Sedimentation Impact on Capacity and Morphology Changes on Bendung River of Palembang City

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Abstract. Bendung River is one of the rivers in Palembang city that experiences overflowing when the rainy season occurs. This river length is 5.47 km, and its watershed area is 18.38 km2. The flood that occurred in the area around the Bendung river has caused material and non-material losses. The flood that occurred was due to the capacity of the Bendung river not being able to accommodate the flood discharge. In addition, backwater from the Musi River which is the estuary of the Bendung river is also one of the causes of flooding. The reduced capacity of the Bendung River is caused by sedimentation that occurs almost along with the river flow.
The research method in this study is sedimentation modeling using HEC-RAS 6.1 1D using cross-sectional data from upstream to downstream of the Bendung river. In this study, primary data was collected, namely floating sediment samples and base sediments. This study aims to determine the amount of sediment in the Bendung river at the time of flooding for a definite return period, analyze the influence of remaining sediment on changes in river morphology and capacity of the Bendung river in Palembang city and provide recommendations for normalization locations on the Bendung river.
From the results of this study, it was found that sediment affects the capacity of the Bendung River and causes vertical morphological changes, both in aggradation and degradation. The location that must be normalized on the Bendung river every year is upstream to the middle part of the Bendung river.

1. Introduction

Palembang City locates on a lowland where the altitude is between 12 and 30m above sea level. There are many small rivers that flow into a main river, Musi river. Due to the topographical configuration and a seasonal heavy rainfall, those rivers had been overflowed and the city had an inundation disaster. Bendung watershed is one of the nineteen watersheds in Palembang City, and the watershed also experiences the inundation disaster frequently due to the flood caused by a poor river maintenance and drainage system [2].

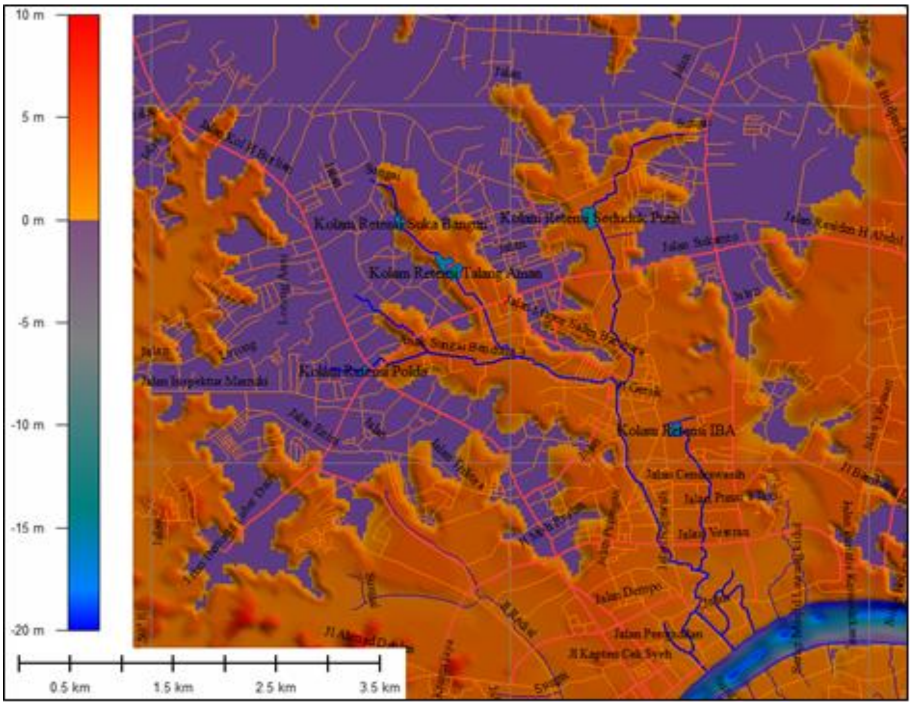

Fig 1. Ground Surface Elevation of Bendung Watershed [4]

Bendung River is one of the rivers in Palembang City that experiences overflowing when the rainy season occurs. This river length is 5.47 km, and its watershed area is 18.38 km2. The flood that occurred in the area around the Bendung river has caused material and non-material losses. The flood that occurred was due to the capacity of the Bendung River not being able to accommodate the flood discharge. In addition, backwater from the Musi River which is the estuary of the Bendung River is also one of the causes of flooding. The reduced capacity of the Bendung River is caused by sedimentation that occurs almost along with the river flow.

