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Frequency Analysis Of Deli River Flood Distribution Plan Using The Gumbel Probability Distribution Method

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Abstract: The Deli river basin is one of the rivers in North Sumatra Province which is in Medan City with an area of 394.88 km2 and a length of 166.01 km. Medan Maimun District which has an area of 2.98 km2 and a population density of 16,520 people/km2. Medan Mimun sub-district is one of the flood-prone areas which is drained by the Deli River. The cause of the flooding that occurred in Medan Maimun District was high rainfall so that the river flow rate increased and drainage was poor. So that the problem of flooding in the Deli river watershed, Medan Maimun sub-district, can hamper community activities, these floods can also harm and endanger the community. The flood discharge plan for each repeat period where the variable used is the maximum daily rainfall for 10 years From 2013-2022 which is sourced from the BMKG Deli Serdang. In this study using frequency analysis and then proceed with the Gumbel Probability Distribution method, Normal Distribution Log Person Type III. The result of this study with hydrological data and distribution test, the suitable method for analyzing the planned flood discharge in the Deli River is Log Person Type III that it can be flood discharge for a 2 year retention period is 10.87149701 m3/sec, 5 year return period is 12.5078977 m3/sec, 10 year return period is 13.17856545 m3/sec, 25 year return period is 13.74739842 m3/sec, 50 year return period is 14.03765049 m3/sec and a 100 year return period is 14.25076212 m3/sec.

Keywords: Rainfall, Deli River, Planned Flood Discharge

INTRODUCTION

Indonesia is a country that is at risk of flooding every year. Floods occurred in several places throughout Indonesia. There are around 464 floods occur in Indonesia every year. In fact, Indonesia is a country with the sixth worst flood disaster in the world.The current system capacity is no longer able to accommodate the flow rate that causes flooding in a certain area. During the rainy season, there is often an increase in flow rate, or an increase in discharge due to various reasons.Amountbulkthe rain that falls is also higher than the daily average, which is around 240-280 mm.Meanwhile, high rainfall and inadequate drainage capacity are the main contributions to the increase in runoff which is the target of the onset of the flood season in the area.

Medan City is the capital city of North Sumatra Province with a population of 2,279,894 people with an area of 26,510 ha (265.10 km2) or 3.6% of the total area of North Sumatra Province. Medan. Natural disasters involving floods always occur when the rainy season comes. The condition of the Deli River and Belawan River in the upstream area has a significant impact on the frequency of flooding in Medan City, which on average occurs 10-12 times each year. The flood disaster in Medan

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City which hit the Karo Regency, Deli Serdang Regency, and Medan City was caused by the current from the upstream river and the city's very poor drainage (Tampubolon,2018).

Flooding is a condition where normally dry land becomes submerged with water. This is caused by high rainfall, poor topography near the basin, and low soil infiltration capacity, which prevents the soil from retaining and absorbing water (Nuryanti et al., 2018). However, flooding can also be caused by circumstances where the river discharge increases as a result of high rainfall which causes it to overflow and inundate the surrounding area. Over the past few years there has been an increase in the number of floods during the rainy season, resulting in varying losses for individuals affected by flood disasters.

Medan Maimun District is one of the sub-districts in Medan City which consists of 6 sub-districts and with an area of2.98 km²and the population density is 16,520 people/km². Meanwhile in 2021, the population of Medan Maimun is 52,247 people. Medan Maimun Districtis one of the flood-prone areas that are fed by the Deli River. The cause of the flooding that occurred in Medan Maimun District was high rainfall so that the river flow rate increased and poor drainage.So that the problem of flooding in the Deli river watershed, Medan Maimun sub-district, can hamper community activities, these floods can also harm and endanger the community.

Based on the information above, this is also a separate problem in estimating the planned flood discharge considering the large losses incurred by floods, especially in the Deli watershed due to the neglect of flow analysis to obtain the value of the planned flood discharge with several return times in the study area. The planning and design of hydraulic structures is highly dependent on the flood discharge design. So a flood discharge plan is needed to assist in flood prevention efforts.

