

Comparison of Manning's Roughness Coefficient Estimation Methods Based on Channel Geometry and Bed-Load Sediment Characteristics in the Way Tapus River

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Article Information	ABSTRACT
Article History Received : June 16, 2025 Revised : June 24, 2025 Published : July 10, 2025	Natural and artificial rivers contain bed-load sediment materials with varying shapes and grain sizes influencing flow resistance, velocity, and discharge. This resistance is expressed by the Manning roughness coefficient (n), whose accurate estimation is essential for hydraulic analysis. While n is commonly obtained from Manning's table, alternative methods based on hydraulic parameters, channel geometry, and sediment characteristics, such as the Keulegan, Mayer-Peter-Muller, Lane and Carlson, Henderson, Raudkivi, Subramanya, and Wong and Parker methods, can be applied for more site-specific estimations. This study utilized primary field data and secondary data to estimate n values using various approaches. The n values ranged from 0.096–0.148 (hydraulic parameters), 0.069–0.136 (channel geometry), and 0.009–0.018 (sediment-based methods). Error analysis comparing calculated and observed discharges showed that the channel geometry method yielded the most accurate results with an average error of 15.59%. In contrast, other methods resulted in significantly higher errors. Thus, the channel geometry approach is recommended for estimating the Manning coefficient in the Way Tapus River.
Keywords: <i>Manning roughness coefficient;</i> <i>Bed-load sediment;</i> <i>Flow resistance;</i> <i>Sediment transport;</i> <i>Way Tapus River.</i>	

INTRODUCTION

Way Tapus River is one of the primary rivers flowing through Bandar Lampung City and forms part of the Way Kuripan Watershed (DAS Way Kuripan). The river originates from the Betung Hills in Teluk Betung Utara District and flows downstream to the Pesawahan Sub-district in Teluk Betung Selatan District. Its flow characteristics, such as velocity, depth, and cross-sectional profile, are influenced by several factors, including channel slope, bed and bank roughness, and geometry (Montjai et al., 2015). These parameters are crucial in understanding the river's hydraulic behavior and are often used in modeling and flood risk analysis.

Preliminary field observations reveal that the upstream section of the Way Tapus River exhibits an irregular top width, a meandering flow pattern, and a relatively steep longitudinal slope ranging between 0.05% and 1%. The riverbanks are predominantly rock, while natural vegetation lines both sides of the channel. These morphological and physical characteristics directly influence the channel roughness or Manning's coefficient (n), critical in determining flow resistance, velocity, and discharge capacity. A higher roughness coefficient generally corresponds to increased flow resistance, reduced velocity, and less efficient water conveyance from upstream to downstream.

Beyond geometric and topographic features, flow resistance in open channels is also significantly affected by the characteristics of the bed material, particularly bed-load sediments. The composition of the riverbed, ranging from fine sand to coarse gravel, introduces microscale roughness that alters the hydraulic behavior of the flow. This sediment-induced roughness is a function of grain size, shape, sorting, and spatial distribution, all contributing to the frictional resistance the flow encounters. Consequently, sediment transport processes can influence Manning's roughness coefficient and affect the overall discharge estimation (Chow, 1959; Maini et al., 2020, 2021, 2024; Zhang et al., 2010).

The complexity of natural rivers such as Way Tapus often results in roughness values that are more variable and less predictable than those observed in artificial channels. Natural rivers are affected not only by sediment size and distribution but also by additional elements such as riparian vegetation, channel meanders, in-stream obstructions, and flood control structures (Arcement & Schneider, 1989; Barnes, 1969). These elements further complicate the estimation of Manning's coefficient, reinforcing the need for a more detailed analysis considering bed material properties as a significant parameter in roughness determination (Bergeron & Carbonneau, 1999; Ghani et al., 2007; Kamphuis, 1974; Limerinos JT, 1970).

Recent studies by Maini et al. (2024) emphasize the distinction between sediment-laden flow and clear water flow regarding hydraulic resistance. Sediments, suspended or transported as bed loads, increase the turbulence and bottom friction, elevating the Manning roughness coefficient. This added resistance is attributed to interactions between particles and water, which modify the flow structure and intensify energy losses along the channel bed.

Various methods have been developed to determine the Manning roughness value. One of the classical methods was proposed by Chow (1959), which classifies roughness values based on the type of riverbed material and channel surface conditions. In addition, other empirical methods have been developed, such as the Strickler (1923) approach (Bonetti et al., 2017; Serrano-Núñez et al., 2022; Strohmeier et al., 2014) which relates roughness values to sediment grain diameter, and the Cowan (1956) method which considers additional factors such as the influence of vegetation and changes in river morphology (Garde & Rangga Raju, 1966). For highly complex river conditions, a composite approach is often used by considering a combination of various elements that affect flow resistance (Aldridge & Garrett, 1973; Allen, 2014; Yen, 2002).

Several empirical and semi-empirical methods have been developed to estimate Manning's roughness based on sediment properties to address this complexity. These include the methods proposed by Keulegan, Mayer-Peter & Müller, Lane & Carlson, Henderson, Raudkivi, Subramanya, and Wong & Parker (Maini, 2024). While these methods are widely referenced in fluvial hydraulics, their relative accuracy and applicability under specific field conditions, such as those observed in the Way Tapus River, remain underexplored.

In the background of the above, this study aims to analyze the Manning roughness coefficient of the Way Tapus River based on bed-load sediment characteristics. By doing so, the study is expected to contribute to more accurate hydraulic modeling and provide a practical reference for river discharge estimation, flood risk assessment, and watershed management planning.

RESEARCH METHODS

This study directly measured hydraulic and sediment parameters in the Way Tapus River, Teluk Betung Utara District, Bandar Lampung City. Measurements include flow velocity, wet cross-sectional area, water surface slope, and sediment sampling. There are six measurement locations determined on the river cross-section, called CSSWT I to CSSWT VI (CSSWT = Cross Section of Way Tapus River), starting from upstream (CSSWT I) to downstream (CSSWT VI). These locations are shown in Figure 1.

Each measurement point is used to obtain primary data in the form of river cross-section geometry and flow velocity. Cross-section measurements are carried out using the river monitoring

method. At the same time, flow velocity is measured using the surface float method, applying a correction factor of 0.85 to estimate the average flow velocity. The data obtained from these six locations are the basis for hydraulic analysis and estimation of Manning's roughness coefficient in the Way Tapus River.

