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FLOOD MODELING FOR THE CISANGGARUNG RIVER IN THE CILENGKRANG VILLAGE USING THE HEC-RAS SOFTWARE

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ABSTRACT
This research aims to model the flood overflow of the Cisanggarung River in Cilengkrang Village using HEC-RAS software. A quantitative method was employed, focusing on hydrological and hydraulic analysis. The hydrological analysis includes rainfall calculation, Thiessen Polygon method, frequency analysis, rainfall intensity, Nakayasu method, and planned discharge calculation. Hydraulic analysis was conducted using HEC-RAS to model flood overflow. The results indicate that the annual rainfall in the study area varies significantly, with the highest recorded rainfall of 1290 mm in 2020. The planned discharge of the Cisanggarung River was calculated at 2137 m^3/second, revealing that the river's cross-section capacity is inadequate for managing flood discharge, particularly near settlements. This study provides critical insights for flood disaster mitigation planning in Cilengkrang Village and surrounding areas. The findings underscore the need for improvements in river management, including recommendations for enhancing river channel capacity and implementing adequate flood control infrastructure. Ultimately, this research contributes to understanding flood risks in the region and offers practical solutions to minimize future flood impacts.

Keywords: Flood modeling, HEC-RAS 6.5, Hydrological analysis

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INTRODUCTION

Indonesia is a country that has many water resources and rivers that play an essential role in people's lives (Sholi et al., 2020; Yusuf et al., 2022). Rivers are a source of clean water and serve as transportation routes, recreational areas, and ecosystems to support biodiversity (Bui et al., 2024; Gu et al., 2025; Ma et al., 2024; Tong et al., 2024). However, with the development of human settlements and activities, issues related to river management, such as floods and erosion, are becoming more frequent. Therefore, effective river management is essential to reduce these negative impacts (Dehghani Darmian & Schmalz, 2024; Huang et al., 2024; Li et al., 2024; Vall-Casas et al., 2024).

Cisanggarung River, located in West Java Province, often overflows during the rainy season, making it vulnerable to floods. The floods disrupt the surrounding communities' daily activities and damage infrastructure and property. More river channel capacity can influence the occurrence of floods as it cannot contain large water flows. Inadequate river channel capacity to contain incoming water flows can lead to flooding in the surrounding areas.

Recent studies have highlighted the growing concerns regarding flood risks in river basins, emphasizing the need for region-specific research. For instance, research by Dewandaru et al. (2023) examined flood control measures in Jombang Regency, while Efrizal et al. (2022) explored drainage effectiveness in Jepara Regency. Expanding upon these works, this study aims to define the specific research problem of flood overflow in Cilengkrang Village, emphasizing its significance for local communities.

This research utilizes the HEC-RAS (Hydrologic Engineering Centers River Analysis System) software, developed by the Army Corps of Engineers, to model flood behavior in the Cisanggarung River. HEC-RAS is an open-source tool widely used by civil engineers and hydrology experts for simulating water flow in open channels (Bharath et al., 2021; Hadi & Almansori, 2023; Phyo et al., 2023; Zeiger & Hubbart, 2021). This study will identify high-risk flood areas and provide recommendations for improving river channel capacity, contributing to better water resource management in the Cisanggarung River.

This research also demonstrates how floods overflow around Cilengkrang Village, which is traversed by the Cisanggarung River, using the HEC-RAS (Hydrologic Engineering Centers River Analysis System) software. The Army Corps of Engineers developed the software, which is open-source and useful for flood and river flow modeling. Civil engineers and hydrology experts use it worldwide to simulate water flow in open channels like rivers. With HEC-RAS, river flow profiles, channel capacities, and flood risks can be analyzed. This research will model the flood overflow of the Cisanggarung River using HEC-RAS. This research aims to identify parts of the river with a high risk of flood overflow and provide recommendations for improvements or interventions to increase river channel capacity. It is hoped that this research can help manage the water resources of the Cisanggarung River, especially in flood risk mitigation.

METHOD

Research Location

This study was conducted from August to September 2024 in the Cilengkrang Village area, through the Cisanggarung River in Cirebon Regency (6°54'55.05" S 108°44'20.00" E). It began by collecting data related to the BBWS (Cimanuk—Cisanggarung).

The method used is the quantitative method, which is a research approach that uses numbers and statistics to systematically collect, analyze, and interpret data (Frick, 2015). This research focuses on hydrological and hydraulic analysis. Hydrological analysis includes rainfall calculation, average rainfall using the Thiessen polygon method, frequency analysis, rainfall intensity, Nakayasu, and planned discharge. Hydraulic analysis uses HEC-RAS software to obtain information about flood levels in the studied area (Estelaji et al., 2024; Kannapiran & Bhaskar, 2024; Rahman & Ali, 2024).

The Nakayasu method, which estimates river flow hydrographs based on adequate rainfall, involves using hydrograph observations from various watersheds. Meanwhile, the Thiessen Polygon method divides the study area into polygons based on the proximity to rainfall measurement stations. This allows for a more accurate estimation of average rainfall across the region.

Additionally, incorporating a flow diagram of the research process would significantly enhance clarity and transparency. This diagram could visually represent the steps from data collection and analysis to applying HEC-RAS modeling. Such an illustration would help readers better understand the methodology and the interconnections between different stages of the research, ultimately strengthening the overall presentation of the study.

RESEARCH AND DISCUSSION

Average Rainfall Method of Thiessen Polygon

The Thiessen Polygon method estimates the average rainfall in a certain area by dividing the area into several polygons, each representing the influence of one measurement station. The polygons are formed so that every point inside is closer to that station than any other station.

