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Assistance in Designing Citarum River Cliff Protection to Control River Erosion in Atirompe Village, Majalaya District, Bandung Regency

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Abstract Rivers are often used as a water source for agriculture, transportation, and water supply needs. One of the causes of riverbank damage is scouring the cliff's foot, which cannot withstand scouring currents. If not addressed immediately, it will cause more severe damage. Citarum River is one river that passes through Atirompe Village, Majalaya District. The riverbanks in the area have a risk of cliff failure. The study objective was to analyze the problem, design the protection, and calculate the budget. The hydrology and riverbank analysis of the Majalaya River has been performed. The steps were essential to analyze the depth and width of the scour caused by the flow of the Citarum River water. Sediment data were collected at three locations, namely the upstream, middle, and downstream of the river segment that will be reviewed. In data processing, to obtain a sediment rating curve, it is necessary to measure the flow velocity, which will later be calculated and used as the flow rate during Total Suspended Solid (TSS) data collection. Using the Hydrology Engineering Center – River Analysis System (HEC – RAS) 6.2 software, the calculations with the Ripley Equation were compared to obtain the scour depth. For the design alternative, constructing a steel sheet pile-type cliff protection structure is one form of planning to protect riverbanks. This study also analyzed the recapitulation of the budgeting for protecting the Citarum riverbanks in Atirompe Village, Majalaya District. Using a standardized unit price, the total cost for the protection is 1.8 billion rupiahs.

1. INTRODUCTION

Rivers are natural resources that provide many benefits for human life. Undeniably, rivers are often used as a water source for agriculture, transportation, electricity, and many more. A watershed is an area bound by ridges/mountains where rainwater that falls in the area will flow towards the main river at a point/station under review. As we know, a river is a body of water that flows from upstream to downstream. The water that flows from upstream to downstream has a flow velocity that will directly result in the movement of soil particles from the riverbed or river body. However, many rivers have been damaged by the speed of the river flow. The river's flow can cause scouring, which causes changes in the cross-section of the river. Starting from minor damage to the river channel, such as erosion and degradation, which, if left unchecked, will develop into significant damage that can cause disasters such as flooding and landslides of riverbanks. One of the causes of riverbank damage is scouring the cliff's foot,

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Figure 1 . Overview of river cliff locations

which cannot withstand scouring currents. These scours get deeper and deeper, reducing the stability of the cliff. If not addressed immediately, it will cause more severe damage. Damage to riverbanks will damage river buildings and endanger people's safety (Guo et al., 2009).

Many cases have occurred in various rivers regarding riverbank damage caused by scouring during floods, especially in the West Java Province. Citarum River is one of the rivers that pass through Atirompe Village, Majalaya District, which is damaged by river cliffs. The community has made many efforts to minimize the cliff damage that occurs, but with changes in the level of rainfall every year, the process of cliff damage continues. As a result, residents' houses around the riverbank will continue to be threatened and cause losses to Atirompe villagers. Planning of riverbank protection structures needs to be done to prevent riverbank failure. In addition, assistance to the community has been done through identifying and analyzing landslide locations (cliff damage) and FGD (Focus Group Discussion) with relevant agencies/government, community, and society. River flows can cause erosion. Erosion that usually occurs in rivers happens on the riverbank. This erosion occurs due to riverbank erosion by water flowing from the top of the cliff or the impact of a strong stream or river current at the river's bend (Alekseevskiy et al., 2008). Therefore, it is necessary to protect the riverbanks to avoid scouring or erosion of the cliffs. The protection can be through riprap, gabions, concrete walls, or other measures (Anglin et al., 2002; Borderon et al., 2017). The construction of the Citarum River cliff protection structure, Atirompe Village, Majalaya District, Bandung Regency, aims to protect housing located on the riverbanks from river water scouring. Figure 1 is an overview of the condition of Atirompe Village, Majalaya Subdistrict, and the location of the cliff that was damaged by scouring. The focus of the study on strengthening the Citarum riverbanks in Majalaya Regency is to analyze the existing conditions before designing riverbank protection and structures and calculate the budget needed for river protection. Therefore, this community service activity aims to design a cliff protection construction with technical drawings and budget plans.

