



## Flood Control Study for Cikeruh River Basin in Bandung City

Muhammad Marshal Syuhada<sup>1</sup>, Regina Dio Oriandra<sup>1\*</sup>, Rifaldi Aji Sarifudin<sup>1</sup>,  
Ardino Abdul Wahab<sup>1</sup>, Mohammad Farid<sup>2</sup> & Joko Nugroho<sup>2</sup>

<sup>1</sup>Master Degree of Water Resources Management, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Jalan Ganesa 10, Bandung 40132, Indonesia

<sup>2</sup>Water Resources Engineering Research Group, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Jalan Ganesa 10, Bandung 40132, Indonesia

\*Email: r.d.oriandra@gmail.com

**Abstract.** The Cikeruh River is located in the regency of Bandung and is part of Citarum River tributary. Flooding's one of the problems that occur in Cikeruh River and it became an important issue in Bandung City as the river flow through economic area of the city. The flood that occurred on the Cikeruh River was caused by a high river with the discharge of 272.53 m<sup>3</sup>/s. But not only because of the high discharge in the river, but also influenced by backwater from the Upper Citarum River which confluence with Cikeruh River. From the flood modeling on the Cikeruh River, it was found that the height of the flood overflow could reach three meters with an almost even distribution of inundation in all locations. As an effort to provide solutions, alternative solutions are provided to overcome this problem, namely by normalizing rivers, river embankments, and retention ponds. Alternatives to river normalization and the construction of retention ponds are deemed unable to completely deal with flooding, so the most effective solution in dealing with this flood is the construction of embankments.

**Keywords:** *Cikeruh River; flood; backwater; 1D modeling; 2D modeling.*

### 1 Introduction

Floods that occur in Greater Bandung are often caused by the capacity of channels or rivers that are too small to accommodate rain runoff [1]. This is coupled with the factor of the Greater Bandung Area or the Bandung Metropolitan Area [2] which is inside the basin, causing the flow that enters the Bandung Basin to originate from the highlands around Bandung. The existence of floods will certainly disrupt activities in Greater Bandung. Bandung is the capital of West Java Province which is the center of provincial government with the largest population in Indonesia.

To support the expansion of West Java's central government and economic activities, the city of Bandung will not be able to stand alone without the support of the surrounding area. This is because even though government and economic activities are centered in the city of Bandung, some people who work in the city

of Bandung choose to live in satellite areas of the city of Bandung. Apart from that, the access points for various commodity goods to the city of Bandung come from these areas. The occurrence of flooding in one part of the area can cause huge losses for the city of Bandung as the center of government.

Floods that occur in this area are caused by the overflow of several rivers. One of the rivers that often cause flooding in the area is the Cikeruh River[3]. This river has an upstream originating from Mount Manglayang and its channel passes through the city of Bandung, so that the discharge is large enough which causes the river's capacity to decrease and floods occur almost every year [12] – [14].



**Figure 1** Study Location of Cikeruh River and Upper Citarum River

The Cikeruh River is located in the regency of Bandung and is part of Citarum River tributary which stretches for 36.63 km with a catchment area of 220.86 km<sup>2</sup>. One of the areas in Bandung that often experiences flooding is in Tegalluar, Bojongsoang District, Bandung Regency which is an area that is passed by the river. This study was conducted to analyze the flood that occurred in Cikeruh River and the role of Upper Citarum River in causing the increase of water level in downstream of Cikeruh River. As stated above that the area around Cikeruh River's an important economic area for Bandung City and Regions around it, it's fundamentally important to do a study on the flood control of Cikeruh River and to decide the most efficient flood control.

## **2 Research methodology**

The research methodology for this study started by collecting the data for hydrology and hydraulics analysis. The data needed are daily rainfall of minimum of 10 years (2011 – 2020), for this study we use data from five rain stations, namely Ujung Berung Rain Station, Jatiroke Rain Station, Cicalengka Rain

Station, Ciparay Rain Station, and Cipaku Paseh Rain Station. Other data we use are DEM (Digital Elevation Model) from DEMNAS, land use from KLHK, and for modeling we use cross-sections of Cikeruh River and Citarum River.

