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# Cross-Sectional Engineering for Lombagin River Flood Management, Bolaang Mongondow Regency

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***Abstract :***

The Lombagin River located in Bolaang Mongondow Regency is one of the longest rivers in the Bolaang Mongondow area. This river is upstream located in Nani Wartabone National Park, Bolaang Mongondow Regency, flows through several districts and empties into the Sulawesi sea. This river is an important river for the people of Bolaang Mongondow, is a source of water to meet various needs especially to irrigate many Irrigated Areas in the area. The main problem today is that rivers often overflow during the rainy season. River overflow water inundated settlements, highways and existing rice fields, resulting in disruption of people's lives, damage to public facilities and infrastructure, crop failure and damage to rice fields and other losses that were not small.

This research aims to obtain the best cross-sectional design to overcome flooding with a 50-year anniversary on the Lombagin river.

The steps taken in this study include: collecting secondary data in the form of discharge data from debit posts in the watershed. Perform data quality analysis. Analyze the frequency of discharge data to obtain the planned discharge. Water level analysis with the help of the HEC-RAS program. Analysis of the best cross-sectional design by creating flooded dikes.

The results obtained, at the time of the 5-year flood anniversary, all the left dikes were safe, while the right embankment overflowed from River Station 14 to 27 with different overflow heights. At the time of the 50th anniversary, all the left levees were still safe, while the right embankment, there was an overflow from River Station 2 to 27, only at River station 1 did not overflow. Flood management will be calculated with a 50-year anniversary. To cope with flooding by 50 years anniversary, the cross-section of the river must be engineered. Cross-sectional engineering by enlarging the cross-sectional area of the river. The method chosen was to add an embankment along the right bank of the river. The additional height of the embankment varies from 0.96 meters to 6.34 meters.

***Keywords* :** *Flood discharge, water level*

## Introduction

The Lombagin River located in Bolaang Mongondow Regency is one of the longest rivers in the Bolaang Mongondow area. This river is upstream located in Nani Wartabone National Park, Bolaang Mongondow Regency, flows through several districts and empties into the Sulawesi sea. This river is an important river for the people of Bolaang Mongondow, is a source of water to meet various needs especially to irrigate many Irrigated Areas in the area. The main problem today is that rivers often overflow during the rainy season. River overflow water inundated settlements, highways and existing rice fields, resulting in disruption of people's lives, damage to public facilities and infrastructure, crop failure and damage to rice fields and other losses that were not small.

The problem of flooding in an area cannot be eliminated, what can be done is to minimize losses due to the flood. One step to minimize is to predict flood discharge that may occur, then it can be known the height of the water level that will occur. With the existing water level data, the best cross-sectional design can be analyzed.

The problem that will be examined is how high the water level will occur in the Lombagin river in the event of flooding with various re-times, and how effective cross-sectional design is needed and what are the dimensions of the flood embankment. The research location is at coordinates 0053'57"N and 124005'39"E.

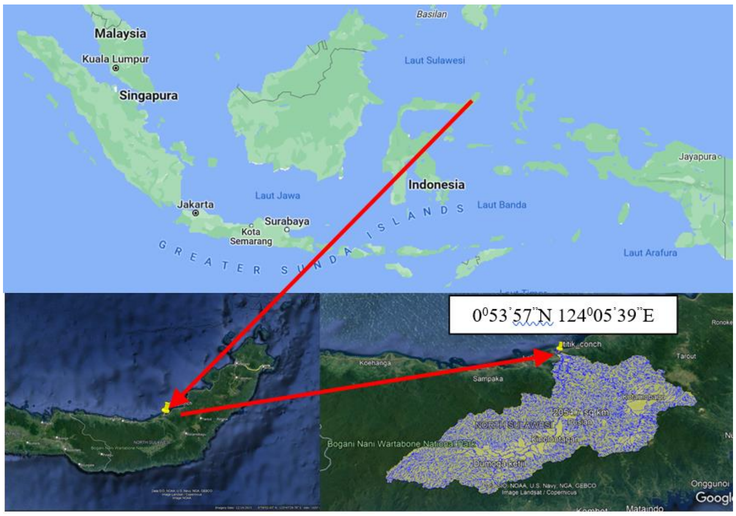



**Fig 1: Area of Research**

## literature review

**Outlier data**.

Outlier data is data that statistically deviates far from its data set. This deviation is partly caused by misreading. The outlier data test is useful for assessing existing rainfall data, whether there is data that deviates too far from the data set. The following are the requirements for testing outlier data based on skewness coefficient $\left(Cs_{log}()\right)$.

Test high and low outliers using the following equation.

1. High outlier test

$$log\ \ Xh\ = \overline{logX} + kn.S_{log} \qquad (1)$$

2. Low outlier test

$$log\ \ XI\ = \overline{logX} - kn.S_{log} \qquad (2)$$

with : $\overline{LogX}$ = average value of log data observation,

$Cslog$ = Skewness coefficient (in log),

$Slog$ = standard deviation (in log),

$Xh$ = high outlier / outlier tinggi (dalam log),

$XI$ = low outlier / outlier rendah (dalam log),

$Kn$ = Outlier test constant (taken from the K value test) which depending on the amount of data analyzed.

If there is outlier data, then the data should be adjusted, taking the upper or lower limit as a reference. Customized data, ready to use.

**Frequency Analysis**

Triatmodjo (2009) stated that analysis of frequency aims to ascertain the probability of an event and its frequency, or return period of such event using probability distribution. The statistical parameters in hydrology analysis are mean, standard deviation, coefficient of variance, coefficient of skewness and coefficient of kurtosis.

Probability distribution is a distribution describing a likelihood of a variance as the substitute of its frequency. One purpose in analysis of probability distribution is to determine return period. Return period is defined as hypothetic time where discharge or rain with a certain quantity will be equalized or exceeded one time at a certain period of time. The function of probability distribution in this research are: 1) Normal Distribution; 2) Log-Norma Distribution; 3) Gumbel Distribution and 4) Log-Pearson Type III Distribution.

***1. Normal distribution type***

The normal distribution is also called the Gaussian distribution.

This distribution is formulated as follows:

$$X_{TR} = \overline{\overline{X}} + S.K \qquad (3)$$

***2. Normal Log distribution type***

The normal log distribution is the result of transformation from the normal distribution by converting variant x into variant x log

$$\log X_{TR} = \overline{\log X} + S_{\log}.K \qquad (4)$$

***3. Gumbel distribution type***

This type of distribution is generally used for maximum data analysis.

$$X_{TR} = \overline{\overline{X}} + S.K_{TR} \qquad (5)$$

with:

$$K_{TR} = 0.78\left[-\ln\left\{-\ln\left(1-\frac{1}{TR}\right)\right\}\right] - 0{,}45 \qquad (6)$$

***4. Pearson Log Distribution Type III***

This distribution is the result of the transformation of the type III Pearson distribution by converting variant x into a log variant x value with the formula

$$Log\,X_{TR} = \overline{Log}X + S\,log.K_{TR,Cs} \qquad (7)$$

dengan : $\overline{X}$= curah hujan rata-rata (mm),

$X_{TR}$ = Nilai curah hujan pada periode ulang yang diharapkan,

$S$ = Standart Deviasi,

$K$ = Faktor frekuensi untuk distribusi normal yang tergantung pada Tr (tabel distribusi normal),

$K_{TR}$ = Faktor frekuensi Gumbel,

$K_{TR,Cs}$ = Faktor Frekuensi Pearson yang dapat dilihat dari tabel pearson dengan memperhitungkan nilai Cs

$Log\,X_{TR}$ = Curah hujan tergantung pada TR dalam log.

