International Journal of Scientific and Technical Research in Engineering (IJSTRE)
www.ijstre.com Volume 8 Issue 5 ǁ Sept-Oct 2023.
ISSN: 2581-9941.

Evaluation of Morphological Changes to the Flood Capacity of the Tambun River in Tolitoli Regency

Rudi Herman[1], Gabriella Ayu Kusuma[1], Nina Bariroh Rustanti[1]
[1]*Postgraduate Program, Tadulako University, Palu, Central Sulawesi, Indonesia*
rudi.herman2@gmail.com; amatirock@gmail.com

Abstract: *Floods are a major problem in Tolitoli Regency which occurs every year where one of them overflows the Tambun River. It is estimated, the flooding is due to narrowing of the river channel, winding river, soil erosion on the riverbanks, and insufficient river capacity. This study aims to identify morphological changes in river cross-sections, changes in river flow due to flood discharge in the Tambun watershed. So that research is also directed to analyze the causes of flooding and provide recommendations for morphological settings and river flood handling. This study uses flood discharge analysis using the HSS Snyder method, and river hydraulics analysis using HECRAS modeling. The HECRAS modeling results show that all sections are unable to serve flood discharge even with a 2-year flood discharge of 200.709 m3/second. Meanwhile, changes in river morphology are affected by the collapse of the river walls and sediment deposits, the current pressure during floods because the capacity of the river is unable to accommodate flood discharge and the influence of people's behavior towards the river. This study recommends normalization along river flood embankments, strengthening river walls with gabions, establishing river banks, construction work to repair river walls and installing warning signs prohibiting damage to river borders.*

Keywords - *flood, morphology, river, Tolitoli*

I. INTRODUCTION

Frequent flooding is a problem and one of the main focuses in Tolitoli District, Central Sulawesi Province. The floods are suspected to be caused by poor drainage systems, river overflows, and community use of river banks. One of the rivers that often experiences flooding is the Tambun River with a watershed area of 132,137 km2. From satellite imagery, the Tambun River is experiencing narrowing in the downstream, meandering upstream and downstream and erosion of the river banks. The local community is always on alert when the dimensional capacity of the river is full (bank full) which occurs every 2-3 months. The evaluation aims to identify the morphological conditions of the river with the cross-sectional capacity of the river to the flood discharge in the Tambun River so that the cause of the flood can be identified and thus recommendations for appropriate treatment can be given.

Rivers experience morphodynamics in response to the flow or movement of sediments. As a result, the morphology changes over time, especially during major floods. Experts say the flow pattern should remain the same in the river as long as the driving force and boundary conditions are consistent over time [1]. Changes in the morphology of the river due to dynamic hydrological conditions and the river will continue to adjust to the dimensions, profile and flow pattern to achieve balance. Where the river tends to balance through erosion and deposition processes [2].

The morphology of the river can be influenced by the area of the watershed, the length and width of the watershed, the slope of the watershed, and the density of the river. In determining river morphology, river geometry data such as river width, river depth, river cross section, river bed slope, and coordinates of river location are needed. From changes in the morphology of the river, it can be seen that the history of the river is a process that develops from time to time. Changes in river morphology are generally caused by flooding. Where flooding is influenced by rainfall, physiography, erosion & sedimentation, river capacity, drainage capacity, sea tides and human activities that cause changes in land use [3].

Research by [4], concluded that after a flood occurs in the meandering area it will cause the collapse of the river wall and changes and dimensions of the river and greater damage. So that the eroded area will experience morphological changes. River repairs are carried out in such a way as to prevent flooding and sedimentation, and ensure that the river channel is always in a stable state [5].

A similar study by [6] on the Puna River using the HEC-RAS program, provides an alternative for handling flood control in the form of river normalization. Sand removal at the bottom of the river can lead to a decrease in the stability of the river banks. Flow fluctuations over a period of time will cause erosion on unstable banks. The result of this erosion will be carried by the stream to the downstream and deposited, before arriving at the estuary. In the long term, this erosion and sedimentation process not only leads to reduced cross-sectional capacity but also causes a change in the configuration of the river channel over time.

Flood management with normalization is carried out on river sections whose capacity does not meet the flood discharge capacity. Normalization of the cross-sectional shape is done by changing the dimensions of the cross-section that can serve Q_{design} [7].

Evaluation or review of river morphology needs to be continuously carried out to monitor morphological changes that occur, thus river evolution data can be used for river development. Systematic data is needed to model changes in river morphology beforehand so that it can provide practical solutions to further improve river geomorphology [8]. Evaluation of the morphology of the Tambun River is focused on sections that often experience flooding, starting from the river mouth (Sta 0) to the upstream of the river with a length of 7 Km.

II. METHODS

Evaluation of river flood morphology requires primary data in the form of river length and cross-section as well as river damage obtained from aerial photographs and river tracing. Secondary data is in the form of watershed boundaries, rainfall data and satellite imagery. A study of the morphological conditions of the river was carried out to determine the morphological classification of the river and its morphological changes and a flood study was carried out by calculating the planned flood discharge in the Tambun watershed. After obtaining the data, an analysis and modeling of the cross-section of the river was carried out using the HEC-RAS program, then a simulation of the planned flood discharge was carried out so that the cross-sectional capacity of the river could be determined.

2.1. River Condition

The survey was carried out by taking satellite imagery to determine the Ground Control Point (GCP) which is adjusted to the coordinates of the Global Positioning System - Real Time Kinematic (GPS RTK) readings which were processed using Agisoft Metashape to process Digital Elevation Model (DEM) and Digital Terrain Model elevation correction data. (DTM), after that it is processed using AutoCAD to get the river situation. The survey was carried out according to the 7,000 meter evaluation zone.

2.2. Analysis of the design flood discharge

Analysis of the planned flood discharge is calculated in accordance with SNI 2415:2016–Procedures for Calculation of Planned Flood Discharge. Planned flood discharge according to Indonesian conditions is recommended to use the Snyder HSS method because it can be calibrated [9]. Previously, an analysis of the frequency distribution of rainfall data was carried out because there was no AWLR post to determine flood discharge. Frequency distribution analysis using Log Pearson III. The data were also evaluated for their distribution suitability using the Chi-Square and Smirnov-Kolmogorov Test methods. Rain intensity calculations are based on land use in the Tambun watershed. The flood discharge design is calculated with a return period of 1 year, 2 years, 5 years, 10 years, 25 years, 50 years and 100 years to determine the fluctuation of the water level when a flood occurs in the Tambun river cross section.