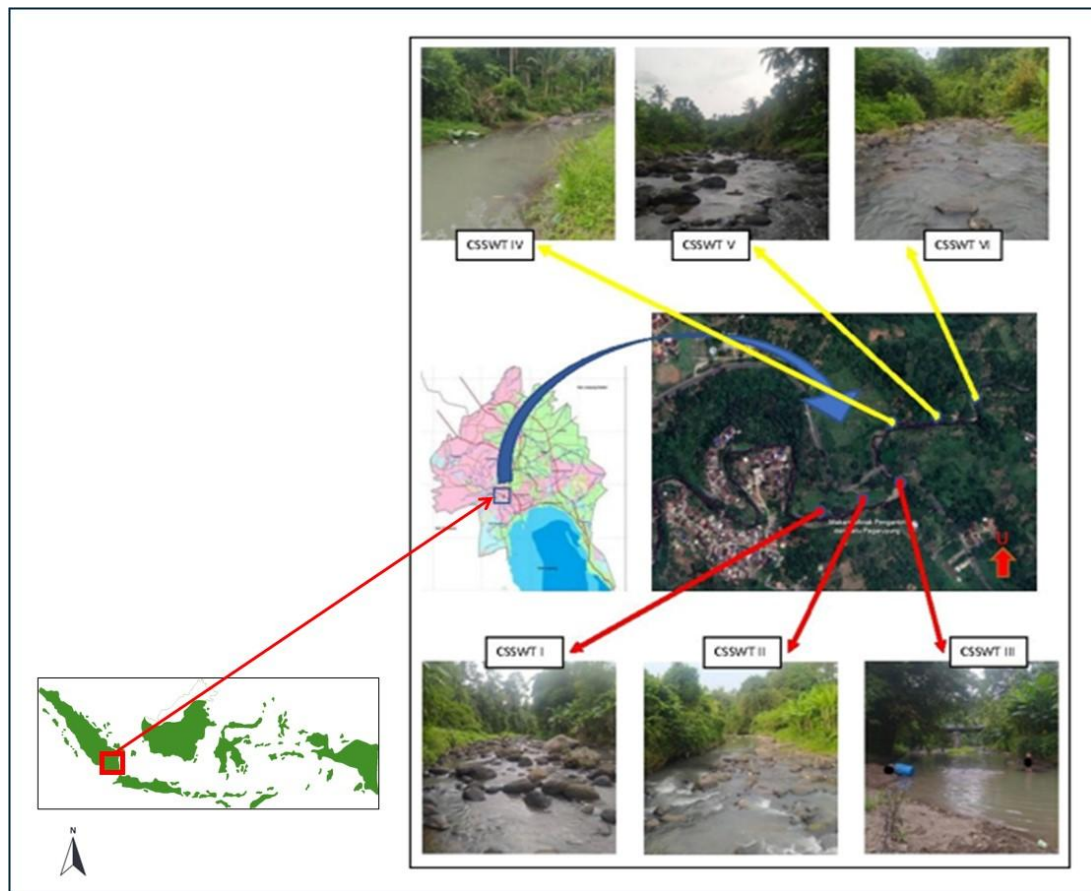


Figure 1. Research location and measurement of each cross section

Flow Velocity

Flow velocity is a quantity that indicates the distance traveled by water flow in an open channel in one unit of time. Generally, flow velocity (V) is expressed in meters per second (m/s). In the field, flow velocity measurements can be carried out using various methods, one of which is the float method.

The float method is based on the principle that the velocity of water flow can be estimated from the speed of the float (V_p) that follows the water surface current. In this method, the float is released on the surface of the flow and the time required to travel a certain distance is recorded. The flow velocity (V) is then calculated based on the float velocity, taking into account the correction for the difference between the surface velocity and the average flow velocity (Triatmodjo, 2017).

$$V_p = \frac{L}{t} \quad (1)$$

$$V = V_p \times k \quad (2)$$

Where:

L = Distance (m);

t = Time (d);

V_p = Float velocity (m/s);

k = Float Coefficient (-)

The flow velocity in an open channel can also be found using the Manning Formula or Manning Equation (Manning, 1891). The Manning Equation is as follows:

$$V = \frac{1}{n} \times R^{2/3} \times S^{1/2} \quad (3)$$

$$R = \frac{A}{P} \quad (4)$$

$$Q = A \cdot V \quad (5)$$

Where:

V = Flow velocity (m/s);

R = Hydraulic radius (m);

S = slope (-);

n = Manning's roughness coefficient value (Unitless);

A = Channel cross-sectional area (m²);

P = Wetted surface circumference of the channel (m)

The wetted cross-sectional area (A) is obtained by measuring the width of the water surface and the depth of the water. The discharge equation obtained is as follows:

Where:

Q = Flow discharge (m³/s);

A = Channel cross-sectional area (m²).

Determining Manning's Roughness Coefficient (n) Based on Hydraulic Parameters

The flow velocity in a channel, whether natural or artificial, is significantly influenced by the physical characteristics of the channel, such as surface roughness, bed slope, and the size and shape of the cross-section. One of the important parameters in hydraulic analysis is the Manning roughness coefficient, which represents the resistance level to flow. The value of this roughness coefficient is not fixed. However, it depends on various factors, including the type and level of channel surface roughness, geometric irregularities, cross-section dimensions, water level, the presence of vegetation, and sediment content. These factors collectively affect the channel's flow velocity distribution pattern and hydraulic capacity. Hence, accurately understanding roughness characteristics is important in designing and evaluating open channel flow systems. The Manning roughness coefficient value in the field can be determined through various approaches. One commonly used method is the hydraulic parameter-based approach, where the roughness coefficient value can be calculated using the following Equation (6) (Chow, 1959; Manning, 1891).

$$n = \frac{1}{V} \times R^{2/3} \times S^{1/2} \quad (6)$$

Manning's Roughness Coefficient Estimation Approach on Natural Channels Using Cowan's Method

Manning's equation is one of the most widely used empirical methods in open-channel hydraulic analysis. This equation shows quite good performance when applied to prismatic or uniform channels, such as artificial channels, where the channel's cross-sectional shape, slope, and surface conditions are relatively constant. However, in non-prismatic channels such as natural

ivers, variations in cross-sectional shape, the presence of vegetation, and irregularities in the bottom conditions of the channel cause the Manning equation to only be able to provide an approximation to the actual flow conditions.