2. Problem Identification

Floods around the Bendung River in Palembang City have caused material and non-material losses. One of the reasons was the decreasing river capacity and backwater during the Musi River flood season, which is the Bendung River's outlet [1]. Floods occur upstream and in the middle of the Bendung River. Almost all of the floods that occur merge with the river. The capacity of the Bendung river is not able to accommodate the flood discharge. Sedimentation causes reduced capacity and also changes in morphology in the Bendung river.

3. The Objective of the Study

The objective of the study is to conduct a study of flood control in the Bendung watershed:

1. Estimate the amount of sediment in the Bendung river at the time of flooding for a discharge return period
2. Analyze the influence of sediment on changes in river morphology and capacity of the Palembang city on Bendung river

4. Research Method

The area to be researched is the Bendung watershed. To perform the modeling, topographic data such as the Digital Elevation Model (DEM) is needed, then the hydrological analysis is carried out using rainfall data from 4 rainfall stations for 20 (twenty) years. After that, hydraulic analysis was carried out by firstly calibrating the model by field data , i.e. instantaneous discharge data.Collection of suspended load data and bedload data were also conducted to support sediment analysis. Numerical modeling of sediment transport analysis that affects river morphology along the study area was conducted using the HEC-RAS 6.1 1D program, based on cross-sectional data from upstream to downstream of the Bendung River.

5. Result

5.1. Topographic Analysis

This topographic analysis aims to determine the parameters of the Bendung watershed using Arc-GIS 10.3 software. The area obtained is 18.38 km^2, the average slope of the river is 0.00019 – 0.00708 and the length of the river is 5.47 km. The Bendung watershed is then divided into 3 sub-watersheds, namely the Upper Left Sub-watershed, the Upper-Right Sub-watershed, and the Downstream Sub-watershed.

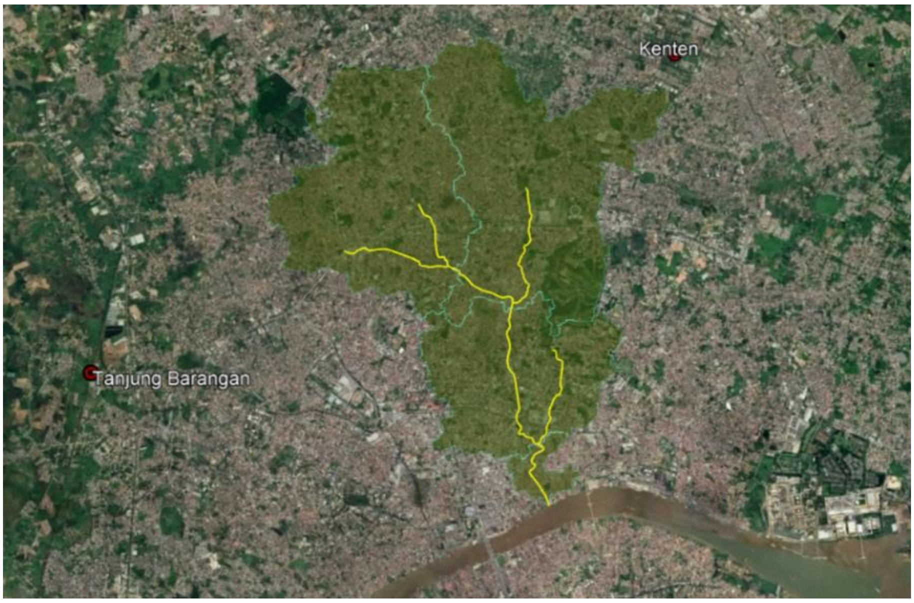

Fig 2 Bendung Watershed Deliniation

Table 1. Area of Sub Watershed

Sub Watershed	Area [km^2]
Left Upstream Sub Watershed	6.99
Right Upstream Sub Watershed	6.97
Downstream Upstream Sub Watershed	3.84

5.2. Hydrologic Analysis

The analysis of the maximum planned rainfall at the research location was carried out using the rain data used for this analysis from 4 rainfall stations with a series data of 20 (twenty) years 2000 – 2019. That rainfall stations are SMB II Meteorological Station, Palembang Climatology Station, Tanjung Barangan Rainfall Station, and Plaju Rainfall Station.