In this study, we will look for a flood discharge plan for each return period of the Deli River in Medan Maimun District which requires maximum daily rainfall data for the area located in Medan City, North Sumatra Province for a period of 10 years from 2013-2022 which is used to design the management building. flood. This study uses a frequency distribution, namely the Gumbel probability distribution method, the Pearson type III log probability distribution, the normal probability distribution and the log normal probability distribution to determine the design flood discharge for return periods of 2, 5, 10, 25, 50 and 100 years, while for the compatibility test using Chi-Square and Kolmogorof –Smirnov to find out whether the method used is suitable for data analysis used or not.

According to research (Sondak et al., 2019) entitled Analysis of Flood Discharge and Water Level of the Girian River, Bitung City using the HSS Soil Conservation Service and SCS Curve Number (CN) methods that all cross sections of the river cannot accommodate river discharge starting from the return period discharge of 25 years until the discharge period returns 100 years.

According to research (Hidayat et al., 2022) with the titleAnalysis of the Design Flood Discharge using the Nakayasu Synthetic Unit Hindrograph Method on the Sokong River, North Lombok Regency using the HSS Nakayasu method. The flood discharge obtained in a 25 year period of 131,32 m^3/s a50 year return period of 146,74 m^3/s, and the100 year return period of 1162.03 m^3/s occurs at 1.5 hours.

LITERATURE REVIEWS

Analysis of the Trend of Increasing Rainfall and Evaluation of Rainfall Data for Drainage Planners in the City of Gunungsitoli (Fricilia, 2020). This study focuses on the design of drainage structures using design flood discharge with rainfall data to determine the dimensions of the essiting channel that corresponds to the design flood discharge using the normal and gumbel distribution frequency distribution method. The fit test used the Chi Square Test and the Smirnov-Kolmogorov Test. From the results of the calculation of the planned flood discharge, the dimensions of the existing drainage channel with a size of 0.4 m × 0.5 m in the Jalan Diponegoro area, Pasar Gunungsitoli Village for return periods of 5, 10, 20 years, etc., cannot accommodate the magnitude of the planned flood discharge in research area. So that from the results of re-planning the dimensions of the drainage channel, the channel dimensions are obtained according to the planned floor discharge, namely 1,2 x 1, 2 m, this dimension is safe for design flood dischage of 5,10, 20, 50, 100 years.

It can be seen in previous studies using four distributions, namely the normal method, normal log, Pearson type III log, and Gumbel but this distribution is only used to predict the largest rainfall that

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occurs. So this study uses the four distribution methods, namely the normal method, normal log, Pearson type III log, and Gumbel to find the planned rainfall value which will be combined with the rational method to determine the flood discharge plan for each return period, because the rational method results are closer measurable discharge to help prevent flooding in Medan Mimun District.