To accommodate this complexity, Chow (1959) developed an approach to estimating the Manning roughness coefficient (n) that considers many physical factors of the channel. This approach is expressed in the form (see Equation 7):

$$n = (n_0 + n_1 + n_2 + n_3 + n_4) \times n_5 \quad (7)$$

Where:

- n_0 = material involved
- n_1 = degree of irregularity
- n_2 = variations of channel cross section
- n_3 = relative effects of obstructions
- n_4 = vegetation
- n_5 = degree of meandering.

The value of each parameter in Equation (1) is arranged based on observations of the physical condition of the channel, as summarized in Table 1.

Table 1 Value for the computation of the roughness coefficient by Equation (7)

Channel Conditions		Values
Material involved	Earth	0.020
	Rock cut	0.025
	Fine Gravel	0.024
	Coarse Gravel	0.028
Degree of irregularity	Smooth	0
	Minor	0.005
	Moderate	0.010
	Severe	0.020
Variations of channel cross section	Gradual	0
	Alternating occasionally	0.005
	Alternating frequently	0.010-0.015
Relative effects of obstructions	Negligible	0
	Minor	0.010-0.015
	Appreciable	0.020-0.030
	Severe	0.040-0.060
Vegetation	Low	0.005-0.010
	Medium	0.010-0.025

	High		0.025-0.050
	Very high		0.050-0.100
	Minor		1
Degree of meandering	Appreciable	n_5	1.15
	Severe		1.3

Source: Chow (1959)

With this approach, the obtained n value better represents the actual channel conditions, especially in natural rivers with complex characteristics. Therefore, the Cowan method can be used to calibrate roughness values in hydraulic simulations or numerical models.

Determining Manning's Roughness Coefficient Based on Sediment Transport (Bed-load)

The roughness parameters used as a representation of roughness units in laboratory experiments must be able to be applied to various types of sedimentary materials, such as sand and gravel, which have varying shapes, sizes, and distributions. In the grain size distribution analysis, it is assumed that larger particles contribute dominantly to flow roughness compared to smaller fine particles.

Determination of Manning's roughness coefficient (n) based on the characteristics of river bed material, especially the material forming the bed load, has been studied through some empirical approaches. Some methods commonly used in the literature include Keulegan (1938) [Eq. 8], Meyer-Peter & Müller (1948) [Eq. 9], Lane & Carlson (1953) [Eq. 10], Henderson (1966) [Eq. 11], Raudkivi (1967) [Eq. 12], Subramanya (1982) [Eq. 13], and Wong & Parker (2006) [Eq. 14] (see Maini, 2024). Each method proposes a formulation that links roughness parameters to the river bed grain size characteristics. The sediment grain sizes commonly used as roughness indicators are D_{90} , D_{75} , and D_{50} , which are generally known as D_n . The D_n value is defined as the diameter of a sediment particle at which $n\%$ of the total volume of material is smaller. This grain size is considered representative in characterizing the relative influence of grains on bed surface roughness and its interaction with flow type and intensity. The selection of the correct D_n value is essential in supporting more accurate roughness parameter estimation, especially in numerical and experimental studies on flow and sediment transport in open channels.

$$n = 0.039 D_{50}^{1/6} \quad (8)$$

$$n = 0.038 D_{90}^{1/6} \quad (9)$$

$$n = 0.026 D_{75}^{1/6} \quad (10)$$

$$n = 0.031 D_{75}^{1/6} \quad (11)$$

$$n = 0.042 D_{50}^{1/6} \quad (12)$$

$$n = 0.047 D_{50}^{1/6} \quad (13)$$

$$n = 0.043 D_{90}^{1/6} \quad (14)$$

RESULTS AND DISCUSSION

Manning's Roughness Coefficient Based on Hydraulic Parameters

The Manning roughness coefficient is calculated based on the river hydraulic parameters using Equation (6). The data used in the calculation are obtained from direct measurements in the field, including flow velocity, channel slope, and river cross-section profile. These values are then

used to calculate each observation location's roughness coefficient (n). The results of calculating the Manning roughness coefficient value based on hydraulic parameters are presented in Table 2.

Based on Table 2, the Manning roughness coefficient (n) values at six observation locations (CSSWT I to CSSWT VI) reflect differences in physical and hydraulic characteristics in each river segment. The highest roughness value was found at the CSSWT V location of 0.1483, followed by CSSWT II (0.1464) and CSSWT III (0.1365). Meanwhile, the lowest roughness value was found at the CSSWT IV location of 0.0959. A combination of hydraulic radius, channel slope, and flow velocity influences the difference in roughness coefficient values. For example, although CSSWT II has a relatively large hydraulic radius (0.7707 m), the low flow velocity value (0.4257 m/s) and slight slope (0.006) contribute to the high roughness value.

In contrast, in CSSWT IV, the flow velocity and channel slope are very low (0.1461 m/s and 0.001, respectively). However, the roughness value is the smallest, which may indicate a relatively smoother or more regular channel condition. The variation of n values at each location indicates that the flow's physical characteristics and the river cross-section's condition significantly affect the hydraulic roughness value. Therefore, the roughness coefficient value selection in river flow analysis needs to consider these parameters so that the hydraulic calculation results are more representative and accurate.

Table 2. Results of Manning Roughness Coefficient Analysis Based on Hydraulic Parameters

No	Location	Area (m ²)	Wet Section Perimeter(m)	Hydraulic Radius (m)	Slope	Velocity, V (m/s)	n
1	CSSWT I	8.7350	16.1181	0.5419	0.011	0.5345	0.1304
2	CSSWT II	8.7689	11.3772	0.7707	0.006	0.4257	0.1464
3	CSSWT III	9.4910	16.3682	0.5798	0.002	0.2279	0.1365
4	CSSWT IV	5.6550	11.4052	0.4958	0.001	0.1461	0.0959
5	CSSWT V	7.5325	17.4463	0.4318	0.017	0.5060	0.1483
6	CSSWT VI	5.4765	12.9631	0.4225	0.012	0.5397	0.1155

This study also compares the results of hydraulic parameter analysis against Manning's roughness coefficient by referring to various previous studies. This comparison aims to evaluate the consistency of roughness coefficient values obtained from field measurements and calculations with previous research results, especially in the relationship between hydraulic parameters such as flow velocity (V), shear velocity (V^*), and Froude number (Fr). With this approach, the study produces locally relevant empirical findings. It contributes to a broader understanding of the factors influencing channel roughness values in natural and controlled flow conditions.