2. METHOD

This study designed Citarum River cliff protection, by modeling the river's existing condition using three kinds of data: hydrology and climatology data, hydraulic data, and spatial data. Continued with an evaluation of the model of erosion-prone areas on riverbanks, designed the riverbank protection, and then modeled the condition after planning using HEC-RAS 6.2. When the design is qualified, then calculate the budget plan. A detailed explanation of the procedure is shown in Figure 2.

2.1 Procedure

In general, the methodology used in conducting this research is as follows.

1. Public consultation meetings, meeting activities, or discussions involved several related parties, including BBWS, village/sub-district officials, and communities active in the disaster sector.

2. The hydrological analysis process began with conducting a survey and collecting the necessary data.

3. Hydraulic analysis was carried out to analyze the damage, causes of damage, and corrective steps that can be taken.

4. Structural designs were prepared to produce recommendations for cliff protection construction designs.
5. A budget analysis was prepared to produce recommendations for estimated costs needed.

The flowchart in Figure 2 illustrates the steps taken and the data needed in this research.

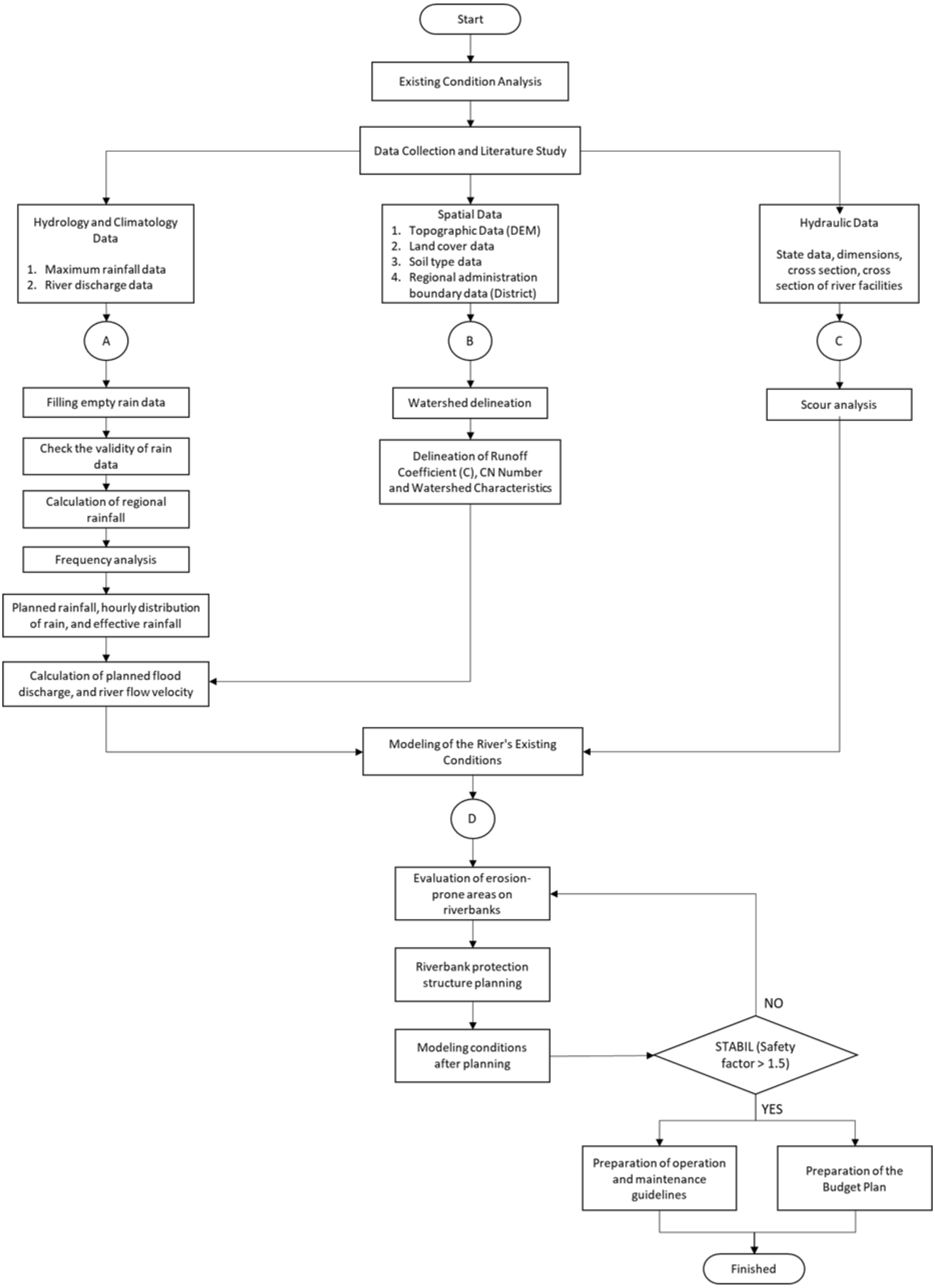

Figure 2 . Project flowchart

2.2 Hydrological analysis

Daily rainfall data were used as hydrology data from the rainfall gauges, such as the Cisanti gauge, Kertasari gauge, and Paseh gauge, with coverage from 2001 until 2022. The accuracy of rainfall measurement from ground measurement depended on the spatial variability. The spatial interpolation method used for an accurate and effective rainfall data process was the Thiessen polygon method. The Thiessen polygon method is commonly used to split the large watershed into several sub-regions resulting from the intersection of vertical bisectors by connecting the interpolated point (rainfall gauge) in pairs (Zhao et al., 2022).

