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Deli River Flood Controlin the Maimun District Area Medan City

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Abstract— Flooding is a common issue in urban areas, caused by high rainfall intensity that increases river discharge and leads to overflow, as the river channel capacity cannot accommodate such large water volumes. In the city of Medan, one of the rivers that passes through the areais the Deli River, which stretches for72 km and has a watershed area of 472.96 km², starting from Karo Regency to Medan City.One of the most urgen turban problems that needs to be addressed is flooding.Sei Mati Subdistrict, located in the Medan Maimun District, is one of the areas in Medan considered prone to flooding, especially in residential zone salong the banks of the Deli River. This research employs aquantitative-based approach. It utilizes both primary and secondary data, suchas maximum rainfall data, crossand long sections of the Deli River, land use data, and the locations affected by floods. These data are then analyzed hydrologically to obta in the design flood discharge.There sults of the hydrologi calanalysis are then further analyzed hydraulically using the HEC-RAS 5.0.7 software. From the hydrological analysis, the planned flood discharge was obtained using the Nakayasu Synthetic Unit Hydrograph (SUH) method, resulting in values of: Q2=358.300m³/s, Q5=434.478m³/s, Q10=491.722m³/s, Q25=571.716m³/s, and Q50=571.716m³/s. From the hydraulic analysis using HEC-RAS 5.0.7, it was shown that thereisan approximate increase in flood height of ±25cmforthe 2-year return period compared to the 2023 flood event, with a total water surface elevation of 3.92 m for the 2-year returnperiod. Therefore,the construction of a5-meter-high levee on the right river bank is necessary.This height has accounted for the minimum peak discharge value in the2ndyear,which is434.378 m³/s.This solution is considered optimal for minimizing flood risk during the 2-year return period along the Deli River.

Keywords: Planned Discharge, Deli River, Flood, Water Surface Elevation, HEC-RAS

1. INTRODUCTION

The geographical conditions of Medan City are areas that have a sloping/flat topography which has been converted into residential and business areas.

As a result of this impact, the general problem in Medan Maimun District is that it is one of the urban areas prone to flooding. intensity of rainfall and the local people's habit of throwing rubbish carelessly, in addition there is a difference in the existing elevation on the left and right where the settlement across the Deli River only has 1 embankment cliff.

According [1],factors causing flooding include. Changes in land use,waste disposal, erosion and sedimentation, slum areas, inadequate flood control systems, high rainfall, river physiography, inadequate river capacity,the influence of hightides, land subsidence, water structures, and damage to flood control structures.

According [2] , channels can be divided into two types: closed and open channels. There are two differences between the two closures. The flow in closed and open channels is called free surface flow, or atmospheric pressure. hydraulic [3]

Many factors contribute to flooding. However, in general, the causes of flooding can be classified into two categories: natural flooding and human- caused flooding. Technical approach in estimating river capacity for flood discharge. [7].

Based on this problem, asaresearcher, I chose this titleasa solution to control flood discharge indeli river. Therefore, it is necessary to first conduct a flood discharge analysis.

As an initial step in flood management efforts,with the aim of analyzing maximum rainfall of 10 years to obtain the planned flood discharge for the next 2.5,10, 25, and 50 years and analyzing the river capacity to overcome flood problems, using the HEC-RAS application version 5.0.7 [4].

1.1 Hydrology

According to Suripin [6], there are three methods used to calculate regional average rainfall:1)Algebraic average, 2) Thiessen polygon method, and 3) Isohyet method.

The equation for calculating average rainfall using the algebraic average method can be formulated as follows:

$$d = \frac{d_1+d_2+d_3+..}{n} = \sum_{i=1}^{n} \frac{d_i}{n} \quad \ldots (1)$$

Thiessen Polygon Method:

$$d = \frac{A_1.P_1+A_2.P_2+ \ldots.+A_n.P_n}{A_1+A_2+A_n} \quad ..(2)$$

Isohyet Method

$$d = \frac{\sum \frac{d_{i-1}+d_i}{2} A_i}{\sum A_i}$$

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1.2 Designed Flood Discharge Analysis

Consider the analysis of planned/design rainfall distribution, the distribution selection must be accurate; therefore, distribution suitability testing is conducted. After obtaining the planned rainfall data, an evaluation is conducted to determine the planned flood discharge. In this study, the method used was the Nakayasu Synthetic Unit Hydrograph (HSS).