Figure 1.
Thiessen Polygon Area

Table 1. Average Rainfall Method of Thiessen Polygon

Year	Rain Station						Mean (mm)
	JatiSeeng (mm)	Thiessen Area (Ha)	Cangkuang (mm)	Thiessen Area (Ha)	Gebang (mm)	Thiessen Area (Ha)	
2012	63	417,26	53	1436,91	50	63304,68	51,6
2013	103		67		60		62,2
2014	33		68		63		64,8
2015	135		73		65		67,5
2016	60		70		59		61,0
2017	77		107		70		72,9
2018	71		116		92		95,1
2019	87		120		106		109,3
2020	86		105		136		139,0
2021	107		85		103		105,6
2022	95		90		73		75,7

$$d = \frac{A1.d1 + A2.d2 + A3.d3 + \cdots An.dn}{A} = \frac{\sum Ai.di}{A} \ldots 1$$

Description:

A = Area (km^2)

d = Average rainfall height of the area

d1, d2, d3, ... dn = Rainfall height at positions 1, 2, 3,... n

A1, A2, A3,... An = Area of influence at positions 1, 2, 3, ... n

Frequency Analysis

Table 2. Gumbel Distribution

OUTPUT GUMBEL						
Year	X Average	Yn	Yt	K	Xt	
2	82,245	0,4996	0,367	-0,140	78,502	
5			1,500	1,056	110,380	
10			2,250	1,848	131,486	Used
20			2,970	2,607	151,732	
25			3,199	2,848	158,154	
50			3,902	3,590	177,938	
100			4,600	4,327	197,575	
					143,681	

$$X_T = Xr + (K.Sx)$$

Description :

XT = Planned rainfall with a period of T years

Xr = Maximum average rainfall

K = Frequency factor

Sx = Standard deviation

Rainfall Intensity Mononobe Method

Table 3. Rainfall Intensity for a Few Hours

Rainfall Intensity for a few hours.							
t (rain time)	Rainfall When Repeated (mm)						
	2	5	10	20	25	50	100
	78,50	110,38	131,49	151,73	158,15	177,94	197,57
Jam	Rain Intensity When Repeated (mm/jam)						
	2	5	10	20	25	50	100
1	27,215	38,267	45,584	52,602	54,829	61,687	68,495
2	17,144	24,107	28,716	33,137	34,540	38,861	43,149
3	13,084	18,397	21,914	25,289	26,359	29,656	32,929
4	10,800	15,186	18,090	20,875	21,759	24,481	27,182
5	9,307	13,087	15,589	17,990	18,751	21,097	23,425
6	8,242	11,589	13,805	15,931	16,605	18,682	20,744
7	7,437	10,457	12,457	14,375	14,983	16,858	18,718
8	6,804	9,567	11,396	13,151	13,707	15,422	17,124
9	6,290	8,844	10,535	12,158	12,672	14,257	15,831
10	5,863	8,244	9,821	11,333	11,813	13,290	14,757
11	5,502	7,737	9,216	10,635	11,085	12,472	13,848
12	5,192	7,301	8,697	10,036	10,461	11,769	13,068
13	4,922	6,921	8,245	9,514	9,917	11,158	12,389
14	4,685	6,588	7,847	9,056	9,439	10,620	11,792
15	4,475	6,292	7,495	8,649	9,015	10,142	11,262
16	4,286	6,027	7,179	8,284	8,635	9,715	10,787
17	4,116	5,788	6,895	7,956	8,293	9,330	10,360
18	3,962	5,572	6,637	7,659	7,983	8,981	9,973
19	3,822	5,374	6,402	7,388	7,700	8,664	9,620
20	3,694	5,194	6,187	7,139	7,441	8,372	9,296
21	3,575	5,027	5,989	6,911	7,203	8,104	8,999
22	3,466	4,874	5,806	6,700	6,983	7,857	8,724
23	3,365	4,732	5,636	6,504	6,779	7,627	8,469
24	3,271	4,599	5,479	6,322	6,590	7,414	8,232

The formula used is:

$$I=T/t^n$$

Where:
I = Rainfall intensity (mm/hour)
R = Total rainfall during a specific period (mm)
t = Duration of the rainfall (hours)
n = Exponent factor, usually 0.6 to 0.8, depending on the local geographical and climatological conditions. Generally, the value of n used in the Mononobe method is 2/3 (0.67).

The Rainfall Intensity Mononobe Method is widely used for estimating rainfall intensity over a specific duration. This empirical method is particularly effective in hydrological studies, where understanding the relationship between rainfall duration and intensity is crucial for flood modeling and water resource management. The method technique is a formula that calculates rainfall intensity (I) based on total rainfall (R) and the duration of rainfall (t) (Bashori & Purwono, 2024; Cyr, 2016; Fajri et al., 2023).

Nakayasu

The Nakayasu method was developed based on observations of natural unit hydrographs originating from many watersheds in Japan. This is one of the synthetic unit hydrograph methods used in hydrology to estimate river flow hydrographs based on adequate rainfall in the river basin area (Febrianto et al., 2023; Rovita Yuniarti, 2022).

