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Study Of Tidal Influence On Flooding In Kecamatan Selakau

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Abstract

Kecamatan Selakau has a considerable risk of flooding, which occurs every year. Because it has a low topography, its location on the coast is undoubtedly greatly influenced by tides and is prone to tidal flooding. In an effort to anticipate and reduce the duration and frequency of rain by arranging the drainage system through technical study activities on drainage channels, especially on the Nyirih River drainage channel, which empties directly into the Selakau River.
This research aims to examine the effect of the Selakau River's tides on the Nyirih River's drainage flow and the combination of tides and rainfall on the incidence of flooding in the Nyirih River channel. The research methodology used is the descriptive method. Hydrological analysis using the maximum daily rainfall data from Tebas Station. Then the Nyirih River water level tidal readings and the design discharge data are used in the hydrodynamic model analysis.
Based on the analysis results using the HEC-RAS Version 6.1.0 software, the water level elevation from sta is at the highest tide conditions without rain. 0+000 to sta. 1 + 466,682 has exceeded the elevation of the existing channel cross-section so that it experiences inundation with a height of 0.02 m–0.4 m, and at sta. 1 + 694,439 to sta. 2 + 073.878, the water level is still below the existing cross-sectional elevation of the channel, so no inundation occurs. It shows that there is no effect or increase in water level elevation that occurs for the highest tide combination conditions with rainfall return periods of 2, 5, 10, and 20 years, and it is the same as the highest tide conditions without rain, which experience inundation with a height of 0.02 m-0.4 m. Normalization is inefficient and unsuccessful in decreasing floods since sea tides extensively impact the Nyirih along the river channel.

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1. Introduction

Selakau is a sub-district in Sambas Regency, established on August 17, 1956, and has an area of 350 km2 (350,000 ha). Because it is a beachfront location on the Natuna Sea's shore, most of Kecamatan Selakau has relatively low terrain (Wiki/Selakau, 2021). Kecamatan Selakau is in great danger of floods due to its low terrain, location on a coastline region heavily impacted by tides, and relatively high rainfall intensity.

This problem occurs due to rising water levels in the Selakau River. Judging from the condition of the drainage channels, which are not yet comparable to services based on the rain catchment area, there is narrowing or siltation and high enough sedimentation that occurs on the canal cliffs so that the channels cannot function optimally.

This article presents the results of a technical study to organize the drainage system of the Selakau Sub-district, specifically the Jalan Sungai Nyirih drainage channel, to predict and minimize the length and frequency of rainfall based on the high flood hazard in the area. This study used the Hydrologic Engineering Center's River Analysis System (HEC-RAS) software version 6.1.0, simplifying river flow modeling.

2. Materials and Methods

2.1. Theoretical Frame Work

Based on the flood problems that occurred in the Selakau sub-district, it is necessary to have efforts and solutions to deal with these problems. So this research was conducted to conduct a technical study to anticipate and reduce the duration and frequency of rain by structuring the existing drainage system in Kecamatan Selakau, especially in the drainage channel for Jalan Sungai Nyirih. This study used the Hydrologic Engineering Center-River Analysis System (HEC-RAS) software version 6.1.0, a hydrodynamic model application program that provides good channel modeling to give the authorized agency an overview of information materials and modeling on drainage channels to improve channel flow.

2.2. Research Location

This research case study took place in the Jalan Sungai Nyirih Drainage Channel, Kecamatan Selakau, Sambas Regency. Desa Sungai Nyirih has an area of approximately 8,250 km2 (825 ha), with drainage channels on the side of the Sungai Nyirih Road along 2,073 km, which flow into two villages, namely Desa Sungai Nyirih and Sungai Rusa .

Figure 1. Research Location (Source: Google Earth Pro Satellite Imagery, 2022)

2.3. Data

This research uses primary and secondary data. Field-measured and observed preliminary data. This research relies on canal conditions, tidal data, and drainage canal cross-sections. Secondary data supports a similar agency study. The Balai Wilayah Sungai Kalimantan (BWSK) I Pontianak provided maximum rainfall data (2010–2021) for the Tebas Station, and Google Earth provided the administrative map of Desa Sungai Nyirih, Kecamatan Selakau.

