Jurnal Teknik Sipil & Perencanaan 27 (1) (2025) p 64 - 74

JURNAL TEKNIK SIPIL & PERENCANAAN

10.15294/jtsp.v27i1/12515

http://journal.unnes.ac.id/nju/index.php/jtsp/index

Analysis of Bed Load in Cibanjaran River, Tasikmalaya Regency, West Java

Ahmad Fakhrur Rozi[1, a)] dan Rakhmat Yusuf[2]

[1]*Civil Engineering Study Program, Faculty of Technology and Vocational Education, University of Education Indonesia*

[a)]*email: fakhrur751@upi.edu*
[b)]*rakhmatyusuf@upi.edu*

Abstract. Cibanjaran River is one of the rivers located in the Galunggung Mountain area, with abundant sand sources, so there is sand mining. Cibanjaran River experiences the impact of mining, one of which is sedimentation. This study aims to determine the mass and mass distribution of bed load of Cibanjaran River from upstream to downstream. It also analyzes the gradation of basic sediments, sediment transport with the Schoklitsch method (1935), and simulations using HEC-RAS 6.5 software. Based on the results of the study, the upstream bottom sediment is poorly graded gravel with sand, the middle is well-graded sand with gravel, and the downstream is poorly graded gravel with sand. It has a specific gravity of 2.75 - 2.8. The mass transport of bottom sediment using the Schoklitsch calculation method is upstream 22,383.53 tons/day, middle 7,844.56 tons/day, and downstream 10,561.30 tons/day. While the results of the HEC-RAS 6.5 simulation produced a mass of sediment transport in the upstream Sta. 10833, which is 26,217.41 tons/day, in the middle of Sta. 6399 is 4,502.31 tons/day, and downstream Sta. 13 is 10,517.47 tons/day. The results of calculations and simulations can be a reference in strategic planning to mitigate the impact of sedimentation, so it is necessary to control mining activities and optimize sediment control infrastructure to maintain the sustainability of the river ecosystem and minimize negative impacts on surrounding communities.

Keywords: Bed Load, Sedimentation, Schoklitsch, Sand mining

INTRODUCTION

A river is a naturally formed water flow on the Earth's surface that collects and distributes water from a high area to a lower area, which is finally accommodated in a lake or sea. Cibanjaran River, located in Tasikmalaya Regency, has a radial pattern that drains water from Mount Galunggung's slopes and is a tributary of the Ciwulan River. It is used for agricultural or fisheries purposes and to meet the surrounding community's needs.

The Galunggung Mountain area of Tasikmalaya Regency has abundant sand resources, so there are many sand mines at that location. Some studies compare the strength of concrete in Galunggung Sand with Cimalaka Sand; the result is that Galunggung Sand has a higher concrete compressive strength than Cimalaka Sand. [1]. Miners wash the sand to produce quality sand. However, the right technology does not support washing, so the mud element is carried in the river flow, which causes sedimentation in the Cibanjaran River. [2]. Another study mentioned that sand mining in the Sukaratu Sub-district harms land and water conditions. [3]. The negative impact on water is the occurrence of sedimentation or sediment buildup, which occurs in the Cibanjaran River.

Sedimentation in the watershed is the process of deposition of sedimentary materials transported by river water flow, which results in a river delta, reduction of the wet cross-section of the river, and narrowing of the watershed. Meanwhile, sediments are formed due to weathering, erosion, transportation, deposition, or hardening processes in a river basin. Sediment is a product of the disintegration and decomposition of rocks. [4]. The scope of disintegration is the process by which rocks are broken into small grains without changing their chemical composition. At the same time, decomposition includes carbonation, hydration, oxidation, and solution processes. Sediment properties can be described as characteristics of mineral grains that include size, shape, specific weight, specific gravity, and fall velocity. [5].

Sediment transport, also called Sediment Transport, is the displacement of granular (non-cohesive) sedimentary material by water that is flowing in the direction of flow, and the amount of sediment transport T is determined from the displacement of a sediment through a cross-section over a sufficient time. [6]. Three types of sediment transport occur in the river channel: Wash Load or Washing Sediment, Suspended Load or Laying Sediment, and Bed Load or Basic Sediment. [7]. *Wash Load or Wash Sediment is a sediment consisting of silt and clay particles that are carried into the river and remain drifting until they reach the sea, or other puddles, and are derived from the weathering process or the weathering process of the watershed land surface, which mainly occurs before the dry season. Suspended Load or Lay Sediment is a sediment of fine sand that floats in the flow because the turbulence of water flow buffers it, and can be the third type of transport if the flow velocity decreases. Bed Load or Basic Sediment is a sediment of large materials with larger grains that move sliding (translate), rolling (rotate) one above the other on the riverbed. The movement reaches a certain depth of the river bed layer. The driving force is the flow's drag or tractive force against the particles.*

The size of sediment particles in a river is diverse because they come from different erosion and water conditions. The diameter of the particle size of a grain reflects the presence of a particle of a different type, the resistance of a particle to weathering, erosion, or abrasion, and the process of transport and deposition of various materials. [8].