Nakayasu has studied flood hydrographs in several rivers in Japan [8]. The Nakayasu Synthetic Unit Hydrograph (HSS), introduced by Nakayasu, is an approach for generating a design flood hydrograph in a river basin. To use this method, when designing a flood hydrograph for a particular river, it is necessary to identify the characteristics or parameters of that river . [6]. The following are the river characteristics and equations used in the design flood analysis:

1.3 Distribution Statistical Parameters

There are several types of known frequency distributions, and in hydrology there are four methods that are generally used in rainfall analysis, the four distribution methods are Normal, Log Normal, Log Pearson III, and Gumbel distributions.[9]

a. Gumbel Method

$$\boldsymbol{XT} = \bar{\boldsymbol{X}} + \boldsymbol{S} \cdot \boldsymbol{K} \quad (4)$$

b. Normal distribution

$$XT = \bar{X} + KT \cdot Sd \quad (5)$$

c. Log Normal Distribution

$$Log\ XT = \overline{Log\ XT} + KT \cdot S\ Log\ X \quad (6)$$

1.4 Rainfall Intensity

Rainfall intensity is the amount or density of rainfall per unit of time (mm/hour). [3]) found that the Intensity-Duration-Frequency (IDF) is essentially a relationship that indicates the intensity, duration, and frequency of rainfall. When analyzing rainfall intensity, short-term data such as 5 minutes, 10 minutes, 30 minutes, 60 minutes, and hours must be analyzed to create an IDF curve. Several formulas exist for analyzing precipitation intensity, including the Van Breen formula and the Mononobe formula.

The difference in the formulas used to determine rainfall intensity lies in the type of rainfall data used. When using daily maximum rainfall data, the Mononobe formula is used. The formula for calculating (Kamiana, 2011) :

$$I = \left(\frac{R_{24}}{24}\right) \quad (7)$$

1.5 Hourly Rainfall Distribution Pattern (Hymetograph)

According to Triatmodjo (2008), when analyzing hourly rainfall distribution patterns, flood events should be assumed based on the average duration of flooding in the area, which can be assumed to be 6 hours in the case of Indonesia. The following are the steps for analyzing hourly rainfall distribution patterns [10].

1. Using the results of the Monobe method of rainfall intensity.
2. Rainfall depth X
3. Percentage of difference in sequential rainfall depth
4. Calculation of the Hietograph value

1.6 Planned/Designed Flood Discharge Analysis

Nakayasu has studied flood hydrographs in several rivers in Japan. (Hadisusanto, 2010). Nakayasu's synthetic unit hydrograph (HSS) introduced by Nakayasu is an approach to generating a design flood hydrograph in a river basin. To use this method, when designing a flood hydrograph in a particular river, it is necessary to discover the characteristics or parameters of the river. [6] . The following are river characteristics and equations in the design flood analysis:

1. The time required from the start of rainfall to the peak of the hydrograph. (time lag.tg)

$$tg = 0.21\ L^{0,70} \quad (8)$$

2. The time required from the moment the center of gravity of the rainfall occurs to the center of gravity of the hydrograph. (Time lag / Tr)

$$Tr = 0,75 \text{ x } tg \quad (9)$$

3. Base flow discharge (Qb)

$$Qb = 0,4715 \text{ x } A^{0,6444} \text{ x } D^{0,943} \quad (10)$$

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4. Peak Flood Discharge (Qp)

$$Qp = \frac{C{\cdot}A{\cdot}R{\cdot}o}{3{,}60\ (0.30\ Tp+To)} \qquad (11)$$

1.7 Hydraulic Analysis

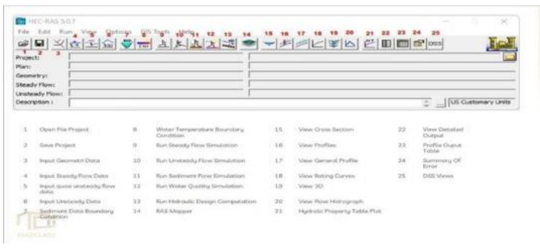
According to [2], channels can be divided into two types: closed and open channels. There are two differences between the two covers. The flow of closed and open channels is called free surface flow, or atmospheric pressure. Types of free surface flow can be grouped based on various criteria used as references. According to Suripin [3] the classification of flows comes in two types due to changes in depth or speed over time: permanently (stable) and permanently (inconsistent). In addition, variations in space allow for the separation of rivers evenly (unevenly). Below is a clarification of hydraulic pressure [3].

