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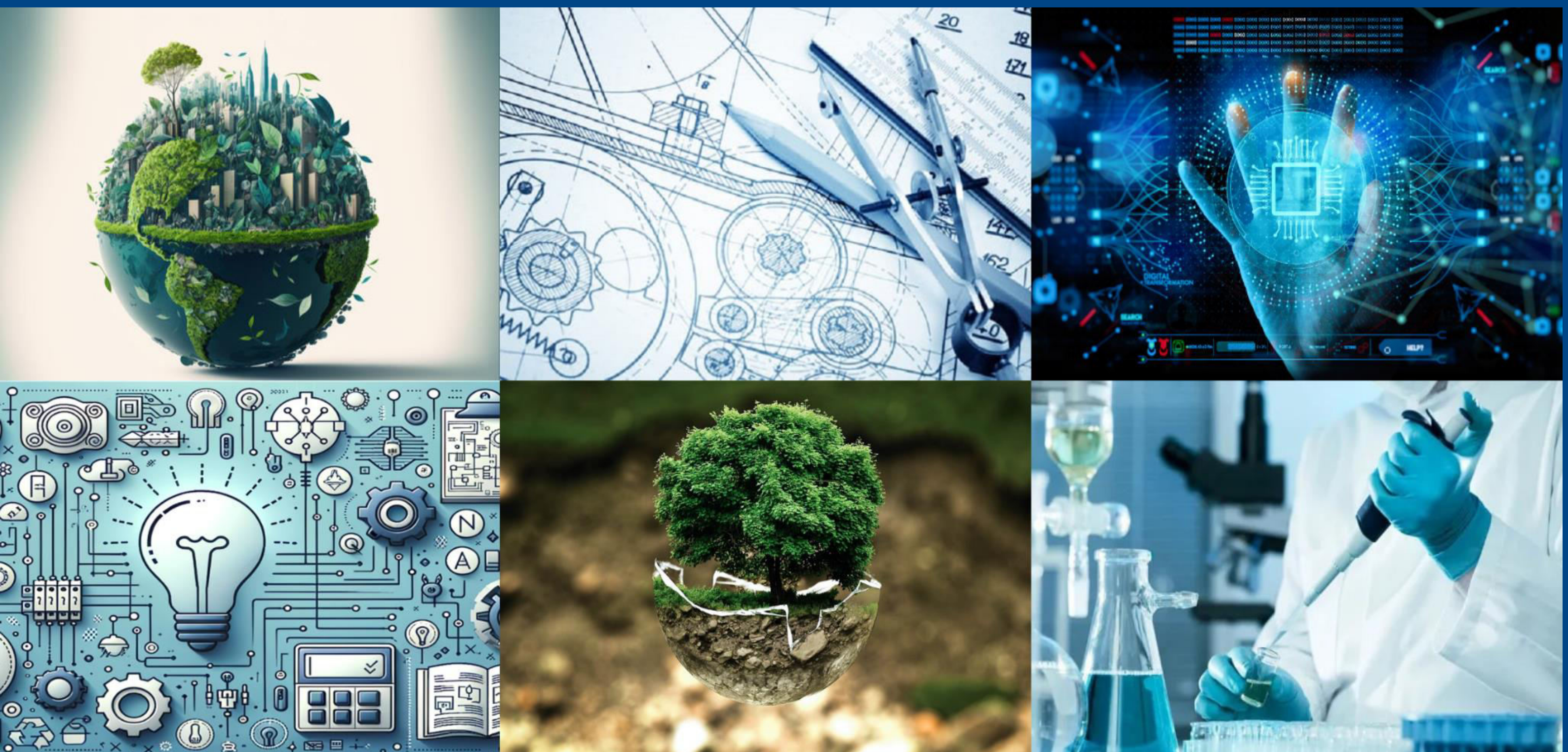

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Determination of Discharge Rate using Geospatial and Bathmetry Data of Proposed Okposi Bridge in Rivers State Nigeria

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ABSTRACT: The study aimed to determine the discharge rate of the proposed Okposi River bridge in Rivers State, Nigeria using geospatial and bathymetric data. The research involved the use of echo sounding and leveling methods to determine the depth of the river crossing and the catchment area's characteristics. The study area, Okposi, experiences seasonal and heavy rainfall, with an annual average of 260C. The bridge spans 163m along the Omoku–Ahoada road, connecting two local government areas. The bathymetric survey revealed a maximum depth of 8.5m and a minimum depth of 1.5m for boat berthing. The mid-stream depth ranged from 4.2m to 8.5m at various distances. The runoff within the catchment area was determined using Dicken's formula, resulting in a discharge rate of 410.004 cu/sec. The maximum discharge of the river was calculated by dividing the highest flood level into equal parts and computing the velocity at each section.

