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Analysis of Komolino-Lino River Flow Using HEC-RAS 6.4.1

Takdir Said[1], Astrid Dwijayanti[1], I Wayan Sutapa[2*]
[1]Public Works and Spatial Planning Department of Banggai Regency, Central Sulawesi, Indonesia
[2]Department of Civil Engineering, Faculty of Engineering, Tadulako University, Central Sulawesi, Indonesia

ABSTRACT: Sedimentation in the Komolino-Lino River channel with a watershed area of 36.90 km2 has reduced the river's capacity. This causes flooding that inundates plantations, irrigated rice fields, residential areas, and social facilities. This study analyzes the river's capacity to pass the design flood discharge and its handling solutions. The research stages include primary and secondary data collection and hydrological and hydraulic data analysis. Primary data in the form of situation measurements, lengthwise and across the river. Secondary data in the form of rainfall data and Komolino-Lino watershed maps. Rainfall data used Hek-Bunta Station with observations for the last 10 years (2014-2023). Design rainfall is calculated using the Log Pearson III Method according to the appropriate statistical parameters. Design flood discharge is computed using the Haspers, Weduwen, HSS Nakayasu, and HSS Snyder Methods. River hydraulic analysis uses the HEC-RAS 6.4.1 program. The selection of discharge and method used depends on the results of the initial HEC-RAS run on existing conditions and the appropriateness of the planned dam. From these results, the design flood discharge Q25 = 150.777 m3/sec was selected using the Snyder HSS Method. From the simulation results of existing conditions, the Komolino Lino River is unable to accommodate flood discharge at a 5-year return period, even in some river sections there is an overflow at an annual discharge (1.01). Therefore, river normalization and river embankments were carried out with an average height of 1.0 m.

KEYWORDS: Hydrological analysis, HEC-RAS, Komolino Lino River

INTRODUCTION

The function of a river is to channel water and sedimentation carried by the flow of water from upstream to downstream. The condition of the river channel is formed naturally according to the natural conditions through which the water flow passes. Natural conditions in the form of geological factors, morphology, vegetation, climate, rainfall, and so on are the cause of the differences in the shape of the river.

These differences in shape, cause differences in river characteristics. In detail, the differences in river characteristics are influenced by river morphology which consists of the main direction of flow, water discharge, river channel width, river depth, river gradient, and river bed roughness coefficient.

The exploitation of natural forest resources, especially those in the River Basin Area (DAS), has occurred over the past few years, resulting in damage to the condition of the DAS which is the supporting area of the river water system.

The impact of DAS damage can be seen in the condition of river morphology, such as the occurrence of faster shallowing of the river bed, causing increasing and widespread flooding and differences in river water level fluctuations during the rainy and dry seasons.

The Komolino-Lino River with a watershed area of 36.90 km2 has experienced sedimentation, resulting in a reduction in the capacity of the river channel. This causes flooding that inundates plantations, irrigated rice fields, residential areas, and social facilities. Several studies on river management to overcome flooding have been carried out in other locations, including The Krueng Tukah River has experienced changes in river conditions, land use, and population growth, causing flooding that damages buildings, agricultural land, and the environment. The calculation results show that the Krueng Tukah River is unable to accommodate flooding for more than Q25 years. (Syahputra, 2018). The results of the study on the Baubau River showed that the designed flood discharge of the Baubau River exceeded the river capacity or had the potential for a flood threat that could cause a flood height of 1 to 5 meters from the normal river water level with a high-risk class status (Nuzul, et al., 2021). The results of the study in the Ciberang River, there was an average decrease in water level of 10.25% and an average increase in discharge of 10.49% (Restu Wigati, et al., 2016). The results of flow modeling with HEC-RAS at the Tugu Dam were simulated in 2 ways. One of the advantages of dam hydraulic design planning using HEC-RAS software is that if there is a new design alternative, it can be simulated faster than analytical calculations (Sintya M.I. & Umboro L., 2017). The results of the study in the Cisadane Hilir Sub-DAS, Pasar Baru Dam to the Kedaung Bridge produced by the HEC-RAS model, floods occurred in 12 sub-districts spread across 3 districts. The area of flood distribution increased with each increase in the recurrence period (Devita E. Z. S., et al., 2022). The results of the HEC-RAS program analysis in Sewu Village, Surakarta City, show that the existence of the new Demangan sluice gate can overcome the flood problems that have occurred so far (Dinar F. F. K., et al., 2022). The results of the HEC-RAS modeling on the Way Kandis River, with the construction of embankments and dams, can reduce the area of flood inundation by 80.81% - 88.54%. (Aprizal & Arju Meris, 2020). The results of the HEC-RAS 5.0.7 simulation on the Dengkeng River, show that the flood inundation in Karangdowo District is 124.72 ha and in Tawangsari District is 30.89 ha (Irawan T., et al., 2021). The results of the HEC-RAS simulation on the Ciliwung River at STA 7+646 to STA 15+049 cannot accommodate the design discharge in the 20-year return period, therefore it is necessary to improve the river in the form of river normalization and embankment elevation (Sebayang, 2018). The results of the HEC-RAS modeling on the Komolino Lino River found that the Komolino Lino Riverbed was unable to pass the design flood discharge. Therefore, it is necessary to plan a 0.50 m high embankment (Sutapa & Bariroh, 2023). The purpose of this study is to analyze the river's capacity to pass the design flood discharge and its handling solutions.