1.8 HEC-RAS

[5] stated that the Hydraulic Engineering Center- River Analysis System (HEC-RAS) is an application designed to describe river flow. The River Analysis System (RAS) program was developed by the Hydraulic Engineering Center (HEC), a division of the Institute for Water Resources (IWR) under the United States Army Corps of Engineers (USACE). HEC-RAS is a one-dimensional flow model for both steady and unsteady flow. The HEC-RAS application is used to model river flow, irrigation channels, drainage channels, and other open channel cross- sections. There are four components of the 1D model in the HEC-RAS application program:

- Calculation of non-uniform flow water surface profiles
- Uniform flow modeling
- Sediment transport calculations
- Water quality calculations.

Below are some of the tools from Hec-Ras:



II. RESEARCH METHODOLOGY

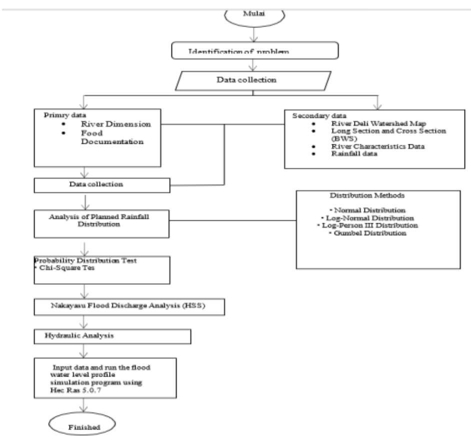
2.1 Location

The research location was conducted directly in the Deli River Basin in Medan City. Geographically, the Deli River Basin is located at coordinates between 3° 29′ 25" - 3° 35' 30" North Latitude and 98° 37′ 30" - 98° 40′ 20" East Longitude.

Information on river topography in the area was obtained by asking BWSS II Medan City employees, then collecting the necessary supplementary data at the Sumatra II River Basin Office (BWSS).

2.2. Data Collection

Data that supports the research and provides an overview of the research's scope. Data collection is obtained through relevant institutions, such as journals, the internet, and other data sources.



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III. RESULTS AND DISCUSSION

3.1. Hydrological Analysis

This hydrological analysis aims to determine the magnitude of the planned flood discharge, which will later be used as input for the HEC-RAS 5.0.7 application. The discharge analyzed is flood discharge with return periods of 2, 5, 10, 25, 50, and 100. The flood discharge calculation method uses rainfall data from the last 10 years, converted into surface runoff. The data used in the flood discharge analysis is rainfall data in Medan for the last 10 years, calculated from 2014 to 2023, obtained from the Sampali Class I Rainfall Station of the Meteorology, Climatology, and Geophysics Agency (BMKG), North Sumatra. Table 1 displays the recapitulation results to obtain Rmax for each year.

Table 1. Summary of Annual Maximum Rainfall for the Last 10 Years

No	Tahun	Hujan Rata-rata (mm)	XI (mm)
1	2014	112	201
2	2015	107	160
3	2016	159	159
4	2017	201	131
5	2018	160	127
6	2019	127	117
7	2020	131	112
8	2021	109	111
9	2022	111	109
10	2023	117	107
		Jumlah	1334
		Banyak Data	10

3.2. Log-Normal Distribution Method

For rainfall data with a value of 10, the Gaussian variable reduction value is determined for a normal distribution. The rainfall value for the t-year (return period) can be determined using the normal distribution method, as shown in the table below:

Table 2. Recapitulation of Rainfall Plans Using the Log Normal Method

Tr (Year)	Ktr (m^3/s)	XT
100	2,326	213
50	2,021	200
25	1,72375	188
10	1,282	171
5	0,842	156
2	0	131

Table 3. Person III Log Distribution Method

Tr (Year)	Ktr (m^3/d)	XT
100	3,072	250
50	2,575	225
25	2,060	202
10	1,340	173
5	0,748	153
2	-0,176	126