METHODS

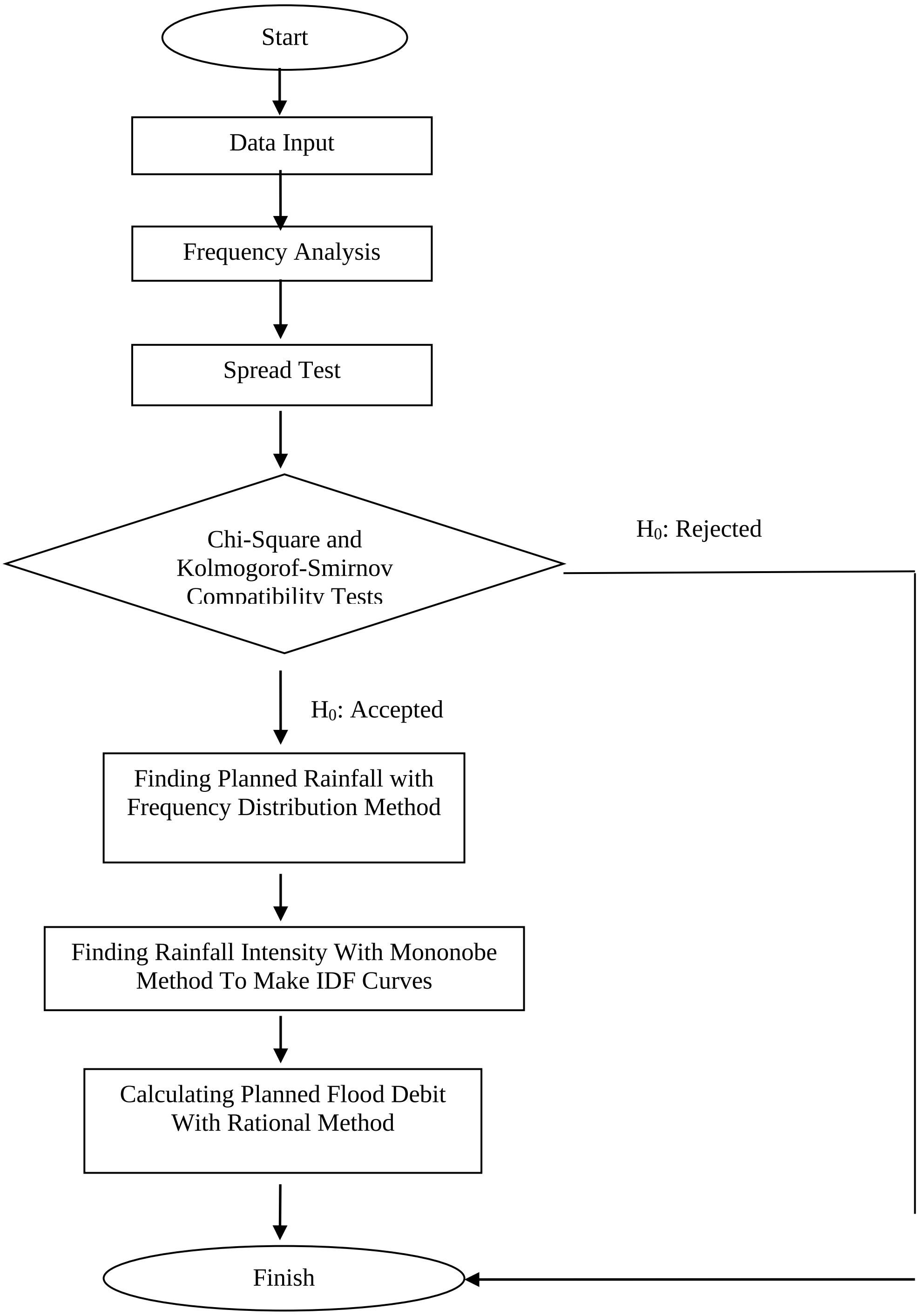

Figure 1. Research Flowchart (flowchart)

This type of research is research with a quantitative approach and the research method used is secondary data analysis method. The data analysis used in this study is the analysis of the planned

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flood discharge frequency in the Deli river using the Gumbel Probability Distribution method. The type of data used by the author is secondary data on daily rainfall for 10 years from 2013-2022 originating from the Climatology and Geophysics Agency (BMKG) Deli Serdang and in the form of a map of the Deil river flow, the length of the river flow and the area of the river flow were obtained from Balai Sumatra River Basin (BWS) II. The procedure in this study includes:

1. Input the data that has been obtained, namely secondary data sourced from the Sumatra II River Basin Office (BWS), namely the map of the Deli river, the length of the Deli river, and the area of the Deli river. Meanwhile, daily rainfall data from 2013-2022 is sourced from the BMKG Deli Serdang.