RESEARCH METHODOLOGY

Research Location

The research location is in Komolino River - Lino, Simpang Raya District, Banggai Regency, Central Sulawesi Province with coordinates $122^0$14'23.83" East longitude and $0^0$55'20.68" South latitude. The calculated distance from Palu City the Provincial Capital is 480 km, with good asphalt road conditions. The research location is presented in the following image:

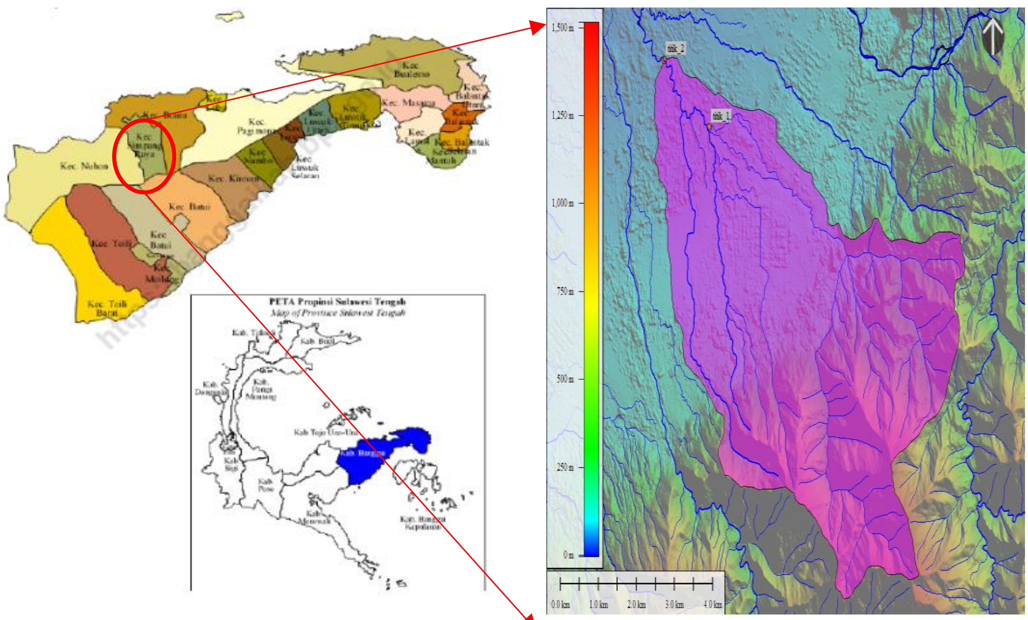


Figure 1. Research Location

Source: Banggai Regency in figures 2023, web and analysis results

Research Data

The data required in this study are secondary data, namely: rainfall data, and the Komolino Lino Watershed Map. Rainfall data used Hek Bunta Rainfall Station with a distance of 11.21 km from the research location, available rainfall data for 10 years (2014-2023). Primary data in the form of longitudinal and transverse sections of the Komolino Lino River. All secondary data were obtained from the Office of Public Works, Human Settlements and Water Resources (Cikasda) of Central Sulawesi Province.

LITERATURE REVIEW

The selection of the rainfall frequency analysis method depends on the statistical parameters except for the Log Pearson type III distribution which does not indicate. Therefore, this study uses the Log Pearson type III Method (Hadisusanto, 2011), (Soemarto, 1987).

The test of the suitability of the frequency distribution used is Chi-Square (Chi-Square) and Smirnov-Kolmogorov (Hadisusanto, 2011), (Soemarto, 1987).

To determine the design flood discharge, peak flood discharge analysis was carried out using the Haspers Method, Nakayasu HSS, and Snyder HSS Method. Flood discharge with the Haspers method uses several equations (Hadisusanto, 2011). Nakayasu has conducted flood hydrograph research on several rivers in Japan. Several equations for analyzing Nakayasu HSS are (Enung, 2016), (Pengki Irawan, et al., 2020), (Elza Patricia Siby, et al., 2013), (M. Ramadani, et al., 2014), (Rico Sihotang, et al., 2011), (Sutapa I W., 2012a), (Sutapa I W., 2012b). Snyder's established a standard unit hydrograph at the beginning of his research, where the rainfall time tr is related to the peak time tp with the equation (Pengki Irawan, et al., 2020), (Elza Patricia Siby, et al., 2013), (Siswoyo, 2011), (Soemarto, 1995).