Land cover is the physical surface of a land Pauleit et al. in [4]. This land cover data is then used to calculate CN. CN is a hydrological model parameter developed by Soil Conservation Service which describes the physical condition of the watershed which has a value of 1-100, Abu-hashim et al in [5].

To determine the empty rainfall using the Reciprocal Method (Bambang, 2009):

$$px = \frac{\sum_{i=1}^n \frac{P_i}{L_i^2}}{\sum_{i=1}^n \frac{1}{L_i^2}} \quad (1)$$

Where  $px$  is the missing rain data at station  $x$ ,  $pi$  is the surrounding rain data for the same period, and  $Li$  is the distance between stations. Mathematically, regional rainfall calculations using the Thiessen Polygon method can be formulated as follows.

$$R = \frac{A_1 \times R_1 + A_2 \times R_2 + \dots + A_n \times R_n}{A_1 + A_2 + \dots + A_n} \quad (2)$$

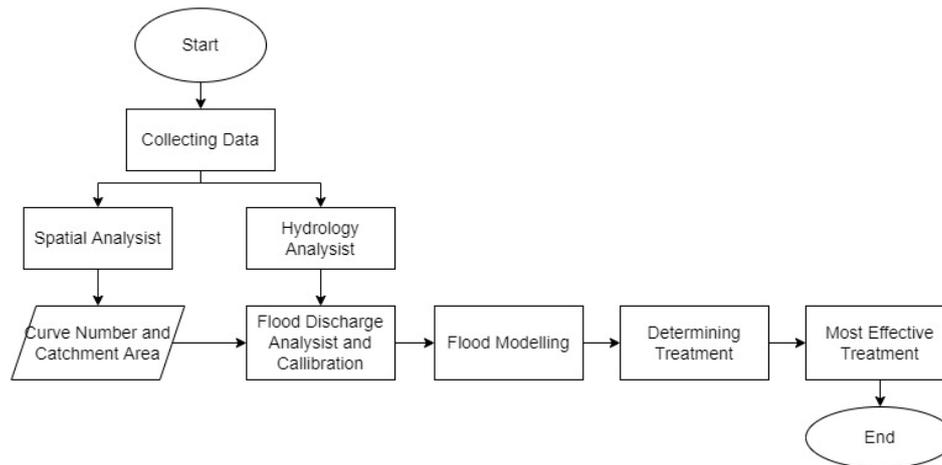
Where:  $R$  is average rainfall;  $R_1, R_2, R_n$  are rainfall at each station; and  $A_1, A_2, A_n$  are the area of influence of each station. Data testing is carried out for each rain station, while the tests carried out for each rain include; Consistency Test (RAMP), Trend Test (Spearman), Stationarity Test (Fisher), and Outlier Test.

Frequency analysis was carried out using the help of Hydrogonomon 4 software to obtain the return period of planned rainfall. For this study, 5 frequency analysis methods were compared, namely Normal, Log Normal, Gumbel, Log Perason III, and GEV using software Hydrogonomon 4. As Reported by Lawlor (2004) frequency analysis is carried out at each rain station first, after obtaining a frequency analysis for each rain station, then the calculation for regional rainfall is carried out using the Thiessen method[9].

The flood discharge analysis in this study was calculated using four Synthetic Unit Hydrograph (HSS) methods, namely the SCS, Nakayasu, Snyder, and ITB methods (with variations of ITB-1a, ITB-2a, ITB-2a, ITB-2b). Calibration is carried out by changing the parameters of each method so that the results are close to the observed discharge. The parameters that are changed by each method are;

SCS changed the  $C_t$  coefficient, Nakayasu changed alpha, Snyder changed the  $C_p$  coefficient, ITB-1a to ITB-2a changed the  $C_t$  and  $C_p$  coefficients [6] – [7].