2. Calculating frequency analysis to determine the type of distribution with statistical parameters in the form of the average value, standard deviation, kurtosis coefficient, and coefficient of variation with the following formula:

   a. Average value

   $$\bar{X} = \frac{\sum X_i}{n} \quad (1)$$

   Where :
   $\bar{X}$ = Average value
   X_i = i-th value
   n = Number of Data

   b. Standard Deviation (S)

   The standard deviation/standard deviation of the data that has been compiled in the Food Recall processing results table can be calculated using the following formula:

   $$S = \sqrt{\frac{\sum(x_i - \bar{X})^2}{(n-1)}} \quad (2)$$

   Where :
   S = Standard Deviation
   x_i = Value x to i to n
   $\bar{X}$= Average value
   n = Number of Samples

   c. Coefficient of Variation (Cv)

   The coefficient of variation (variation coefficient) is a comparison value between the standard deviation and the calculated average value of a distribution. The following formula is used to calculate the coefficient of variance:

   $$C_V = \frac{S}{\bar{X}}$$

   Where : (3)
   C_V = coefficient of variance
   S = standard deviation
   $\bar{X}$ = the average value of the variant

   d. Skewness Coefficient (Cs)

   Skewness is a value that indicates the degree of asymmetry of a distribution shape. The calculation of the skewness coefficient uses the following formula:

   $$C_S = \frac{n\sum_{i=1}^{n}(X_i - X)^3}{(n-1)(n-2)S^3} \quad (4)$$

   Where:

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Cs = skewness coefficient
Xi = variant value to i
$\bar{X}$ = the average value of the variant
n = amount of data
S = standard deviation

e. Curtoral Coefficient (Ck)

$$C_K = \frac{\frac{1}{n}\sum_{i=1}^{n}(X_i - \bar{X})^4}{S^4} \qquad (5)$$

Where:
C_K = Curtoral Coefficient
X_i = i-th value
$\bar{X}$ = Average value
n = Number of Data
S = Standard Deviation

3. Determine the appropriate type of distribution based on existing statistical parameters to select the appropriate method for the existing rainfall data.

4. Perform a fit test with Chi-Square and Kolmogrov-Smirnov to find out whether the type of distribution that can be obtained is H0: accepted or H0: rejected. If accepted, the analysis can be continued, but if rejected, the analysis cannot be continued.

5. Perform rainfall analysis for re-planning 2, 5, 10, 25, 50 and 100 for rainfall data Frequency distribution analysis using the normal distribution method, Normal Log Distribution, Gumbel Distribution, and Orang III Log Distribution with return periods of 2, 5, 10, 25, 50 and 100. With the following formula:

a. Normal Distribution
The formula for calculating the planned flood discharge based on the Normal Distribution:

$$X_T = \bar{X} + K_T S \qquad (6)$$

Information :
X_T = Planned discharge with a return period of T years
$\bar{X}$ = Average maximum rainfall
K_T= Other frequency factors depending on "t", the value obtained from Gauss Reduction Variation Table
S =Standard deviation

b. Gumble distribution

$$X_T = \bar{X} + \frac{Y_t - Y_n}{S_n}.S \qquad (7)$$

Information :
XT = Debit plan
$\bar{X}$= average rainfall
N = Many years of observation data
S = standard deviation
Yn = Reduced mean (relationship with lots of data, n)
YT = Reduced variate (relationship with return Period, t)
Sn = Reduced standard deviation (relationship with the amount of data, n).