*(Soewarno: Hidrologi, aplikasi metode statistik untuk analisa data)*

**Energy Equation**

Steady flow is a flow where its velocity is constant at a period of time. Natural flow is generally unsteady, caused by hydraulic geometry of channel, irregular pattern of river, plants along river slope, hydraulic structure, transformation of river bed, etc. Component of steady flow is used to determine water surface profile at steady flow. Such component can model the water surface profile at sub-critical flow, supercritical flow and combination of both. Water surface profiles are computed from one cross section to the next by solving the energy equation with an iterative procedure called the standard step method. The energy equation is written as follows:

$$Y_2 + Z_2 + \frac{\alpha_2 V_2{}^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 V_1{}^2}{2g} + he \qquad (8)$$

Where:

$Y_1$, $Y_2$ = depth of water at cross sections $Z_1$

$Z_2$ = elevation of the main channel inverts $V_1$

$V_2$ = average velocities (total discharge/total flow area)

$\alpha_1$, $\alpha_2$ = velocity weighting coefficients

g = gravitational acceleration

$h_e$ = energy head loss

**Flood discharge and water level**

Research on flood discharge and water level of several rivers in North Sulawesi.

Study of Prediction of Discharge Amount and Elevation of Planned Flood Water Level in Popontolen River, Tumpaan District. Journal of Civil Static Vol 10 No 1 Year 2022 ISSN: 2337-6732.

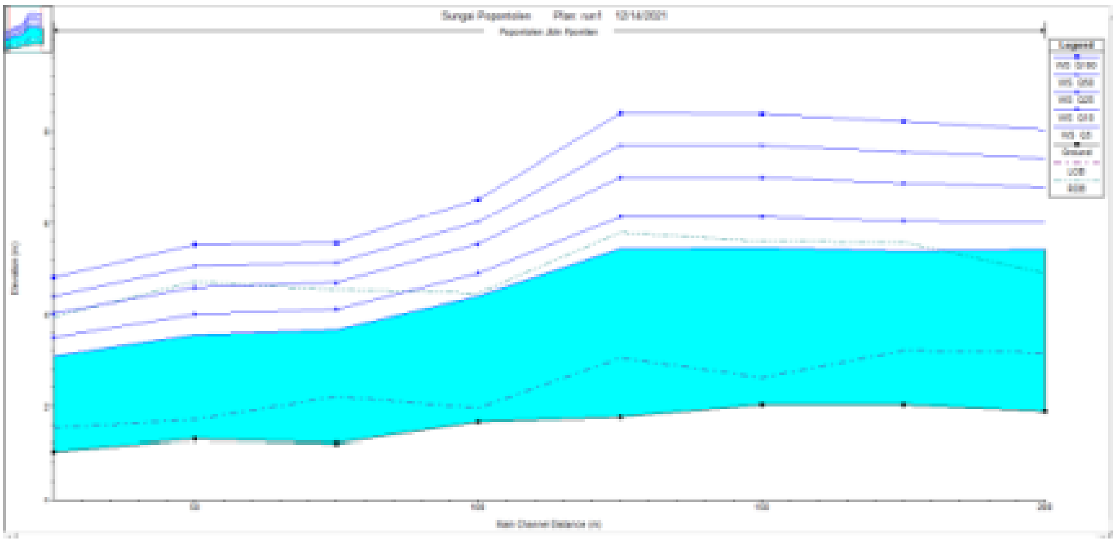


**Figure 2. Water level longitudinal cut of the river**

Cross-sectional capacity analysis of the Tondano river discharge in the Tubir Village area, Paal 2 Village (Lalamentik, 2021). https://ejournal.unsrat.ac.id.

Research on flood discharge in the Binjeita Bolaang Mongodow river shows that the return periods of 25, 50 and 100 years, amounting to 2 m3/sec, 2.5 m3/sec and 3 m3/sec, (Sumarauw, 2022). https://www.internationaljournalssrg.org/IJCE/2022/Volume9-Issue11/IJCE-V9I11P105.pdf.

Research on flood discharge in the Pulisan river of North Minahasa shows for various recurrences; 2, 5, 10 and 25 years, the discharge that occurs is: 17.2 m3/s, 22.8 m3/s, 28.1 m3/s and 36.5 m3/s. (Mananoma, et al, 2022). Journal of Southwest Jiaotong University, Vol. 57 No. 6 Dec 2022.

## I. RESEARCH METHODOLOGY

### Watershed

The watershed studied is the Lombagin River at the upstream point of the Kayak Bridge. From the analysis, it was found that the area of the Lombagin watershed at the review point was 2054.7 km2.

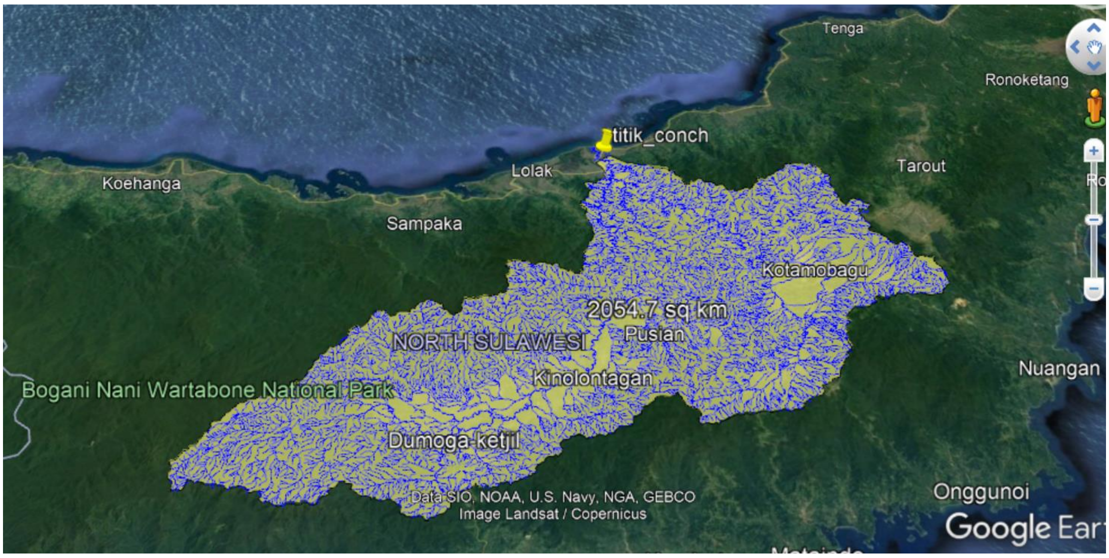



**Figure 3. The Lombagin watershed at the review point**

### Discharge Flood Plan

To calculate the planned flood discharge in the river, it can be done in 2 ways:

1. If there is sufficient instantaneous discharge measurement data and meets the requirements. Plan discharge can be analyzed by analyzing the frequency of discharge data from instantaneous measurable discharge data.
2. If there is no instantaneous discharge data available, or the data is insufficient. Plan discharge can be analyzed from rain data.

On the Lombagin River there is a discharge measuring station, so the planned flood discharge analysis will use measured discharge data.

### Measured Discharge Data

There is measurement discharge data in the Lombagin River. The available data is the AWLR measurement discharge data of the Lombagin River at the Ongkag Komangaan point. Discharge data is available throughout the 11 years of observation. This data is eligible for frequency analysis of discharge data.

**Table 1. Lombagin River measured discharge data at the Komangaan Ongkag point**

| No | Year | Debit (m3/det) AWLR Komangaan |
|---|---|---|
| 1 | 2004 | 717.113 |
| 2 | 2010 | 344.205 |
| 3 | 2011 | 501.77 |
| 4 | 2013 | 370.692 |
| 5 | 2014 | 609.197 |
| 6 | 2015 | 220.597 |
| 7 | 2016 | 151.606 |
| 8 | 2017 | 295.777 |
| 9 | 2018 | 256.494 |
| 10 | 2019 | 130.498 |
| 11 | 2020 | 187.971 |

Source: BWS Sulawesi 1

**Estimating Discharge At The Point Of Review**

The discharge of the Lombagin river at the review point was estimated from measured discharge data at the Komangaan AWLR point using a comparative analysis of watershed area.


**Figure 4. The Lombagin River watershed at the observation point and at the Ongkag Komangaan point**

**Table 2. Area of the Lombagin Watershed**

| The Lombagin watershed at the point | Area (km2) |
|---|---|
| Review | 2054.7 |
| AWLR Ongkag Komangaan | 647.87 |

The estimated discharge at the review point is the discharge at the Ongkag Komangaan AWLR point multiplied by the watershed area at the review point divided by the watershed area at the Ongkag Komangaan AWLR point.