Determination of the flood discharge method is carried out to determine which HSS method is best for use in the subsequent flood analysis. To determine the method used in this study using the bankfull capacity method from the Cikeruh River and Upper Citarum River.

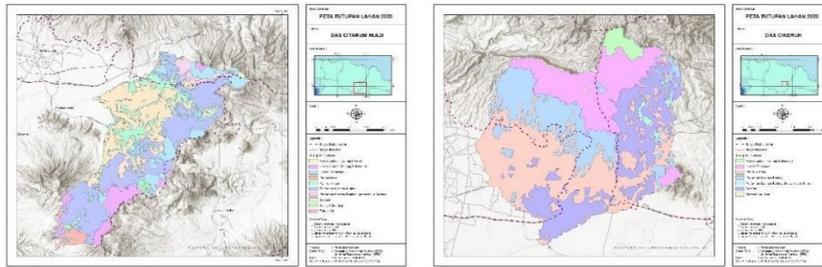


**Figure 2** Methodology flowchart

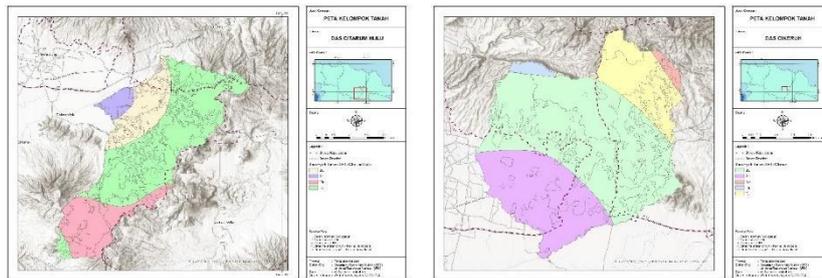
### 3 Results and Discussion

#### 3.1 Hydrological Analysis

The watersheds of the study locations in the Cikeruh River and Upper Citarum River were obtained from the results of watershed delineation using ArgGIS 10.5 software with topographic data from DEMNAS, with an area of 220.86 km<sup>2</sup> in the Cikeruh Watershed, while the area of the Upper Citarum watershed is 514.69 km<sup>2</sup>. From the results of the delineation it was also obtained that the longest river flow in the Cikeruh DAS reached 36.63 Km with a river slope of 0.051, for the Upper Citarum DAS itself the longest river flow was detected to be 41.75 Km with a slope of 0.007.



**Figure 3** Land Cover Map of the Upper Citarum and Cikeruh Watersheds



**Figure 4** Map of Upper Citarum and Cikeruh Watershed Land Groups

In this study the watershed land cover used is the land cover from the Ministry of Environment and Forestry in 2020, while the soil types in the watershed with the HSG class are obtained from soil classification data Food and Agriculture Organization (FAO). From the analysis results Curve Number it was found that for the Upper Citarum Watershed it had a CN of 77.18 while for the Cikeruh Watershed it had a CN of 78.96.

Rainfall data used in this study uses data from five rain stations, namely Ujung Berung Rain Station, Jatiroke Rain Station, Cicalengka Rain Station, Ciparay Rain Station, and Cipaku Paseh Rain Station. The Cikeruh Watershed is influenced by three rainfall stations, namely Ujung Berung Rain Station (57.38%), Jatiroke Rain Station (40.82%), and Ciparay Rain Station (1.80%). The Upper Citarum Watershed itself is affected by four rainfall stations, namely Jatiroke Rain Station (6.82%), Cicalengka Rain Station (30.91%), Cipaku Paseh Rain Station (43.56%), and Ciparay Rain Station (18.72%). In accordance with SNI 1724: 2015 the rainfall data used is for 10 years from 2011 – 2020.

From the results of the analysis it was decided that the method to be used for the analysis frequency is Generalize Extreme Value (GEV) method. So the planned rainfall is obtained for each station with a return period of 2 years - 25 years. So by using the Thiessen method, the regional rainfall is obtained.

