.00	0.27	17.03	5.09	3.98	3.30	3.36	3.54	36.31	Qd3
18.00	0.23	14.81	4.43	3.57	3.17	2.79	2.94	31.71	Qd3
19.00	0.20	12.88	3.85	3.11	2.84	2.68	2.44	27.79	Qd3

From the table above, the peak discharge occurs at hour 4.46, with a flood discharge of 314.18 m³/s.

Table 15. Recapitulation of Unit Flood Hydrograph for Seputuk Watershed

T	Return Period			
	2 Year	5 Year	10 Year	25 Year
0,00	0,00	0,00	0,00	0,00
1,00	6,70	8,21	9,28	10,70
2,00	37,09	45,46	51,36	59,23
3,00	103,94	127,41	143,96	166,01
4,00	218,28	267,58	302,32	348,63
4,46	314,18	385,15	435,15	501,80
5,46	299,18	366,76	414,37	477,84
6,00	292,14	358,14	404,63	466,61
7,00	261,95	321,12	362,81	418,39
8,00	226,40	277,54	313,57	361,60
8,77	189,42	232,21	262,36	302,55
9,00	161,41	197,87	223,56	257,81
10,00	133,88	164,12	185,43	213,83
11,00	110,16	135,05	152,58	175,95
12,00	91,57	112,25	126,82	146,25
13,00	76,90	94,28	106,51	122,83
14,00	64,81	79,45	89,77	103,52
15,00	53,78	65,93	74,49	85,91
15,22	47,58	58,33	65,91	76,00
16,00	41,72	51,14	57,78	66,63
17,00	36,21	44,52	50,30	58,00
18,00	31,71	38,87	43,91	50,64
19,00	27,79	34,07	38,49	44,30

From the table above, the peak discharge occurs at hour 4.46, with a flood discharge of 314.18 m³/s for a 2-year return period, 385.15 m³/s for a 5-year return period, 435.15 m³/s for a 10-year return period, and 501.80 m³/s for a 25-year return period.



Picture 5. Debit banjir rancangan HSS Nakayasu DAS Seputuk

h. Design Flood Discharge Using the Rational Method

Seputuk Watershed (DAS Seputuk):

Watershed Area (A) = 170,59 km²

River Length = 41,20 km

Runoff Coefficient (C) = 0,45

Upstream Elevation = 300 m

Downstream Elevation = 75 m

River Slope Calculation = $S = \frac{E_1 - E_2}{L} = \frac{300 - 75}{41,2 \times 1000} = 0,007$

Rian Watershed (DAS Rian):

Watershed Area (A) = 75,59 km²

River Length = 19 km

Runoff Coefficient (C) = 0,45

Upstream Elevation = 300 m

Downstream Elevation = 75 m

River Slope Calculation = $S = \frac{E_1 - E_2}{L} = \frac{300 - 75}{19 \times 1000} = 0,012$

Formula for Flood Discharge Calculation:

$$Q = 0,278 \cdot C \cdot I \cdot A$$

1) Time of Concentration (Tc) Calculation

After determining the watershed slope (S), the time of concentration (Tc) is calculated using the following equation:

Example Calculation for Seputuk Watershed:

$$T_c = 0,0195 L^{0,77} \cdot S^{-0,385}$$

$$T_c = 0,0195 \times 41,20^{0,77} \cdot 0,007^{-0,385}$$

$$T_c = 2,318 \text{ minutes}$$

$$T_c = 0,039 \text{ hours}$$

2) Rainfall Intensity Calculation

According to Loebis (1992), rainfall intensity (mm/hour) can be derived from daily rainfall data using the Mononobe equation. The rainfall intensity for the Seputuk Watershed is calculated using the following formula:

Example Calculation for Seputuk Watershed:

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

$$I = \frac{143,05}{24} \left(\frac{24}{0,039} \right)^{2/3}$$

$$I = 433,793 \text{ mm/hours}$$

3) Flood Discharge

Table 16. Rational Method Output for Seputuk River

Num ber	Return Period	Design Rainfal	S	Tc (minutes)	Tc (hours)	I (mm/hour)	Watershe d Area A (km ²)	C	Q (m ³ /second) Q =0,278.C.I. A
1	2	116,69	0,007	2,318	0,039	353,980	170,590	0,45	75,752
2	5	143,05	0,007	2,318	0,039	443,940	170,590	0,45	92,863
3	10	161,62	0,007	2,318	0,039	490,277	170,590	0,45	104,920
4	25	186,38	0,007	2,318	0,039	565,377	170,590	0,45	120,991

Note: Excell Analysis

Table 17. Rational Method Output for Rian River

Num ber	Return Period	Desig n Rainfa ll	S	Tc (minute s)	Tc (hours)	I (mm/hou r)	Watersh ed Area A (km ²)	C	Q (m ³ /second) Q =0,278.C.I. A
1	2	116,69	0,007	2,318	0,039	353,980	170,590	0,45	75,752
2	5	143,05	0,007	2,318	0,039	443,940	170,590	0,45	92,863
3	10	161,62	0,007	2,318	0,039	490,277	170,590	0,45	104,920
4	25	186,38	0,007	2,318	0,039	565,377	170,590	0,45	120,991

Note: Excell Analysis

Table 18. Recapitulation of Flood Discharge Using Nakayasu and Rational Methods

Return Period (Year)	Qt (m ³ /second)			
	Seputuk River		Rian River	
	Nakayasu	Rasional	Nakayasu	Rasional
2	314,18	75,75	200,25	57,33
5	385,15	92,86	245,48	70,28
10	435,15	104,92	277,35	79,41
25	501,80	120,99	319,83	91,57

Note: Excell Analysis

Based on the comparison of the design flood discharge analysis results in the table, it can be observed that each method produces a peak discharge value. When comparing the flood discharge results between the two methods, it is evident that the Nakayasu Synthetic Unit Hydrograph (HSS) Method yields a relatively higher design flood discharge than the Rational Method.

