Research Article

Determination of optimal navigation route from Opobo channel to the bonny river entrance: rivers state, Nigeria

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Abstract

The study area is not always navigable at all times and have impede safe navigation such as passages of boats and loaded barges of varying sizes. The fear of unknown bathymetric components and the need to determine optical navigational route in the river channel under study are inevitable. The research adopted quantitative method of depth determination, tidal and river current velocity measurement. Tidal observations were carried out in 30 minutes interval for a period of two months, acoustic bathymetric and current velocity measurement were also carried out to determine the river bed topography and current flow rate in the study area. The results from the bathymetric charts shows that only one optimal navigational route exist at low tide and three optimal navigational routes to the Opobo channel from the entrance of the Bonny River. The result also revealed that the main Opobo channel is navigable at all times (low or high tide). Lowest and highest sounded depth of 0.10m and 16.70m were noted. The study also revealed a high river current velocity of 0.434m/s at Opobo channel entrance to the Bonny River and a semidiurnal tide with two low and two high water respectively.

Keywords: navigation, route, depth, Opobo, bonny

Introduction

Background to the study

Navigation processes involve also the control, order and monitoring of the movement of vessels, crafts, barges or other transportation processes from one point to another. Bathymetric surveys can provide information for a navigation that is free from vessel grounding. Some of the factors hindering charting of water-ways in Nigeria are mostly due to possibility of grounding in shallow water (<5m) waters, and inaccessibility of some marine environments by the conventional ship-based systems.[1] Other associated problems such as high cost of equipment, personnel and rigorous field survey procedure impede on waterways mapping. Navigational channels are characterized by natural processes such as climate changes, anthropogenic activities that may result to sediment dynamics along the channels. These processes also impact on riverbed characteristics, including channel widening, sediment deposition, proximal floodplain scour and destruction of near-shore structures. These processes may impact on safe navigation along a channel.[2]

A river channel can be considered to be relatively stable when its water flow and sediment dynamics are in balance over time. Changes in either of these two factors, may result to channel dynamics in terms of its slope, depth, width, meander pattern, and bed composition and vegetation density. Water-Notes, (2000) and Chil,[3] asserted that the extent and rate of these adjustments are dependent on the extent and rate of changes in the water flow and sediment load. Bathymetric information also provides viable means for monitoring and provision of optimal navigational routes for shipping traffic safety and determining other hazardous marine features.[4]

Monitoring of navigational channels is associated with difficulties including the extensive areas of water bodies. This situation has led most developing nations of the world paying attention to the charting of their water ways. The Bonny River is arguably the most important shipping route into Rivers State, Nigeria. Its expanse of water, requires constant study to ensure safe navigation. Bonny River is one of the delta arms of the River Niger. Its tidal prediction tables show that the river is a semi diurnal tidal river that has two alternating crests (High Water - HW)) and troughs (Low Water - LW)) within 24 hours cycles.[5] Several docks, ports and wharfs along the channel are used by companies owned by organizations servicing the oil and gas, mining and transportation industries. Their locations are for ease of moving bulky supplies, in and out of their location to oil and gas mining sites mostly located offshore of the coast of Nigeria.

The study area is not always navigable at all times during tidal processes which may impede safe navigation such as passages of boats and loaded barges of varying sizes. The phobia of unknown bathymetric components such as tides levels, sea bed topography, river currents and other navigational hazards among users of the river channel under study are inevitable, this prompted the need to provide accurate sea bed topographic information, tidal cum current velocity measurement for timely response of navigational challenges that may result to bolt mishaps, submerge or stocked in the study area. Tidal process may affect the bathymetry of the channel. The determination of an optimal route for these moving vehicles for the avoidance of mishaps, accidents, collisions etc., is vital for the security of life and property. The application of surveying and geomatics techniques to study this phenomenon provides the bases for decision support and implementation within the marine environment which is the focus of study for this work.

The study is aimed to determine the optimal navigation routes within the Opobo Channel into Bonny River, in Rivers State Nigeria, the objectives of the study include; to Obtain the tidal information of the Opobo channel along the Bonny River, determination of seabed configuration, measurement of River current velocity and production of charts depicting the optimal route for navigating through the Opobo Channel from the Bonny River entrance.

