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Simulation of the effect of floodway on Batang Kandis River flood control

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Abstract. Floods often occur in Padang City, mainly in the areas of Pasia Nan Tigo Village and Lubuk Buaya Village, caused by the overflow of Batang Kandis when heavy rains occur (intensity of rainfall >15mm/hours). To decrease the river overflow an artificial canal with 300 m long and 50 m wide (floodway) was constructed to bypassing the river flow from the Batang Kandis River to the ocean. In order to find out the effects of the floodway, four scenarios are performed the scenario 1 and 2 were the simulation condition of Batang Kandis River before and after the construction of floodway. While to increase the effectiveness of floodway, simulations 3 and 4 were carried out. Scenario 3 was the combination of floodway with normalization and embankment. To prevent the entry of seawater into the Batang Kandis River, because the floodway is affected by the tide of the sea, then 3-door motion weir was simulated namely scenario 4. Scenario 4 was the combination of floodway normalization, embankment, and a 3 door motion weir. From the simulations, we found that the floodway was effective to decrease the water surface level up to 15 m and 20 m during 10 years and 25 year return period of discharge respectively. From the scenario 3, we found that the embankment with 1.5 m and 2 m was effective to prevent overflow by 10-year and 25-year return period of discharge respectively. While for scenario 4 the water level rises 0.5 m due to motion weir So, that it is needed to extend the embankment with 0,5m high.

1. Introduction

Flooding is a condition of the river that cannot accommodate the flow of water passing through, because of that runoff occurs [1]. To minimize flooding requires an effort to control floods both structurally and non-structurally [2].

Floods in the Padang City of West Sumatera often occur mainly in the area of Pasia Nan Tigo Village and Lubuk Buaya Village, caused by the overflow of Batang Kandis when heavy rains (intensity of rainfall > 15 mm/hour), see in Figure 1 and Figure 2 .

On March 22, 2016, there was a flood due to overflowing Batang Kandis River with a flood height of up to 120 cm in residents House in Lubuk Buaya Area, see in Figure 3 (a) and 3 (b). Flood control efforts have been carried out by constructing a floodway of approximately 300 m long, 50 m wide and construction of a 700 m long embankment on the left side of the Batang Kandis River.

According to the results of interviews with local residents, the construction of a floodway can reduce the area of flood inundation. However, floods still occur accompanied by the emergence of new problems that are enter of seawater into a Floodway during a tide. So that the rice fields around Batang Kandis River failed to harvest, see in Figure 3(c)



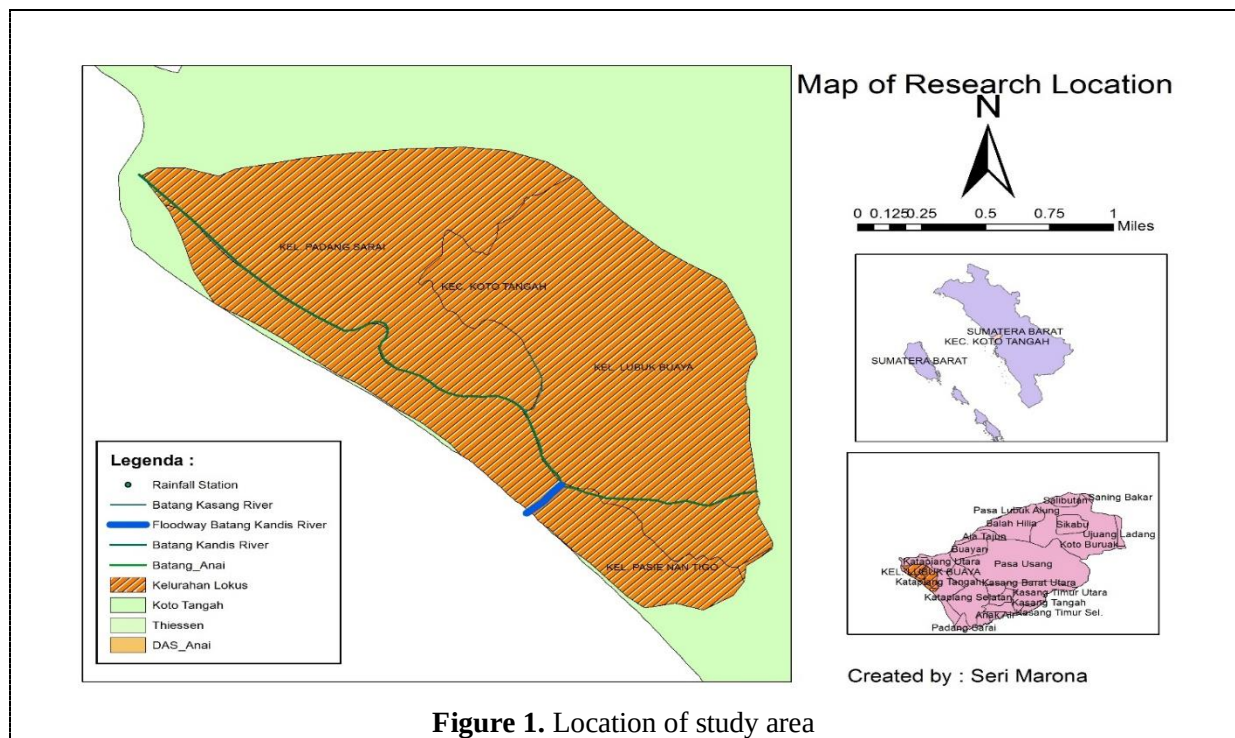


Figure 1. Location of study area



Figure 2. Google Earth map of study area and location of floodway access on 2018



Figure 3. Flooding on March 22, 2016 (a) and (b) flood in the residents house; (c) flood in the rice field area

