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Hydraulic Analysis of Flood Characteristics in Way Sekampung Watershed Using HEC-RAS with Various Return Periods

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Abstract: A river is a flow of water that flows in one direction from a high area to a low area by gravity or from upstream to downstream. Although there have been many studies using HEC-RAS software, its application in Way Sekampung watershed still needs further evaluation. The purpose of this study is to analyze the high elevation of overflow that occurs at the reviewed location and analyze the comparison between permanent and non-permanent flows of flood tide elevation in Way Sekampung watershed. The flood discharge values for the 10, 25, 50, and 100-year re-periods were 506.01 m^3/s, 576.82 m^3/s, 627.01 m^3/s, and 675.20 m3/s, respectively. Meanwhile, in the hydraulic analysis, the high elevation of the flood water level of the unsteady flow was obtained from the results of the hydraulic analysis using the HEC-RAS V6.5 application at 10, 25, 50 and 100 years repeatedly, namely 177.57 meters, 179.63 meters, 183.86 meters, and 192.73 meters in the upstream part. In addition, in the downstream part, 95.49 meters, 97.53 meters, 101.28 meters, 106.52 meters were obtained for each re-period. and experienced overflow heights of 5.57 m, 6.54 m, 6.99 m, and 16.03 m during the 10-year, 25-year, 50-year, and 100-year periods. From the results of the research that has been carried out, it is concluded that in the upstream and downstream areas there will be no flooding because the flood water level is still lower than the high elevation of the left and right river banks.

Keywords: flood discharge; HEC-RAS hydraulic analysis; flood overflow; way of the village

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1. Introduction

A river is a flow of water that flows in one direction from a high area to a low area by gravity or from upstream to downstream. Water flows such as rivers or seas that provide ease of living for the surrounding community can also pose an annual flood risk that must be faced by the community [1]. The increase in population indirectly causes various problems in watersheds, especially along riverbanks, due to high human activities that have an impact on environmental damage and an increased risk of flooding and erosion [2]

Although there have been many studies using HEC-RAS software, its application in Way Sekampung watershed still needs further evaluation. An in-depth understanding of the accuracy of hydraulic modeling, especially in the watershed-specific geographical and hydrological contexts, is a must. Additionally, it is important to analyze the impact of changing river flow conditions on the environment and surrounding communities in order to identify appropriate mitigation and management efforts.

Flooding is one of the negative impacts of various destructive human activities around rivers, such as tree felling, garbage disposal, and uncontrolled development, all of which contribute to changes in water flow and increased flood risk [3].

One of the preventive measures to reduce the impact of floods is to provide information related to flood zoning and conduct flood disaster risk analysis. This is done through a map of the potential distribution of floods resulting from modeling visualizations. With this approach, communities can understand flood-prone areas and take appropriate precautions based on the data generated from the model [4].

Watershed management includes vegetation maintenance activities in the upstream part of the watershed, revegetation to control or reduce the speed of surface flow and soil erosion, maintenance of natural vegetation, or planting of appropriate waterproof vegetation, along drainage embankments, channels and other areas to control excessive flow or soil erosion, special regulation of flood control buildings along the bottom of streams that are prone to erosion [5]. Therefore, it is necessary to conduct research on water level analysis in Way Sekampung Watershed due to rain with high intensity when it occurs at the same time with the aim of obtaining water level values and can be used as material for further research. It is hoped that the results of this research can be the basis for sustainable water resource management, flood risk mitigation planning, and sustainable development policies in Way Sekampung watershed.

2. Research Methodology

2.1.Location

Geographic Information System (GIS) applications can be applied for various purposes, as long as the processed data has a geographical reference. This means that the data must include information about phenomena or objects that can be displayed in physical form and have a clear location in geographic space. In addition, to obtain accurate watershed boundaries and areas, existing DEMs need to be improved in quality according to the characteristics of each watershed area [6]. The data must include coordinates or other information that indicates a specific position on the earth's surface so that it can be spatially mapped and analyzed. The research location is in Way Sekampung watershed, Lampung as shown in **Figure 1**.

Figure 1. Research location.

2.2. Data Collection

This research is strengthened by secondary data obtained from two sources. First, the Mesuji Sekampung River Area Center (BBWS MS) provides hydrological data in the form of daily rainfall for the

2003-2022 period. Second, spatial data in the form of the National Digital Elevation Model (DEMNAS) SRTM 30m was downloaded from the Indonesian geospatial website for spatial analysis.

2.3. Data processing

The data analysis in this study focuses on hydraulic analysis that requires primary data. This primary data includes information about river conditions and rainfall. Data processing began with hydrological analysis to determine planned rainfall in Way Sekampung watershed. Furthermore, flood discharge data was processed and simulated using HEC-RAS 6.5 software. This simulation produces a map of flood overflow height along the river.

2.4. Data analysis

The data analysis in this study is divided into three main stages:

1. Hydrological Analysis

This hydrological analysis begins with the calculation of the area of influence from the rain station in Way Sekampung Watershed. In this study, the rain station at the research location reviewed is the R.067 Rain Station which has an area of 432.81 km^2.

2. Flood Discharge Analysis

Flow discharge is a function of the velocity and area of the wet cross-section, which can be expressed by volume per unit time or the amount of liquid flowing through the flow latitude per unit time [7]. The calculation of the design discharge was carried out using the Nakayasu Synthetic Unit Hydrograph method. The planned flood hydrograph is intended to obtain flood discharge with a re-period to obtain the flood water level at the research site. The parameters needed in the calculation of the Synthetic Unit Hydrograph (HSS) are watershed area, river slope, river length, number of river confluences, network density and river order [8].