**Table 1** Planned Rainfall and Regional Rainfall

Rain Station	Return Period (mm)			
	2 years	5 years	10 years	25 years
Ujung Berung	81.95	96.34	104.61	113.82
Jatiroke	105.03	143.26	165.39	190.18
Cicalengka	91.22	112.36	123.33	134.5
Cipaku Paseh	98.53	127.1	147.98	176.81
Ciparay	84.6	105.63	120.93	141.98
Cikeruh watershed	91.42	115.66	129.71	145.50
Upper Citarum Watershed	94.11	119.63	136.49	158.13

The observation discharge used for this calibration is the debit recorded at the Cikeruh – Cikuda Water Check Post (PDA) located on the Cikeruh River. The largest debit recorded on this PDA was on December 15, 2017 with discharge of 29.16 m<sup>3</sup>/s. The calibration result parameters are then used to carry out a flood discharge analysis using the HSS method for the Cikeruh River and the Upper Citarum River.

**Table 2** Maximum Flood Discharge for All Cikeruh Watershed Methods

T	Discharge Analysisist Methods (m <sup>3</sup> /s)						
	Nakayasu	SCS	Snyder	ITB-1a	ITB-2a	ITB-1b	ITB-2b
2	127.45	135.38	138.49	136.76	130.27	136.20	126.80
5	190.66	202.53	196.94	204.58	194.87	203.74	189.69
10	242.87	257.99	232.12	260.61	248.24	259.54	241.64
25	288.57	306.54	272.53	309.65	294.95	308.37	287.11

**Table 3** Maximum Flood Discharge for All Upper Citarum Watershed Methods

T	Discharge Analysisist Methods (m <sup>3</sup> /s)						
	Nakayasu	SCS	Snyder	ITB-1a	ITB-2a	ITB-1b	ITB-2b
2	286.67	308.62	279.63	311.55	291.72	310.54	287.04
5	430.32	463.28	408.79	467.67	437.90	466.16	430.88
10	530.43	571.06	498.28	576.49	539.79	574.62	531.13
25	663.27	714.07	616.71	720.85	674.96	718.51	664.13

To determine which HSS will be used, it is necessary to analyze the determination of HSS using the bankfull capacity method from the river under review with a return period discharge of 2 (two) years. From the results of the bankfull analysis

this found that Snyder's HSS was the closest to bankfull capacity then the hydrograph used in flood modeling is the HSS Snyder. The results of Snyder's hydrographic analysis on the Cikeruh and Citarum watersheds can be seen in the image below. Then for modeling the discharge used is the flood discharge with a return period of 25 years according to SNI 6278: 2015.

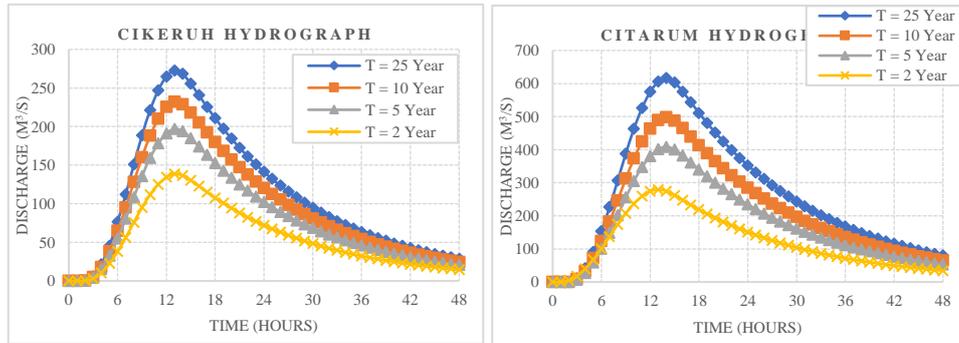
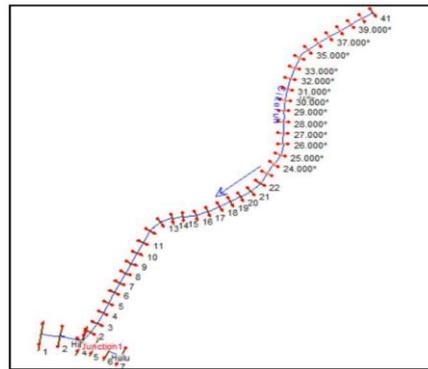