2.4. Analysis Method

After all the data is collected, it will be processed and analyzed. The steps in this analysis method are:

a) Perform an analysis of the maximum daily rainfall.

b) Conduct a suitability test for rainfall distribution in two stages, namely,

- *Statistical descriptor test of rainfall*

Table 1. Statistical Descriptor Test Parameter Values

Method	Cv	Ck	Cs
Normal	$\frac{\sigma}{V}$	3	0
Gumbel Tipe I	$\frac{\sigma}{V}$	5,402	1,139
Log Pearson Tipe III	0,3	$\left\{\frac{n(n+1)}{(n-1)(n-2)(n-3)}\frac{\sum\left(\log X-\overline{\log X}\right)^4}{S^4}\right\}-\frac{3(n-1)^2}{(n-2)(n-3)}$	$\frac{n\sum\left(\log X-\overline{\log X}\right)^3}{(n-1)(n-2)(S_{\log X})^3}$

- *Chi-Square Test*

A chi-squared test is a statistical hypothesis test used to analyze contingency tables when the sample sizes are large. To put it another way, the primary goal of this test is to determine whether or not two categorical variables (two dimensions of the contingency table) may be considered independent in their ability to affect the test statistic (values within the table). Here is the chi-squared test equation;

$$\chi h^2 = \sum_{i=1}^{G} \frac{(O_i - E_i)^2}{E_i} \quad (1)$$

χh^2 : Calculated chi-square parameters
G : Number of subgroups
O_i : The number of observed values
E_i : Total theoretical value

c) Look for return period rainfall of 2, 5, 10, and 20 years based on one of the methods determined from the previous analysis. The formula used is:

$$R = Average + K_T.S \quad (2)$$

d) The mononobe method searches for rain intensity in relatively short rain duration conditions. The formula used is:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t_c}\right)^m \quad (3)$$

With:

I : Rain intensity for the appropriate duration with a specific return period.

R_{24} : Maximum daily rainfall (mm) according to the return period.

t : Duration of rain (hours).

tc : stands for time spent concentrating

$$\left[\frac{0{,}87 \times L^2}{1000 \times S}\right]^{0{,}385} \qquad (4)$$

L : The length of the farthest point in the area until the flood observation point (km).

S : The average slope of the main channel.

e) Calculating flood discharge using Snyder's HSS for periods of 2, 5, 10, and 20 years.

$$t_p = C_t (L \times L_c)^{0.3} \qquad (5)$$

$$q_p = 2{,}75 \frac{C_p}{t_p} \qquad (6)$$

With:

tp : Time lag or delay time (in hours).

L : River length (km).

Lc : Length of the river from the checkpoint to the point on the river closest to the center of gravity of the catchment area (km).

qp : Hydrographic unit peak (l/s).

Cp and Ct : The basic characteristic coefficients

f) Hydraulic analysis with hydrodynamic modeling using the HEC-RAS program The modeling steps using the HEC-RAS application are as follows:

- *Creating Project Files*

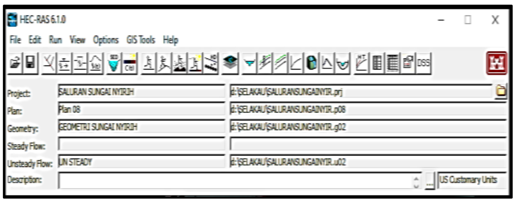

Figure 2. Initial Appearance of the HEC-RAS Application

- *Creation of Channel Geometry*

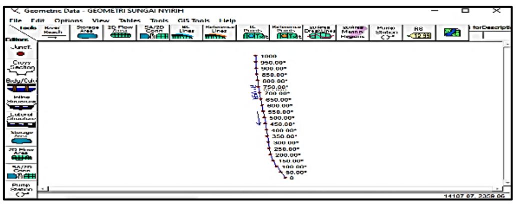

Figure 3. Example of Channel Geometric Data Input

- *Enter* channel cross-sectional data

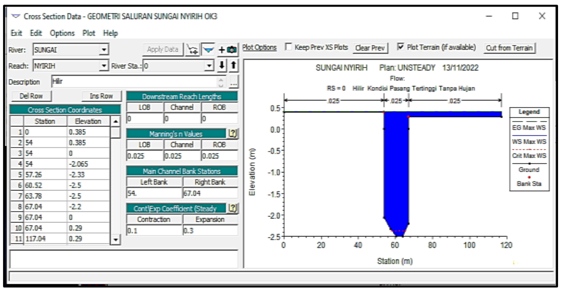

Figure 4. Channel Cross Section Data Input

- Enter debit data (unsteady flow) and boundary conditions

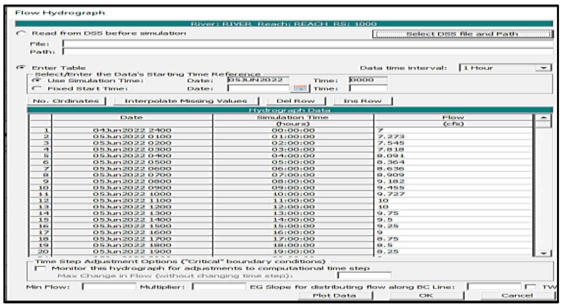

Figure 5. Unsteady flow channel discharge data

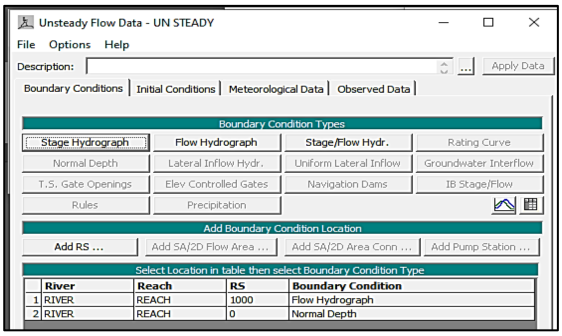

Figure 6. Input channel boundary condition data

- *Running* program HEC-RAS

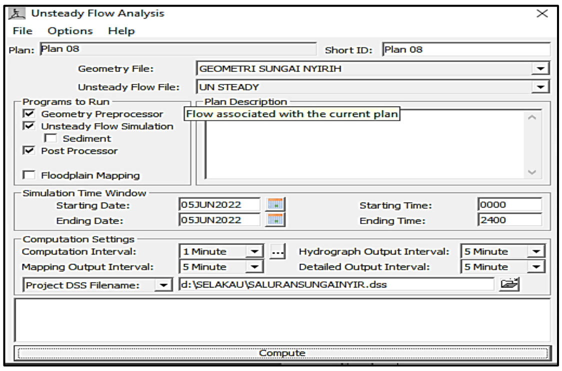

Figure 7. Analysis of the unsteady flow channel

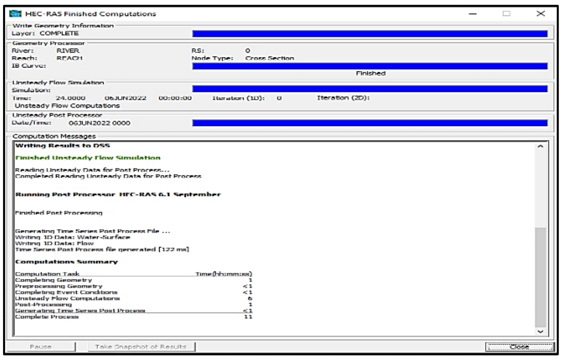

Figure 8. Running the HEC-RAS Program

The following is a flowchart of the research conducted:

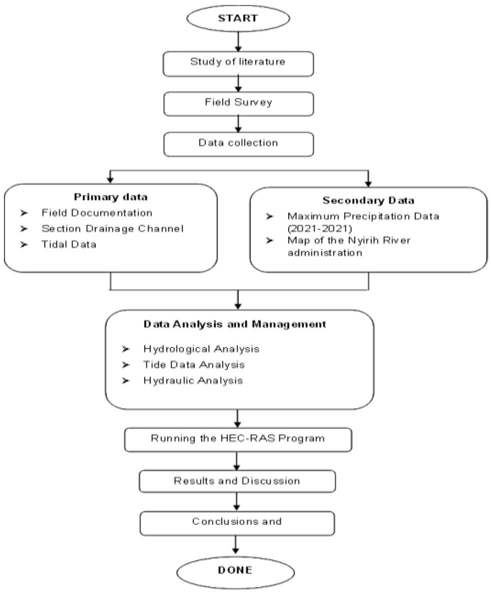

Figure 9. Research Flowchart

3. Results and Discussion

3.1. Rain catchment area

The boundaries of the catchment area or called the catchment area are the areas that can drain runoff water, either due to surface runoff or groundwater, into the canal. The Catchment Area is located along the Sungai Nyirih drainage channel, Kecamatan Selakau, Kabupaten Sambas Proviinsi Kalimantan Barat.