3. Hydraulic Analysis

In this research, hydraulic analysis was carried out using one-dimensional permanent flow (energy equation) and impermanent flow (Saint Venant equation) on HEC-RAS software version 6.5. Flood discharge data from Nakayasu HSS and tidal data are fed into HEC-RAS to simulate water flow in rivers and calculate flood water level [9,10]. One of the key inputs for hydraulic analysis is the planned flood discharge, which was previously determined through hydrological calculations. This discharge was estimated using the Nakayasu Synthetic Unit Hydrograph (HSS) method, a reliable technique for simulating flood hydrographs based on rainfall-runoff characteristics of the watershed. The resulting discharge value is essential for accurately modeling water flow and flood behavior. The results of the HEC-RAS program include graphs or tables, with graphical presentations showing the cross-section of the drainage channel, the water level profile along the channel, flow variables such as velocity, as well as perspective images of the channel [11]. In this study, HSS Nakayasu is one of the data needed in hydraulic modeling analysis using HEC-RAS. HEC-RAS is an application program for modeling flows in rivers, the River Analysis System (RAS), created by the Hydrologic Engineering Center (HEC) which is a division within the Institute of Water Resources (IWR), under the U.S. Army Corps of Engineers (USACE) [12].

3. Results and Discussion

3.1. Watershed Delineation

The determination of watershed boundaries in this study was carried out by determining the outlet points at the Way Sekampung Dam and the BatuTegi Dam as existing references. Gravity (naturally) water flows from high areas to low areas, from mountains, mountains to valleys, then to lower areas, to coastal areas and finally to the sea [13]. The length of the main river for the Way Sekampung watershed in this study is 19.98 km. The results of the delineation show that the area of the watershed is 432.81 km^2 with an average river slope of 0.5%.

3.2. Hydrological Analysis

Daily rainfall data for the Way Sekampung watershed area was collected during the period 2003-2022. This data was obtained from the Mesuji Sekampung River Area Center (BBWS). In this study, the rain station at the research location reviewed is the R.067 Rain Station which has an area of 432.81 km^2.

The determination of rainfall distribution can be done through the analysis of maximum rainfall data obtained by frequency analysis method. In this case, the Log Pearson Type III distribution was chosen as the right parameter to describe the rainfall distribution pattern. The results of the viewing frequency analysis presented in **Table 1.**

Table 1. Log Pearson Method Type III Frequency Analysis

No	Log (X)	Log ($X-\bar{X}$)	Log $(X-\bar{X})^2$	Log $(X-\bar{X})^3$	Log $(X-\bar{X})^4$
1	1.9332	0.2803	0.0785	0.0220	0.0062
2	1.8098	0.1569	0.0246	0.0039	0.0006
3	1.7834	0.1305	0.0170	0.0022	0.0003
4	1.7704	0.1175	0.0138	0.0016	0.0002
5	1.7441	0.0911	0.0083	0.0008	0.0001
6	1.7124	0.0595	0.0035	0.0002	0.0000
7	1.6902	0.0372	0.0014	0.0001	0.0000
8	1.6775	0.0245	0.0006	0.0000	0.0000
9	1.6687	0.0157	0.0002	0.0000	0.0000
10	1.6572	0.0042	0.0000	0.0000	0.0000
11	1.6351	-0.0178	0.0003	0.0000	0.0000
12	1.6300	-0.0230	0.0005	0.0000	0.0000
13	1.6254	-0.0276	0.0008	0.0000	0.0000
14	1.6182	-0.0347	0.0012	0.0000	0.0000
15	1.6137	-0.0393	0.0015	-0.0001	0.0000
16	1.6066	-0.0464	0.0022	-0.0001	0.0000
17	1.5760	-0.0770	0.0059	-0.0005	0.0000
18	1.5097	-0.1433	0.0205	-0.0029	0.0004
19	1.4130	-0.2399	0.0576	-0.0138	0.0033
20	1.3847	-0.2683	0.0720	-0.0193	0.0052
∑	29.5774	0.0000	0.9739	0.1449	0.1347

After frequency analysis using the Pearson Type III Log Method, the planned rainfall calculation for 10, 25, 50, and 100 years is carried out, according to the planned recurrence period. The rainfall analysis of the design in this study uses Log Pearson Type III Distribution.

3.3. Flood Discharge Analysis

Plan flood discharge refers to the maximum discharge that is expected to occur in a river or channel, which is determined based on a specific re-period. This recurrence period is the average frequency or time interval at which a flood discharge of that magnitude is expected to repeat itself within a certain period of time [14].

The flood discharge analysis using the Nakayasu Synthetic Unit Hydrograph (HSS) method conducted in this study has limited data. In analyzing this method, data such as watershed area, average slope of the river, flow coefficient, etc. are needed. Here is the data used in the calculation:

Length of the main river (L) = 19.98 km
Watershed area (A) = 432.81 km^2
River slope = 0.005
Drainage coefficient (C) = 0.7

From the data used, the unit hydrograph for each re-periodic period can be seen in **Figure 2**.

