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The Analysis of the Vertical Clearance of the Jembatan 1 on Samarinda City, East Kalimantan

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Abstract— *The Samarinda City is traversed by several natural rivers. The Karang Mumus River is the second longest and the second larges river that crosses Samarinda City after the Mahakam River. The first bridge built across the Karang Mumus River in the early 1900s was then known as Jembatan 1. This bridge connects the city area to Selili Village. The flow under the bridge functions as traffic for small vessels such as boats and speed boats. This research aims to analyze the height of the flood water level under the bridge in relation to the vertical clearance of the bridge. Flood water level elevation is predicted using HECRAS simulation by inputting 50-year flood discharge. The Nakayasu flood discharge is based on design rainfall resulting from regional rainfall frequency analysis. The 50-year flood discharge is 535.31 m^3/s. HEC-RAS simulation results show that the flood water level at the highest tide is +1.98 m. The height of the free space (Clearance, C) of this bridge uses the criteria for a bridge on a natural river whose condition is not yet known (C= 2.5 m). So the lowest elevation of the bridge upperstructure is at least +4.48 m. This elevation is still in accordance with the current condition of the existing bridge.*

Keywords—*Flood water level; Jembatan 1 Samarinda; Vertical Clearance.*

I. INTRODUCTION

The Samarinda City is traversed by several natural rivers. The Karang Mumus River is the second longest and the second larges river that crosses Samarinda City after the Mahakam River. The first bridge built across the Karang Mumus River in the early 1900s was then known as Jembatan 1. This bridge connects the city area to Selili Village. The flow under the bridge functions as traffic for small vessels such as boats and speed boats.

Based on the condition of the age of the bridge and the traffic under the bridge, it is deemed necessary to routinely check the availability of vertical clearance on the bridge. This can be approached by simulating the water surface elevation when a flood occurs under the bridge.

Flood simulation through a cross-section of the river under the bridge and its surroundings in this research uses the Hydrologic Engineering Center-River Analysis System (HEC-RAS) application. Where flood discharge used as input in modelling using Nakayasu flood hydrograph analysis.

The benefits of this research is to obtain the height of the existing bridge's clearance during flooding at the same time as high tide conditions, as a reference in making policies regarding whether the elevation of the bridge's upper structure is fixed or needs to be raised.

II. LITERATURE REVIEW

A. The Bridge

A bridge is an construction whose purpose is to continue a road through a lower obstacle. (Struyk, 1984). These obstacles are usually other roads, namely, waterways or regular traffic.

In general, bridge has 3 main parts, namely the upper structures, the substructures and the foundation. The upper structures in the part of the bridge that functions to receive loads directly. The substructures is the part of the bridge that is useful for supporting the upper structure constructions. While foundation is the part of the bridge that plays the role of carrying of the entire load of the bridge.

Bridge clearance is a precautionary distance provided to avoid damage to the bridge's upper structure due to impacts from drifting objects passing under the bridge. Vertical clearance is measured from the flood water surface to the lowest limit of the bridge upper structure.

The amount of clearance varies, depending on the type of river and objects under the bridge (Dirjen Bina Marga, 2017). The minimum vertical clearance under the bridge: C=1.0 m for natural rivers that carry drift; C=1.5 m for natural rivers that carry drifts when they flood; C=2.5 m for natural rivers whose conditions are unknown.

B. Regional Rainfall Analysis

The rainfall required for the preparation of a water utilization plan and flood control plan is the average regional rainfall (area rainfall), not rainfall at a certain point (point rainfall). This rainfall is called regional rainfall and is expressed in mm. (Sosrodarsono, 1993)

There are three types of methods commonly used to calculate regional average rainfall: 1. Algebraic average, 2. Thiessen polygon, and 3. Isohyet. Thiessen polygon method is more accurate than the algebraic average method. This method is suitable for flat areas with an area of 500-5,000 km^2, and the number of rain measuring posts is limited compared to its area.

