1. Introduction
The mechanism of sediment bed transport that occurs in open channels in natural rivers is very complicated and complex. There are many parameters related to sediment flow and transport. Information on the characteristics of bed sediment material flow is needed in planning and operations regarding hydraulic structures. The direct sampling method is more reliable than the calculation method in predicting sediment discharge in a river or open channel. Many obstacles were encountered during field measurements, and sediment sampling often could not be carried out following the required sampling standards. This will have an impact on the prediction results obtained. The estimation of river flow may require the attention of engineers. The water endurance is specified in the water depth and velocity estimation, which is conventionally depicted by the equation. In this equation, the channel and the flow characteristics that induce resist the force or lose energy to the flow [1]. The review shows that many factors influence the flow in a meandering river: the shape of the cross-section, flow depth, sinuosity, Reynolds no, roughness ratio, side slope, etc. [2]. Early studies focused on deepwater zones with relatively small roughnesses, such as plain rivers. The Manning formula is an empirical relation that accounts for the flow velocity, hydraulic radius, and channel slope in plain rivers [3]. The friction factor values in gravel-bed rivers depend on the particle size of the bed material, bedforms, channel geometry, longitudinal slope, and non-dimensionalized flow depth (flow depth/sediment size) as a
hydraulic condition. Among these parameters, grain size and bedforms have the greatest impact on the friction factor and sediment transport in most gravel-bed rivers with the deep flow [4]. The flow resistance consists of two parts: 1) grain resistance or skin friction which depends on the bed grain size, and 2) form resistance which depends on the bedform geometry and flows depth. Flow resistance is a fundamental control of flow hydraulics in streams and rivers. It is not only determining the amount of water a channel can convey through its influence on velocity (and thus flow depth) but also controlling the distribution of shear stress around the channel boundary and the magnitude and distribution of bed and bank erosion. Therefore, a thorough understanding of flow resistance is necessary to improve natural hazard prevention and mitigation [5]. Flow resistance in rivers and open channels are of enormous importance in river engineering. Furthermore, its dynamics vary from compartment to compartment depending upon the bottom roughness and the variability of lateral flow depths. Accurate estimation of river flow resistance is important to predict the stage-discharge relationship in rivers, thus evaluating the likelihood of river flooding and issuing warnings of flooding. The issue of deciding the flow velocity and depth in a channel for a known discharge, remains a frequently revised topic in fluvial engineering. One of the important causes is the trouble in deciding precisely friction factors in a river channel [6].

The degree of roughness depends on several factors. The most important in open-channel flow are surface roughness of the bed material, cross-section geometry, channel variations, obstruction to flow, type and density of vegetation, and degree of channel meandering. In general, all factors that tend to cause turbulence and retardance of flow, hence energy losses, increase the roughness coefficient. Those that cause smoother flow conditions tend to decrease the roughness coefficient [7].

Similar research has examined the grain character of the sediment to evaluate a channel roughness formula to obtain a channel roughness formula that was appropriate for its use and application [8-11]. The relationship between the characteristics of the riverbed material and its geometry shows that the middle part of the river has the highest content of coarse-grained soil (d_{0.150} mm). In contrast, at the edge of the river it has the highest content of fine-grained soil (d_{0.150} mm). Meanwhile, [9] researched the distribution pattern of surface sediments based on water depths to determine the condition of the Dompak island waters, namely the reclamation of the mangrove area and being developed into an international ferry port area. For [10], he carried out direct measurements on the Opak River, which originates at Mount Merapi. Analysis of the measurement data to obtain the frictional velocity u* and the numerical integration constant Br using the Clauser method. The flow velocity distribution pattern in natural rivers does not always have a maximum value in the middle section. The flow velocity distribution increases as it approaches the surface and vice versa with sediment concentration. The value of sediment concentration decreases as it approaches the surface and is larger at the bottom of the channel.

Meanwhile, [11] conducted a study to determine the size of the transported sediment grains against the current velocity in the waters of the Pawan River, Ketapang Regency. Water parameters that affect sediment deposition in the Pawan River meandering channel type. The study results obtained information on current velocity and grain size, which caused silting and narrowing of the river cross-section.