Figure 10. Catchment Area in the Nyirih River

3.2. Hydrological analysis

3.2.1. Maximum Daily Rainfall Analysis

Table 2. STA Maximum CH Data Summary. Slash (2012-2021) (Analysis Results, 2022)

Year	1 Daily	2 Daily	3 Daily	4 Daily	5 Daily
2021	117.00	145.00	199.00	229.00	266.00
2020	124.00	153.00	153.00	166.00	166.00
2019	110.00	145.00	145.00	191.00	191.00
2018	120.00	175.00	199.00	209.00	209.00
2017	83.00	138.00	155.00	213.00	221.00
2016	130.00	165.00	185.00	247.00	247.00
2015	90.00	133.00	165.00	184.00	249.00
2014	140.00	175.00	200.00	250.00	270.00
2013	88.00	137.00	150.00	225.00	225.00
2012	90.00	142.00	195.00	195.00	250.00
Amount	1092.0	1508.0	1746	2109	2294
Average	109.20	150.80	174.60	210.90	229.40

3.2.2. Suitability Test of Rainfall Distribution

There are two stages of testing, namely:

a) Test Statistical Descriptors

Table 3. Statistical Descriptor Test Results (Analysis Results, 2022)

The calculation results		Normal	Type I gumbe l	Type III Pearso n logs
Cs	0.026	0	1.139	-0.136
Ck	1.793	3	5.402	1.668
Cv	0.184	0.184	0.184	0.3

Table 4. The results of calculating the relative error percentage (Analysis Results, 2022)

Statistical Descriptors	Normal	Type I gumbel	Type III Pearson logs
ε Cs	0.00%	97.72%	119.11%
ε Ck	40.23%	66.81%	7.48%
ε Cv	0.00%	0.00%	-38.51%
Average	13.41%	54.84%	29.36%

Based on the statistical descriptor test table, the normal distribution method is taken. because it has a relatively small average percentage of overall error, namely a value of 13.41%.

b) *Goodness of Fit Test:* Chi Square Test (χ^2)

- *Normal Method Testing*

$$X = X_{rata\text{-}rata} + k.S \qquad (7)$$

Table 5. Testing the Normal Method (Analysis Results, 2022)

Testing the Normal Method										
Normal Method	X	=	Xrata-rata	+	K	x	SD		
	X	=	109.200	+	K	x	20.143		
P = 1 - 0,2 = 0,8	X	=	109.200	+	-0.84	x	20.143	=	92.280
P = 1 - 0,4 = 0,6	X	=	109.200	+	-0.25	x	20.143	=	104.164
P = 1 - 0,6 = 0,4	X	=	109.200	+	0.25	x	20.143	=	114.236
P = 1 - 0,8 = 0,2	X	=	109.200	+	0.84	x	20.143	=	126.120

Table 6. The results of the chi-square test using the Normal Method (Analysis Results, 2022)

Method	Opportunity	X	Limit Value	Oi	Ei	(Oi - Ei)²	χh²	Decision	dk	χh² tabel
Normal	P = 1 - 0,2 = 0,8	92.280	< 92.280	4	2	4	2.00	Received	2	5.991
	P = 1 - 0,4 = 0,6	104.164	92.280 - 104.164	0	2	4	2.00			
	P = 1 - 0,6 = 0,4	114.236	104.164 - 114.236	1	2	1	0.50			
	P = 1 - 0,8 = 0,2	126.120	114.236 - 126.120	3	2	1	0.50			
			> 126.120	2	2	0	0.00			
			Amount	10	10		5.00			

The tested method can be used (accepted) if the value of chi-squared **(χh^2)** is calculated using the chi-squared **(χh^2)** table.

- Testing the Gumbel Method Type I

$$a = \frac{1,283}{S} \quad (8)$$

$$Y = a(X - X_o) \quad (9)$$

Table 7. Testing the Gumbel Method Type I (Analysis Results, 2022)

Testing the Gumbel Method Type I					
Gumbel Method Type I	X	=	(Y + 6.379) / 0.064		
P = 1 - 0,2 = 0,8	X	=	(-0.476 + 6.379) / 0.064	=	92.668
P = 1 - 0,4 = 0,6	X	=	(0.087 + 6.379) / 0.064	=	101.507
P = 1 - 0,6 = 0,4	X	=	(0.671 + 6.379) / 0.064	=	110.676
P = 1 - 0,8 = 0,2	X	=	(1.510 + 6.379) / 0.064	=	123.848

