International Journal of Recent Engineering Science
ISSN: 2349-7157/ https://doi.org/10.14445/23497157/IJRES-V12I2P110

Volume 12 Issue 2, 92-103, Mar-Apr 2025

Original Article

Flow Characteristics in Rivers through the Relationship between Flow Depth and Velocity Distribution

Ayeni. A. T[1], Folorunso. O. P[2], Ayeni. O.O[3]

[1]*Department of Civil Engineering, Afe Babalola University Ado Ekiti (ABUAD).*
[2]*Department of Civil Engineering, Ekiti State University Ado Ekiti (EKSU).*
[3]*Department of Civil Engineering. The Federal Polytechnic, Ado Ekiti (FEDPOLYADO)*

[3]*Corresponding Author : ayeni_oo@fedpolyado.edu.ng*

Received: 16 February 2025 Revised: 21 March 2025 Accepted: 05 April 2025 Published: 16 April 2025

Abstract *- This study examines the flow characteristics of the upstream, midstream and downstream sections of River Ogbesse by analyzing the relationship between velocity variations and depth of flow across transect points. Results indicate a consistent relationship, with velocity decreasing as depth decreases due to increased frictional resistance in shallower flows. At depths of 1.25 meters, velocity values were highest, ranging from 0.885 to 0.939 m/s across transect points, while at depths of 0.25 meters, velocities reduced significantly to values between 0.146 and 0.155 m/s. This uniform trend highlights the critical role of depth in regulating flow dynamics, as deeper flows experience reduced friction from the channel bed and banks, facilitating faster velocities.The findings align with established hydraulic theories and emphasize the interplay of depth, velocity, and roughness in natural channels. Localized variations in velocity across transects are attributed to channel-specific factors, including width, slope, and roughness, underscoring the complex dynamics of flow behaviour. These insights are essential for hydraulic structure design, enabling improved predictions of flow dynamics for flood control, erosion prevention, and efficient water transport. The study provides valuable site-specific data that contribute to a broader understanding of river hydraulics, supporting sustainable water resource management.*

Keywords *- Depth of flow, Frictional resistance, River Ogbesse, Inverse Relationship*.

1. Introduction

Flow characteristics studies in rivers are crucial for understanding human life and environmental management (Builders et al., 2021; Ding et al., 2022; Fuentes-Pérez et al., 2022). These studies are crucial for flood control (Builders et al., 2021; K. et al., 2010), as precise flow characteristics help predict and prepare for events, preventing inadequate planning and potential property damage (Fuentes-Pérez et al., 2022; Xu et al., 2013), loss of life, and community disruptions (Paul et al., 2017; Xu et al., 2013). Uncontrolled flooding can also lead to the degradation of natural systems (Fuentes-Pérez et al., 2022; Xu et al., 2013).

River flow affects the habitat needs of watersheds and aquatic species (Paul et al., 2017; Xu et al., 2013). A lack of knowledge of these flow patterns may lead to irregular water management practices, such as excessive water extraction or dam activities that disrupt natural flow regimes. This might harm fish populations, reduce biodiversity, and degrade water quality, harming the river's environment and aquatic life. (Gharbia et al., 2016; Omoyajowo et al., 2022) .

Productivity in agriculture may also decline. For irrigation, several farming techniques depend on steady river flows. (Fuentes-Pérez et al., 2022; Trösch, 2009). Inaccurate flow characterization can lead to either water shortages or surpluses, both of which can be disastrous (De Doncker et al., 2009; Tzanakakis et al., 2020). Water shortages may stress plants and limit yields, while surpluses can cause waterlogging and soil erosion (Story, 2011). Furthermore, understanding sediment movement is impacted by insufficient flow characterization (Pan et al., 2023; Wu et al., 2023). River channels and floodplains are shaped by natural processes called sediment deposition and erosion. Inadequate river flow data can cause mismanagement that has unforeseen repercussions, such as increased sedimentation in reservoirs that lowers their capacity and efficacy or excessive erosion that undermines infrastructure and riverbanks (Mohammed, 2017).

Flow characteristic studies have had substantial impacts on the broader environment. These studies have helped build flood forecasting systems.(Hossen et al., 2022; Jahura et al., 2024). Flow characterization has improved water resource management, thereby enhancing water availability for different purposes (Adongo et al., 2022; Guzha et al., 2018). Flow characterization studies provide guides in infrastructural projects in urban slums, decreasing flood risks and improving sanitation. Flow characterization studies offer valuable insights for infrastructural projects in urban slums, aiding in reducing flood risks and enhancing sanitation systems.(Collischonn et al., 2005). These efforts collectively result in better livelihoods, food security, and living conditions.

Research on flow characterization can be effectively undertaken in controlled laboratory environments or by observing natural open channel systems, thereby enabling comprehensive analysis of fluid dynamics and behaviour (Aberle & Smart, 2003; Buffington & Montgomery, 1999). The decision to study flow characteristics in either a natural river or a controlled laboratory environment depends on the study's specific objectives, limitations, and expected outcomes. Each setting offers unique advantages and challenges, affecting the amount and type of information obtained from the research.

Poor management of river hydrodynamics in Nigeria has led to dam failures and severe flooding. These issues result from the insufficient analysis of water flow behavior, sediment transport, and environmental interactions, leading to less effective dam designs and flood control systems. The 2012 flooding disaster in Nigeria underscores the urgent need for research into river hydrodynamics. The overflow of the Niger and Benue rivers resulted in extensive devastation, affecting 30 out of 36 states, displacing over two million individuals, and causing damages amounting to billions. Factors contributing to the disaster included the mismanagement of water releases from the Kainji, Jebba, and Shiroro dams and heavy rainfall. The absence of comprehensive hydrodynamic data led to inadequate flood forecasting and deficient infrastructure, exacerbating the disaster's impact. This case illustrates the necessity for advanced hydrological research, improved dam management, and urban planning to mitigate future flooding risks and protect lives and property.