Table 4. Synthetic Unit Hydrograph Analysis Parameters Using the Nakayasu Method

t (Hour)	Qt (m^3/s)	Q Correction (m^3/s)
0	0	0
1	0,21	0,21
2	1,10	1,13
3	2,91	2,99
4	5,80	5,96
5	9,90	10,17
6	15,34	15,76
6,614	19,39	19,91
7	18,16	18,65
8	15,32	15,73
9	12,93	13,28
10	10,91	11,20
11	9,20	9,45
12	7,76	7,97
13	6,55	6,73
13,701	5,82	5,97
14	5,53	5,68
15	4,66	4,79
16	3,94	4,04
17	3,32	3,41
18	2,80	2,88
19	2,36	2,43
20	1,99	2,05
21	1,68	1,73
22	1,42	1,46
23	1,20	1,23
24	1,01	1,04
24,331	0,96	0,98
Amount	171,20	175,85
VLL (m3)	616330,22	633046,8
TLL (mm)	0,97	1,00

Figure 1.
Nakayasu Area

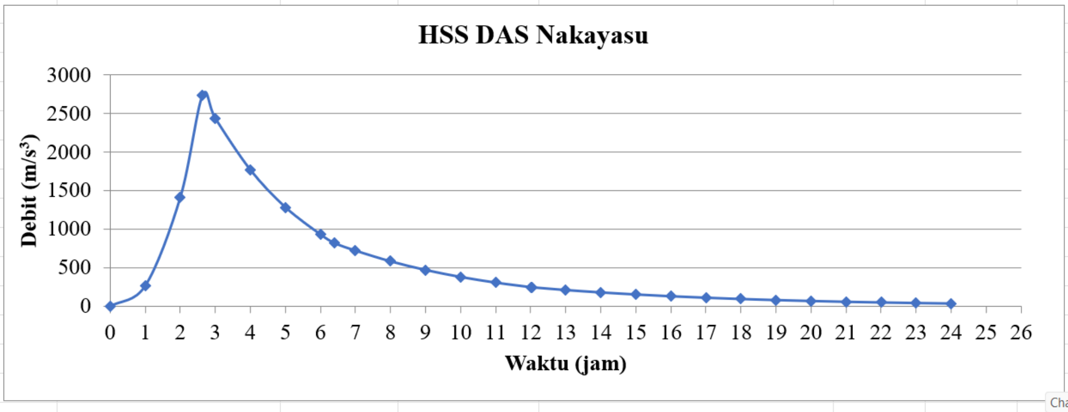

Chart 1.
HSS DAS Nakayasu

The HSS Nakayasu formula is as follows:

$Tg = 0{,}4 + 0{,}058 \times L$ for $L > 15\ km$ (2.35)

$Tg = 0{,}21 \times L$ for $L < 15km$ (2.36)

$Tr = 0{,}5 \times Tg, up\ to\ Tg$ (2.37)

$Tp = Tg + 0{,}8 \times Tr$ (2.38)

$$Qp = \frac{A \times Rc}{3{,}6 \times (0{,}3 \times Tp + T_{0,3})} \quad (2.39)$$

for t < Tp

$$Qt = Qp \times \left(\frac{t}{Tp}\right)^{2,4} \quad (2.40)$$

for $Tp < t < Tp + T_{0,3}$

$$Qt = Qp \times 0{,}3^{\left(\frac{t-Tp}{T0{,}3}\right)} \quad (2.41)$$

for $Tp + T_{0,3} + 1{,}5T_{0,3}$

$$Qt = Qp \times 0{,}3\left(\frac{(t-Tp)(1{,}5 \times T_{0,3})}{1{,}5 \times T_{0,3}}\right) \quad (2.42)$$

for t > Tp

$$Qt = Qp \times 0{,}3\left(\frac{(t-Tp)+(1{,}5\times T_{0,3})}{1{,}5\times T_{0,3}}\right) \quad (2.43)$$

Debit Plan

Based on the results of the hydrological analysis using the frequency distribution method, the planned discharge value is 2137.411 m³/second. This discharge is calculated for a specific return period that reflects the potential for flooding within a certain period in the study area. This discharge value indicates the magnitude of water flow that needs to be anticipated in flood control infrastructure planning (Efrizal et al., 2022; Rizani et al., 2023; Rovita Yuniarti, 2022; Sholi et al., 2020).

Table 5. Flood Discharge Analysis for a 25-Year Return Period

Kala Ulang 25 Tahun								
Waktu	Debit	R1	R2	R3	R4	R5	R6	Q (Debit Banjir Rencana)
t	m³/det	8,869	13,193	72,360	18,808	10,503	7,753	
0	0,000	0,000						0,000
1	0,214	1,896	0,000					2,110
2	1,128	10,007	2,820	0,000				13,956
3	2,986	26,481	14,886	15,468	0,000			59,820
4	5,955	52,818	39,390	81,642	4,021	0,000		183,826
5	10,174	90,234	78,567	216,039	21,220	2,245	0,000	418,479
6	15,758	139,767	134,222	430,908	56,153	11,850	1,657	790,316
7	18,648	165,401	207,902	736,154	112,002	31,358	8,747	1280,213
8	15,735	139,558	246,032	1140,259	191,342	62,547	23,147	1818,620
9	13,276	117,753	207,591	1349,389	296,377	106,854	46,169	2137,411
10	11,202	99,355	175,156	1138,556	350,735	165,510	78,875	2019,389
11	9,452	83,831	147,789	960,664	295,935	195,866	122,173	1815,710
12	7,975	70,733	124,698	810,566	249,697	165,263	144,580	1573,513
13	6,729	59,682	105,215	683,921	210,683	139,442	121,990	1327,661
14	5,678	50,357	88,776	577,062	177,765	117,655	102,930	1120,223
15	4,790	42,489	74,905	486,900	149,991	99,272	86,848	945,195
16	4,042	35,850	63,202	410,825	126,556	83,761	73,278	797,515
17	3,410	30,249	53,327	346,636	106,782	70,674	61,829	672,908
18	2,878	25,523	44,995	292,477	90,098	59,632	52,169	567,771
19	2,428	21,535	37,965	246,779	76,021	50,315	44,018	479,060
20	2,049	18,170	32,033	208,221	64,143	42,453	37,140	404,210
21	1,729	15,331	27,028	175,688	54,121	35,820	31,337	341,055
22	1,458	12,936	22,805	148,238	45,665	30,224	26,441	287,767
23	1,231	10,915	19,242	125,077	38,530	25,501	22,310	242,805
24	1,038	9,209	16,235	105,534	32,510	21,517	18,824	204,869
							Qmaks(m³/det)	2137,411