The study also delineated the digital elevation model and contour of the proposed Okposi Bridge catchment area using Surfer 10.0 software. The geology of the area consists of sand, silt, gravel, clay, and loam, with an average annual rainfall of 2000 mm. The study provided essential data for designing the bridge, ensuring its stability and safety during and after construction.

In conclusion, the research successfully determined the discharge rate of the proposed Okposi River bridge using geospatial and bathymetric data. The findings will be crucial for designing a structurally sound bridge that can withstand the seasonal variations in rainfall and river depth. This study highlights the importance of incorporating geospatial and hydrological data in bridge design to prevent potential failures and ensure the safety of infrastructure in flood-prone areas.

KEYWORDS: Bridge, Bathymetry, Hydrologic Analysis, Geographic Information System, Discharge, Run-off.

I. INTRODUCTION

Bridges are constructed as a passage way over low ground or valley, water and other obstruction (O'Brien, et, al., 2014). The communication route over the bridge may be a road way, footpath, or a cycle track, railway track or tramway. Geo-spatial data are required to provide earth surface raging from the nature of the terrain, the size and shape of the site, the direction of the route and the geographic data required for engineering design.

The construction of bridges over a river crossing the depth of the river is required either using echo sounding, lead line method or probing method in other to determine the depth information so as to provide the length pier to be used within the river section.

The depth information so provided will inform the height of the keep of the bridge design.
The hydraulics and hydrological investigations are very important for proper bridge design due to improper study of hydrological data, the bridge structure may fail (Arthivi et., al, 2019), (Birhanu et., al, (2020). The discharge of river is depending on the catchment area and rainfall intensity at that particular location point (Armulya et., al, 2018). The assessment of flood risk can be done by different scales and the mitigation of flood can done by collecting information by various hydrological flooding modelled (Arzazkhan et., al, 2019). A result of flood of river runs out and submerges

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nearby areas (Azhar, 2017). The total annually sediment discharge has estimated as for the mean hydrological period. Bridge failures caused by floods due to heavy rain across most river is common and natural disasters [Hua and Jia-dong, (2016). HEC-RAS model were used to find sudden unexpected flood levels by peak flood event records were used as inputs for study for 50 years and above return period as described by Hakim et., al, 2018). The continuous measurement of the flow of rivers in difficult to do (Khyati, Pritika & Bijal, 2018). It is difficult to determine in field the coefficient roughness (n) in natural rivers (Luay (2014). Generally, the flood affecting parameters are discharge, runoff gauge, land use and rainfall intensity of that particular area Ritica & Deepali, 2016). The magnitude of flood design is necessary for the design of bridges, spillways, reservoirs and drainage openings etc. (Sunilkumar. & Vargheese, (2017). The retention period parameters are governing the river flood are rainfall, runoff and catchment characteristics (Sunil, et., al, 2014). The selected study area is affected by different river flood effects highly it is very important to develop mitigation plan for the particular study area it will help for controlling future heavy disaster (Vipinkumar, & Sahita, 2015).

In other to provide the requisite discharge rate of the proposed bridge site the geo-spatial data of the catchment is necessary to prevent future erosion of the bridge abutment and to retain the waterway during and after construction of the bridge.

The aim of the study is to determine the discharge rate of the proposed Okposi River bridge construction using geo-spatial and bathymetric data. The objective of this study are as follows:

1. To determine the depth of the river crossing,
2. To determine the geo-spatial data of the catchment area,
3. To determine the rate of discharge of the proposed bridge site,
4. To produce a geo-spatial data map of the bridge catchment area.