Studies on open channel flow characteristics focus on the relationship between flow depth and velocity distribution. Chow (1959) emphasized the link between velocity distribution, flow depth, and channel geometry, though it has limited application to irregular natural channels. Rouse (1937) provided equations connecting velocity profiles to flow depth and roughness but did not consider complex systems. Knight and Demetriou (1983) examined lateral velocity redistribution in compound channels using computational and experimental methods, which require significant resources for irregular geometries.

Engelund and Hansen (1967) investigated sediment transport's interaction with flow depth and velocity, focusing more on sediment than channel geometry. Guo (2011) developed models for non-linear depth-velocity relationships using computational techniques, but they lack validation in diverse natural conditions. Julien (2002) combined analytical methods and case studies to show riverbed geometry's effect on flow dynamics, relevant to specific rivers. Nezu and Rodi (1986) detailed turbulence structures in open-channel flows with experimental data, but their findings are less applicable to large, natural river systems.

This research examines the correlation between flow depth and velocity distribution in the Ogbesse River, emphasizing the impact of depth variations on flow velocity patterns. Understanding this relationship is crucial for maintaining riverine ecosystem health, sediment transport, and flood management.

The study incorporates in-situ measurements using devices such as current meters to gather high-resolution flow data across various river cross-sections. Statistical analysis interprets the collected data to create comprehensive velocity distribution profiles. The outcomes are expected to contribute to improved river management strategies, ecological conservation efforts, and sustainable engineering approaches for flood control and habitat restoration.

2. Theoretical Background

2.1. Rivers: Unraveling Their Complex Dynamics and Vital Role

In Nigeria, inadequate management and lack of understanding of the hydrodynamic properties of rivers have resulted in significant negative impacts, including dam failures and severe flooding (Abaya et al., 2014). The hydrodynamics of a river system consist of examining water flow patterns, sediment movement, and the interactions between water and the surrounding environments (Ben Meftah, 2022; Pan et al., 2023). A lack of understanding in these areas can lead to improper water resource management and infrastructure development, such as poorly designed dams and inadequate flood control systems.

One significant consequence of these misunderstandings is dam failure, which may occur when dams are constructed without proper consideration of the river's flow dynamics and sediment load. For instance, the Lagdo Dam in Cameroon releases excess water that flows into Nigeria, often overwhelming the capacity of local reservoirs and resulting in severe flooding downstream. This situation underscores the importance of cross-border hydrodynamic assessments and cooperation in river basin management.

In addition to dam failures, the misinterpretation of river hydrodynamics significantly contributes to urban flooding. Numerous Nigerian cities are located along rivers, where unregulated urban expansion and insufficient drainage systems exacerbate the risk of flooding, as illustrated in Plate 2.

Plate 1. Poor management and misinterpretation of river hydrodynamics have led to dam failures and catastrophic flooding. (Abaya et al., 2014)

2.2. Rivers: Understanding Their Dynamics and Importance

Rivers are essential components of the Earth's hydrological cycle, serving as natural open channels that enable the transportation of water across various landscapes. As illustrated in Figure 1, they facilitate water flow from higher elevations to lower-lying areas such as oceans, lakes, and interconnected rivers (Wu et al., 2023; Xu et al., 2013). These systems are water conduits and play significant roles in shaping surrounding landscapes, influencing ecosystems, and providing essential resources for human societies (Cao et al., 2022; De Doncker et al., 2009). Rivers create interconnected habitats and biodiversity along their banks and within their waters (Salih et al., 2012; Uralov et al., 2021). It provides habitats for various plant and animal species, playing an important role in maintaining the planet's ecological balance (Cao et al., 2022; Uralov et al., 2021).

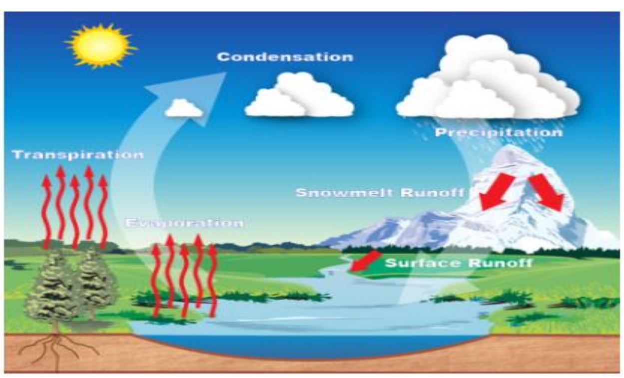

Fig. 1 Hydrological Cycle , Van Noordwijk et al.. (2014).

Rivers have played a significant role throughout human history, serving as transportation routes (Olowe & Kumarasamy, 2018), sources of freshwater (Fuentes-Pérez et al., 2022), and locations for settlements and economic activities.

Rivers have been pivotal in the development of civilizations by providing sustenance, facilitating trade routes, and serving as a source of livelihood for communities globally. Understanding the characteristics of rivers as open channels is essential to comprehending their broader significance and the factors influencing their behaviuor (Buffington & Montgomery, 1999; Mccabe, 2010). This includes studying their hydrodynamics (Wu et al., 2023), sediment transport processes (Southard, 2006), interactions with surrounding landscapes (Buffington & Montgomery, 1999), and responses to human activities such as damming, pollution, and climate change. Effective management of rivers necessitates a holistic approach that balances human needs with environmental sustainability, ensuring the continued health and resilience of these vital natural systems for future generations (Kim et al., 2021; Ogwueleka & Christopher, 2020).

3. Materials and Method

3.1. Site Selection

The Ogbesse River is chosen due to its accessibility and importance as a major perennial river in Southwestern Nigeria. Its tropical climate and rainforest vegetation support local socio-economic, religious, recreational, cultural, and agricultural activities (Kaine & Ogidiaka, 2022). The river is located geographically between longitudes 5°26'E to 6°34'E and latitudes 6°43'N to 7°17'N. It originates from Awo Ekiti in Ekiti State and flows through Ogbesse town, approximately five kilometres from Akure in the Akure North Local Government Area of Ondo State, Nigeria. The river extends for about 22 km from its source until it merges with the 265 km long River Ose (Kaine & Ogidiaka, 2022). Its flow pattern changes with the seasons and weather, providing data for analyzing different flow conditions from low flows in dry periods to high flows during floods. This variation helps understand flow dynamics under various scenarios.

