EVALUATION OF FLOOD MITIGATION PLAN FOR CIBALIGO RIVER, CIMAHI CITY, WEST JAVA PROVINCE

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ABSTRACT: Cibaligo river is one of the major rivers that flow in Cimahi city. During the rainy season, the river is often causing a flood, especially in Melong sub-districts. Several mitigation alternatives have been prepared by the Government of Cimahi City, such as normalization of the river, and construct retention pond. This research is aimed to simulate the mitigation plan hydraulically to examine the effectiveness of the plan alternative. The simulation was done using HEC-RAS software for existing conditions and the condition with mitigation alternatives. The input for simulation collected from 3 nearest climatological stations, whereas SRTM, SPOT 6, and Cimahi City land used map used as a physical condition data input of catchment. A topographical survey was done to measure both cross and long sections of the river and used as simulation input of existing conditions. Two dimensional HEC-RAS simulation applied for each mitigation alternatives such as river normalization, construction of detention pond, and combination of both river normalization and retention pond. The simulation shows that the construction of 125 000 m3 retention ponds has a minimal effect. The combination of both river normalization and construction of ±315.000 m3 retention pond can prevent the area from inundation only for 2 years rainfall period; therefore, other mitigation plans have to be prepared to prevent the area from the flood.

Keywords: Cibaligo, Flood, HEC-RAS, Normalization, Retention pond.

1. INTRODUCTION

As most of the urban areas in a developing country where population growth and land used changes gone very fast, Cimahi city is prone to flood problem, moreover when there are five river flows through the area. One of the rivers is the Cibaligo river, which is also knonw to some people as the Cilember river. During the rainy season, the river often caused a flood in a residential area, especially in the Melong sub-district. On 10th November 2017, the overflow affects the TOL Road, which crossed by the river [1]. The recent flood happened on 1st November 2019 (Fig.1.) Two primary causal factors of the problem are the land used changes in the upstream area and the reduction of river capacity. The land-use changes in the upstream area were due to the development of the residential and industrial zone, which are difficult to be avoided, and almost impossible to be restored to its natural condition. The river capacity continuously reduced due to the sedimentation resulting from upstream erosion and the narrowed river cross-section caused by illegal occupancy of the riverbank by the resident [2].

To cope with those flood problems, the Government of Cimahi City has a plan to increase river capacity by normalizing the river and build a retention pond to restrain the runoff during high river flow rate. The choice to normalize the river and construct a retention pond taken to resolve the problem as soon as possible. To ensure the effectiveness of the plan, a hydraulic simulation using HEC-RAS, validate the result.

Fig.1. Cibaligo Flood 1st November 2019

2. STUDY AREA

The study area located in Cimahi City, West Java Province. The Cibaligo river flows from north to south across Cimahi city. The catchment area of the river cover 14.3 Km2 [Fig.2.].The point of interest in this research is in the Melong sub-district, where the floods often occur in a residential area and affect the Tol Road [Fig. 3].
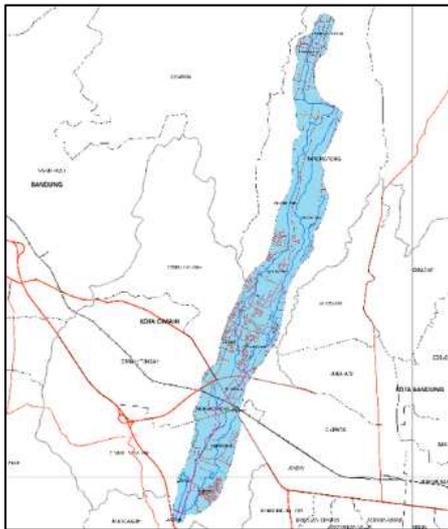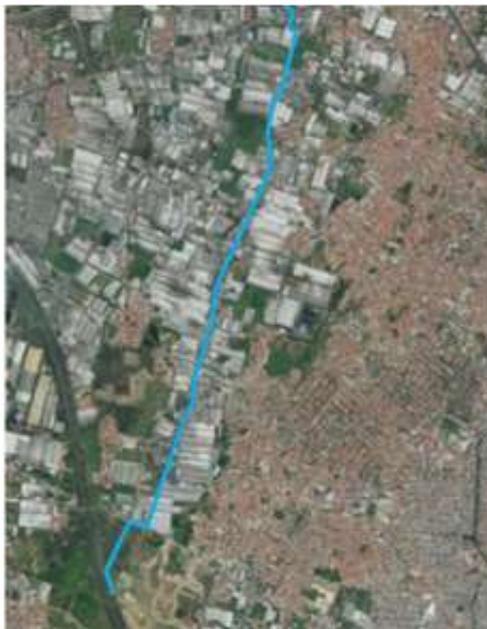

Fig. 2 Cibaligo Catchment Area.