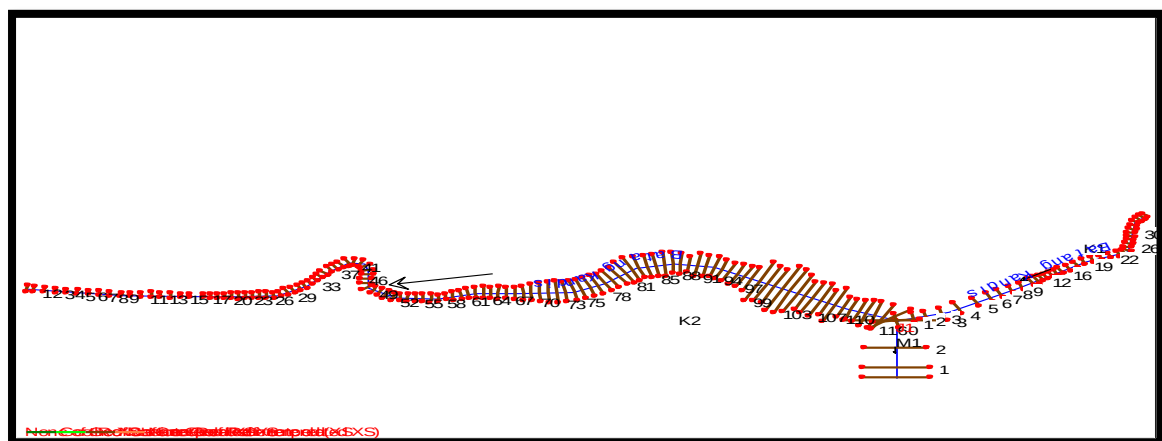


Figure 4. Cross section of Batang Kandis River

Based on the above background, the authors are interested in reviewing the Simulation of the Effect of the Flood control on the Overflow of Batang Kandis River Flood using HEC-RAS 4.1.0.

2. Research Methods

The location of the study was conducted at Batang Kandis River in Lubuk Buaya. Starting from segment 1 of Batang Kandis River (K1: Point 36-0), segment 2 (K2: 116-0) and Floodway (M1: 3-0).

The research methods include three main things as the followings:

2.1. Topographic and Bathymetric Measurements,

The data source comes from the primary data in the form of direct measurements using the Echosounder Garmin 585. The measurement starts from Lubuk Buaya Railway bridge until downstream of Batang Kandis and Muara Baru Batang Kandis, see in Figure 5. The result of the Bathymetry measurement data can produce a Batang Kandis contour map. From the contour, a cross-section of the river is made with intervals at 20 m, see in Figure 4, which will be used in the HEC-RAS 4.1.0 simulation.

Garmin 585 echosounder specifications as follows :

- Frequency: 50/200 kHz
- Maximum depth: 1500 ft
- Cone angle: 20 degrees
- Depth capacity is dependent on water salinity, bottom type, and other water conditions.

Bathymetry data were measured to obtain longitudinal profile and cross-profile data on the Batang Kandis river channel. Measurements are carried out on May 5, 2018, starting from 08.00 WIB until 13.00 WIB. The measurement was carried out by 6 people consisting of 1 observer of water level fluctuations, 2 people installed and monitored the equipment, 1 documentation person, 1 person for boat direction command and 1 boat driver.

From the results of the Track boat which is carried out as many as four trajectories, transversal data profile over Batang Kandis can be obtained. From the longitudinal profile of the 4 trajectories, a river contour is created to describe the profile across Batang Kandis which will be used in the HEC-RAS 4.1.0 simulation.

Difficulties in measuring that are to measure the edge of the river cannot be reached. to overcome it, theodolite is used in profile measurements on river banks.

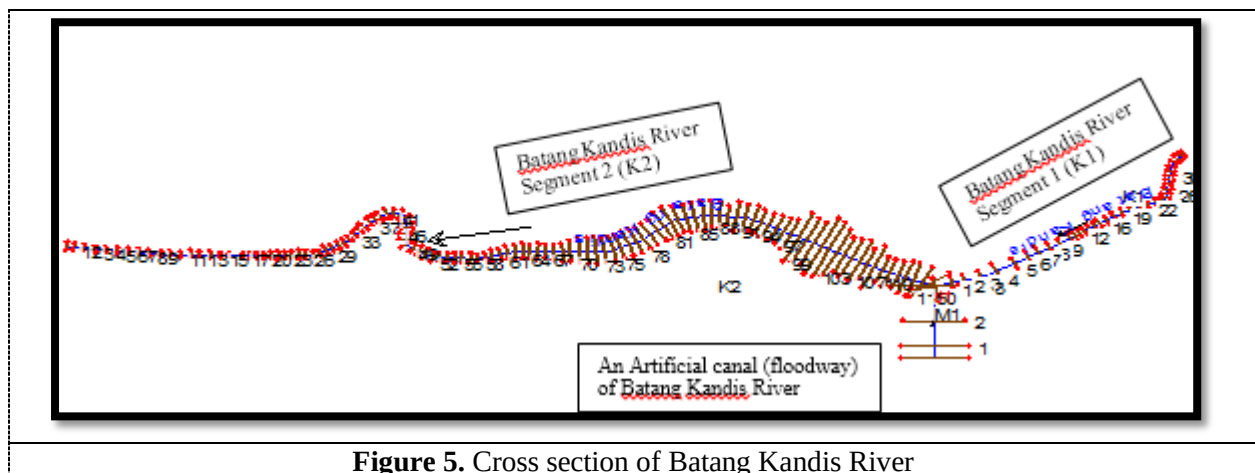


Figure 5. Cross section of Batang Kandis River

2.2. Hydrology calculations

Discharge design was calculated using the Snyder alexeyev Sintetik Unit (HSS) Hydrograph method with a 10-year return period and a 25-year return period. The selection of the Snyder alexeyev HSS calculation method is based on SNI 2415: 2016, which is the best method because it can be calibrated, while other methods are not accurate unless calibrated with Indonesian conditions [4].

Formation of initial hydrograph comes from the relation between effective rainfall and direct runoff. The relation is one of the components of the general watershed model. The unit hydrograph theory is the first application of linear system theory in hydrology.

Three rain station is used to calculate effective rainfall. They are the rain station of Khatib Sulaiman, Batu Gadang, and Kasang. Horton method is used to calculate effective rainfall while Log Pearson III for rainfall distribution.

2.3. Batang Kandis Flood Control Simulation and Validation

Table 1. The following is the scenario used to simulate the Batang Kandis River

No.	Initial Condition of Scenario
1	The Batang Kandis River before the construction of floodway
2	The Existing condition after the construction of floodway
3	Simulations in scenario 2 combination with normalization and addition of embankments to the Batang Kandis River
4	Simulation in scenario 3 combination with 3 door motion weir

2.3.1. Boundary Condition. Boundary conditions as controls in modeling. The boundary conditions are the boundary conditions in the upstream and downstream sections of each river segment. The Batang Kandis schematic can be seen in Figure 4.