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YT, Yn and Sn values have been defined in the table

c. Normal log distribution
The formula for calculating the planned flood discharge based on the Normal Log Method:

$$Log\ X_T = Log\ \bar{X} + K_T . S\ Log\ X \quad (8)$$

Log Xt = Planned debit logarithm value with period birthday T(mm)

Log X = Average value of Log Xt $= \frac{\sum_{i=1}^{n} Log\ X_i}{n}$ (9)

S Log X = Standard deviation from Log$\bar{X}$ $= \sqrt{\frac{\sum_{i=1}^{n}(\log X - Log\ X)^2}{n-1}}$ (10)

KT = Frequency factor herein depends on "t", the value of which obtained from the Gauss Reduction Variation Table

d. Distribution of Log Persons III
Formula :

$$Log\ X_T = Log\ \bar{X} + K_{Tr} . S . Log\ X \quad (11)$$

Log XT = Planned debit logarithm value with period birthday T(mm)

Log X = Average Value of Log Xi (mm)
Sd log X = Standard deviation from Log X

$$= \sqrt{\frac{\sum_{i=1}^{n}(\log X_I - Log\bar{X})^2}{n-1}} \quad (12)$$

K_{Tr} = Frequency coefficient, obtained based on the relationship Cs value with return period T,

$$C_s = \frac{n . \sum_{i=1}^{n}(\log X_I - Log\bar{X})^2}{(n-1)(n-2)(S . LogX)^2}$$

6. Conduct flood discharge analysis for planned return periods of 2, 5, 10, 25, 50 and 100 for rainfall data using the rational method.

Rational Method

$$Q = 0{,}00278\ C . I . A \quad (13)$$

Information :
Q = Debit (/sec)m^3
C = Surface flow coefficient
I = Rainfall Intensity
A = Watershed Area (Km^2)

RESULTS

The results of the research data to be analyzed are sourced from BMKG Deli Serdang, namely maximum daily rainfall data for 10 years from 2013-2022 which will be used to find design flood discharges assisted by Microsoft Excel software.
Table 1. Research Data

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Data Year	Maximum Daily Rainfall (mm/day)	Maximum Rainfall Occurrence Date
2013	111	11-December
2014	165	19-December
2015	90	25-November
2016	84	09-September
2017	135	02-December
2018	147	09-October
2019	159	05-May
2020	146	29-January
2021	124	26-November
2022	132	23-June
N=10	1293	

Source: NORTH SUMATRA CLIMATOLOGICAL STATION

Table 1 explains that the highest rainfall for 10 years, namely 165 mm, occurred on December 19, 2014. From the maximum daily rainfall data, the pattern of distribution is then calculated using frequency analysis calculations. The distributions that will be searched for frequency analysis include the normal distribution, gumbel distribution, normal log distribution, and Pearson type III log distribution.

Frequency Analysis

The frequency distribution is a forecasting, in the sense of the probability for the occurrence of a hydrological event which serves as the basis for hydrological planning calculations to anticipate every possibility that will occur. The basis for calculating the frequency distribution is parameters related to data analysis which include the average, standard deviation, coefficient of variation, and skewness coefficient.

Table 2. Results of Frequency Analysis of the Gumbel Distribution and Normal Distribution Methods

Parameters	**Results**
Average rainfall (X)	129,3
Standard Deviation (S)	27,38227326
Coefficient of Variance (Cv)	0,211773188
Skewness Coefficient (Cs)	−0,526513072
Kurtosis Measurement (Ck)	1,652291758

Table 3. Results of Frequency Analysis of the Normal Log and Log Person III Distribution Methods

Parameters	**Results**

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Average rainfall (X)	2,101872542
Standard Deviation (S)	0,093919155
Coefficient of Variance (Cv)	0,044683563
Skewness Coefficient (Cs)	−1,202969192
Kurtosis Measurement (Ck)	0,15579967

Spread Test

The statistical parameter test used to test the distribution of this research is the parameter distribution test. Before carrying out an analysis of the distribution of the planned flood discharge based on the results of the frequency analysis for each distribution, the data must meet the distribution test requirements, so that the distribution meets the predetermined requirements and can be used for further analysis.