Based on that, a study was conducted on the Pondo Poboya River, a rainfed river. The Pondo Poboya River is one of the rivers that originate in the Parigi Regency. The research was conducted by observing field conditions and direct measurements in natural rivers with various parameters related to flow velocity, water depth, and sediment bed material. This river is the rainfed river. When the climate is rainy, the river has full of water along the river to the estuary. However, when the dry season, the water still flows until the middle part of the river, with varying water depths between 10 cm to 50 cm. The bedload sediment characteristics have unique behavior. Therefore, this research was conducted.

2. Materials and Method
The location of the research is the Pondo Poboya river which is in Palu, Central of Sulawesi. Administratively, the Pondo-Poboya River is located in Mantikulore District, Palu City, Central Sulawesi Province. Palu City is geographically located in the middle of Donggala Regency.
on the shore of Palu Bay which extends from east to west, located at a geographical position of 119°04'5"–120°00'1" East Longitude and 0°36'–0°56' South Latitude with an area of 395.06 Km² or 39.506 Ha, consisting of 8 sub-districts and 45 urban villages. Mantikulore District itself is a division of East Palu District and South Palu District. It is located at a position between 0°44'50" and 0°49'50" south latitude and 119°50'00" and 119°56'00" east longitude, with a land area of 206.8 km². The topography of the Mantikulore region consists of about 60% plains, about 25.71% hills, and about 14.29% mountains. The Pondo-Poboya watershed has a watershed area of 6,464.95 Ha (Permenhut No. SK. 511/Menhut-V/2011; 7 September 2011). The Pondo-Poboya watershed is bordered by several mountains, including Bulu Masomba, Bulu Sigandia, Bulu Ranuwau, and Bulu Palombo. The upstream part of the Pondo-Poboya River itself is located in the Poboya village. It flows through 3 other villages, namely Lasoani, Tanamodindi, and Talise villages, then empties into Palu Bay. The existence of the Pondo-Poboya River, which flows from east to west, becomes the natural boundary between Talise Village, Mantikulore District, and Besusu Timur Village, East Palu District. The picture below shows the location of the research.

The research was conducted by collecting primary data. The primary data taken are the bedload sediment sampling, flow velocity, cross-sectional area of flow, and wet cross-sectional area of flow. Sediment bedload sampling was carried out in each part of the river, upstream, middle, and downstream. Each section is taken ten cross-sections. These 3 points are taken for each section, namely the cross-section's left, middle, and right sections. The picture below showed that the point of the bedload sediment sampling.
Data collection of river cross-sectional area and river wet cross-sectional area is measured directly using the theodolite, meter gauge, and GPS. Because the flow depth varies, the velocity data collection and the measurement of the wet cross-sectional area of the flow are only carried out when there is water flowing. Sediment data collection was done manually using a shovel. The sediment taken is estimated to weigh 500 grams to meet the requirements of the grain gradation analysis. The sampling bedload sediment was carried out to Soil Mechanics Laboratory for analysis. The Soil Mechanics Laboratory was in Civil Engineering Faculty at Tadulako University, Palu. Perform sieve analysis testing in the laboratory that refers to grain size analysis (ASTM 422-63). Inspection of grain gradation using a set of sieves. The sediment data was sieved using a sieve and weighed. Then the results of sieving and weighing are entered into a graph to see the analysis of the gradation of sediment grains. Meanwhile, the velocity and the cross-sectional area data were used to analyze the friction factor using the equation of Manning, Raudkivi, Subramanya, and Meyer Peter Müller empirically.

3. Results and Discussion
Water depth is one of the variables that should not be forgotten in the geometric design/calculation of open channels. The effect of hydraulic changes on flow capacity is also primarily determined by the water depth factor. The roughness coefficient \( n \) will decrease when the water level and flow velocity increase. When the water depth is lower, the irregularity of the riverbed will stand out and the effect will be visible. Based on the measurement data in the field, the average water depth obtained at each location is shown in Table 1.