Sedimentation that occurs today in the Cibanjaran River, causes a decrease in the ability of the river to hold water so that flooding occurs in the downstream area and reduces water discharge at Situ Gede Tasikmalaya Regency, so it is necessary to conduct research on the mass of bottom sediment and simulate its distribution to find out how sedimentation occurs and can find out the phenomena and conditions that occur. If this continues, it can harm the environmental balance and function if sand mining is not appropriately managed. [9]. This research aims to determine the gradation of basic sediments in the Cibanjaran River, the amount of basic sediment transport by empirical methods in the Cibanjaran River, and to simulate the distribution of basic sediments at the bottom of the Cibanjaran River.

METHODOLOGY

This research was conducted in the upper, middle, and lower reaches of the Cibanjaran River. Data collected included sediment samples, location maps, rainfall data, temperature data, and land-use maps.

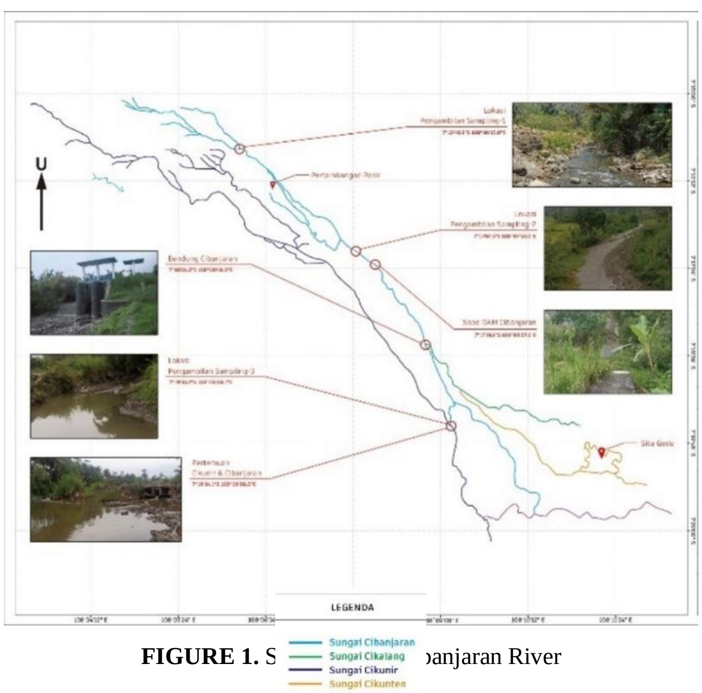

FIGURE 1. S anjaran River

This research design uses surveys and modeling. Surveys were conducted for bed sediment collection, river condition observations, and other research observations. The location of bed load sampling in Cibanjaran River is as shown in the Cibanjaran River scheme, in the upstream, namely in Sinagar Village, Sukaratu District, Tasikmalaya Regency, West Java with coordinates 7°15'41.0 "S 108°06'12.3 "E, which is a natural river area without being disturbed by significant activities other than human activities. The middle location is Jl. Cisinga, Sinagar, Kec. Sukaratu, Tasikmalaya Regency, West Java, with coordinates 7°17'07.3 "S 108°07'53.0 "E, is located after sand mining and before the Sabo dam and dam building. And downstream in Tawangbanteng, Sukaratu sub-district, Tasikmalaya regency, West Java, coordinates 7°19'33.2 "S 108°09'08.1 "E, which is the location after the building of Sabo Dam Cibanjaran and Cibanjaran Dam. Then, for hydrological analysis, rainfall data were selected based on the nearest rainfall stations: Gunung Satria, Tejakalapa, and Cikunten Stations.

Modeling analysis using HEC-RAS 6.5 software, one of which is used to simulate the distribution of bottom sediments in the Cibanjaran River by inputting field data, numerical results of sediment gradation, and data obtained from processing results. A sieve test is carried out using a sieve shaker tool to determine the gradation of basic sediments. Meanwhile, the Schoklitsch 1935 method and simulation results from HEC-RAS 6.5 software were used to determine the value of sediment transport. Schoklitsch is a scientist who first used water discharge parameters to determine bed load. [10].

The basic sediment transport formula based on Schoklistsch is as follows:

$$Q_b \quad = 2{,}5\,.\left(S^{\frac{3}{2}}\right).(q - q_o)Q_b = 2{,}5\,.\left(S^{\frac{3}{2}}\right).(q - q_o)$$

Which one:

$$q_o \quad = 0{,}00532\,.\frac{D_{50}}{S_0^{4/8}} \quad (m^3/s)$$

The volume of basic sediment fill for the entire width of the river is as follows:

$$T_b \quad = Q_b \text{ x } B$$

Description:

Q_b = Bed sediment transport discharge (m3/s)/m
D_{50} = 50% sediment diameter (mm)
q = River discharge (m3/s)
S_0 = Slope of the river bed
T_b = Volume of base fill for the entire river width (m3/s)
B = River Width (m)

Furthermore, the grain size classification is based on the American Geophysical Union (AGU), as in Przedwojkski's book. [11] As follows:

TABLE 1. Grain Size Classification According to the American Geophysical Union (AGU)

Interval/Range (mm)			Name
4096	-	2048	Very Large Boulders
2048	-	1024	Large Boulders
1024	-	512	Median Boulders
512	-	256	Small Boulders
256	-	128	Large Cobbles
128	-	64	Small Cobbles
64	-	32	Very Coarse Gravel
32	-	16	Coarse Gravel
16	-	8	Medium Gravel
8	-	4	Fine Gravel
4	-	2	Very Fine Gravel
2	-	1	Very Coarse Sand
1	-	1/2	Coarse Sand
1/2	-	1/4	Medium Sand