C. Design Rainfall Analysis

Design rainfall analysis is used to determine probability of maximum daily rainfall in a certain return period, the amount of rainfall being equalled or exceeded. There are 4 distribution methods that are often used, namely the Normal Method, Log Normal, E.J. Gumbel and Log Pearson Type III. The four types of distribution need tp be tested for suitability using the

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Smirnov-Kolmogorov test and Chi-Square test. The rain design resulting from this appropriate distribution will later be used to calculate rain intensity.

Rainfall intensity is the amount of rain mass that falls and is expressed in terms of the volume of rain per unit of time. If the available rainfall information is solely daily rainfall data, then the rain intensity can be determined using the Mononobe formula. (Suripin, 2003):

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

Where:

I_t : Rainfall intensity for the duration of rain t (mm/hour)
t : Duration of precipitation (hours)
R_{24} : Maximum rainfall for 24 hours (mm)
A : catchment area is a plain bounded by ridges or topographic boundaries to receive, store and drain rainwater that falls on it into river channels and flows into tributaries and main rivers, which then gather together into lakes, rivers or seas.

D. Design Flood Discharge

The designed flood discharge can be used as measured river discharge data or if there is no discharge recording, then the flood discharge is calculated from rain through hydrograph analysis.

The determination of the Nakayasu Synthetic Unit Hydrograph necessitates the following attributes of the flow area parameters: The greatest length of the principal river flow; Catchment area; Time base of hydrograph; Duration from rain surface to hydrograph peak (time of peak), and Duration from the intense point of rain to the intense point of the hydrograph (time lag). (Soemarto, 1987)

The calculation is as follow:

$$Q_P = \left(\frac{C.A.R_0}{3{,}6(0{,}3T_P + T_{0,3})}\right)$$

Where (Fig.1):

Q_P : Peak flood discharge (m^3/s)
R_0 : Unit precipitation (1/mm)
T_P : Time period from rain surface to hydrograph peak (hour)
$T_{0,3}$: Time required for discharge to decrease from peak to 30% from peak discharge (hour)
A : Watershed area (km^2)
C : run off coefficient

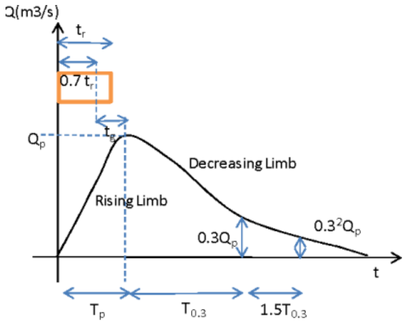

Fig. 1 Nakayasu Synthetics Unit Hydrogaph
(A.B. Safarina, et.al., 2011)

Next, calculating the design discharge for various recharges with the following equation: (Sri Harto, 1993)

$$Qk = U_1R_1 + U_2R_{1-1} + U_3R_{1-2} + \ldots U_nR_{1-(n-1)} + Bf$$

Where:

Qk : Flood hydrograph ordinate at 1st hour
Un : Unit hydrograph ordinate
R1 : Net rain at 1st hour
Bf : Base flow

E. Flood Water Level Analysis

Hydraulics analysis river cross-sections was calculated using HEC-RAS program. With this analysis, it is possible to determine the water surface elevation in a cross-section of a river when water flows through the river. The results of this analysis for planning the placement of the bridge.

HEC-RAS is a software program designed to model flows in the River Analysis System (RAS) river. HEC-RAS is capable of conducting one-dimensional calculations on steady flow water table profiles, one/two-dimensional computations on unsteady flow water level profiles, sediment transport calculations, water quality assessments, and hydraulic design elements. HEC-RAS is a software application that combines graphical user interface capabilities, hydraulic analysis, data management and storage, graphics, and reporting (Istiarto, 2014).

III. Research Methodology

The first analysis carried out is regional rainfall analysis based on watershed map and rain recording stations that are close to each other and are within the scope of the watershed. Regional rainfall calculations use the Thiessen Polygon method. Next, determine the type of regional average rainfall frequency distribution using 4 methods, namely, Normal, E E. J. Gumbel, Log Normal and Log Pearson Type III Distribution. This rainfall design was evaluated for distribution appropriateness utilizing the Smirnov-Kolmogorov test and Chi-Square test. The design rainfall amount according to the type of distribution is used as input in calculating flood discharge. This flood discharge serves as input data within the HEC-RAS application. HEC-RAS simulation produces a water level profile, so that the highest flood elevation that will occur can be known. Based on the vertical free space requirements, the minimum elevation for the placement of the bridge upper structure can be determined.

