Correlation Between Flow Velocity and Discharge in the Walanae River, South Sulawesi, Indonesia

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Abstract:
Rivers, as natural flow systems, possess dynamic characteristics. Mathematically, river discharge is greatly influenced by the river's cross-sectional area. However, due to its natural variability, the relationship between these two parameters can vary significantly. This study focuses on the correlation between flow velocity and discharge in the Walanae River, located in South Sulawesi, Indonesia. The study, which concentrates on the upstream, midstream, and downstream areas, includes data collection on river flow and cross-sectional area. Measurements were taken under both normal and flood conditions. The findings reveal differences in the mathematical relationships across the three locations, under both flow conditions. These variations in flow characteristics are associated with the condition of riverbank vegetation, as well as the levels of erosion and sedimentation.

Keywords: discharge, velocity, river cross-sectional area.

1. INTRODUCTION

The highly dynamic river ecosystem is primarily characterized by river flow attributes such as velocity and discharge. This dynamism is also marked by fluctuating flow discharge, which can even trigger water overflow along the riverbanks. River engineering studies involve monitoring activities such as cross-sectional area, flow velocity, and flow discharge. These studies are crucial for decision-making related to the protection of lives and property from the dangers of floods and landslides [1].

Research on the physical characteristics of rivers contributes to river management, such as irrigation and dam planning, flood water level prediction, and river ecosystem conservation. Areas with high flow discharge require stronger riverbank protection structures. Specifically, flow discharge is influenced by flow velocity and the cross-sectional area of the river. Flow velocity is a parameter that indicates the surface or roughness of river flow acceleration (v).

Flow velocity refers to how fast water moves within a given time unit. Various factors influence flow velocity, including river slope, bed roughness, channel depth and width, as well as physical obstructions such as bends, vegetation, and structures. River flow tends to be faster in steep river conditions. Additionally, a muddy riverbed is an indication of high channel roughness [2][3]. Bottom channel vegetation such as water lilies causes a reduction in flow velocity.

Rivers with wide cross-sections tend to have slower flow velocity, while narrow cross-section rivers generally exhibit higher flow velocity. Natural river channels are often overgrown with grasses or trees. The presence of vegetation obstructs water flow, thereby reducing velocity.

In general, river management is aimed at preventing river ecosystem degradation, such as the loss of vegetation along riverbanks, riverbank collapses, and the risk of inundation in areas on both sides of the river. The magnitude of such risks is usually related to flow velocity. Due to the physical diversity of rivers, flow velocity varies at each location, which in turn affects changes in river discharge.

Another important parameter in river flow is discharge, which refers to the volume of water flowing per unit of time. Discharge is influenced by both flow velocity and the river's cross-sectional area. Flood events in rivers are indicated by an increase in discharge and water level. Therefore, measuring flow velocity and discharge as frequently as possible is necessary to obtain sufficient supporting data.

River protection planning against the risks of flooding and erosion takes flow velocity into account. The relationship between flow velocity and river cross-section irregularities reflects inconsistencies in riverbed geometry. This condition is unfavorable for river management.

The Walanae River is one of the major rivers in Indonesia. Its flow, utilized by communities in three regencies, has significant socio-economic impacts. Statistical data from 2023 indicates that more than 300,000 people are at risk due to flooding from this river. On the other hand, the river contributes to irrigation water supply for agricultural needs [4].

2. RESEARCH METHOD

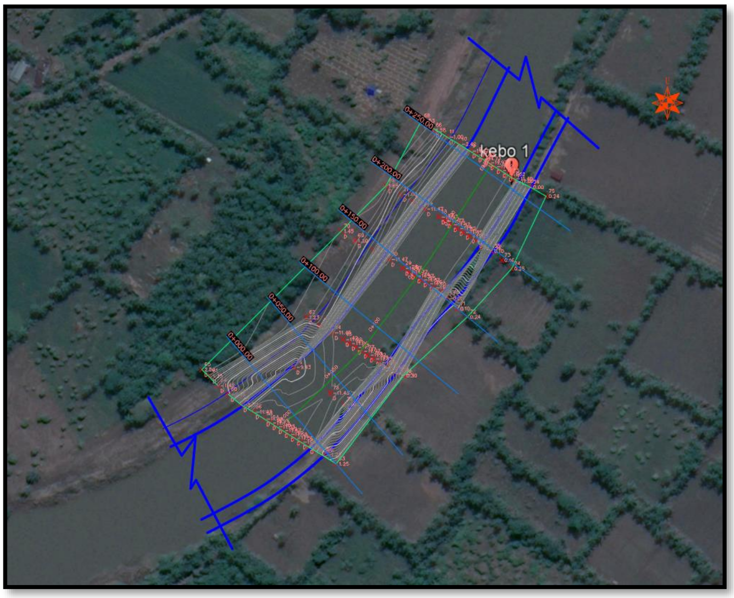
The measurement of river cross-sectional area and flow velocity was conducted at three locations: upstream, midstream, and downstream. Table 1 describes the data collection locations.