**Table 3. Forecast discharge at the review point**

| Year | Debit max (m3/det) |
|---|---|
| 2004 | 2274.302 |
| 2010 | 1091.636 |
| 2011 | 1591.348 |
| 2013 | 1175.638 |
| 2014 | 1932.050 |
| 2015 | 699.617 |
| 2016 | 480.814 |
| 2017 | 938.048 |
| 2018 | 813.463 |
| 2019 | 413.870 |
| 2020 | 596.144 |

Source: Analysis results

**Data Quality Test**

Hydrological data before use needs to be carried out quality tests. Test the quality of the data will use the Outlier Test. The Outlier test is to see if any data has strayed too far from its data set. Data outliers are data that statistically deviate far from its data set. Testing outlier data based on skewness coefficient (Cslog)

**Uji Outlier data debit**

**Table 4. Statistical parameters**

| | |
|---|---|
| (Slog)= | 0.2418 |
| Cslog = | -0.1114 |

Allowable upper limit

$$\log Xh = \overline{\log X} + kn.S_{\log}$$

log Xh = 3.02

Xh = 1040.92 mm

Allowable lower limit

$$\log Xl = \overline{\log X} - kn.S_{\log}$$

log Xl = 1.97

Xl = 92.38 mm

From the Outlier test obtained, there is no Outlier data.

**Frequency Analysis of Discharge Data**

Frequency analysis is to obtain the planned rain magnitude.

There are 4 frequency distributions commonly used in hydrological analysis.

1. Normal Distribution
2. Normal Log Distribution
3. Type I Gumbel Distribution
4. Pearsson Type-III Log Distribution

**Table 5. Statistical data parameters**

| | |
|---|---|
| Cs = | 0.7187 |
| Cv = | 0.0585 |
| Ck = | -1.0041 |

**Table 6. Statistical data parameter requirements**

| Distribution | Data | | Condition | | Conclusion |
|---|---|---|---|---|---|
| | Cs | Ck | Cs | Ck | Cs |
| Normal | 0.7187 | -1.0041 | 0 | Normal | 0.7187 |
| Log Normal | | | 0.1756 | Log Normal | Non-compliant |
| | | | | | Non-compliant |
| Gumbel | | | 1.14 | Gumbel | Meet |

From the above analysis it can be concluded that the distribution of data tends to follow the distribution of Log Pearsson Type-III. So to calculate the planned discharge will use the Pearsson Type-III Log distribution.

**Distribusi Log Pearsson Type-III**

$$\log X_{TR} = \overline{\log X} + S_{log} . K_{TR,Cs} \qquad (9)$$

with:

*Log* $X_{TR}$ = Debit plan log series

*LogX bar* = Average log series data

*Slog* = Standard deviation of log series data

$K_{TR,Cs}$ = Frequency factor

Slog = 0.242

Cslog = -0.111

Log X bar = 2.491

Plan debits with 5 and 50 years (mm) birthdays are obtained as shown in the following table.

**Table 7. Plan discharge**

| Birthday (Year) | Plan Debit (m3/sec) |
|---|---|
| 5 | 496.94 |
| 50 | 943.75 |

**Water Level Analysis with HEC-RAS**

This study used Steady flow surface profiles in the analysis. Based on available hydraulic data, the hydraulic model was based on a one-dimensioanl steady state computation. HEC-RAS is capable of performing one-dimensional water surface profile calculation for steady gradually varied flow in natural or constructed channels. The model also can be used in the subcritical, supercritical, and mixed flow regime. The equation for basic profile calculation involves cross section subdivision for conveyance calculations; Manning’s n for the main channel; velocity weighting coefficient alpha; and friction loss.

***River Geometry Data***

River characteristics obtained from field measurements are shown in the following table.

Table 8. Characteristics of the Lombagin River

| Lombagin River Channel | Sum *Cross Section* | Groove Length(m) | Base Slope (S) | Elevation (m) | |
|---|---|---|---|---|---|
| | | | | Hulu | Downstream |
| 1 | 27 | 1071 | 0,002 | 5,249 | 3,381 |

The following is the length of the river *section of each cross section* based on images of field measurements.

**Table 9. Distance Between *Measured Cross Sections***

| River Sta. | ID Sta. | Panjang (m) | River Sta. | ID Sta. | Panjang (m) |
|---|---|---|---|---|---|
| 27 | 1 | 49.8 | 13 | 15 | 25 |
| 26 | 2 | 50 | 12 | 16 | 25 |
| 25 | 3 | 50 | 11 | 17 | 49.9 |
| 24 | 4 | 49.7 | 10 | 18 | 50 |
| 23 | 5 | 49.7 | 9 | 19 | 49.6 |
| 22 | 6 | 49.9 | 8 | 20 | 25 |
| 21 | 7 | 50 | 7 | 21 | 25 |
| 20 | 8 | 50 | 6 | 22 | 50 |
| 19 | 9 | 49.7 | 5 | 23 | 50 |
| 18 | 10 | 25 | 4 | 24 | 48.8 |
| 17 | 11 | 25.3 | 3 | 25 | 50 |
| 16 | 12 | 23.9 | 2 | 26 | 50 |
| 15 | 13 | 24.9 | 1 | 27 | 0 |

| | | |
|---|---|---|
| 14 | 14 | 24.8 |

**River Geometry Schematization**

Schematization of river geometry natural conditions.

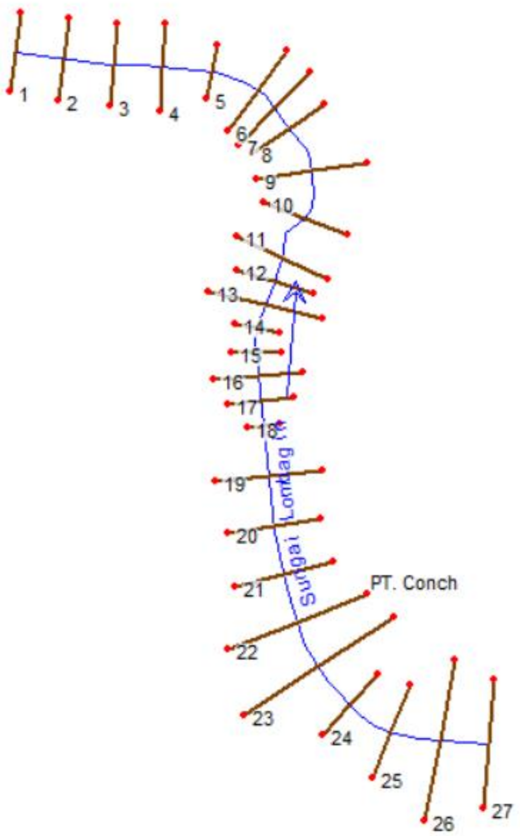
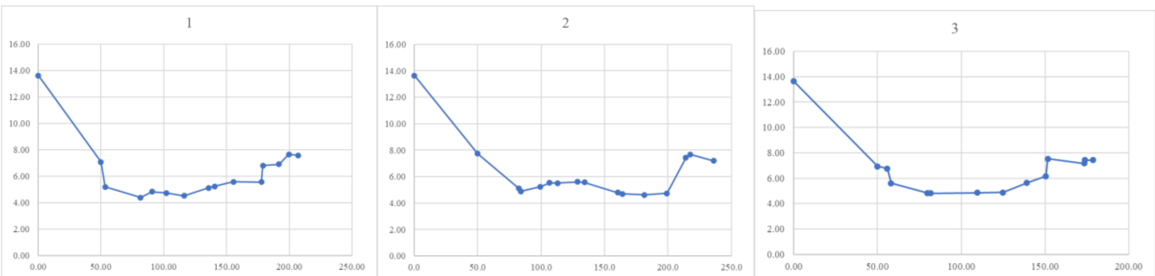



**Figure 5. Pipeline Geometry schematization at the review point**

***Data* Cross Section**

Cross-section data used as input for hydraulic analysis is field measurement data. The following is cross-section *data* from field measurements at the research site.