A. Research Sites

The research location is on the Samarinda City, East Kalimantan Province. This location is showed in Fig. 1 below.

B. Maximum Daily Rainfall

Rain data for 2008-2020 that occurred in the Karang Mumus watershed was recorded at nine rain recording stations in Samarinda. The rain stations are Sta. Karang Paci, Sta. Rapak Dalam, Sta. Rawa Makmur, Sta. Tanah Merah, Sta. Lempake, Sta. Pampang, Sta. Sempaja, Sta. Sei Siring, and Sta. Temindung. (Balai Wilayah Sungai Kalimantan IV Samarinda-Kalimantan Timur, 2021)

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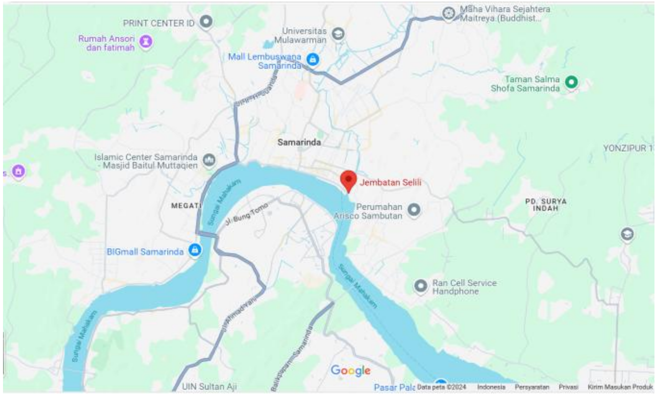

Fig. 1 Location of Jembatan 1 (Selili), Samarinda (Google Earth, 2024)

C. *River Basin and the Land Use*

Karang Mumus river basin and its land use are shown in Fig 2 and Fig. 3 below.

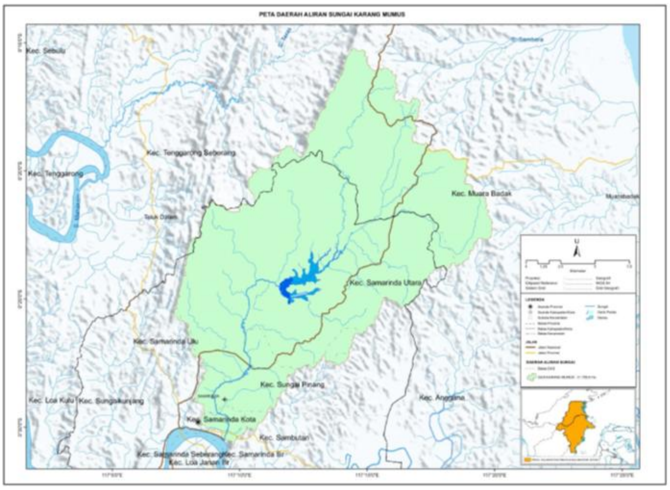

Fig. 2 The Karang Mumus River Basin
(PT. Antusias Raya, PT. Super Tehik Pratama, CV. Serba Prima)

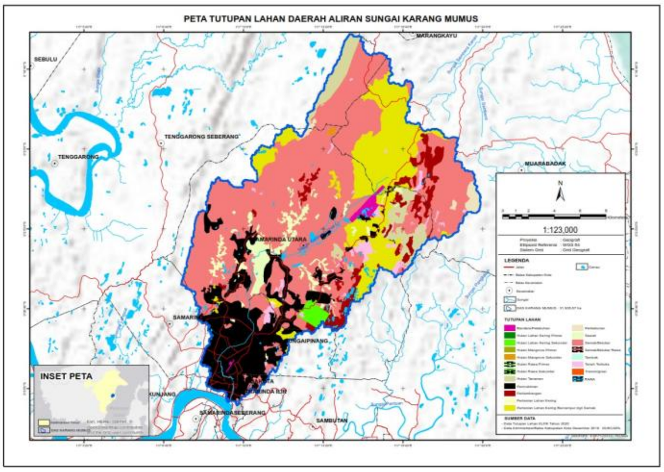

Fig. 3 The Land Use of Karang Mumus River Basin
(PT. Antusias Raya, PT. Super Tehik Pratama, CV. Serba Prima)

IV. Result and Discussion

A. *Regional Rainfall Analysis*

The method used is Thiessen Polygons and the polygons are shown in Fig.4 below.