II. MATERIAL AND METHODS

2.1 Study Area

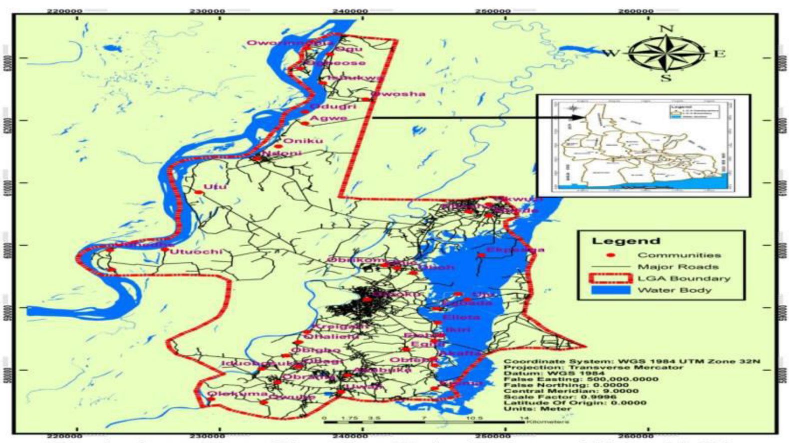
Okposi is situated Geographically at 04^0 N latitude 07^0E to 07^0E Longitude. It is in the Ogba/Egbema/Ndoni Local Government area of River State.

The study area rainfall is seasonal, variable and heavy (Ajuru, mercy and Mom, 2016). The annual rainfall is characterized with heavy – intensity within the month of June September of about 4862mm and low intensity within the month of October to January of about 1900mm.

The mean monthly temperature ranges from 25^0C to 32^0C and mean annual rainfall is 26^0C (world weather information service, 2016).

The Okposi bridge spans 163m along the Omoku–Ahoada road with a width of 15m. it serves as a gateway connecting the Ahoada–East Local Government area and the Ogba/Egbema/Ndoni Local Government area of Rivers State Nigeria.