2.3. Hydraulics Analysis with HEC-RAS Modeling

The analysis uses the help of the HEC-RAS 5.0.7 program to analyze the river cross-section capacity. The data entered the HEC-RAS program are river schematics (long) and river cross-section, planned flood discharge for a certain return period for steady flow simulation, and other variables such as the roughness coefficient (manning).

2.4. Recommendations for Regulation of Morphology and Management of River Floods

Recommendations are given after knowing the problems that occur in Tambun watershed. It is hoped that the recommendations will be in line with the needs for morphology regulation and river flood management, both physical and non-physical efforts so that they are more integrated to control the destructive power of water in Tambun watershed.

III. RESULT AND DISCUSSION

3.1. River Condition

From the results of satellite imagery and adjustment of coordinates with the GPS RTK, it can be seen that the flow of the Tambun River and its use on the banks of the river. There are also points of river damage that need to be studied to evaluate their morphology. Further recommendations for handling will be given. The following is the topography of the Tambun River data according to the section to be evaluated.

Table 1. Coordinate Points for the Tambun River Monitoring Location

No	Review Point	Coordinate		Elevation (mDPL)	Slope (i)	Info
		x	y			
1	Mouth of Tambun River	112989.915	252419.622	4.070		Sta. 0
					0.00263	
2	Tambun Bridge	112045.113	253541.838	9.750		Sta. 2400
					0.00316	
3	Dapalak Bridge	111007.616	254351.161	15.580		Sta. 4450
					0.00185	
4	Mine Area	110650.943	255943.797	19.820		Sta. 7000

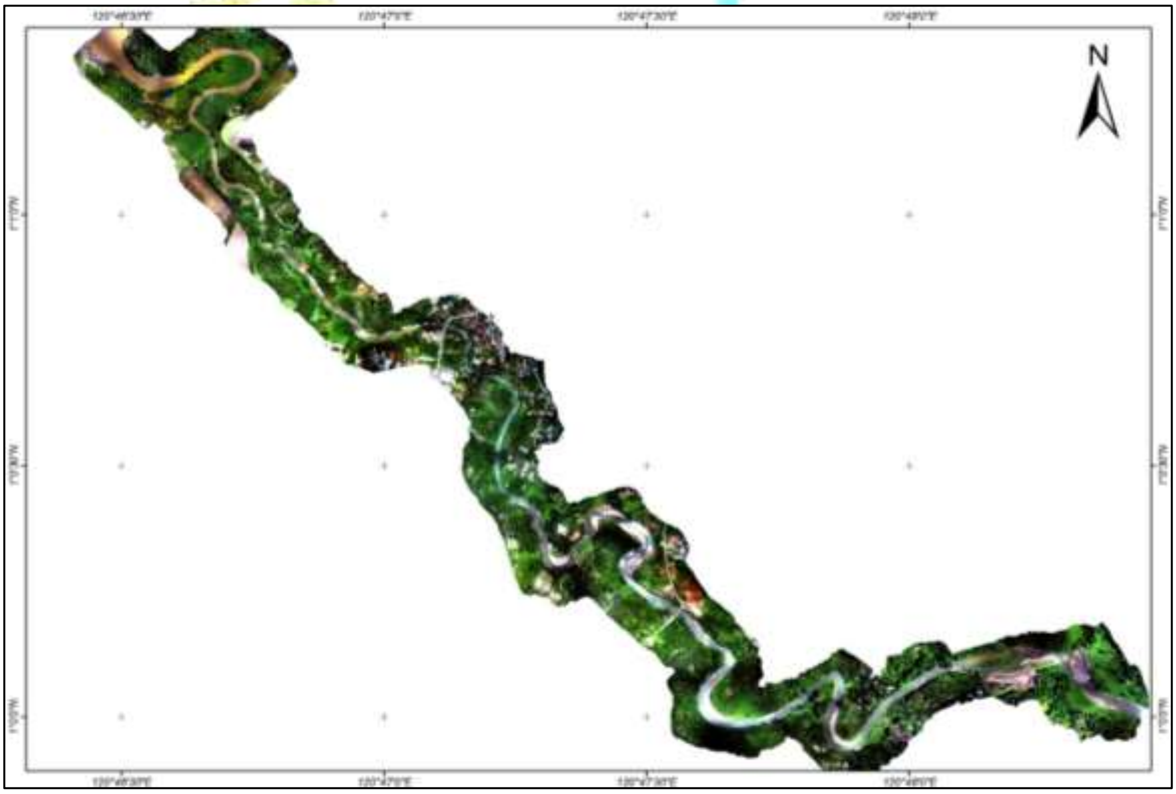

Figure 1. Results of Aerial Photo Mapping

3.2. Analysis of the design flood discharge

In the Tambun watershed there are no water estimating posts, so the flood discharge is calculated using Snyder's HSS using rainfall data obtained from the Buntuna rainfall station owned by GAW Lore Lindu Bariri.

Table 2. Maximum Rainfall data obtained from the Buntuna Rainfall Station

No	Year	Maximum Rainfall (mm)
1	2013	130
2	2014	177
3	2015	83.5
4	2016	116
5	2017	253
6	2018	128
7	2019	109
8	2020	129
9	2021	132
10	2022	189

Rainfall frequency analysis is used to find the relationship between the magnitude of extreme events and the frequency of events using a probability distribution. The following is an analysis of the frequency of rainfall in Tambun watershed:

Table 3. Rainfall Frequency Analysis

No	Year	Rinfall (mm)	(Xi - Xo)	(Xi - Xo)²	(Xi - Xo)³	(Xi - Xo)⁴
1	2017	253.00	108.35	11,739.72	1,271,998.93	137,821,084.38
2	2022	189.00	44.35	1,966.92	87,233.01	3,868,784.12
3	2014	177.00	32.35	1,046.52	33,855.00	1,095,209.34
4	2021	132.00	-12.65	160.02	-2,024.28	25,607.20
5	2013	130.00	-14.65	214.62	-3,144.22	46,062.82
6	2020	129.00	-15.65	244.92	-3,833.04	59,987.03
7	2018	128.00	-16.65	277.22	-4,615.75	76,852.31
8	2016	116.00	-28.65	820.82	-23,516.56	673,749.58
9	2019	109.00	-35.65	1,270.92	-45,308.39	1,615,244.00
10	2015	8350	-61.15	3,739.32	-228,659.57	13,982,532.76
Total		**1,446.50**	**0.00**	**21,481.03**	**1081985,13**	**159,265,113.54**
Average X_0		**144.65**				

$$S = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\bar{x})^2}{n-1}} = \sqrt{\frac{21{,}481.03}{10-1}} = 48.855$$

$$Cs = \frac{n\sum_{i=1}^{n}(Xi-\bar{x})^3}{(n-1)(n-2)S^3} = \frac{10\ x\ 1{,}081{,}985.13}{(10-1)(10-2)(48.855)^3} = 1.289$$

$$Ck = \frac{\frac{1}{n}\sum_{i=1}^{n}(Xi-\bar{x})^4}{S^4} = \frac{\frac{1}{10}(159{,}265{,}113.54)}{(48.855)^4} = 2.8$$

$$Cv = \frac{S}{\bar{x}} = \frac{48.855}{144.65} = 0.338$$

Based on the distribution requirements and the results of the calculation of the distribution factor, the suitability of the statistic parameters above is suitable for the Log Pearson III method.

Table 4. Rainfall Analysis with Log Pearson III

No	Year	Rainfall	Log Xi	Log Xi - Log Xrt	(Log Xi - Log Xrt)²	(Log Xi - Log Xrt)³	(Log Xi - Log Xrt)⁴
1	2017	253.00	2.40	0.26	0.07	0.02	0.00
2	2022	189.00	2.28	0.14	0.02	0.00	0.00
3	2014	177.00	2.25	0.11	0.01	0.00	0.00
4	2021	132.00	2.12	-0.02	0.00	0.00	0.00
5	2013	130.00	2.11	-0.03	0.00	0.00	0.00

6	2020	129.00	2.11	-0.03	0.00	0.00	0.00
7	2018	128.00	2.11	-0.03	0.00	0.00	0.00
8	2016	116.00	2.06	-0.,08	0.01	0.00	0.00
9	2019	109.00	2.04	-0.10	0.01	0.00	0.00
10	2015	8350	192	-0.22	0.05	-0.01	0.00
	Total		**21.40**	**0.00**	**0.17**	**0.01**	**0.01**
	Average (Log $\bar{x}$)		**2.14**				

$$S = \sqrt{\frac{\sum_{i=1}^{n}(Log\ Xi - Log\ \bar{x})^2}{n-1}} = \sqrt{\frac{0.17}{10-1}} = 0.136$$

$$Cs = \frac{n\ \sum_{i=1}^{n}(Log\ Xi - Log\ \bar{x})^3}{(n-1)(n-2)S^3} = \frac{10\ x\ 0.01}{(10-1)(10-2)(0.136)^3} = 0.544$$

Table 5. Rainfall Analysis with Pearson Log Type III method

No	Period (T)	S	Log X	Cs	K_T	Y = Log X + (K_T x S)	X_T
1	1.01	0.136	2.140	0.544	-1.922	1.879	75.688
2	2	0.136	2.140	0.544	-0.090	2.128	134.321
3	5	0.136	2.140	0.544	0.804	2.250	177.719
4	10	0.136	2.140	0.544	1.325	2.320	209.168
5	25	0.136	2.140	0.544	1.922	2.402	252.198
6	50	0.136	2.140	0.544	2.331	2.457	286.656
7	100	0136	2.140	0.544	2.716	2.510	323.297

To determine the distribution equation has been calculated to represent the statistical distribution of sample data, it is necessary to test the fit of the distribution using the Chi-Square and Smirnov-Kolmogorov Tests.

Table 6. Weibull Method Opportunities

No	Rainfall (mm)	Log CH	Opportunity (%)
1	83.50	1.922	9.091
2	109.00	2.037	18.182
3	116.00	2.064	27.273
4	128.00	2.107	36.364
5	129.00	2.111	45.455
6	130.00	2.114	54.545
7	132.00	2.121	63.636
8	177.00	2.248	72.727
9	189.00	2.276	81.818
10	253.00	2.403	90.909

Number of classes (G) = 1 + 3.322 Log n = 4.332 ≈ 5

Degrees of freedom (DK) = G – (α + 1) = 2

Frequency (Ei) = $\frac{n}{G}$ = 2

Added restrictions (D_x) = $\frac{Xmax - Xmin}{G-1} = \frac{2.403-1.922}{5-1}$ = 0.120

Initial limitation = X_{min} – (0.5 x D_x) = 1.862

Table 7. Chi-Square Test Calculation

No	Boundary Value			O_f	E_f	$(O_f\text{-}E_i)^2$	$(O_f\text{-}Ei)^2/E_i$
1	1.862	< x <	1.982	1	2	1	0.5
2	1.982	< x <	2.102	2	2	0	0.0
3	2.102	< x <	2.223	4	2	4	2.0
4	2.223	< x <	2.343	2	2	0	0.0
5	2.343	< x <	2.463	1	2	1	0.5
		Total		**10**	**10**		3.0

From the results of the calculation above, it is obtained that Chi-Square value (X^2count) is 3.0 while the Table Chi-Square value (X^2critical) at the significant level (α = 5% / 0.05) and degrees of freedom (DK) = 2 is obtained by the distribution critical X^2 is 5.991. Because the calculated X^2count is smaller than the critical X^2 critical (3.0 <5.991), the distribution equation can be accepted.