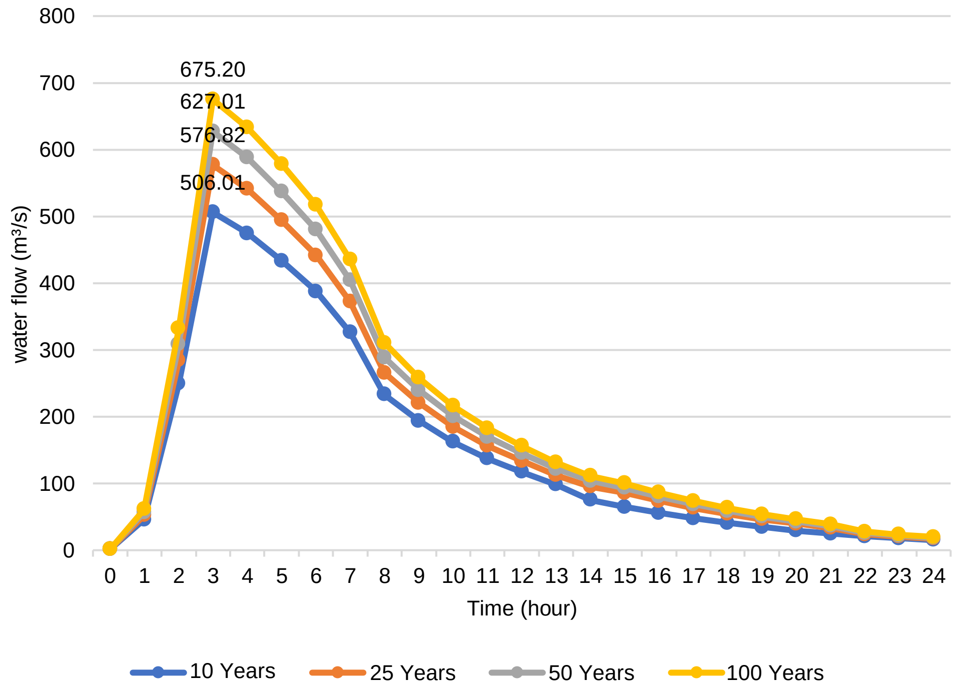

Figure 2. Nakayasu synthetic unit hydrograph.

The flood discharge values for the 10, 25, 50, and 100-year re-periods were 506.01 m^3/s, 576.82 m^3/s, 627.01 m^3/s, and 675.20 m^3/s, respectively.

3.4. Hydraulic Analysis

In analyzing the hydraulic boundary of a natural channel or river, calculations are generally carried out based on three basic equations, namely the continuity equation, the energy equation, and the momentum balance equation [15]. On this research, hydraulic analysis was carried out using a one-dimensional inconsistent flow on HEC-RAS software version 6.5.

The results of hydraulic analysis at the location that reviewed Way Sekampung for a re-scaling period of 10, 25, 50, and 100 years analyzed the height of the water level elevation and the height of the overflow that occurred. **Figures 3 and 4** show the visualization of the transverse cut from the results of the unsteady flow modeling in each re-period. The upstream boundary condition in this study is at the very end location, which is at the cut-off point of 20000, while the downstream boundary condition in Way Sekampung watershed in this study is at the cut-off point of 2500.