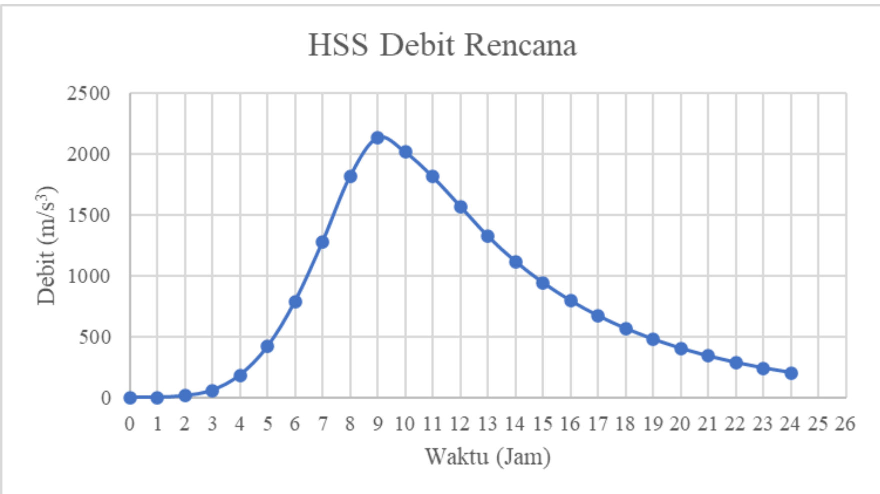

Chart 2.
Planned Unit Hydrograph Discharge (HSS)