The rainfall data from the four rain stations above was then tested for data consistency. Frequency distribution analysis and frequency analysis were carried out after consistency test. It aims to obtain the design rainfall data of various return periods based on the most suitable distribution between the theoretical rain distribution and the empirical rain distribution.

After testing the rain data, and analysis of the annual maximum daily rainfall of the region is carried out. In this study, the Bendung watershed is divided into several sub-watersheds. That watersheds name are The Upper Left Bendung Sub Watersheds, Upper Right Bendung Sub Watersheds, and Downstream Bendung Sub Watersheds. Regional maximum daily rainfall analysis was carried out using the Thiessen polygon method, which was modeled in Arc GIS 10.3 software.

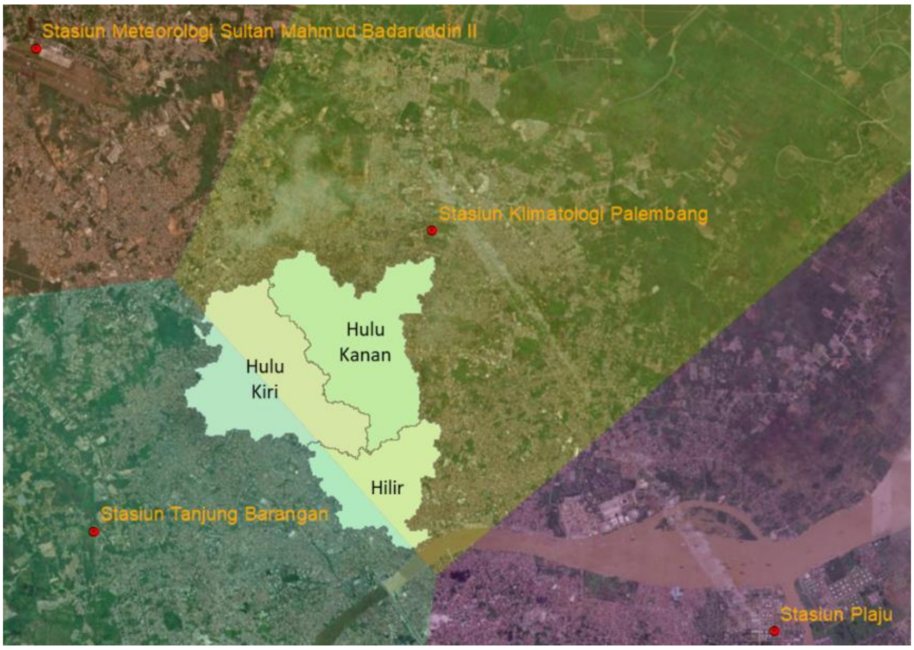

Fig 3. Polygon Thiessen of Bendung Watershed

From the modeling results, it is found that only 2 rain stations are used in the Bendung watershed area, namely the Palembang Climatology Rainfall Station and the Tanjung Barangan Rainfall Station. The area affected by the Tanjung Barangan Rain Station is 4.22 km^2 and the Palembang Climatology Rainfall Station is 14.16 km^2. Then the regional rainfall calculation is based on the sub-watershed and sorted from the largest rainfall value.

The next stage is testing the frequency analysis and infiltration analysis of the regional rainfall data for later analysis of the planned flood discharge [3]. In the analysis of flood discharge, the planned stages are modeled with HEC-HMS for each Sub-watershed. In addition, the sub-watershed parameters are also inputted in the form of a catchment area, composite watershed CN value, selected synthetic rainfall unit hydrograph, and time of concentration (Ct) and Time Lag values.