3.4. Flood Analysis Plan

Main River Length (L) = 72.00 km Watershed Area (A) = 344.84 km² Unit Rainfall (R0) = 1 mm

River Slope (Sb) = 0.00611 Irrigation Coefficient (C) = 0.300

Based on the data from each parameter, the unit hydrograph can be calculated as follows:

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1. Delay Time (tg)
   For L > 15 km, the equation used is tg = 0.21 x L x 0.70

   = 0.21 x 72.00 x 0.70

   = 4.576 hours

2. Duration of Rainfall (Tr) Tr = 0.75 x tg
   = 0.75 x 4.576

   = 3.432 Hours

3. Flow coefficient (α)
   $0,47\ x\ (A\ x\ L)^{0,25}$

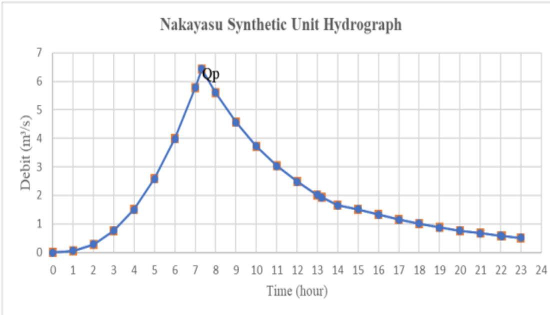

Figure 1. Nakayasu Synthetic Unit Chart of Deli River

3.5. Deli River Flow Simulation

In assessing the existing capacity of the Deli River to accommodate the planned flood discharge based on hydrological analysis with return periods of 2, 5, 10, 25, 50, and 100 years, a hydraulic analysis in the form of flow simulation is necessary. In this study, the hydraulic analysis uses HEC-RAS 5.0.7 software to provide an overview of the water level profile in one-dimensional flood analysis and the flood inundation area using two- dimensional flood analysis.

A. Water Level Simulation Results (One Dimension)

One-dimensional river flow analysis is an analysis that determines the flood level on the existing Deli River based on the existing conditions of the Deli River and the planned flood discharge. The river geometry used in the one-dimensional simulation is based on measurements from the North Sumatra Provincial River Basin Office. The existing river data from this agency are not used in their entirety; instead, the geometric data is combined with actual field conditions because the measurements do not all take into account existing water structures on the river, such as embankments. The following are the results of the Deli River flow simulation based on the planned flood discharge for 2, 5, 10, 25, 50, and 100 years:

Figure 2. Simulation Results of 1-dimensional Stationary Map (Source: Author's Analysis, 2025)

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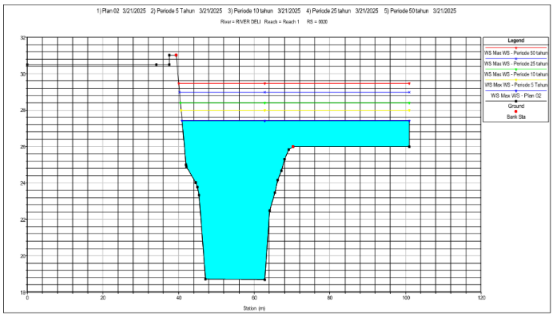

Figure 3. River Flow Simulation Results of Running the River Cross Profile STA 0020 (Source: Author's Analysis, 2025)

B. Flood Inundation Area Simulation Results (Two Dimensions)

The planned flood discharge with hourly duration is due to the flood inundation analysis using unsteady flow simulation. After preparing all the data to be used to run HEC-RAS, the next step is to input each river basin data, such as the planned flood discharge and river slope values. The existing river length analyzed in two dimensions is STA 0 + 016 - 0 + 044. The following are the results of the two-dimensional Deli River flow simulation:

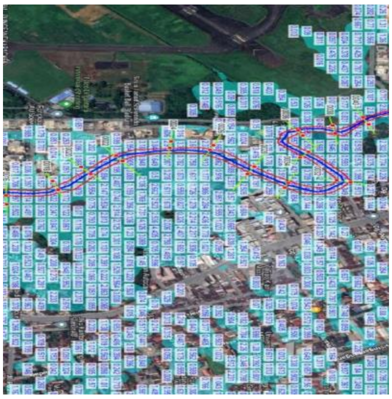

Figure 4. Flood Area of the Deli River at 2-Year Return Period (Source: Author's Analysis, 2025)