This difference may be influenced by several factors, such as watershed area, which affects the accuracy of the Rational Method. The Rational Method has limitations concerning watershed size, as it is typically applicable for small watersheds, approximately 100-200 acres or 40-80 hectares (Subarkah, p. 49).

Meanwhile, the Seputuk Watershed and Rian Watershed cover areas of 170.59 km² and 75.59 km², respectively. When converted to hectares, this amounts to 17,059 ha for Seputuk and 7,559 ha for Rian, making the Rational Method less effective in these cases.

For future research, it is recommended to divide the Seputuk and Rian Watersheds into sub-watersheds with an area range of 40-80 hectares when applying the Rational Method. This approach would improve the accuracy and effectiveness of the maximum flood discharge calculations for these watersheds.

3. Discussions

The findings of this study indicate that the methodology employed in the calculation of design flood discharge yields significant variations, depending on the approach utilized. The Synthetic Unit Hydrograph Nakayasu method resulted in higher flood discharges compared to the Rational Method, highlighting the importance of selecting an appropriate method in hydrological analysis.

From the analysis, the Log Pearson Type III method proved to be more suitable for calculating design rainfall compared to the Gumbel method. This conclusion is supported by the goodness-of-fit tests using the Chi-Square and Smirnov-Kolmogorov methods, which demonstrated that the Log Pearson Type III distribution more accurately represents the rainfall data in the study area. The difference between these two methods may be attributed to the asymmetrical distribution and inherent trends in the observed rainfall data, which align more closely with the Log Pearson Type III distribution.

Furthermore, the hydrological analysis using the Nakayasu method revealed that the peak discharge in the Seputuk watershed for return periods of 2, 5, 10, and 25 years was 314.18 m³/s, 385.15 m³/s, 435.15 m³/s, and 501.80 m³/s, respectively. Meanwhile, in the Rian watershed, the peak discharge for the same return periods was 200.25 m³/s, 245.48 m³/s, 277.35 m³/s, and 319.83 m³/s, respectively. The differences between these watersheds can be explained by variations in catchment area sizes and physical characteristics, such as topography, land use, and soil infiltration capacity.

Conversely, the Rational Method produced significantly lower discharge values. In the Seputuk watershed, peak discharge values for return periods of 2, 5, 10, and 25 years were 75.75 m³/s, 92.83 m³/s, 104.92 m³/s, and 120.92 m³/s, respectively. For the Rian watershed, the corresponding values were 57.33 m³/s, 70.28 m³/s, 79.41 m³/s, and 91.57 m³/s. The lower discharge values obtained using the Rational Method may be attributed to its limitations, as it is primarily designed for small watersheds with relatively uniform rainfall and hydrological characteristics.

These findings suggest that the Nakayasu method is more appropriate for estimating design flood discharge in the Seputuk and Rian watersheds compared to the Rational Method. One of the key factors affecting the effectiveness of the Rational Method in this study is the relatively large watershed areas: 170.59 km² for Seputuk and 75.59 km² for Rian. According to the literature, the Rational Method is more accurate for catchment areas below 80 ha. Therefore, for larger catchments, this method may not provide representative results.

Moreover, the study highlights the need for effective land-use management in mitigating flood risks in the study area. Land-use analysis indicates that suburban areas and plantations dominate land use in both watersheds, covering 63.97 km² and 42.65 km² in Seputuk, and 28.35 km² and 18.90 km² in Rian, respectively. This suggests a high potential for surface runoff, particularly in areas where natural vegetation has been converted into built-up or agricultural land.

The implications of these findings underscore the necessity of developing and implementing more effective flood mitigation strategies in Muruk Rian District, particularly along the Simpang Seputuk road section. Recommended measures include enhancing drainage capacity, constructing levees or retention ponds, and implementing hydrology-based early warning systems to minimize flood

risks. Additionally, utilizing spatial data-based flood prediction models and comprehensive hydrological analysis can enhance future flood management planning.

In conclusion, this study provides valuable insights into the hydrological characteristics of Muruk Rian District and serves as a crucial foundation for policymakers to design more effective and sustainable flood risk management strategies.

Conclusion

Based on the rainfall distribution analysis using the Log Pearson Type III Method, the design rainfall for return periods of 2, 5, 10, and 25 years are 116.69 mm/hour, 143.05 mm/hour, 161.62 mm/hour, and 186.32 mm/hour, respectively.

The flood discharge potential calculated using the Nakayasu Synthetic Unit Hydrograph (HSS) Method for the Seputuk Watershed with return periods of 2, 5, 10, and 25 years are 314.18 m³/s, 385.15 m³/s, 435.15 m³/s, and 501.80 m³/s, respectively. For the Rian Watershed, the corresponding flood discharges are 200.25 m³/s, 245.48 m³/s, 277.35 m³/s, and 319.83 m³/s.

Using the Rational Method, the flood discharge potential for the Seputuk Watershed with return periods of 2, 5, 10, and 25 years are 75.75 m³/s, 92.83 m³/s, 104.92 m³/s, and 120.92 m³/s, respectively. For the Rian Watershed, the respective flood discharges are 57.33 m³/s, 70.28 m³/s, 79.41 m³/s, and 91.57 m³/s.

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