Method	Opportunity	X	Limit Value	Oi	Ei	(Oi - Ei)²	χh²	Decision	dk	χh² tabel
Type I gumbel	P = 1 - 0,2 = 0,8	92.668	< 92.668	4	2	4	2.00	Received	2	5.991
	P = 1 - 0,4 = 0,6	101.507	92.668 - 101.507	0	2	4	2.00			
	P = 1 - 0,6 = 0,4	110.676	101.507 - 110.676	1	2	1	0.50			
	P = 1 - 0,8 = 0,2	123.848	110.676 - 123.848	3	2	1	0.50			
			> 123.848	2	2	0	0.00			
			Amount	10	10		5.00			

The tested method can be used (accepted) if the value of chi-squared (χh^2) is calculated

- Testing the Log Pearson Type III

$$\text{Log } X = \text{Log } X_{Rata\text{-}rata} + k(S_{logX}) \quad (10)$$

Table 9. Testing the Type III Log Person Method (Analysis Results, 2022)

Testing the Type III Log Person Method									
Type III Log Person Method	Log X	=	Log Xrata-rata	+	K	x	S LogX		
	Log X	=	2.031	+	K	x	0.081		
P = 1 - 0,2 = 0,8	X	=	2.031	+	0.040	x	0.081	=	2.035
P = 1 - 0,4 = 0,6	X	=	2.031	+	0.079	x	0.081	=	2.038
P = 1 - 0,6 = 0,4	X	=	2.031	+	0.352	x	0.081	=	2.060
P = 1 - 0,8 = 0,2	X	=	2.031	+	0.857	x	0.081	=	2.101

Tabel 10. The results of the chi-square test with the Log Person Type III method (Analysis Results, 2022)

Method	Opportunity	X	Limit Value	Oi	Ei	(Oi - Ei)²	χh²	Decision	dk	χh² tabel
Type III Pearson logs	P = 1 - 0,2 = 0,8	2.035	< 2,035	4	2	4	2.00	Received	2	5.991
	P = 1 - 0,4 = 0,6	2.038	2,035 - 2,038	0	2	4	2.00			
	P = 1 - 0,6 = 0,4	2.060	2,038 - 2,060	1	2	1	0.50			
	P = 1 - 0,8 = 0,2	2.101	2,060 - 2,101	3	2	1	0.50			
			> 2,101	2	2	0	0.00			

The tested method can be used (accepted) if the value of chi-squared **(χh^2)** is calculated using the chi-squared **(χh^2)** table.

So it was concluded that based on the results of the chi-square test (χh^2) of rain data and adjusting the results of the descriptor test in the previous test, the analysis method was the Normal Distribution Method.

3.2.3. Seeking Rain During the Return Period

The Chi Kuadrat (χ^2) test, which tries to establish the best way of rainfall distribution analysis, discovered that the Normal Approach is the best method. The rain distribution analysis approach discovered that the Normal method is the most appropriate way for determining the rainfall period of (R_2, R_5, R_{10}, and R_{20}).

The following is a summary of the findings of the rainfall computation analysis for specific return periods.

Table 11. Recap of Return Period Rain Analysis (Analysis Results, 2022)

No.	Period	K_T	Rainfall (mm)
1	R_2	0,00	109.200
2	R_5	0.84	126.120
3	R_{10}	1.28	134.983
4	R_{20}	1.64	142.234

3.2.4. Rainfall Intensity

The Mononobe Method is used to determine rainfall intensity. The assumption is for rainfall with a relatively short duration (length of time) of rain. Using equation (3), the rainfall intensity at each return period is as follows;

Table 12. Rain Intensity for 2, 5, 10, and 20 Years (Analysis Results, 2022)

No.	Return Period (Year)	R_{24} (mm)	t (jam)	Intensity (mm/jam)
1	2	109.200	0.091	42.384
2	5	126.120	0.091	48.951
3	10	134.983	0.091	52.391
4	20	142.234	0.091	55.206

The table above shows that the amount of rainfall intensity is directly related to the maximum rainfall return period or that the bigger the number/value of the maximum rainfall return period, the greater the amount of rainfall intensity that occurs. Likewise, vice versa, the smaller the number/value of the maximum rainfall return period, the lesser the rainfall intensity that arises. This is one of the factors causing the inundation problem that occurs in Sungai Nyirih.