HEC-RAS 6.5 Modeling Results

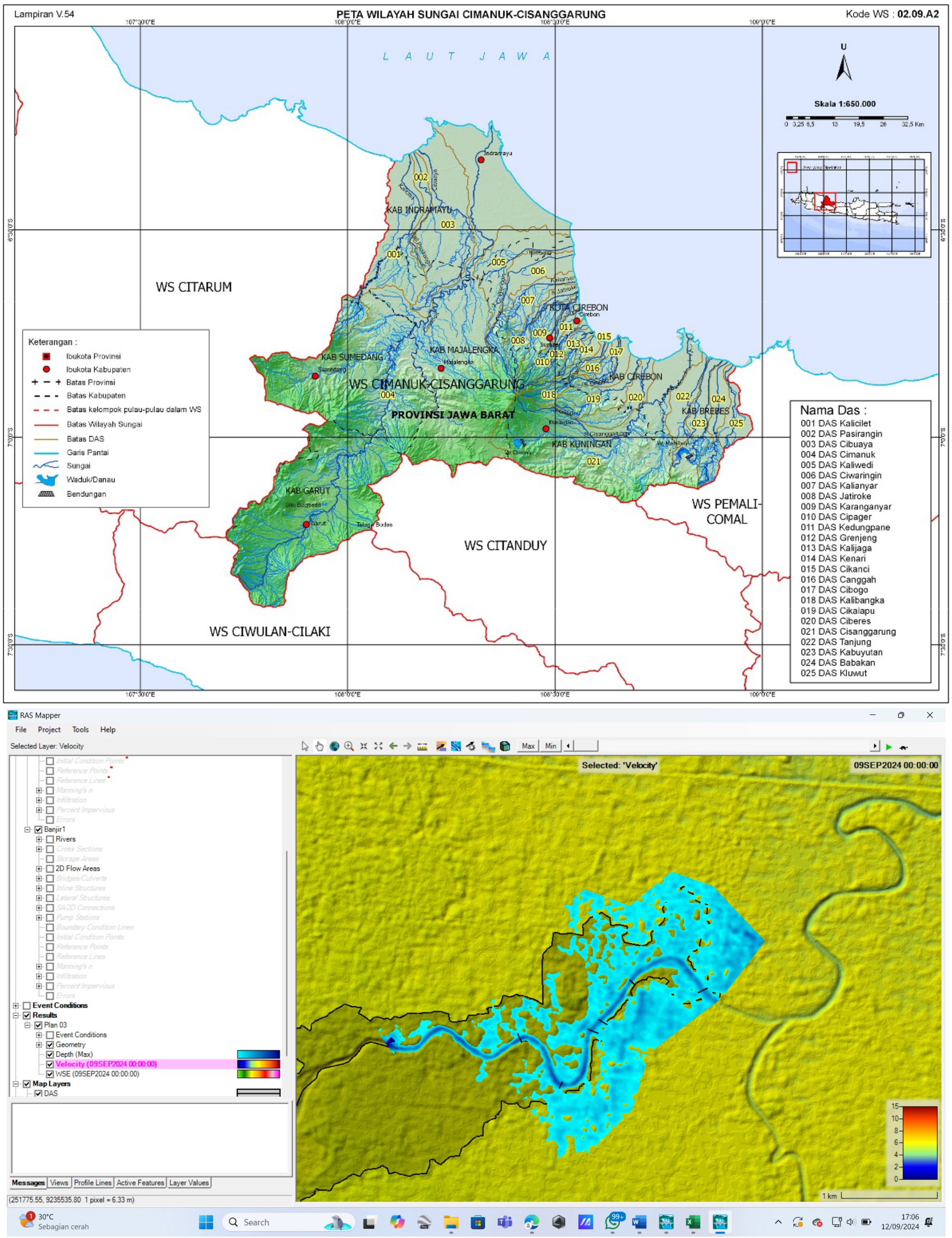

Chart 3.
Flood distribution in HEC-RAS modeling

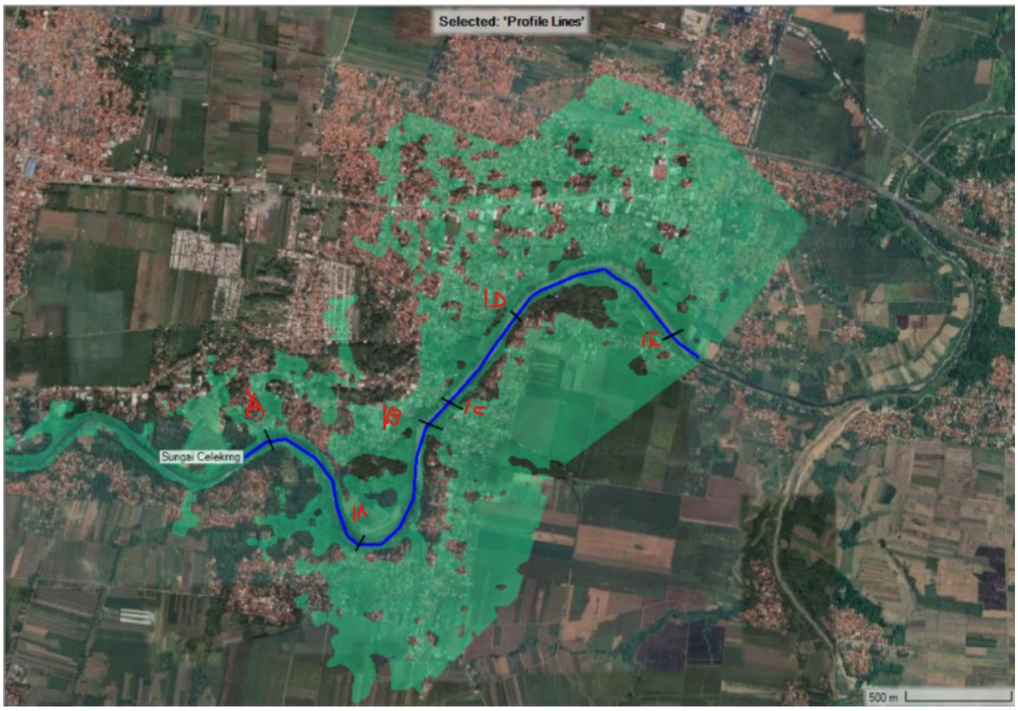

Figure 3.
Flood simulation modeling with HEC-RAS 2D

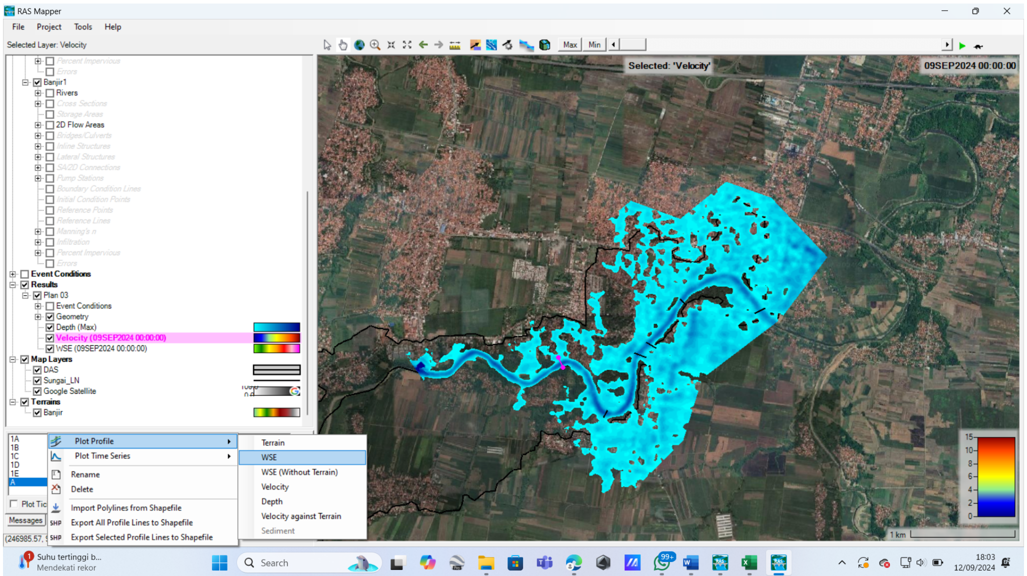