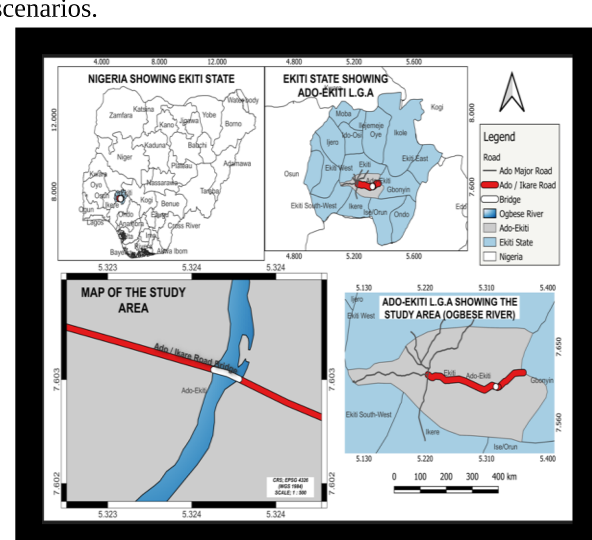

Fig. 2 Overview of Ogbesse River, along Ijan Rd. Ado Ekiti

3.2. Materials

The research materials included a Price AA Current Meter for velocity measurements, calibrated rods for depth measurement, GPS devices for precise location tracking, measuring tapes, and levelling instruments for channel slope measurement. Data loggers stored field measurements. Safety gear, such as waders and flotation devices, ensured secure data collection in the river environment. A canoe provided access to various points along the river and served as a platform for deploying instruments like current meters and depth gauges.

3.3. Methods

To measure the discharge and flow dynamics of the Ogbesse River, a structured methodology was employed involving the following key steps :

3.3.1. Selection of Straight Sections

The sections of the river with minimal obstructions were carefully selected to ensure uniform flow and reduce turbulence. This approach facilitated accurate measurements of flow velocity and distribution.

3.3.2. Designation of Transect Points

Three transect points (A3, A2, A1) were positioned at intervals of 25 meters from upstream to downstream. These points were marked perpendicular to the flow direction and evenly segmented across the river width for systematic data collection.

3.3.3. Measurement of River Width

The river width at each transect point was measured using measuring tapes, with stable markers ensuring consistent alignment for subsequent surveys. The widths were divided into equal segments for detailed profiling.

3.3.4. Field Survey Timing

Surveys were conducted in January and September 2023 to capture seasonal variations in flow dynamics, encompassing both high and low flow conditions.

3.3.5. Deployment of Current Meter

A current meter was used to measure flow velocities systematically, starting at the riverbank and progressing across each transect.

3.3.6. Velocity Measurements

Vertical Direction

Velocity was measured at multiple depths (e.g., 0.5, 1.5 meters) along the vertical profile of the river at each transect point.

Horizontal Direction

Measurements were taken across each segment of the transects, capturing variations from the riverbanks to the central channel.

Plate 2. Field Survey works at the area of study

Plate 3. Deployment of velocity measuring device at Ogbesse River

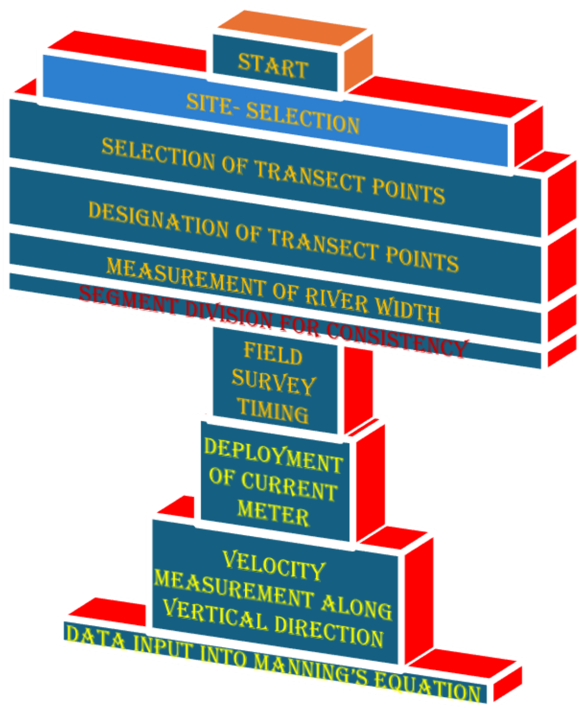

Fig. 1 Flow Chart of the experimental procedure for the research work

3.3.7. Data Analysis Using Manning's Equation

Collected velocity data was input into Manning's equation to calculate flow parameters, such as discharge and channel roughness, providing insights into the river's hydraulic behavior.

3.3.8. Plotting and Analysis

Velocity data was plotted to visualize horizontal and vertical distribution patterns. The analysis highlighted variations influenced by seasonal changes, riverbed structure, and flow dynamics.

3.4. Data Collection

Three sampling points were chosen along the river: upstream (A1), mid-stream (A2), and downstream (A3), each 25 meters apart, to capture flow characteristics. Velocity measurements were taken at depths of 0.25, 0.5, 0.75, 1.0, and 1.25 meters to analyze vertical velocity distribution. Additionally, five cross-sectional points were selected at intervals of 3.0 meters across the river at distances of 0.6, 3.6, 6.6, 9.6, and 12.6 meters from the bank to examine horizontal velocity distribution. This provided a detailed profile of both vertical and horizontal flow velocities. Utilizing both longitudinal and cross-sectional sampling techniques yields a comprehensive dataset, crucial for accurately characterizing the river's flow dynamics. This data is essential for subsequent hydrological and environmental studies. The modified method, as described by (Reprint & Meftah, n.d.)