The result from the Thiessen polygon was regional rainfall data in the catchment area, and annual maximum daily rainfall was calculated. Subsequently, the frequency analysis was computed using the Gumble method. The frequency analysis aims to know the relationship between the magnitude of extreme or maximum events that occur to the frequency of events using a probability distribution (Faisal & Gaffar, 2012; Sen et al., 1998). The Gumbel method was used in the frequency analysis processing because it was very suitable for use in tropical climates such as Indonesia, and the study location was in the tropics.

2.3 Hydraulic model

Google Earth Pro was used to analyze the decline of river cliffs in the Atirompe region from 2013 until 2022. The results would determine the location of the vulnerable condition that needed to be considered and continued with sediment transport analysis using HEC-RAS 6.2 software. HEC-RAS is a computer program that makes a one or two-dimensional model of either a steady or unsteady flow, specialized in modelling water through rivers, canals, and drains. Also, it can calculate the movement, such as sediment transport and chemical pollutants (Al-Hussein et al., 2022).

2.4 Hydraulic parameters calculation

According to the book (Chow et al., 1988), the scour cross-section can be calculated using the equation Boussinesq created and Ripley refined (16-25). The equation below is the scour depth.

$$y = 6,35D\left(\sqrt{0,437 - \left(\frac{x^2}{T^2}\right)} - 0,433\right)\left(1 + \left(\frac{xK}{r_o}\right)\right)$$

y = dept (ft)
x = abscissa (ft)
D = hydraulic depth (ft)
T = width of the water surface (ft)
r_o = outer curvature radius (ft)
K = 17,52 (Chow, 1959)

3. RESULT AND DISCUSSION

The riverbank area has experienced landslides since 2013 and continue until recent years. It was found that the river cliffs need a river protection structure of 50 meters. A scour analysis was performed with the HEC–RAS software to measure the length of the riverbank, the depth of scour, and the width of the scour caused by the flow of the Citarum River water (Wang et al., 2023).