Table 2. The boundary conditions used in the model simulation in this study are:

No	River Segment	Boundary Condition
1.	Batang Kandis River Segment 1 Upstream Downstream	the slope of the river at normal depth is 0.009 Junction
2.	Batang Kandis River Segment 2 Upstream Downstream	the slope of the river at normal depth is 0.008 where the river flows into Batang Anai
3.	New River most of Batang Kandis River Upstream Downstream	the slope of the river at a normal depth is 0.005 Tides and seawater with sinusoidal equations in floodway Batang River. Tidal duration taken 24 hours equalizes the input duration of other boundary conditions. The tidal profile is shown in figure 5

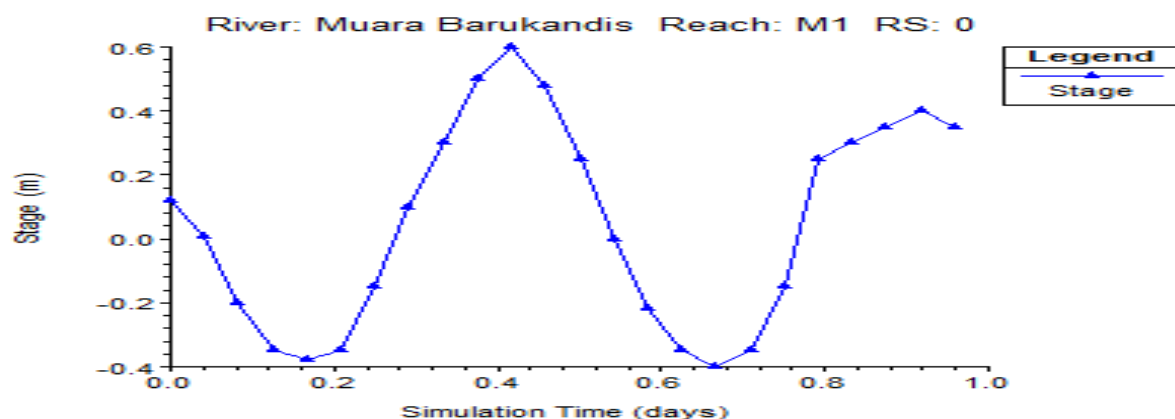


Figure 6. Tidal profile

2.3.2. Validation. Data validation aims to compare simulation results data with field data. Because the alleged water post or measuring building is not in the Batang Kandis, that is the reason why the validation was made to make a temporary measuring post. The temporary measuring post is located at Batang Kandis Section K1 RS: 2, see figure 7 and 8. By Comparing flow velocity and water level data in the K1 RS: 2 as the result of HEC-RAS simulation with a flood on March 22, 2016.



Figure 7. Measuring post



Figure 8. Floods inundate residents' houses in Lubuk Buaya area.

3. Results and Analysis

3.1. Hydrologic Calculation

The calculation of the flood discharge plan uses the Snyder method because the data on the alleged water post is not available. Thus using the maximum daily rainfall data of three rainfall station, they are Batu Gadang, Kasang and Khatib Sulaiman posts with a 9-year data period (2009-2017) can be seen in Table 3.

The position of Khatib Sulaiman PU rainfall station is located at coordinates $0^{\circ} 54'14.4''$, $100^{\circ} 21'5.76''$ in Padang City. Kasang rainfall station is located at coordinates $0^{\circ} 46'30''$, $100^{\circ} 19'00''$ located in Padang Pariaman District and Batu Gadang rainfall station located at coordinates $0^{\circ} 33'20.16''$, $100^{\circ} 20'25.08''$.

Table 3. Maximum daily rainfall data each rainfall station for 2009-2017

No	Tahun	PCH Kasang	PCH PU Khatib.S	PCH Batu Gadang
1	2009	195.0	195	192.0
2	2010	294.0	270	110.0
3	2011	173.0	206	128.3
4	2012	194.0	100	140.0
5	2013	193.0	128	155.0
6	2014	157.0	145	125.0
7	2015	200.0	200	180.0
8	2016	260.0	220	170.0
9	2017	240.0	160	150.0
	n	9	9	9
	Mean	211.8	180.4	138.9

After obtaining maximum daily rainfall data on each post, then the data is tested by the Grubbs and Becks 'Outlier method, Trend Test (Spearman), T-test, F Test and Independent Test. The test results show that a). The data used do not show significant deviation from the data set so that the data can be

used, b) The rain data used shows that there is a trend, c). Data has uniform variants, stable average, and independent.

After testing the data, the area precipitation is calculated using the Thiessen polygon method. Based on the test results the distribution data used is Log Pearson type III. Therefore the projected rainfall was obtained for the 10-year return period is 231 mm and 25 years is 258 mm. After calculating the projected rainfall, then proceed with the calculation of net Rain (net) the duration of rain taken from the duration of the rain when the flood occurred on March 22, 2016, which is 8 hours. Therefore net projected rainfall was obtained for the 10 year return period is 202.77 mm and 25 years is 229.70 mm.

For the calculation of hydrograph units, hydrograph can be made directly due to 1mm sufficient rainfall. The model will be simulated in HEC-RAS 4.1.0 (Unsteady Flow), and the simulation can be seen in Figure 9.

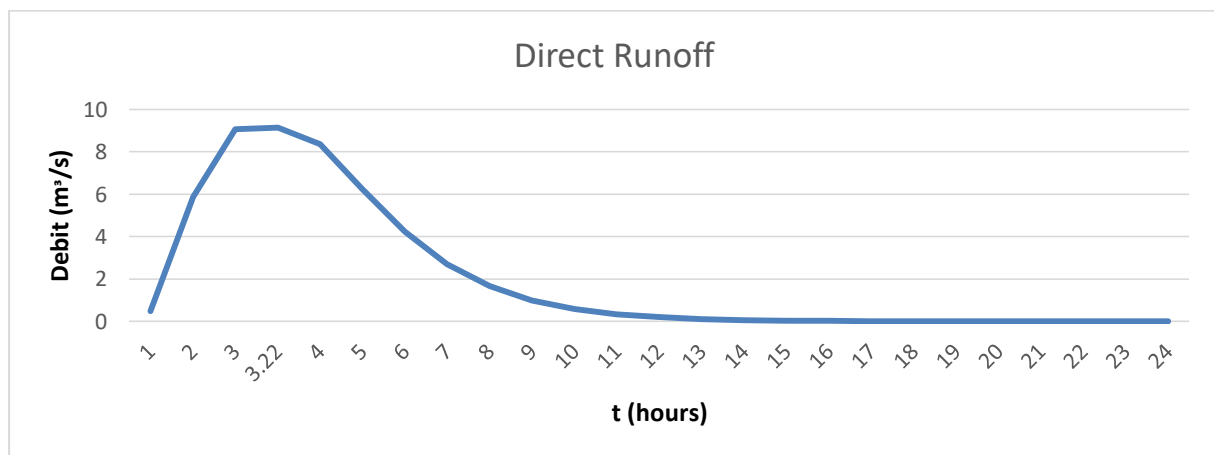


Figure 9. Direct runoff

The results of the projected flood discharge calculation for a 10-year return period ($Q_{max} = 157.33 \text{ m}^3/\text{s}$) and 25 years ($Q_{max} = 178.13 \text{ m}^3/\text{s}$). Calculation of Manning roughness is based on the sensitivity test method, by trial and error with n values and comparing them to the results of velocity validation measurements in the field. The following are the results of the sensitivity test (figure 10)