Materials and methods

Study area

The study area, Opobo Channel that leads into the Bonny River is characterized with bends and turns: as shown in Figure 1, a typical character of a river at its final phase, and has on parts of its banks mangrove vegetation cover. The channel is also a major means of transportation for some communities within the area, and a source of livelihood as activities such as fishing, hand-picking of shell fishes amongst other activities occurs regularly along the river and its bank. With regular activities such as fishing and transportation of people and goods along Bonny River, there is need to monitor the changes that may occur as a result of sedimentation and other related processes such as shoreline erosion that can impede safe navigation and passage of boats and loaded barges of varying sizes.

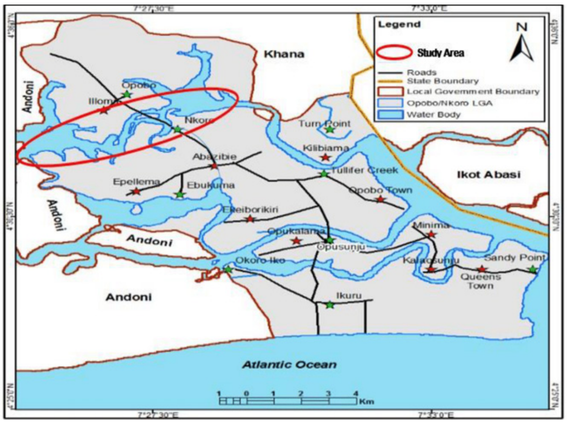

Figure 1 Opobo Channel.

Source: Office of the Surveyor General of Rivers State of Nigeria

Study area

The Opobo channel and its tributaries are located within Rivers State in the Niger Delta. It is defined by the following geographical coordinates 07º 16' 28".52E, 04º 29' 55".89N to 07º 16' 28".36E, 04º 29' 30".44N to 07º 16' 46".79E, 04º 30' 38".36N to 07º 15' 28".19E, 04º 31' 35".89N to 07º 14' 55".64E, 04º 31' 23".54N and 07º 14' 13".32E, 04º 32' 57".14N. Located along Opobo channel are towns such as Amaobi, Amagbomowe, Eferewori, Sorai etc as shown in Figure 1. Bonny (or Ibani) is an island town and a Local Government Area of Rivers State, on the Bight of Bonny. It is also the capital of the Kingdom of Bonny. Between the 15th and 19th centuries, it was a major trading post of the eastern delta and served as a major export point for palm oil. In recent times, the region serves as an export point for the Bonny Light Crude oil variety and much of the petroleum related produced in Rivers State is piped to Bonny for export. It has the biggest LNG Gas plant in Nigeria with seven (7) trains. The Opobo channel and its environs is characterized by mangrove forest and swampy terrain with overlaying mud and silts deposits. Opobo people speak Ibo and Igbani as their local dialect. Fishing, trade, and lumbering are the main economic activities.[6]

Bathymetric instruments used for the study

The equipment used for the bathymetric operation are presented in Table 1. The field research and observation method adopted for this research is the classical method of acoustic bathymetry. The single beam echo sounder, emits pulse of sound and measures the time it travels to the seafloor and reflected and be detected by a hydrophone aboard a ship. The methodology adopted in this study is the principle of acoustic Bathymetry. This is shown using Equation 1 as follows:

$D = 1/2Vt$ (Eq. 1)

Where:

D = sounded depth

V = speed of sound in water

t = two-way travel time of sound

Table 1 Survey Equipment Listing

Navigation and Positioning Systems	Details
Survey Vessel	AHTS JASCON 39
Differential Global Positioning System (DGPS)	CNAV 2050 DGPS
Navigation Software	QPS QINSy 8.10 with QC System
Time Synchronisation	GPS PPS (RS232 Edge Detection)
Bathymetric Systems	
Single beam Echo Sounder	ResonNavisound 210
Gyrocompass	TSS Meridian Surveyor & SG Brown 1000S
Primary Motion Reference Unit	TSS DMS 05
Secondary Motion Reference Unit	SBG Ekinox
Sound Velocity Profile	Valeport Model 106 Current Meter
Level instrument	
100m tape	

Calibration/test of instrument

Prior to fieldwork, survey instruments were calibrated and tested using different methods to ascertain the levels of integrity and possible errors.

Two peg-test

The two-peg test was carried out on the levelling instrument to ascertain the accuracy and the error budget of the leveling instrument. The test result proves the reliability of the level instrument.

Procedures for two peg test includes

I. A fairly flat terrain was chosen, two rod positions were placed on point (A and B) on a stable surface about 30m apart, the level instrument was set up midway of about 10m between the observation staff at C.