The sampling points were strategically selected for accuracy and ease of data collection (Table 3.1) based on the river's flow characteristics and accessibility. Advanced instruments measured flow velocity, water depth, and riverbed profile in situ. Current meters and velocity loggers captured flow velocities at various depths while wading rods measured river depth. Measuring tapes determined distances between sampling points, notebooks recorded observations, and a levelling instrument ensured accurate elevation and slope measurements. The study used various tools and methodologies to gather accurate data for analyzing the river's flow characteristics. This method ensured that the data was reliable and could be used to understand the hydrological behavior of the river.

4. Results and Discussion

This section presents the results of the flow characteristics of the River Ogbesse during the dry seasons of November 2023 and February 2024. The analysis provides a detailed assessment of the velocity components and their spatial distribution, which is important for understanding the river's hydrodynamics during these low-flow periods. Understanding these characteristics is crucial for predicting flow behavior, assessing sediment transport, and evaluating potential environmental impacts associated with seasonal variations in discharge.

4.1. Summary of Results

Tables 2a and 2b present a comprehensive summary of the geometric measurements of the river within the study area. These measurements include key parameters such as river depth, width, and cross-sectional area, all of which influence the river's flow dynamics. By analyzing these parameters, it is possible to determine variations in velocity distribution across different river sections. The data obtained provide insight into the interaction between channel morphology and flow characteristics, which is essential for effective river management, flood risk assessment, and hydraulic modelling. Furthermore, the results contribute to a broader understanding of how river hydrodynamics respond to seasonal changes, aiding in sustainable water resource management and environmental conservation efforts.

Table 1. The locations of all the water wells examined within the study area

Longitudinal Direction	Depth of Flow (m)	Cross-sectional Direction (m)	Geo-reference Coordinates	
			Latitude	Longitude
Upstream (A_1)	1.25	0.6	7.63605	5.21872
	1	3.6	7.65154	5.22717
	0.75	6.6	7.65776	5.23244
	0.5	9.6	7.66643	5.24251
	0.25	12.6	7.64713	5.20481
Mid-stream (A_2)	1.25	0.6	7.65758	5.21746
	1	3.6	7.63605	5.21128
	0.75	6.6	7.67436	5.21862
	0.5	9.6	7.66243	5.21042
	0.25	12.6	7.62043	5.22732
down-stream (A_3)	1.25	0.6	7.61952	5.20421
	1	3.6	7.61884	5.20172
	0.75	6.6	7.61023	5.19462
	0.5	9.6	7.61997	5.19245
	0.25	12.6	7.60696	5.22157

4.1.1. Results of the Velocity Distribution Versus Depth of Flow

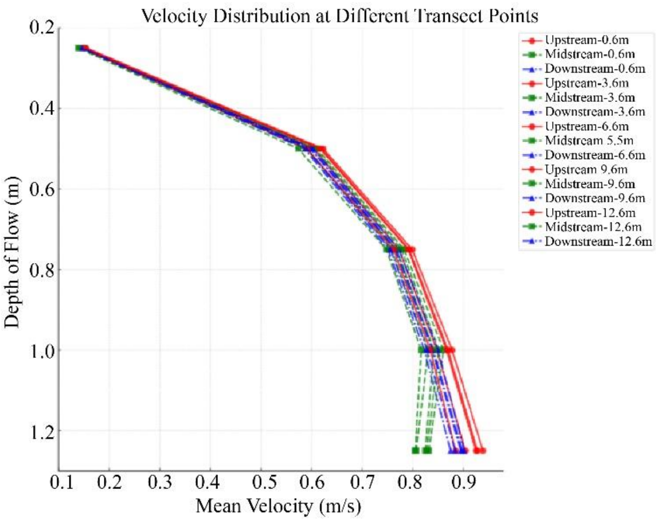

Fig. 2 Unified plot illustrating the relationship between velocities and flow depths at different points upstream of River Ogbesse (at transect points 0.6, 3.6, 6.6, 9.6, and 12.6 meters).

Figure 4 The graph illustrates how velocity varies with depth at different transect points along the river. It shows data for upstream, midstream, and downstream sections, making comparing flow characteristics across locations easy. As depth decreases, velocity consistently reduces due to increased friction near the riverbed. The upstream, midstream, and downstream velocity trends are similar across all transects, suggesting a relatively uniform flow pattern. The use of distinct colors, markers, and line styles ensures clarity, while the inverted depth axis correctly represents the natural vertical profile of the river. Deeper flows have higher velocities due to reduced frictional resistance, whereas shallower flows experience more friction, slowing down the flow. Variations in velocities at the same depths across points can be attributed to local channel conditions such as width, roughness, or slope. The plot demonstrates fluid dynamics in this river system.

This information is helpful for hydraulic structure design:

- Predicting Load on Structures: Deeper water flows at higher velocities help estimate forces on structures.
- Erosion Prevention: Lower velocities in shallower sections inform strategies for erosion protection.
- Customization of Design: Velocity variations provide data for site-specific design adjustments, improving efficiency.

4.1.2. Results of Discharge in relationship to the Coefficient of Roughness

Figure 5 illustrates a consistent inverse relationship between discharge and the coefficient of roughness at various points along the channel. As the coefficient of roughness increases, discharge decreases, indicating higher flow resistance due to increased roughness. The consistent inverse relationship across different points and figures underscores the critical importance of roughness in regulating discharge. Understanding and managing this relationship is crucial for effective water management strategies and infrastructure planning. It informs the design and maintenance of channels to optimize flow efficiency by minimizing roughness where possible.