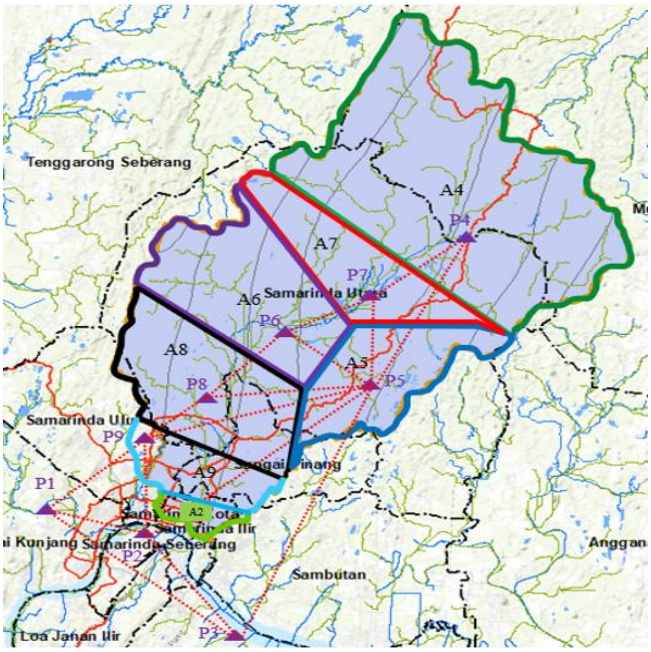

Fig.4 The Thiessen Polygon of Karang Mumus River Basin

And the regional rainfall calculations are summarized in Table 1 below.

TABLE I. The Regional Rainfall

Maksimum Daily Rainfall, Xi (mm)									Regional Rainfall
Karang Paci	Rapak Dalam	Rawa Makmur	Sei Siring	Tanah Merah	Lempake	Pampang	Sempaja	Temindung	
82,7	63,9	74,1	69,4	53,6	70,30	64,1	90,80	132,00	73,47
35,0	30,0	99,2	91,0	105,3	97,20	80,0	122,70	74,20	94,31
60,0	83,6	106,6	82,3	79,1	83,50	81,8	88,30	86,50	83,15
31,0	50,2	91,5	71,7	207,7	114,70	96,4	91,50	105,50	98,35
99,0	87,8	92,8	80,2	117,5	89,30	77,2	80,20	98,90	85,88
132,5	118,4	100,9	128,5	226,7	107,10	96,1	57,00	84,30	118,66
110,0	120,2	92,8	103,5	81,1	106,30	77,2	100,50	102,50	98,33
80,2	69,4	65,9	53,0	30,0	52,00	80,0	80,00	78,80	59,17
77,0	105,2	72,8	133,2	90,7	70,00	80,7	85,00	120,10	105,59
96,0	42,7	41,6	90,6	183,1	84,20	228,8	80,00	102,30	114,08
122,0	135,9	45,2	78,7	130,6	120,00	80,0	124,00	233,00	105,16
132,8	76,4	73,6	120,6	140,2	73,00	78,4	116,10	99,70	107,62
125,0	123,0	95,8	109,4	165,3	95,00	185,5	56,30	94,10	114,35

B. *Design Rainfall*

The results of rainfall calculations using the Normal Method, E. J. Gumbel Method, Normal Log Method and Log Person III Method are presented in the Table II below.

TABLE II. Design Rainfall

Return Period (Year)	Design Rainfall (mm)			
	Normal	E.J. Gumbel	Log Normal	Log Pearson III
10	119.03	127.17	122.74	117.76
20	125.29	139.72	131.85	120.69
50	132.41	155.96	143.06	124.33
100	151.25	168.13	151.25	125.90

The results of parametric tests on rain design using all three methods are shown in the following table below.