Figure 5 Flood hydrograph

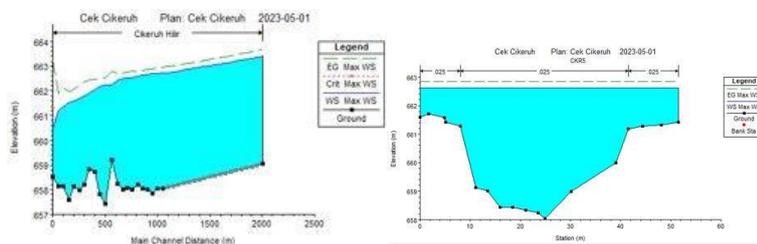
### 3.2 Hydraulics Analysis (Flood Modeling)

The Cikeruh River meets the Upper Citarum River downstream, due to the influence of the Upper Citarum discharge which causes it to occur *backwater* in Cikeruh downstream. Therefore a hydraulic analysis was carried out by including the geometry of the Cikeruh River which intersects with the upstream Citarum River. Therefore, 1D flood modeling will be carried out *running* twice, namely the first time when the Cikeruh River was not influenced by *backwater* Upper and second Citarum rivers When influenced by the presence *backwater* from the Upper Citarum River.

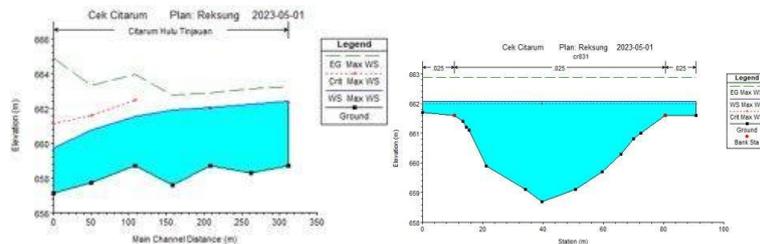
This modeling is done by using *software* HEC-RAS, modeling is run in 1D and 2D, where in 1D modeling the results obtained are flood points every *cross-section* while for 2D modeling it will produce a map of the distribution of floods in areas affected by the Cikeruh River flood. The flood modeling carried out is in the flood prone area of the Cikeruh River with a length of 2 Km which is divided into 41 *cross-section* and for simulation *backwater* from the Upper Citarum River is modeled as long as 0.32 Km which is divided into 7 *cross-section*.



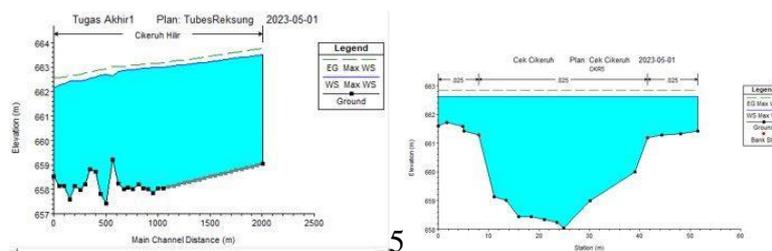
**Figure 6** Combined Cross-Section of the Cikeruh River & Citarum-Hulu River