The water depth of the Pondo Poboya River has varied (Table 1). Because of the dry season, the water depth variation is uneven flow. During the dry season, the river water flow is influenced by the riverbed porosity and roughness value. Comparing the water depth upstream of the river to the downstream showed that the further downstream, the lower the flow depth. This happens because the further downstream, the wider the wet cross-section, so the lower the flow depth.
Table 1. Water depth along the river

| Location of sampling velocity flow | Average depth measurement (h in meter) |
|-----------------------------------|----------------------------------------|
| Upstream of river                 | I  0.04 | II  0.09 | III  0.11 | IV  0.10 | V  0.08 | VI  0.04 | VII 0.01 |
| Middle part of river              | I  0.10 | II  0.14 | III  0.12 | IV  0.12 | V  0.13 | VI  0.05 | VII 0.03 |
| Downstream of river               | I  0.07 | II  0.13 | III  0.12 | IV  0.09 | V  0.07 | VI  0.02 | VII 0.01 |

Source: Field measurement results (2020)

3.1. River-bed Slope Measurement

The riverbed slope measurement was done with GPS (Geographic Positioning System) along 7.6 km. This measurement represents the length of the river. When the morphology is straight, the measurement was taken 500 m interval. For the meandering morphology, the measurement was conducted at a 100 m interval. The table below shows the results of the riverbed measurement.

Table 2. River-bed Measurement

| Benchmark | Benchmark Interval (ΔX) (m) | Elevation (ΔH) (m) | Heigh Different (ΔH) (m) | River-bed Slope (S = ΔH / ΔX*100) |
|-----------|-----------------------------|-------------------|--------------------------|-----------------------------------|
| CS 1      | 53.5                        | 158.8             | 1.1                      | 0.0204                            |
| CS 2      | 117                         | 257.7             | 1.92                     | 0.01643                           |
| CS 3      | 315                         | 255.8             | 6.45                     | 0.02048                           |
| CS 4      | 370                         | 249.3             | 8.56                     | 0.02314                           |
| CS 5      | 230                         | 240.8             | 5.5                      | 0.0239                            |
| CS 6      | 332                         | 235.3             | 7.16                     | 0.02156                           |
| CS 7      | 430                         | 228.1             | 10.07                    | 0.02343                           |
| CS 8      | 198                         | 218               | 3.6                      | 0.01816                           |
| CS 9      | 870                         | 214.4             | 18.22                    | 0.02094                           |
| CS 10     | 290                         | 196.2             | 6.32                     | 0.02181                           |
| CS 11     | 505                         | 189.9             | 8.91                     | 0.01765                           |
| CS 12     | 660                         | 181               | 14.37                    | 0.02178                           |
| CS 13     | 520                         | 166.6             | 10.72                    | 0.02061                           |
| CS 14     | 420                         | 155.9             | 8.74                     | 0.02081                           |
| CS 15     | 358                         | 147.2             | 6.38                     | 0.01781                           |
| CS        |                             |                   |                          | 0.020594                           |

Average 0.020594

Source: Field measurement results (2020)

The results of the measurement showed that the riverbed slope has a steep slope. It is because of the morphology of the river. This steep slope is due to meandering the river in certain parts and straight in other parts. When taking measurements in the field, it is difficult to determine whether meandering occurs in the shape of the river or the flow of water. This difficulty happens because when measuring, water only flows in the middle part of the cross-section of the river. When the river is straight as the same location the flow is meandering.
3.2. River Hydraulics Calculation
In this research, river hydraulics were calculated based on river discharge at each sampling location. The picture below shows the river cross-section sketch to calculate the river hydraulic parameter. The wet cross-area of the river that water flowing (Figure 3). For the part of the river that the water is not flowing, the cross area measure by meter gauge to know the morphology of the river area.

