International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 2 Feb 2021, pp: 634-643 www.ijaem.net ISSN: 2395-5252

Assessment of the Hydraulic Geometry of River Yedzeram at Lokuwa Bridge, Wuro-Gudeand Wuro-MayoChannel Section, Adamawa State, North East Nigeria

[1]Kadmiel Oliver, [1]Ezekiel Yonnana, [1]Wesley Philemon [2]Ibrahim Bobboi, [2]Auwal Umar, and [3]Jackson Matapa.

[1]Department of Geography, Adamawa State University Mubi, Adamawa State, Nigeria
[2]Department of Geography, Federal Collage of Education Yola, Adamawa State, Nigeria
[3]Department of Geography, Federal Army University Bue, Borno State, Nigeria

Submitted: 10-02-2021 Revised: 20-02-2021 Accepted: 26-02-2021

ABSTRACT: It is hydrologic and geomorphologic significance to understand the flow characteristics of a stream in terms of channel morphology dynamics and management of stream water resources for sustainable uses.The Hydraulic Geometry of River Yedzeram at Lokuwa Bridge, Wuro-Gude and Wuro-Mayo Channel Section, Adamawa State, North East Nigeria was analyzed.The results of the daily water level revealed that the higher water levels were recorded at Mayo-Bani gauging station than at the Mubi gauging stations (Wuro-Gude and Lokuwa Bridge,) due to the additional inflow of water from the adjoining streams and run offs. The findings indicated that there was an established relationship among the area's Total Annual Rainfall and Annual Mean Discharge within the three stations, which implied that the ephemeral flow characteristic exhibited by the stream sections were strongly tied to area's rainfall regime coupled with other climatic and anthropogenic factors such as high evaporation rates and excessive water withdrawals for municipal and agricultural uses. Field study discovered that the cross-sectional profile of river Yedzeram at Lokuwa Bridge, Wuro-Gude and Wuro Mayo 2018 and 2019 were harmonious throughout the study periods in the study stretch, except that some few similarities in some portions of the channel where the cross-sectional profiles were found lopsided, due to the erosion and deposition activities in some parts of the channel. The turbulence of the river was rapid (supercritical) because the Froude number was greater than one. The supercritical pattern of flow observed was an indication of high channel roughness and high flow velocities of the stream section. The calculated stream power (ω) at Lokuwa Bridge was $2273.42 Jm^{-2}s^{-2}$, at Wuro-Gude was $4511.071 Jm^{-2}s^{-2}$ and at Wuro-Mayo was $7053.87 Jm^{-2}s^{-2}$. Since the stream power of the (3) stations were $< 1 Jm^{-2}s^{-1}$ and $> 12{,}000 Jm^{-2}s^{-1}$, it was not sufficient to move boulders meters in diameter, but could define the work capability of a stream, most especially in terms of sediment detachment, entrainment and transportation.Continual hydro-morphologic monitoring, data collection and development of strong policies on in-stream and riparian land disturbances within the entire Mubi section of the stream are recommended by (Yonanna2020).

Keywords: River Yedzeram, Stream Flow Behaviour,Hydraulic Geometry, Hydro-Morphologic Monitoring, and River turbulence.

I. INTRODUCTION

Today, in geomorphology the concept that is receiving increasing attention is the assessment of river condition or River assessment. In both of these fields, river condition is often assessed relative to a reference reach, or a reach that is known or suspected to be largely unmodified or in a natural state. However, the identification of a suitable reference reach can be very difficult in regions that have been heavily modified by humans (Elizabeth, Melissa and Scott 2007). Hydraulic geometry has been used to determine the baseline geomorphic character in stream restoration designs (Jong-Seok Lee 2003) and has recently been proposed as a preliminary method for determining in-stream flow requirements for habitat assessments (Jowett, 1998). The quantitative measurement of hydraulic characteristics of a river, such as the water surface width, the average water depth,the suspended load, and the flow velocity, change with its discharge as a simple power function, at a cross-section (Ishak, Musa, and Abdullah 2015).

As River Styles involves some subjective interpretation, this study explores an additional geomorphic approach using quantitative scaling relationships between reference and concept of downstream hydraulic geometry, as originally proposed by Leopold and Maddock (1953), can be used to assess how simple fluvial parameters along a reach, such as channel width, depth and mean velocity, vary in the downstream direction. The relationship established between the hydraulic characteristics and the discharge of a river is expressed as the hydraulic geometry. The velocity is the ratio of the particle displacement divided by the elapsed time between images (Yonanna 2020). A representative stream velocity is then estimated using a correction factor to account for channel roughness (Nagle 2000). Finally, stream discharge is estimated using an area-velocity method (Yonanna 2007). While such applications are typically reserved to describe changes along single river channels, it is possible that the downstream hydraulic geometry relations may extend throughout river networks where climatic and geologic controls are similar. If so, this would decrease the problem of locating reference reaches in reasonably natural condition as the potential for locating undisturbed reaches would substantially increase.