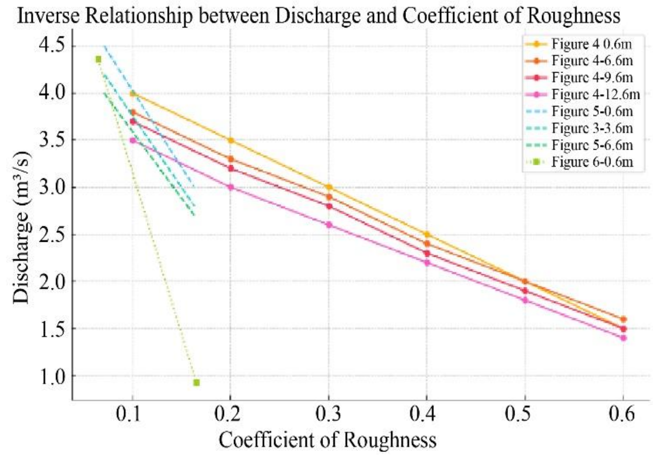

Fig. 5 Plot of discharge and coefficient of roughness distribution in River Ogbesse

The information has negative implications for hydraulic structure design, as increased roughness reduces discharge, leading to higher flow resistance and less efficient water transport. This can elevate flood risks, increase maintenance costs, and create design challenges. Conversely, it is also positive because it provides engineers with valuable insights for designing improved structures. By accounting for the roughness-discharge relationship, engineers can optimize designs to minimize the effects of roughness, ensuring more efficient water flow and enhanced hydraulic performance.

4.1.3. Results of Coefficient of Roughness and Depth of Flow

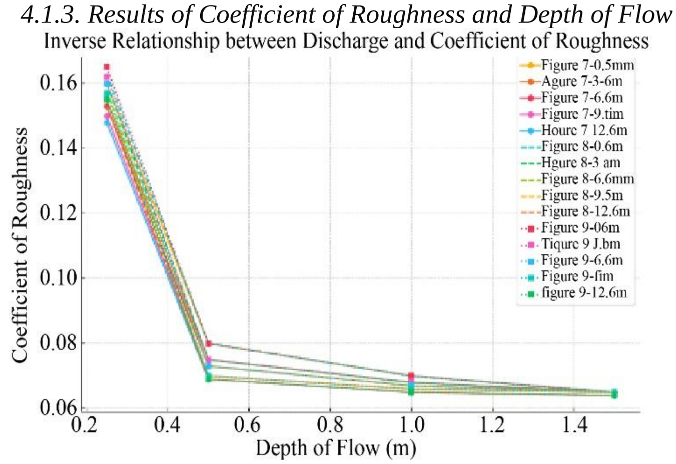

Fig. 6 Combined plot of the depth of flow and coefficient of roughness in River Ogbesse

Figure 6 examines the relationship between flow depth and the coefficient of roughness at various points along the River Ogbesse. The data indicate an inverse relationship, where roughness increases as depth decreases. This trend is consistently observed across different locations along the river, suggesting a general behavior in the river system where shallower flows experience greater frictional resistance. Understanding this relationship between depth and roughness is crucial for effective river management and engineering. Increased roughness at lower depths implies higher resistance, affecting flow velocity and overall flow dynamics. This knowledge is essential for designing water channels, flood control systems, and irrigation networks. Together, the figures provide a comprehensive understanding of how roughness varies with depth and its implications for managing river flow. The information presents challenges for hydraulic structure design by highlighting increased roughness at shallower depths, leading to higher flow resistance. This can complicate efficient water flow management, posing difficulties for the design of hydraulic structures such as channels, culverts, and flood control systems. However, the data also offer valuable insights for engineers. By understanding that roughness increases with decreasing depth, engineers can make design adjustments to minimize resistance, thereby improving the efficiency of structures and ensuring their effectiveness under various flow conditions.

4.1.4. Results of Velocity and Coefficient of Roughness in River Ogbesse

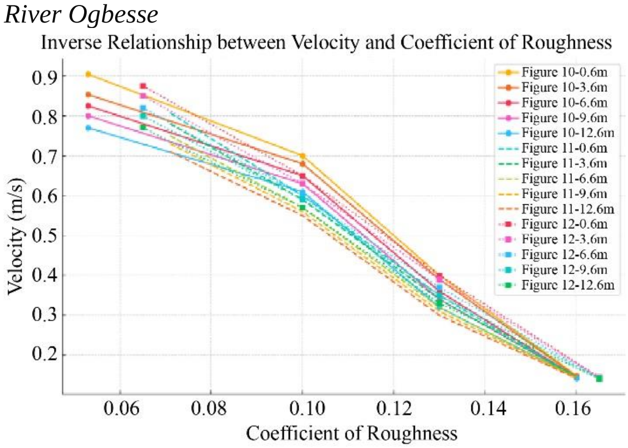

Fig. 7 Plot of depth of flow and coefficient of roughness in River Ogbesse

Figure 7 examines the relationship between velocity and the coefficient of roughness at various points along the River Ogbesse (0.6m, 3.6m, 6.6m, 9.6m, and 12.6m). The Figure shows an inverse relationship between the variables; the data indicates that as the coefficient of roughness increases, the velocity decreases across all measured points. As roughness increases, velocity decreases, indicating increased frictional resistance in the channel. This consistent pattern across different points and datasets highlights the importance of understanding and managing roughness in hydraulic engineering and river management.

This information is important for hydraulic structure design because it reveals that increased roughness at shallower depths leads to higher flow resistance, which can affect the efficiency of managing water flow through channels, culverts, and flood control systems. Additionally, understanding how roughness varies with depth provides useful insights for engineers to make informed design adjustments to minimize resistance and improve the efficiency of structures under various flow conditions.

4.1.5. Results of Discharge and depth of flow in River Ogbesse

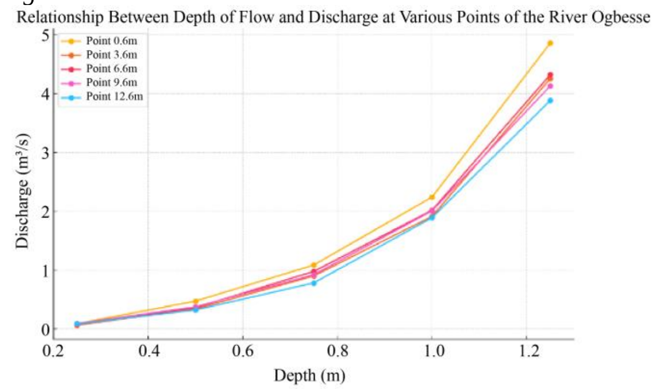

Fig. 8 Plot of velocity discharge and depth of flow in River Ogbesse

Figure 8 visualizes the relationship between flow depth and discharge at various points along the River Ogbesse. As depicted, a distinct trend indicates that as depth increases, discharge correspondingly rises across all measured points (0.6m, 3.6m, 6.6m, 9.6m, and 12.6m). The data reveal that shallower depths correlate with lower discharge rates, while greater depths permit substantially higher discharges.