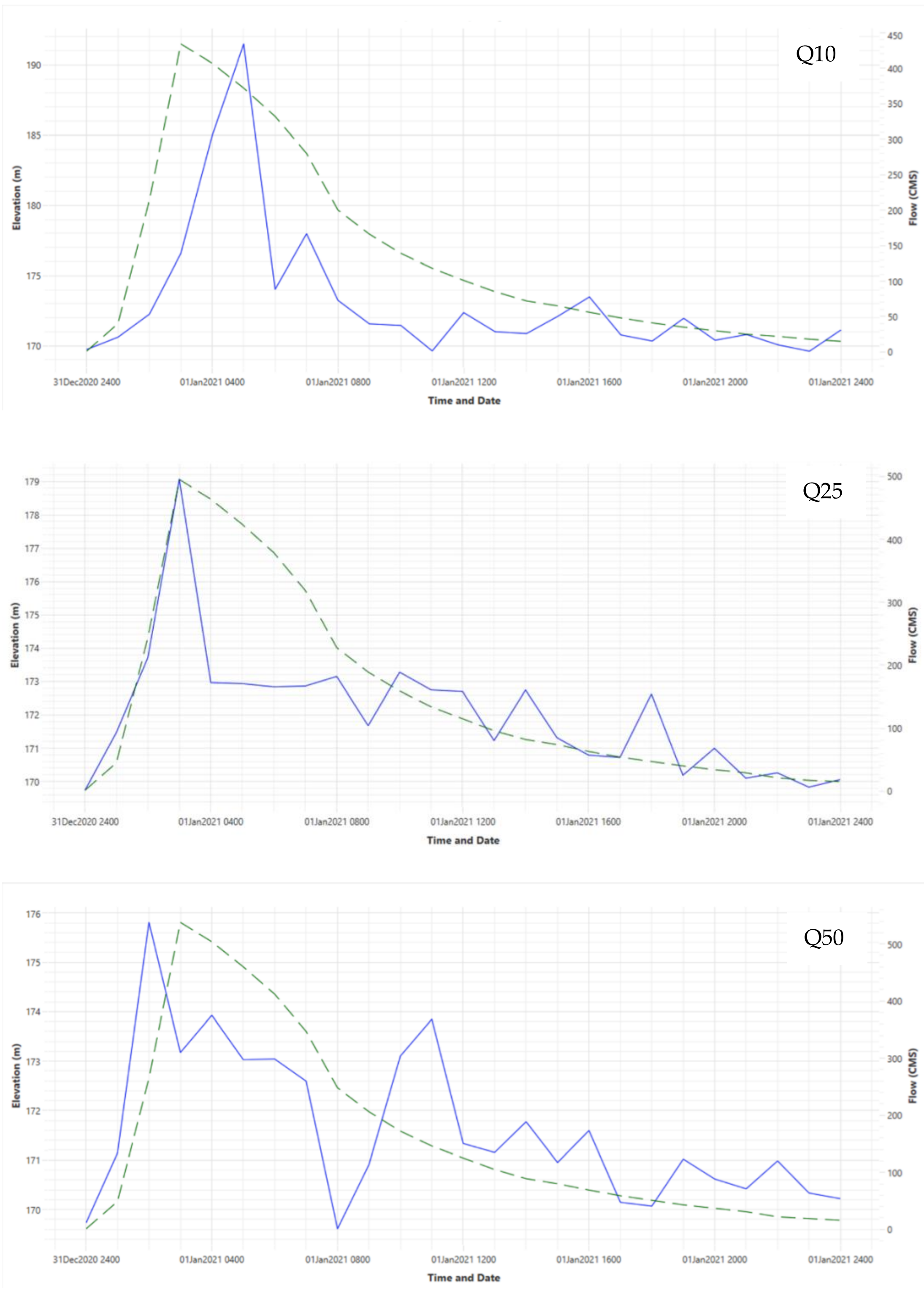

Figure 3. Flow graph and hydrograph upstream.

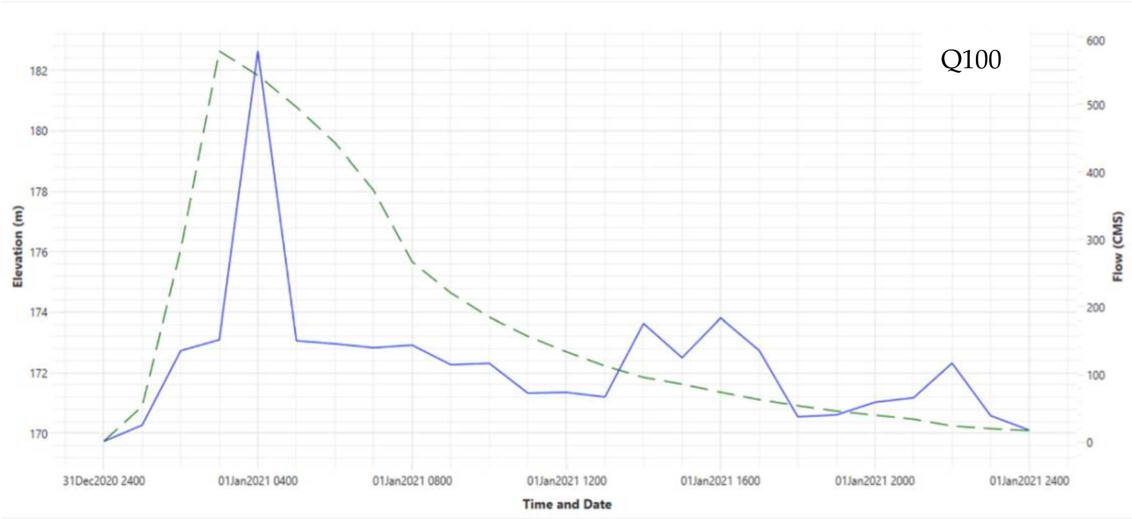

Figure 3. Flow graph and hydrograph upstream (continued).