Field measurement of flow, however, can be quite challenging, based on site and flow conditions such as river bank, channel roughness, river cover, riverslope, volume of water, velocity of water and turbidity (Muhamad et al, 2013). Quite some decades say over 100 years, Stream gauging stations have been used as the standard method of measuring open-channel flow (Costa et al., 2002). Since the flow velocity varies at different points in a stream cross section, calculating the average velocity at many points within that cross section is highly recommended (Fall, 2015). Streams are vital features of both natural and cultural landscapes (Yonanna 2020). Beside their aesthetic beauty, they serve as very important life sustaining components of the ecological system in terms of habitat for aquatic lives and water supply for terrestrial flora and fauna. As a matter of fact, the importance of streams to man as sources of water for consumption, domestic, industrial, transportation, recreation and agriculture uses among others, cannot be under estimated (Oliver 2016). However, as dynamic features of the fluvial systems, streams are subject to vast changes in their morphological (form) and cascading (process) components, which could result to either excesses or deficits in their water contents; deformations in their channel morphologies or complete extinction. Such changes can only be ascertained if the flow behaviour of the river system is well understood, in this case, the application of the concept of hydraulic geometry is key and inevitable (Yonnana 2020). Hydraulic geometry is of fundamental importance in planning, design, and management of river engineering and training works (Vijay 2003).Discharge data enable populations to distribute and manage finite water supplies (Oliver 2018). Effective water management requires accurate discharge measurements (Chan 2013). Discharge is a critical parameter necessary for designing hydraulic structures, evaluating aquatic habitat, and any general river or stream studies (Caliente 2009). However, continuous flow monitoring is generally a labor-intensive and costly endeavor (Grant, 1997).

One of the major components of the hydrologic cycle that can be measured for large geographic areas with reasonable accuracy is surface runoff (Herschy 2002), specifically open-channel flow, is a water management in many diverse applications, including water supply management, pollution control, irrigation, flood control, energy generation, and industrial use can never be carried out without Flow necessary information (Herschy, 2002). Therefore, the purpose of this study is to unveil the hydraulic geometry of river Yedzeram and its relations within channel sectionsof Lokuwa Bridge, Wuro-Gude and Wuro-Mayoand to consider its potentials for use in assessments of river channel condition and its impact.

II. MATERIALS AND METHODS

Description of the Study Area

The channel studied extended from Lokuwa Bridgeto Wuro-Mayo is the channel of RiverYedzeramconsequent stream in Yedzeram Sub-basin. It is located between 13° 11’ 12”E, and 13° 30’ 00”E of Equator, and between latitudes 10° 06’ 30”N, and 10° 26’ 54”Nof the Prime Meridian (Figure 1), covering a length of 33km - from Lokuwa Bridge in Mubi north Local Government Area to Wuro-Mayo in Hong Local Government Area (Google Map 2020). The stream channel is ephemeral by nature and characterized by gravel to sand bed material with small areal floodplains which support some irrigation agricultural activities in the area (Yonanna 2020). The channel reach is almost moderately a meandering channel and the sinuosity index value is 1.46 (Oliver 2020). The field visitation 2019 revealed that the bank materials are predominated by sandy loam.

The study area is of tropical wet and dry climate type, coded Aw in the Koppen’s climate classification scheme. The temperature regime of the area is warm to hot throughout the year owing to high radiation income with a slight cool period from November to February. The area experiences gradual increase in temperature from January (33.9°C) to April (39.6°C) with annual maximum occurring in April. The wet season which runs from June to October yields annual rainfall amounts of 970mm to 1200mm (Adebayo, 2004). However, greater amounts have been recorded in recent times. These rainfall amounts contribute immensely to the area's stream flow characteristics owing to the influences of its geology (Basement complex rock types) and shallow to moderately deep soils over a rugged relief (Yonanna 2020).