TABLE III. Parametric Test Results

Method	Criterion		Result
E. J. Gumbel	Ck ≈ 5.4	3,90	Not eligible
	Cs ≈ 1.14	-0,86	
Normal	Cs ≈ 0	-0,86	Not eligible
	Ck ≈ 3	3,90	
Log Normal	$Ck = Cv^8 + 6\ Cv^6 + 15\ Cv^4 + 16\ Cv^2 + 3$	3,03	Not eligible
	$Cs = Cv^3 + 3\ Cv$	0,13	
Log Pearson III	Ck = Bebas	4,98	Eligible
	Cs = Bebas	-1,26	

The results of non-parametric tests using the Smirnov-Kolmogorov test and Chi-Square test are summarized in Table IV as follows.

TABLE IV. Non Parameter Test Results

Method	Smirnov - Kolmogorov	Result (Δ max)		Chi - Square	Result (X^2)	
	Δ max < Δ kr			$X^2 < X^2$ Kritis		
E. J. Gumbel	Δ max < 0.34	0,148	Eligible	$X^2 < 5.991$	0.805	Eligible
Normal	Δ max < 0.34	0.113	Eligible	$X^2 < 5.991$	1.500	Eligible
Log Normal	Δ max < 0.34	0,187	Eligible	$X^2 < 5.991$	0.833	Eligible
Log Pearson Tipe III	Δ max < 0.34	0,158	Eligible	$X^2 < 5.991$	0,395	Eligible

From the both distributions assessed for adequacy, it is evident that the suitable distribution for the rainfall data is Log Pearson III. Then the design rain used in the next calculation is the 50 year return period design rain based on Log Pearson III, which is 124.33 mm.

C. *Runoff Coefficient*

The area of Karang Mumus Watershed based on the previous map of the in Fig. 4, is 319.387 km^2. Based on the catchment area and land use in Fig. 3, the watershed runoff coefficient value is 0.275. Then the effective rainfall for the 50 year return period is 34.22 mm.

D. *Design Flood Discharge*

Effective rainfall in the earlier calculation must determine the distribution of hours to assess the design flood discharge. The rainfall distribution pattern in Indonesia varies between 4-7 hours daily, and for this analysis, 5 hours has been selected. The effective rainfall distribution of hours is computed utilizing the Mononobe Method.

The results of the distribution of each hour effective rain are summarized in the Table V below.

TABLE V. The Effective Rain of Each Hour

Time (hour)	Rasio	Effective Rain of Each Hour XT_{50} (mm)
0,5	0,9283	31,7627
1,0	0,5848	20,0092
1,5	0,2053	7,0235
2,0	0,1520	5,2008
2,5	0,1243	4,2519
3,0	0,1066	3,6483
3,5	0,0942	3,2232
4,0	0,0849	2,9044
4,5	0,0776	2,6546
5,0	0,0717	2,4526

The Nakayasu Synthetic Unit Hydrographs for the Karang Mumus Watershed is presented in the following Fig.5

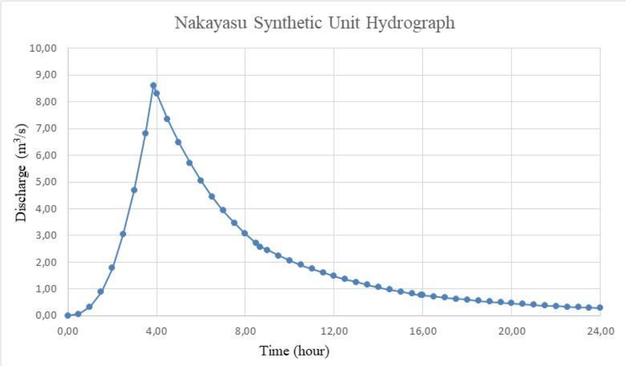

Fig. 5 The Nakayasu SUH of Karang Mumus River

And next is to calculate the flood hydrograph for a return period of 50 years. Fig.6 below is a flood hydrograph for the Karang Mumus River with a return period of 50 years.