Figure 5. Flood Inundation Area of the Deli River at 5-Year Return Period (Source: Author's Analysis, 2025)

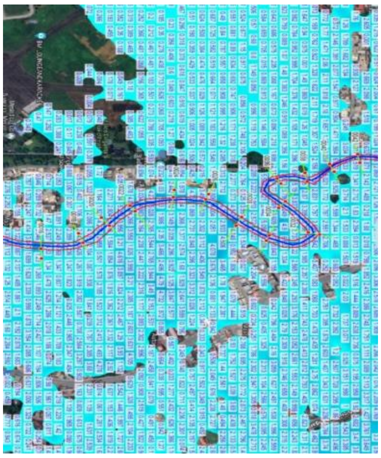

Figure 6. Deli River Flood Inundation Area at 10- Year Return Period (Source: Author's Analysis, 2025)

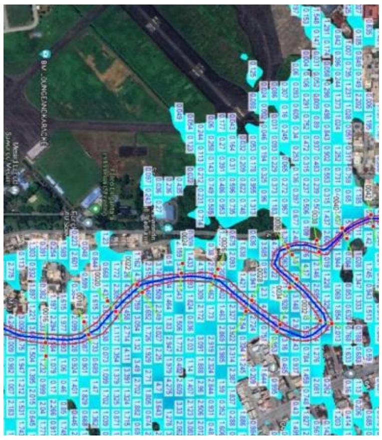

Figure 7. Deli River Flood Inundation Area at 25- Year Return Period (Source: Author's Analysis, 2025)

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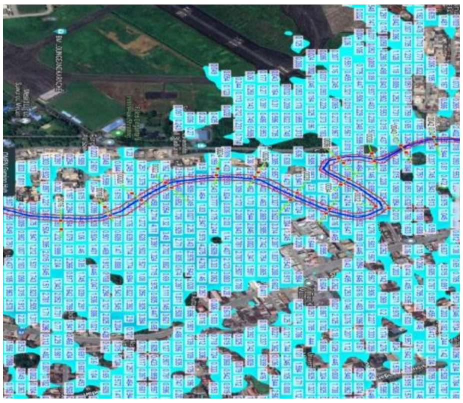

Figure 8. Flood Area Flood Area of the Deli River at 50-Year Return Time Source: Author's Analysis, 2025 Flood Area of the Deli River at 50-Year Return Time (Source: Author's Analysis, 2025)

III.CONCLUSION

Based on the description in the discussion, it can be concluded:

1. The planned flood discharge is obtained from a hydrological analysis, starting with rainfall frequency analysis, rainfall intensity analysis using the Mononobe method, hourly rainfall distribution pattern analysis (Hydograph) using the Alternating Block Method (ABM) method, effective rainfall analysis, and finally, flood discharge analysis using the Nakayasu Synthetic Unit Hydrograph (HSS Nakayasu) method. The planned flood discharge results are (Q2) = 358,300 m3/s, Q5 = 434,478 m3/s, Q10 = 491,722 m3/s, Q25 = 571,716 m3/s, and Q50
= 571,716 m3/s.
2. Flood heights in neighborhoods VIII and IX of Sei Mati sub-district, based on the planned flood discharge, are as follows:
2-Year Return Period (Q2 Max) = ± 1.75 meters; 5-Year Return Period (Q5 Max) = ± 2.10 meters; 10-Year Return Period (Q10) = ± 2.40 meters; 25-Year Return Period (Q25) = ± 3 meters;
50-Year Return Period (Q50) = ± 4 meters
Based on the results of the flow simulation using HEC-RAS 5.0.7, it appears that there was an increase in flood height of ± 25 cm during the 2-year return period from the 2023 flood of ± 370 cm due to the overflow of the Deli River
3. An alternative solution to address the flooding problem in Neighborhoods VIII and IX, Medan Maimun District, can be obtained through hydrological and hydraulic analysis. This solution could include the construction of water infrastructure in the form of a 5-meter-high embankment. This takes into account the minimum Qpuncak (designed flood discharge) value in Year 2, which is 358,300 m3/d. This solution is considered optimal for minimizing flooding during the 2-year return period on the Deli River. The planned embankment is located on the right side, as it is functionally effective in maintaining and preserving the existing natural ecosystem.

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