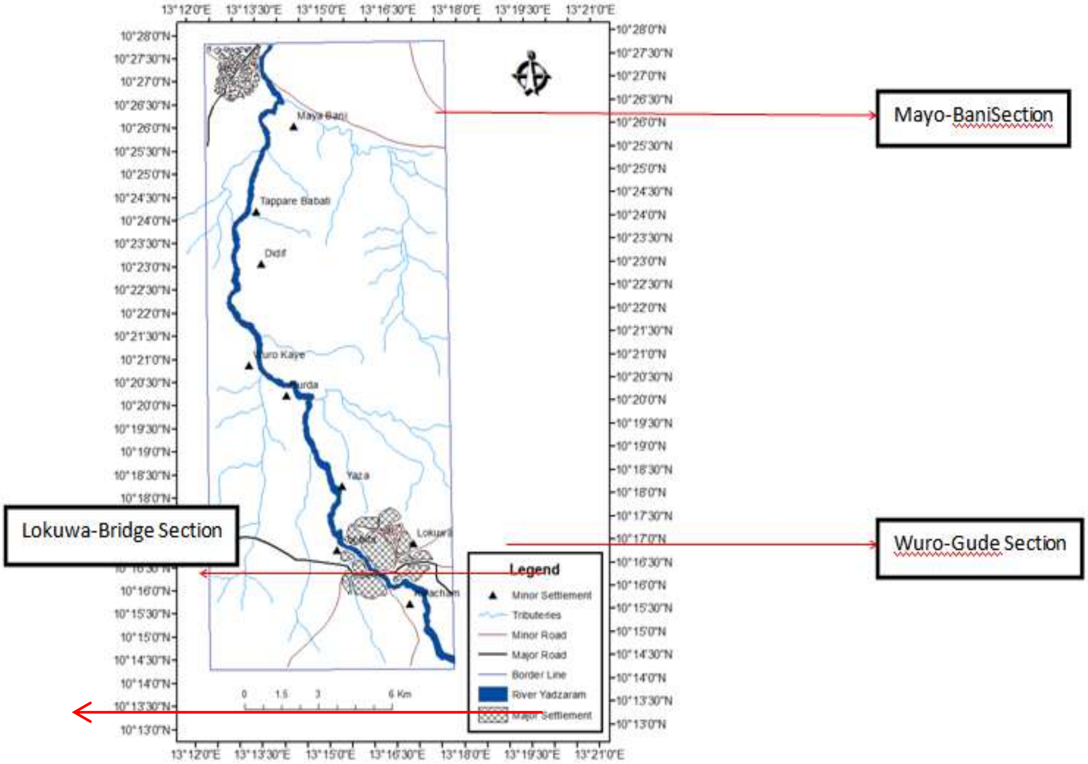


Figure 1: the study area

Materials and Equipment

The equipment used during fieldwork, and other analyses included Steel meter tape, Leveling Instrument, Leveling Staff, Ranging poles, Hand-held GPS, staff Gauges, probe meter, Stopwatch, Weighing Balance, laptop for digitizing map, and other relevant computer Hardware, and Software (David, 2014, and Yonanna, 2007).

Data on channel widths, channel bed-gradient (slope), channel bank-full depths, stream flow velocity, flow discharge, channel bed level, stream gauge, stream behavior, and stream power were collected through intensive fieldwork. Data on the amount of runoff that entrained the channel was obtained from measurements involving the use of stream flow, where the daily, weekly or monthly discharge obtained from the discharge measurement using wading (probe) methods. Putting the total length of the river under consideration, section of about 33km in length, from Lokuwa Bridge to Wuro-Mayo(Google map 2019) was used for this study. Three (3) sites were selected for staff gauging, stream flow measurement, and sediment collection on the condition of proximity, accessibility to the river, presence of complex planform geometry (meander, multiple points, concaves, convex, bars), characteristics of historical evolution of the channel pattern, as put by (Billy 2014).

Sample Procedure

Area sampling technique through equal increment of width, using the same transit rate for all verticals and the same bill along the same cross-section was used. The cross-section of the river was divided into a meter each with its distinct boundary. After dividing the cross-section into a meter as section or unit, systematically samples were adopted and drawn from each section so that the total samples equaled to the numbers of meters for the whole cross-section as puts by (Fulford, 2013). Using the above discharge procedure, river discharges at the selected point were obtained in the rainy seasons of the 2018 and 2019 hydrological years precisely during the months of August September and October.

The channel bank-full widths, and depths were measured directly at the sample stations using steel tape, and leveling staff. While the Steel meter tape was used for measuring of the distances between the selected sample points, and the channel width, as used by (Jungiang, Jie, Paul, and Meirang 2017, David 2014, Yonnana 2007, and Mehmet, Musa, and Abdullah 2015).

III. FIELD EXPERIMENT

To measure the width (Plate 2) and depth (Plate 3) of a stream, ranging pole was placed at the wetted edge on each stream bank. String line was tightened to both ranging poles running across the stream; line level was used in the field kit to insure the string line was leveled. The loose end of the tape measure was attached to one of the ranging poles using the spring clamp in the field kit, while one of the teammates holds the other end of the tape measured on the opposite stream bank. The tape measure was placed directly beside the level string line. One person took the staff to measure the depth of the water at given distance one (1) meter interval across the stream while the tape measure was used to establish these points.

Plate 1 width measurement

Plate 2 Depth measurement

The measurement of intervals continued until the edge of the water on the opposite side of the stream bank was reached. The depth measurements at every interval was called out, and recorded on the Stream Flow Field Sheet. The depths were added up on the Stream Flow Field Sheet. This procedure was repeated one (1) meter downstream from where the first cross section was measured. The cross sectional area was computed for this section, and recorded on the Stream Flow Field Sheet. The two cross sectional area figures were added together and divided by two to get an average cross sectional area. The information was recorded on the Stream Flow Field Sheet (Noah, Gerard, David, and Bernard, 2005, Xie-kang, Bing-jie, Xing, and Li-giong, 2016).