Hydraulic parameters measured directly in the field play a significant role in determining flow resistance, which is represented by the Manning roughness coefficient (n) value. To understand the effect of the roughness coefficient on flow velocity and Froude number (Fr), an analysis of measurement data was conducted in the Way Tapus River. The results were then compared with data from laboratory studies using flumes conducted by Williams (1970) and Mashau (2006), as well as field studies in the Mississippi River (Toffaleti, 1968), Batu Rusa River (Maini et al., 2021), and Way Lunik River (Kiranaratri et al., 2025).

The results of the analysis of the relationship between the Manning roughness coefficient (n) and the average velocity (hydraulic parameter) to shear velocity (V/V^*) are shown in Figure 2. Data in the Way Tapus River (present study) show that the greater the value of n , the V/V^* ratio tends to decrease. It is indicated that increasing flow roughness causes the relative velocity to shear stress to become smaller.

Furthermore, Figure 3 shows the relationship between the Froude Number (Fr) value and the Manning roughness coefficient. It can be seen that the higher the Fr value, the lower the n

value. This phenomenon indicates that the flow characteristics, both supercritical and subcritical, significantly affect the magnitude of the hydraulic roughness value.

The trend of the analysis results in the Way Tapus River is consistent with experimental data from physical models of flumes (Mashau, 2006; Williams, 1970) and field data from the Mississippi River (Toffaleti, 1968), Batu Rusa River (Maini et al., 2021), Way Lunik River (Kiranaratri et al., 2025), and Way Lunik River (present study). All studies show that a decrease follows an increase in the velocity ratio (V/V^*) in the Manning roughness coefficient value. It confirms that the roughness coefficient directly influences the distribution and magnitude of flow velocity in rivers and open channels.

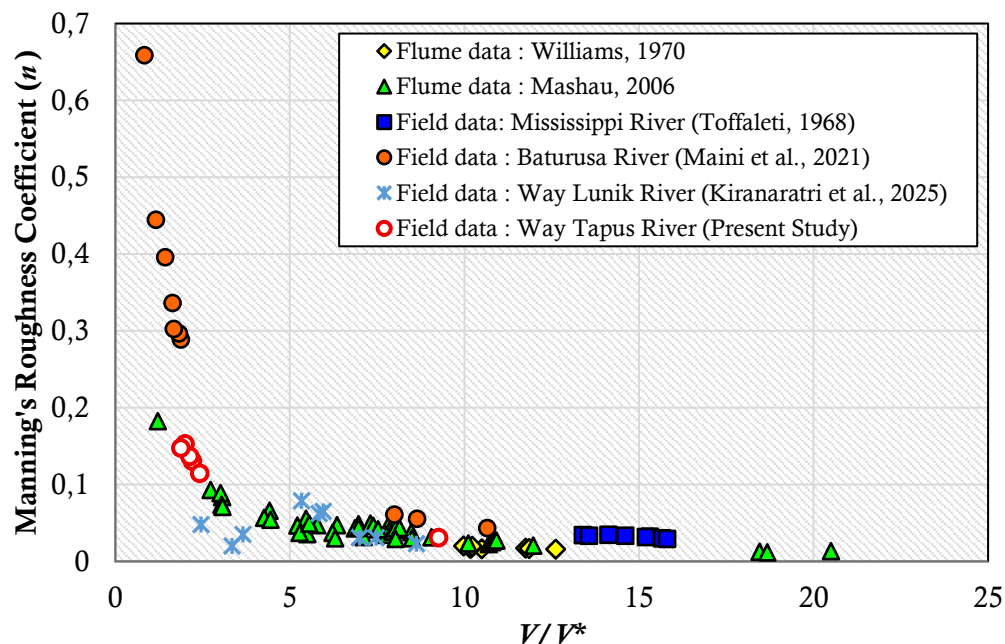


Figure 2. A comparison of the influence of velocity on the Manning roughness coefficient was made based on a review of previous studies.

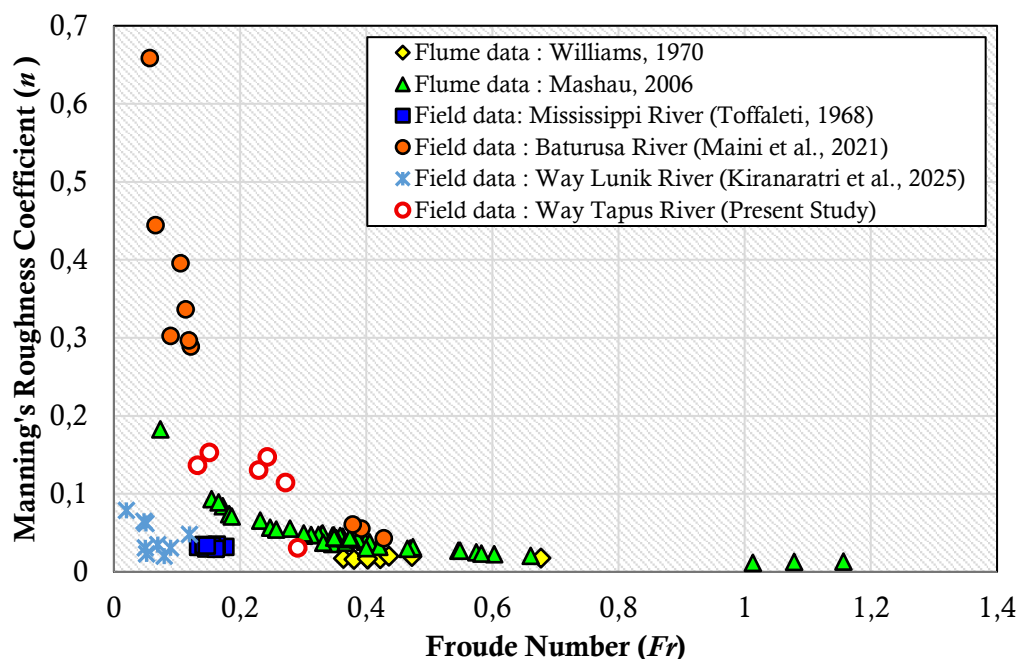


Figure 3. Comparison of the influence of the Froude number (Fr) on the Manning roughness coefficient based on a review of previous studies.