This pattern underscores the river's capacity to convey more water with increased depths, emphasizing the significance of depth in determining discharge capacity. The marked decline in discharge observed at lower depths and the variances in discharge across different points emphasize the sensitivity of discharge rates to alterations in channel characteristics, such as width and slope, which impact the river's flow capacity.

This information is particularly beneficial for hydraulic structure design. It underscores the critical relationship between flow depth and discharge, enabling engineers to predict how variations in depth influence a river's ability to transport water.

Such understanding is essential for designing structures like dams, weirs, and channels that efficiently manage water flow, mitigate flooding risks, and facilitate irrigation. By optimizing designs based on depth-discharge relationships, hydraulic engineers can enhance water resource management and ensure the stability and effectiveness of hydraulic systems.

5. Conclusion

The assessment of flow characteristics along River Ogbesse reveals a fundamental relationship between velocity and variations in depth of flow. The unified trends depicted in the data demonstrate a consistent inverse relationship, where velocity decreases as the depth of flow decreases. This behavior underscores the critical role of depth in governing flow dynamics, as deeper flows exhibit higher velocities due to reduced frictional resistance from the channel bed and banks, while shallower flows experience significant velocity reductions attributed to increased friction.

This relationship highlights the importance of depth as a determining factor in the efficiency and behavior of water flow. The consistent patterns observed across various transect points affirm that the river system behaves uniformly, with localized variations in velocity arising from specific channel conditions such as changes in width, roughness, or slope. These findings emphasize that deeper river sections facilitate smoother, faster flows, whereas shallower areas are prone to slower, more resistant flows due to heightened frictional interaction.

Understanding the interplay between velocity and depth of flow is essential for assessing the hydraulic characteristics of the river. This knowledge not only provides insight into the natural behavior of the river but also informs the design and management of hydraulic structures. By accurately predicting how changes in depth affect velocity, engineers can develop more effective strategies for managing flow, reducing erosion, and optimizing water transport systems. The relationship between velocity and depth is foundational in evaluating flow characteristics and supports informed decision-making for sustainable river management and hydraulic engineering.

The findings from the assessment of flow characteristics along the upstream of River Ogbesse align with and contribute to the existing body of research on the relationship between velocity, depth of flow, and channel characteristics in river systems. Studies such as those by Leopold and Maddock (1953), which explored hydraulic geometry and the interdependence of flow parameters, support the observed inverse relationship between velocity and depth. Their foundational work highlighted how deeper channels, with reduced roughness effects, facilitate higher velocities—a trend confirmed by this study.

Further corroboration comes from Chow’s (1959) principles of open channel hydraulics, which discuss the influence of channel resistance on flow dynamics. Chow's work establishes that frictional resistance from the bed and banks intensifies as depth decreases, a phenomenon observed in the River Ogbesse, where shallow sections consistently exhibit reduced velocities. These findings align with empirical studies on flow resistance by Yen (2002), which emphasize the role of the coefficient of roughness in modulating velocity and discharge.

Additionally, recent studies in hydrology, such as those by Ferguson (2007), have explored localized variations in flow due to changes in channel morphology, supporting the notion that channel-specific factors, including slope, width, and roughness, contribute to velocity variations across transects. This study's observations of local variations in the River Ogbesse affirm Ferguson's conclusions, emphasizing the complex interplay of depth and velocity modulated by channel characteristics.

Linking the results of this study to established works in the field contributes to a deeper understanding of the mechanics of river flow. The insights gained are consistent with theoretical and empirical models, reinforcing the significance of depth-velocity relationships in predicting flow behavior and informing the design of hydraulic structures. This study complements the existing literature by offering specific, site-based data from the River Ogbesse, which can serve as a case study for similar environments in hydrological and hydraulic engineering research.

Acknowledgments

The authors wish to acknowledge the Hydraulics and Hydrology Laboratory unit of the Civil Engineering Department, Federal Polytechnic Ado Ekiti, Ekiti State.

References

[1] O. Agbonkhese Agbonkhese et al., "Flood Menace in Nigeria: Impacts, Remedial and Management Strategies," *Civil and Environmental Research*, vol. 6, no. 4, pp. 32-41, 2014. [Google Scholar] [Publisher Link]

[2] J. Aberle, and G. M. Smart, "The Influence of Roughness Structure on Flow Resistance on Steep Slopes," *Journal of Hydraulic Research*, vol. 41, no. 3, pp. 259-269, 2003. [CrossRef] [Google Scholar] [Publisher Link]

[3] Miriam Judith Adongo et al., "Seasonal Variation in Physicochemical Properties of Groundwater, a Case Study of Kamiti-Marengeta Subcatchment Kiambu, Kenya," *Journal of Water Resource and Protection*, vol. 14, no. 2, pp. 72-85, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[4] Mouldi Ben Meftah, "Flow Hydrodynamic in Open Channels: A Constantly Evolving Topic," *Water*, vol. 14, no. 24, pp. 1-6, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[5] John M. Buffington, and David R. Montgomery, "Effects of Sediment Supply on Surface Textures of Gravel-Bed Rivers," *Water Resources Research*, vol. 35, no. 11, pp. 3523-3530, 1999. [CrossRef] [Google Scholar] [Publisher Link]

[6] Philip F. Builders, Boma B. Mohammed, and Yahaya Z. Sule, "Preparation and Characterization of a Poly-Herbal Tea with Effective Antioxidant Properties," *Science World Journal*, vol. 15, no. 4, pp. 29-34, 2020. [Google Scholar] [Publisher Link]