II. After temporary adjustment was done, the level was sighted to point (A) to get a staff reading of 1.526m, then to (B) to get a reading of 1.501m. the difference between A and B is 0.025m

III. The level was thereafter be moved to a point say 3m from position (A), and a new reading to A and B was observed. Staff reading on position (A) was observed to be 1.257m and staff reading on position (B) = 1.234m. The difference between position A and B was obtained to be 0.023. This indicates that the level instrument is in good condition and can be used for ground data acquisition.

Establishment of river gauges

Establishing a river gauge involves transferring the height from a benchmark to the water level so that the reduced level of the water can be deduced. A river gauge or tidal gauge may be in the form of a graduated piece of metal or wooden plate or pole which is installed at the edge of a water body so that the water level can be read off the plate. In establishing a river gauge, care must be taken to install the gauge at a place where water level variations do not go below or above the graduation of the gauge.

Echo sounder calibration and equipment checks (bar check)

Calibration of acoustic sounding instruments (echo sounder) is important as testing any land survey equipment for inherent errors and its precision. This is done to maintain consistency in the depth pinged. As acoustic wave travels through the water medium, it is affected by speed, salinity, temperature and pressure of the water.[5,7] This either slows the wave or increases the wave from the transducer to the seabed and its return signal. The bar check enables the echo sounder to be set correctly by inputting parameters into the echo sounder obtained from the sound velocity profile computed by observing salinity, temperature and depth. It is a routine before commencing any sounding operations. The cable/rope of the bar check was marked at 1.0m intervals to 10.0m and this was used to confirm the transducer draft during the bar check. A single Beam Echo-Sounder (ResonNavisound 210) transducer was mounted on a pole and side mounted on Jascon39. Then a systematic graduated base plate deployed below the Echo-Sounder transducer in water.

The following procedure was adopted during bar check:

I. The transducer and the echo sounder were set up on the survey boat.

II. The boat pulled toward the creek edge and anchored

III. The draft of the transducer was measured and recorded.

IV. The Echo sounder was powered- 'on'

V. The draft value was entered into the Echo sounder.

VI. The metal plate attached with graduated rope was then lowered directly below the transducer at different depths to obtain readings for comparism. Once it is confirmed, that the echo sounder reading correlates with the graduated rope, the echo sounder was deployed and sounding commenced.

VII. At the end of the sounding operation similar process was repeated to confirm the integrity of the acquired data.

The bar check illustration is as shown in Figure 2.

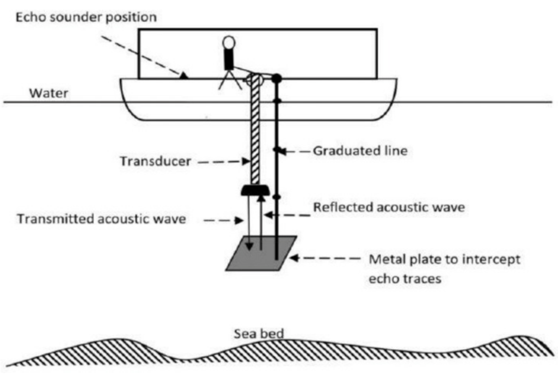

Figure 2 Echo sounder Calibration method (Source: Ojinnaka, 2007).[5]

Projection and reference datum

All positions acquired were referenced to Universal Transverse Mercator (UTM) Zone 32N, (WGS-84) datum. Documents used for comparisons, such as charts and prior surveys were referenced to or adjusted to UTM Zone 32N, WGS-84. All software used on the survey contains the referenced datum parameters.

Depth soundings

As shown in Figure 3, Transducer (probe) launches ultrasound, and then measure delta-T between the emission wave and the reflected wave. Acoustic propagation velocity in water is V, transducer (probe) transmits ultrasound, acoustic emission by the probe to the bottom of the sea, reflected back by the bottom and received by the transducer, then measure the round-trip time the acoustic experienced by t, as shown in equation 2. At the same time, read the scale on the junction pole to get the value of the draft (draft is the value between the water surface and the bottom of the transducer).