2.2 Study Area Maps



Study Area Map Showing Ogba/Egbema/ Ndoni LGA

Source: OSM, 2024

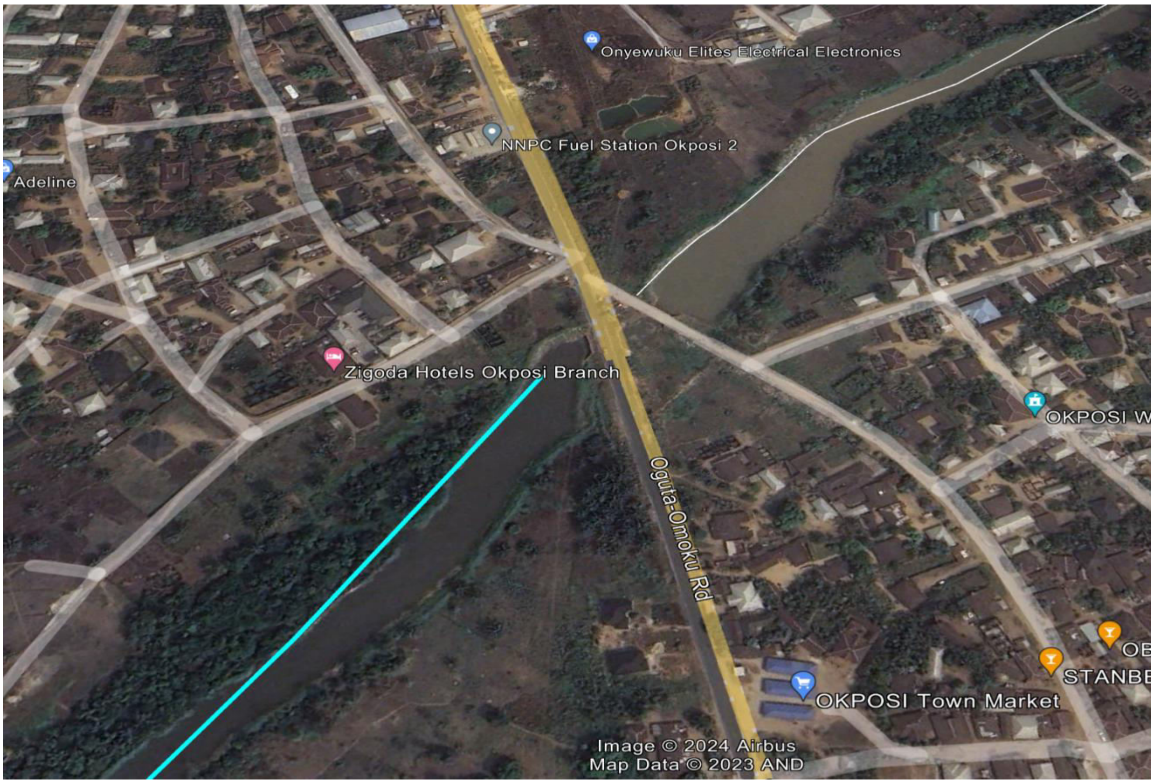


Plate 1.1: Showing Image of the Study Area.
Source: Airbus imagery, 2024.

III. GEO-SPATIAL DATA ACQUISITION

The method of Traversing and levelling was used in determining the length, elevation, and size of the study area with the aid of Leica TS06 total station instrument and the data stored electronically in a PC card which was later downloaded and processed with Leica Geo-office tool software.

The Okposi River depth was derived from bathymetric survey using a single beam echo sounding equipment, Midas echo sounding system interfaced with a HI target V30 GNSS receiver which provides the positions of the sounded depths at an interval of 10m with a 20 HP Yamaha engine boat at a speed of 10 knots per hours since the river is not a tidal river. The River has a width of eight point five meters (8.5m) and a length of 7.8km which was sounded to provided adequate geo-spatial data for the bridge design and hydrologic data.

3.1.1 Depth Determination

The single beam echo sounder was used to determine the depth of the Okposi River. The echo sounder uses the principle acoustic pulse transmission of signal from the echo sounder unit through the transducer to the River bed whereby the double transit time of the acoustic signal is recorded and the sound velocity in water is known the depth of the river bed from the transducer can be computed using the equation

$$d={}^{1}/_{2}\,(+)\ x\ c \qquad \dots \text{ equ } (1.0)$$

where, d = distance of the signals double transit time
c = velocity of sound in water the sounding depths obtained from the equ (1.0) is further reduced to a reference water surface elevation for a non-tidal river using the following procedure

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The levelling staff is set up on a bench mark and back sight reading is taken on it as (a) and simultaneously a fore sight reading is taken to the water surface as b) and the fore sight of observation is noted and another back-sight reading is taken to the water surface and closes back with a fore sight reading to the bench mark as (d) an the readings recorded an reduced to obtain the water surface elevation. This is expressed as,

$H_{bm} + (a) = H_{wsE}$ … equ (2.0)

$H_{wSE} + C = \underline{+}H_{BM}$ …equ (3.0)

Hence, final water surface elevation is converted with

$HWSE = \underline{+}\ M$

Where M is the value of the differences obtained.

The depths from the echo sounder are they subtracted from the water surface elevation obtained the fictional depths obtained of the river bed.

3.1 determination of Run off

Determination of Runoff within the bridge catchment area was obtained empirically using Dicken's formula: (Ahuja & Birdi, 2015; Singh et., al, 2022).

$Q = CA\ ^{3}/4$ --- eq (4.0)

Where Q = discharge in cu.m/sec

A = catchment area in sq. Km

C = an empirical constant depending upon the nature of the catchment area which affects run-off

This formula is considered as the catchment area of the proposed Okposi bridge is not that large.

A = **165357.609SqMtrs**

C= 0.05

Therefore **Q= 410.004cu/sec.**

Table 1.0: showing Determination of the Time of Concentration using Kirprich Equation.

Travel Time, Tt
Kirpich Equation

Adjustment Factors (Rossmiller 1980)	Multiply By
For flow in well-defined channels, bare-earth overland flow or flow in mowed channels	1
For flow in natural grassed channels	2
For flow in concrete channels	0.5

Calculations:

Clear Table

Reach ID	Slope S ft/ft input	Length L ft input	Adjustment Factor from table above input	Flow Velocity V fps output	Flow Time Tf minutes output
Overland	100.0000	206.692	N/A	4.09	0.84
1					
2					
3					
4					
5					
Sum		207		Computed Tc =	0.84
				Minimum Tc =	
				User-Entered Tc =	

Land Use	Place "X" by Landuse
Urban	
Non-Urban	0.5

Source: Authors Excel computation, 2024.