Interval/Range (mm)			Name
1/4	-	1/8	Fine Sand
1/8	-	1/16	Very Fine Sand
1/16	-	1/32	Coarse Silt
1/32	-	1/64	Medium Silt
1/64	-	1/128	Fine Silt
1/128	-	1/256	Very Fine Silt
1/256	-	1/512	Coarse Clay
1/512	-	1/1024	Medium Clay
1/1024	-	1/2048	Fine Clay
1/2048	-	1/4096	Very Fine Clay

The flow chart in this study is as follows:

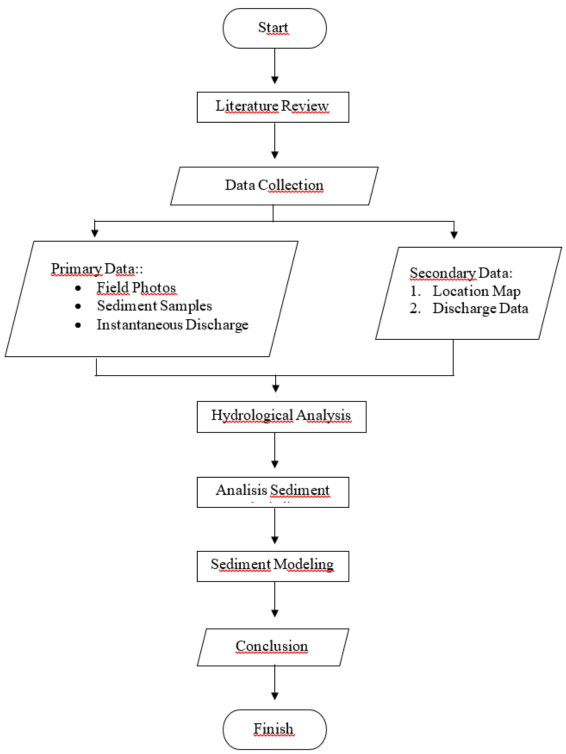

FIGURE 2. Research Flow Chart

RESULTS AND DISCUSSION

Sediment gradation is obtained from the sieve test results using a sieve shaker tool, which then receives data from soil presentation passes and is retained based on different sieve diameters. The samples tested were 1000 grams, which had been dried first in a drying machine for 1 × 24 hours with a temperature of 110 ± 5 0C. Based on the results of sample testing, the percentage level of grain types based on sieve passes is adjusted based on the Grain Size Classification table according to the American Geophysical Union (AGU) in Przedwojkski's book [11], and grain descriptions based on SNI 6371: 2015 on Procedures for Classifying Soils for Engineering Purposes with the Soil Unification Classification System (ASTM D 2487-06, MOD). The classification and description of grains at the Cibanjaran River Study site are as follows:

- In the Upper Cibanjaran River, the percentage level of gravel grain types is 56.04%, sand is 42.97%, and mud or clay is 0.99% of the total sediment sample. Based on this percentage, the grain samples in the Upper Cibanjaran River are gravel samples poorly graded with sand.
- In the middle of Cibanjaran River, the percentage level of gravel grain types is 39.32%, sand is 29.87%, and mud or clay is 20.81% of the total sediment sample. Based on the percentage obtained, it can be categorized that the grain sample in the middle of the Cibanjaran River is a well-aggraded sand sample with gravel.
- In the Lower Cibanjaran River, the percentage level of gravel grain types is 43.41%, sand is 42.68%, and mud or clay is 13.91% of the total sediment sample. And based on this percentage, it can be categorized that the grain sample in the Lower Cibanjaran River is a poorly graded gravel sample with sand..

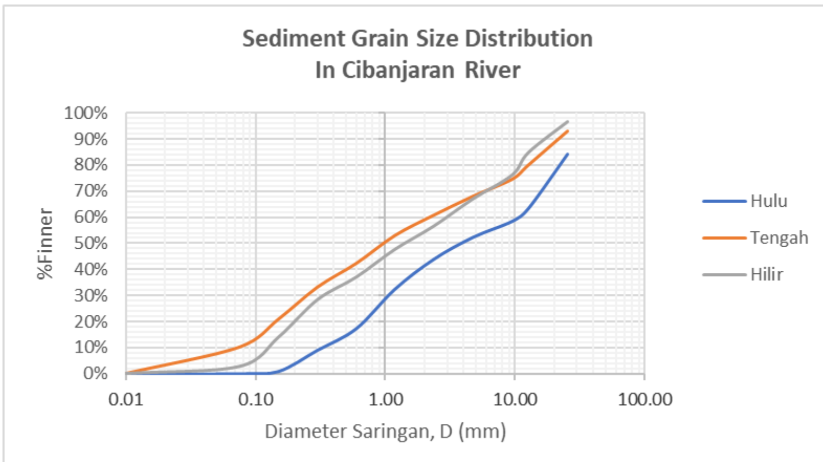

FIGURE 3. Sediment Grain Size Distribution Graph

Based on the graph above, the middle of the Cibanjaran River has a finer grain type than the downstream. This is because sand mining is upstream in the Central Study Location of the Cibanjaran River, which causes erosion either due to mining or human activities. In addition, it is also influenced by the existence of the Cibanjaran Dam and the Cibanjaran Sabo Dam downstream, causing the slope of the riverbed to change with the building, so that it makes a new slope, where the new slope has a smaller slope value than the old slope before the river building. The speed in the middle of the Cibanjaran River tends to slow down, and because of these various factors, fine grains accumulate in the middle of the Cibanjaran River. The location scheme based on the slope of the Cibanjaran Riverbed is as follows:

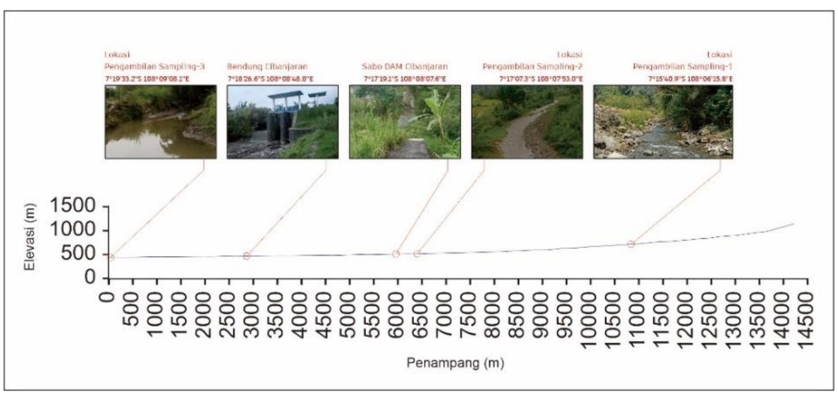

FIGURE 4. Schematic of Cibanjaran Riverbed Slope

The specific gravity value of the study samples based on the testing obtained for the Upper Cibanjaran River is 2.8419 which has a reasonably high category, indicating that the sediments in the upper reaches are primarily composed of heavy minerals or denser particles, in the Middle Cibanjaran River is 2. 7681 is slightly lower than upstream, which could reflect an increase in the proportion of finer grains (such as silt and clay), which usually have a lower specific gravity. In the Lower Cibanjaran River 2.7577, which is the lowest value of the three locations, this indicates that the sediments in the downstream contain more material with a lower specific gravity, which may be caused by an increase in the content of silt and clay.

As for the sieve test, the middle location has a finer sediment composition than the downstream location. While in the specific gravity test, the specific gravity value of the center is greater than that of the downstream. Therefore, even though the sediments downstream are coarser, the specific gravity downstream is smaller than in the middle because specific gravity depends on the mineral composition of the sediment, not just the grain size. Coarser sediments downstream may contain minerals with lower specific gravity, such as quartz, common in the river, rather than heavy minerals such as magnetite, which may be more dominant in the middle of the river. Therefore, despite their larger size, their mineral composition can be lighter.

Sediment transport analysis uses an empirical method based on Schoklitsch's equation. The process was chosen because previous researchers often used the method, and it became a reference. Besides, Schoklitsch is unique because the method dominates the sediment transport calculation based on discharge. The amount of sediment transport with the Schoklitsch method [10] Which is as follows:

TABLE 2. Sediment Mass Transport with the Schoklitsch Method

T (Year)	Q (m3/s)	Solid Sediment Mass (ton/day)			Solid Sediment Mass (ton/year)		
		Upstream	Midstream	Downstream	Upstream	Midstream	Downstream
2	68.60	11748.35	4117.35	5543.27	4288147.53	1502831.05	2023292.69
5	84.20	14419.99	5053.65	6803.84	5263296.31	1844582.85	2483400.32
10	94.70	16218.21	5683.86	7652.30	5919646.44	2074608.10	2793088.16
20	104.90	17965.05	6296.06	8476.51	6557243.72	2298061.20	3093927.77
25	107.30	18376.07	6440.11	8670.45	6707266.61	2350638.40	3164713.56
50	119.60	20482.56	7178.35	9664.36	7476133.91	2620096.55	3527490.73
100	130.70	22383.53	7844.56	10561.30	8169989.77	2863266.10	3854875.01

Based on the results of the Schoklitsch method, the parameters that significantly affect the size of sediment transport are the magnitude of the discharge value and the condition of the river cross section, following its uniqueness that dominates the sediment transport equation based on the discharge there is a relationship between discharge and sediment mass as can be seen in the following graphs and relationship patterns.

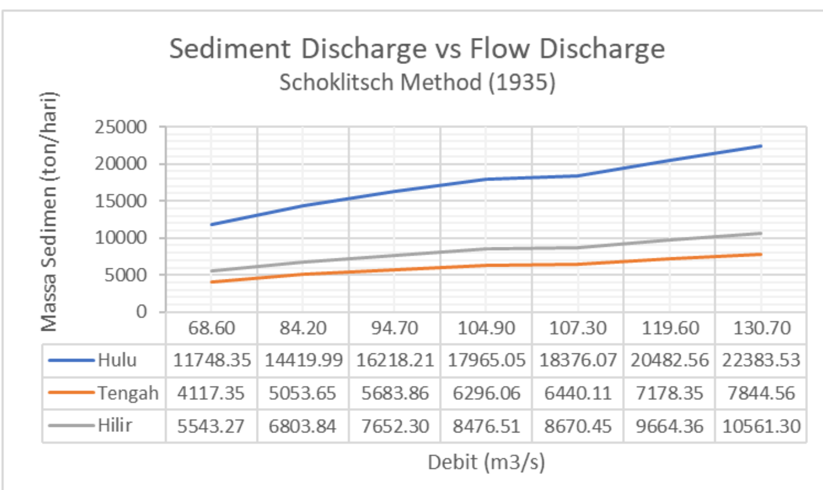

FIGURE 5. Pattern of Sediment Mass Transport Relationship with Discharge Schoklitsch Method