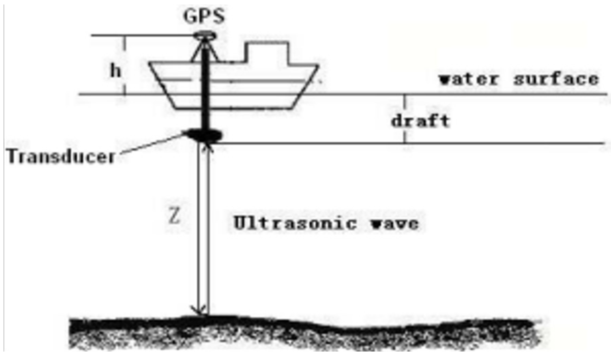

Figure 3 Depth Determination, Source: (Ojinnaka, 2007).[5]

Corrections to echo soundings

Observed echo sounder depths were corrected for all departures from true depths attributable to the method of sounding or to faults in the measuring apparatus. These could include draft, velocity, heave, roll, pitch, heading, and navigation timing error corrections.

Positioning system

The positioning system used for the survey was the CNAV 2050 DGPS installed on an AHTS JASCON 39 survey vessel to compute vessel position from direct satellite observations to get the actual position.

Data reduction, download and processing

The raw depths obtained from ResonANavisound 210 (33 KHz/210KHz) single beam echo sounder were reduced by considering the depth of the transducer to the water surface which is known as draft. After the survey, the data was downloaded from the echo-sounder with a removable drive and then transferred to a computer for sorting and elimination of redundancies using Microsoft Excel. After sorting, the data was transferred to Hypack and ArcGIS software for further processing and cartographic finishing. After sorting and cleaning on MS Excel to delete erroneous and false data, the procedure on Hypack for processing the depths was carried as follows:

I. The values of the depth were copied into a text file and saved in the Hypack directory.

II. The data were later import into Hypack working environment.

III. The data was saved in XYZ format

IV. The XYZ file were converted into matrix form at specified interval

V. Then we exported the depths values to DXF format

VI. Then the depth was imported to Arcmap for cartographic enhancement and finishing.

Flow Measurement with current meter valeport CM 106

The Valeport CM 106 is a propeller type of current meter was operated in a self-recording and logging mode as well as direct reading (real time) mode. To have a reliable measurement with Valeport CM 106, the inner part of the impeller was filled up with water, and the meter balanced on a horizontal position before being launched into the water. The suspension assembly were moved along the main frame to quickly achieve balance.

Results

During the study period the tidal value of the Opobo Channel ranged from 0.9 m to 1.7 m (Table 3 and Figure 4). The tidal results indicate the tide is semi-diurnal with two tides low and two high tides of approximately equal size each lunar day.

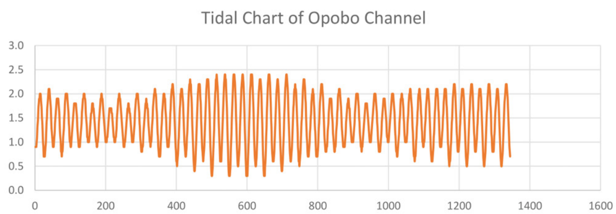

Figure 4 Water level reading indicating the rise and fall of water along the Opobo River.

Source: Author's field results, 2022.

The tidal information of Opobo river

Tidal Readings was carried out on Monday 2/1/2022 at about 12:00am and was taken till 11:.30pm on 2/28/2022. The river level was read out on an interval of 30 minutes. During this period, all observation were referenced to the Lowest Astronomical Tide (LAT) and the lower water level was observed to be 0.3m while the highest water level was 2.4 m as shown on Figure 4, Table 2.

Table 2 Opobo River Tidal Readings (Source: Author, 2022)

S/N	Date	Time		Sounded values (m)
1	2/1/2022	12:00	AM	0.9
2	2/1/2022	12:30	AM	0.9
3	2/1/2022	1:00	AM	0.9
4	2/1/2022	1:30	AM	0.9
5	2/1/2022	2:00	AM	1
6	2/1/2022	2:30	AM	1.1
7	2/1/2022	3:00	AM	1.3
8	2/1/2022	3:30	AM	1.4
9	2/1/2022	4:00	AM	1.5
10	2/1/2022	4:30	AM	1.7

(**Source:** Author field data, 2022)

The tidal information of the Opobo channel

Seabed configuration (depth information) of the study area

The second objective of this research work was to obtain the configuration of the seabed of the channel. To achieve this objective, bathymetric survey covering the section of Opobo channel that leads to the entrance of the Bonny River (Figure 5) was conducted using the acoustic system that employed the Single beam echo sounder (SBES). Channel information consisting of Eastings, Northings and Depth (Three dimensional data) were observed from the survey. A total of 3,355 points was acquired during the survey. After sorting and cleaning on MS Excel to remove erroneous and false reading, associated with the acquired data, a total number of 3335 points were left. Total length of sounding lines for the whole exercise was 9.02 km. The result gave the study the following information.