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These results show that the watershed surface is not necessarily the main factor in determining the maximum discharge for a rainfall.

3.2 Determination of the maximum discharge

Determination of the maximum discharge of the proposed Bridge was carried out after carrying out the bathymetric survey of the river, the cross section of the river was plotted in an Auto-CAD 2008 file format, the highest flood level of the river with an elevation of 23m above mean sea level was marked and divided into equal parts as shown in figure and the velocity at each section of the river was computed and determined using floating rod and the summations of these gives the total maximum discharge as shown in the equation Ahuja & Birdi, 2015).

$Q = V_1a_1 + V_2\, a_2 + V_3a_3+V_4a_4+V_5\, a_5....+V_na_n$ ……………………………equ.(4.0)

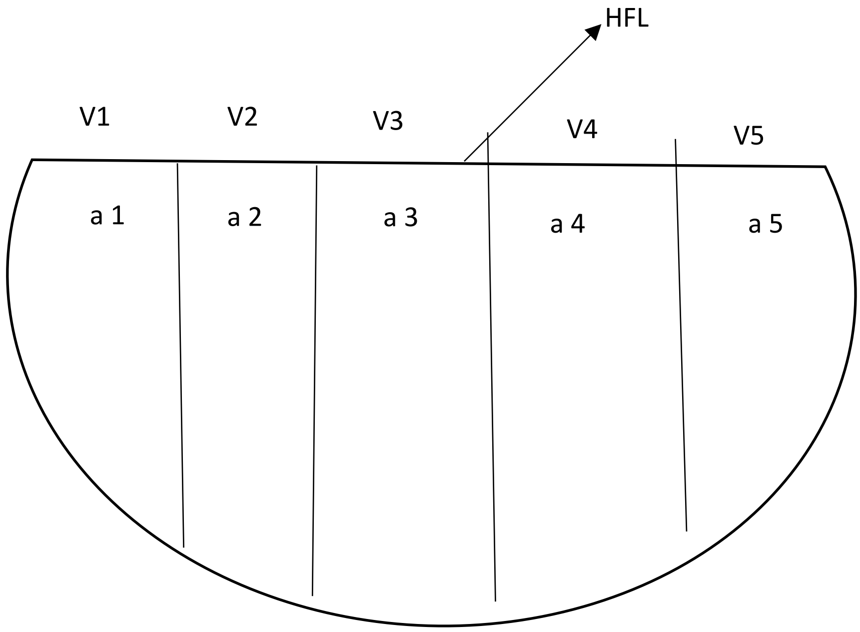

Figure 2.0: Showing a Mid-stream section of the Okposi River.
Source: Author, 2024

IV. RESULT AND DISCUSSION

The obtained depth of the river is shown in table – the maximum depth is 8.5m and minimum depth for a boat to berth is 1.5m. Mid-stream depth ranges from 4.2m to 8.5m at a distance of 6.5m to 9m.

Table 1.1 – Showing the Final Reduced Depth of Okposi River

Point ID	latitude	longitude	Depth (m)	Water Surface Elevation(m)	Reduced Depth(m)
DP31	4.941381229	6.271078126	9.900	0.538	9.362
DP32	4.941696976	6.27154819	10.700	0.538	10.162
DP33	4.942224264	6.272227171	8.500	0.538	7.962
DP34	4.942600024	6.272680039	7.700	0.538	7.162
DP35	4.943026802	6.273142849	9.000	0.538	8.462
DP36	4.943568239	6.273831401	9.800	0.538	9.262

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DP37	4.944212676	6.274360891	9.200	0.538	8.662
DP38	4.944572169	6.27489766	9.700	0.538	9.162
DP39	4.944908666	6.275560314	10.000	0.538	9.462
DP40	4.945112437	6.276114013	10.400	0.538	9.862
DP41	4.945152656	6.276438557	10.800	0.538	10.262
DP42	4.945167824	6.276819847	11.400	0.538	10.862
DP43	4.945208739	6.277109054	12.200	0.538	11.662
DP44	4.945188227	6.277300641	12.700	0.538	12.162
DP45	4.945154953	6.277434522	13.000	0.538	12.462
DP46	4.944943857	6.277968183	12.000	0.538	11.462
DP47	4.944725888	6.278361666	11.600	0.538	11.062
DP48	4.944494049	6.278607715	11.200	0.538	10.662
DP49	4.944176824	6.279017978	10.500	0.538	9.962
DP50	4.943761749	6.279319678	10.700	0.538	10.162
DP51	4.94334151	6.279671357	8.800	0.538	8.262
DP52	4.942910477	6.279915351	7.000	0.538	6.462
DP53	4.942438758	6.280153183	7.000	0.538	6.462