Hydraulic analysis using the HEC-RAS hydrodynamic model. HEC-RAS software is a river analysis system from the Center for Hydrological Engineers, a hydraulic computer program for modeling hydraulic components. This program calculates the height and velocity of water in the river and builds a one- or two-dimensional model to simulate water movement, both in steady and unsteady states (USACE, 2010).

Hydraulic Parameter Calculation

The hydraulic characteristics of the Komolino Lino River were calculated using a one-dimensional steady flow model. The conventional step approach is used to calculate the water surface height and energy degree lines for two adjacent cross-sections (Dragan, et al., 2014)

RESEARCH RESULTS AND DISCUSSION

Hydraulic Analysis

River Geometry

The measurement locations for the longitudinal and transverse cross-sections of the Komolino Lino River are presented in the following figure:

Figure 2. Measurement location of the Komolino Lino River

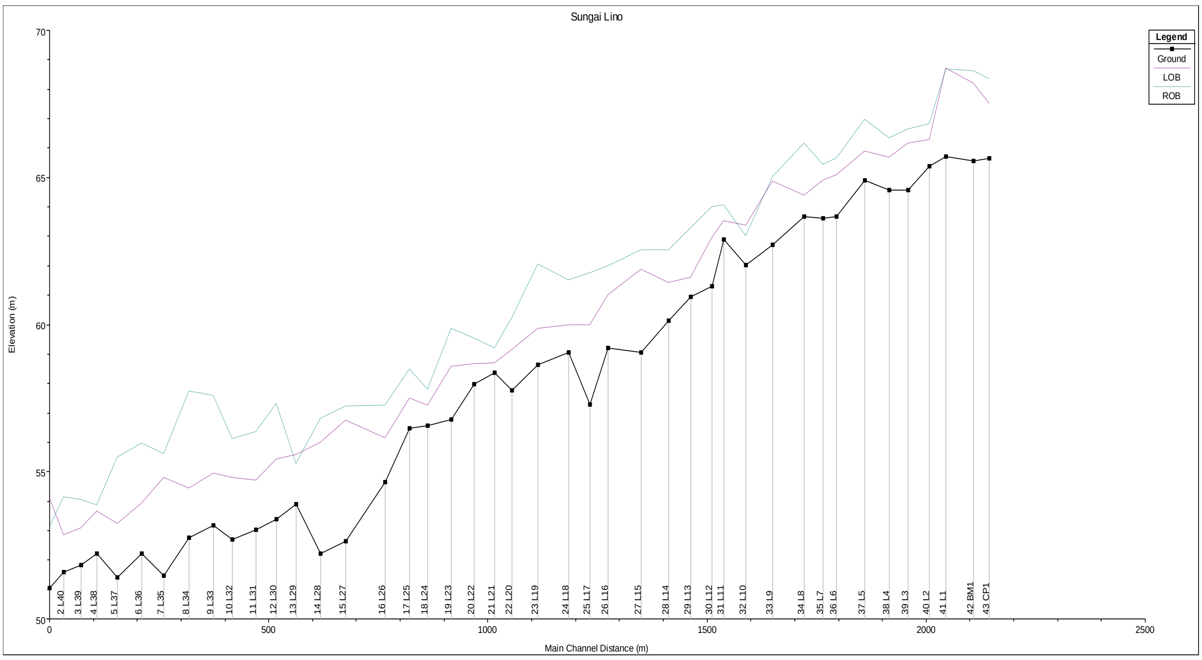


Figure 3. Longitudinal section of the Komolino Lino River

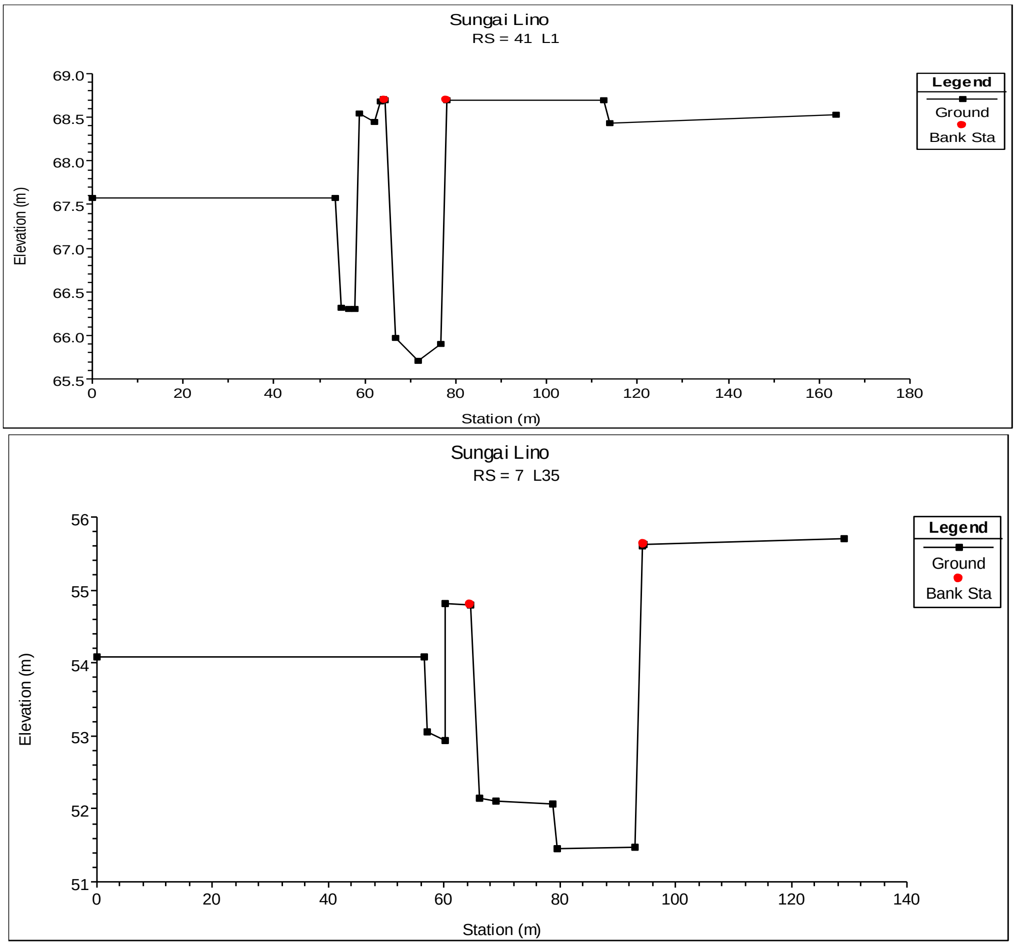


Figure 4. Geometrics of the Komolino Lino River

Boundary conditions

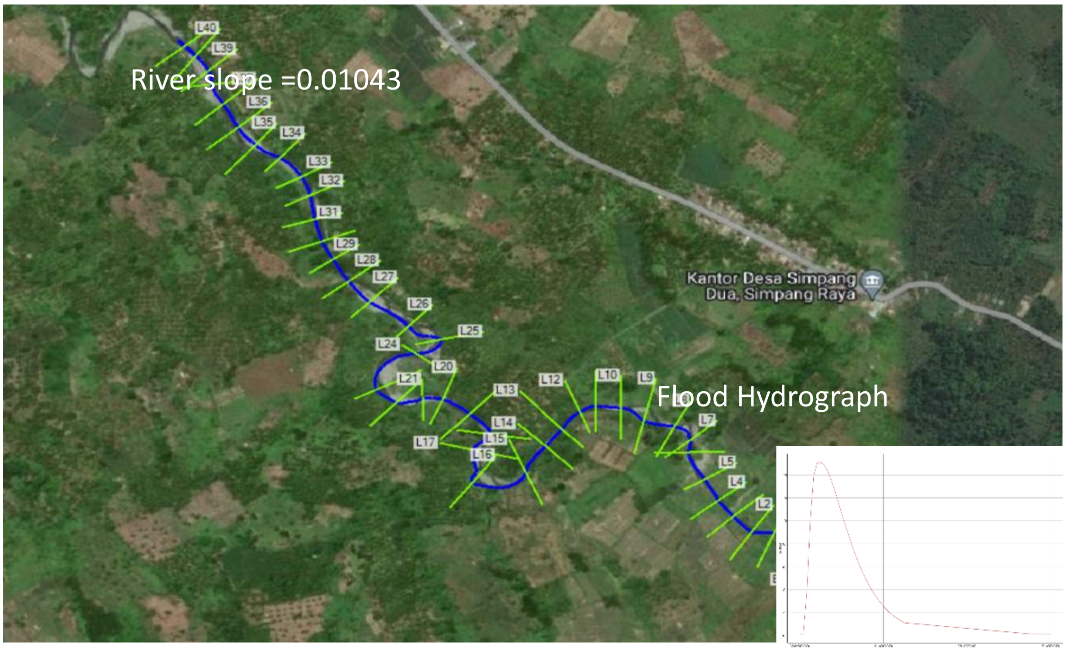


Figure 5. Simulation boundary conditions

The boundary conditions used in this simulation are in the upstream part in the form of a design flood hydrograph and in the downstream part the normal depth of the river. Based on the initial running results of HEC-RAS on the longitudinal and transverse sections of the Komolino Lino River, the flood discharge used in simulating the hydraulics of the Komolino Lino River is the design discharge for a 25-year return period using the Snyder Method (Q_{25} = 150.777 m^3/s).