**Figure 7** Results of the 1D Modeling of the Cikeruh River without Backwater



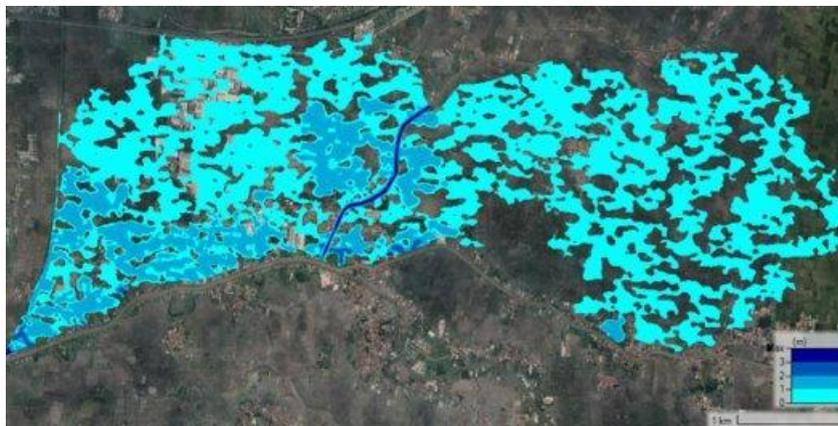
**Figure 8** 1D Modeling Results of the Upper Citarum River with Sections



**Figure 9** Cikeruh Flood 1D Modeling with Backwater with Sections

From the results of the flood modeling above, it can be seen the difference in the Cikeruh River when a flood occurs without any influence input *backwater* from the Upper Citarum River and when there is input *backwater*. Observed at the cross-sectional points of RS 18 on the Cikeruh River flood elevation when not available *backwater* is +662.62 m (Fig. 5) and elevation When there is *backwater* increased to +662.94 m (Fig. 7). This means that the flooding in the Cikeruh River was affected by *backwater* from the Upper Citarum River.

From the results of the 1D modeling above, it was found that 39 points on the right support and 40 points on the left support were flooded, the average flood elevation on the left support was 0.86 m while on the right support was 0.99 m. Then in the 2D modeling in Figure 8 you can see the areas of flood inundation that spread throughout the study locations in Figure 19. The results of the 2D modeling found that the highest flood inundation reached 3 m.



**Figure 10** 2D Cikeruh Flood Modeling

### 3.3 Solutions

From the results of the hydrological and hydraulic analysis carried out above, it can be seen that using a flood discharge with a return period of 25 years, the floods that occur are predicted to inundate almost all of the study locations. So it is necessary to do flood management in the area. In this study, researchers provide alternative flood management recommendations, namely by building retention ponds on the Cikeruh River, Normalizing the Cikeruh River, and also building river embankments along the flood points of the Cikeruh River. Of the alternatives offered, the researcher will provide the most effective solution in dealing with flooding in the Cikeruh River

### 3.3.1 Retention Pool

The retention pond is planned to be in the upper reaches of the Cikeruh River, namely in the study area where flooding occurs which can be seen in Figure 20. The planned area of the retention pond is 19.6 Ha with an area of catchment area for the Retention Pond of 137.07 km<sup>2</sup>. This pond is designed to accommodate a flood water volume of 951.149,92 m<sup>3</sup>. In analyzing the effectiveness of a reservoir needs to be done Reservoir Routing or tracing the reservoir, so that it can be seen how much the decrease in discharge has occurred as a result of this reservoir. This study uses the HEC-HMS software to perform reservoir routing, by using initial condition inflow=outflow. The type of spillway used in the analysis process is a broad-crested spillway with a length of 10 m.

In Figure 9 below, the yield hydrograph is obtained routing in the reservoir, it can be seen that the decrease in discharge when it occurs outflow only small that is equal to 2.5 m<sup>3</sup>/s. This can happen because of the large flood discharge that occurs, with a small reservoir it will not be able to significantly reduce the flood discharge.