Table 8. Calculation Smirnov-Kolmogorov Test

Year	Xi	P(x) =			P'(x) =m/(n-1)	P'(x<)	D
		m	m/(n+1)	P(x<)			
	1	2	3	4 = 1 - (3)	5	6 = 1 - 5	7 = 4 - 6
2015	83.50	1	0.091	0.909	0.111	0.889	0.020
2019	109.00	2	0.182	0.818	0.222	0.778	0.040
2016	116.00	3	0.273	0.727	0.333	0.667	0.061
2018	128.00	4	0.364	0.636	0.444	0.556	0.081
2020	129.00	5	0.455	0.545	0.556	0.444	0.101
2013	130.00	6	0.545	0.455	0.667	0.333	0.121
2021	132.00	7	0.636	0.364	0.778	0.222	0.141
2014	177.00	8	0.727	0.273	0.889	0.111	0.162
2022	189.00	9	0.818	0.182	1.000	0.000	0.182
2017	253.00	10	0.909	0.091	1.111	-0.111	0.202

From the results of the calculation above, the D_{max} value is 0.202, while the $D_{critical}$ value is at a significant level (α = 5% / 0.05) and the number of data is 10, which is 0.410. Because the D_{max} value is smaller than the $D_{critical}$ value (0.202 <0.410), the distribution equation meets the requirements.

In order to calculate the flood discharge, it is necessary to know the rainfall intensity and effective rainfall according to the return period with the supporting data for the watershed area (A) of 132.137 Km^2, the length of the main river (L) of 18.44 Km and the slope of the river (S) of 0.00250. Time of rain concentration and runoff coefficient are calculate based on land use in the following Tambun watershed:

$$Tc = \left(\frac{0.87 \ x \ L^2}{1000 \ x \ S}\right)^{0,385} = \left(\frac{0.87 \ x \ (18.440)^2}{1000 \ x \ 0.00250}\right)^{0.385} = 6.409 \approx 6 \text{ hr}$$

Table 9. Determination of Runoff Coefficient (C) based on Land Use

No	Watershed Land Use Types	Area, A	C	C x A
1	Primary Dryland Forest	37.762	0.300	11.329
2	Secondary Dryland Forest	21.336	0.300	6.401
3	Primary Mangrove Forest	0.280	0.050	0.014
4	Thicket	4.047	0.300	1.214
5	Plantation	1.000	0.450	0.450
6	Settlement	1.501	0.400	0.600
7	Dryland Agriculture	47.901	0.400	19.160
8	Mixed Dryland Agriculture	16.861	0.400	6.744
9	Ricefield	0.398	0.400	0.159
10	Pond	1.051	0.050	0.053
	Total	**132.137**		**46.124**

$$C = \frac{C1.A1 + C2.A2 + \cdots + Cn.An}{\Sigma A} = \frac{46.124}{132.137} = 0.349$$

With the Mononobe formula, the following is the calculation of Rain Intensity with a return period:

$$I_2 = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}} = \frac{134.321}{24}\left(\frac{24}{1}\right)^{\frac{2}{3}} = 46.566 \text{ mm/hr}$$

After knowing the intensity of rainfall, then to obtain effective rain then:

X_{eff} = I x C = 46.566 x 0.349 = 16.255 mm/hr.

Calculations for other return periods per year (Yr) are presented in the following table:

Table 10. Rain Intensity (I) in the Tambun Watershed

Rain time (t)	Rain Intensity, I with return period (mm/hari)						
	1 Yr	**2 Yr**	**5 Yr**	**10 Yr**	**25 Yr**	**50 Yr**	**100 Yr**
	75.688	134.321	177.719	209.168	252.198	286.656	323.297
1	26.240	46.566	61.612	72.515	87.432	99.378	112.081
2	16.530	29.335	38.813	45.681	55.079	62.604	70.607
3	12.615	22.387	29.620	34.861	42.033	47.776	53.883
4	10.413	18.480	24.451	28.777	34.697	39.438	44.479
5	8.974	15.925	21.071	24.800	29.901	33.987	38.331
6	7.947	14.103	18.659	21.961	26.479	30.097	33.944

Table 11. Effective Rainfall in the Tambun Watershed

Rain time (t)	Effective Rainfall (mm/hari)						
	1 Yr	**2 Yr**	**5 Yr**	**10 Yr**	**25 Yr**	**50 Yr**	**100 Yr**
	75.688	134.321	177.719	209.168	252.198	286.656	323.297
1	9.159	16.255	21.506	25.312	30.520	34.689	39.124
2	5.770	10.240	13.548	15.946	19.226	21.853	24.646
3	4.403	7.814	10.339	12.169	14.672	16.677	18.809
4	3.635	6.451	8.535	10.045	12.112	13.767	15.526
5	3.132	5.559	7.355	8.657	10.438	11.864	13.380
6	2.774	4.923	6.513	7.666	9.243	10.506	11.849

Analysis of the planned flood discharge uses the HSS Snyder method (for a watershed area of 30-30,000 Km^2) and this method is in accordance with the directives in SNI 2415:2016 - Procedure for calculating planned flood discharge. The basic data used in HSS Snyder calculations are described as follows:

1) Look for the time from the heavy point of rain to the peak discharge (t_p) / *Time Lag*

   t_p = Ct x $(L \times Lc)^n$ = 1.2 x $(18.440 \times 13.865)^{0.3}$ = 5.804 Hr

2) Knowing the Effective Rainfall Duration (t_c)

   t_c = tp / 5.5 = 5.804 / 5.5 = 1.055 Hr

3) Calculating the Time Base Value of the Hydrograph (T_b) / *Time Base*

   Tb = 5 x t_p + tc/2 = 5 x 5.804 + 1/2 = 31.518 Hr

4) Calculating Flood Peak Time (Tp)

   Value tc > tr Assuming, a correction is made to tp with the formula

   Tp = $t_p + 0{,}25\ (t_r - t_c)$ = 5,804 + 0,25 (1 – 1,055) = 5.790 Hr

5) Calculating Peak Discharge (Qp)

   Qp = $0.278 \times \frac{Cp \times A}{Tp}$ = $0.278 \times \frac{0.59 \times 132.137}{5.790}$ = 3.743 m^3/s

From the acquisition of the peak discharge value, a correction of discharge per unit time was obtained, a correction at the peak discharge of 4.432 m^3/s was obtained. To obtain the flood discharge per return period plan, the correction discharge per flood time is multiplied by the effective rain that occurs in the DAS, along with the recapitulation of the planned flood discharge using the HSS Snyder method in Tambun Watershed:

Table 12. Recapitulation of Planned Flood Discharge for HSS Snyder Method

t (hr)	Specific Return Period Plan Flood Discharge (m^3/s)						
	Q1	**Q2**	**Q5**	**Q10**	**Q25**	**Q50**	**Q100**
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.004	0.008	0.010	0.012	0.015	0.017	0.019
2	2.337	4.147	5.487	6.459	7.787	8.851	9.983
3	15.940	28.288	37.428	44.051	53.114	60.371	68.087
4	39.761	70.562	93.360	109.881	132.486	150.587	169.836

5	65.112	115.552	152.886	179.940	216.958	246.601	278.122
6	101.993	181.003	239.484	281.863	339.848	386.281	435.657
7	112.178	199.078	263.399	310.011	373.786	424.856	479.163
8	113.097	200.709	265.556	312.549	376.847	428.335	483.087
9	105.410	187.067	247.507	291.306	351.233	399.222	450.252
10	92.548	164.242	217.307	255.763	308.378	350.512	395.315
11	77.898	138.243	182.908	215.276	259.563	295.027	332.738
12	62.956	111.726	147.823	173.982	209.774	238.435	268.913
13	49.122	87.175	115.341	135.752	163.678	186.042	209.822
14	37.327	66.243	87.645	103.155	124.376	141.369	159.439
15	27.795	49.328	65.265	76.814	92.616	105.271	118.727
16	20.375	36.158	47.841	56.306	67.890	77.166	87.029
17	14.750	26.177	34.634	40.763	49.149	55.864	63.005
18	10.572	18.763	24.825	29.218	35.228	40.042	45.160
19	7.517	13.339	17.649	20.773	25.046	28.468	32.107
20	5.308	9.421	12.464	14.670	17.688	20.104	22.674
21	3.728	6.616	8.753	10.302	12.422	14.119	15.924
22	2.606	4.624	6.119	7.201	8.683	9.869	11.131
23	1.814	3.220	4.260	5.014	6.045	6.871	7.749
24	1.259	2.234	2.956	3.479	4.194	4.767	5.377
25	0.871	1.545	2.045	2.407	2.902	3.298	3.720
26	0.601	1.066	1.411	1.661	2.002	2.276	2.567
27	0.414	0.734	0.971	1.143	1.378	1.567	1.767
28	0.284	0.504	0.667	0.786	0.947	1.077	1.214
29	0.195	0.346	0.458	0.539	0.650	0.738	0.833
30	0.134	0.237	0.314	0.369	0.445	0.506	0.570
31	0.091	0.162	0.214	0.252	0.304	0.346	0.390
32	0.064	0.114	0.150	0.177	0213	0.242	0.273
Max	**113.097**	**200.709**	**265.556**	**312.549**	**376.847**	**428.335**	**483.087**

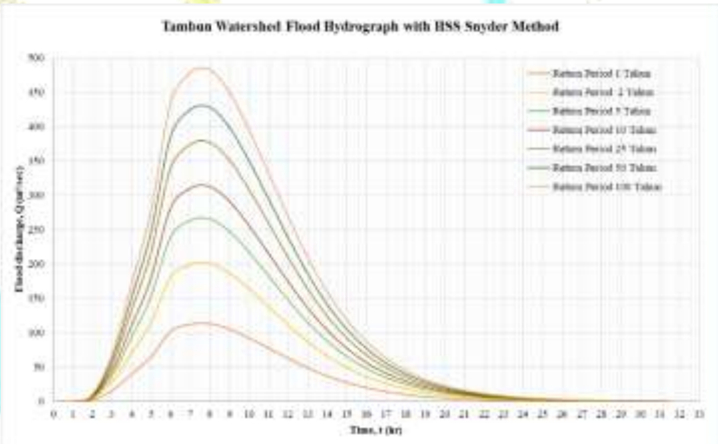

Figure 2. Tambun Watershed Flood Hydrograph HSS Snyder Method

3.3. Hydraulics Analysis with HEC-RAS Modeling

Entering river cross-sectional data into HEC-RAS is conducted based on the results of mapping the situation with aerial photographs that have been corrected through the agisoft application to obtain an elevation that is suitable for field conditions. Based on the length of the review section of 7,000 meters, with a spacing of 50 meters between river cross sections, 140 river cross sections are made of geometric data. In this study did not take into account the existence of tributaries and the influence of tides. In this study, the manning coefficient (n) was used for Tambun River of 0.03 based on the characteristics of the pavement type on a natural cross-section of river in the form of soil, the condition of winding cliffs, slopes and grass. The following are the simulation results of the longitudinal and transverse sections of the planned flood discharge in Tambun watershed:

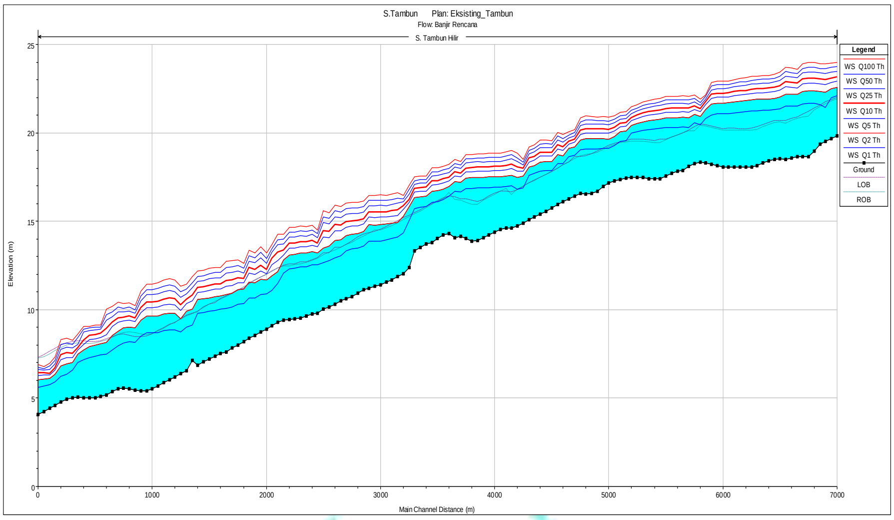

Figure 3. Long Section Profile of Tambun River View Section

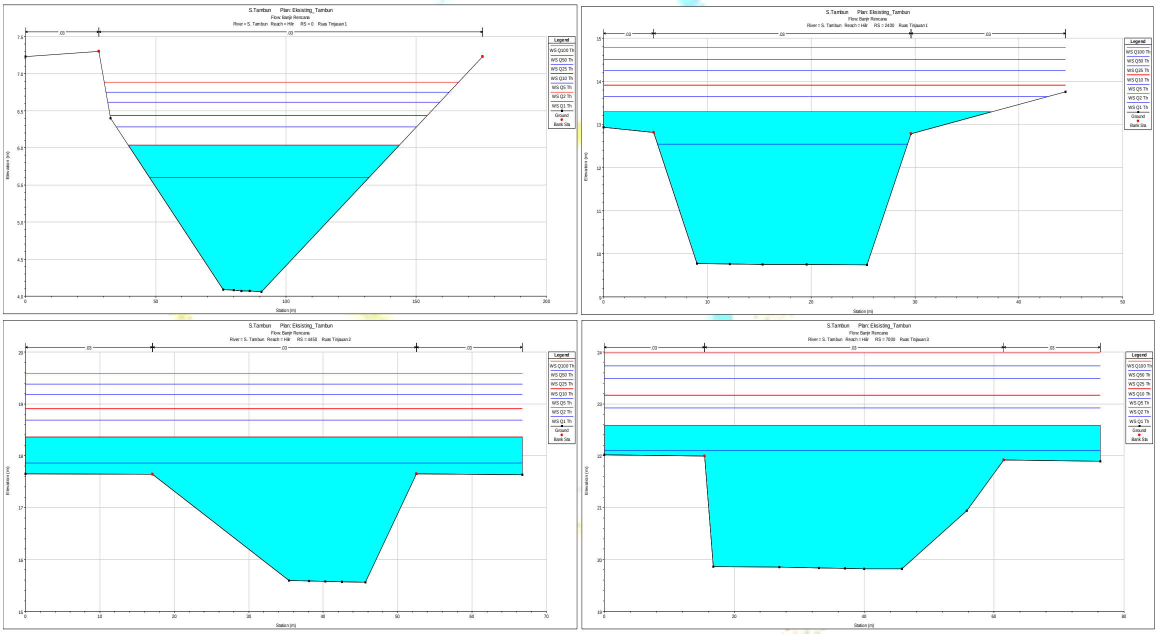

Figure 4. Cross Section Profile Sta. 0, Sta. 2400, Sta. 4450 dan Sta. 7000

From the simulation results of the existing condition of the Tambun River according to the review section, during the 2-year return period discharge, the river has experienced overtopping in almost all sections of the review, both the left and right embankments. Floods with a return period of 2 years did not overtake only a few stakes, namely Sta 3150, Sta 2100, Sta 2050, Sta 2000, Sta 1950, Sta 1900 and Sta 1800, Sta 600 to Sta 0 (river mouth).

3.4. Evaluation River Morphology

In general, the characteristics of Tambun watershed based on its shape are classified in semi-radial type (flow is concentrated at one point of the main river flow and spreads out but tends to be narrow and elongated like the type of bird feather). The river channel has a meandering channel classification, especially in the upstream and middle sections of the review. This river bend often changes its course from year to year. In some parts of the river there are deposits in the corners of the river channel.

Determine the morphological changes to the river cross section, a comparison of the conditions of the previous cross section and the alignment of the focal point or binding point of the bank station / river embankment to the right was conducted to see the trend of changes that occurred. On the cross section of the river, symbols a), b) and c) to provide an overview of the changes that have occurred.

From Figure 5 the comparison of the cross sections of Sta 2050-2200 has the same trend of change in a) left embankment, b) canal bottom, and c) right embankment. The following is a review of morphological changes in the cross section of the river:

a) Changes in the embankment from 2017 to 2018 were caused by river crossing & normalization activities. The river channel was aligned at Sta 2100-2150 and treated with earthen embankments to form the desired river channel and cross section. In 2023, the left embankment will shift due to the scouring of the water currents on the outer bend.
b) Changes in the channel base from year to year are getting deeper. The channel bed scour occurred on the left side of the flow by 50-70 cm from 2018 to 2023.
c) Changes to the right embankment from the results of normalization in 2018 tend to return to the 2017 cross section. There has been a buildup of sediment again at the bend on the inside of the river.

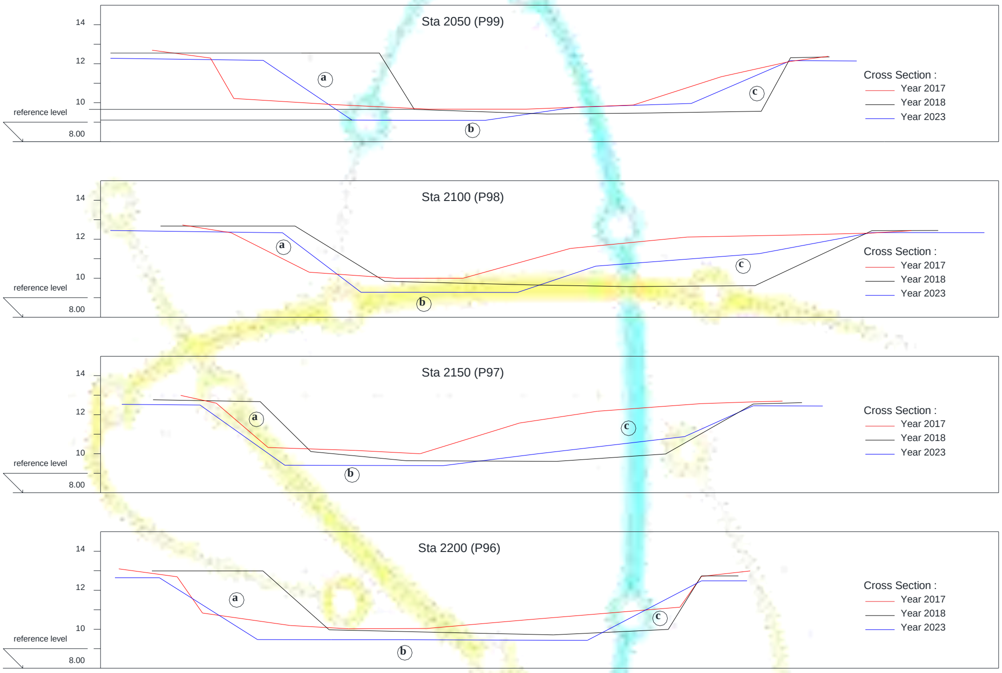

Figure 5. Comparison of River Cross Sections at Sta 2050-2200

There was erosion of the cliffs on the left side of the river due to the position of the outer bend of the river and accumulation of sediment on the right side due to the position of the bend in the river. Over time, accompanied by currents due to flooding that occurs every year, the river channel gets deeper and returns to the shape of the channel before normalization was carried out because the construction of the earthen embankment was not accompanied by cliff reinforcement, especially on the outer bends of the river.