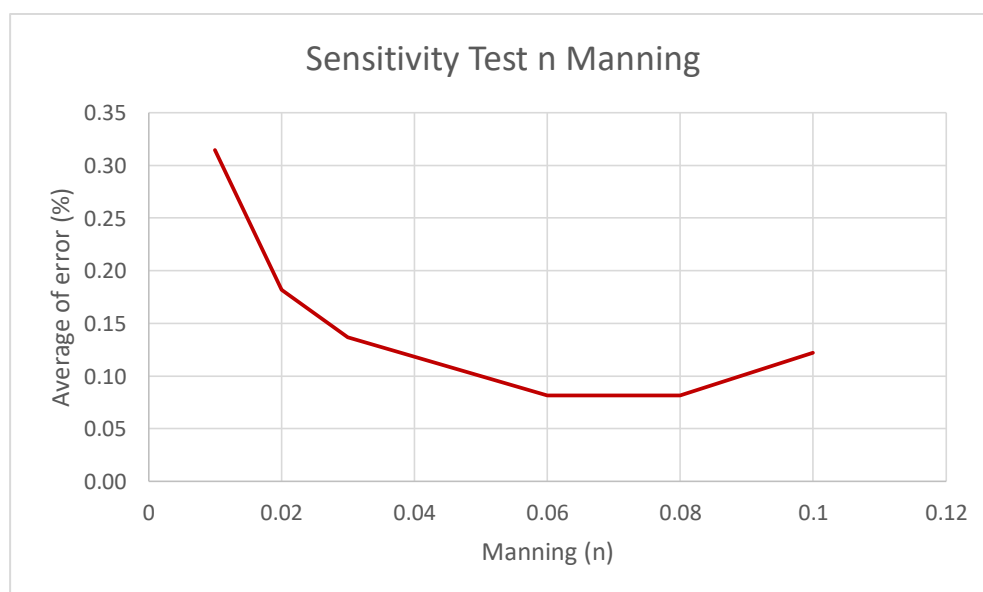


Figure 10. Sensitivity test chart

Based on the results of the sensitivity test calculation, the closest n values are 0.06, 0.7 and 0.08. From the results of visualization of field conditions: a). Leftover Bank (LOB) is 0.06 because the banks are still in a natural condition with trees, b). Right over Bank (LOB) is 0.06 because the banks are still in a natural condition with the presence of trees, c). The main channel is 0.07 because in this section the flow is slow, the river is deep and close to the river mouth.

3.2. Simulation of Batang Kandis River Flood Control and Validation

The simulation of the adequacy of the river channel in flowing the projected debit which is focused on whether there is runoff or not along the modeled Batang Kandis flow. The discussion for the results of each model is as follows.

3.3. *The river condition before the Construction of Muara Baru (Scenario 1).* In scenario 1 the river is simulated in the condition that the Muara Baru Batang Kandis has not yet been built. Simulated debit data are 10-year return period and 25-year return period debit data. Flow simulation results on river transversal profiles as shown in Figures 11, 12 and 13:

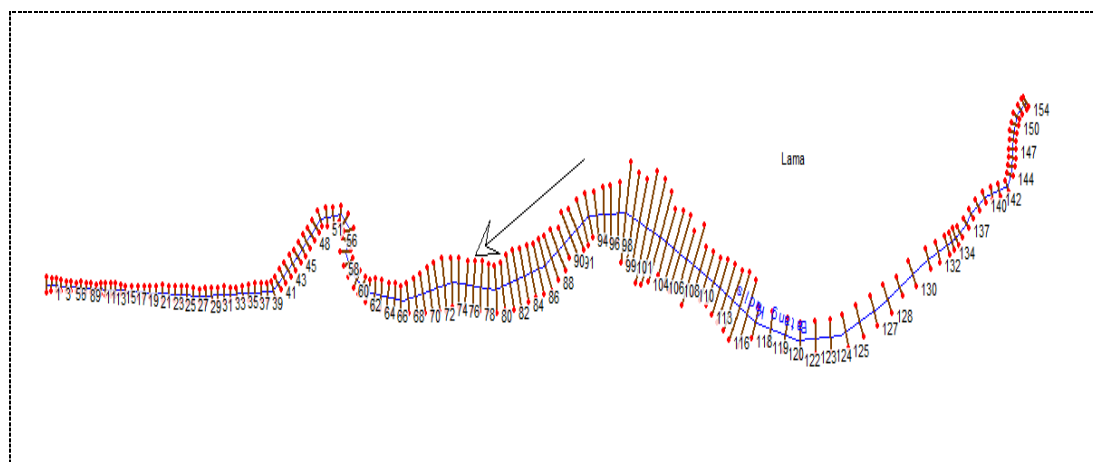


Figure 11. River schematic (Scenario 1)

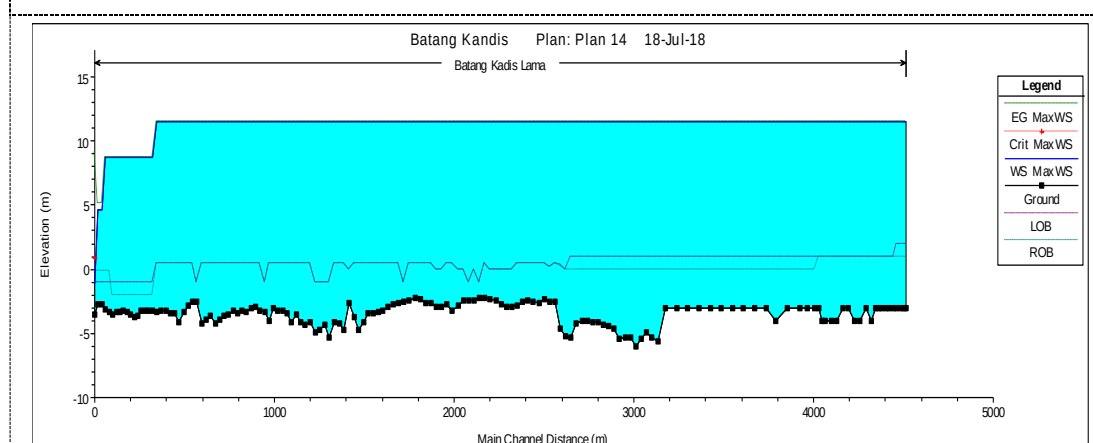


Figure 12. Cross and over sections of Batang Kandis Lama flow (scenario 1) with Q.10