3.2.5. Flood Discharge Analysis

The maximum flood discharge analysis uses the Snyder synthetic unit hydrograph (HSS) method in this research. The analysis results are as follows;

Table 13. STA Maximum Debt Recap 0+42.857 (Analysis Results, 2022)

Return Period	Q (m^3/det)
2	0.018
5	0.021
10	0.022
20	0.024

The following is a recapitulation of the calculation of the maximum discharge made in graphical form using the Snyder method of synthetic unit hydrograph for STA: 0 + 42.857, as in the following graph;

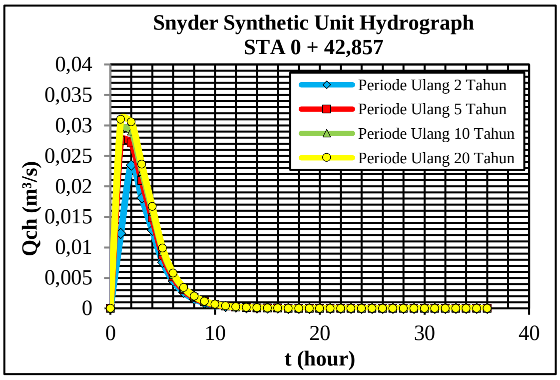

Figure 11. The maximum discharge with the Snyder Synthetic Unit Hydrograph STA. 0+42.857

3.3. Tidal Analysis

Based on the prediction of sea tides.com 2022, the tide with the highest coefficient that occurs during the full moon in the Sungai Nyirih is October 09, 2022. Thus, the tidal observation or water level observation in this study was carried out for 24 hours, from October 09, 2022, to October 10.

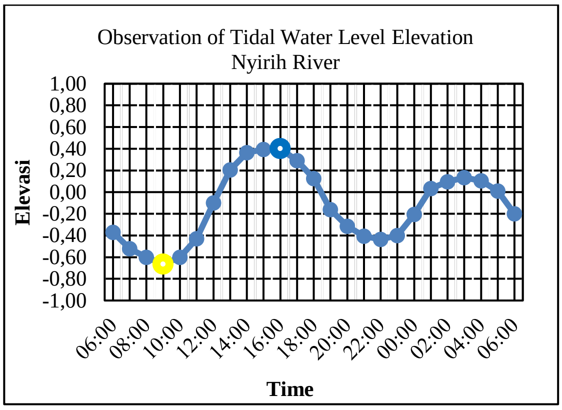

Figure 12. Tidal Data for the water surface elevation Nyirih River

3.4. Hydraulic Analysis

Applied Hydraulics Analysis (manual) integrated with the existing equations by running the Hydraulics Analysis program on the Channel Hydrodynamics Modeling with the help of one of the software tools Hydrologic Engineering Center River Analysis System (HEC-RAS Version 6.1.0).

The geometry layout of the HEC-RAS model of the Sungai Nyirih channel, which has a length of 2,073 km, has 12 stations, each 200 meters apart.

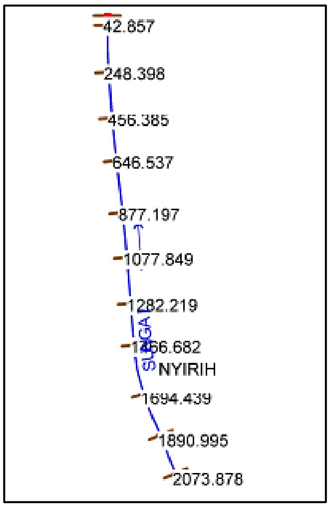

Figure 13. Geometry Layout of the Nyirih RiverCanal HEC-RAS Model

The cross-sectional data of the Sungai Nyirih canal is as follows.