The hydraulic analysis showed that the decrease in the Citarum River cliff area had reached 3.8 meters to 4.2 meters since 2013. Sediment data were collected at three locations, namely the upstream, middle, and downstream of the river segment, that would later be reviewed. In the data processing and modelling, the data in the upstream part would be used to determine the flow rate of water and sedimentation discharge that flows from the earliest conditions. One of the parameters used in modelling riverbank scours was data on the particle size distribution of sediments. Sediment data collection is taken directly in the field by taking several sediment samples on the riverbank. In data processing, to obtain a sediment rating curve, it is necessary to measure the flow velocity, which will later be calculated and used as the flow rate that flows during TSS data collection. The speed measurement was done using a current meter, and direct measurements were made during TSS data collection. The wet cross-sectional area was also measured to calculate the flow rate when in the field. From the results of measuring the flow velocity and wet cross-sectional area, it would get the flow value of the river flow and could also calculate how much the Manning coefficient (n) in the river was.

The sediment transport model being reviewed was simulated under two conditions: when a base flow discharge occurred and when a bank-full capacity discharge occurred. The base flow discharge was obtained based on the results of calculations whose data were obtained by making direct measurements in the field. The data of flow velocity and cross-sectional area measured at the time of data collection in the field would represent the river's base flow because, on the previous day and the day of data collection, there was no flood in the area where the data were collected.

The results of the calculation of the scour cross section using the Ripley equation and the modelling results using the HEC-RAS 6.2 software were compared. One section, P297, was taken for comparison. Moreover, in that section, there was scour with a maximum depth of 0.28 meters at a bank full discharge condition using the Ripley Equation. Using the HEC-RAS 6.2 software, it was found that section P297 scour occurred with a maximum depth of 0.2412 meters when the discharge condition was bank-full. With this, the calculation results using the HEC-RAS 6.2 software and the Ripley Equation had a minimal difference, namely 0.0412m. Figure 3 shows the process of collecting data on community service activities. The sediment sampling process, Flow velocity measurement, HEC-RAS modelling, and cross-section design were among them.

For the design alternative, constructing a steel sheet pile-type cliff protection structure was one form of planning to protect river cliffs. The characteristic feature of steel sheet piles was that they were slender in shape by relying on clamping resistance at the depth of their impingement. They could also be combined with an anchor/anchored system adapted to the design results to solve problems on riverbanks. Three bend locations were analyzed from the scour modeling results, and the required steel sheet pile needs will be calculated. The steel sheet pile used was the W400 type with a width of 400 mm, a height difference of 100 mm, and a thickness of 10.5 mm. After identifying the typical sheet pile that will be used, a calculation was carried out on the elevation of the steel sheet pile that will be piled and planted. The main requirement of the steel sheet pile erection was that the foot foundation of the steel sheet pile must be more profound than the maximum scour. The analysis results used a typical W400 sheet pile with a length of 10 meters and an embedded sheet pile of 8 meters (4/5H) appearing on the surface of 2 meters. The following are the results of calculations for the design of steel sheet piles and the elevation of the base pile steel piles.

Because the flow velocity at the review location tended to be not too large and was below the average speed limit for 200 mm grain-size crushed stone, which was 3.9 m/s, gabions could be used as an alternative to riverbank protection. After preparing the work plan, it was necessary to calculate the costs needed to build the planned structure. The preparation of this Budget Plan referred to the Regulation of the Minister of PUPR No.28/PRT/M/2016 concerning Guidelines for Analysis of Unit Prices for Public Works and Minister of PUPR Regulation Number 1 of 2022 concerning Guidelines for the Preparation of Estimated Costs of Construction Works in the Public Works and Public Housing Sector. AHSP calculations were needed to calculate the cost of labor, materials, and equipment to get unit prices for certain types of work. This unit price analysis stipulates a calculation of the unit price of wages for labor, materials, and equipment as well as work which is technically detailed based on a work method and assumptions (Minister of Works and Public Housing et al., 2016). By those described in a technical specification, design drawings, and unit price components for rehabilitation/maintenance activities and infrastructure improvement. The recapitulation of the proposed budget is presented in Table 1. Table 1 illustrates development costs and can be adapted for other locations with similar cases and adjusted to the location, conditions, and users' needs.