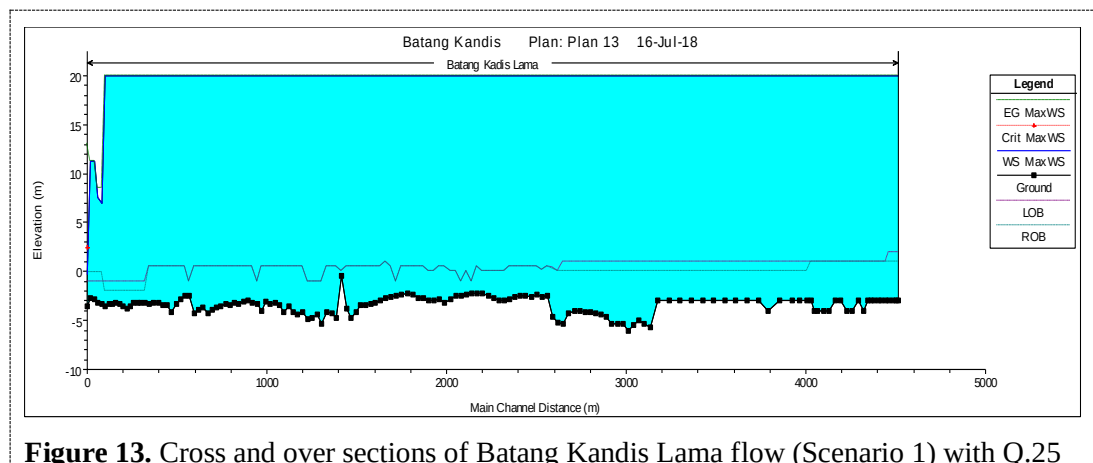


Figure 13. Cross and over sections of Batang Kandis Lama flow (Scenario 1) with Q.25

Based on Figure 12 and Figure 13 the over sections of Batang Kandis River can be seen that there is a flood over the river and Muara Baru both in Q_{10} and Q_{25} .

Table 4. Simulation result of scenario 1

Return Period	Debit (m ³ /s)	Number of flood point (point)	Maximum flood elevation (m)
Q ₁₀	157,33	154	13.5
Q ₂₅	178.13	154	20

Based on the simulation results in the table above the maximum number of fixed points and flood height increases with a larger return period of debit.

3.4. Existing Condition (Scenario 2). In this scenario, the river is simulated with river topography conditions in accordance with the conditions in the field. Simulated debit data is 10-years return period and 25 years return period. Flow simulation results for scenario 2 can be seen in Figure 14, Figure 15 and Figure 16. Flow simulation results on river transversal profiles as shown in Figures 14, 15 and 16:

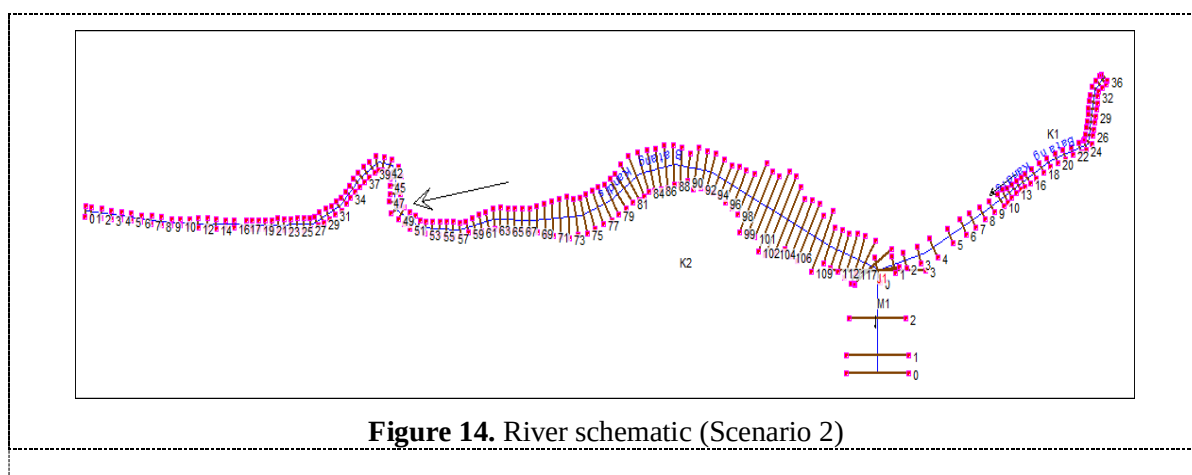


Figure 14. River schematic (Scenario 2)

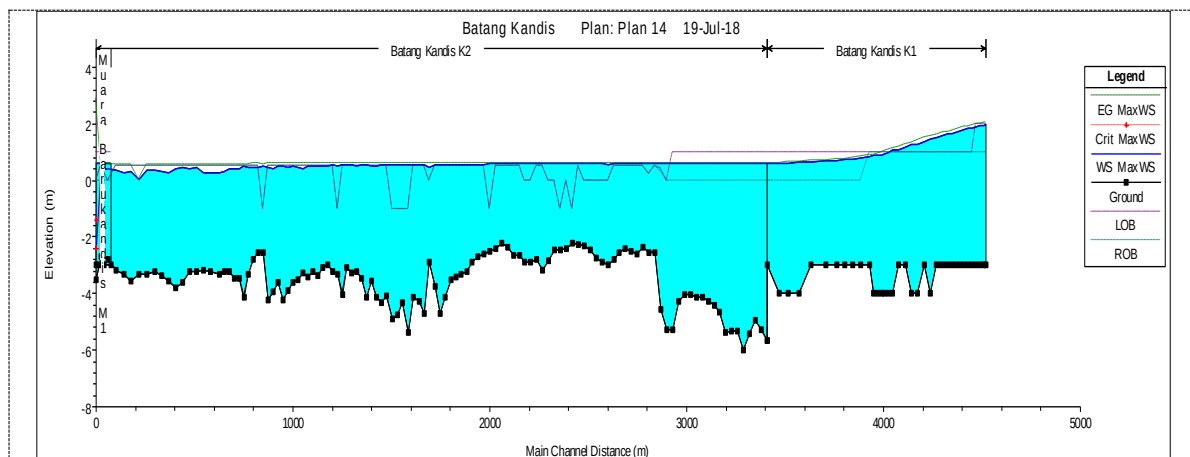


Figure 15. Cross and over section of Batang Kandis Flow (K1) existing condition (scenario 2) with Q.10