Highest Depth of the Channel = 16.7 m

Lowest Depth of the Channel = 0.1 m

Average Depth of the Channel = 5.47 m

The seabed depth ranged from 7.2 m to 8.2 m during the sampling period (Table 3). Insert a paragraph here explaining the main results about the topic above.

For better understanding of the seabed configuration, a three dimensional (3D) map Digital Elevation Model (DEM) was created. It is a representation of a terrain's surface created from elevation data. In general terms, DEM consists of the Digital Surface Model (DSM) and the Digital Terrain Model (DTM). DSM covers the ground surface indicating the vegetation, infrastructures and other details that can be found on the ground, while DTM is a representation of the ground surface excluding all forms of details that can be found on the surface. It is a bare-earth DEM. The DTM of the study area Table 3.1 was created using Surfer 13 software. The Digital Terrain Model (DTM) of the study area is showed in Figure 5. Explain something about this topic to those who are not familiarized with the theme.

Table 3.1 Flow Velocity Measurement Results in m/s (Source: Author, 2022)

Valeport 106 CM		POINT A	POINT B	POINT C
POSITIONS		304329.4	305467.5	307910.4
		502154	500839.7	497709
Daily Average	2/1/2022	0.416	0.426	0.326
	2/2/2022	0.371	0.487	0.532
	2/3/2022	0.538	0.56	0.439
	2/4/2022	0.421	0.488	0.343
	2/5/2022	0.356	0.407	0.416
	2/6/2022	0.581	0.349	0.42
	2/7/2022	0.349	0.3.21	0.379
	2/8/2022	0.511	0.522	0.325
Weekly Average		0.443	0.463	0.397
All Average	0.434			

The result of the flow measurements carried out at three different locations across the Opobo channel indicated that the flow velocities are different from one point of the river to the other. Also, the flow velocity at the center of the river had the highest flow rate; hence has the highest contribution to the change in the configuration of the seabed thereby impeding navigational activities along the center of the Opobo channel to the entrance of Bonny River. This satisfied the objective three of the study. The flow velocity measurement results on the three sampling stations are shown in Table 3. Insert a paragraph here explaining the main results about the topic below.

Table 3 Sample of Acoustic bathymetric data of the study area

S/N	Easting (m)	Northings (m)	Reduced Depth (m)
1	304329.4	502154	8.2
2	304316.8	502169.7	8.1
3	304303.7	502184.7	8
4	304290.9	502200.1	7.8
5	304278.1	502215.4	7.8
6	304265.3	502230.8	7.5
7	304252.5	502246.2	7.4
8	304239.6	502261.5	7.3
9	304226.8	502276.8	7.2
10	304214	502292.2	7.5

Production of charts for the study area depicting the optimal navigational route through the Opobo channel to bonny river entrance

The result from the bathymetric chart shows that there exists one optimal navigational route to the Opobo channel at low tide as shown in (Figure 5) and three optimal navigational routes to the Opobo channel from the entrance of the Bonny River as shown in (Figure 5). The result also demonstrated that the main Opobo channel is navigable at all times (low or high tide). From the navigational map, the red depths indicate area of extremely low depths of 1m and below which area are not favorable for navigation either at low tides or high tides. The current velocity is high with 0.434m/s at the Opobo channel entrance to the Bonny River. This may contributes to increased sediment deposition and depth insufficiency along the entrance of Bonny River thereby impeding on the navigability on the channel. In line with objective four of the study, two bathymetric charts showing optimal route were produced using Arc-Map 10.3 vector base software (Figure 6). However, the red colored depth data on the Sounded Chart of the Opobo channel indicates areas of extreme shallow depths of 1 m (Figure 6), while the areas with cyan colors are areas of depths above 4 m (Figure 7).[8–10]

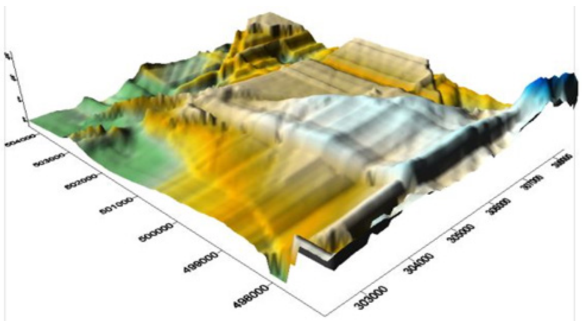

Figure 5 Digital Terrain Model (DTM) of the Study Area.