River discharge measurements at sample stations were carried out using the wading (probe) Method (Plate 3). Wading method is normally suitable in situations where there is no bridge, where the bridge is too high from the river, or when the flow depth is less than 0.5m (UBRBDA, 2014). Stream velocity Data were obtained at the respective selected sites in Lokuwa Bridge, Wuro-Gude and Wuro-Mayoby probe meter method.

Plate 3 discharge measurement

Plate 4 Records

The result was recorded on the Stream Flow Field Sheet each time(plate 4). The times for each of the velocity trials were added up, and divide by the number of trials (2) to get an average velocity time. The Stream Flow Field Sheet was used to calculate surface velocity. The distance (100 meters) was divided by average velocity time to get average surface velocity in meter per second. Next, the result was multiplied by the velocity correction factor of 0.8 to get average corrected velocity as put by (Nagel 2020).

The velocity correction factor has been added to adjust for the fact that water velocity at the surface was faster than water velocity closer to the bottom of a stream. This factor was used to get a more accurate stream flow calculation. Finally, the stream flow was calculated by multiplying average correction velocity by average cross sectional area. The result was in CMS (cubic meter per second).

IV. METHODS OF ANALYSIS

Channel bed gradient (slope) data analysis

The channel bed gradient (slope) was computed using the formula: - $S = \frac{E2 - E1}{D}$, (equation 1) where: S is the gradient, E is the Channel bed elevation in meters and D is the distance between two successive elevation points.

The Streams Mean Velocity (V) Data Analysis

The stream mean velocity of the study stretch was obtained using the following mathematical formula: -$\bar{V} = \frac{\sum P_I}{N}$, (equation 2) Where I=Number of observations. As recommended by MFP51 Stream Flow meter Operational Manual. However, Nagle (2000) recommended that velocity values obtained by wading method be multiplied by factor of 0.8 so as to reduce the error factor to acceptable limit, and obtain more realistic readings. Therefore; the mean velocity (V) was multiplied by the factor 0.8 in order to obtain the more realistic mean velocity V× 0.8(equation 3).

Discharges (Q) data analysis

Discharges (Q) values were computed as the product of cross-sectional Area (A) and mean $\bar{v}$ velocity. In this case, the more realistic Mean Velocity (V×0.8) was used.River discharges values were obtained from computation of obtained data as follows: -$Q = \bar{v} A$, (equation 4). Where Q is Discharge (m^{3s-1}); $\bar{v}$ is mean velocity and A is cross sectional area of the river at the sample station.

Cross-sectional Area (A) data analysis

The cross-sectional Area (A) was obtained at gauge points using the formula: - $A_C = (\frac{w_2 - w_1}{2})d$ (equation 5) where; A_C is the cross-sectional Area, W_1 is the 1st width of the channel W_2 is the 2nd with of the channel and d is the depth of the channel.

River Turbulence Computation

Goudie (1981) suggested that, the turbulence behavior of the river can be determined using the Froude Number expressed as: - $F_r = \frac{v}{\sqrt{dg}}$, (equation 6) Where v = flow velocity, d = flow depth, g = gravitational acceleration (9.81m^{-1}). If < 1, the flow is sub- critical or tranquil, If > 1, the flow is supercritical, If = 1, the flow is critical.

Stream Power Computation

The stream power of the river in terms of energy expended per unit area as presented by Thomas and Goudie (2000) was computed as follows:- $\omega = \rho g d v s$, (equation 7) Where ρ = density of water (1000gcm^{-3}), g = gravitational acceleration (9.81m^{-1}), d = flow depth, v = flow velocity and(s) = Channel slope. If the value of ω ranges from < 1 J $m\text{-}2s^{-1}$ in inter-rill flow to > 12,000J $m\text{-}2s^{-2}$ in riverine flood flows the latter is sufficient to move boulders meters in diameters (Goudie, 1981).

V. RESULTS AND DISCUSSIONS

Channel bed gradient (slope) data analysis

Table 1 present the vertical intervals of point1 and point 2 of the 3 study sections of Yedzeram channel (elevation from the sea level), distance between the points (horizontal equivalence) and the gradient of the channels (slope). It entails that the slope increases through the flow direction due to gradual entrenchment and transportation as revealed by Nagel (2000) and Yonanna (2007).