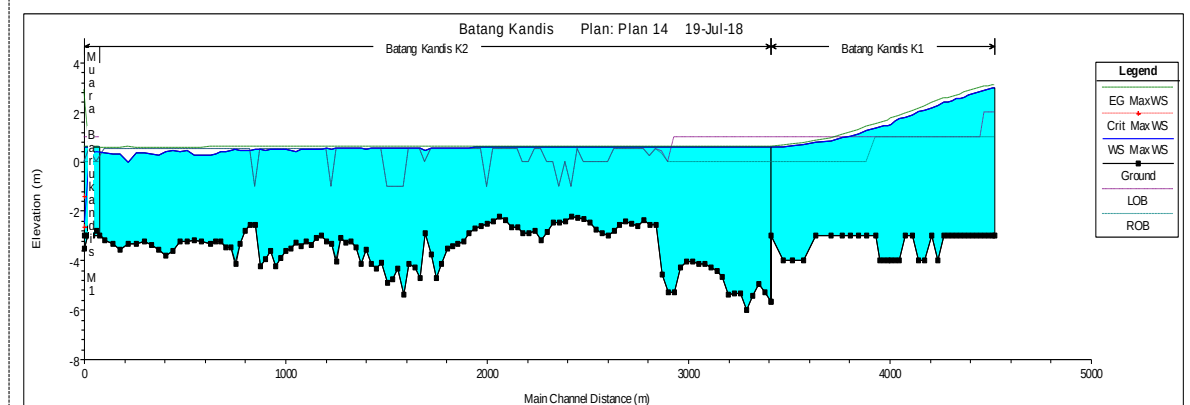


Figure 16. Cross and over section of Batang Kandis Flow (K1) existing condition (scenario 2) with Q.25

Based on Figure 11 and 12 over sections of the Batang Kandis River can be seen that there is a flood over the river and Muara Baru both in Q_{10} and Q_{25} . The simulation results in scenario 2 in each return period can be seen in table 5:

Table 5 Scenario simulation results 2

Return Period	Debit (m^3/s)	Number of flood point (point)	Maximum flood elevation (m)
Q_{10}	157,33	98	0,8
Q_{25}	178,13	147	1

Based on the simulation results in the table above the maximum number of points and flood height increases with a larger return period of debit.

3.5. Addition of Embankments and River Normalization (Scenario 3). Scenario 3 is simulated by installing the embankment to reach an elevation of 1.5 meters above sea level. Based on the results of scenario 2 the position will be safe if the elevation of embankment reaches 1.5 m above sea level to prevent the runoff. According to the simulation results on the debit of Q_{10} and Q_{25} , flood happens in almost every river. The Handling is done by the embankment installation on the left and right of the river and normalization of the river. Whereas river widening was not possible because many residential areas along Batang Kandis, modeling of embankment installation was modeled using a

debit with a 25-year return period. The selection of projected debit is to secure the embankment design if there is a 25-year return flow. After the embankment is constructed until 1.5m above sea level in the Batang Kandis River and 1.5m in Muara Baru Batang Kandis, the runoff does not occur again, can be seen in figures 17.

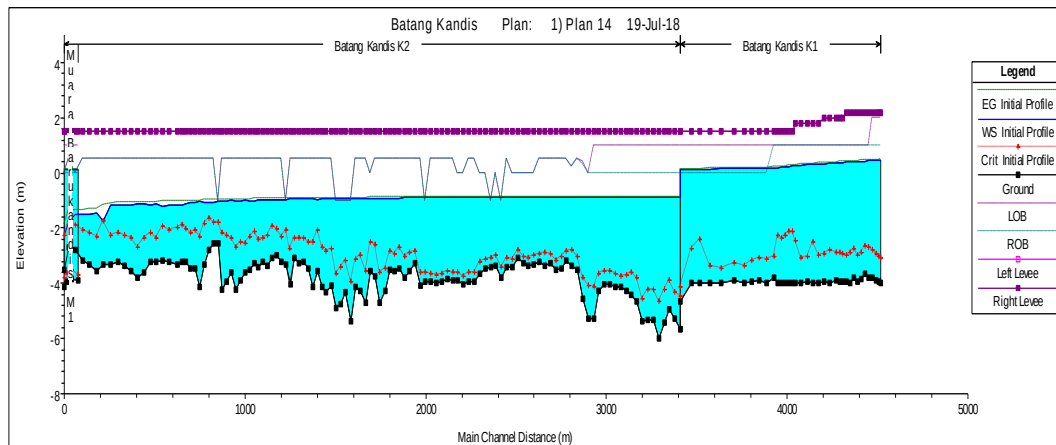


Figure 17. Addition of embankment and river normalization (scenario 3) with Q.10.

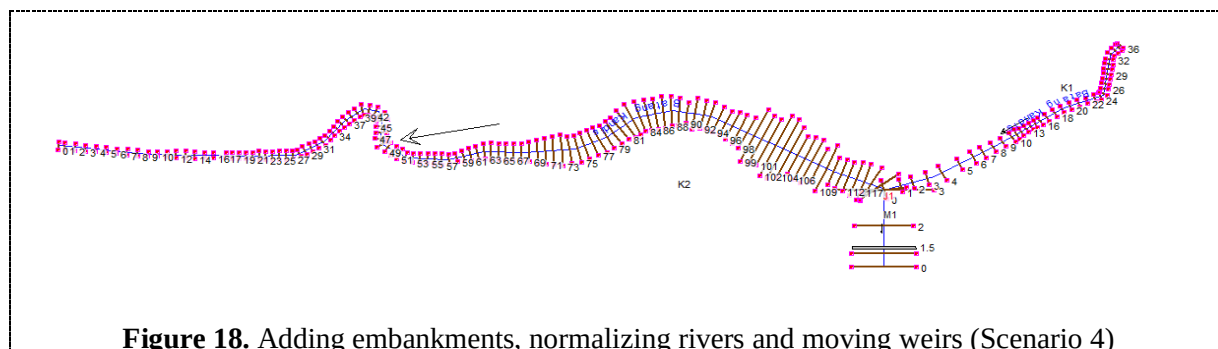
Based on Figure 20 the over sections of the Batang Kandis River shows no flooding along the river and Muara Baru both in Q10 and Q25. The simulation results in scenario 3 in each return period can be seen in table 6:

Table 6 Scenario simulation results 3

Return Period	Debit (m^3/s)	Number of flood point (point)	Maximum flood elevation (m)
Q ₁₀	157,33	-	-
Q ₂₅	178,13	-	-

Based on the simulation results in the table above, it can be seen that there is no runoff along the area.