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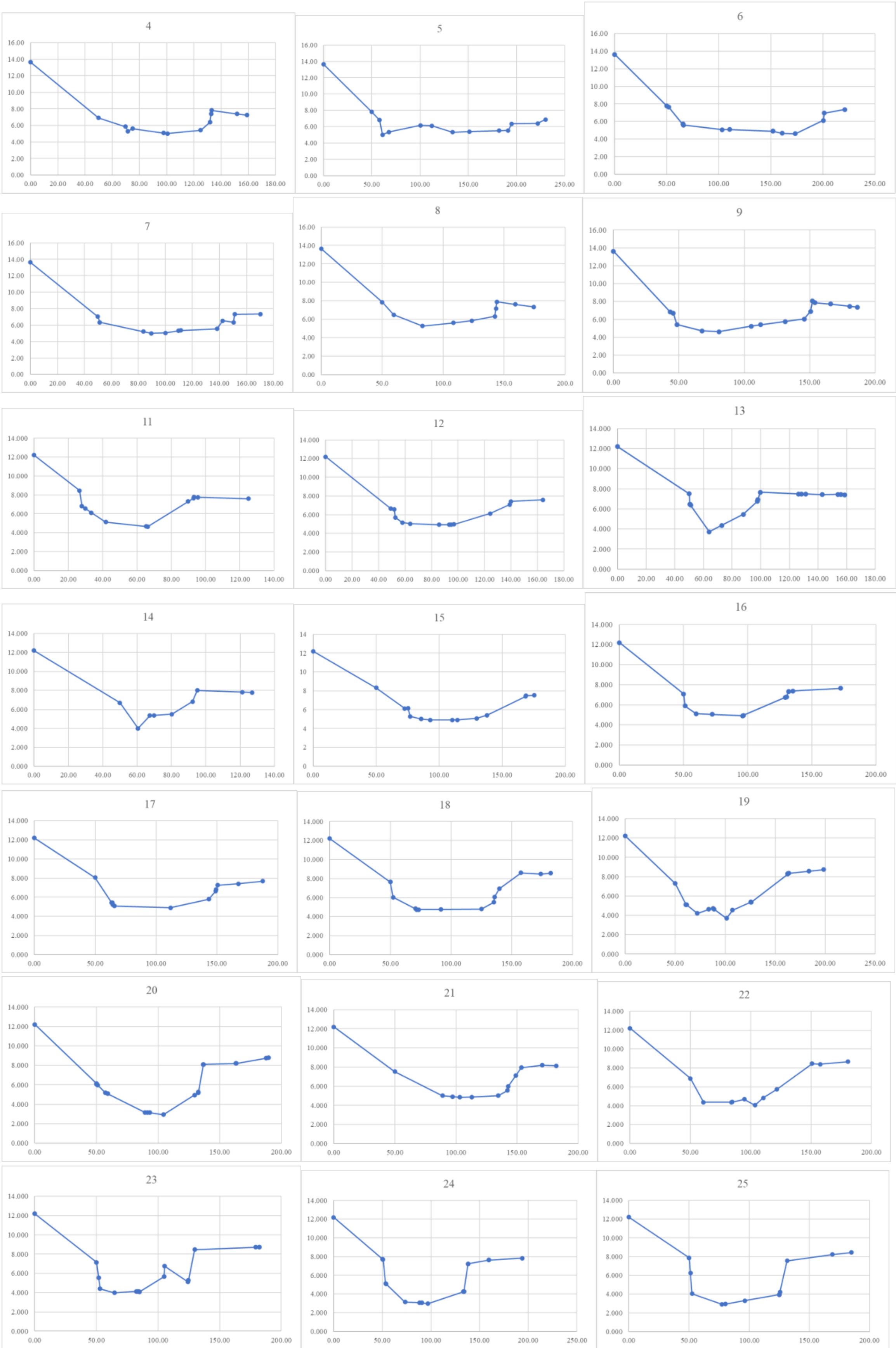

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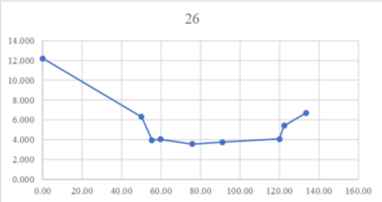


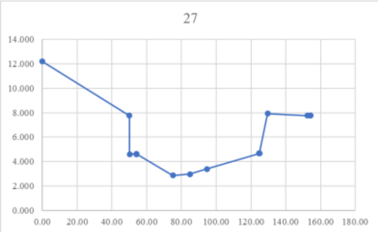




**Figure 6. Cross-sectional cross section data 1 - 27**

***River Channel Carrying Capacity Analysis***

Analysis of river channel carrying capacity was carried out using *HEC-RAS* 5.0.7 software. To use this *software,* it is necessary to input river geometry data in the form *of cross* and long sections, *the slope of the river bed (*S*), and the amount of planned flood discharge.* To determine the capacity of the river view, an approach is made where the planned discharge is according to the results of hydrological analysis. Using downstream boundary conditions in the form of normal *depth* and average base slope S = 0.001.

The results of the HEC-RAS 5.0.7 simulation with the amount of flood discharge planned for Q25, and Q50 at the Lombagin river review point are as follows.

5th Anniversary
Q5 = 496.94 m3/sec

**Table 10. Simulation Results for 5 Years Anniversary**

| River Sta. | ID Sta. | Min Ch El (m) | WS Elev. (m) | LOB Student. (m) | ROB Elev. (m) | Top Width (m) | L Freeboard (m) | R Freeboard (m) |
|---|---|---|---|---|---|---|---|---|
| 27 | 1 | 4.41 | 10.23 | 13.63 | 6.83 | 152.87 | 3.4 | -3.4 |
| 26 | 2 | 4.63 | 10.23 | 13.63 | 7.41 | 185.03 | 3.4 | -2.82 |
| 25 | 3 | 4.82 | 10.2 | 13.63 | 7.53 | 126.03 | 3.43 | -2.67 |
| 24 | 4 | 5 | 10.16 | 13.63 | 7.81 | 107.19 | 3.47 | -2.35 |
| 23 | 5 | 5 | 10.19 | 13.63 | 6.88 | 200.58 | 3.44 | -3.31 |
| 22 | 6 | 4.6 | 10.19 | 13.63 | 6.94 | 171.9 | 3.44 | -3.25 |
| 21 | 7 | 5.01 | 10.16 | 13.63 | 7.32 | 124.99 | 3.47 | -2.84 |
| 20 | 8 | 5.26 | 10.13 | 13.63 | 7.9 | 113.79 | 3.5 | -2.23 |
| 19 | 9 | 4.6 | 10.14 | 13.63 | 8.08 | 129.9 | 3.49 | -2.06 |
| 18 | 10 | 5.19 | 8.81 | 12.2 | 7.93 | 40.75 | 3.39 | -0.88 |
| 17 | 11 | 4.65 | 8.88 | 12.2 | 7.76 | 69.8 | 3.32 | -1.12 |
| 16 | 12 | 4.92 | 8.99 | 12.2 | 7.41 | 111.59 | 3.21 | -1.58 |
| 15 | 13 | 3.73 | 8.67 | 12.2 | 7.66 | 62.09 | 3.53 | -1.01 |
| 14 | 14 | 4 | 7.94 | 12.2 | 8 | 56.13 | 4.26 | 0.06 |
| 13 | 15 | 4.91 | 7.88 | 12.2 | 7.39 | 113.76 | 4.32 | -0.49 |
| 12 | 16 | 4.91 | 7.65 | 12.2 | 7.34 | 87.3 | 4.55 | -0.31 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 11 | 17 | 4.9 | 7.72 | 12.2 | 7.26 | 98.96 | 4.48 | -0.46 |
| 10 | 18 | 4.74 | 7.69 | 12.2 | 6.94 | 90.13 | 4.51 | -0.75 |
| 9 | 19 | 3.7 | 7.67 | 12.2 | 8.27 | 108.84 | 4.53 | 0.6 |
| 8 | 20 | 2.95 | 7.69 | 12.2 | 8.09 | 98.76 | 4.51 | 0.4 |
| 7 | 21 | 4.84 | 7.38 | 12.2 | 7.95 | 98.08 | 4.82 | 0.57 |
| 6 | 22 | 4.06 | 7.41 | 12.2 | 8.45 | 94.67 | 4.79 | 1.04 |
| 5 | 23 | 3.99 | 6.49 | 12.2 | 6.76 | 54.48 | 5.71 | 0.27 |
| 4 | 24 | 2.97 | 6.48 | 12.2 | 7.24 | 85.08 | 5.72 | 0.76 |
| 3 | 25 | 2.92 | 6.41 | 12.2 | 7.55 | 78.35 | 5.79 | 1.14 |
| 2 | 26 | 3.58 | 5.96 | 12.2 | 6.71 | 76.04 | 6.24 | 0.75 |
| 1 | 27 | 2.86 | 5.94 | 12.2 | 7.94 | 76.6 | 6.26 | 2 |