Table 1: Channel bed gradient (slope) at Lokuwa Bridge, Wuro-Gude and Wuro-Bani

	Point 1 vertical Interval (m)	Point 2 vertical Interval (m)	Distance between points (m)	Gradient (slope)
Lokuwa Bridge	575.20	2 574.80	100	0.004
Wuro-Gude	599.00	598.93	100	0.007
Wuro-Bani	549.83	549.36	100	0.047

Source: Fieldwork 2019

The Stream Mean Velocity at Lokuwa Bridge, Wuro-Gude and Wuro-Mayo

The stream mean velocity during 2019 at Lokuwa Bridge depicts that the total velocity for the time frame at Lokuwa channel width was 7986.91m s^{-1}, numbers of observation was 40 and the Average Velocity for the time frame was 199.75m s^{-1}; At Wuro-Gude total velocity was 7415m s^{-1}, numbers of observation was 40and the average Velocity for the time frame was 185.375m s^{-1} and at Wuro-Bani total velocity for the time frame was 6070.99m^{-s}, numbers of observation was 40, while the average Velocity for the time frame was 151.775m s^{-1}.

This result indicated that, at Lokuwa-Bridge the channel with was narrow owing to accumulation of water which leads to swift and rapid motion of flow eventually velocity increases. The same condition happened at Mayo-Bani station. Unlike Wuro-Bani were the channel with was up to53m leading to wide spread of flow within the channel resulting to gentle flow and subcritical nature of turbulence.The monthly peak water levels at Mubi (lokuwa Bridge and Wuro-Gude stations in 2018 and 2019 (fig 2 & 3) clearly justifies this.

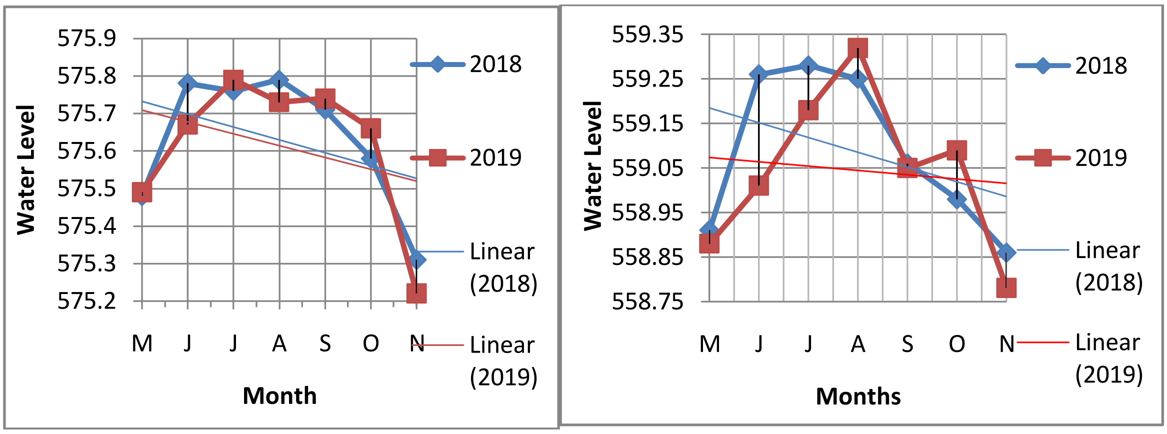


Figure 2: Hydrographs showing the monthly peak water levels at Mubi (lokuwa Bridge and Wuro-Gude stations in 2018 and 2019.Source: Fieldwork 2019

The bank-full with of Yedzeram channel at Lokuwa-Bridge was 1.31m at the right and 1.02m at the left, that of Wuro-Gude constituted 0.98m and 0.42m at the right and left of the channel banks, while that of Wuro-Bani were 0.62m and1.1m at right and left banks of the channel. This entails that the banks at Wuro-gude are vulnerable to spill over than those of Lokuwa Bridge and Wuro-Bani, which eventually cause flooding consequently result to destruction of human properties. In addition, the results obtained from the plotted hydrographs of the daily water level reveals that the higher water levels were recorded at Mayo-Bani gauging station than at the Mubi gauging stations (Wuro-Gude and Lokuwa Bridge) due to the additional inflow of water from the adjoining streams and run offs.