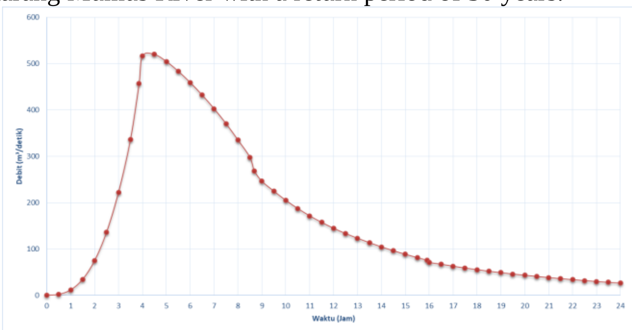

Fig. 6 Flood Hydrograph with Return Period of 50 Years

Based on the calculation results, it is found that Q_{50} is 535.31 m^3/s.

E. *Flood Water Level Analysis*

The flood water level elevation on the cross section and longitudinal section of the Karang Mumus River near Jembatan 1 Samarinda will be searched using the HEC-RAS application. The longitudinal cross section of the river profile that is reviewed starts from the Sta. 0+000 to Sta. 0+225 in the upstream direction.

The cross sections that will be reviewed are the sections near the bridge, namely at Sta. 0+050; Sta. 0+075; Sta. 0+100, and Sta. 0+125. The cross sectional position of the river profile is shown by the red line in the aerial photo in Fig. 7 below.

The flood discharge for the 50 year return period input into the HEC-RAS application on the longitudinal section and cross sections of the river produces a water level profile as shown in Fig. 8; Fig. 9; Fig. 10; Fig. 11; Fig. 12; and Fig. 13 follow in sequence below.


Fig. 7 Position of the Cross Section of the Karang Mumus River

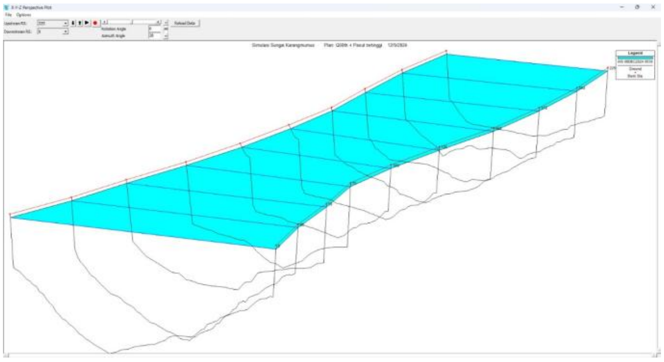
Fig. 8 Longitudinal Water Surface Profile

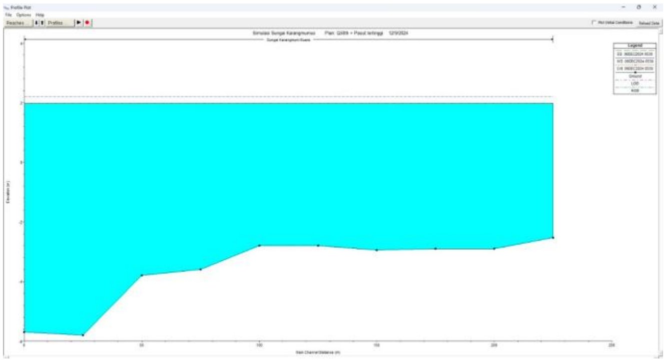
Fig. 9 Water Level Profile on Sta. 0+000

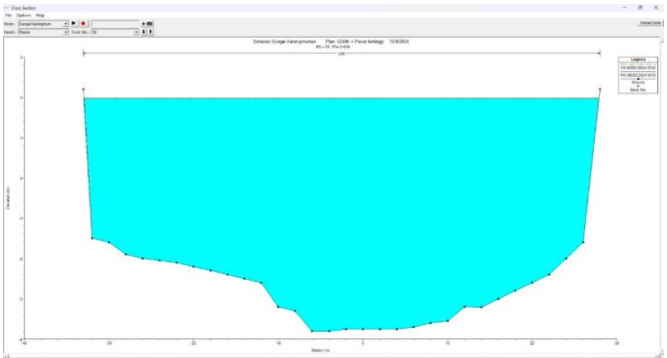
Fig. 10 Water Level Profile on Sta. 0+050

The result of running simulations for Q50 on the river section show that the flood water level is +1.98 m. This elevation is still below the river bank elevation, namely +2.4 m.