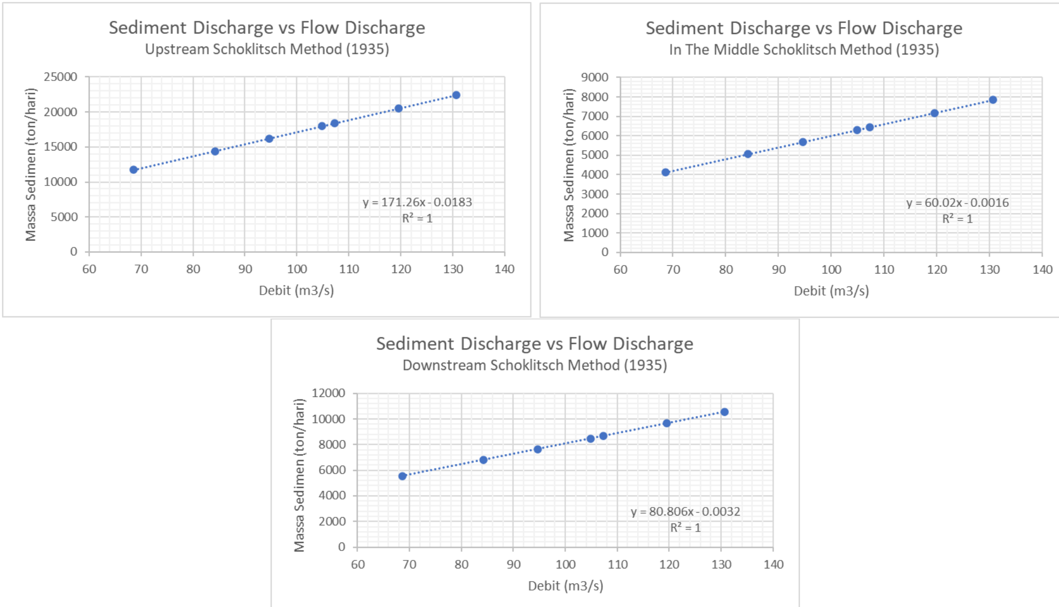

FIGURE 6. Relationship of Sediment Mass Transport with Discharge at Upstream, Middle, and Downstream Schoklitsch Method

Based on the graph, the sediment mass transport rate rises with the magnitude of the discharge value. Based on the relationship pattern, getting a regression value of 1 at each study location shows that the regression model has a perfect fit, where changes in the discharge value will fully explain changes in sediment mass transport.

The sediment mass distribution is obtained from the modeling results in the HEC-RAS software. The data used are the discharge data from the HEC-HMS software for 73 hours, river cross-section data from upstream to downstream, and sediment testing data or sieve analysis. The method used in the sediment simulation in HEC-RAS is the Toffaleti method because this method has the closest results to the original conditions in the field. The discharge used in modeling uses a return period of 2 years, 5 years, 10 years, 20 years, 25 years, 50 years, and 100 years.

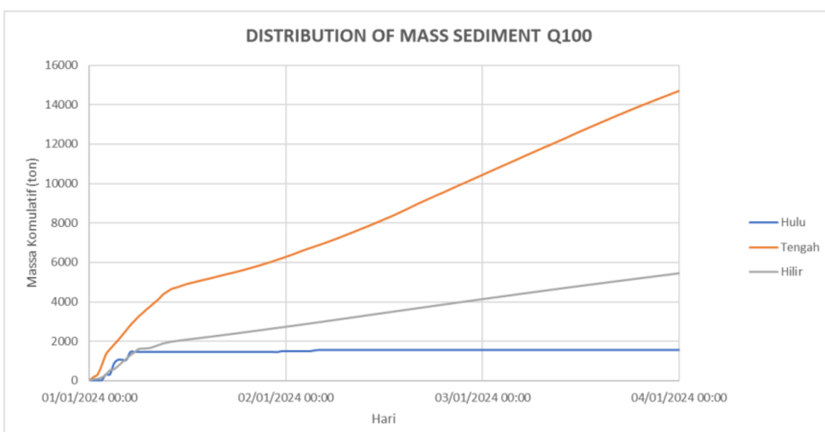

FIGURE 7. Upstream, Midstream, and Downstream Sediment Mass Distribution at 100-Year Return Period Discharge

The results of sediment mass distribution in HEC-RAS vary depending on the discharge and river cross section; the middle sediment is greater in mass distribution per day than the sediment upstream and downstream. The result of sedimentation is aggradation or degradation, as happened at the study site in the final hour after modeling. This study observed the influence of several sediment mass parameters: discharge, velocity, Froude number, base slope, and shear stress. However, of the parameters monitored, the most significant relationship to the increase or decrease in bottom sediment mass is the discharge parameter, which has a robust and significant relationship.