HEC-RAS Running Results for Existing Conditions

The results of running HEC-RAS for existing conditions are presented in the following figure;

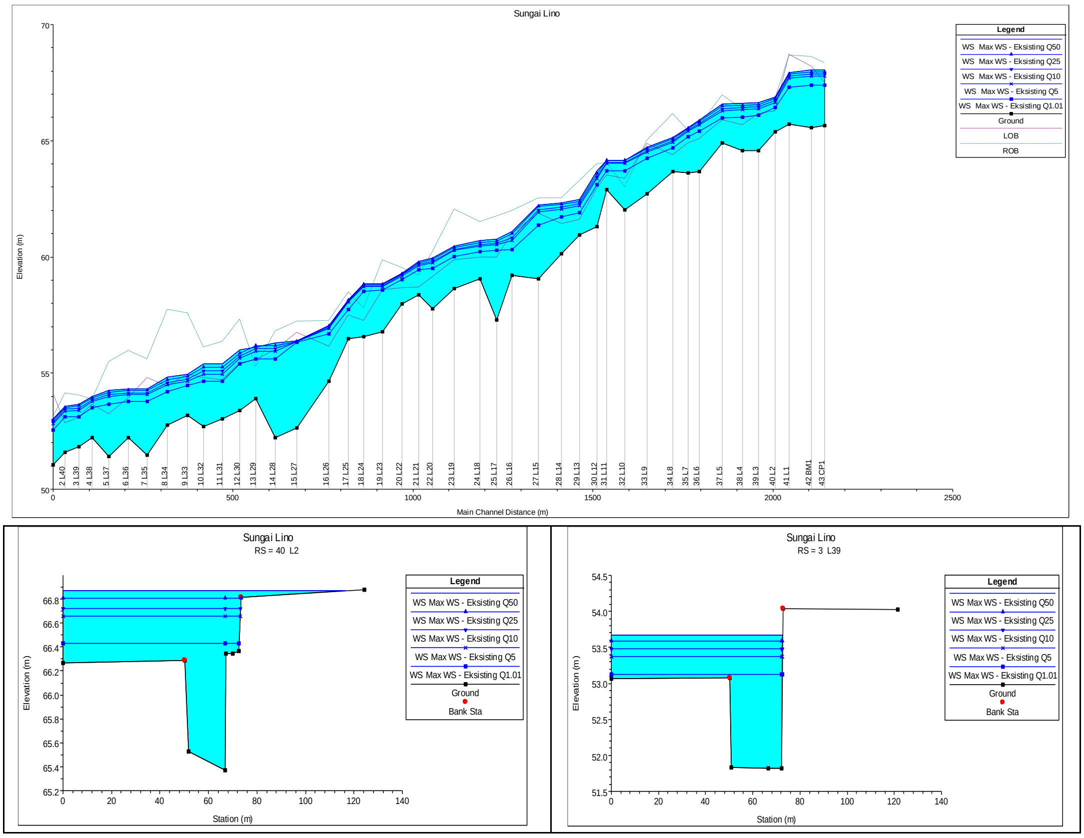
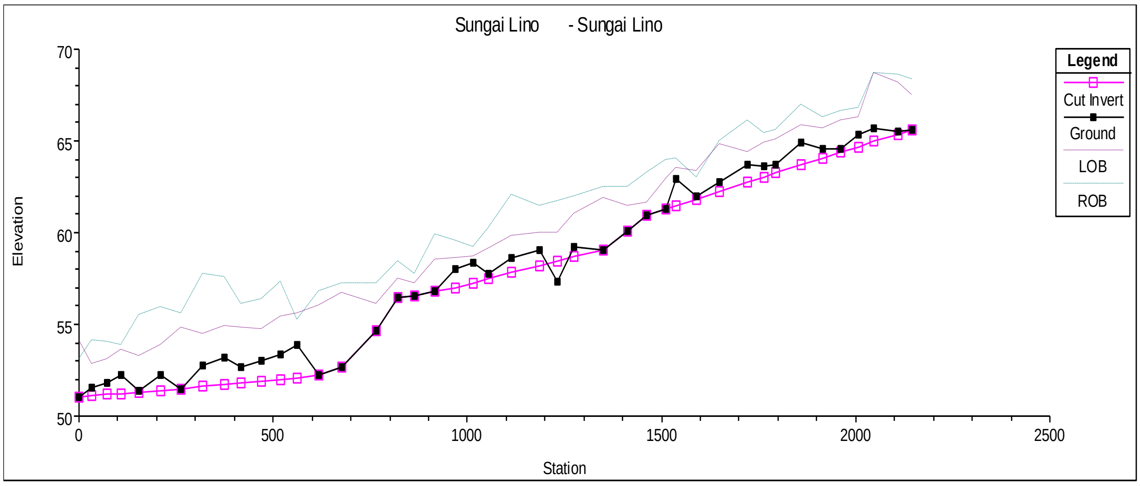


Figure 6. Results of running HEC-RAS on existing conditions of the Komolino Lino River

The simulation results show that the storage capacity of the Komolino Lino River cannot accommodate flood discharge at a 5-year return period, even in some sections where there is an overflow at the annual discharge (1.01). This can be seen from the longitudinal and transverse sections of the model where there is water overflowing to the left or right banks of the river. The flood water level elevation (MAB) Q_{25} in the upstream is at +67.97. While in the downstream MAB is at +52.98.