Table 2. Return Period Discharge

Tr	SCS	ITB-1b	ITB-2b
2	77.56	78.19	99.52
2.33	80.37	81.04	102.94
5	92.74	93.56	117.93
10	102.96	103.93	130.33
25	115.88	117.03	145.99
50	125.47	126.74	157.61
100	134.98	136.39	169.14
200	144.46	146.00	180.63
1000	166.42	168.26	207.25

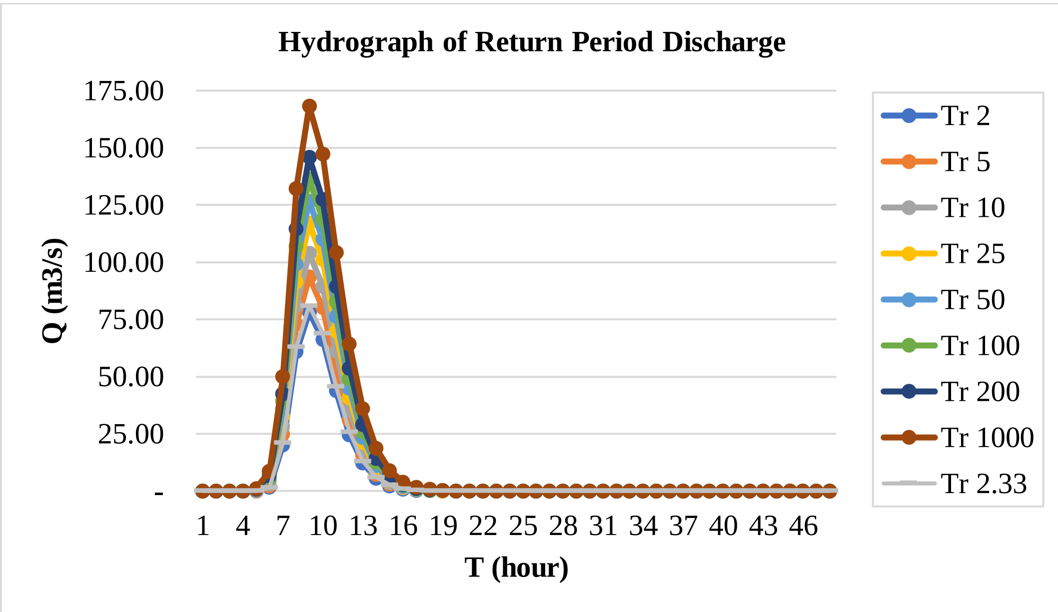

Fig 4. Hydrograph of several Return Period

5.3. Hydraulic Model Analysis

In this study, calibration of bankfull discharge and manning values the cross-section downstream of the Bendung River. This aims to determine the design discharge and also the manning value that will be used in the HEC-RAS model, due to the absence of measurement discharge in the field. By using cross-sectional data on the downstream part, the Wet Cross-sectional Area (A) is 28.6 m^2, Wet Circumference (P) 17.8 m, Hydraulic Radius (R) 1.61 m, Slope (S) 0.00019, Manning(n) 0.017.

$$V = \frac{1}{n} R^{2/3} S^{0.5} = 0.92 \text{ m/s}$$
$$Q = A \times V = 81.21 \text{ m}^3/\text{s}$$

When compared with the flood discharge value that has been analyzed previously, the calibration of the discharge is close to the discharge value of the 2.33year return period using the ITB-1B method. In addition, calibration of the manning value (n) was also carried out and obtained n = 0.021 which will be the next input in hydraulic modeling.

The modeling boundary conditions in this study are:
1. Cross-section of Bendung river at Sta.0+025 to Sta.5+475
2. Tidal data in the form of Water Level at the downstream of the Bendung River
3. Data for flood discharge plans for the return period
4. Data retention pool
5. Data on the operation pattern of pumps and sluice gates.