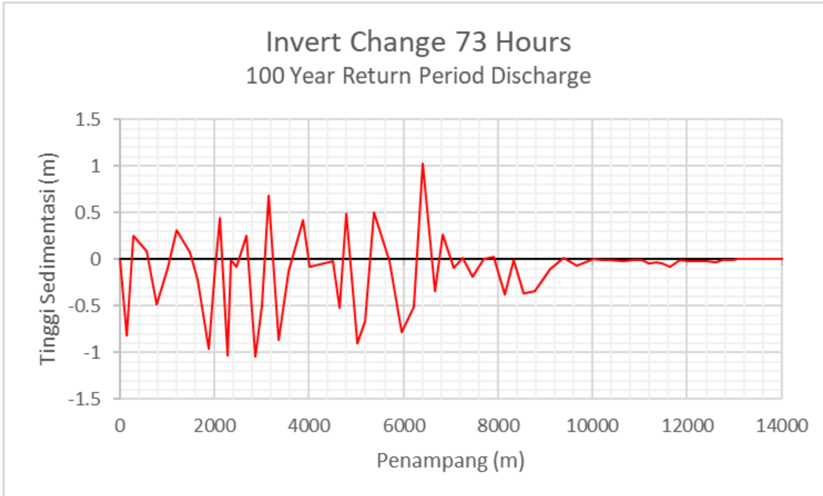

FIGURE 8. Invert Change for 73 hours at 100-Year Return Period Discharge

Based on the graph above, erosion occurs more than sediment accumulation, so that for erosion that occurs, treatment or treatment of the river cross section is needed by giving reinforcement or making sediment control buildings, such as sabo dams, in the middle of the river or other sediment control buildings. The accumulation of sediment or agradation does not occur too much, so to handle it, do dredging routinely in places that experience accumulation, especially at Sta. 6399 has the highest and most significant buildup, with a buildup as high as 1.024081 m or 14396.68 tons. This is done to maintain the condition of the river cross-section so that it is always sufficient to accommodate flood discharge.

The cross-sectional changes at the Study location are in the upper, middle, and lower reaches of the Cibanjaran River. In the Upper Cibanjaran River or at Sta. Ten thousand eight hundred thirty-three experienced a decrease in elevation in the cross-section due to sediment erosion or degradation. The degradation that occurred during 73 hours with a return period of 100 years was as high as 0.9959084 cm or 96.73762 tons.

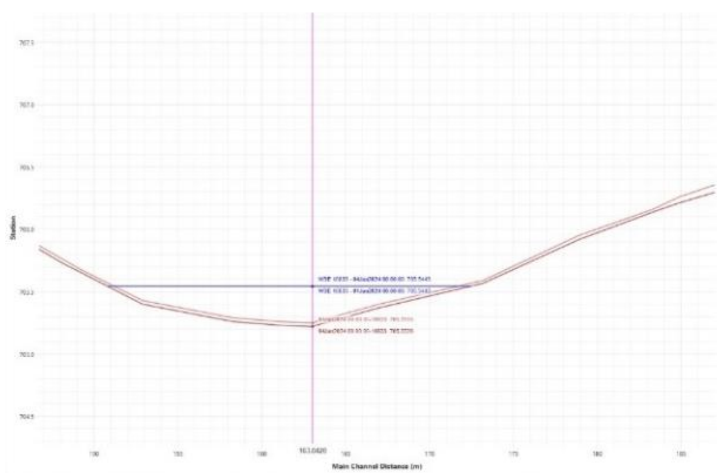

FIGURE 9. Cross-sectional changes upstream of Sta. 10833 for 73 hours

While changes in the cross section in the middle of the Cibanjaran River or at Sta. 6399 experienced aggradation or increased elevation due to sediment buildup. Agradation that occurs for 73 hours with a return period of 100 years is as high as 1.024081 m or 14396.68 tons.

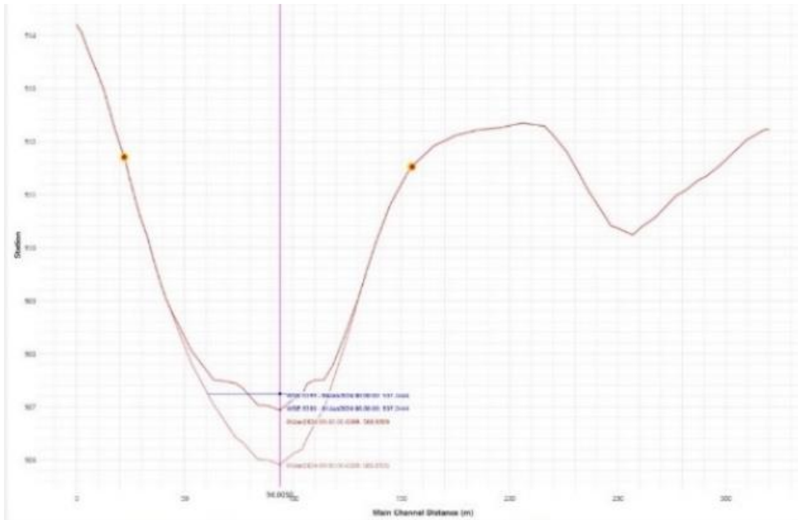

FIGURE 10. Cross-Sectional Change at Center Sta. 6399 for 73 hours

Then the cross-sectional changes in the Lower Cibanjaran River or at Sta. 13 experienced degradation or decreased elevation in the cross section due to sediment erosion. The degradation that occurred during 73 hours with a return period of 100 years was as high as 1,197794 cm or 1,559638 tons.