[7] Ping Cao et al., "Experimental Study on the Impact of Pulsed Flow Velocity on the Scouring of Benthic Algae from a Mountainous River," *Water*, vol. 14, no. 19, pp. 1-14, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[8] Walter Collischonn et al., "Forecasting River Uruguay Flow Using Rainfall Forecasts from a Regional Weather-Prediction Model," *Journal of Hydrology*, vol. 305, no. 1-4, pp. 87-98, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[9] L. De Doncker et al., "Determination of the Manning Roughness Coefficient Influenced by Vegetation in the River Aa and Biebrza River," *Environmental Fluid Mechanics*, vol. 9, pp. 549-567, 2009. [CrossRef] [Google Scholar] [Publisher Link]

[10] Shao-wei Ding et al., "Impact of Depth Ratio on Flow Structure and Turbulence Characteristics of Compound Open Channel Flows," *Water Science and Engineering*, vol. 15, no. 3, 265-272, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[11] Diane P. Dupont, and Steven Renzetti, "Household Behavior Related to Water Conservation," *Water Resources and Economics*, vol. 4, pp. 22-37, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[12] Juan Francisco Fuentes-Pérez, Francisco Javier Sanz-Ronda, and Jeffrey A. Tuhtan, "An Open Surface Drifter for River Flow Field Characterization," *Sensors*, vol. 22, no. 24, pp. 1-15, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] Abdalkarim S. Gharbia et al., "Ground water Quality Evaluation Using GIS Based Geostatistical Algorithms," *Geoscience and Environment Protection*, vol. 4, no. 2, pp. 89-103, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[14] A.C. Guzha et al., "Impacts of Land Use and Land Cover Change on Surface Runoff, Discharge and Low Flows: Evidence from East Africa," *Journal of Hydrology: Regional Studies*, vol. 15, pp. 49-67, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[15] Md. Nazmul Hossen, Shahpara Nawaz, and Md. Humayain KabirFlood, "Research in Bangladesh and Future Direction: An Insight From Last Three Decades," *International Journal of Disaster Risk Management*, vol. 4, no. 1, pp. 15-39, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[16] Sultana Jahura, M. Zulfiquar Ali Islam, and M.G Mostafa "Impact of Water Scarcity on Domestic Water Use in Drought-prone Barind Tract , Bangladesh : A Sociological Perspective," *Indonesian Journal of Social and Environmental Issues*, vol. 4, no. 3, pp. 267-279, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[17] Kathryn Holt et al., "*An Examination of Household Drinking Water Storage and Management Practices in Bonao, Dominican Republic from September 2005-January 2006*," Thesis, Georgia State University, pp. 1-2, 2010. [Google Scholar]] [Publisher Link]

[18] E.A. Kaine, and E. Ogidiaka, "Water Quality Assessment of Ogbese River, Ekiti State Using Biological Approaches," *Journal of Applied Sciences*, vol. 22, no. 6, pp. 342-350, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[19] Jaeyoung Kim, John R. Jones, and Dongil Seo, "Factors Affecting Harmful Algal Bloom Occurrence in a River with Regulated Hydrology," *Journal of Hydrology: Regional Studies*, vol. 33, pp. 1-14, 2021.[CrossRef] [Google Scholar] [Publisher Link]

[20] Declan McCabe, "Rivers and Streams: Life in Flowing Water," *Nature Education Knowledge*, pp. 1-14, 2010. [Google Scholar] [Publisher Link]

[21] Ali Mohammed, "*Developing Methodologies for Sustainable Groundwater Management in sub-Saharan Africa: A Case Study of the Chad Basin Around Maiduguri, Nigeria*," Doctoral Thesis, Abertay University, pp. 1-289, 2017. [Google Scholar] [Publisher Link]

[22] Toochukwu Chibueze Ogwueleka, and Igibah Ehizemhen Christopher, "Hydrochemical Interfaces and Spatial Assessment of Usuma River Water Quality in North-Central Nigeria," *Scientific African*, vol. 8, pp. 1-12, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[23] Kayode O. Olowe, and Muthukrishna vellaisamy Kumarasamy, "Assessment of Some Existing Water Quality Models," *Nature Environment and Pollution Technology*, vol. 17, no. 3, pp. 939-948, 2018. [Google Scholar] [Publisher Link]

[24] Koleayo Omoyajowo et al., "Public Awareness, Knowledge, Attitude and Perception on Microplastics Pollution Around Lagos Lagoon," *Ecological Safety and Balanced Use of Resources*, vol. 12, no. 2, pp. 35-46, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[25] Li Pan et al., "Experimental Study of the Hydrodynamics of an Open Channel with Algae Attached to the Side Wall," *Water*, vol. 15, no. 16, pp. 1-15, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[26] Michael J. Paul et al., *Algal Indicators in Streams: A Review of Their Application in Water Quality Management of Nutrient Pollution*, Biodiversity and Conservation, United States Environmental Protection Agency, pp. 1-44, 2017. [Google Scholar] [Publisher Link]

[27] Mouldi Ben Meftah, *Flow Hydrodynamic in Open Channels: Interaction with Natural or Man-Made Structures*, MDPI AG, pp. 1-264, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[28] Suhair S. Salih et al., Water Characteristics and Treatment : A Review, *American-Eurasian Journal of Agricultural & Environmental Sciences*, vol. 12, no. 12, pp. 1536-1542, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[29] John Southard, *Introduction to Fluid Motions, Sediment Transport and Current-Generated Sedimentary Structures*, E- Book, pp. 1-541, 2006. [Google Scholar] [Publisher Link]

[30] Aslinda Hassan et al., *An Automated Irrigation System Using Arduino Microcontroller*, Chapter - 1, UTem Press, pp. 1-90, 2018. [Google Scholar] [Publisher Link]

[31] Walter Trösch, *Water Treatment: Technology Guide: Principles - Applications - Trends*, Springer, pp. 394-397, 2009. [CrossRef] [Google Scholar] [Publisher Link]