Source: field downloaded data, 2022

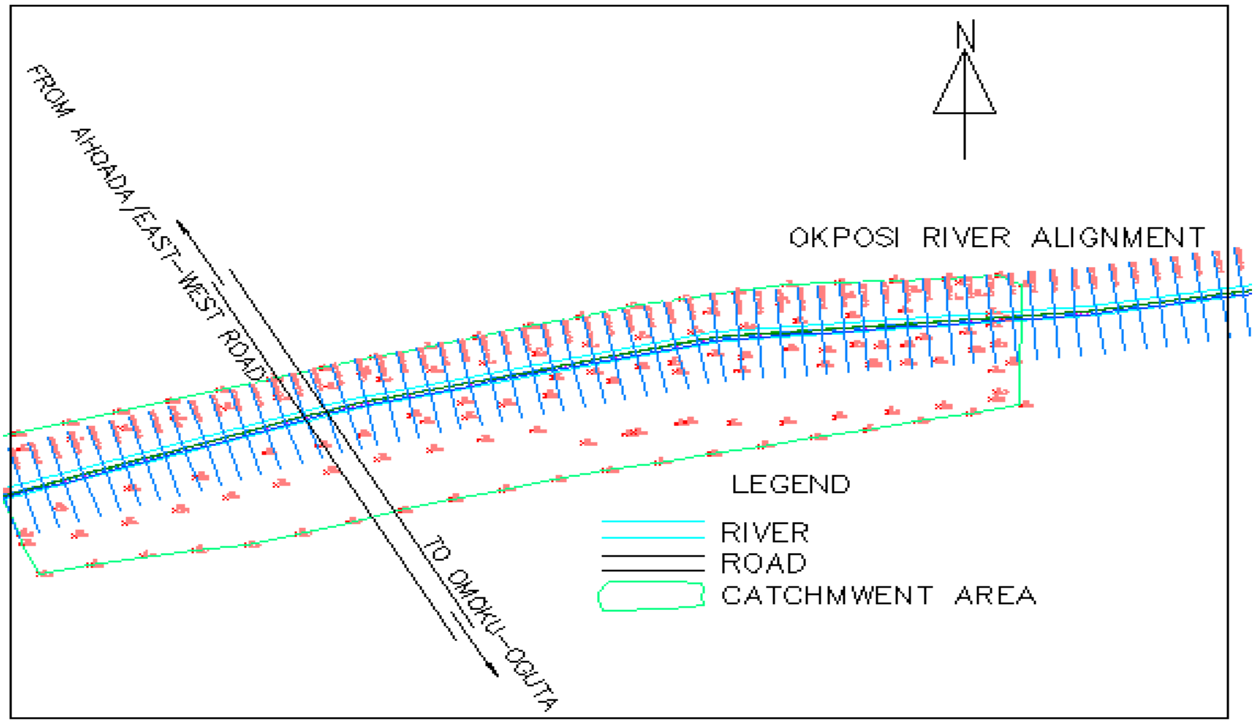

Figure 3.0: Showing the Catchment Area and Alignment of The Okposi River.

Source field data, 2022.

Figure 3.0 shows the catchment area of the okposi river and the alignment of the okposi river with the road cutting across where the proposed bridge is to be designed.