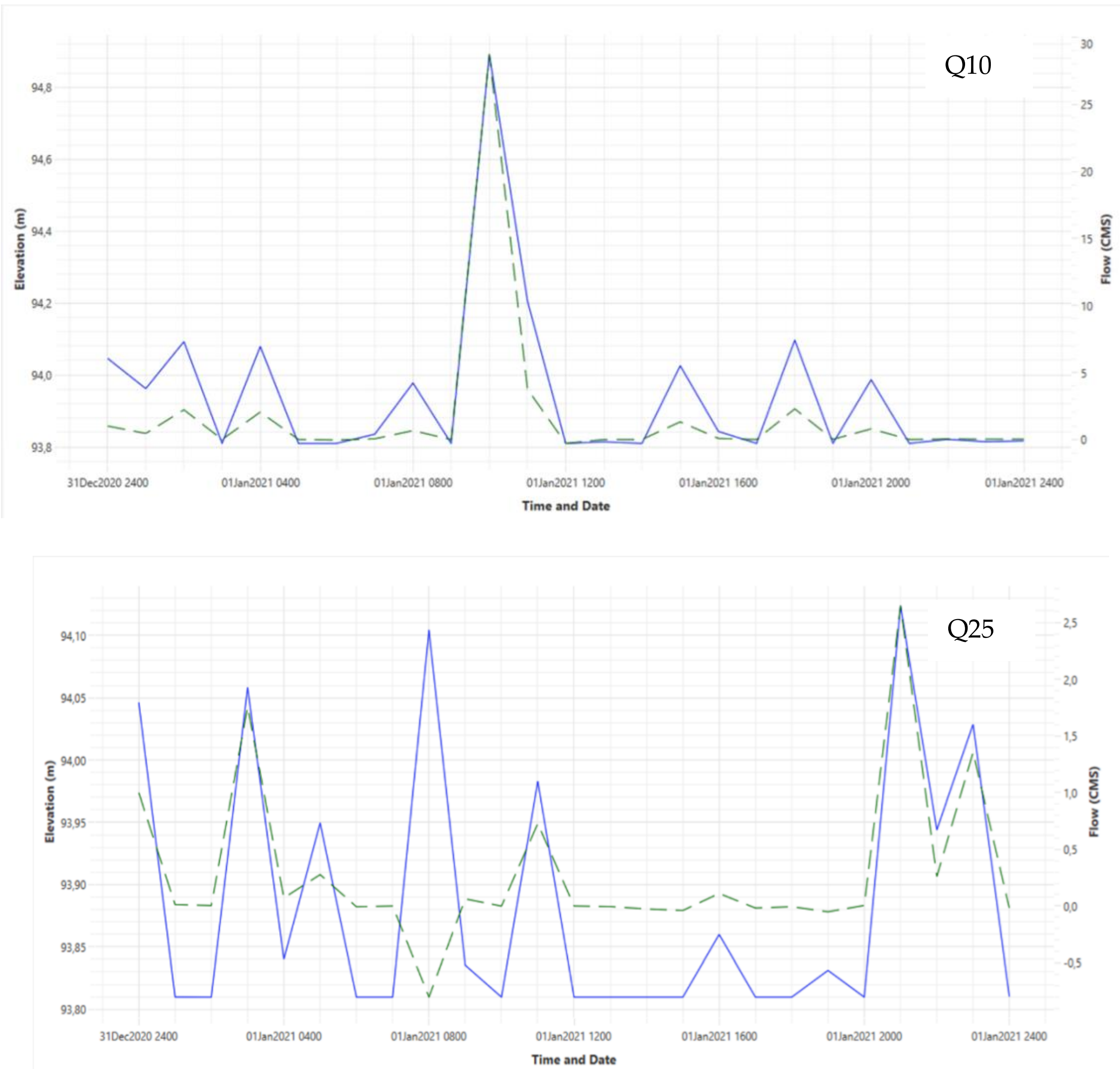

Figure 4. Flow graph and hydrograph downstream

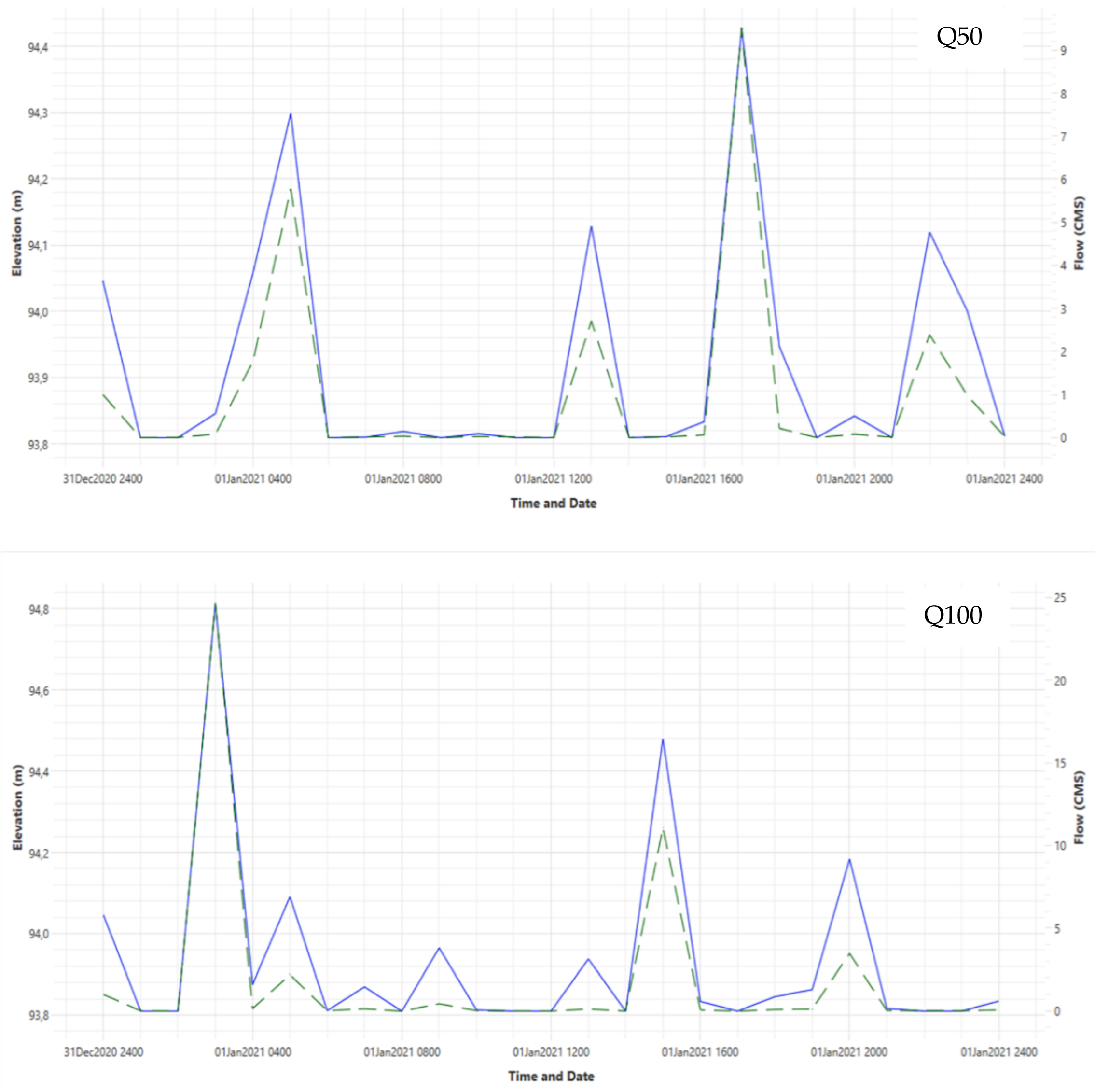

Figure 4. Flow graph and hydrograph downstream (continued).