Table 1: Research Locations and Sample Points

Region	Location	Number of Sample Points
Upstream	Barae	21
Midstream	Mariorilau	21
Downstream	Kebo	21

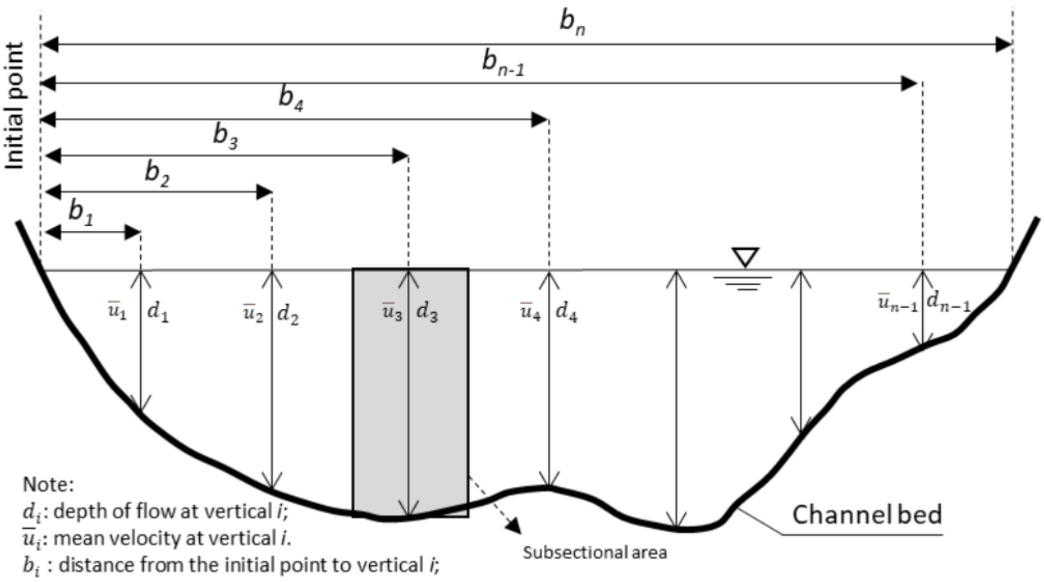
Figure 1: Sample Collection Point in Barae

Figure 2: Sample Collection Point in Kebo



The measurement of the river's cross-sectional area included the measurement of river width and depth. The researchers took into account changes in cross-sectional shape caused by the variability of the riverbed. Flow velocity was measured using a current meter, following the method introduced by [5].

Figure 3: Flow Velocity Measurement Method [5]



There are two methods for measuring river flow velocity, depending on whether the river is under normal flow or flood conditions. Normal flow is characterized by water levels that do not exceed the riverbanks. A river flood occurs when the water level rises and overflows the riverbanks, inundating areas that are normally dry. The flow discharge at each point was calculated using the following formula:

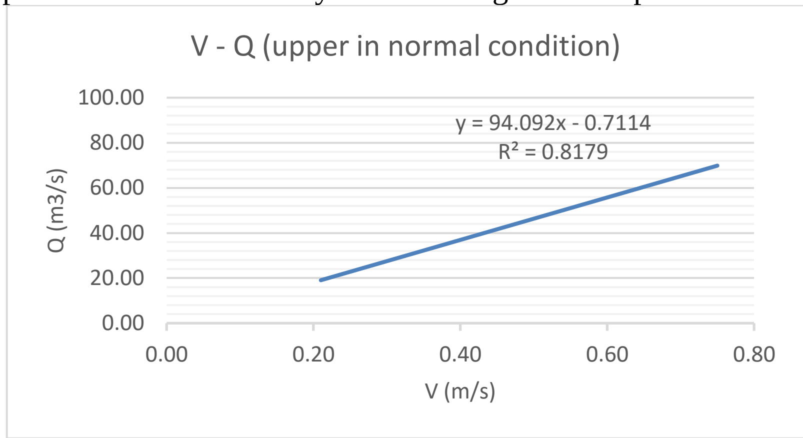
$$q_i = \bar{u}_i \left(\frac{b_{i-1}+b_{i+1}}{2}\right) d_i \qquad (1)$$