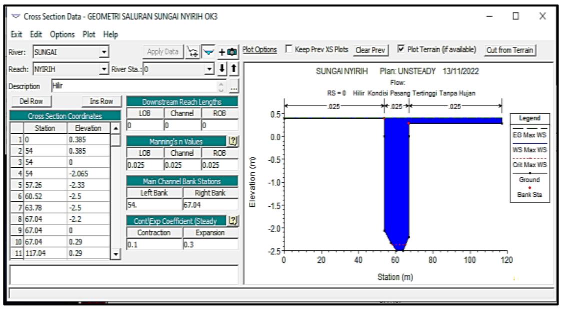

Figure 14. Cross-section data from the measurement results of STA 0 and 000

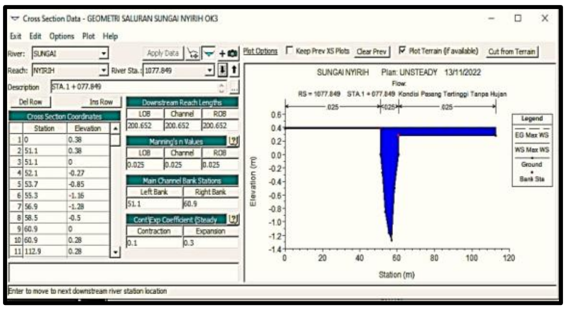

Figure 15. Cross-section data from the measurement results of STA 0 and 000

Cross-section data from the measurement results of STA 1 + 0.784

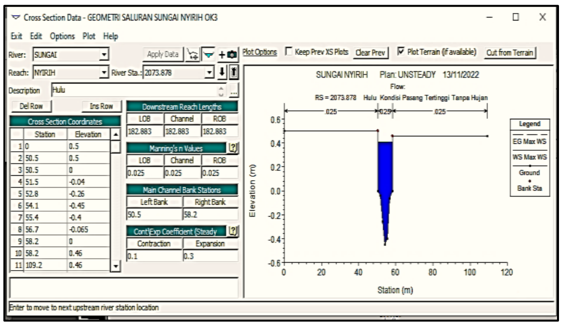

Figure 16. Cross-section data from the measurement results of STA 2 + 073.878

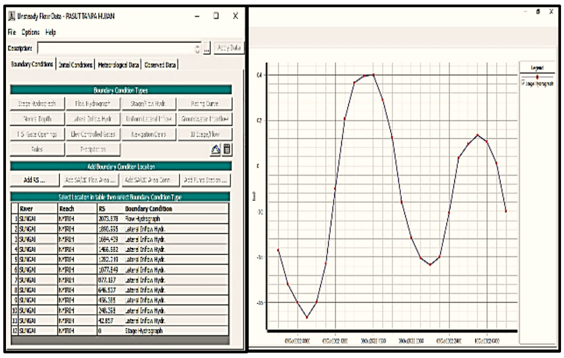

Figure 17. The downstream stage hydrograph due to the tides of the Sungai Selakau

The highest tide elevation is 0.4 m, and the lowest ebb is -0.665 m..

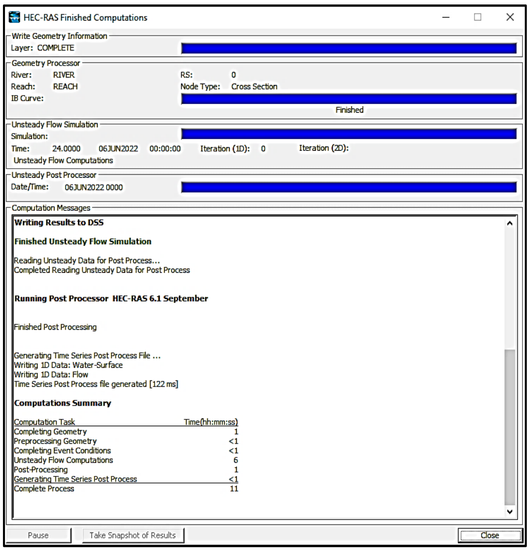

Figure 18. Running the HEC-RAS Program

For simulation results of tidal conditions without rain as follows;

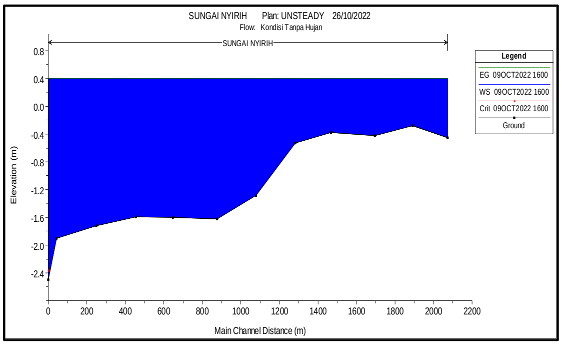

Figure 19. Simulation results of the water level profile in the longitudinal cross-section of the Sungai Nyirih channel for low tide conditions without rain

Figure 19 shows the water level in the longitudinal section of the channel for high tide conditions without rain. The water level from Sta. 0 to Sta. 2073 is 0.4 m.