Fig. 3 Study Area

3. DATA AND METHODS

Rainfall data collected from three nearby climatological stations; they are St. Husein, St. Cipeusing, and St. Dago Pakar. The data collected

for a period of the year 2008 to 2017. As seen in Table 1. the average maximum daily rainfall was calculated using the arithmetic mean method. Based on the average rainfall data, frequency distribution was analyzed using the Gumbel Distribution method, Pearson Log Type III Distribution, Normal Log Distribution, and Normal Distribution [3].

The rain frequency distribution was tested using the Chi-Square and Smirnov-Kolmogorov method. The discharge flow was calculated using the Rational Method, applying The frequency distribution, which meets Chi-Square and Smirnov-Kolmogorov criteria.

Table 1 Maximum Daily Rainfall

No	Year	Maximum Daily Rainfall (mm)			Average (mm)
		St. Hussein	St. Cipeusing	St. Dago Pakar	
1	2008	72	48	80	66.667
2	2009	105	37	73	71.667
3	2010	113.4	29	104	82.133
4	2011	57.4	88	43	62.800
5	2012	67.6	50	70	62.533
6	2013	140	30	95	88.333
7	2014	149	73	79	100.333
8	2015	135.5	83	85	101.167
9	2016	102	83	86	90.333
10	2017	62	79	187	109.333
	Total (mm)				835.300
	Average (mm)				83.530
	Maximum (mm)				109.333
	Minimum (mm)				62.533

The discharge of Cobaligo River was calculated based on the effective rainfall. The effective rainfall is apart of the rain that discharged into the river. Effective rain is equal to the total rain that falls on the catchment minus the loss of water (infiltrate and evaporate). The amount of effective rainfall in the catchment depends on rainfall intensity, land topography, tillage system, and plant growth rate [4]. The effective rainfall is then used to calculate the hourly rain distribution using the Alternating Block Method (ABM) method. The Alternating Block Method (ABM) is a simple way to make a hyetograph plan from the IDF curve [5]. The flood discharge is then calculated using the HSS Nakayasu method [6].

The river simulation was carried out using the 2D-HEC-RAS software. The software used in several rivers and hydrological studies in Indonesia [7], [8]. The model requires topographical data, which in this study, the SRTM format [Fig.4] used as a data resource [9]. The drainage cross-section data obtained from the result of a direct field survey while the river normalization data and the dimension of retention pond data collected from the Cimahi City Government [10].

4. RESULT AND DISCUSSIONS

Based on the output of the data suitability test using the Chi-Square and Smirnov-Kolmogorov methods, only Pearson Type III Log Distribution meets the requirements [Table 2.]. The result of rainfall distribution calculations shown in the resume [Table 3].
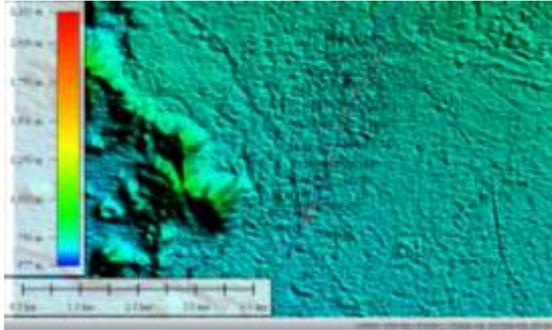

Fig 4. Contour Map in SRTM Format.

Table 2. Sutability Test.

No	Distribution Methods	Criteria	Result	Conclusion
1	Gumbel	Cs = 1.1396	0,089	Not Suitable
		Ck = 5.4002	2,568	Not Suitable
2	Normal	Cs ≈ 0	0,089	Not Suitable
		Ck ≈ 3	2,568	Not Suitable
3	Log Normal	Cs = Cv³ +	-0,105	Not Suitable
		Ck = Cv⁸ + 6Cv⁶ + 15Cv⁴ + 16Cv² + 3	2,473	Not Suitable
4	Log Pearson III	None	-0,105 2,473	Suitable

Table 3. Rainfall Distribution.