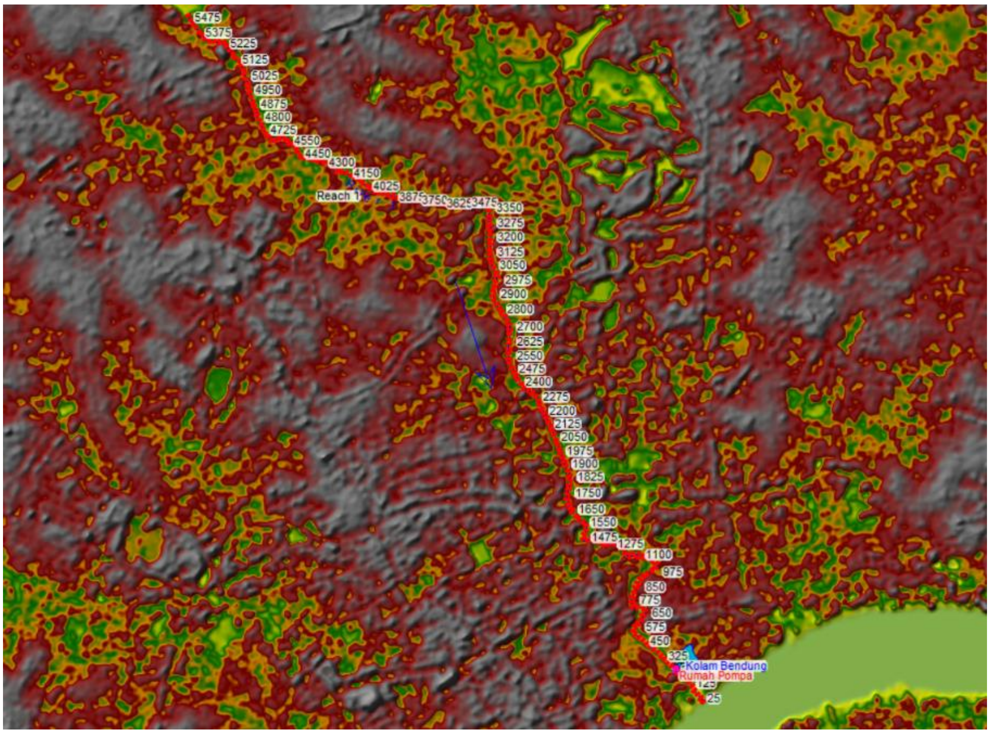

Fig 5. Set Up Models

The boundary conditions used in the modeling are adjusted to the conditions in the field. Details of the boundary conditions in the modeling are described in the following figure. The planned return flood discharge is obtained from the results of the previous hydrological analysis. The water level downstream of the Bendung River was obtained from field measurements.