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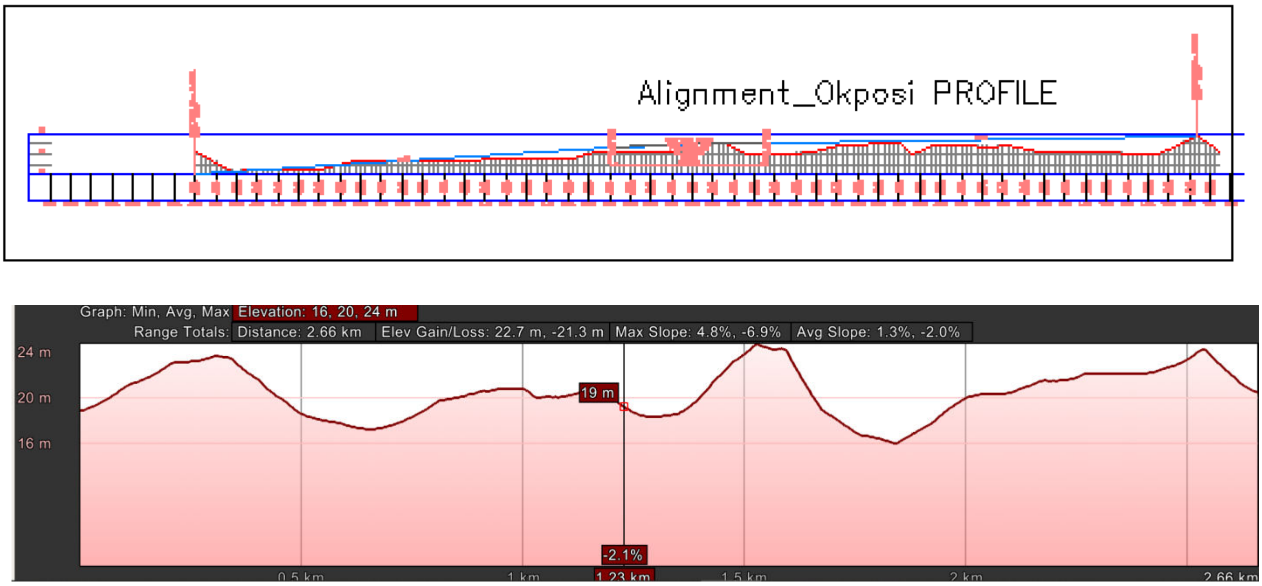

Figure 4.0: showing the River bed configuration of the Okposi River

Figure 4.0 shows that the depth of the River curvilinear as it is shallow at both sides of the edges and deeper at middle stream.

The Proposed Okposi catchment area digital elevation model was delineated using Surfer 10.0 software as shown in figure 3.1 and the contour shown in figure 3.2.
The digital elevation model shows the three-dimensional color representations of the proposed Okposi Bridge Catchment area. The colors, lighting, overlays, and mesh are represented on a 3D surface.

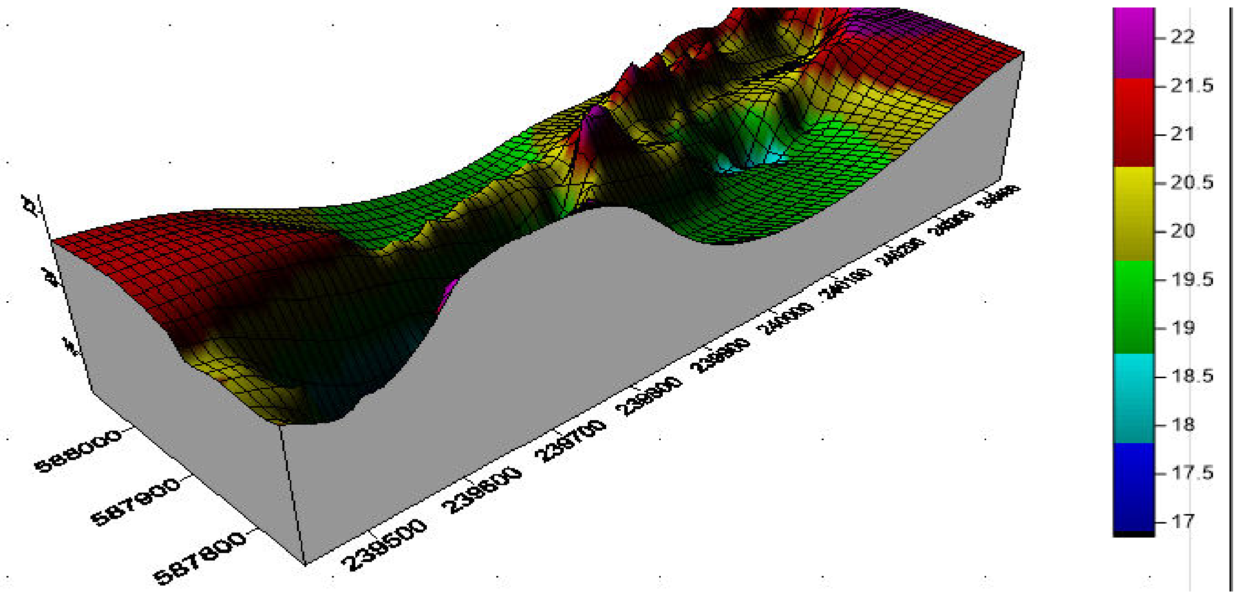

Figure 3.1: Showing Digital Elevation Model of the Proposed Okposi Bridge Catchment area.