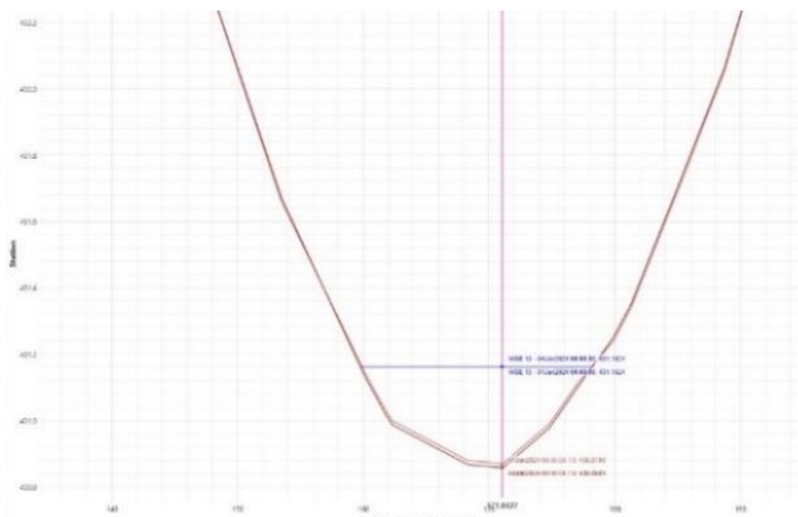

FIGURE 11. Cross-sectional Changes in Downstream Sta. 13 for 73 hours

Furthermore, the basic sediment mass transport in the Cibanjaran River, based on the simulation results using HEC-RAS 6.5 with a 100-year return period discharge, can be found in the Upper Cibanjaran River or at Sta. 10833, which is 26,217.41 tons/day, in the middle of the Cibanjaran River or at Sta. 6399 is 4,502.31 tons/day, and at the Cibanjaran River Downstream or Sta. 13 is 10,517.47 tons/day. The mass transport of bottom sediments results from the agradation and degradation of the riverbed from upstream to downstream. Degradation occurs more in the middle and downstream of the river than sediment aggradation, and upstream has a less significant change. This is influenced by several factors, one of which is the flow discharge factor flowing in the river. The comparison of sediment mass transport simulation results from HEC-RAS software with the results of the basic sediment mass transport of the Schoklitsch method (1935) in the upstream, middle, and downstream, or at Sta. 10833, Sta. 6399 and Sta.. 13 are as follows:

TABLE 3. Schoklitsch Method Bed Sediment Mass Transport and HEC-RAS Simulation Results

Study Location	Station	Schoklitsch (1935) (ton/day)	HEC-RAS (ton/day)
Upstream	10833	22383.53	26217.41
Midstream	6399	7844.56	4502.31
Downstream	13	10561.30	10517.47

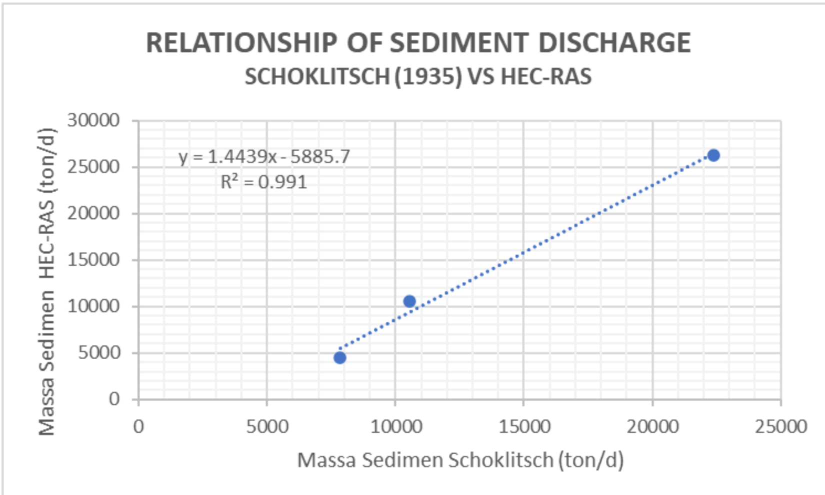

FIGURE 12. Relationship between Schoklitsch Sediment Mass Transport and HEC-RAS Simulation Results

The relationship pattern above shows that the value of $y = 1.4439x - 5885.7$ $R^2 = 0.991$, has a match rate of 99.10% and can be categorized as modeling having a perfect match. The comparison graph of the Basic Sediment Mass in the Upper, Middle, and Lower Cibanjaran River based on empirical calculations with the Schoklitsch Method (1935) and simulation results in HEC-RAS 6.5 as shown below:

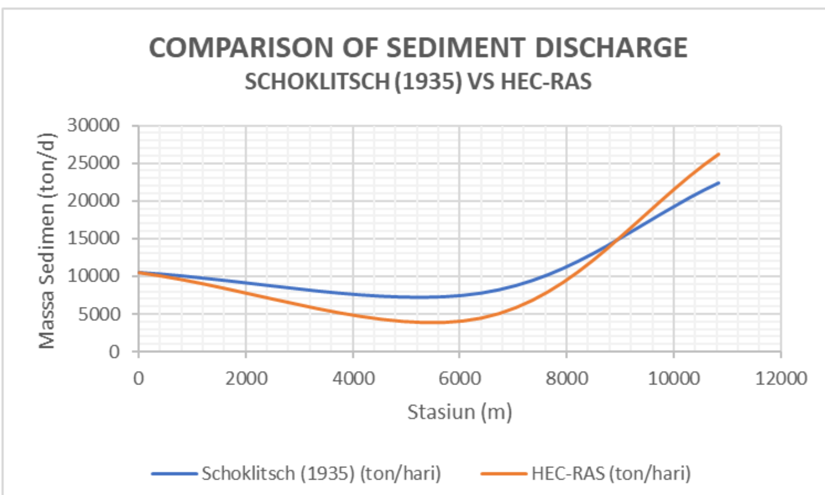

FIGURE 13. Comparison of Schoklitsch Bed Sediment Mass Transport with HEC-RAS Simulation Results