Based on **Figures 3 and 4**, it can be observed that the elevation height (represented by the blue line) and the flow or discharge (represented by the green dashed line) across the different return periods (with the x-axis representing time) generally do not show significant variations among the 10-year, 25-year, and 50-year return intervals. In these cases, both the water level elevation and the discharge patterns exhibit relatively similar trends, indicating that the hydrological response remains fairly consistent for events with these frequencies.

However, a noticeable shift becomes apparent at the 100-year return period. At this point, the elevation of the water level begins to rise considerably higher compared to the other return periods. This indicates that extreme flood events, which statistically occur once in a century, lead to a significantly greater increase in water surface elevation. The disparity in elevation becomes more pronounced, suggesting that the magnitude of such rare events has a much stronger impact on water levels. This highlights the importance of accounting for such extreme scenarios in flood risk management, infrastructure design, and mitigation planning, as the consequences can be far more severe than those associated with more frequent events.

After that, the elevation of the flood water level at the reviewed location as a result of the planned flood discharge that has been obtained can be seen in **Figure 5** and **Figure 6**.

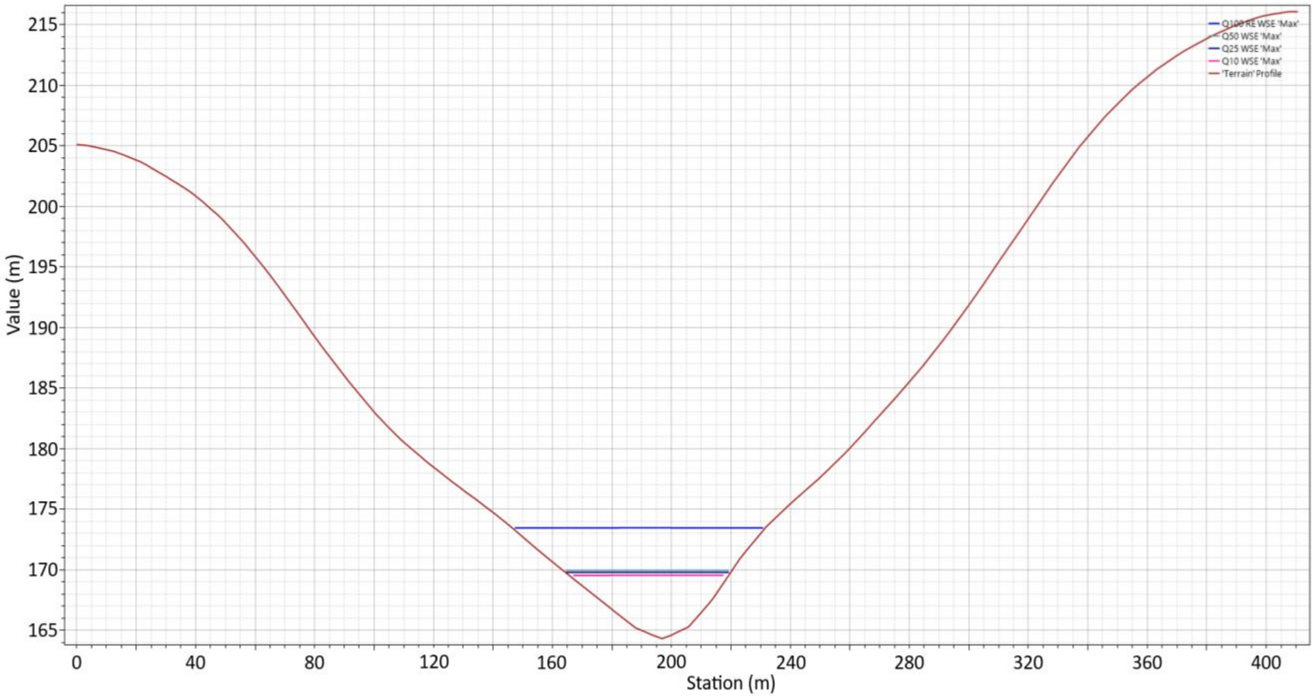

Figure 5. Transverse cut at the upstream point.