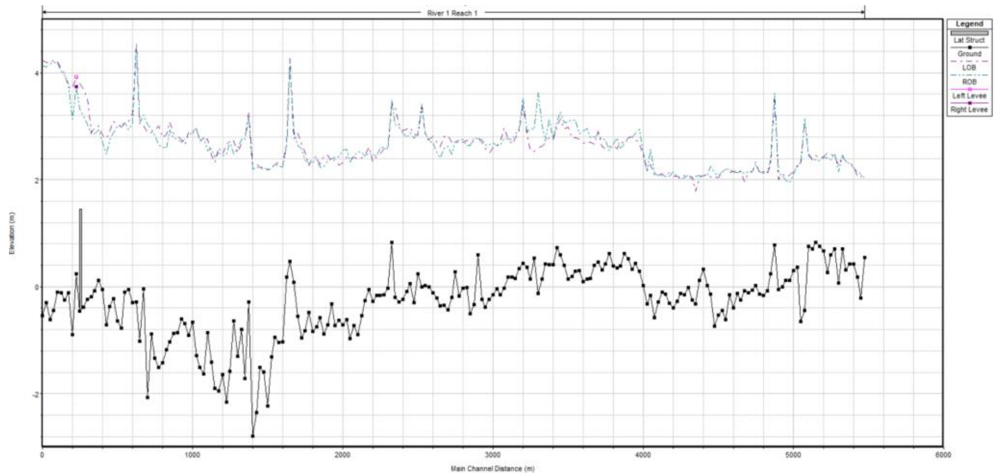

Fig 6. Long Section of Bendung River

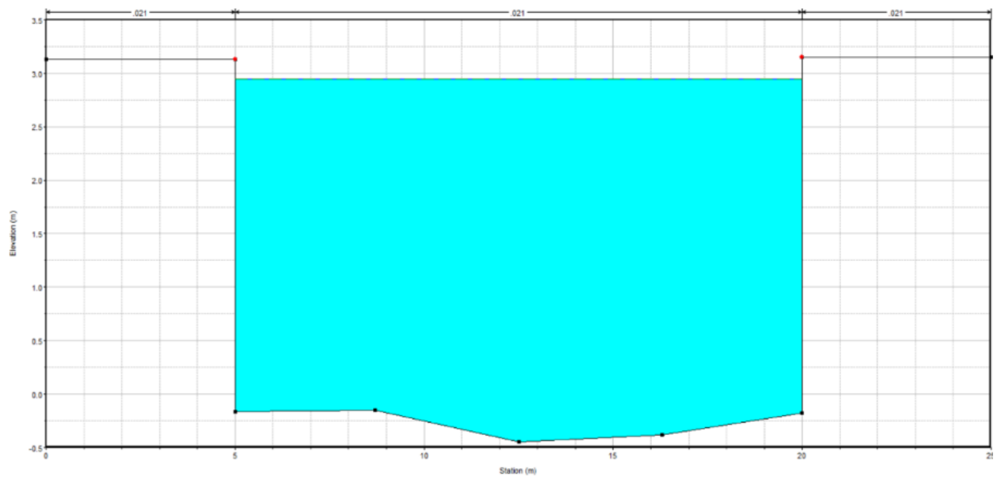

Fig 7. Cross Section of Upperstream Bendung River

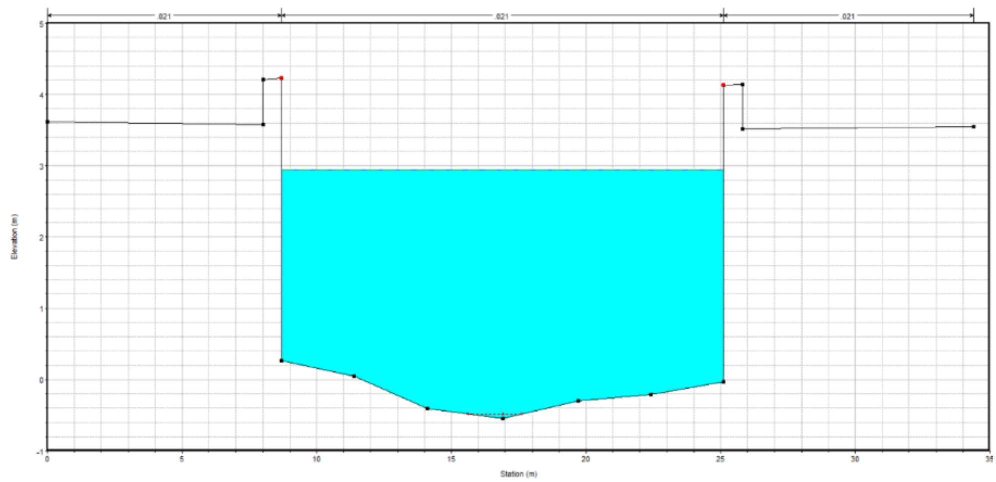

Fig 8. Cross Section of Downstream Bendung River

5.4. River Morphological Analysis

The modeling boundary conditions in this study are same with the hydraulic analysis's model. Based on the results of the analysis of sampling in the field, the sediment discharge curve of the Bendung River is obtained as follows:

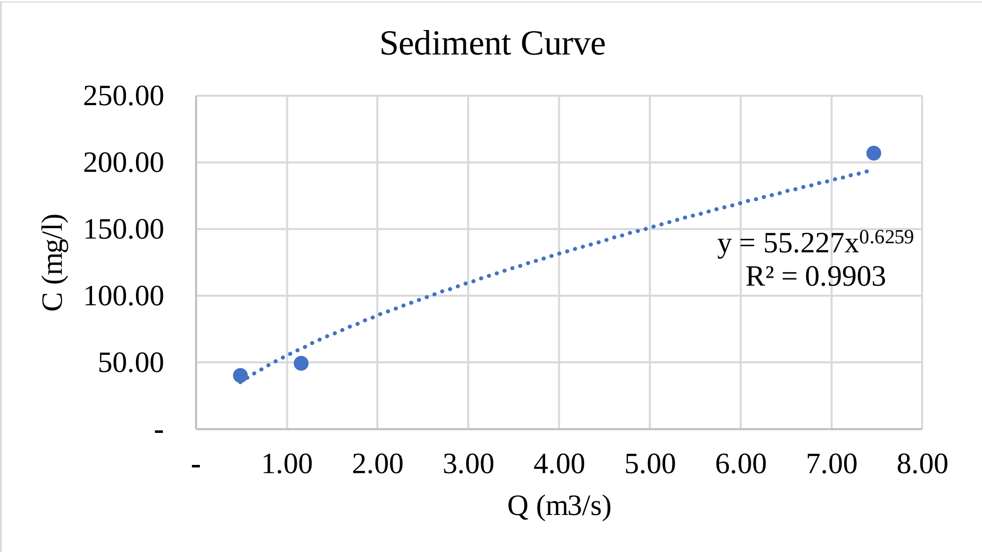

Fig 9. Sediment Curve of Bendung River

The boundary conditions used in the modeling are adjusted to conditions in the field, the grain gradation is adjusted to the sediment sampling point in the field. And for the discharge used in this research modeling is flood discharge with a certain return period.

1. Bankfull Discharge condition

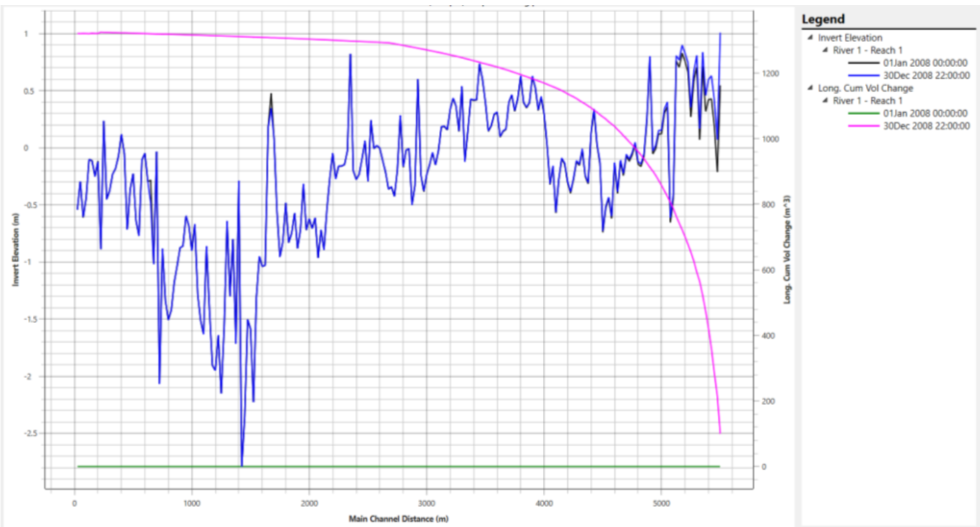

Fig 10. River Bed Changes of Bankfull Discharge Daily 1yr

The modeling uses bankfull and daily discharge data. From the modeling results, it can be seen that there is an aggradation from upstream to STA 1+000, then the model is stable or in balance to the downstream point. It was found that the Bendung River carried sediment up to the downstream point for one year amounting to 1,267.60 m^3.