CONCLUSION

The gradation of basic sediments in the Cibanjaran River based on the results of basic sediment testing in the Upper Cibanjaran River is gravel that is poorly graded with sand, in the Middle Cibanjaran River is sand that is well graded with gravel, and in the Lower Cibanjaran River is gravel that is poorly graded with sand. Specific gravity in the Upper Cibanjaran River obtained a value of 2.8419, in the middle of the Cibanjaran River is 2.7681, and in the Lower Cibanjaran River, 2.7577. Then the amount of basic sediment mass transport using the Schoklitsch (1935) method in the study area, namely in the Upper Cibanjaran River, is 22,383.53 tons/day, in the Middle Cibanjaran River, 7,844.56 tons/day, and in the Lower Cibanjaran River, 10,561.30 tons/day. Meanwhile, based on the results of the HEC-RAS 6.5 simulation, the distribution of basic sediment mass in the Cibanjaran River based on the discharge of the return period of 2 years to 100 years produces varied data. At the discharge of the 100-year return period obtained at the Upstream of the Cibanjaran River or Sta. 10833, which is 26,217.41 tons/day, in the middle of the Cibanjaran River or at Sta. Six thousand three hundred ninety-nine is 4,502.31 tons/day, and in the Lower Cibanjaran River or at Sta. 13 is 10,517.47 tons/day. The mass transport of bottom sediments results from the agradation and degradation of the riverbed from upstream to downstream. Degradation occurs more in the middle and downstream of the river than sediment aggradation, and upstream has a less significant change. This is influenced by several factors, one of which is the flow discharge factor flowing in the river.

Based on the results of these calculations and simulations, it can be a reference in strategic planning to mitigate the impact of sedimentation, so it is necessary to control mining activities and optimize sediment control infrastructure to maintain the sustainability of the river ecosystem and minimize negative impacts on surrounding communities. And for further research, conduct a Study of the Effect of Sabo Dam Cibanjaran and Cibanjaran Weir on Basic Sediment Transport in the Lower Cibanjaran River, or perform a Check Dam Placement Study on the Upper Cibanjaran River as an Effort to Minimize Sediment Transport in the Lower Cibanjaran River.

REFERENCES

[1] D. Prasetyo, D. A., Adrilian, "Analisis Pengaruh Perbandingan Pasir Galunggung Dengan Pasir Cimalaka Terhadap Kuat Tekan Beton Mutu Rendah. Jurnal TEDC, 15(3)," 2021.

[2] R. Nuryati, "Dampak Penambangan Pasir Galunggung terhadap sosial ekonomi dan budaya masyarakat sekitar penambangan di Kabupaten Tasikmalaya," *Has. Rev..*, 2015.

[3] D. W. Suherman, D. T. Suryaningtyas, and S. Mulatsih, "Impact of Sand Mining to the Land and Water Conditions at Sukaratu Sub District, Tasikmalaya District," *J. Nat. Resour. Environ. Manag.*, vol. 5, no. 2, pp. 99–105, Dec. 2015.

[4] V. M. Ponce, *Engineering Hydrology, Principles and Practice*. New Jersey: Prentice-Hall Inc., 1989.

[5] R. Hambali and Y. Apriayanti, "Studi Karakteristik Sedimen Dan Laju Sedimentasi Sungai Daeng," *J. Fropil*, vol. 4, no. 2, pp. 165–174, 2016.

[6] P. Mardjikoen, *Transpor Sedimen*. Yogyakarta: Pusat Studi Ilmu Teknik Universitas Gadjah Mada, 1987.

[7] M. Mustakim, "Analisa Fungsi Tampungan Sedimen Pada Checkdam Sungai Alo Terhadap Laju Sedimen Ke Danau Limboto," *Gorontalo J. Infrastruct. Sci. Eng.*, vol. 4, no. 1, pp. 34–42, 2021

[8] R. Aryangganis, "Analisa Angkutan Sedimen Dasar Pada Hilir Sabodam Kali Nangka Desa Belanting Kecamatan Sambelia Kabupaten Lombok Timur," *Tek. Sipil Univ. Muhammadiyah Mataram*, vol. 7, no. 2, pp. 33–48, 2020.

[9] P. M. Hasibuan, "Dampak Penambangan Bahan Galian Golongan C Terhadap Lingkungan Sekitarnya Di Kabupaten Deli Serdang," *J. Equal.*, vol. 11, no. 1, pp. 1–5, 2006.

[10] M. Pabintan, A. S. Sukri, and T. S. Putri, "Analisis Angkutan Sedimen Dasar Pada Hilir Sungai Kambu Kota Kendari," *J. Ilm. Tek. Sipil*, vol. 7, no. 2, pp. 109–116, 2019.

[11] B. Przedwojkski, *River Training Techniques: Fundamentals, Design and Application*. 1995.