No	Return Periods	Probability Distribution			
		Gumbel	Normal	Log Normal	Log Pearson III
1	2	80.136	83.530	82.035	82.339
2	5	101.602	97.879	97.669	97.795
3	10	115.101	105.395	107.013	106.779
4	25	130.841	112.712	116.968	117.112
5	50	144.806	118.549	125.569	124.203
6	100	157.365	123.332	133.086	130.850

Base on rainfall distribution results, the rainfall intensity was calculated using Mononobe methods. The rainfall intensity presented in Figure 5.

The effective rainfall depth was calculated using The Soil Conservation Service (SCS) method. Table 4 shows the effective rainfall depth.

The rainfall hyetograph was generated using Alternating Block Method (ABM). For all return periods of rain, the heytograph shows that the maximum rainfall intensity occurs in the 3rd hour [Table 5].
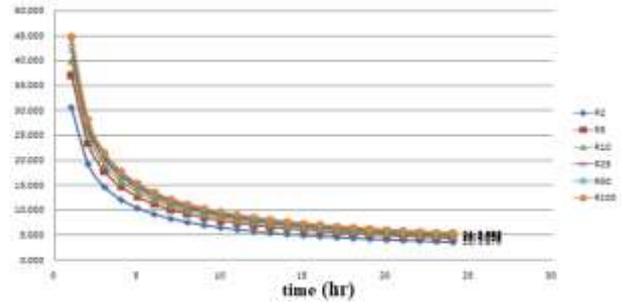

Fig.5. Rainfall Intensity Curve.

Table 4. Effective Rainfall Depth

Return Periods	CN	S [mm]	P [mm]	Pe [mm]
2			82.339	51.775
5			97.795	65.897
10	88.046	34.485	106.779	74.247
25			117.112	83.949
50			124.203	90.656
100			130.850	96.974

Table 5. Rainfall Intensity

t [hour]	R2 [mm]	R5 [mm]	R10 [mm]	R25 [mm]	R50 [mm]	Q100 [mm]
1	3.493	4.445	5.008	5.663	6.115	6.541
2	5.195	6.612	7.450	8.423	9.096	9.730
3	28.493	36.265	40.860	46.199	49.890	53.367
4	7.406	9.426	10.620	12.008	12.967	13.871
5	4.136	5.264	5.931	6.706	7.242	7.746
6	3.053	3.886	4.378	4.950	5.345	5.718
Total	51.775	65.897	74.247	83.949	90.656	96.974

The flood discharge was calculated using the Nakayatsu method, the Nakayasu method. As shown in Figure 6. that the maximum discharge for two years return period was noted 50 m3/sec with a duration of 2 hours, whereas for five years return period, the maximum discharge is 50 m3/sec for 2 hours rain.
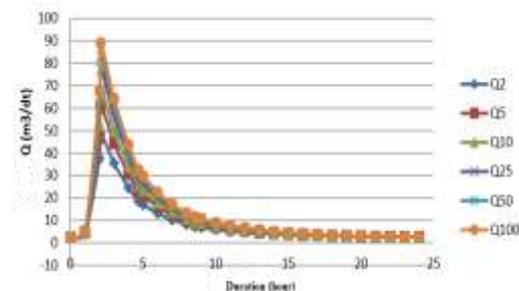

Fig.6 Hydrograph HSS Nakayatsu

The 2D simulation runs for three conditions, i.e., the existing condition, construction retention pond, condition for river normalization, and retention pond. The current condition of the river is varied from the upstream to downstream. Several cross-

sections resulted from field survey was used as an input. The cross-sectional nodes presented in Figure 7. and the river long section presented in Figure 8.

The HEC-RAS simulation shows that even for two years rainfall return period, the overflow occurred in some areas [Fig. 9]. The simulation also shows the inundated area in the downstream area near TOL Road. The total inundation area for two years and five years of rainfall periods are 93 009 m2 and 99.341 m2 consecutively [Fig. 10, Fig. 11]. The water depth in the inundation area was varied from 20 to 50 cm for two years return periods, and 25 to 60 cm for five year return periods.