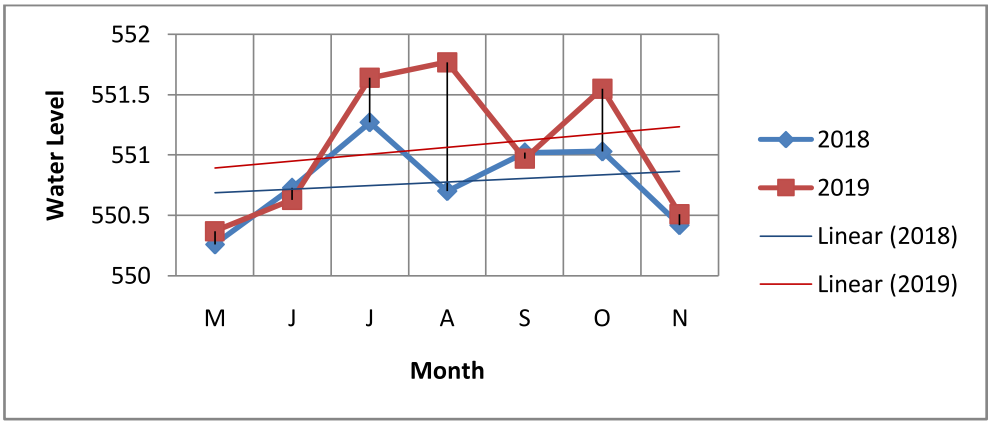


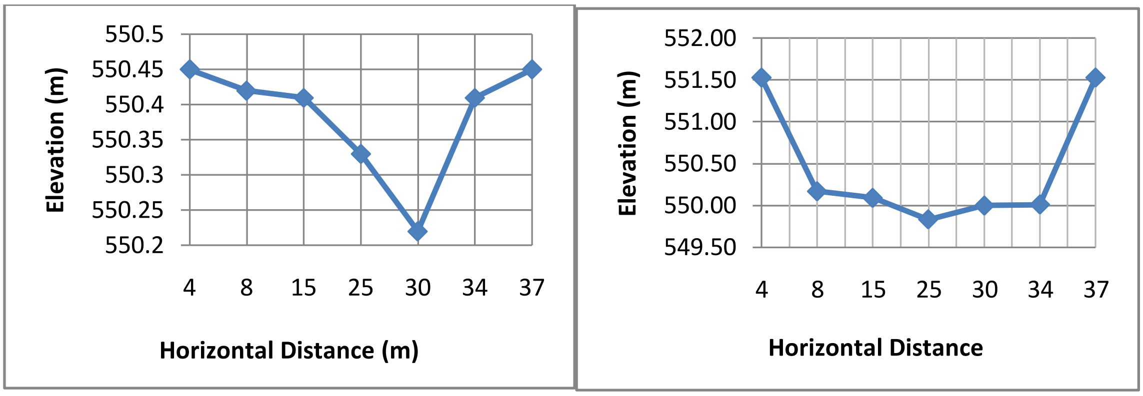
Figure : Hydrographs showing the monthly peak water levels at Mayo-Bani station in 2018 and 2019.Source: Fieldwork 2019

Discharges (Q) Analysis of Yedzeram Channel at Lokuwa Bridge, Wuro-Gude and Wuro Mayo

Discharges (Q) analysis of Yedzeram channel at Lokuwa Bridge indicated that the average velocity was109.78ms^{-1}, cross-sectional area was 6.295m^2 while the stream flow was 691.136m^{3}s^{-1}. That of Wuro-Gudethe average velocity was 120.264m s^{-1}, cross-sectional area was 7.912m^2 while the stream flow was 951.424m^{3}s^{-1}. At Wuro-Bani, the average mean velocity was 93.4ms^{-1}, cross-sectional area was 21.057m^2, while stream flow was 196.752m^{3}s^{-1}.This indicated that there is an established relationship among the area's Total Annual Rainfall and Annual Mean Discharge within the three stations, which implies that the ephemeral flow characteristic exhibited by the stream sections were strongly tied to area's rainfall regime coupled with other climatic and anthropogenic factors such as high evaporation rates and excessive water withdrawals for municipal uses.

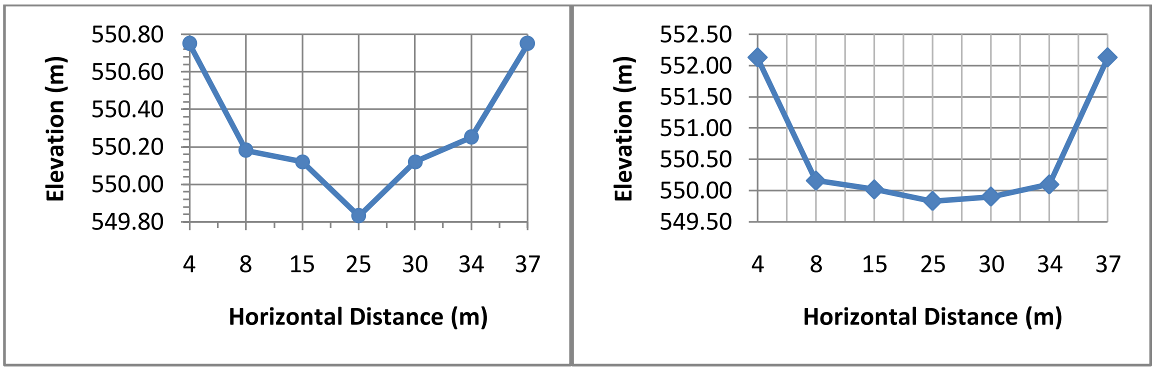
Cross-Sectional Area (A) of Yedzeram Channel at Lokuwa Bridge, Wuro-Gude and Wuro Mayo

Cross-sectional Area (A) of Yedzeram channel at Lokuwa Bridge in 2019 was 6.295m^2 that of Wuro-Gude in 2019 was 7.912m 2, while that of Wuro-Bani in 2019 was 21.057m 2.Field study discovered that the cross-sectional profile of river Yedzeram atLokuwaBridge, Wuro-Gude and Wuro Mayo 2018 and 2019 were partially harmonious throughout the study period in the study stretch, except that some few similarities in some portions of the channel where the cross-sectional profile was found lopsided, due to the erosion and deposition activities in some parts of the channel as show in (figure 5, 6 and 7).