3. RESULTS AND DISCUSSION

- **Results**

The results of the flow velocity and cross-sectional area measurements were analyzed to obtain the river discharge values. The presentation of the calculation results is supported by mathematical equations. The analysis of the relationship between flow velocity and discharge at the upstream section of the Walanae River is shown in Figure 4 (normal conditions) and Figure 5 (flood conditions).

Figure 4: Relationship Between Flow Velocity and Discharge in the Upstream Area (Normal Conditions)



The upstream section of the Walanae River, located in Barae Village, Soppeng Regency, showed an average flow velocity of 0.375 m/s under normal conditions. The highest and lowest velocities recorded were 0.75 m/s and 0.375 m/s, respectively, while the average cross-sectional area of the river during normal flow was 83.13 m^2.

Figure 5: Relationship Between Flow Velocity and Discharge in the Upstream Area (Flood Conditions)

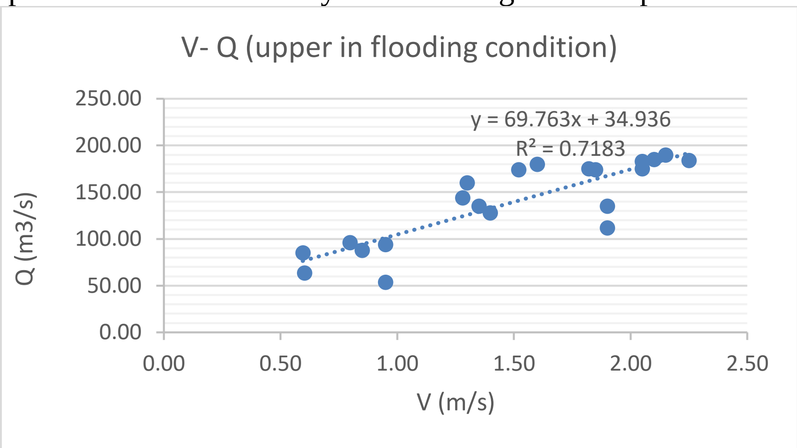


Figure 5 shows that the significance level of discharge relative to velocity under normal conditions was 81.79%, while under flood conditions it was 71%. This indicates that during flooding, the river cross-section and its characteristics vary widely, which reduces the influence of velocity on discharge.

Land visualization along both sides of the river indicates dense vegetation, and cultivation activities along the riverbanks are minimal. This suggests a low risk of bank erosion and minimal impact on the river's cross-sectional shape.

In the midstream area, specifically in Mariorilau Village, flow velocity under normal conditions ranged between 0.10 m/s and 0.57 m/s. During flood events, flow velocity increased to between 0.45 m/s and 1.25 m/s. The analysis of the relationship between flow velocity and discharge in the midstream section of the Walanae River is presented in Figure 6 (normal conditions) and Figure 7 (flood conditions).

Figure 6: Relationship Between Flow Velocity and Discharge in the Midstream Area (Normal Conditions)