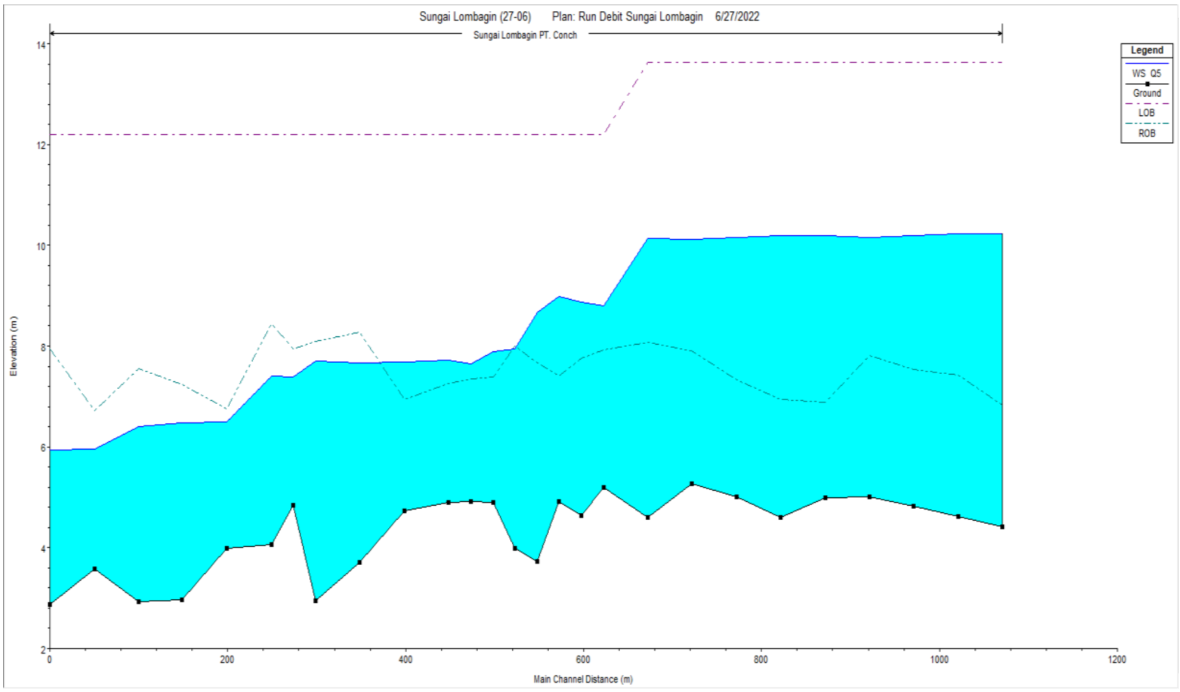


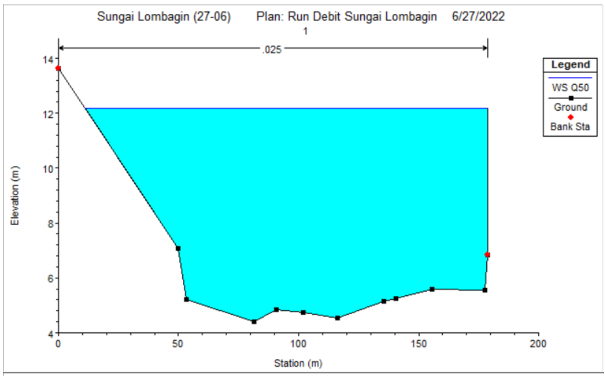

**Figure 7. Longitudinal Profile of Lombagin River Channel Against 5-Year Plan Flood Discharge**

50th Anniversary
Q50 = 943.75 m3/sec

**Table 11. Simulation Results for 50th Anniversary**

| River Sta. | ID Sta. | Min Ch El (m) | WS Elev. (m) | LOB Elev. (m) | ROB Elev. (m) | Top Width (m) | L Freeboard (m) | R Freeboard (m) |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 27 | 1 | 4.41 | 12.17 | 13.63 | 6.83 | 167.68 | 1.46 | -5.34 |
| 26 | 2 | 4.63 | 12.17 | 13.63 | 7.41 | 201.54 | 1.46 | -4.76 |
| 25 | 3 | 4.82 | 12.13 | 13.63 | 7.53 | 140.42 | 1.5 | -4.6 |
| 24 | 4 | 5 | 12.07 | 13.63 | 7.81 | 121.42 | 1.56 | -4.26 |
| 23 | 5 | 5 | 12.13 | 13.63 | 6.88 | 217.19 | 1.5 | -5.25 |
| 22 | 6 | 4.6 | 12.12 | 13.63 | 6.94 | 188.45 | 1.51 | -5.18 |
| 21 | 7 | 5.01 | 12.07 | 13.63 | 7.32 | 139.5 | 1.56 | -4.75 |
| 20 | 8 | 5.26 | 12.03 | 13.63 | 7.9 | 130.25 | 1.6 | -4.13 |
| 19 | 9 | 4.6 | 12.05 | 13.63 | 8.08 | 142.08 | 1.58 | -3.97 |
| 18 | 10 | 5.19 | 10.2 | 12.2 | 7.93 | 46.67 | 2 | -2.27 |
| 17 | 11 | 4.65 | 10.29 | 12.2 | 7.76 | 79.78 | 1.91 | -2.53 |
| 16 | 12 | 4.92 | 10.47 | 12.2 | 7.41 | 124.72 | 1.73 | -3.06 |
| 15 | 13 | 3.73 | 9.96 | 12.2 | 7.66 | 75.79 | 2.24 | -2.3 |