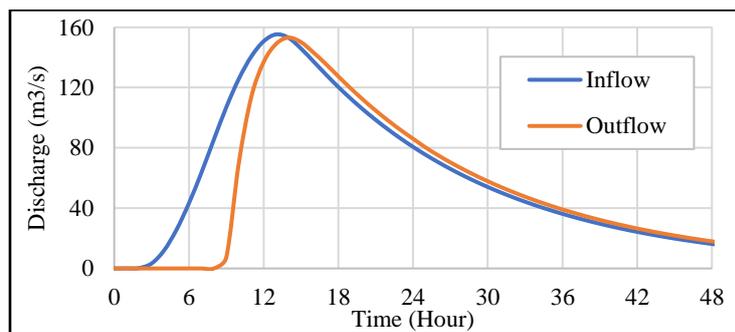


Figure 11 Reservoir Routing Retention Pond Results

### 3.3.2 River Normalization

Normalization is designed to include widening and dredging the river bed by sloping the left and right river banks, but still following the shape of the cross section and slope of the existing river. Obtained 2 normalization templates. RS. 1 - 18: 3.5 m deep, 20 m wide bottom, and 2.5 dip slope. hospital 19 - 41: 3.5 m deep, 20 m wide bottom, and 3 ditch slope.

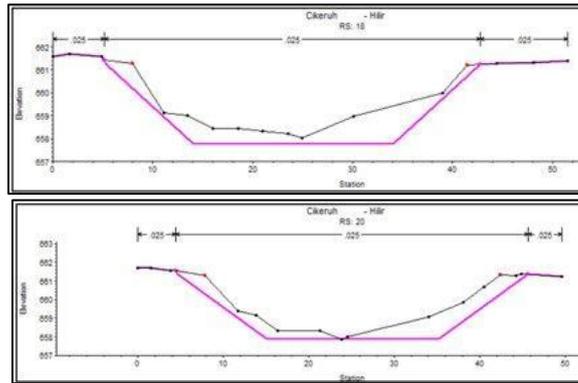


Figure 12 Two River Normalization Templates at RS 18 and RS 20.

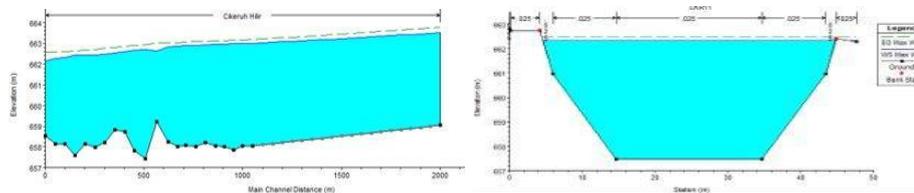
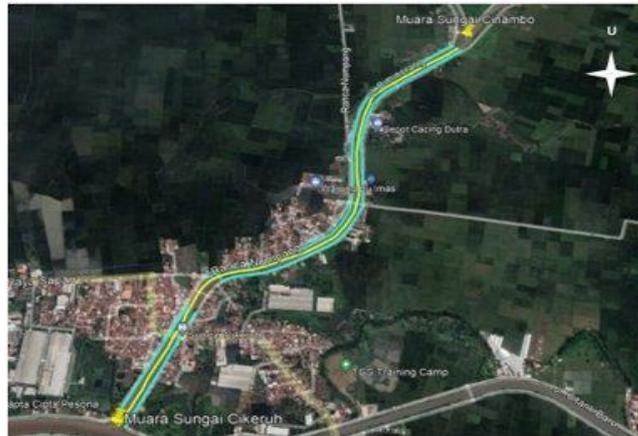