Manning's Roughness Coefficient Based on River Geometry Factors

Manning's roughness coefficient analysis at each cross-section of the Way Tapus River cross section (CSSWT) is based on river geometry data presented in Table 3. Determination of roughness values is carried out by observing the condition of the natural channel cross section in the field at six CSSWT points. Furthermore, the river characteristics are classified according to Table 1 according to Chow (1959), which includes parameters n_0 to n_5 . Manning's roughness coefficient value is calculated using Equation (7), which considers factors such as the type of river bed material, surface conditions, channel straightness, changes in cross-section, and vegetation. The calculation results show variations in Manning's roughness values (n) at each observation point, as shown in Table 3. The roughness values range from 0.069 to 0.136. The highest value was recorded at CSSWT II, which has riverbed characteristics in the form of coarse gravel and geometric conditions that tend to change and affect flow. In contrast, the lowest value is found in CSSWT IV, with river conditions covered by fine gravel and relatively frequent changes in channel geometry but not having much effect on flow.

Table 3. Results of Manning's Roughness Coefficient Analysis Based on Cowan's Geometry Method

Location	Description of Field Assessment Data in Rivers						n
	n_0	n_1	n_2	n_3	n_4	n_5	
CSSWT I	Rock cut	Severe	Alternating occasionally	Severe	Medium	Minor	0.120
CSSWT II	Coarse Gravel	Rough	Alternating occasionally	Severe	Low	Medium	0.136
CSSWT III	Fine Gravel	Moderate	Alternating occasionally	Severe	Low	Appreciable	0.122
CSSWT IV	Fine Gravel	Moderate	Alternating frequently	Appreciable	Low	Minor	0.069
CSSWT V	Rock cut	Severe	Alternating occasionally	Severe	Medium	Minor	0.120
CSSWT VI	Rock cut	Severe	Alternating occasionally	Severe	Medium	Minor	0.120

Manning's Roughness Coefficient Based on Bed-Load Sediment

The determination of the Manning roughness coefficient (n) value is greatly influenced by the characteristics of the channel bed surface, especially the type and size of the bed-load material. Bed materials of sand, gravel, and large rocks will produce different flow roughness levels. Therefore, the physical properties of bed sediment, such as dominant grain diameter, gradation, grain shape, and distribution, must be analyzed to obtain a representative roughness coefficient value. This approach is important to improve accuracy in flow hydraulic calculations, especially in open channel flow studies that involve significant sediment transport.

Table 4. Results of Manning's Roughness Coefficient Analysis Based on Sediment Transport Material (Bed-Load)

Method	Manning's Roughness Coefficient Value					
	(n)					
	CSSWT I	CSSWT II	CSSWT III	CSSWT IV	CSSWT V	CSSWT VI
Keulegan	0.0133	0.0105	0.0117	0.0130	0.0115	0.0112
Meyer-Peter and Muller	0.0155	0.0115	0.0150	0.0154	0.0142	0.0146
Lane dan Carlson	0.0181	0.0138	0.0164	0.0180	0.0158	0.0158
Henderson	0.0117	0.0089	0.0106	0.0116	0.0102	0.0102
Raudkivi	0.0143	0.0113	0.0126	0.0140	0.0124	0.0121
Subramanya	0.0160	0.0127	0.0141	0.0156	0.0138	0.0135
Wong and Parker	0.0146	0.0116	0.0129	0.0143	0.0127	0.0124

Analysis of Manning's roughness coefficient (n) values was carried out using seven empirical methods, namely the Keulegan, Mayer-Peter and Muller, Lane and Carlson, Henderson, Raudkivi, Subramanya, and Wong and Parker methods. The roughness coefficient values were calculated for six observation locations in the multi-level open channel (CSSWT I to CSSWT VI) to obtain an overview of roughness variations based on different methods (see Table 4 and Figure 4).

Generally, the highest roughness coefficient values were obtained from the Lane and Carlson method, with values between 0.0138 and 0.0181. It is indicated that this method provides conservative or higher roughness estimates than others. Conversely, the Henderson method consistently obtained the lowest values, with n values ranging from 0.0089 to 0.0117.

The Keulegan and Henderson methods showed relatively lower results than other methods, with a tendency for stable n values in the range of 0.010 to 0.013. The Mayer-Peter-Muller and Subramanya methods produce medium to high values, with n values reaching up to 0.0155 and 0.0160, respectively. Raudkivi and Wong & Parker's values show relatively moderate and consistent calculation characteristics, falling between the high and low-value methods.

Variations in n values between locations also indicate the influence of local physical conditions on hydraulic roughness. For example, at the CSSWT I location, most methods provide relatively higher values than other locations, indicating the influence of geometric factors or channel bottom surface conditions. These results indicate that the selection of Manning's roughness coefficient calculation methods must consider flow characteristics and channel physical conditions, considering the significant differences between methods. Using several methods simultaneously can help obtain a more representative range of n -value estimates and improve the reliability of open-channel hydraulic analysis results.