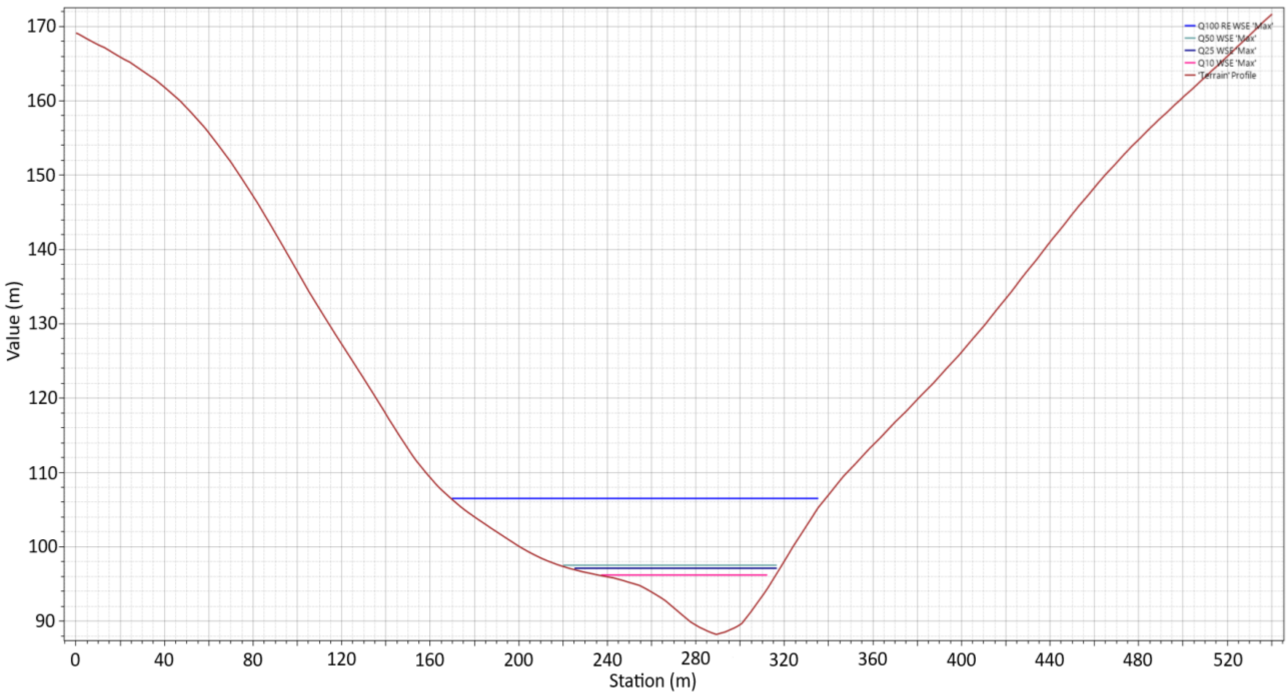

Figure 6. Transverse cut at the downstream point.

Furthermore, the cut extends the elevation of the flood water level in the upstream, middle, and downstream parts of the location being reviewed can be seen in **Figure 7.**

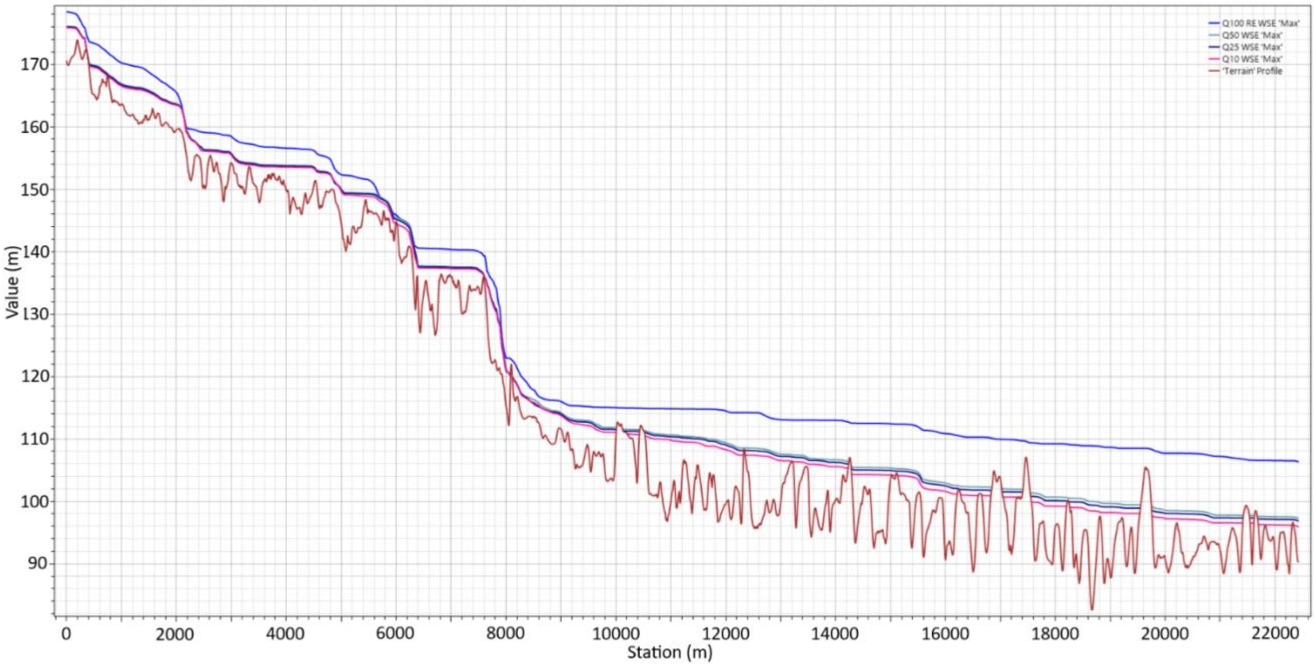

Figure 7. Profile water level elevation extends each re-interval.

From **Figure 5-7**, the highest water overflow that occurred at the site reviewed at the 10-year, 25-year, 50-year, and 100-year periods using HEC-RAS showed that there was no flooding at the research site. The high results of the overflow have been presented in **Table 2**.

Table 2. High Yield Overflow Way Sekampung

Repeat Time	Overflow Height (m)
10 Years	5.57
25 Years	6.54
50 Years	6.99
100 Years	16.03

From the results of running the HEC-RAS program that has been carried out, the highest flood water level elevation and total discharge for the unsteady flow modeling as presented such as **Table 3**

Table 3. Elevation of Water Level Upstream and Downstream.

No	Repeat Time (Tahun)	Elevation (meter)			
		Upstream	Embankment	Downstream	Embankment
1	10	+177.57	>+200	+95.49	>+150
2	25	+179.63		+97.53	
3	50	+183.86		+101.28	
4	100	+192.73		+106.52	

Table 3 shown that the highest water level elevation for the 100-year return period is still much lower than the elevation of the existing embankments, both at the upstream location and at the downstream location of the river. From this condition, it can be concluded that there is no runoff in the river, even though the flow coefficient is taken at 0.7. The coefficient value is taken as 0.7 because when a flood occurs, it is assumed that the area is already filled with residential housing.