Morphological changes are affected by the collapse of river cliffs and sediment deposits in river bends. Community behavior also contributes to morphology changes such as throwing garbage in the river which causes piles on riverbanks and free sand mining by the surrounding community. The handling of the construction that has been carried out on this river, namely the cutoff and strengthening of the cliffs, needs to be maintained so that the channel that has been made does not return to its natural condition or move to an area where the condition of the cliffs is weaker due to water energy when a flood occurs.

Floods in Tambun River can affect the stability of the river channel because the embankments/ riverbanks have not been handled as a whole. The land allotment in this section of the review is dominated by dry land agriculture and settlements, with overtopping of all river sections so that there is a need for comprehensive protection for the Tambun River.

3.5. Recommendations for Regulation of Morphology and Management of River Floods

Broadly speaking, it is necessary to carry out normalization of the river (increasing the capacity of the riverbed) on the entire cross-section because the current condition of the cross-section is not capable of serving the dominant discharge from the river with a return period of 2 years. Rivers in natural conditions are expected to be able to serve a bank full capacity with dominant discharge from relatively stable natural flows.

This normalization activity is the primarily alternative for flood management on Tambun River. However, from the simulation results with HEC-RAS there are still several river sections that have not been able to serve a 2-year flood discharge even though they have been normalized to the maximum for the cross section of the river (i.e. the upper width of the river), so that at some Sta stakes it is recommended to use embankments of landfills both on the left and river right. Landfills can be used from excavated sediments but need to be compacted.

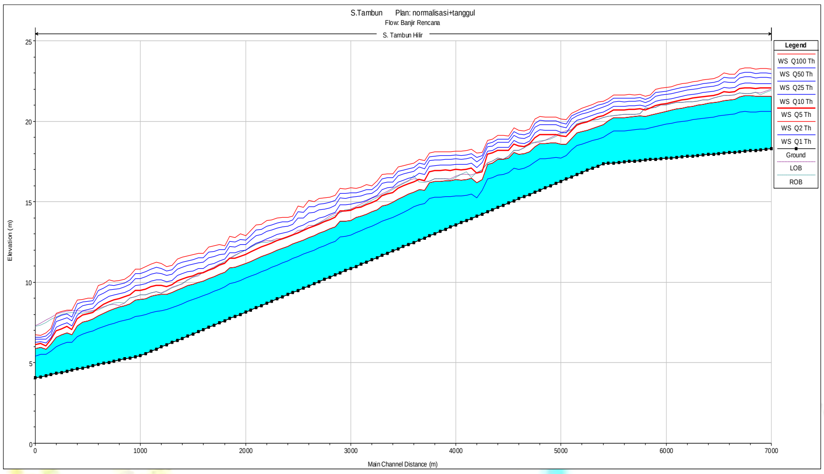

Figure 6. Long Section Profile of Normalization Results

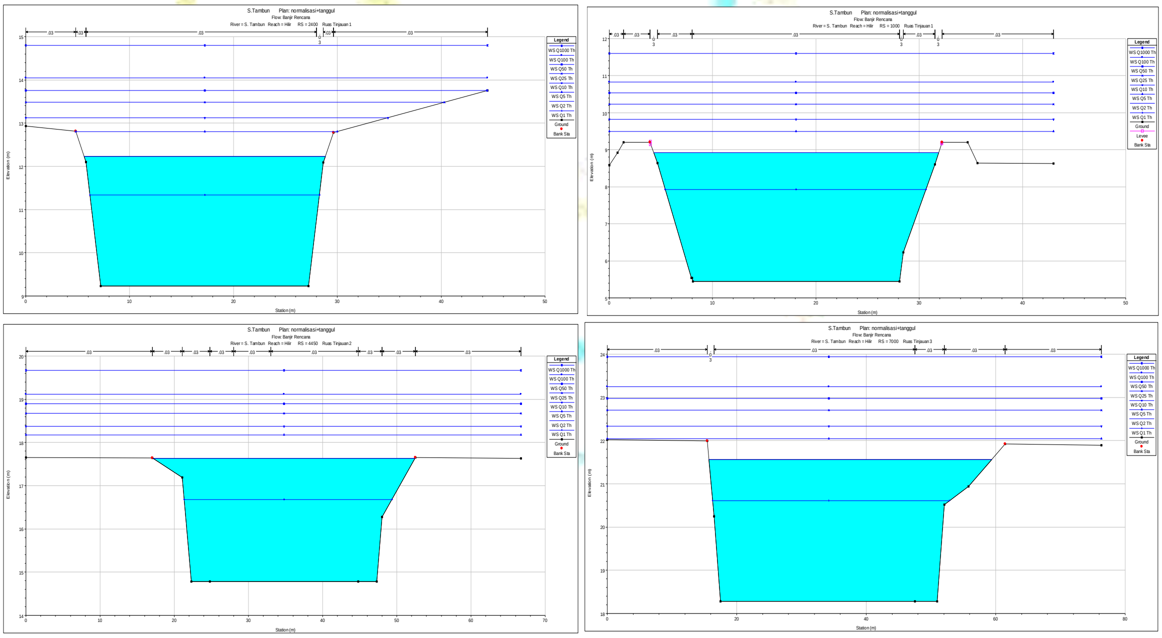

Figure 7. Cross Section Profile of Normalization (Sta. 1000, Sta. 2400, Sta. 4450 and Sta. 7000)

Long-term management needs to be considered by building a flood embankment on the Tambun River so that it has a river capacity that is able to carry a 10-year flood discharge because in some segments the capacity of the river after normalization has not been able to serve 10-year floods. This design uses a 2-year discharge period as well as the planned flood embankment because it adjusts to the local government's financing capacity..