[32] Vasileios A. Tzanakakis, Nikolaos V. Paranychianakis, and Andreas N. Angelakis, "Water Supply and Water Scarcity," *Water*, vol. 12, no. 9, pp. 1-16, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[33] Bakhtiyor Uralov et al., "Hydraulic Modes of Damless Water Intake," *IOP Conference Series: Materials Science and Engineering: VII International Scientific Conference "Integration, Partnership and Innovation in Construction Science and Education"*, Tashkent, Uzbekistan, vol. 1030, pp. 1-11, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[34] Meine van Noordwijk et al., "Pricing Rainbow, Green, Blue and Grey Water: Tree Cover and Geopolitics of Climatic Teleconnections, *Current Opinion in Environmental Sustainability*, vol. 6, pp. 41-47, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[35] Chenhui Wu et al., "Hydrodynamics Affected by Submerged Vegetation with Different Flexibility Under Unidirectional Flow," *Frontiers in Marine Science*, vol. 9, pp. 1-21, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[36] XU Wei-gang et al., "Effects of Vegetation on River Flow: A Review," *Chinese Journal of Applied Ecology*, vol. 24, no. 1, pp. 251-259, 2013. [Google Scholar] [Publisher Link]

Appendix

Table 2(a). Comprehensive summary of the geometric measurements of the river taken within the study area

	Transect points	0.6m					3.6m					6.6m				
Upstream	Depth of flow (m)	1.25	1	0.75	0.5	0.25	1.25	1	0.75	0.5	0.25	1.25	1	0.75	0.5	0.25
	Mean Velocity	0.904	0.848	0.773	0.604	0.149	0.928	0.87	0.793	0.619	0.151	0.939	0.878	0.799	0.623	0.155
	Cross-Sectional area (A^2)	5.375	3.8	2.475	1.4	0.575	5.375	3.8	2.475	1.4	0.575	5.375	3.8	2.475	1.4	0.575
	Manning's roughness	0.053	0.06	0.056	0.058	0.16	0.062	0.058	0.055	0.056	0.156	0.061	0.058	0.054	0.056	0.154
	Discharge	4.861	3.222	1.914	0.845	0.086	4.759	3.193	2.052	1.232	0.919	4.848	3.23	2.063	1.233	0.918
Mid-stream	Depth of flow (m)	1.25	1	0.75	0.5	0.25	1.25	1	0.75	0.5	0.25	1.25	1	0.75	0.5	0.25
	Mean Velocity	0.807	0.831	0.758	0.592	0.146	0.828	0.852	0.778	0.607	0.15	0.832	0.861	0.783	0.611	0.15
	Cross-Sectional area (A^2)	5.375	3.8	2.475	1.4	0.575	5.375	3.8	2.475	1.4	0.575	5.375	3.8	2.475	1.4	0.575
	Manning's roughness	0.071	0.061	0.057	0.059	0.163	0.069	0.059	0.056	0.057	0.159	0.069	0.059	0.055	0.057	0.159
	Discharge	3.885	3.033	1.988	1.22	0.922	4.022	3.121	2.023	1.227	0.92	4.05	3.157	2.033	1.228	0.92
Down=stream	Depth of flow (m)	1.25	1	0.75	0.5	0.25	1.25	1	0.75	0.5	0.25	1.25	1	0.75	0.5	0.25
	Mean Velocity	0.875	0.823	0.751	0.586	0.145	0.898	0.841	0.768	0.599	0.148	0.902	0.85	0.773	0.603	0.149
	Cross-Sectional area (A^2)	5.375	3.8	2.475	1.4	0.575	5.375	3.8	2.475	1.4	0.575	5.375	3.8	2.475	1.4	0.575
	Manning's roughness	0.065	0.061	0.058	0.059	0.165	0.064	0.06	0.056	0.058	0.161	0.063	0.059	0.056	0.058	0.16
	Discharge	4.357	3	1.975	1.218	0.923	4.525	3.075	2.005	1.223	0.921	4.561	3.11	2.015	1.225	0.921

Table 2(b). Comprehensive summary of the geometric measurements of the river taken within the study area

	Transect points	**9.6m**					**12.6m**				
Upstream	Depth of flow (m)	1.25	1	0.75	0.5	0.25	1.25	1	0.75	0.5	0.25
	Mean Velocity	0.925	0.867	0.791	0.617	0.152	0.885	0.835	0.762	0.591	0.146
	Cross-Sectional area (A^2)	5.375	3.8	2.475	1.4	0.575	5.375	3.8	2.475	1.4	0.575
	Manning's roughness	0.061	0.058	0.054	0.056	0.154	0.065	0.061	0.057	0.059	0.163
	Discharge	4.737	3.182	2.048	1.231	0.919	4.427	3.049	1.995	1.22	0.923
Mid-stream	Depth of flow (m)	1.25	1	0.75	0.5	0.25	1.25	1	0.75	0.5	0.25
	Mean Velocity	0.825	0.842	0.768	0.589	0.142	0.805	0.817	0.748	0.574	0.139
	Cross-Sectional area (A^2)	5.375	3.8	2.475	1.4	0.575	5.375	3.8	2.475	1.4	0.575
	Manning's roughness	0.069	0.06	0.056	0.059	0.167	0.071	0.062	0.058	0.061	0.171
	Discharge	4.005	3.078	2.005	1.219	0.924	3.869	2.975	1.971	1.213	0.926
Down=stream	Depth of flow (m)	1.25	1	0.75	0.5	0.25	1.25	1	0.75	0.5	0.25
	Mean Velocity	0.895	0.839	0.765	0.598	0.147	0.884	0.829	0.756	0.59	0.146
	Cross-Sectional area (A^2)	5.375	3.8	2.475	1.4	0.575	5.375	3.8	2.475	1.4	0.575
	Manning's roughness	0.064	0.06	0.057	0.058	0.161	0.065	0.061	0.057	0.059	0.163
	Discharge	4.504	3.065	2.001	1.223	0.922	4.423	3.023	1.984	1.22	0.923