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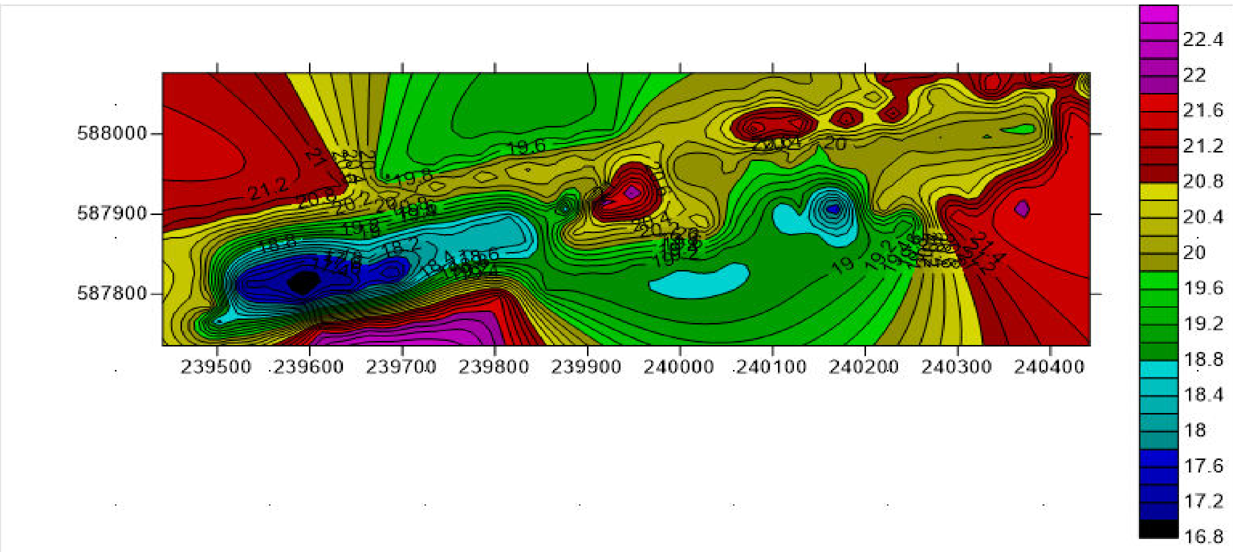

Figure 3.2: Showing Contour of the Proposed Okposi Bridge Catchment area.

The contour shows a two-dimensional representation of the catchment three-dimensional data. The Contours define lines of equal elevation values across the catchment extents. This also shows the Okposi river depth configuration that will inform design engineers of the proposed bridge.

4.1. Hydrological detail of proposed Okposi river bridge area

The study area is of relatively undulating marshy terrain from the field elevation data varies from 17m to 22m above mean sea level. The general geology, soils and land use or land cover of the rivers, and flood paths and catchments crossing the Okposi River. Geologically the Okposi River catchments are in an area of sand, silt gravel, clay and loam. The mean annual rainfall of the area ranges Okposi receives 2000 mm (90.3 in) of rainfall per year, or 180 mm (7.5 in) per month (Climate top, 2024). The driest weather is in December when an average of 20.2 mm (0.8 in) of rainfall (precipitation) occurs. The wettest weather is in September when an average of 367.1 mm (14.5 in) of rainfall (precipitation) occurs Climate top, 2024).

V. CONCLUSION

This study establishes that the proposed Okposi River bridge can be designed with the obtained geospatial and hydrologic data provided.

This study recommends that geospatial data provided by surveyors and hydrological data provided by hydrologists, Nigeria Hydrological Services Agency and water resources managers are important to design engineers for bridge and other constructions in the built environment.

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