Table 4. Distribution Test Results for Rainfall Data

SPREAD TYPE	CONDITION	CALCULATION RESULTS	CONCLUSION
Normal Distribution	$C_S = 0$ $C_K = 3$	$C_S = -0,526513072$ $C_K = 1,652291758$	Does not meet the
Normal Log Distribution	$C_S \approx 3C_V + {C_V}^2 = 3$ $C_K \geq 0$	$C_S = -1,202969192$ $C_K = 0,15579967$	Does not meet the
Gumble distribution	$C_S = 1.1396$ $C_K = 5,4002$ 2,5	$C_S = -0,526513072$ $C_K = 1,652291758$	Does not meet the
Distribution of Log Persons III	$C_S \neq 0$	$C_S = -1,202969192$ $C_K = 0,15579967$	Fulfil

Based on table 4, the selection of the distribution of rainfall above shows that the distribution test that is accepted and suitable for use in this study is the Log Person III Distribution.

Frequency Distribution Match Test

To test the suitability of the Pearson Log Method Type III, the Chi-Square and Smirnov - Kolmogorov fit tests were used to test the distribution of observations. Does the sample meet the distribution requirements tested or not.

The calculation of the Chi-Square test is as follows:

Table 5. Log Person Compatibility Test Results with the Chi-Square Test

intervals	Eph	Of	Ef-Of	(Ef-Of)2	$\frac{(\mathbf{Ef-Of})^2}{EF}$
X < 1.99758	2,5	2	0.5	0.25	0.1
1.99758< X <2.070882	2,5	1	1.5	2.25	0.9
2.070882 < X < 2.14418178	2,5	3	-0.5	0.25	0.1
1.14418278 < X < 1.217483944	2,5	4	-1.5	2.25	0.9
Amount	10	10	0	5	2

The results obtained from the compatibility test using the Chi-Square test found that the value of X count = 2 and X table = 3.841, it can be seen that the value of X count is smaller than X table which is 2 < 3.841 then H0: accepted, it can be concluded that the distribution of Log Person III is acceptable to determine the planned flood discharge.

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Calculation of the Kolmogorof –Smirnov Compatibility Test is as follows:

Table 6. Results of Compatibility Test of Log Person III Method with Kolmogorof –Smirnov

Xi	Log Xi	Empirical Probability (Pe) (%)	K	Wide Area Under the Normal Curve	P(xi)	Theoretical Opportunity (Pt) (%)	Delta P =[Pt-Pe] (%)
165	2.217483944	9.090909091	1.161150186	0.877	0.123	12,3	3.209090909
159	2.201397124	18,18181818	0.999581227	0.5398	0.4602	46.02	27.83818182
147	2.167317335	27.27272727	0.657298777	0.7454	0.2546	25,46	1.812727273
146	2.164352856	36.36363636	0.627524851	0.7357	0.2643	26,43	9.933636364
135	2.130333768	45.45454545	0.285852068	0.6141	0.3859	38,59	6.864545455
132	2.120573931	54.54545455	0.187828546	0.5753	0.4247	42,47	12.07545455
124	2.093421685	63.63636364	-	0.4681	0.5319	53,19	10.44636364
111	2.045322979	72.72727273	0.084876697	0.2843	0.7157	71.57	1.157272727
90	1.954242509	81.81818182	-	0.0694	0.9306	93.06	11.24181818
84	1.924279286	90,90909091	0.567958995	0.0375	0.9625	96.25	5.340909091
			- 1.482731257				
			- 1.783668723				
X logs Average	**2.101872542**	**S**	**0.099566278**	**DeltaMax(%)**			**27.83818182**

The results obtained from the compatibility test using Kolmogorof –Smirnov found that the Delta max table value = 0.2783818182 in the 2nd data. By using a 5% degree of confidence, we get Do = 0.409. It can be seen that the Delta max table value is smaller than the Do Critical value, namely 0.2783818182 < 0.409, then H0: is accepted, it can be concluded that the Log Person III distribution method is acceptable for determining the planned flood discharge.