![Figure 3. The river cross section sketch](image)

As shown field results calculation
b1, b2, b3, b4, b5, dan b6 = 0.5 m
b7 = 0.22 m
h1 = 0.04 m            h8 = h2-h1 = 0.05 m
h2 = 0.09 m            h9 = h3-h2 = 0.02 m
h3 = 0.11 m            h10 = h3-h4 = 0.01 m
h4 = 0.10 m            h11 = h4-h5 = 0.02 m
h5 = 0.08 m            h12 = h5-h6 = 0.04 m
h6 = 0.04 m            h13 = h6-h7 = 0.03 m
h7 = 0.01 m

a. Calculated value of d
   d1 = 0.502 m
   d2 = 0.503 m
   d3 = 0.501
   d4 = 0.500 m
   d5 = 0.501 m
   d6 = 0.502 m
   d7 = 0.212 m^2
   d8 = h7 = 0.01 m^2

b. Calculate the wet cross section area (P)
P = d1+d2+d3+d4+d5+d6+d7+d8 = 3.24 m

c. Calculate the river cross section area (A)
   Calculate A1 = 0.01 m^2
   Calculate A2 = 0.033 m^2
Calculate $A_3 = 0.05 \text{ m}^2$
Calculate $A_4 = 0.052 \text{ m}^2$
Calculate $A_5 = 0.045 \text{ m}^2$
Calculate $A_6 = 0.03 \text{ m}^2$
Calculate $A_7 = 0.013 \text{ m}^2$
From the results of the calculation of each area of the river, the total area obtained is:
$A_{\text{total}} = A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8 = 0.233 \text{ m}^2$

d. Calculating the hydraulic radius of the river:
$R = \frac{A}{P} = \frac{0.233}{3.24} = 0.072 \text{ m}$

e. Calculating the velocity of the river flow:
$V = \frac{\text{length of river part}}{\text{time}}$
$= \frac{5}{6.20}$
$= 0.806 \text{ m/sec}$

f. Calculating river discharge:
$Q = A \times V$
$Q = 0.233 \times 0.806$
$Q = 0.188 \text{ m}^3/\text{sec}$

The results of river hydraulics calculations at other locations can be seen in the following table

| River measurement location | River width (m$^2$) | P (m) | V (m/sec) | S (m) | R (m) | Q (m$^3$/sec) |
|----------------------------|---------------------|-------|-----------|-------|-------|---------------|
| Upstream of river          | 3.22                | 0.233 | 3.24      | 0.806 | 0.0209| 0.072         | 0.188         |
| Middle part of river       | 3.65                | 0.3403| 4.02      | 0.759 | 0.0209| 0.0847        | 0.2582        |
| Downstream of river        | 2.65                | 0.2365| 3.09      | 1.008 | 0.0205| 0.766         | 0.2384        |

Source: Analysis result (2020)

The table above showed that as the further downstream, the width of the river is irregular. Usually, the further downstream, the wider the cross-section of the river. This condition is because the flow velocity slows down, and sedimentation occurs. The sedimentation will affect wider the cross-section of the river. In the Poboya river, sedimentation occurs in the middle part river. Because at the downstream river, there is a little part of water flowing. Sedimentation spreading around the middle part of the river.

### 3.3. Calculation of Bed Load Sediment Sieve Analysis

The sieve analysis test aims to obtain the size of the bedload sediment diameter ($d_{50}$, $d_{65}$, and $d_{90}$). The bedload sediment materials samples to be tested were taken from twenty different cross-sections. The following is a table of test results:
Table 4. Test results and sieve analysis calculations for bedload sediment samples in the Upstream River

| Shive No. | Opening (mm) | Weight (gr) | Cumulative Weight (gr) | Restrained (% | Passing (%) |
|-----------|--------------|-------------|------------------------|---------------|-------------|
| #3/8      | 10.000       | 0.000       | 0.000                  | 0.000         | 100.000     |
| #4        | 5.000        | 159.450     | 159.450                | 53.035        | 46.965      |
| #8        | 2.380        | 71.780      | 231.230                | 76.910        | 23.090      |
| #30       | 0.600        | 53.570      | 284.800                | 94.728        | 5.272       |
| #50       | 0.300        | 11.150      | 295.950                | 98.437        | 1.563       |
| #100      | 0.150        | 3.320       | 299.270                | 99.541        | 0.459       |
| #200      | 0.075        | 1.040       | 300.310                | 99.887        | 0.113       |
| Pan       | 300.310      |             | 99.887                 | 0.113         |             |

Source: Analysis results (2020)

And then, the results of gradation bedload sediments analysis make it to the graph to know the percentage of passed diameter of bedload at $d_{50}$, $d_{60}$, and $d_{90}$.