| 14 | 14 | 4 | 9.08 | 12.2 | 8 | 66.6 | 3.12 | -1.08 |
| 13 | 15 | 4.91 | 9.37 | 12.2 | 7.39 | 131.82 | 2.83 | -1.98 |
| 12 | 16 | 4.91 | 9.13 | 12.2 | 7.34 | 101.79 | 3.07 | -1.79 |
| 11 | 17 | 4.9 | 9.21 | 12.2 | 7.26 | 114.54 | 2.99 | -1.95 |
| 10 | 18 | 4.74 | 9.16 | 12.2 | 6.94 | 106.3 | 3.04 | -2.22 |
| 9 | 19 | 3.7 | 9.18 | 12.2 | 8.27 | 131.73 | 3.02 | -0.91 |
| 8 | 20 | 2.95 | 9.18 | 12.2 | 8.09 | 111.97 | 3.02 | -1.09 |
| 7 | 21 | 4.84 | 8.99 | 12.2 | 7.95 | 119.2 | 3.21 | -1.04 |
| 6 | 22 | 4.06 | 9.01 | 12.2 | 8.45 | 120.87 | 3.19 | -0.56 |
| 5 | 23 | 3.99 | 7.65 | 12.2 | 6.76 | 60.34 | 4.55 | -0.89 |
| 4 | 24 | 2.97 | 7.64 | 12.2 | 7.24 | 87.34 | 4.56 | -0.4 |
| 3 | 25 | 2.92 | 7.51 | 12.2 | 7.55 | 81.01 | 4.69 | 0.04 |
| 2 | 26 | 3.58 | 7.07 | 12.2 | 6.71 | 89.65 | 5.13 | -0.36 |
| 1 | 27 | 2.86 | 7 | 12.2 | 7.94 | 78.21 | 5.2 | 0.94 |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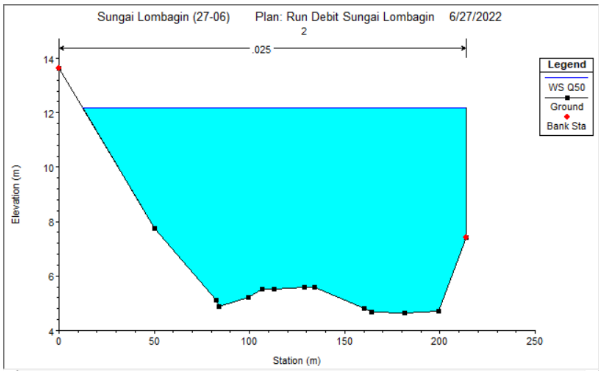
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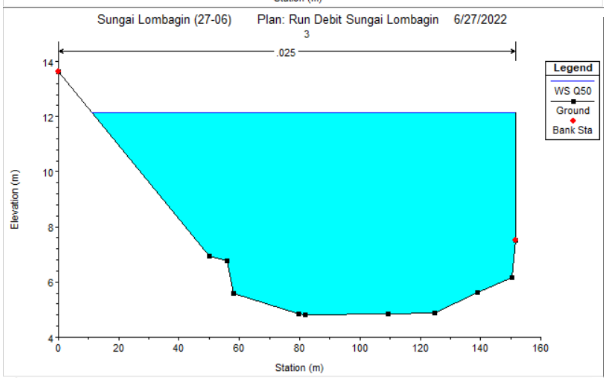
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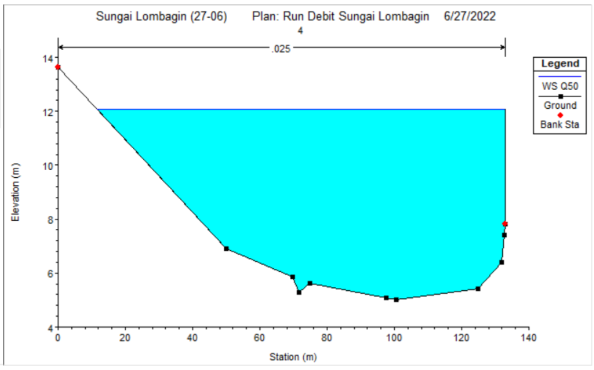
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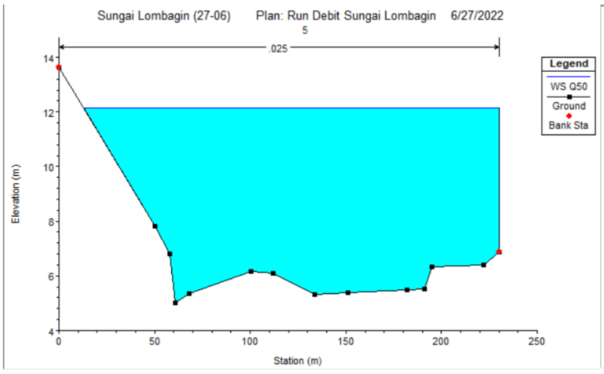
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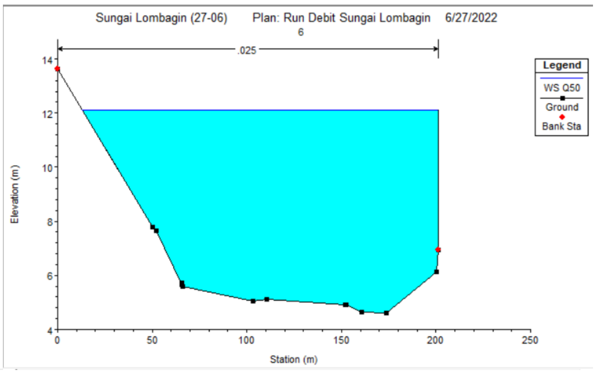