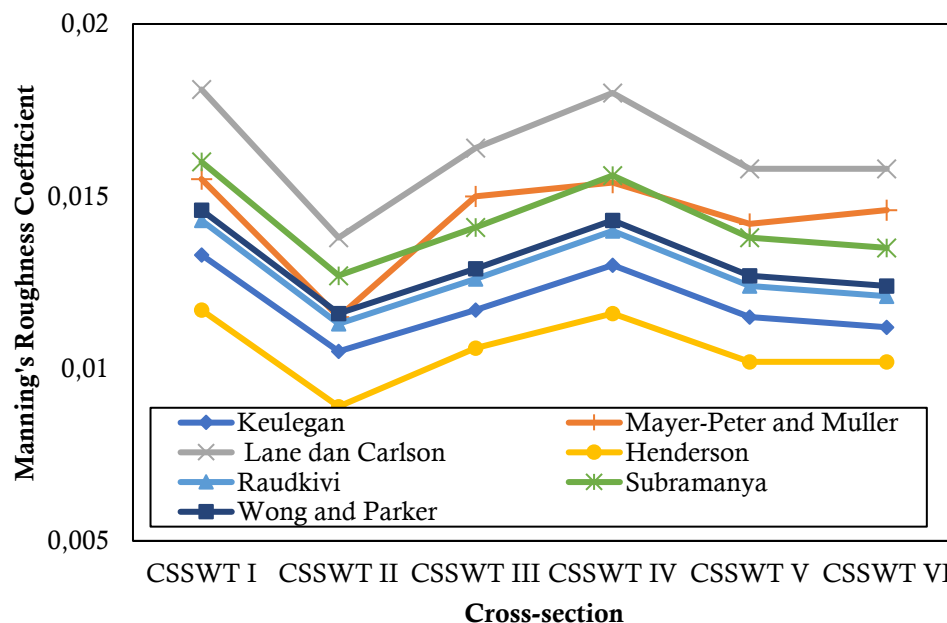


Figure 4. Manning's Roughness Coefficient Based on Sediment Transport Material (Bed-Load) Various Methods

Flow Discharge Estimation Using Manning's Roughness Coefficient Parameters

The flow velocity calculation is carried out using the Manning formula (Equation 3), where the flow velocity is greatly influenced by the value of the channel roughness coefficient (n). The value of n depends on the type of channel-forming material, where channels lined with fine soil such as clay or silt have lower flow resistance than rocky or gravel channels. It causes the flow velocity in the earth channel to be higher for the same geometry and slope conditions.

From Figure 5, it can be seen that the results of the velocity calculation using several methods provide varying values for the measured flow velocity in the field. Almost all methods show higher velocity calculation results than the measured data (above the perfect agreement line). This indicates that most methods overestimate flow velocity, especially at higher flow velocities (above 0.04 m/s).

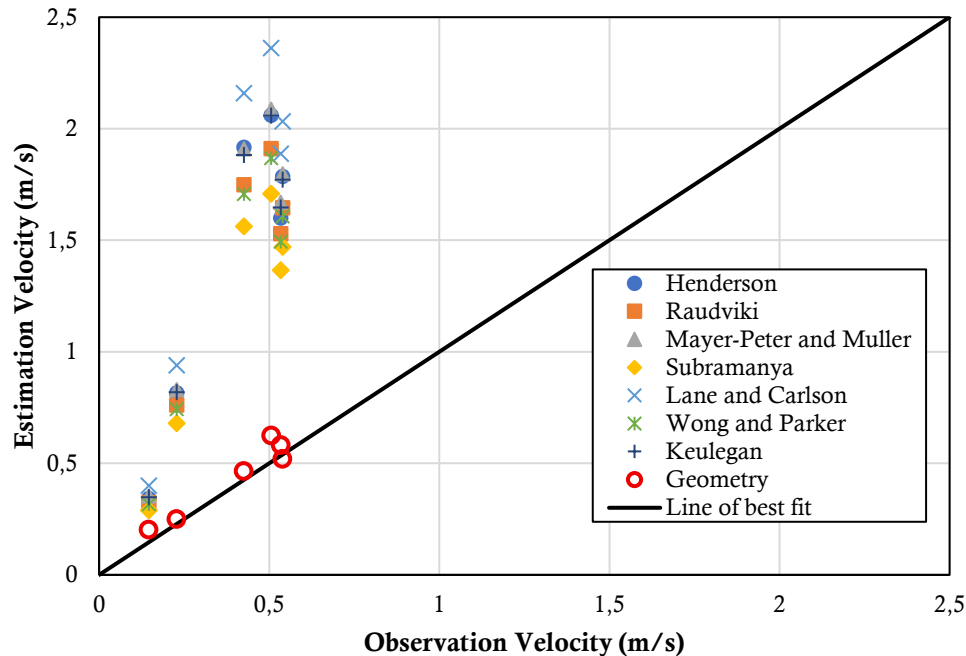


Figure 5. Comparison Between Measured Velocity and Estimated Flow Velocity Using Manning's Roughness Coefficient Parameters of Various Methods

The flow rate was calculated using Eq. (5), which is the product of the cross-sectional area of the flow and the flow velocity. Figure 6 compares the measured discharge based on geometric parameters and discharge from various empirical methods (MPM, Keulegan, Raudkivi, etc.) at six observation points (CSSWT 1 to CSSWT 6). The graphical results show that the calculation of discharge based on geometric parameters gives the closest results to the measured discharge. Meanwhile, other methods, such as Keulegan and Henderson, show a similar pattern but slightly higher than the measured discharge. In contrast, methods based on the base material gradation approach, such as the Subramaya method and MPM, show considerable variations in discharge at specific points, especially at CSSWT 2 and CSSWT 5, which causes significant deviations from the actual values (see Figures 6 and 7).

The percentage deviation is used to evaluate how much deviation there is between the calculated discharge and the actual field data. Figure 7 shows that the discharge calculation based on geometric parameters has the most minor percentage deviation, only around 15.59%. This value shows that the approach using geometric parameters (based on the Manning roughness value from the Cowan table) can more accurately represent the Way Tapus River's condition.

In contrast, other methods based on the gradation of the sediment transport bed material (bed-load), such as the Henderson, Raudviki, MPM, Keulegan, Wong and Parker, Lane and Carlson methods, show very high deviation values, ranging from 200% to 350%. It is due to several limitations, including the following: These methods only consider the parameters of bed material gradation without considering the characteristics of river walls and suspended sediments. They do not consider the influence of river shape, such as narrowings, bends (meanders), and bank vegetation that increase flow roughness. The presence of large rocks that block the river cross-section locally increases the drag effect, which is not captured by the basic bed-load model alone.