![Grain analysis distribution upstream of the river](image)

Figure 4. The grain analysis distribution upstream of the river

From the plot of the graph in Figure 4 the grain size of the bedload sediment material is obtained: $d_{50} = 5.2$ mm, $d_{60} = 6.8$ mm, and $d_{90} = 9$ mm

Table 5. Test results and sieve analysis calculations for bedload sediment samples in the Middle part of the River

| Shive No. | Opening (mm) | Weight (gr) | Cumulative Weight (gr) | Restrained (% | Passed (%) |
|-----------|--------------|-------------|------------------------|---------------|------------|
| #3/8      | 10.000       | 0.000       | 0.000                  | 0.000         | 100.000    |
| #4        | 5.000        | 115.050     | 115.050                | 38.267        | 61.733     |
| #8        | 2.380        | 47.160      | 162.210                | 53.953        | 46.047     |
| #30       | 0.600        | 79.890      | 242.100                | 80.526        | 19.474     |
| #50       | 0.300        | 32.940      | 275.040                | 91.482        | 8.518      |
| #100      | 0.150        | 23.200      | 298.240                | 99.198        | 0.802      |
| #200      | 0.075        | 2.140       | 300.380                | 99.910        | 0.090      |
| Pan       | 0.000        | 300.380     | 99.910                 | 0.090         |            |

Source: Analysis results (2020)
And then, the results of gradation bedload sediments analysis make it to the graph to know the percentage of the passed diameter of bedload at $d_{50}$, $d_{65}$, and $d_{90}$.

![Graph showing grain analysis distribution at the middle part of the river.](image)

**Figure 5.** The grain analysis distribution at the middle part of the river

From the plot of the graph in Figure 5, the grain size of the bedload sediment is obtained: $d_{50} = 3$ mm, $d_{65} = 5.5$ mm, and $d_{90} = 8.2$ mm.

| Shive No. | Opening (mm) | Weight restrained (gr) | Cumulative restrained (gr) | Restrained (%) | Passed (%) |
|-----------|--------------|------------------------|---------------------------|----------------|------------|
| #3/8      | 10.000       | 0.000                  | 0.000                     | 0.000          | 100.000    |
| #4        | 5.000        | 84.120                 | 84.120                    | 27.979         | 72.021     |
| #8        | 2.380        | 58.030                 | 142.150                   | 47.281         | 52.719     |
| #30       | 0.600        | 116.010                | 258.160                   | 85.867         | 14.133     |
| #50       | 0.300        | 31.010                 | 289.170                   | 96.182         | 3.818      |
| #100      | 0.150        | 10.530                 | 299.700                   | 99.684         | 0.316      |
| #200      | 0.075        | 0.560                  | 300.260                   | 99.870         | 0.130      |
| Pan       | 0.030        | 300.290                | 99.880                    | 0.120          |            |

**Table 6.** Test results and sieve analysis calculations for bedload sediment samples downstream of the River

The dry weight of the sample before filtering: 300.29 gr  Date of testing: 10/12/2020

Source: Analysis results (2020)

And then the results of gradation bedload sediments analysis make it to the graph to know the percentage of the passed diameter of bedload at $d_{50}$, $d_{65}$, and $d_{90}$. 
The plot of the graph in Figure 6 showed that the grain size of the bedload sediment material is obtained: \(d_{50} = 2.2 \text{ mm} \), \(d_{65} = 4 \text{ mm} \), and \(d_{90} = 7 \text{ mm} \).

The grain sediment distribution from the upstream of the river showed that the further downstream, the smaller the grain diameter. This condition is due to the lower water flow. The water depth along the river is getting lower. The water not flowing until downstream because the porosity of the bed river is high. The composition of sand indicates this in the middle, which is almost 90%.

3.4. Calculation of Roughness Coefficient

After testing the sieve analysis on the bed sediment sample, several methods of calculating the sediment roughness value are carried out to compare the roughness value.