Fig. 7 Cross sectional Nodes

Fig. 8 Existing River Long Section

Fig. 9 Simulation of Existing Codition (2 Year Return Period)

Fig. 10 Inundated area Existing Condition for 2 Years Return Period.

Fig. 11 Inundated area Existing Condition for 5 Years Return Period.

The second simulation was carried out for condition with 125.000 m3 retention pond, which located beside the Tol Road [Fig.12] and the cross-section presented in Figure 13.

Fig.12 Location of Retention Pond.

Fig. 13 Cross Section of 125 000 m³ Retention Pond

The simulation result shows that the 125 000 m3 retention pond gives a minimal impact on the inundated area [Fig. 14 and Fig 15]. The reduction of the inundation area was insignificant, whereas the water depth reduces by 2 to 8 cm.

Fig. 14 Simulation with 125 000 m3 Retention Pond for 2 year Return Period.
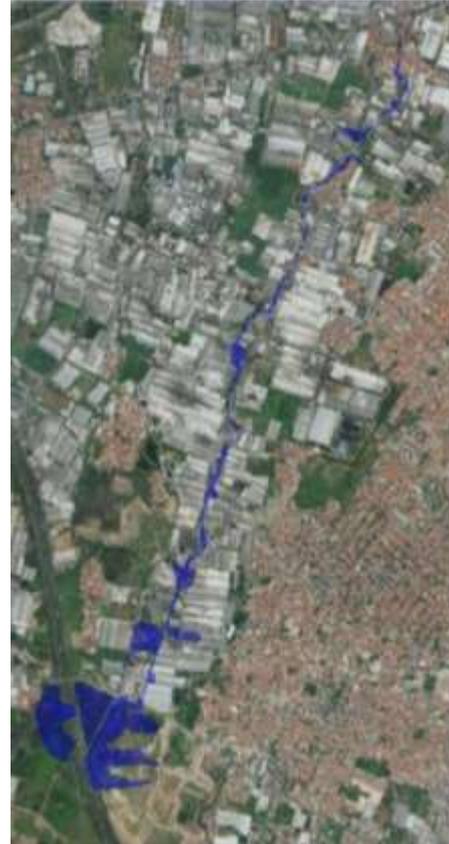
Fig. 15 Simulation with 125 000 m3 Retention Pond for 5 year Return Period

The third simulation condition was normalization of the river and construction of ±315.000 m3 retention pond. The third simulation result shows that for a two year return period, the inundation area was significantly reduced [Fig 16].

No inundated area shows in two years return periods simulation, but for five years return period, an area of 27 000 m2 inundated with a water depth varied from 20 to 40 cm [Fig. 17].

5. CONCLUSION

Based on the simulation result using two-dimensional HEC-RAS software for the existing condition of the river, the flood occurs every year. Constructing a 120 000 m3 retention pond gives a minimal impact to both inundation area and water depth. River normalization and construction of 315 000 m3 only sufficient to prevent the Melong sub-district from two year return period flood, whereas for five years return period inundation area still occurs. To increase the effectiveness of flood mitigation, water conservation, such as the construction of infiltration well in the upstream

region, must be promoted.

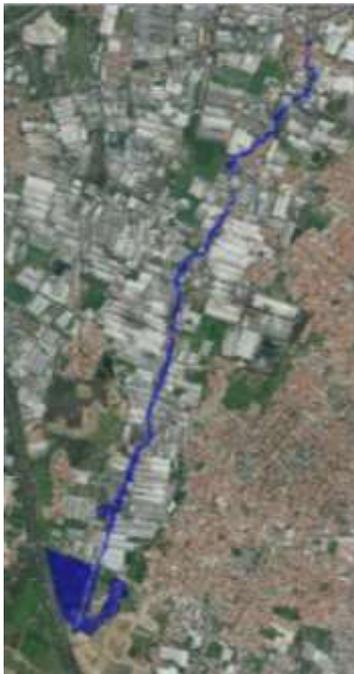Fig. 16 Simulation with 315.000 m3 Retention Pond for 2 year Return Period.

Fig. 17 Simulation with 315.000 m3 Retention Pond for 5 year Return Period.

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