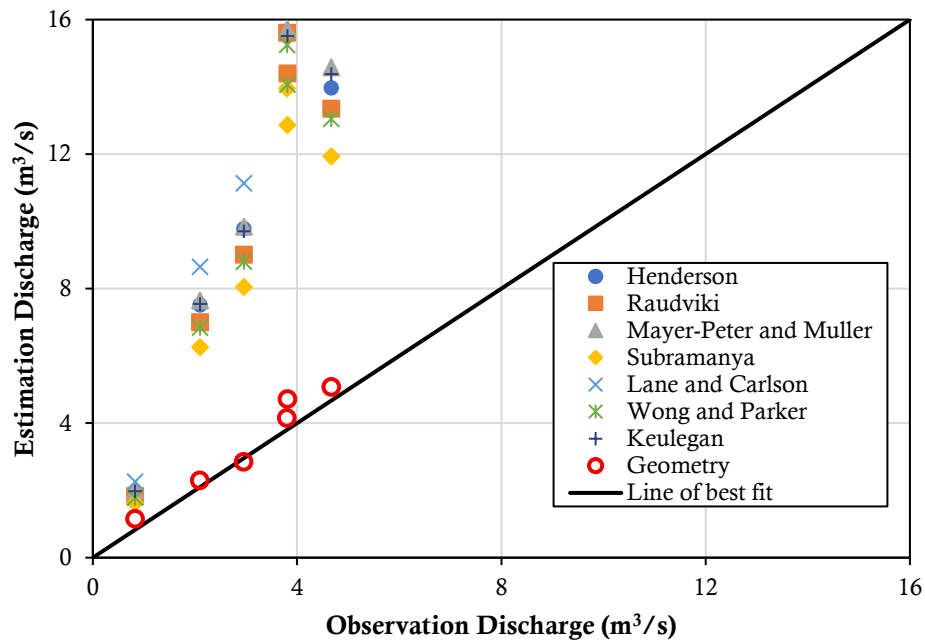


Figure 6. Comparison Between Measured Discharge and Estimated Flow Discharge Using Manning's Roughness Coefficient Parameters of Various Methods

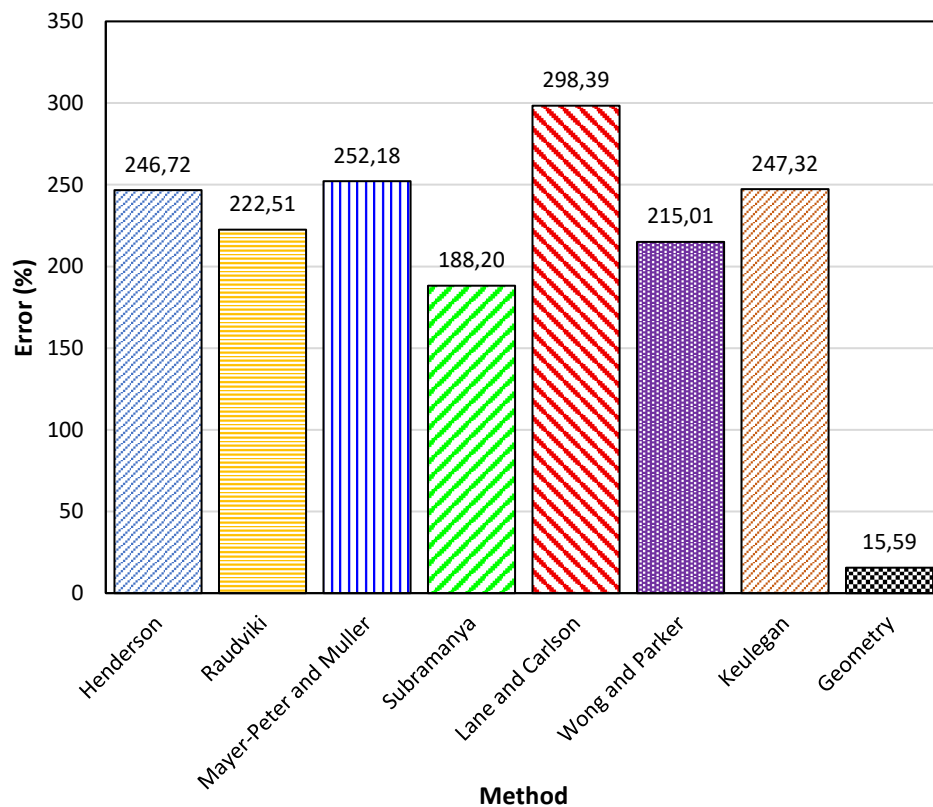


Figure 7. Average error of flow discharge calculation based on Manning's roughness coefficient from each method in the Way Tapus River.

CONCLUSION

Based on the analysis conducted in the Way Tapus River, the Manning roughness coefficients derived from hydraulic parameters ranged from 0.0959 to 0.1483, while those based on geometric parameters varied between 0.0690 and 0.1357. Meanwhile, the values obtained from sediment transport-based methods were generally lower, ranging from 0.0089 to 0.0181 depending on the method applied. Hydraulic parameters significantly influence the Manning roughness coefficient, where smoother, straighter, and steeper channels tend to have lower roughness due to increased flow velocity. Conversely, bends and certain cross-sectional shapes reduce flow velocity and consequently increase roughness values. In terms of discharge estimation accuracy, the geometric parameter approach produced the lowest average percent error of 15.76%, which is significantly smaller compared to sediment-based methods, all of which yielded errors exceeding 200%. This indicates that the geometric approach is more representative and reliable for modeling the actual flow conditions in the Way Tapus River.