Planned Rainfall

Before calculating the planned flood discharge, what must be calculated is the planned rainfall using the Log Person III distribution method. Before calculating the planned rainfall, first look for the KTR value of each return period by looking at the value of Skewness coefficient (Cs) from the Log Person III method.

Table 7. Planned Rainfall for Each Period

PUH	KTR	Maximum Daily Rainfall (mm/day)
2	0.195445397	131.8950833
5	0.843821848	151.7482098
10	1.085346778	159.8848794
25	1.280752939	166.7860698
50	1.377366944	170.3074635
100	1.44704033	172.8929747

It can be seen in Table 7 that the maximum daily rainfall for each return period has increased. The highest maximum daily rainfall occurs in the return period of 100 years, namely172.8929727 mm/day.

Rainfall Intensity

To get the rain intensity in a 12-hour period from daily rainfall data, the Mononobe formula is used as shown in the image below which is shown in the form of the IDF curve below.

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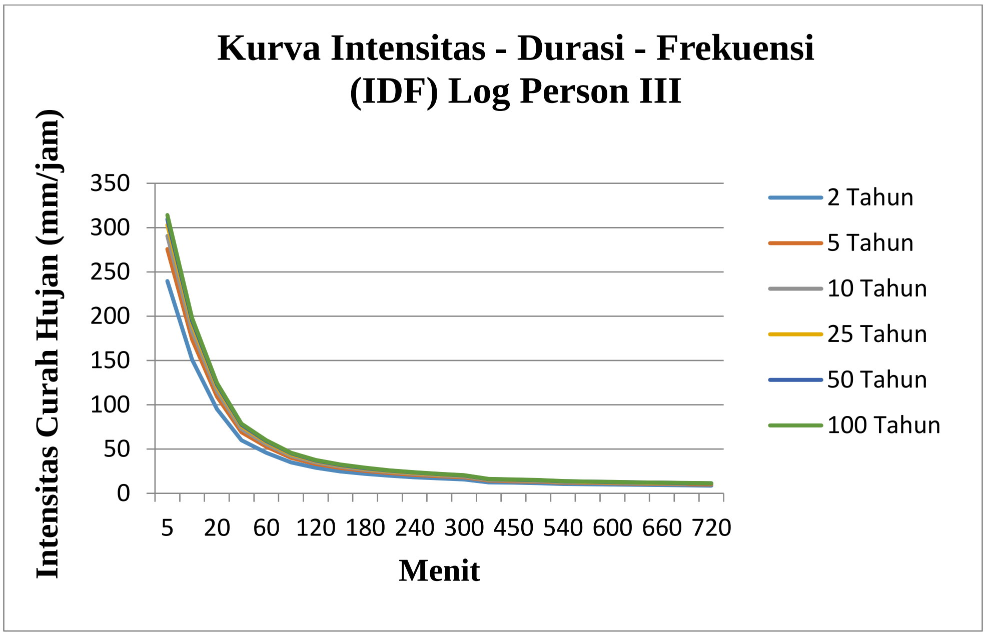

Figure 2. CurvesIntensity Duration Frequency(IDF) Log Person III

Based on Figure 2, the calculation of rainfall intensity is obtained by obtaining the intensity in the return period of 2 (I2) years, namely 239,669272 mm/hour , return period 5 (I5) years is 275,744797 mm/hour, the return period 10 (I1) years is 290,5301068 mm/hour, return period 25 (I25) is 303,070402 mm/hour, return period 50 (I50) year is 309,469199 mm/hour and return period 100 (I100) years is 314,1673847 mm/hour . The calculations obtained that High rain fall intensity occurs for a short duration. It can be concluded that heavy rain usually occurs in a short time and light rain occurs in a long time.