Figure 4.
Flood simulation modeling with HEC-RAS 2D

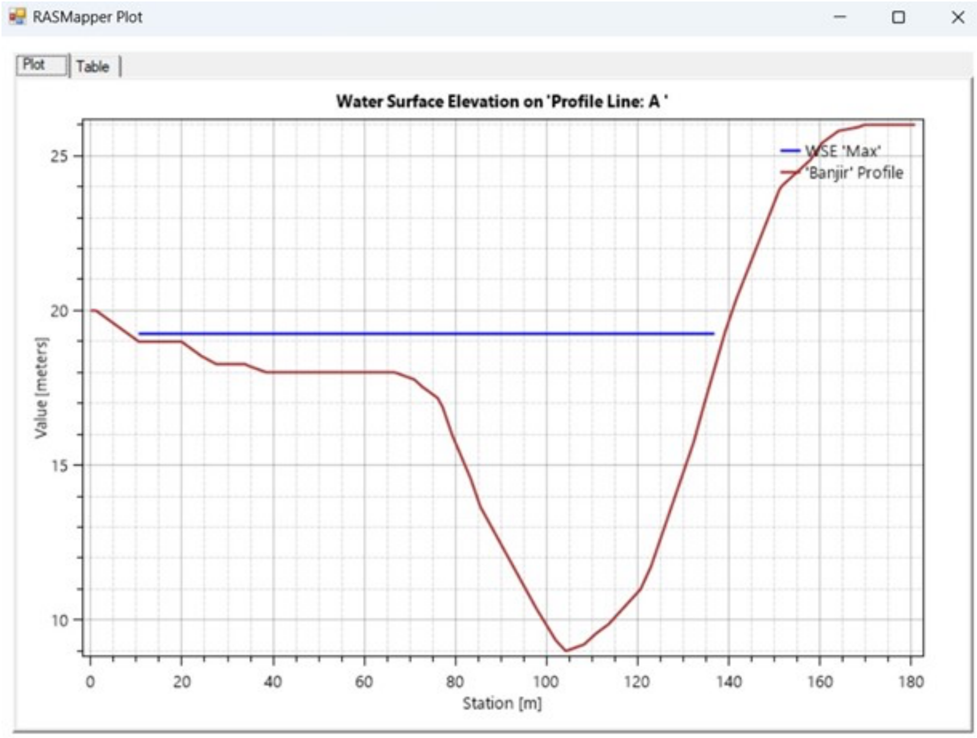

Chart 4.
Water Surface Elevation on "A"

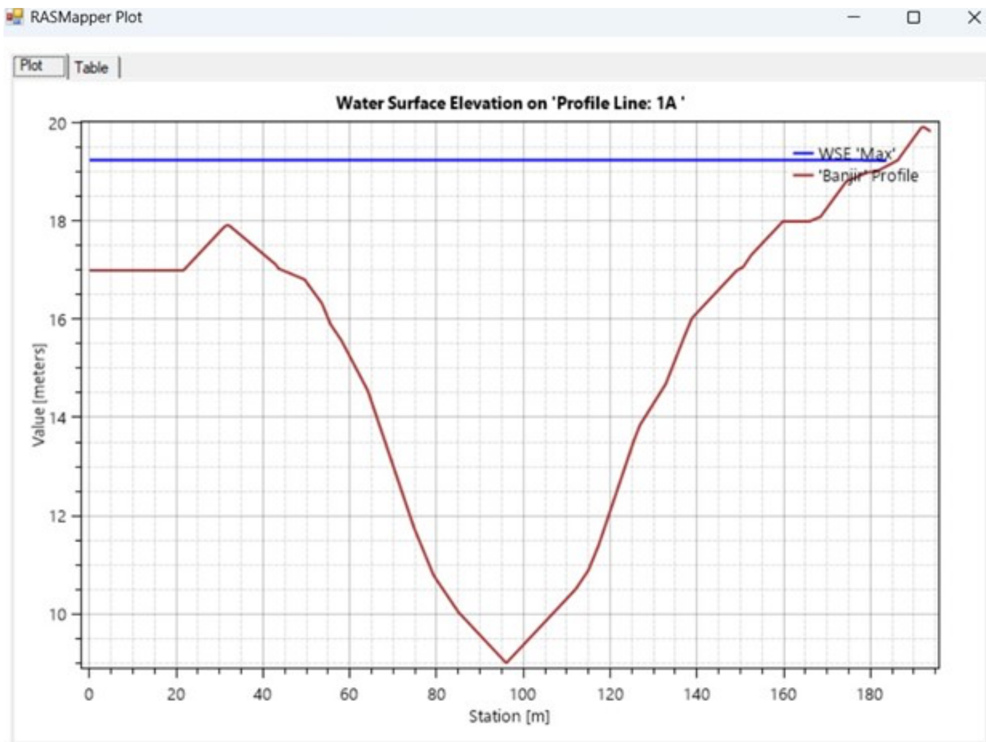

Chart 5.
Water Surface Elevation on "1A"