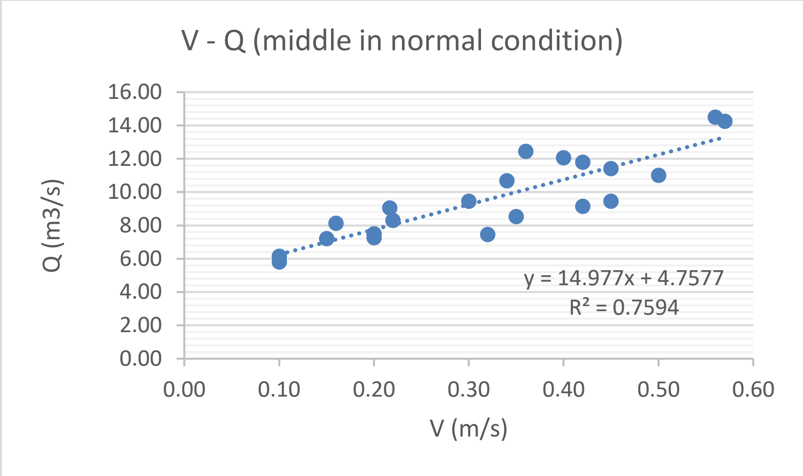
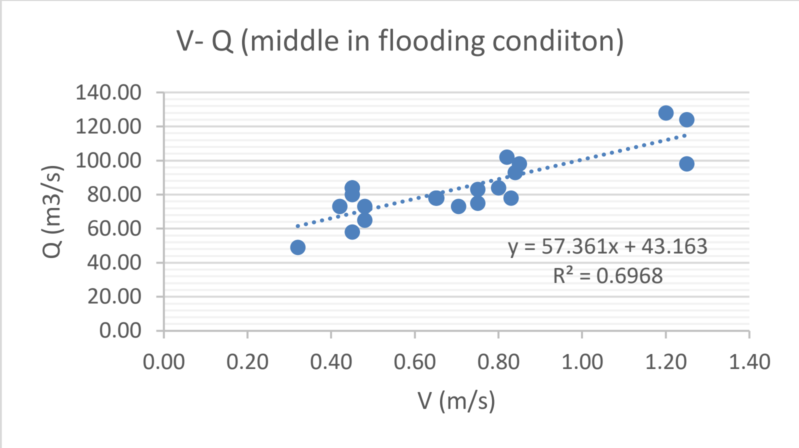


Figure 7: Relationship Between Flow Velocity and Discharge in the Midstream Area (Flood Conditions)



In the midstream region, the significance values between the two parameters are relatively similar—0.7594 under normal conditions and 0.6968 during flooding. This indicates variability in river conditions due to high erosion rates, which contribute to increased sedimentation on the riverbed and sediment transport in the flow. High sediment transport increases channel roughness, which affects both flow velocity and discharge.

Based on Figure 2, which shows land use along the riverbanks, there appears to be a pattern of crop cultivation. This contributes to high surface erosion risk, resulting in soil particles being carried into the river. During flooding, sediment transport increases, which leads to a lower significance value in the relationship between flow velocity and discharge.

The downstream section of the Walanae River is an area with a high flood risk. Lake Tempe, located at the river's mouth, has high sediment accumulation, causing backflow into the river channel. Severe riverbank damage, marked by significant erosion, results in a highly irregular river cross-section.

The variability in river discharge in this area can be observed in Figures 8 and 9, which show low significance values. Under normal conditions, the correlation coefficient is 0.6550, decreasing to 0.6116 during flooding. At some points, flow velocity increases sharply, while at others, it is very low.

Figure 8: Relationship Between Flow Velocity and Discharge in the Downstream Area (Normal Conditions)

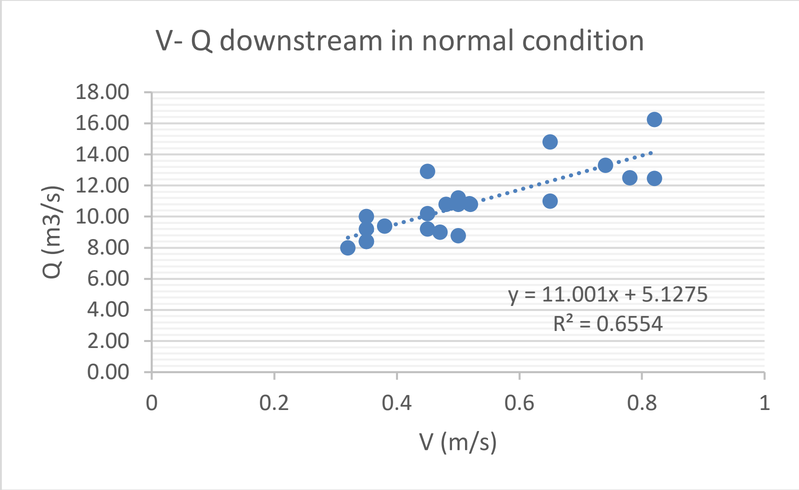
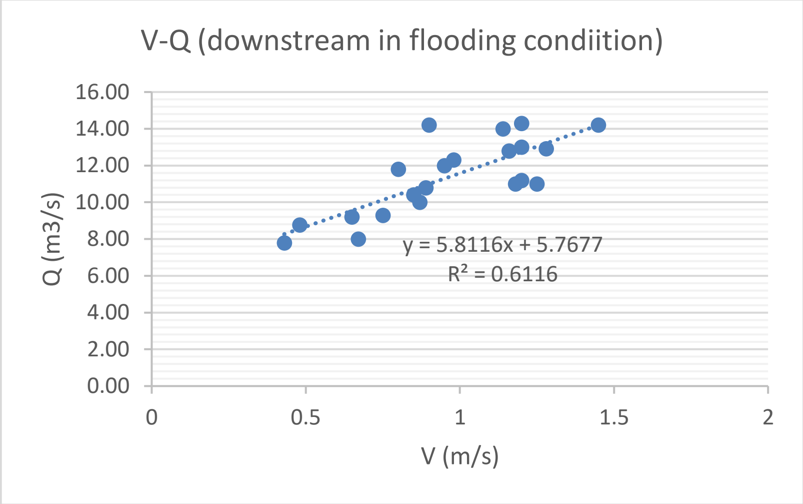