Results of Running HEC-RAS Normalization Design

It is planned to carry out river normalization with dimensions that are almost the same as the existing river. With a riverbed width of between 10-25 m, river height ±1 - 1.5 m, river design slope of 0.00145 - 0.00683, and embankment slope of 1: 0.5. The discharge boundary condition is the same as the existing condition. This aims to see the condition of the flood water level with the same load as the existing river condition load. For more details, it is presented in the following image



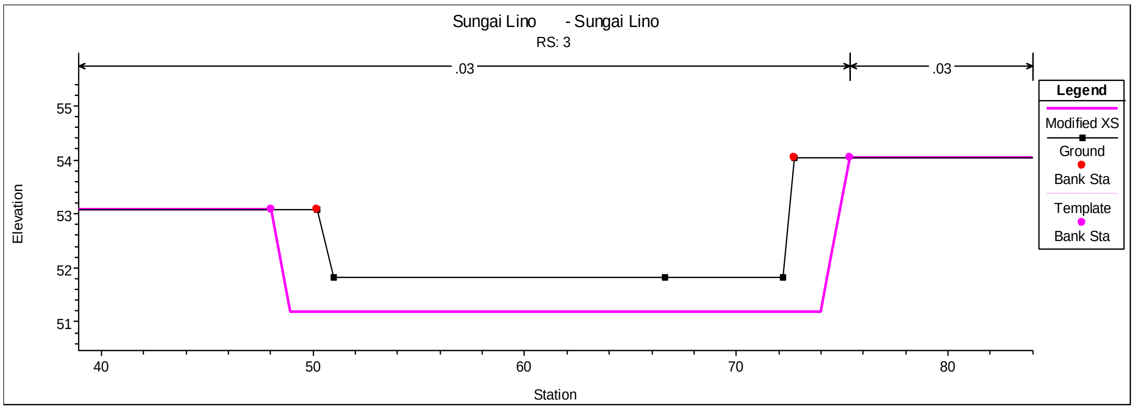
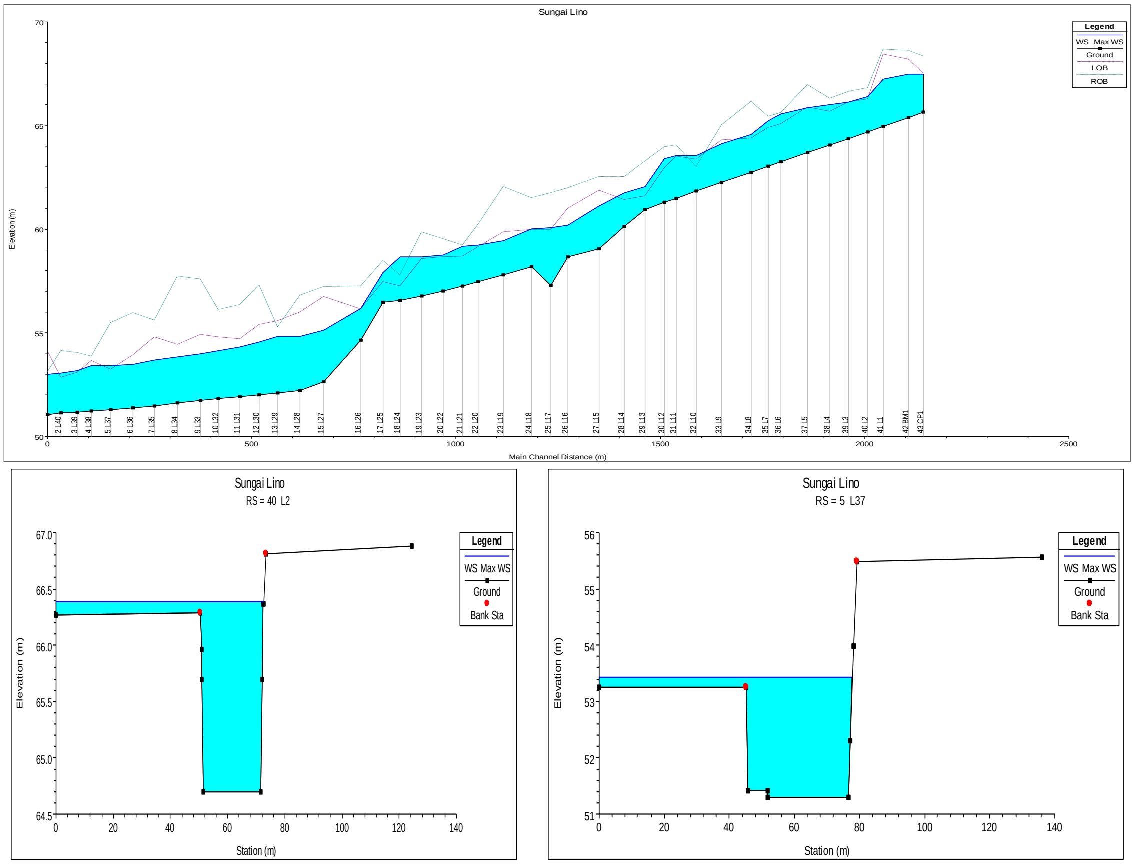