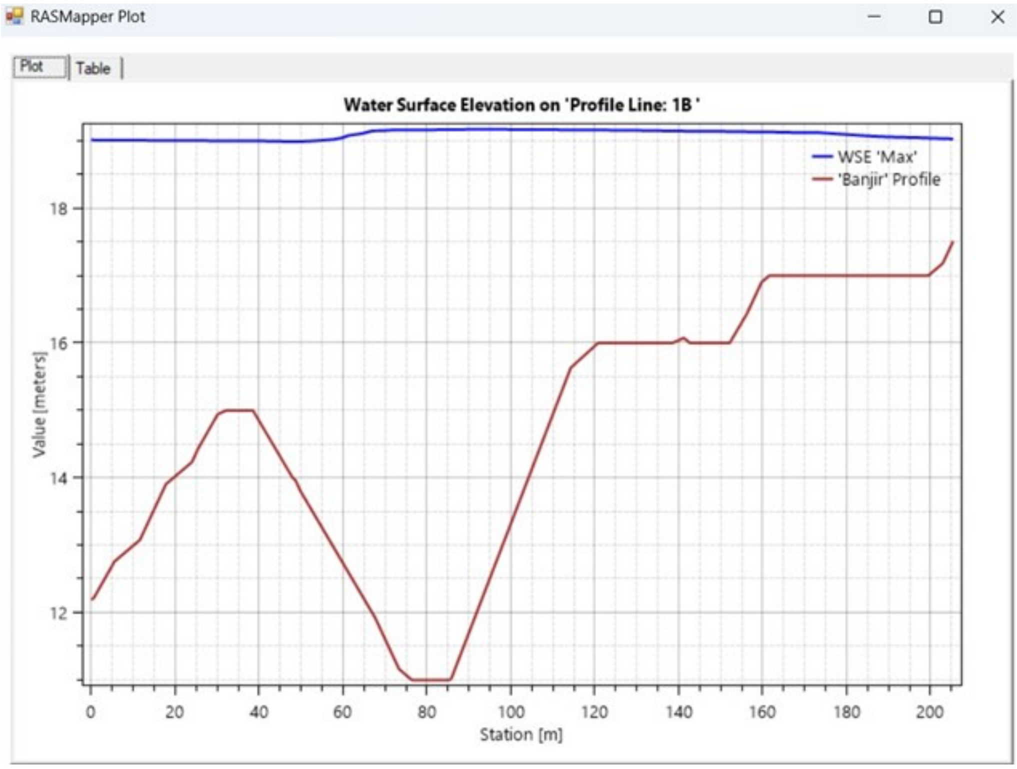

Chart 6.
Water Surface Elevation on "1B"

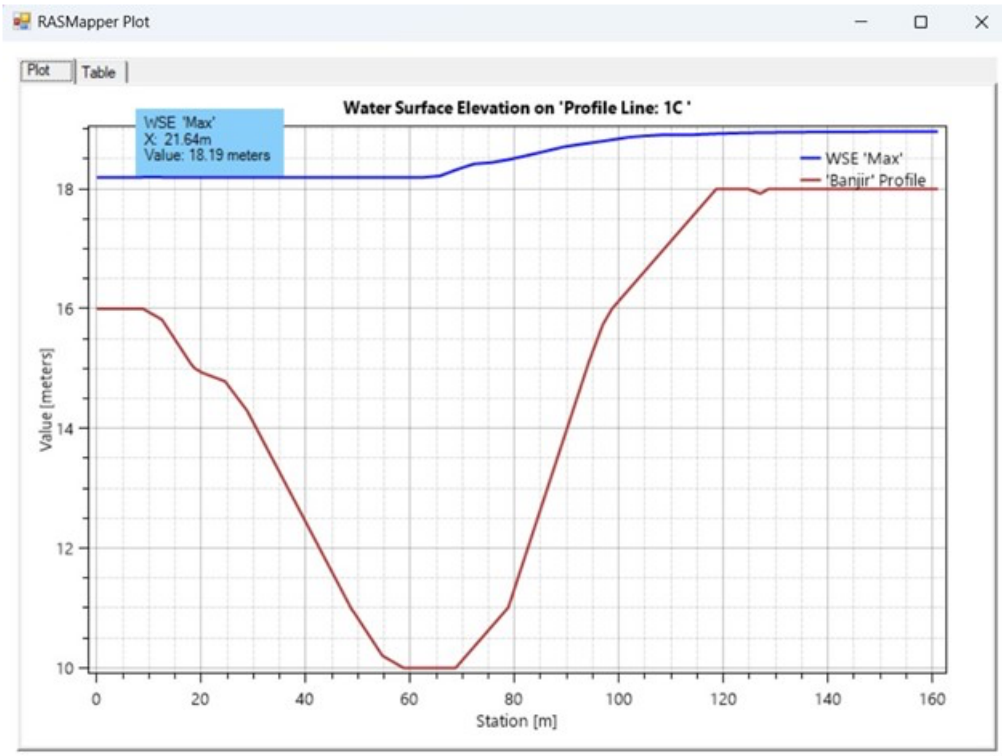

Chart 7.
Water Surface Elevation on "1C"