2. Flood Discharge (25 years return period)

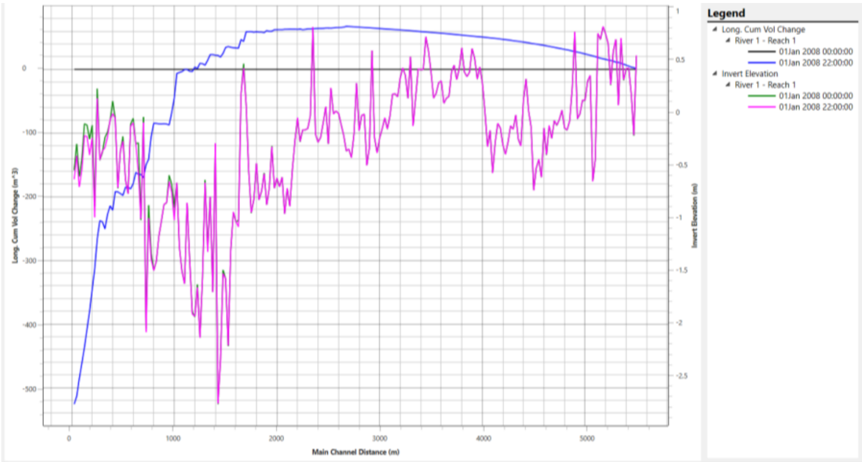

Fig 11. River Bed Changes of Flood Discharge (TR 25)

From the modeling results, it was found that in the upper part of the Bendung River, when the flood occurred, aggradation began to occur. Then from STA 2+600, the modeling results start to stabilize then at the point of STA 1+800 degradation begins to occur down to the downstream point or STA 0+025. If seen from the modeling results, during the flood event for the 25 year return period, the Bendung River carried sediment out of the river to the Musi River as much as 1,125.31 m^3.

3. Flood Discharge (50 years return period)

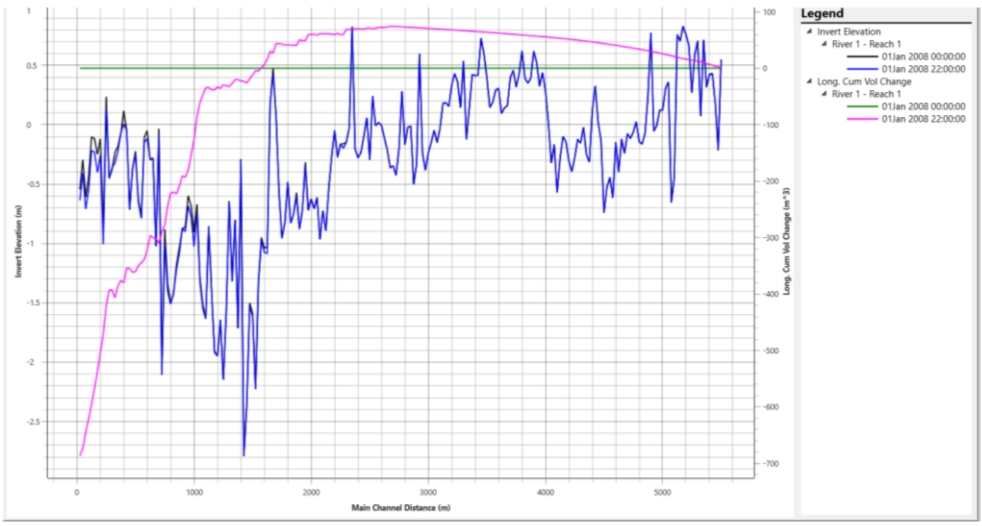

Fig 12. River Bed Changes of Flood Discharge (TR 50)

From the modeling results, it was found that in the upper part of the Bendung River, when the flood occurred, aggradation began to occur. Then from STA 2+600 the modeling results start to stabilize then at the point of STA 1+800 degradation begins to occur down to the downstream point or STA 0+025. If seen from the modeling results, during the flood event for the 25 year return period, the Bendung River carried sediment out of the river to the Musi River as much as 1,125.31 m^3.

6. Conclusion

Conclusion for this paper are:

1. During flood discharge 0f 25 years return period,Bndung river carried out 1,125.31 m^3 of sediment and carried out 1,182.24 m^3 of sediment during flood discharge of 50 years reaturn period
2. There are insignificant degradation at some point in the lower reaches of the Bendung river when modeling using daily discharge bankfull scenario with pump turned on, STA.0 + 725 to STA.0 + 100 amounted to 53.12 m3/ year. This is due to the effect of the pump when it is turned on.
3. There is no lateral change in the morphology of the Bendung river, this is because along the river, riverbank reinforcement has been carried out. But there is a vertical morphological change in the Bendung river, both in aggradation and degradation.
4. Sedimentation at Bendung river is estimated to reduce the capacity of the Bendung river by 35%.

7. References

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