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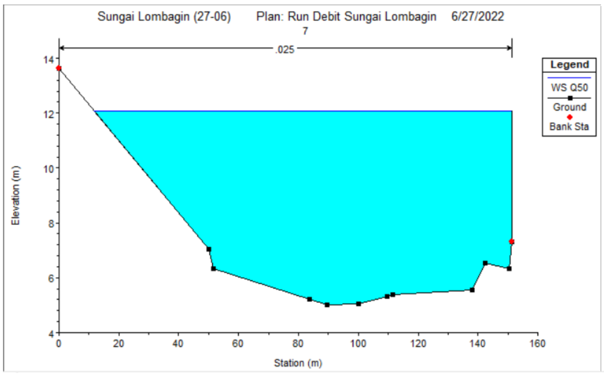
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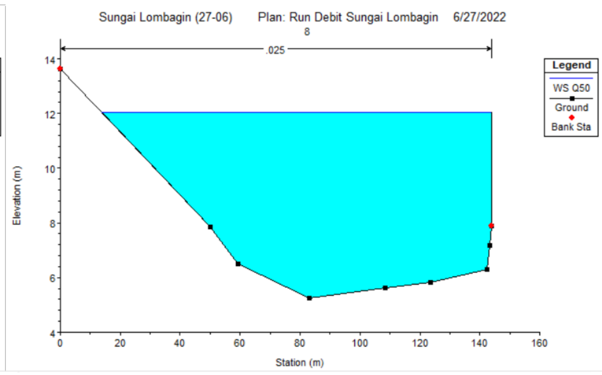
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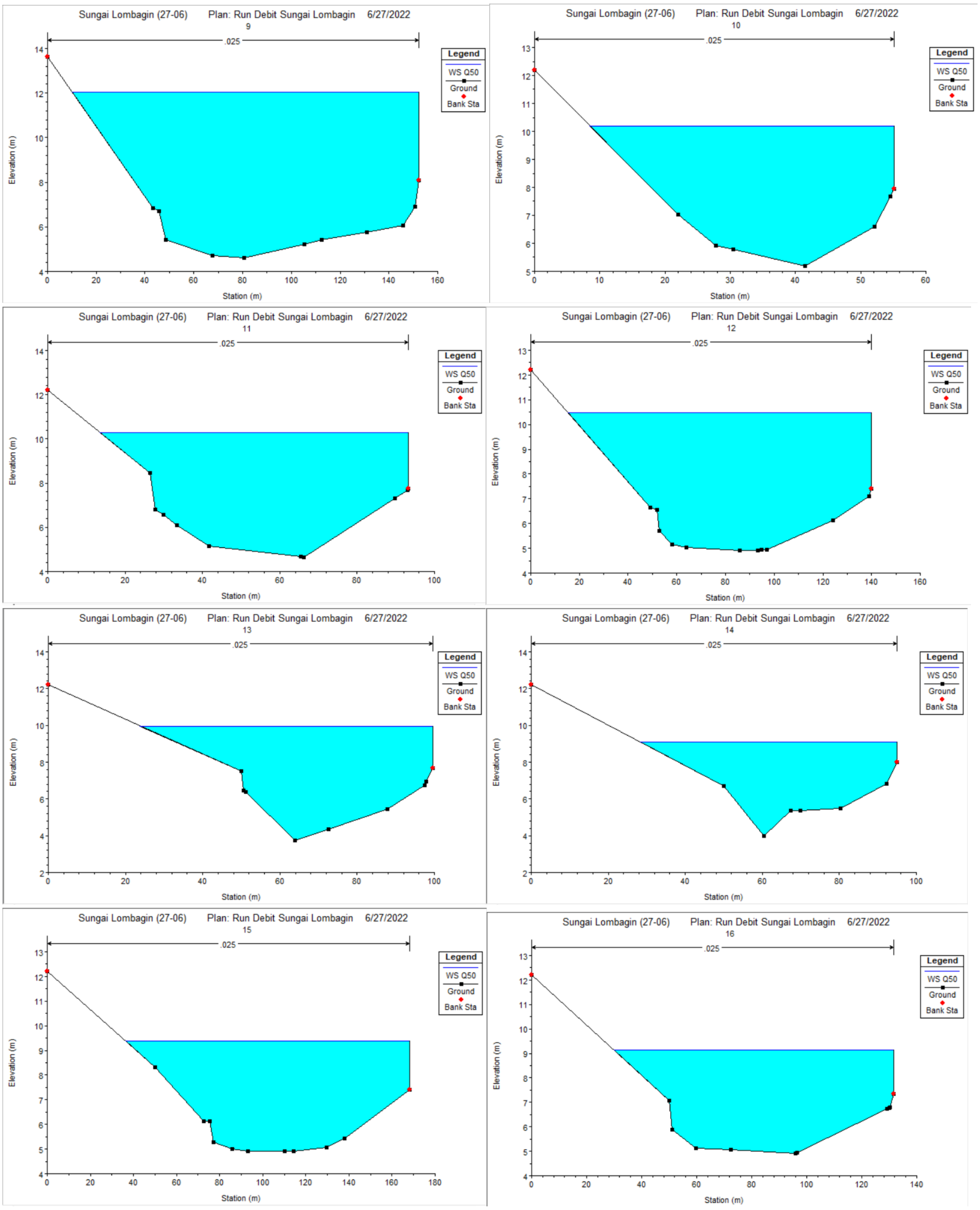
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Sungai Lombagin (27-06) Plan: Run Debit Sungai Lombagin 6/27/2022
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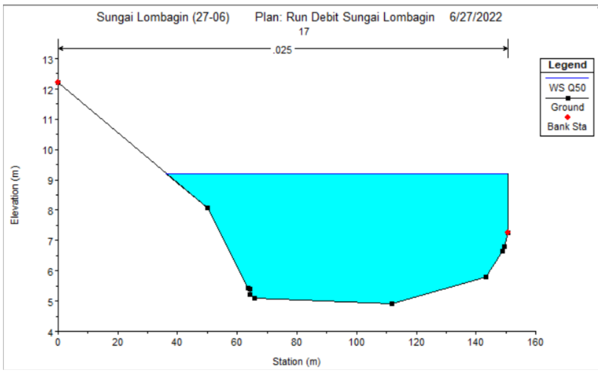
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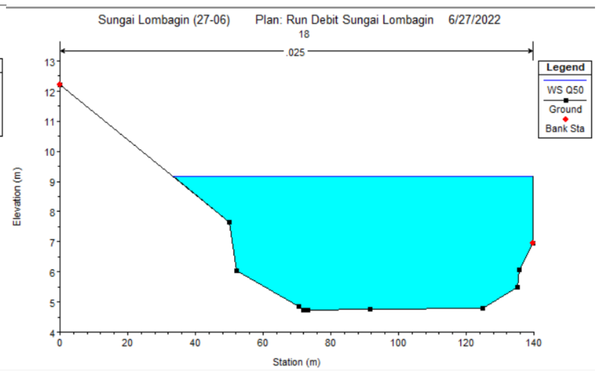
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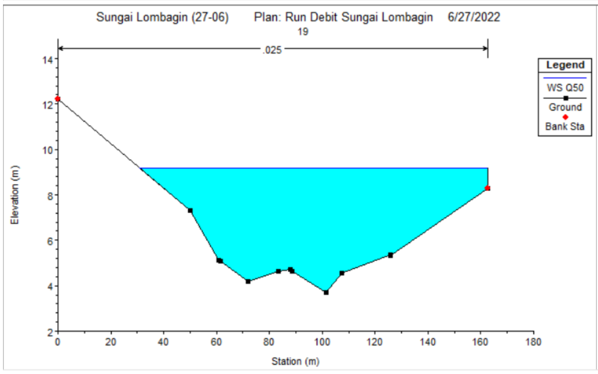
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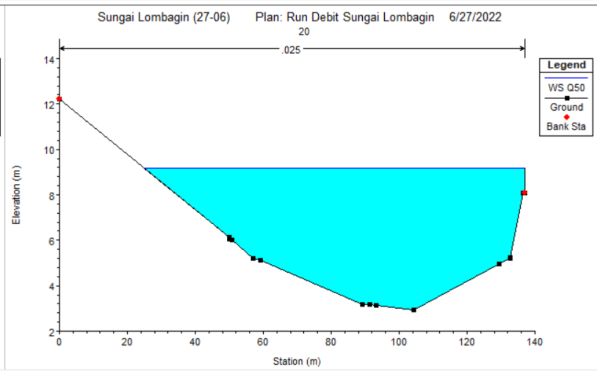
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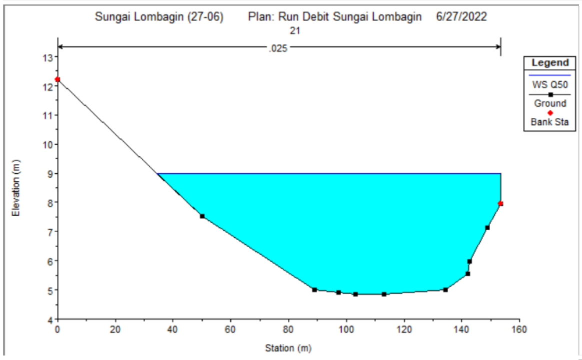
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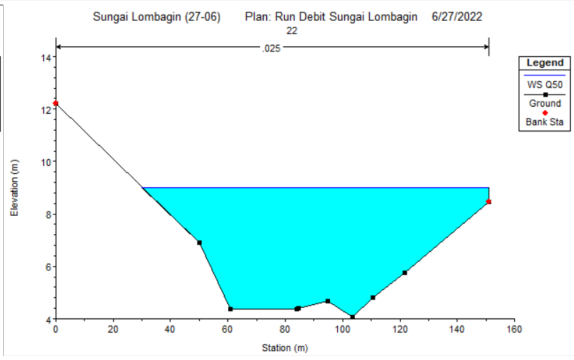
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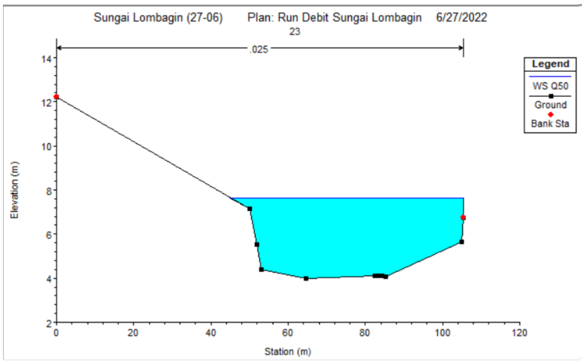
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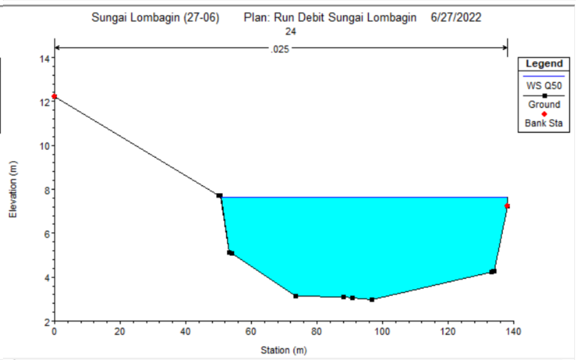
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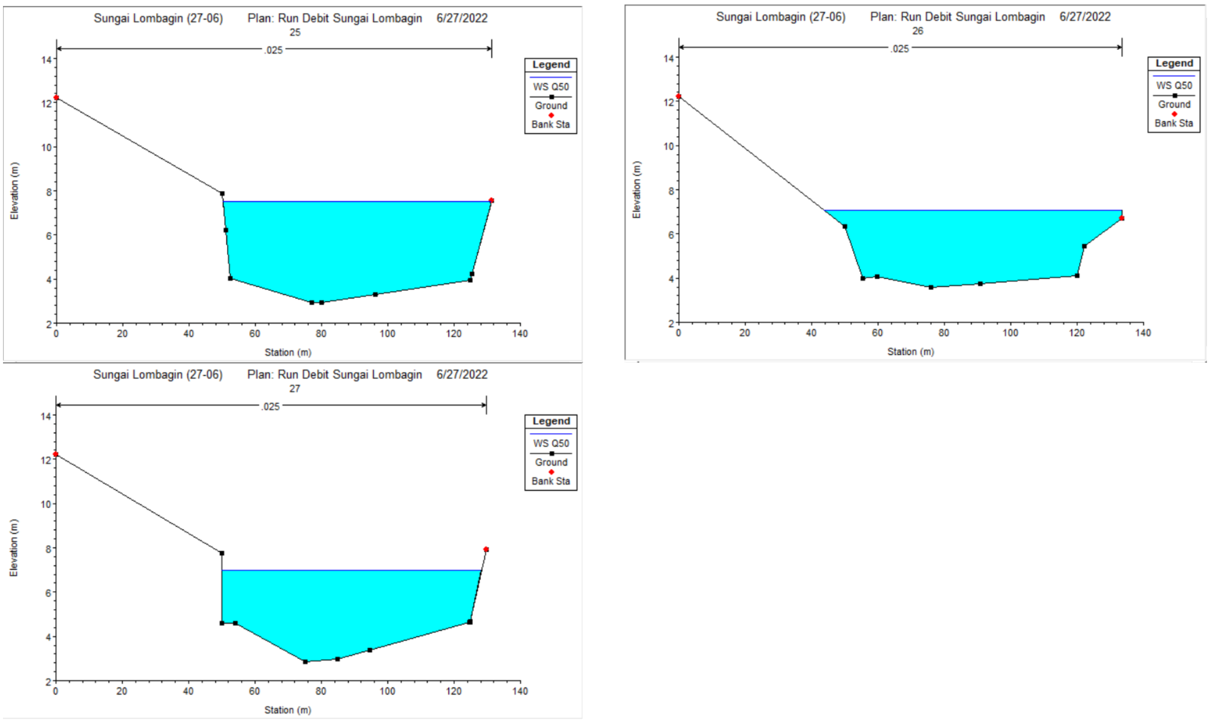