Manning Roughness Coefficient

\[
v = \frac{1}{n} x R\left(\frac{2}{3}\right) x S^{\frac{1}{2}} \]

\[
n = \frac{R^2 x S^{\frac{1}{2}}}{V} \]

\[
n = \frac{0.0725 x 0.0095^{\frac{3}{2}}}{0.806} \]

\[
n = 0.030744 \]

Raudkivi Roughness Coefficient

\[
n = 0.013 x D_{65}^{1/6} \]

\[
n = 0.013 x 7 \]

\[
n = 0.0152 \]
Information:

\(D_{65}\) is the diameter of grain sediment materials in which 65% of the grain fraction passes the sieve.

Subramanya Roughness Coefficient

\[
n = 0.047 * D_{65}^{1/6}
\]

\[
n = 0.047 * 7
\]

\[
n = 0.0152
\]

Meyer Peter Muller Roughness Coefficient

\[
n = \frac{D_{50}^{1/6}}{26}
\]

\[
n = \frac{6.1^{1/6}}{26}
\]

\[
n = 0.0391
\]

The results of the calculation of the roughness coefficient (n) for each location reviewed and the average coefficient on the Pondo-Poboya River are shown in Table 7 and Table 8.

Table 7. Recapitulation of roughness coefficient calculation (n) Pondo-Poboya River

| Cross-section          | Manning | Raudkivi | Subramanya | Meyer P. Muller |
|------------------------|---------|----------|------------|-----------------|
| Upstream of river      | 0.03074 | 0.0152   | 0.0478     | 0.0391          |
| Middle part of river   | 0.03638 | 0.0152   | 0.0478     | 0.0391          |
| Downstream of river    | 0.02563 | 0.0154   | 0.0470     | 0.0385          |

Source: Calculation analysis (2020)

Table 8. Roughness coefficient (n) average Pondo-Poboya River

| Empirical equation       | Roughness Coefficient (n) |
|--------------------------|---------------------------|
|                          | Minimum       | Maximum       | Average       |
| Manning                  | 0.0256        | 0.0364        | 0.0310        |
| Raudkivi                 | 0.0152        | 0.0154        | 0.0153        |
| Subramanya               | 0.0470        | 0.0478        | 0.0474        |
| Meyer Peter Muller       | 0.0385        | 0.0391        | 0.0388        |

Source: Calculation analysis (2020)

Table 7 for sharing the review location shows that the minimum roughness coefficient is 0.0152 and the maximum roughness coefficient is 0.0478. In the Manning roughness formulation, the minimum roughness value is 0.02563. The maximum roughness coefficient is 0.0364, with an average value of 0.0310. When matched with the roughness coefficient value contained in the Manning table, this value is not much different, namely clean natural channels, straight, and clean winding.

Table 9. Relationship between roughness coefficient with water depth

| Empirical equation       | Roughness coeff. To water depth | R²      |
|--------------------------|---------------------------------|---------|
| Manning                  | \(n = 1.0922h - 0.0333\)         | 0.48    |
| Raudkivi                 | \(n = 0.05749h - 0.0286\)        | 0.003   |
| Subramanya               | \(n = 0.0025h + 0.0457\)         | 0.068   |
| Meyer Peter Muller       | \(n = 0.0018h + 0.0374\)         | 0.069   |

Source: Results of analysis (2020)

Table 9 shows that the Manning formula has a better relationship than the other formulas. Therefore, Manning’s roughness formula is suitable for the Pondo Poboya River.
4. Conclusion
The analysis results showed that the bed load distribution of the Pondo Poboya river has unique characteristics because the bedload materials from the upstream of the river along with to the downstream of the river are not suitable with another usual river. It's because the river of Pondo Poboya is a river fed. The river has residual bed load materials of the rainy season before. So that is why the bedload distribution has differed from the usual river. From the relationship between the roughness to the water, depth showed that the Manning empirical equation has a good relationship with the water depth. So that the Manning equation is suitable used to apply the roughness coefficient for the Pondo Poboya River.

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