Figure 7. River Normalization Design Plan

The results of the simulation run on the Komolino Lino River show that with the planned normalization design, there is a significant decrease. The decrease in MAB can reach 40-60 cm compared to existing conditions. However, there are still several river sections where the water is overflowing. Locations that are still overflowing are planned to be overcome by building embankments.



Upstream **Down Stream**

Figure 8. River Normalization Simulation Results

Results of Running HEC-RAS Normalization and Embankment Design

Locations that are still overflowing will be addressed with flood embankments. The average embankment height is 1.0 m above the riverbank.

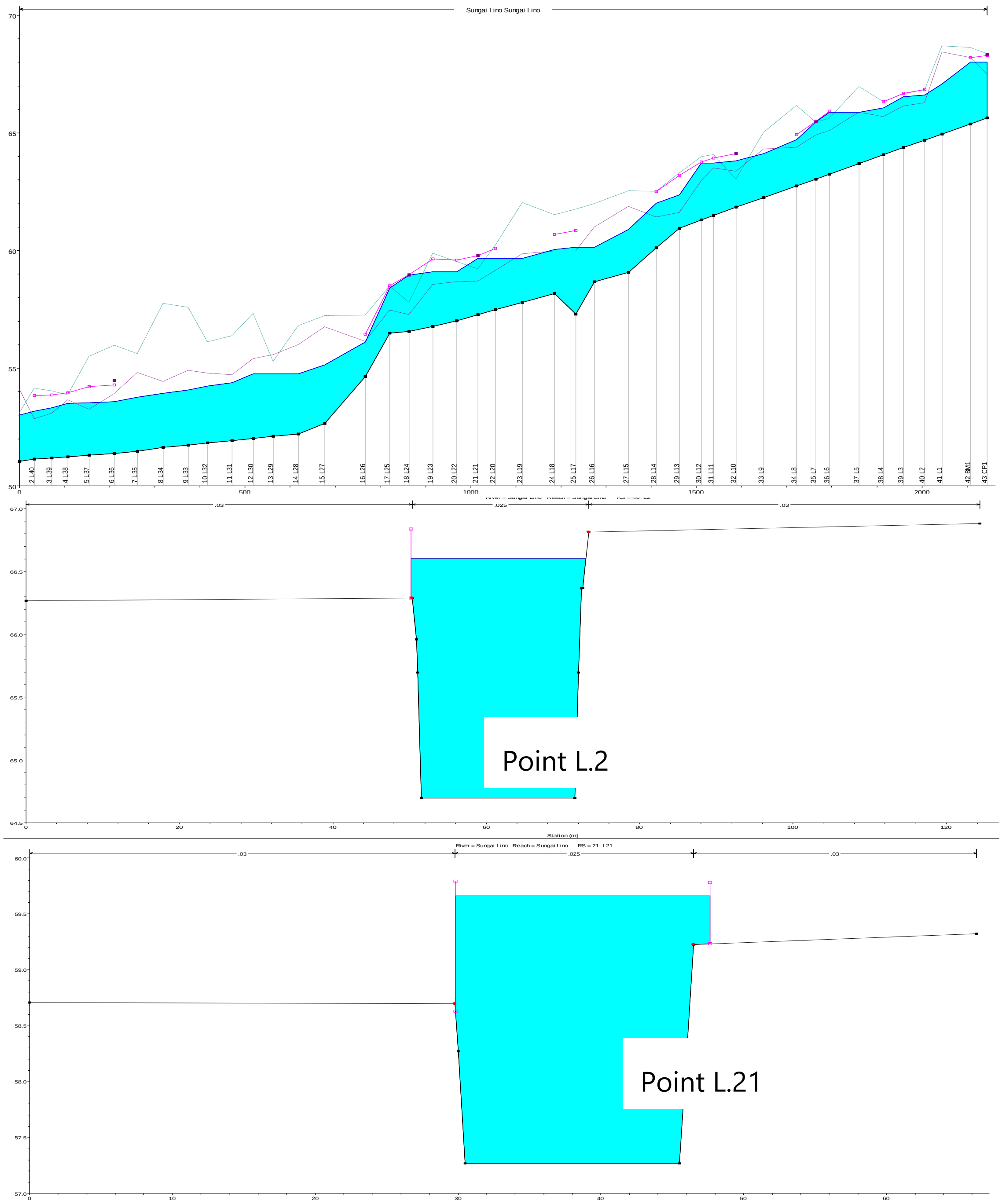


Figure 9. Results of the Embankment Plan Simulation

The Q_{25} discharge flow profile and the Komlino Lino River embankment plan are presented in the following table:

Table 1. Q_{25} Discharge Flow Profile and the Komolino Lino River Embankment Plan

River Sta		Min Ch El (m)	Levee El Left (m)	LOB Elev (m)	W.S. Elev (m)	ROB Elev (m)	Levee El Right (m)	Top Width (m)	Froude # Chl
43	CP1	65.64	68.29	67.5	68.02	68.36	68.33	50.49	0.46
42	BM1	65.39	68.21	68.2	68.02	68.62		17.59	0.72
41	L1	64.96		68.45	67.08	68.69		21.35	0.97
40	L2	64.7	66.84	66.29	66.6	66.81		22.77	0.9
39	L3	64.38	66.68	66.13	66.55	66.65		17.01	0.96
38	L4	64.07	66.33	65.68	66.07	66.33		16.81	1.1
37	L5	63.7		65.88	65.89	66.97		46.91	0.73
36	L6	63.25	65.92	65.08	65.89	65.61		23.21	0.98

River Sta	Min Ch El (m)	Levee El Left (m)	LOB Elev (m)	W.S. Elev (m)	ROB Elev (m)	Levee El Right (m)	Top Width (m)	Froude # Chl
35 L7	63.04	65.5	64.92	65.47	65.44	65.48	13.81	1.18
34 L8	62.75	64.94	64.39	64.71	66.16		17.54	1.12
33 L9	62.26		64.3	64.13	65.01		70.28	1.17
32 L10	61.84	64.13	63.38	63.81	63.03	64.13	31.3	1.07
31 L11	61.5	63.92	63.52	63.71	64.08		40.04	0.61
30 L12	61.31	63.77	62.95	63.71	63.99		12.64	1.2
29 L13	60.95	63.2	61.62	62.37	63.29		32.43	1.22
28 L14	60.12	62.52	61.42	62.01	62.52		16.63	1.2
27 L15	59.07		61.87	60.9	62.53		16.83	1.26
26 L16	58.67		61	60.15	61.99		30.56	1.09
25 L17	57.29	60.86	59.98	60.13	61.76		22.03	0.83
24 L18	58.18	60.68	59.98	60.05	61.5		22.61	0.92
23 L19	57.81		59.87	59.66	62.05		30.87	0.76
22 L20	57.48	60.1	59.15	59.66	60.22		28.12	0.58
21 L21	57.27	59.79	58.7	59.66	59.23	59.78	17.83	0.81
20 L22	57.01	59.6	58.66	59.11	59.54		23.16	0.77
19 L23	56.77	59.65	58.56	59.11	59.88		92.96	0.16
18 L24	56.57	58.97	57.27	58.96	57.79	58.96	56.31	0.7
17 L25	56.48	58.5	57.47	58.42	58.49		21.46	1.16
16 L26	54.65	56.45	56.14	56.1	57.26		24.84	1.58
15 L27	52.65		56.76	55.15	57.23		12.48	1.11
14 L28	52.21		56	54.75	56.81		42.04	0.53
13 L29	52.1		55.57	54.76	55.28		63.83	0.55
12 L30	52.02		55.4	54.76	57.31		27.74	0.63
11 L31	51.92		54.71	54.39	56.37		58.92	0.7
10 L32	51.82		54.8	54.24	56.12		27.42	0.67
9 L33	51.74		54.91	54.08	57.59		28.56	0.68
8 L34	51.63		54.43	53.93	57.74		29.07	0.66
7 L35	51.46		54.8	53.78	55.62		32.02	0.73
6 L36	51.38	54.3	53.92	53.57	55.98	54.47	33.67	0.61
5 L37	51.3	54.22	53.25	53.53	55.49		32.59	0.53
4 L38	51.24	53.95	53.66	53.51	53.87		27.27	0.62
3 L39	51.18	53.86	53.08	53.32	54.04		28.09	0.67
2 L40	51.13	53.84	52.84	53.16	54.14		28.78	0.71
1 L41	51.05		54.1	53.02	53.12		72.06	1.16

From Table 1, it can be seen that several sections need to be addressed even though normalization has been carried out. Likewise, there are several sections that experience critical flow (Fr > 1) so that more protection is needed on these sections.

CONCLUSION

The conclusions that can be drawn from this analysis are: the flood discharge used is Q25 = 150.777 m3/sec with the Snyder Method. The Komolino Lino Riverbed is unable to pass the design flood discharge. It is necessary to normalize the river and plan an embankment 0.50 m high from the designed flood water level. The height of this embankment is planned according to the amount of flood discharge from the embankment height determination guidelines. For river sections that experience critical flow (Fr > 1), better embankment reinforcement is needed.

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