Flood discharge plan with rational method

The existing rainfall data in the Deli watershed in the Medan Maimun sub-district used table 1. And from the results of the frequency analysis the data used the normal distribution, gumbel distribution, normal log distribution, and type III Pearson log distribution. Using the distribution test, the values that meet the distribution are the Pearson log type III conditional distribution. and Kolmogorov – Smirnov test that type III pearson log distribution is acceptable. then the rainfall plan is issued table 7 with the Pearson log type III distribution method.

To find the results of the design flood discharge using the Rational method, primary data is needed, namely the area of the Deli watershed and the runoff coefficient and rainfall intensity for each return period. For the area of the Deli river basin, it is 349.88 km^2, while for the runoff coefficient, it is C = 0.95 (Urban Settlement Area). So the planned flood discharge can be obtained using the rational method using equation 13, namely:

2 Years Retrun Period (Q2)
$Q = 0{,}00278 \times 0{,}95 \times 11{,}76527 \times 349{,}88$
Q =10,87149701 m^3/sec

5 Years Retrun Period (Q5)
$Q = 0{,}00278 \times 0{,}95 \times 13{,}5362 \times 349{,}88$
Q =12,5078977 m^3/sec

10 Years Retrun Period (Q10)
$Q = 0{,}00278 \times 0{,}95 \times 14{,}26201 \times 349{,}88$
Q =13,17856545 m^3/sec

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25 Years Retrun Period (Q25)
Q = 0,00278 x 0,95 x14,8776 x 349,88
Q = 13,74739842 m^3/sec

50 Years Retrun Period (Q50)
Q = 0,00278 x 0,95 x15,19172 x 349,88
Q =14,03765049 m^3/sec

100 Years Retrun Period (Q100)
Q = 0,00278 x 0,95 x 15,42235x 349,88
Q =14,25076212 m^3/sec

Table 8. Flood Discharge Result Plan Using Rational Method

PUH	KTR	Maximum Daily Rainfall (mm/day)	Rainfall Intensity	Q Design (m^3/sec)
2	0.195445397	131.8950833	11.7652682	10.87149701
5	0.843821848	151.7482098	13.53620122	12.5078977
10	1.085346778	159.8848794	14.26200613	13.17856545
25	1.280752939	166.7860698	14,87760419	13.74739842
50	1.377366944	170.3074635	15.19171856	14.03765049
100	1.44704033	172.8929747	15.4223506	14.25076212

DISCUSSIONS

Analysis of maximum daily rainfall data for 10 years using the Gumbel probability distribution method, the Pearson type III log probability distribution, the normal probability distribution and the normal log probability distribution which were calculated using the help of excel software. Before proceeding to the flood discharge analysis stage, each method was tested for distribution and with statistical parameters so that the suitable method for rainfall data used in this study was Log Person III. After testing the distribution of the Log Person III method, it was tested for compatibility with Chi-Square and Kolmogorof –Smirnov so that from the two compatibility tests H0: was accepted. it can be concluded that to determine the planned flood discharge is to use the Log Person III method. So that this research can be continued by determining the planned flood discharge using the rational method. In this study only use rainfall variables because there are limitations in obtaining river flow discharge variables. My suggestion for further research is to add research variables to river flow discharge so that the results of the analysis obtained can be seen which variable is closer to the measured flood discharge.

CONCLUSION

Based on the results of the Chi-Square fit test that the value of X count < X table is 2 < 3.841, and for the Kolmogorof –Smirnov fit test it is found that by using a 5% degree of confidence the value of Delta max is smaller than Critical Do which is 0.27838118 < 0, 41, for the two compatibility tests, H0: is accepted. it can be concluded that to determine the planned flood discharge is to use the Log Person III method with the results of the planned flood discharge, namely a 2-year return period of 10.87149701 m³/sec, a 5-year return period of 12.5078977 m³/sec, a 10-year return period of 13.17856545 m³/sec , 25 year return period of 13.74739842 m³/sec, 50 year return period of 14.03765049 m³/sec, and 100 year return period of 14.25076212 m³/sec.

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