3.6. Addition of Embankments, Normalizing Rivers and Moving Weirs (Scenario 4). Scenario 4 is carried out by constructing a Moving Weir on the Muara Baru section of Batang Kandis. The Moving weir is built on RS 1 + 0.5 m. Simulation Results Scenario 4 can be seen in Figure 18, Figure 19, Figure 20 and Figure 21.



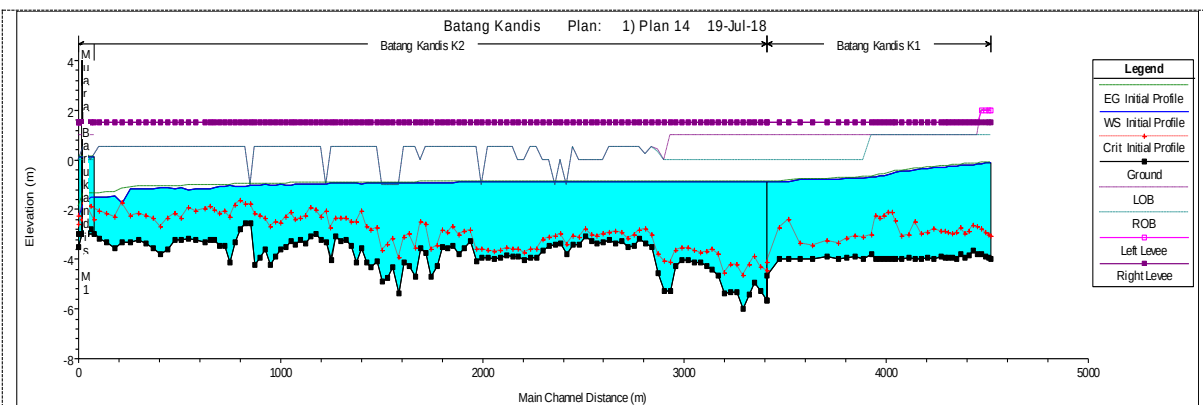


Figure 19. Over section scenario 4 with Q.10

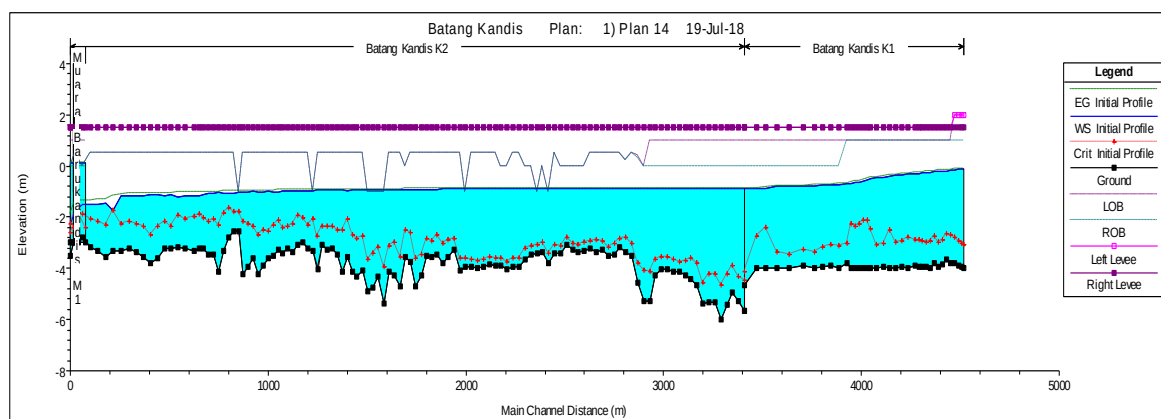


Figure 20. Over section scenario 4 with Q.10

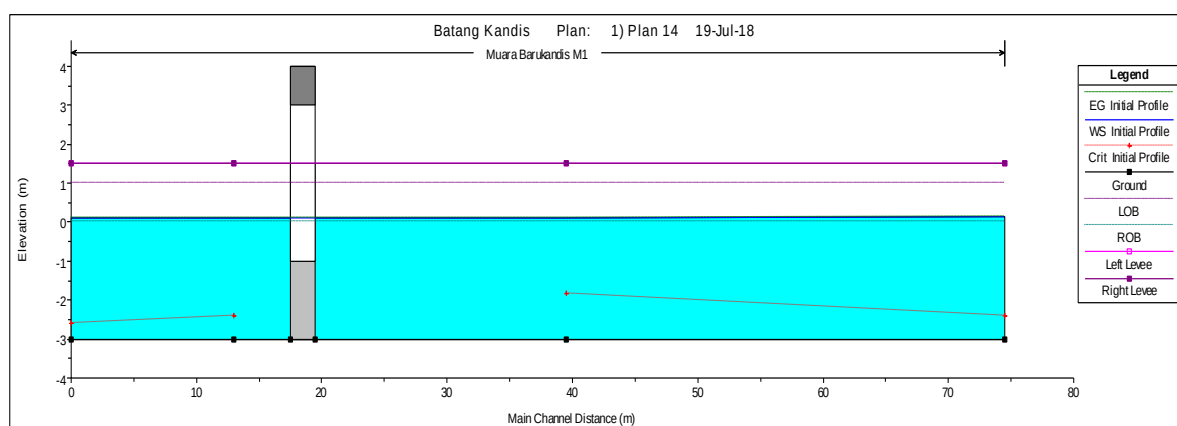


Figure 21. Over section scenario 4 with Q.10

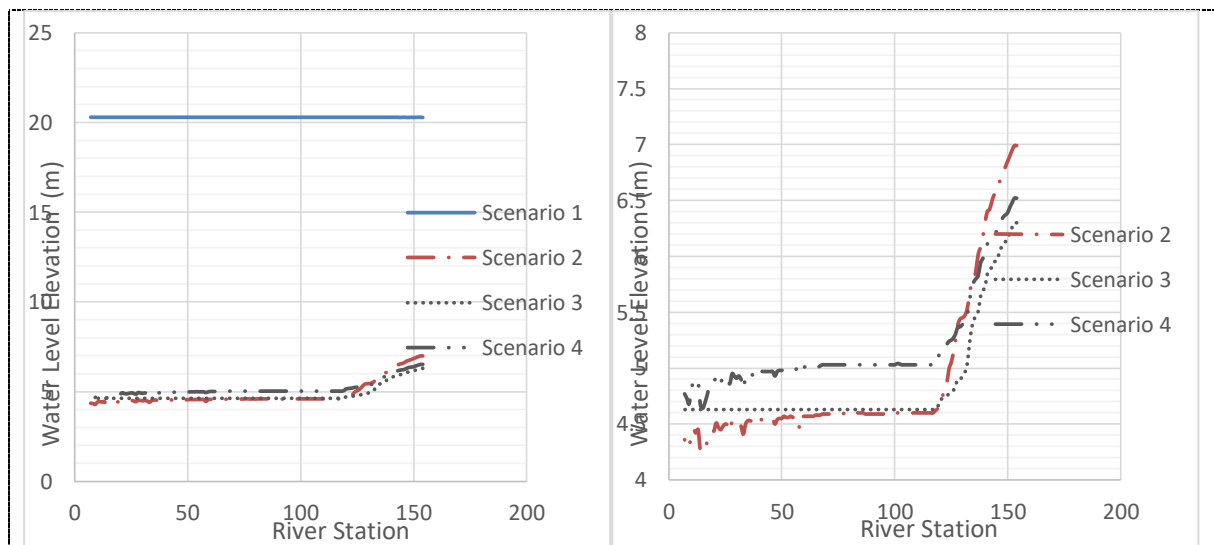
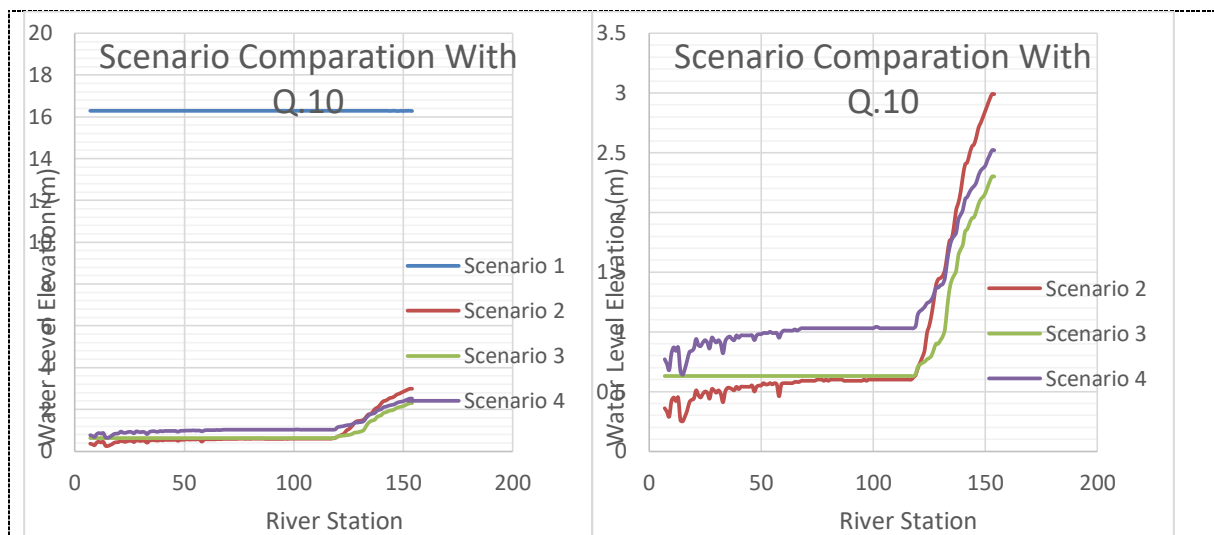
Based on Figure 13 and Figure 14 the over sections of the Batang Kandis River shows that there is no flooding along the river and Floodway both in Q10 and Q25. It can be seen in Figure 15 that in RS 1 + 0.5 m in floodway on Batang Kandis was built a 3-door moving weir also no runoff. The simulation results in scenario 4 in each return period can be seen in table 7:

Table 7. the Result simulation of scenario 4

Return Period	Debit (m ³ /s)	Number of flood point (point)	Maximum flood elevation (m)
Q ₁₀	157,33	-	-
Q ₂₅	178,13	-	-

Based on the simulation results in the table above, it can be seen that there is no runoff along the area.

According to the simulation results conducted on four scenarios, a resume of water level before and after the construction of floodway on Batang Kadis (Floodway) can be made.

**Figure 22.** Water level for Q₂₅ years periode**Figure 23.** Scenario comparison

Based on Figure 22 and 23, it can be seen that Floodway affects the decreasing of water level by the maximum is 15 meters.

The results of the modeling data validation and field conditions are as follows:

- The Result of instantaneous flow velocity measurement conducted by BWS Sumatra V using the buoy method on March 22, 2018, is 1.65 m / s. While the peak flood debit result for the 10-year return period is 1.55 m / s, the debit difference is 0.1 m / s,
- A Temporary measuring post was also made on July 9, 2018, at Batang Kandis Section K1 RS: 2 picture, b) The instantaneous flow velocity measured from K1 RS: 3 to K1 RS: 2 with the buoy method was 1.2 m / s, whereas Flow velocity simulation results in K1 RS: 2 are 0.98 m³ / s. There is a speed difference of 0.22 m / s,
- interview with the community about the March 22, 2016, flood.

4. Conclusion

Several conclusions can be concluded from this study are as follows:

- Based on the simulation results in scenario 1 which is before the construction of Muara Baru with a peak debit of $Q_{10} = 157.33 \text{ m}^3 / \text{s}$ there are 154 flood points with a flood elevation is 15 m. While $Q_{25} = 178.13 \text{ m}^3 / \text{s}$ there are 154 flood points with a maximum flood elevation is 20 m.
- Based on the simulation results in scenario 2 with peak debit $Q_{10} = 157.33 \text{ m}^3 / \text{s}$ there are 98 flood points with a maximum flood elevation is 0.8 m. While $Q_{25} = 178.13 \text{ m}^3 / \text{s}$ there are 147 flood points with a maximum flood elevation is 1 m.
- In scenario 3 after the embankment is constructed until an elevation 1.5 m and an elevation 2m in K1-RS 18 to K1-RS 36 there is no more flood point.
- In scenario 4 the moving weir and embankment do not occur inundation.
- In order to remove the inundation area due to a 25-year return period flood, it is necessary to build an embankment reaching 2.5 m elevation.

5. References

- [1] Indarto 2016 Hidrologi (Jakarta: Bumi Aksara)
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