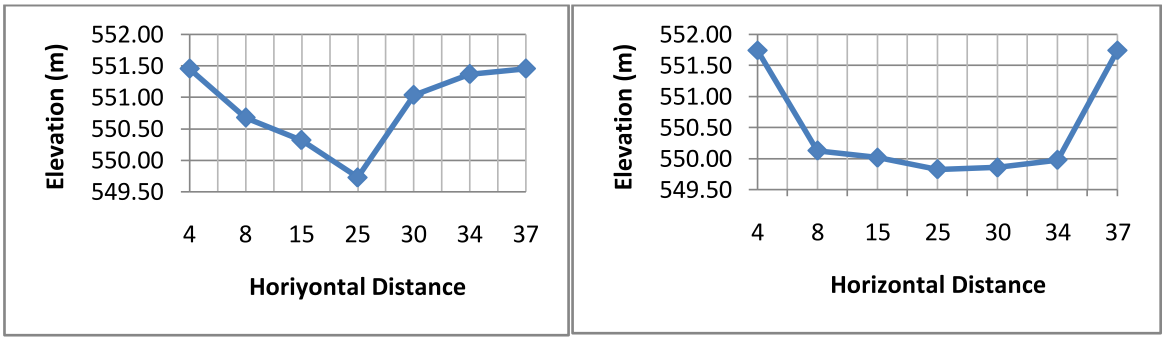
(June 2018). (June 2019).

Figure 5: Channel Profile of Yedzeram at Lokuwa Bridge Source: Fieldwork 2019



(July 2018). (July 2019).

Figure 6: Channel Profile of Yedzeram at Wuro-GudeSource: Fieldwork 2019



(July 2018). (July 2019).

Figure 7: Channel Profile of Yedzeram at Wuro-Bani.Source: Fieldwork 2019

Stream Turbulence of River Yedzeram at Lokuwa Bridge, Wuro-Gude andWuro-Mayo in 2019

Based on the result obtained from wading method, the stream turbulence of the channel reach calculated at Lokuwa Bridge was 48.25, the Froude number of the discharge at 109.75ms^{-1} velocity was 48.25, the turbulence of the river was rapid (supercritical) because the Froude number was greater than one.The stream turbulence of the channel reach atWuro-Gudewas calculated as 51.95, the Froude number of the discharge at 120.26ms^{-1} velocity was 51.95, the turbulence of the river was rapid (supercritical) because the Froude number was greater than one. The stream turbulence of the channel at Wuro-Mayo reach was 23.3, the Froude number of the discharge at 93.4ms^{-1} velocity was 23.30s^{-1}. The turbulence of the river was rapid (supercritical) because the Froude number was greater than one.The supercritical pattern of flow observed was an indication of high channel roughness and high flow velocities of the stream section. This observation correlates with the assertion of Nagle (2000) that stream turbulence is a product of channel roughness and flow velocity. Though characteristically supercritical by turbulence, the flow pattern of the stream section apparently influences substantial bed load transport (James, 2018), channel banks erosion, meandering behaviour and lateral channel migration at several times (Yonnanaet al, 2020).

Stream Power of River Yedzeram at Lokuwa Bridge, Wuro-Gude and Wuro-Mayo

The calculated stream power (ω) at Lokuwa Bridge was 2273.42Jm^{-2}s^{-2}, at Wuro-Gudewas4511.071Jm^{-2}s^{-2}andat Wuro-Mayowas 7053.87Jm^{-2}s^{-2}. Since the stream power of the (3) stations were< 1Jm^{-2}s^{-1} and > 12,000 Jm^{-2}s^{-1}, they were not sufficient to move boulders meters in diameter, but could define the work capability of a stream, most especially in terms of sediment detachment, entrainment and transportation.

VI. CONCLUSION

This study examined the Hydraulic Geometry of River Yedzeram at Lokuwa Bridge, Wuro-Gude and Wuro-Mayo Channel Section, Adamawa State, North East Nigeria. The study was restricted to current characteristics of the flow and geometry of the channel for 2 years. The findings of the study revealed some considerable hydraulic geometry of the sections of the River

Yedzeramwithin the 2 years years (2018 through 2019). Humanactions such as construction of pavements, urbanization and increasing land cultivation were discovered as additional actionswhich resulted to increasing discharges to the stream channel. The resulting effects lead to changes in the hydro-morphologic characteristics of the river section through sediment transport, river bed and banks erosion, stream meandering, channel widening and shrinking. These result todestruction of riparian land uses, land reclamation, channel disturbance and pollution of in-stream ecosystemsas major implications.