From the analyses in this study, recommendations have been made to overcome the problem of cliff damage due to the scouring of the river currents that pass through Atirompe Village, Majalaya District, which has threatened the surrounding residential environment. Recommendations from the results of the studies and analyses were conveyed through Focus Group Discussion (FGD) activities: Assistance in the Design of Citarum River Cliff Protection Due to River Erosion in Majalaya District, Bandung Regency by the Center for Water Resources Development (PPSDA – ITB) to related agencies such as BBWS, Village/District apparatus, Garda Caah Community, Jaga Balai Community and Destana (Disaster Response Village) which was held on 27 August 2022 (Junnaedhi et al., 2017; Rohmat et al., 2022).

The mentoring process has been held since the start of research activities to help the local community. Assistance activities included analysis of community needs based on discussions and interviews, surveys of research locations, data collection, and outreach. The mentoring process also bridged discussions between academics, policymakers, communities, and society (Junnaedhi et al., 2017). Other

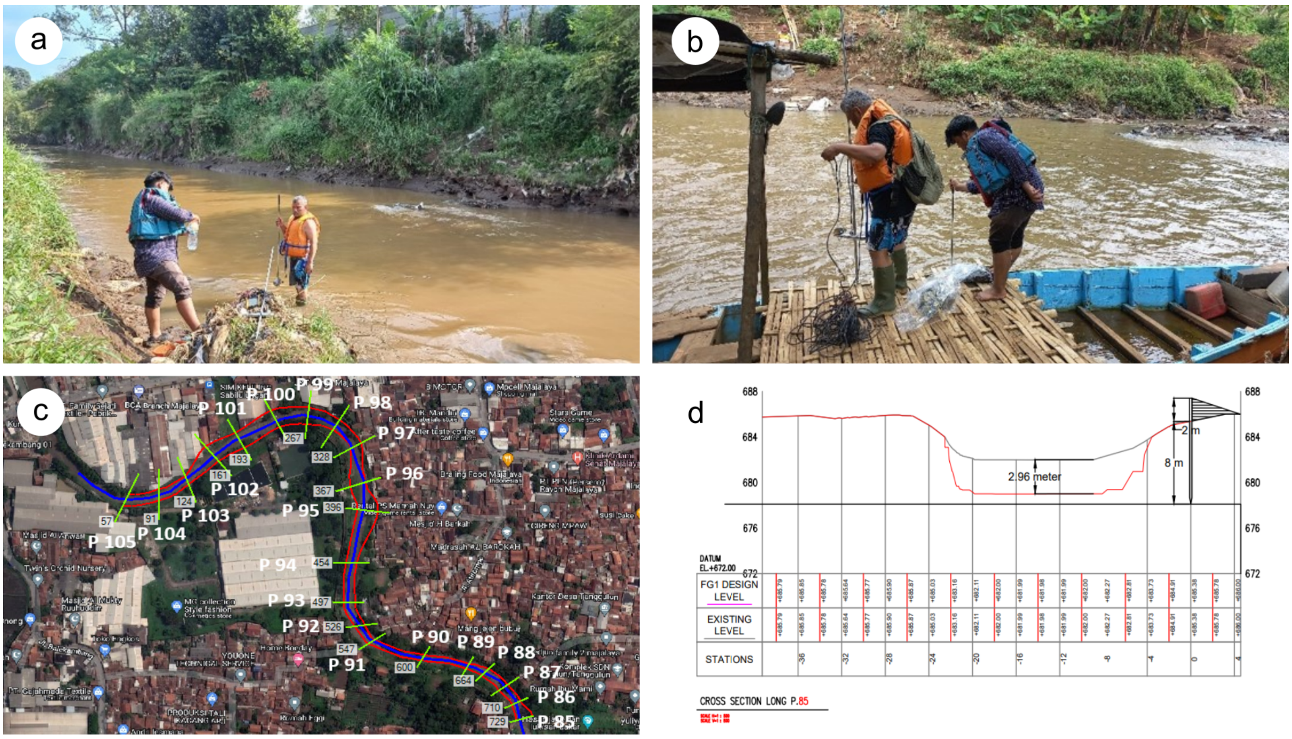

Figure 3 . (a) Sediment sampling; (b) Flow velocity measurement; (c) HEC-RAS modelling; (d) Cross-section design

Table 1 . Budget recapitulation

No.	Quantity	Unit	Work Description	Work Price Unit	Total Price
			I. Preparatory Work		
1	18.00	m²	Make directors keet	IDR877,684.05	IDR15,798,312.90
2	1.00	Ls	Tool mobilization	IDR100,000,000.00	IDR100,000,000.00
3	607.00	m	Measurement and installation of Bouw Plank	IDR53,744.00	IDR32,622,608.00
4	1.00	unit	Creating job boards	IDR1,505,497.87	IDR1,505,497.87
			II. Implementation Work		
5	298.39	m³	Excavation work	IDR123,781.81	IDR36,935,254.29
6	298.39	m³	Excavation setting	IDR32,080.96	IDR9,572,637.65
7	3178.87	m³	Masonry installation work	IDR370,355.02	IDR1,177,310,462.43
8	116.79	m²	Concrete block formwork installation work	IDR925,355.55	IDR108,072,274.68
9	973.28	m	Installation of dolken crows d = 8 - 10 cm	IDR158,205.75	IDR153,978,492.36
			III. Completion Work		
10	18.00	m²	Disassemble directors keet	IDR13,301.43	IDR239,425.74
			Total		IDR1,636,034,965.92
			PPN 11%		IDR179,963,846.25
			Total + PPN 11%		IDR1,815,998,812.17
			TOTAL		IDR1,815,998,812.17