3.4. Flood Inundation Mapping

Based on the research results above, the flood inundation that occurs can be mapped as presented in the following **Figure 8** and **Figure 9**.

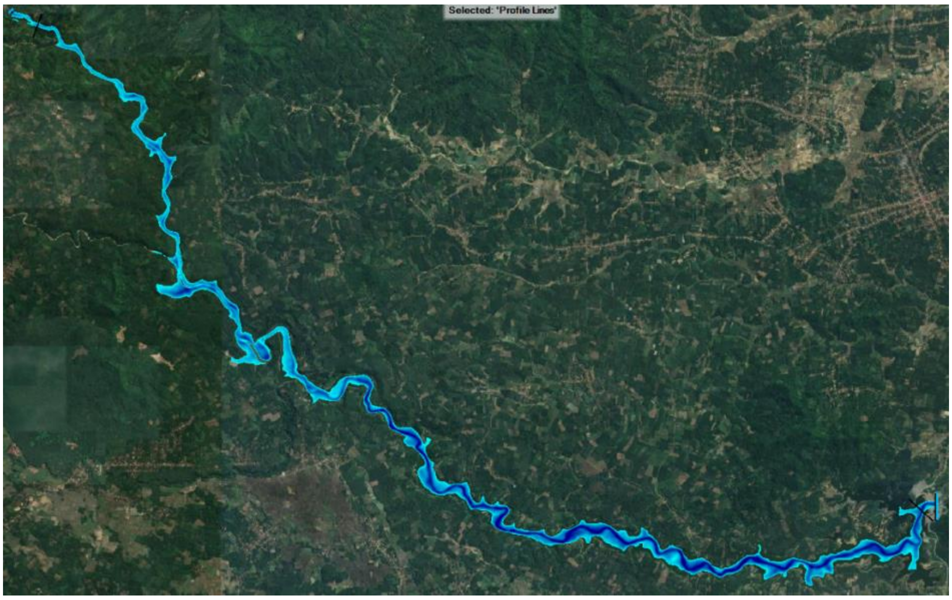

Figure 8. Flood inundation mapping for return period of 2 years

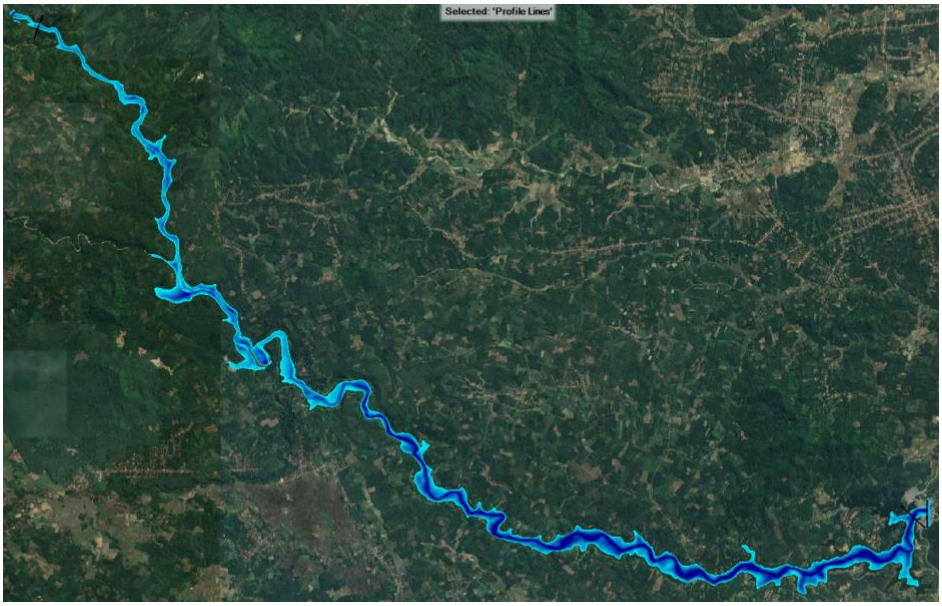

Figure 9. Flood inundation mapping for return period of 100 years

From the results of flood mapping, there is almost no difference between a return period of 2 years and a return period of 100 years. This is because even though this study uses a drainage coefficient of 0.7, the slope of the left and right banks of the river is very steep, so the area of inundation that occurs is not like inundation that occurs in relatively large areas.

4. Conclusion

Based on the results of the data analysis conducted in this study. So the following conclusions can be drawn:

1. The height of the flood water level of the unsteady flow was obtained from the results of hydraulic analysis using the HEC-RAS V6.5 application at 10, 25, 50, and 100 years repeatedly, namely 177.57 meters, 179.63 meters, 183.86 meters, and 192.73 meters in the upstream section. In addition, in the downstream part, 95.49 meters, 97.53 meters, 101.28 meters, 106.52 meters were obtained for each re-period.
2. From the results of modeling that have been carried out at the review location, the elevation of the water level at Way Sekampung shows that during the 10-year, 25-year, 50-year, and 100-year re-periods, the overflow height is 5.57 m, 6.54 m, 6.99 m, and 16.03 m.
3. There is no flooding in the study area. This is because the elevation of the embankments on the left and right of the river, both upstream and downstream, is much higher than the flood elevation at the 100-year return period.

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