VII. RECOMMENDATION

Constant temporal monitoring,coupled withgenerating data are very important for long term and more reliable assessment of the stream flow behavior and noticing of changes for proper action to take.Policies on humanactivities resulting to channel disturbances should be established by the appropriate authorities.

REFERENCE

[1]. Billy (2014), Analysis of channel morphology of the brazos river along a selected study site for river assessment.International Journal of Scientific & Engineering Research, Volume 6, Issue 7.

[2]. Chang and Hill (1977) Assessing Sediment Loading from Agricultural Croplands in the Great Lakes Basin.The Journal of American Science, 1(2).Assessing Sediment Loading from Croplands.

[3]. Caliente T. (2009).Measuring Discharge with a Rectangular Weir: Australia,Ta.

[4]. David A. (2014). The Quantitative Assessment of River Reach Morphology. A thesis submitted infulfilment of the requirements for the Degree of Doctor of Philosophy at the School of Land and Food, University of Tasmania

[5]. Elizabeth G., Melissa B., and Scott M., (2007), hydraulic geometry in river channel networks a method for the assessment of river condition.New South Wales.

[6]. Goudie, A. (1981). The Human Impact: Man's Rolein Environmental Change. England: Basil Blackwell.

[7]. Ishak Y., Musa E., Abdullah M.,. (2015). Determining the Hydraulic Geometry Parameters of Seyhan River.American Journal of Engineering, Technology and Society. Vol. 2, No. 4, pp. 77-84.

[8]. Jong-Seok L, Pierre Y. J. (2006). Downstream Hydraulic Geometry of Alluvial Channels.

[9]. Journal of Hydraulic Engineering Volume 132 Issue 12 - December Colorado State Univ., Fort Collins Junqiang Xia Jie Li Paul Carling Meirong Zhou (2017). Dynamic adjustments in bankfull width of a braided reach. Article (PDF Available) in Water Management 172(4):1-34.

[10]. Noar (2005) N Evaluation of River Stability by Morphological Assessment Infrastructure University Kuala Lumpur Research Journal Vol.5 No.1 2017

[11]. Maddock (1976), Most frequent particle paths in a plane: Am. Geophys. Union Trans., v. 32, p. 222-226.

[12]. Mehmet (2015). Assessment of some bed load formulas based on sediment sampling E proceedings of the 36th IAHR World Congress 28 June – 3 July, 2015, The Hague, the Netherlands.

[13]. Muhamad B. G., Toriman M.E., Mushrifah I., 1Pan I. L., KamarudinM.K.ANor A.A., Mazlin M., and Sharifah S.A. (2013).River Flow Conditions and DynamicState Analysis of Pahang River.American Journal of Applied Sciences, 10 (1), 42-57 ISSN: 1546-9239 doi:10.3844/ajassp.Malaysia.

[14]. Nagle, G. (2000). Advanced Geography, New York, Oxford.

[15]. Oliver K. (2016)Assessment of Channel Sedimentation of Selected Reach of River Benue inYola. An undergraduate project submitted to the Department of Geography, Adamawa State University Mubi, Adamawa State Nigeria.

[16]. Oliver K. Wesley P. & Timothy S. (2018) Volumetric Assessment of Suspended Load Sediment of Selected Reach of River Benue in some Parts of Adamawa State. The Environmental Studies: A Multidisciplinary Journal,Vol. 1, Issue 4, pp 47-59. Calaba, Nigeria.

[17]. Upper Benue River Basin Development Authority Yola (2014), instrument for discharge measurement and sample collector.

[18]. Vijay R. and Deng N. (2003)Effects of smoothing and regridding in numerical meander migration models. Water Resources Research 43 (1) art. no. W01401.

[19]. Xie-kang Wang, Bing-jie Wang, Xing-nian Liu, Li-qiong Zhang and Xie-kang Wang (2016) Effects of river width changes on

flow characteristics based on flume experiment Article First Online.

[20]. Yonnana, E. (2007). Assessment of Channel Morphologic Characteristics of the Middle Course of River Yedzeram, Mubi Northeastern Nigeria. An MSc Geomorphology Thesis submitted to the Department of Geography, Federal University of Technology Yola, Adamawa State Nigeria.

[21]. Yonnana E., Samuel H., Thomas J., Oliver K., and Alheri J. (2020) Analyses of Trends in Stream Flow Behaviour of Mubi Section of River Yedzeram, Northeastern Nigeria.Jalingo Journal of Social and Management Sciences Volume 2, ISSN 2659-0131, Jaling, Nigeria.

International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 03 Issue: 02 DOI: 10.35629/5252

www.ijaem.net
Email id: ijaem.paper@gmail.com