			Be Rounded		IDR1,816,000,000.00

studies that are quite relevant to this community service activity include Updating Standard Operating Procedures and Flood Vulnerability Maps for Strengthening Community-Based Flood Early Warning Systems in South Bandung, Force (Flood Resilience Community Enhancement) – Increasing Community Resilience Against Floods, and Development of Science Audience (Citizen Science) in Flood Risk Reduction (Marchezini et al., 2017; Paul et al., 2018). These studies were conducted in Majalaya District using the bottom-up approach. The relevance of community service activities and other research results related to efforts to control the destructive power of water, increase institutional capacity, and gather public participation.

The research was conducted based on the needs of the results of discussions and interviews with the community. The benefits gained by embracing the community's involvement were data and real problems in the field. In addition, the community's responses as a representative of society were essential in implementing this activity. The support provided by the community for this study was beneficial in the research process.

4. CONCLUSION

GPS measurements have shown that the riverbank has experienced landslides since 2013, with a measured elevation decrease of 3.8–4.2 m. To prevent further disaster, the riverbank must be protected with a 50 m-long river protection structure. An alternative design was recommended, constructing a protective structure using steel sheet piles. The steel sheet pile uses a typical W400 sheet pile with a length of 10 meters with an embedded sheet pile length of 8 meters (4/5H); therefore, the sheet pile part that appears on the surface is 2 meters. Because the flow velocity at the observation site tends to be not too large and is below the average speed limit of crushed stone grain size 200 mm, gabions can also be used as an alternative for riverbank protection. Using the standard unit price, the total price for this protection is 1.8 billion rupiahs. The community can use the results of the recapitulation of the costs of this research activity as a basis of reference for submitting funding to the stakeholders involved and absorbing the company's CSR funds.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

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