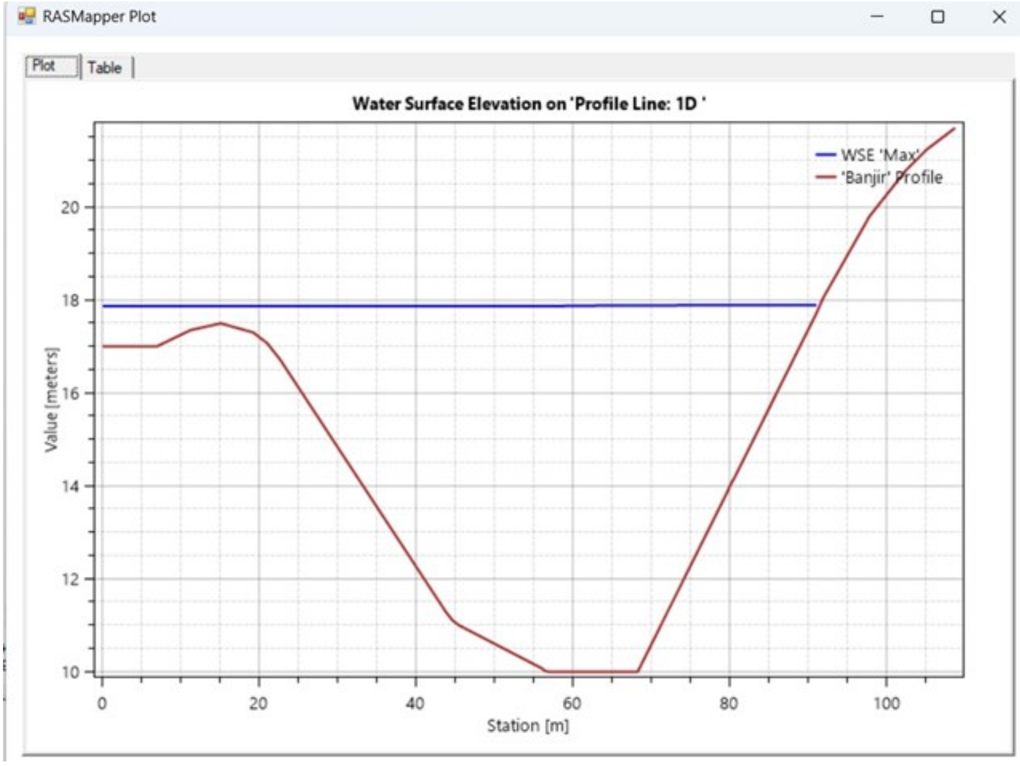

Chart 8.
Water Surface Elevation on "1D"

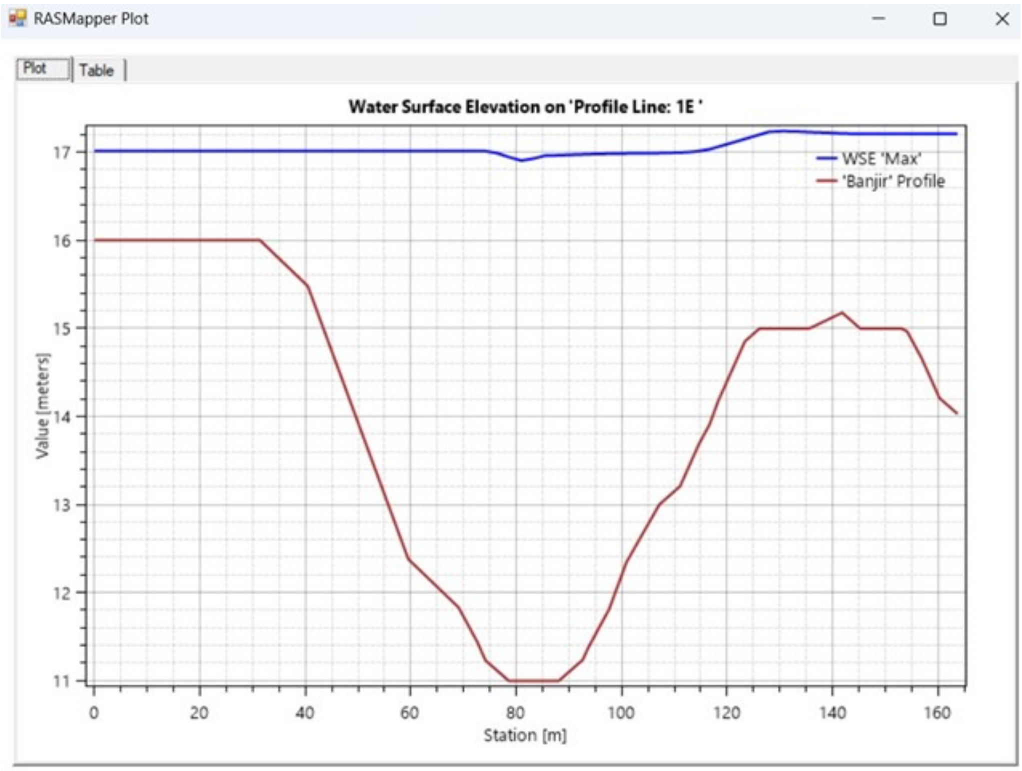

Chart 9.
Water Surface Elevation on "1E"

CONCLUSION

This study has effectively highlighted the significant variability in annual rainfall in the Cilengkrang Village area, with the highest recorded rainfall reaching 1290 mm in 2020. The calculated, planned discharge of 2137 m^3/second for the Cisanggarung River underscores the urgent need for adequate flood disaster mitigation measures. HEC-RAS modeling indicates that the river's cross-section capacity cannot accommodate flood discharge, particularly in areas near settlements.

Several recommendations have been proposed to enhance flood mitigation in Cilengkrang Village, including increasing the river's cross-section through widening or excavation, constructing flood walls, and developing flood control infrastructure such as small dams or embankments. Additionally, implementing an early warning system will enable residents to take preventive actions ahead of potential floods.

Reflecting on future research possibilities, exploring advanced modeling techniques and long-term monitoring of flood patterns would be beneficial, which could further improve flood risk assessments in the region. Emphasizing the practical implications of these recommendations is crucial; implementing such measures can lead to improved community safety, reduced property damage, and better management of water resources. Overall, this research provides valuable insights into flood dynamics and offers actionable strategies to mitigate flood risks, thereby enhancing resilience in Cilengkrang Village and its surroundings.

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