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REFERENCES

- Aldridge, B. N., & Garrett, J. M. (1973). Roughness coefficients for stream channels in Arizona. In *Open-File Report* (Issue February).
- Allen, T. G. (2014). *A Study of the Variability Versus the Assumed Constancy of Manning's n* [All Graduate Theses and Dissertations, Utah State University]. <https://digitalcommons.usu.edu/etd>
- Arcement, G. J., & Schneider, V. R. (1989). Guide for selecting Manning's roughness coefficients for natural channels and flood plains (USA. Department of the interior. Geological survey water-supply paper 2339). *United States Geological Survey Water-Supply Paper 2339*.
- Barnes, H. H. (1969). Roughness characteristics of natural channels. *Journal of Hydrology*, 7(3). [https://doi.org/10.1016/0022-1694\(69\)90113-9](https://doi.org/10.1016/0022-1694(69)90113-9)
- Bergeron, N. E., & Carbonneau, P. (1999). The effect of sediment concentration on bedload roughness. *Hydrological Processes*, 13(16). [https://doi.org/10.1002/\(sici\)1099-1085\(199911\)13:16<2583::aid-hyp939>3.3.co;2-j](https://doi.org/10.1002/(sici)1099-1085(199911)13:16<2583::aid-hyp939>3.3.co;2-j)
- Bonetti, S., Manoli, G., Manes, C., Porporato, A., & Katul, G. G. (2017). Manning's formula and Strickler's scaling explained by a co-spectral budget model. *Journal of Fluid Mechanics*, 812. <https://doi.org/10.1017/jfm.2016.863>
- Chow, V. Te. (1959). *Open-Channel Hydraulics*. Ven Te Chow. McGraw-Hill, New York, 1959. xviii+ 680 pp. Illus. \$17. *Science*, 131(3408).
- Cowan, W. L. (1956). Estimating hydraulic roughness coefficients. *Agricultural Engineering*, 37(7).
- Garde, R. J., & Rangga Raju, K. G. (1966). Resistance Relationships for Alluvial Channel Flow. *Journal of the Hydraulics Division*, 92(4). <https://doi.org/10.1061/jycej.0001498>
- Ghani, A. A., Zakaria, N. A., Kiat, C. C., Ariffin, J., Hasan, Z. A., & Abdul Ghaffar, A. B. (2007). Revised equations for manning's coefficient for sand-bed rivers. *International Journal of River Basin Management*, 5(4). <https://doi.org/10.1080/15715124.2007.9635331>
- Henderson, F. M. (1966). *Open Channel Flow* (Macmillian).
- Kamphuis, J. W. (1974). Determination of Sand Roughness for Fixed Beds. *Journal of Hydraulic Research*, 12(2 (1974)). <https://doi.org/10.1080/00221687409499737>
- Keulegan, G. H. (1938). Laws of turbulent flow in open channels. *Journal of Research of the National Bureau of Standards*, 21(6). <https://doi.org/10.6028/jres.021.039>

- Kiranaratri, A. H., Pangestu, B. P., & Maini, M. (2025). Karakteristik Koefisien Kekasaran Manning pada Aliran dengan Transpor Sedimen di Sungai Way Lunik. *Jurnal Teknik Gradien*, 17(01), 1–12.
- Lane, E. W., & Carlson, E. J. (1953). Some factors affecting the stability of canals constructed in coarse granular materials. *Proc., IAHR 5th Congress*.
- Limerinos JT. (1970). Determination of The Manning Coefficient From Measured Bed Roughness in Natural Channels. *US Geological Survey Water Supply Paper*.
- Maini, M. (2024). *Pengaruh Transpor Sedimen terhadap Koefisien Kekasaran Manning di Saluran Terbuka* [Dissertation, Universitas Gadjah Mada]. <https://etd.repository.ugm.ac.id/penelitian/detail/243794>
- Maini, M., Kironoto, B. A., Istiarto, & Pamudji, A. P. (2024). Evaluating Manning's Roughness Coefficient for Flows with Equilibrium and Non-equilibrium Sediment Transport. *Jordan Journal of Civil Engineering*, 18(1), 65–80. <https://doi.org/10.14525/JJCE.v18i1.06>
- Maini, M., Legono, D., & Laksitaningtyas, A. P. (2020). Evaluasi Estimasi Koefisien Kekasaran pada Eksperimen Model Fisik. *Jurnal Ilmiah Desain & Konstruksi*, 19(1). <https://doi.org/10.35760/dk.2020.v19i1.3464>
- Maini, M., Mashuri, M., & Susanti, J. E. (2021). Efek Angkutan Sedimen Bed-Load Terhadap Hambatan Aliran di Sungai Baturusa Pulau Bangka. *Jurnal Teknik Sipil*, 28(1). <https://doi.org/10.5614/jts.2021.28.1.5>
- Manning, R. (1891). On the flow of water in open channels and pipes. *Trans. Institution Civil Engineering*, 20.
- Mashau, M. S. (2006). Flow Resistance in Open Channels with Intermediate Scale Roughness. *M.Sc. Thesis, Department of Civil Engineering, Witwatersrand University, Johannesburg*.
- Meyer-Peter, E., & Müller, R. (1948). Formulas for Bed-Load Transport. *Proceedings of the 2nd Meeting of the International Association of Hydraulic Research*.
- Montjai, A. A., Rombang, J. A., & Kalangi, J. I. (2015). Analisis Koefisien Kekasaran Sungai di Sungai Sario dengan Persamaan Manning. *Cocos*, 6(12).
- Raudkivi, A. J. (1967). Analysis of Resistance in Fluvial Channel. *Journal of the Hydraulics Division*, 93(5). <https://doi.org/10.1061/jycej.0001697>
- Serrano-Núñez, V., Watson-Hernández, F., Guzmán-Arias, I., Chavarria-Pizarro, L., & Quesada-Alvarado, F. (2022). Correction of Empirical Equations Known as “Strickler-Type” for the Calculation of the Manning's Roughness Coefficient for Costa Rica's Northern Pacific Conditions. *Hydrology*, 9(5). <https://doi.org/10.3390/hydrology9050071>
- Strohmeier, S. M., Nouwakpo, S. K., Huang, C. H., & Klik, A. (2014). Flume experimental evaluation of the effect of rill flow path tortuosity on rill roughness based on the Manning-Strickler equation. *Catena*, 118. <https://doi.org/10.1016/j.catena.2014.01.011>
- Subramanya, K. (1982). *Flow in open channels. Volumes 1 and 2*.
- Toffaletti, F. B. (1968). *A Procedure for Computation of the Total River Sand Discharge and Detailed Distribution, Bed to Surface*.
- Triatmodjo, B. (2017). Hidrologi Terapan. *Buku Hidrologi Terapan*, 2(2).
- Williams, G. P. (1970). Flume Width and Water Depth Effects in Experiments. *Geological Survey Professional Paper 562-H*.
- Wong, M., & Parker, G. (2006). Reanalysis and Correction of Bed-Load Relation of Meyer-Peter and Müller Using Their Own Database. *Journal of Hydraulic Engineering*, 132(11). [https://doi.org/10.1061/\(asce\)0733-9429\(2006\)132:11\(1159\)](https://doi.org/10.1061/(asce)0733-9429(2006)132:11(1159))
- Yen, B. C. (2002). Channel Flow Resistance: Centennial of Manning's Formula. *Water Resources Publications, LLC., Highlands Ranch, Colorado, U.S.A.*
- Zhang, G. H., Luo, R. T., Cao, Y., Shen, R. C., & Zhang, X. C. (2010). Impacts of sediment load on Manning coefficient in supercritical shallow flow on steep slopes. *Hydrological Processes*, 24(26). <https://doi.org/10.1002/hyp.7892>