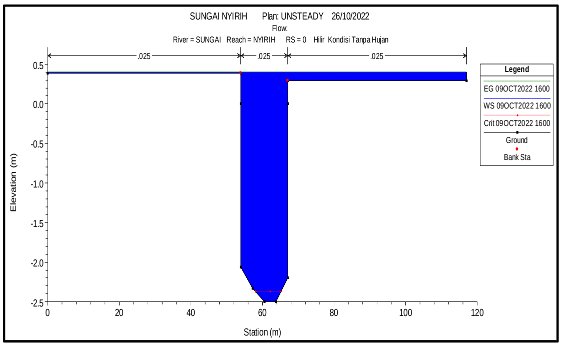

Figure 20. Simulation results of the water level profile in the cross-section of Sta. 0 for tide conditions without rain

Figure 20 shows the simulation results of the water surface profile in the cross-section of Sta. 0 for tide conditions without rain. The water level reaches 0.4 m and exceeds the existing elevation of the channel section. This results in inundation.

In the same way, modeling was done for each channel node under review using HEC-RAS software. The conditions reviewed are tidal conditions without rain and combined tides and rainfall. The following table compares the water level elevation in each condition.

Table 14. Comparison of water level elevation in the Nyirih River channel in each condition (Analysis Results, 2022)

No.	STA	Catchment Area Area (Km^2)	Maximum Water Level (m)				
			Without Rain, Tidal	Tidal + Return Rain Period 2 Years	Tidal + Return of the Rainy Season 5 years	Tidal + Rainfall with a 10-year return period	Tidal + Return of the Rainy Season 20 years
1	0 + 000	0.000	0.400	0.400	0.400	0.400	0.400
2	0 + 42.857	0.004	0.400	0.400	0.400	0.400	0.400
3	0 + 248.398	0.036	0.400	0.400	0.400	0.400	0.400
4	0 + 456.385	0.034	0.400	0.400	0.400	0.400	0.400
5	0 + 646.537	0.031	0.400	0.400	0.400	0.400	0.400
6	0 + 877.197	0.089	0.400	0.400	0.400	0.400	0.400
7	1 + 077.849	0.093	0.400	0.400	0.400	0.400	0.400
8	1 + 282.219	0.089	0.400	0.400	0.400	0.400	0.400
9	1 + 466.682	0.073	0.400	0.400	0.400	0.400	0.400
10	1 + 694.439	0.102	0.400	0.400	0.400	0.400	0.400
11	1 + 890.995	0.103	0.400	0.400	0.400	0.400	0.400
12	2.073.878	0.087	0.400	0.400	0.400	0.400	0.400

According to Table 15. Comparing the water level elevation in the Sungai Nyirih River channel in each condition shows that the water level elevation in all conditions has the same elevation, namely 0.4 m. This happens because the tides very heavily influence the Sungai Nyirih area. Then the presence of conditions without rain and the combination of rainfall for periods of 2, 5, 10, and 20 years do not affect the water level during high tide conditions because the view of the catchment area is small, and the resulting discharge is also minimal.

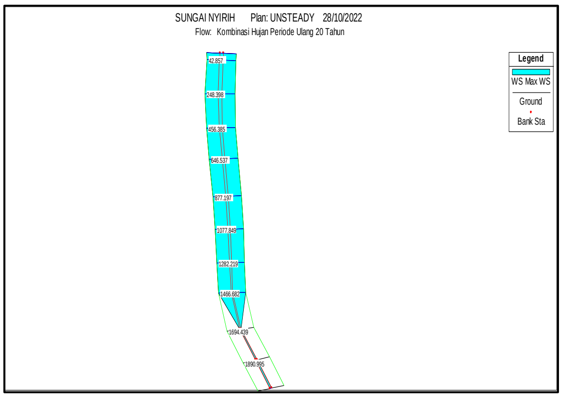

Figure 21. Simulation results of area distribution Nyirih River flooding by HEC-RAS

From the simulation results, the water level at the stations can be observed in Figure 21 in the flood distribution area that occurs in the Sungai Nyirih channel.

4. Conclusion

The results of computation, analysis, and simulation using the HEC-RAS software application show that when the highest tide occurs, and there is no rain, the water level rises above the existing channel's peak so that there is inundation from sta. 0+000 to sta. 1 + 466,682 with a height of 0.02 m to 0.4 m, and from sta. 1 + 694,439 to sta. 2 + 073.878, the water level is still below the channel's existing cross-sectional elevation, so there is no inundation.

It demonstrates that there is no effect or elevation increase in the water level that occurs in the conditions of combined tides with rainfall return periods of 2, 5, 10, and 20 years and that it is the same as the highest tide conditions without rain, which experience inundation with a height of 0.02-0.4 m. The resultant flow is modest because the Nyirih is greatly influenced by sea tides along the river channel and the small catchment area.

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6. Author's Notes

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