**Figure 8. Water level in Cross section 1 - 27**

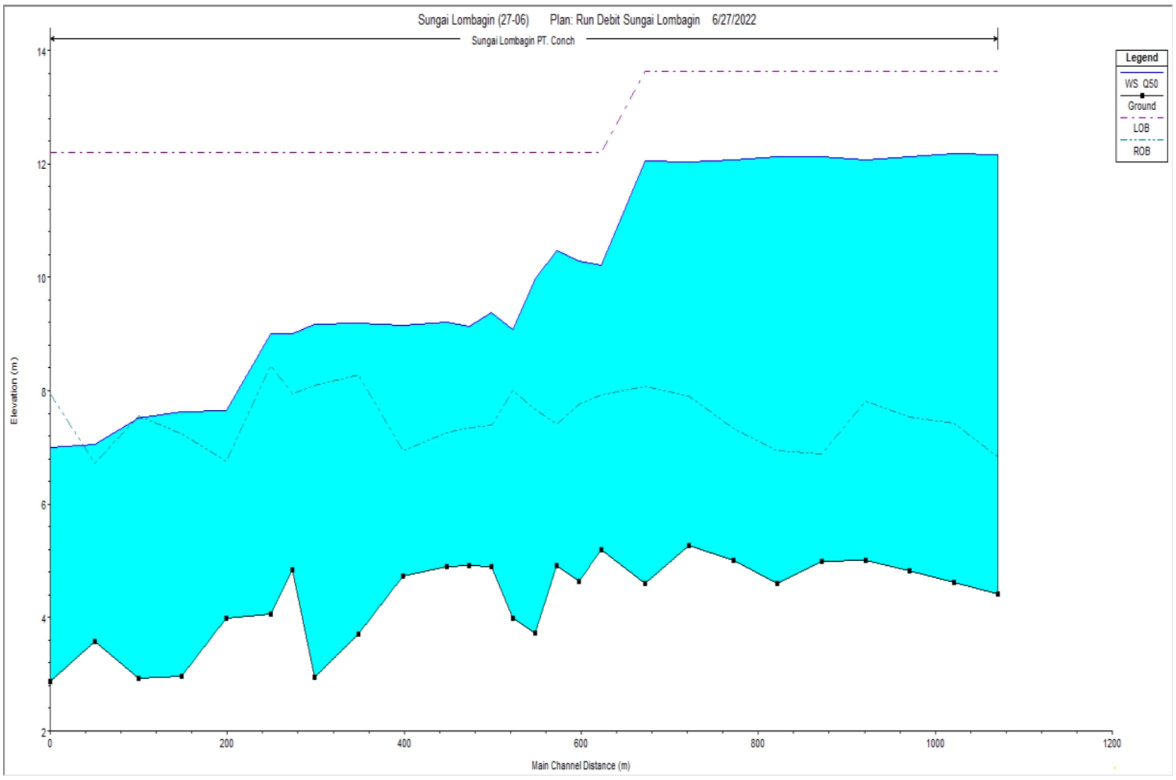


**Figure 9. Longitudinal Profile of the Lombagin River Channel against Flood Discharge 50-Year Plan**

The total length of the river section reviewed is 1071 m. Results showed that in Q5 and Q50, the left embankment of the river was safe, but the right embankment of the river overflowed. There needs to be cross-sectional engineering to overcome overflow. The cross-sectional area was enlarged by adding embankments along the right side of the river. The required height of the embankment varies from 0.96 meters to 6.34 meters. The height of the embankment for each cross section is shown in the following table.

**Table 12. Required embankment height**

| River Sta. | ID Sta. | WS Elev. (m) | ROB Elev. (m) | Right embankment requirement including 1m(m) freeboard |
|---|---|---|---|---|
| 27 | 1 | 12.17 | 6.83 | 6.34 |
| 26 | 2 | 12.17 | 7.41 | 5.76 |
| 25 | 3 | 12.13 | 7.53 | 5.6 |
| 24 | 4 | 12.07 | 7.81 | 5.26 |
| 23 | 5 | 12.13 | 6.88 | 6.25 |
| 22 | 6 | 12.12 | 6.94 | 6.18 |
| 21 | 7 | 12.07 | 7.32 | 5.75 |
| 20 | 8 | 12.03 | 7.9 | 5.13 |
| 19 | 9 | 12.05 | 8.08 | 4.97 |
| 18 | 10 | 10.2 | 7.93 | 3.27 |
| 17 | 11 | 10.29 | 7.76 | 3.53 |
| 16 | 12 | 10.47 | 7.41 | 4.06 |
| 15 | 13 | 9.96 | 7.66 | 3.3 |
| 14 | 14 | 9.08 | 8 | 2.08 |
| 13 | 15 | 9.37 | 7.39 | 2.98 |
| 12 | 16 | 9.13 | 7.34 | 2.79 |
| 11 | 17 | 9.21 | 7.26 | 2.95 |
| 10 | 18 | 9.16 | 6.94 | 3.22 |
| 9 | 19 | 9.18 | 8.27 | 1.91 |
| 8 | 20 | 9.18 | 8.09 | 2.09 |
| 7 | 21 | 8.99 | 7.95 | 2.04 |
| 6 | 22 | 9.01 | 8.45 | 1.56 |
| 5 | 23 | 7.65 | 6.76 | 1.89 |
| 4 | 24 | 7.64 | 7.24 | 1.4 |
| 3 | 25 | 7.51 | 7.55 | 0.96 |

| | | | | |
|---|---|---|---|---|
| 2 | 26 | 7.07 | 6.71 | 1.36 |
| 1 | 27 | 7 | 7.94 | - |

## conclusion

The results obtained: on the Lombagin river at the review point, at the time of the 5-year flood anniversary, all the left levees were safe, while the right embankment overflowed from River Station 14 to 27 with different overflow heights. On the 50th anniversary, all the left levees were still safe, while the right embankment, there was an overflow from River Station 2 to 27, only at River station 1 there was no overflow. Flood management will be calculated with a 50-year anniversary. To cope with flooding by 50 years anniversary, the cross-section of the river must be engineered. Cross-sectional engineering by enlarging the cross-sectional area of the river. The method chosen was to add an embankment along the right bank of the river. The additional height of the embankment varies from 0.96 meters to 6.34 meters.

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