Figure 13 Modeling Results After Normalization

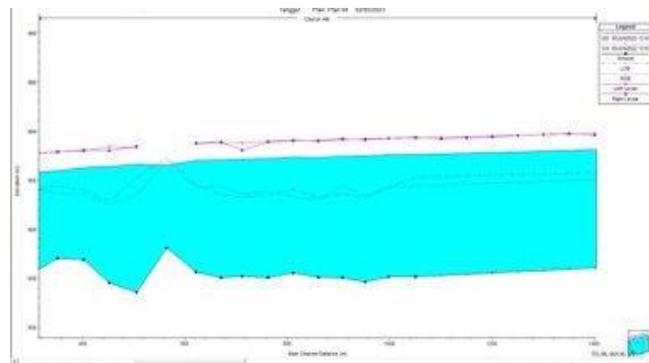
From the modeling results after normalization on the Cikeruh River, the flood elevation in the river has indeed decreased in flood elevation where the average flood elevation on the left flank is 0.37 m and the right flank is 0.52 m, however flooding still occurs in the 40 left flank points and 38 right flank. This treatment alternative is better for flood control than retention ponds, but it is still not fully effective in dealing with flooding in the study area.

### 3.3.3 River Embankment

The height of the embankment is obtained from the height of the flood plus the height of the guard. According to module 8 Fundamentals of River Channel and Construction Planning, River Technical Planning Training (2017) for Q designs between 200 – 500 m<sup>3</sup>/s, guard height of 0.8 m. The height of the ladder is designed to adjust the height of the flood at each point *cross*-section with a maximum embankment height of 2.5 m. And the smallest embankment height is 0.90 m, and the average embankment height is 1.7 m



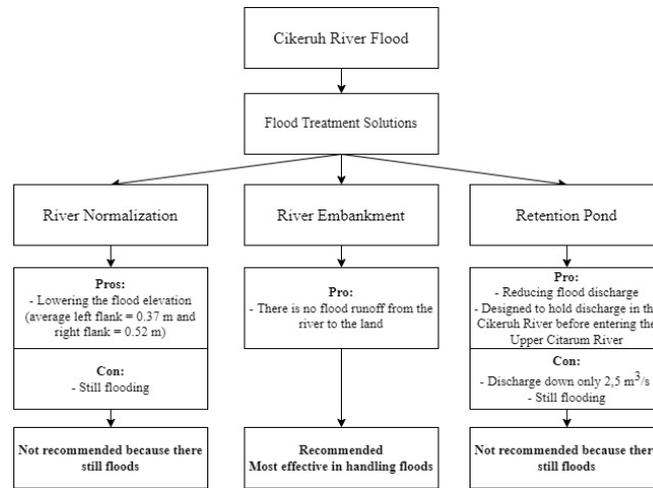
**Figure 14** Embankment Planning Trace



**Figure 15** Modeling Results after the Embankment

After the addition of dikes along the river, then running the 1D modeling again with the results in Figure 13 and the flood conditions after handling with embankments in Table 16 shows that with the construction of these embankments at points that previously overflowed during floods with a return period of 25 years, no runoff occurs anymore.

### 3.3.4 Treatment Selections



**Figure 16** Selection of Flood Treatment

After analyzing the alternative treatments above, it is necessary to select the most effective recommendations for handling floods in the Cikeruh River. Researchers have created flowchart for pros and cons or the pros and cons of each alternative in Figure 16.

## 4 Conclusion

The study compares the flood discharge in Cikeruh and upstream Citarum watersheds as cause of flooding, from the study the maximum discharge of Cikeruh River with 25 years return period is 272.53 m<sup>3</sup>/s and maximum discharge of Upper Citarum River is 616.71 m<sup>3</sup>/s. The floods in downstream Cikeruh were caused by high discharge and backwater from Upper Citarum, with flood heights ranging from 0 to 3 meters. The study considered three alternatives: retention pond, river normalization, and river embankment. The retention pond was not recommended, normalization did not completely prevent flooding, while the construction of a river embankment was found to be the most efficient solution.

In this study, the authors in the choice of treatment in the Cikeruh River only considered from the results of the analysis which of the three alternatives could effectively deal with flooding. So one of the suggestions given by the author is to do an economic analysis with attention of cost benefit ratio. Apart from that, treatment can be done non-physically, such as establishing a river border line.

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### **Acknowledgement**

This research was funded by the Institute for Research and Community Services of Institut Teknologi Bandung (LPPM ITB) through ITB Excellent Research 2023.