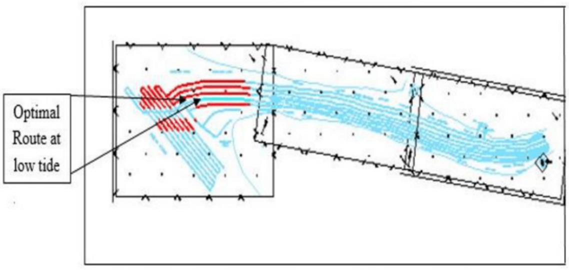

Figure 6 Sounded Chart of the Opobo channel on Low tide.

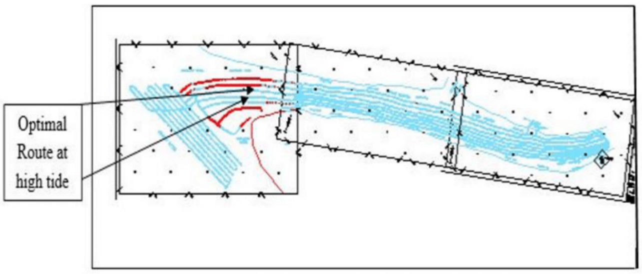

Figure 7 Sounded Chart of the Opobo channel on high tide.

Discussion & conclusion

This research has evaluated and shown the potentials of acoustic bathymetry and its corresponding tidal with River current velocity information in determining the optimal route from Opobo Channel to the entrance of Bonny River. Through the bathymetric data collected from different measurements at high and low tide from the study area at different epochs, sufficient parameters relating to the channel, indicated that there is a narrow channel navigating along the Opobo channel to the entrance of bonny river.

Recommendations

I. All navigation through the channel (Optimal Navigational Route) by mariners and oil exploration companies should be at high tides and with the assistance of a navigator.

II. Area of depth 1 meter along the channel should be avoided by users of the waterways.

III. Geotechnical and hazard survey of the Opobo channel and the entrance of the Bonny River need to be carried out and documented for use by individuals and cooperate organization that continually move within the route.

Acknowledgments

None.

Conflicts of interest

The author declares there is no conflict of interest.

References

1. Ekpa AU, Eyakndue NL. Determination of a Section of Woji River bad depths for Safe Navigation. *Nigerian Journal of Environmental Sciences and Technology (NIJEST).* 2017;1(1):55–68.
2. Jimoh OA, Hamid-Mosaku IA, Oguntade OF, et al. Investigation of Sediment Accumulation in Ojo Creek using Geostatistical Techniques. *Journal of Engineering Research*. 2020;25(3).
3. Chil TY. *Reclamation Managing Water in the West: Erosion and Sediment Manual*. Denver Colorado: U.S. Department of Interior Bureau of Reclamation Sedimentation and River Hydraulic Group. 2006.
4. Olusegun AA, Sankey BL, Chukwu JO, et al. Bathymetric Survey and Topography Changes Investigation of Part of Badagry Creek and Yewa River, Lagos State, Southwest Nigeria. *Journal of Geography, Environment and Earth Science International*. 201722(4):1–16.
5. Ojinnaka OC. Principles of Hydrographic Surveying-From Sextant to Satellite. Published by EL 'DEMAK, 9, Ani Street, Ogui New Layout, Enugu, Enugu State, Nigeria. ISBN: 978-8143-10-5. 2007.

6. Wizor CH, Uranta FI. Rural Service Centre and Rural Development in Opobo/Nkoro Local Government Area of Rivers, Nigeria. *International Journal of Applied Science and Mathematical Theory*. 2020;6(1):69–85.

7. Eze PI, kurotamuno PJ, Kpama SB. Assessment of Bathymetric Components of Ogbogoro Section of New Calabar River, Rivers State, NigeriA. *International Journal of Research Publication and Reviews*. 2022;3(7):309–320.

8. Badejo OT, Evarie P, Anorue N. *Tidal Harmonic Analysis and Bonga Field*. FIG Working Week 2013. Environment for Sustainability Abuja, Nigeria. 2013. p. 6–10.

9. Chukwu FN, Badejo OT. Bathymetric Survey investigation for Lagos Seabed Topographic Changes. *Journal of Geosciences and Geomatics*. 2013;3(2):37–43.

10. Kim V, Robert CG. Human impact on river planform within the context of multi-timescale river channel dynamics in a Himalayan river system. *Geomorphology*. 2021;381:107659.

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