To get an idea of the ideal cross-sectional dimensions of the Tambun River, several Sta. Simulation scenario with scour treatment in the form of gabions as needed at each Sta by adjusting the coefficients on the riverbanks taking into account the height of the river embankment for discharges of more than 200 m3/s (2 yearly discharge), namely 1.0 meters of additional flood embankments. In the cross section simulation, the width of the river bed is set at 30-40 meters and the upper width adjusts the slope of the river wall 1:1 with a river depth of 3 - 3.5 meters.

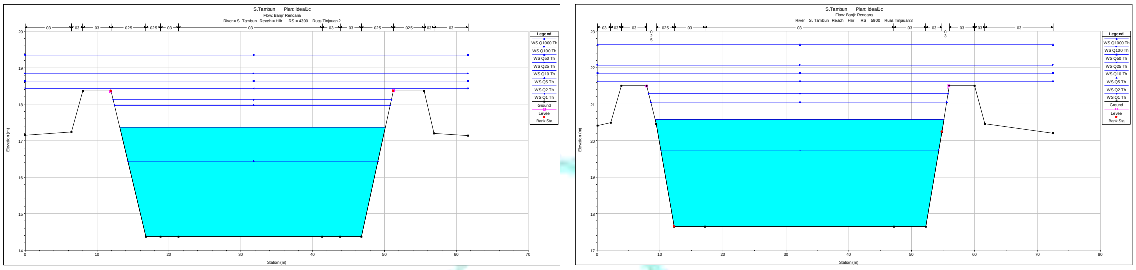

Figure 8. Flood Simulation of Tambun River's Ideal Cross Section at Sta 4300 and Sta 5900

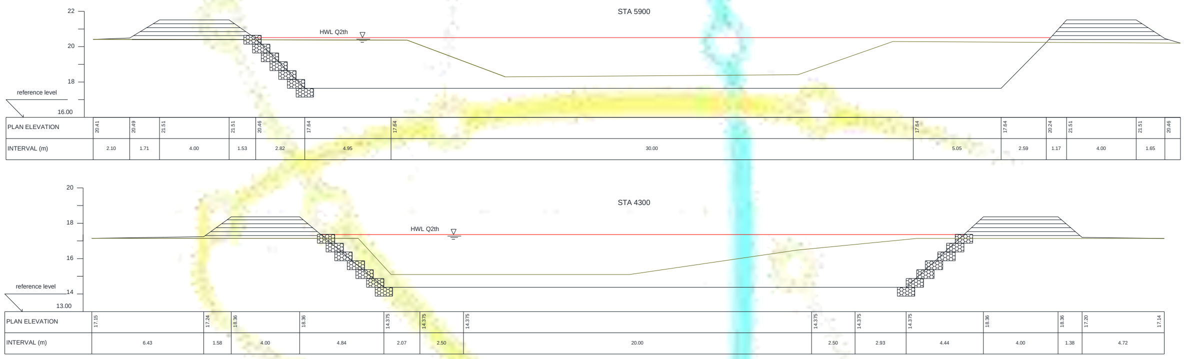

Figure 9. Ideal Cross Section of the Tambun River at Sta 4300 and Sta 5900

Other physical support activities that can reduce the spread of floods that occur around Tambun River are the repair and construction of urban drainage systems. According to what the community feels, the drainage conditions around residents' homes are very bad, so the local government needs to pay attention. However, to support the creation of balance and order, it is hoped that the local residents can also participate by making an independent disposal system around the house. Wastewater is directed and channeled to the nearest drainage system.

In addition to regulating morphology and handling river floods with technical or physical civil activities, it is also necessary to support non-physical activities as follows:

1) Determination of River Boundaries and Regional Regulations concerning River Boundaries, It is necessary to immediately stipulate regional regulations regarding river boundaries to minimize the construction of settlements around rivers and maintain the sustainability of rivers. Determination of river borders must be in accordance with the Direction of the Regulation of the Minister of Public Works and Public Housing Number: 28/PRT/M/2015 concerning Determination of River Boundary Lines and Lake Boundary Lines. The Tambun River can be classified as a river without banks and outside urban areas, so according to Paragraph 6 (1) for small rivers with a watershed area of <500, then in (3) it is stated that the river boundary is determined to be at least 50 fifty meters from the left and right banks. river banks along the river channel. Before implementing river border regulations, socialization or appeals to the public should be carried out regarding the meaning and importance of establishing river boundaries. In the implementation of this determination, the community is also involved so that no community feels disadvantaged and after the regulations regarding the determination of river boundaries must regulate land use..
2) Regulation of Mining

Considering that there are rock (gravel and sand) mining activities at Sta 6300 – Sta 7000, it is necessary to carry out an assessment of sedimentation and mining control on Tambun River so that no exploitation of sediment products in this section occurs. The study is intended to provide limits on the space for excavating sediment and the volume of sediment that is permitted to be dredged.

3) Installation of warning signs and prohibitions
The appeal to the public to help protect and preserve the environment and the prohibition of littering, especially in river bodies. If a local regulation regarding the determination of river borders has been stipulated, it is necessary to determine the boundaries for development around the river.

IV. CONCLUSION

The Tambun watershed has the characteristics of a semi-radial watershed, a dendritic flow pattern, a meandering river channel, a G-type morphology that has a high rate of bank erosion. Changes in river morphology are influenced by soil erosion processes in the watershed and river bank erosion (bank collapse and sediment deposits), flow pressure during floods because the river's capacity is unable to serve flood discharge, as well as the influence of residents due to river processing. Based on the results of a flood simulation using the HEC-RAS program, the capacity of the river cannot serve the dominant flood discharge for a return period of 2 years, resulting in an overflow. The recommendation for managing river morphology and flood management in the Tambun watershed is to normalize the river channel along the 7000 m with treatment according to the conditions of each problematic part of the river. To increase the capacity of rivers that can serve floods every 2 years. Then construction of flood embankments, strengthening of cliffs with gabion construction, stipulation of river border area regulations, arrangement of mining and installation of signs calling for a prohibition on the use of river border areas.

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