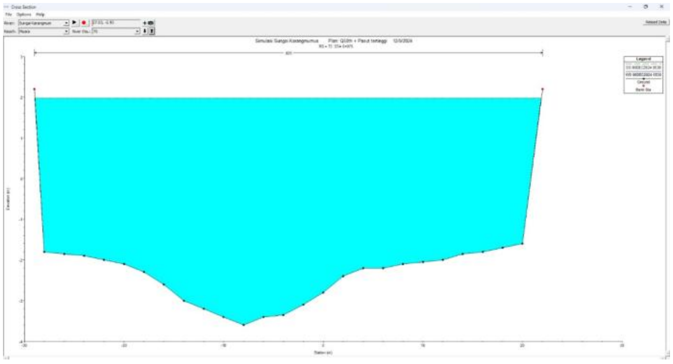
Fig. 11 Water Level Profile on Sta. 0+075

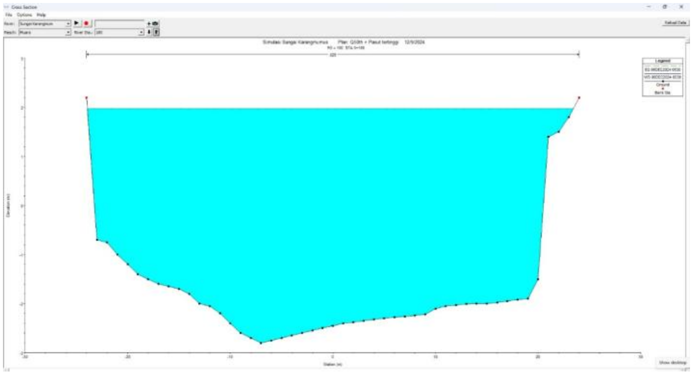
Fig. 12 Water Level Profile on Sta. 0+100

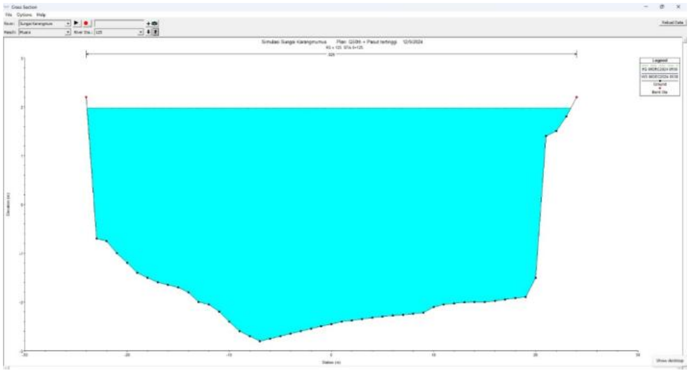
Fig. 13 Water Level Profile on Sta. 0+125

According to Kriteria Perencanaan Jembatan dan Pembebanan Jembatan Bab 1 Kriteria Desain jembatan, the clearance under the bridge varies depending on the type of river and the objects beneath it. For Jembatan 1, C = 2.5 m is used, which is more suitable for natural rivers whose conditions are unknown, considering that the traffic is small ships/ boats ans similar.

So the lowest elevation of the bridge upper structure is +1.98 + 2.5 = +4.48 m. this height is in accordance with the current condition of the existing bridge.

V. Conclusion

The results of this research are that the Karang Mumus River discharge with a 50 year return period of 535.31 m^3/s at high tide will produce a flood water level of +1.98 m. And the minimum placement of the upper structure of this bridge is at an elevation of +4.48 m.

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Analysis of flood water level elevation is one way to maintain the vertical free space of bridges. Several factors that should also be taken into account are the sediment flow rate and local scour which not only affect clearance but also the stability of the structure under the bridge.

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