Figure 9: Relationship Between Flow Velocity and Discharge in the Downstream Area (Flood Conditions)



Flow velocity in the downstream region, especially when backflow from the river mouth occurs, is also influenced by the volume of sediment transport. Additionally, the increased flow velocity poses a risk of heightened energy impact on riverbank walls, leading to bank erosion. This is clearly observed in the field, with riverbank erosion occurring along large portions of the river.

The above findings illustrate that the variability in river flow velocity is highly complex and closely related to river morphology and geometry. This data is crucial for the design of structures as part of river control efforts. On the other hand, riverbank protection can also be achieved by strengthening the presence of protective vegetation such as bamboo, grasses, and trees.

- **Discussion**

The complexity and dynamics of river flow are characterized by variations in flow velocity and concentration. Additionally, differences in flow velocity between the lower and upper parts of the river are generally influenced by river morphology. Unfortunately, these conditions are highly dynamic and can change rapidly due to fluctuations in rainfall. Therefore, accurate estimation of flow velocity and discharge, which forms the basis for planning riverbank protection structures, is essential.

The condition of the floodplain is also an important indicator of changes in river flow velocity. An increase in floodplain width can reduce river flow velocity and, simultaneously, lead to increased sediment deposition either on the riverbed or within the floodplain area [6]. This condition is further exacerbated by anthropogenic activities such as sand mining, which causes depressions in the riverbed. As a result, flow velocity increases and contributes to river degradation [7].

4. CONCLUSION

The findings of this study indicate that the relationship between flow velocity and discharge is highly variable. The correlation between these two parameters reflects the condition of river flow and cross-section. Variations in flow velocity in the upstream, midstream, and downstream regions are closely related to changes in the river's cross-sectional profile.

REFERENCES:

1. F. Bahmanpouri, A. Eltner, S. Barbetta, L. Bertalan, and T. Moramarco, “Estimating the average river cross-section velocity by observing only one surface velocity value and calibrating the entropic parameter,” *Water Resour. Res.*, vol. 58, no. 10, p. e2021WR031821, 2022.
2. K. Kawanisi, M. Razaz, K. Ishikawa, J. Yano, and M. Soltaniasl, “Continuous measurements of flow rate in a shallow gravel-bed river by a new acoustic system,” *Water Resour. Res.*, vol. 48, no. 5, 2012.
3. B. Q. Nguyen, S. A. Kantoush, and T. Sumi, “Assessing the multidimensional impacts of riverbed sand mining on geomorphological change and water transfer rate: A comprehensive investigation of Central Vietnam’s Vu Gia Thu Bon River system,” *J. Hydrol.*, vol. 654, p. 132853, 2025.
4. S. Rijal, M. Nursaputra, and H. U. Dari, “Flood Susceptibility Analysis Using Frequency Ratio Method in Walanae Watershed.,” *Int. J. Sustain. Dev. Plan.*, vol. 19, no. 3, 2024.
5. Y.-C. Chen, Y.-C. Hsu, and E. O. Zai, “Streamflow measurement using mean surface velocity,” *Water*, vol. 14, no. 15, p. 2370, 2022.
6. M. Naghavi, M. Mohammadi, and G. Mahtabi, “Numerical simulation of flow velocity distribution and shear stress in meandering compound channels,” *Iran. Water Res. J.*, vol. 15, no. 1, pp. 23–34, 2021.
7. A. Islam, B. Sarkar, U. D. Saha, M. Islam, and S. Ghosh, “Can an annual flood induce changes in channel geomorphology?,” *Nat. Hazards*, pp. 1–28, 2021.