

Application of GIS in Evaluation of Coastal River Bathymetry, A Case Study of Opobo Channel, Rivers State, Nigeria

Ezeugwu M. U¹, Idhoko K.E², Nnamah, P.O³ and Ofuenyi J. O⁴

Department of Surveying and Geo-informatics, Faculty of Environmental Sciences, Nnamdi Azikiwe University, Awka, Nigeria.

ABSTRACT :Opobo Channel is the lower section of Imo River-II, adjoining the Estuary into the Atlantic. The channel connects two important towns, Opobo in Rivers State and IkotAbasi in Akwa Ibom of Nigeria. The unexplored socio-economic potential of these towns has been hindered by poor navigability of the only marine channel from the sea. Opobo Channel was only and lastly dredged in 1996 when Aluminium Smelting Company of Nigeria (ALSCON) became operational. A marine vessel delivering petroleum products to Synergy Tank Farm in IkotAbasi ran aground in 2014 at the Estuary due to reduced channel bathymetry and estuarine accretion. A bathymetry survey was conducted in February 2015 to determine the existing water depth profile of the 14km (7.64 nautical miles) channel from the Estuary to IkotAbasi, hence its navigability. Computer assisted data analysis using Geographical Information System (GIS) was employed to assess and evaluate the acquired bathymetric data. Based on planned deployment of 8m maximum draft vessel, 45% of the channel, was discovered to be deeper than 8m while the rest is less. This shows that for safe year-round navigation, 55% of the channel requires dredging. The data was further used to create a dredge limit of 12m water depth and the total volume of material to be dredged was computed. It is recommended that periodic bathymetric survey be planned to continuously monitor rate of siltation along the Channel, including the Estuary and the Fair-way sections. It is expected that with further bathymetric data acquisition and analysis, it will be possible to predict when subsequent maintenance dredging shall be conducted to keep the channel open and free for safe all-year-round navigation.

Keywords:-bathymetric survey, morphology, accretion, siltation, sediment budget, estuaries, hydrography, water depth, GIS.

I. INTRODUCTION

Opobo Channel is the main marine link from two major coastal towns, Ikot Abasi and Opobo to the Atlantic. Opobo is land locked with no motorable land access, while IkotAbasi is not. The geographical location of IkotAbasi has a great untapped socio-economic potential, which is hindered by poor navigability of the marine channel from the sea. Due to the existing dual carriage express road leading to the nearest capital cities of Port Harcourt and Uyo, if fully developed, IkotAbasi could serve as the next major sea-port (inland) in the south-south region of Nigeria.

The main objective of the hydrographic survey is to assess the existing water depth and its suitability for safe navigation between IkotAbasi and the Opobo Channel estuary. According to (Payoyo, 1994), coastal and marine areas are ever increasing in value to the welfare of nations and her citizens. These areas provide natural, social and economic functions that contribute to increased quality of life. In addition to the aforementioned, the coastal environment is instrumental in determining climate that beneficially affects all life on Earth. Some social and economic functions include tourism, commercial and recreational fishing, oil and gas development, and construction (Eckert, 1979; Prescott, 1985; Gomes, 1998). It is clear therefore that coastal and marine areas are of vital importance to human life and the nation as a whole, which IkotAbasi could be explored to full benefit. The facts that approximately 71% of the planet's surface is covered with water and that these are as rich and productive as the land in terms of food and transport, increase the importance of hydrographic measurements (Erkaya and Hoşbaş, 1998; Ozgen and Algul, 1977).

The navigability of Opobo channel is the key to unlock the potential of IkotAbasi leading to development of a port that will not only add to the nation's revenue but also improve the life of impoverished indigenes of IkotAbasi and environs. The backbone to this is the morphological characteristics of the channel, i.e., the channel width and water depth. The channel width ranges from 1m to 1.7km, which is of no concern, irrespective of morphological changes over time. The main concern is water depth which is a function of the sediment

dynamics and the resulting hydrographic profile of the channel bed. In today's dynamic world of advancing technology, computer assisted data analysis currently plays an important role in creating a graphical representation of scenes for easy understanding and appreciation by its audience. This serves as a vital key in decision-making for coastal protection, development and management, especially of national and natural resources of great help to man-kind.

Geographic Information System (GIS) is a computer-based information management system used to digitally represent and analyze geo-spatial features. It is used to input, store, manipulate, analyze and output spatially referenced data (Burrough and McDonnell, 1998). A GIS can be distinguished from database management systems or from visualization packages through its specialized capability for spatial analysis. The use of GIS for coastal zone management has expanded rapidly during the past decade and references are numerous (Durand, 1994; Populus, 2000; Wright and Bartlett, 2000). GIS is commonly used in efficient and effective data management for hydrographic data (Millett and Evans, 2009). This computer assisted data analysis tool, was considered as best fit and therefore, used to manipulate the acquired bathymetric data to create a visual representation of channel water depth profile in different forms. Such as:-

1. Existing water depth and bottom profile, between IkotAbasi and the estuary.
2. Considering maximum vessel draft of 8m, section with sufficient depth was shown, including section with insufficient water depth that will require dredging.
3. A threshold water depth limit of 12m was assumed for uniform dredging, and then the volume of material to be dredged was computation.

II. STUDY AREA

Opobo Channel is the lower section Imo River-II, located south-south region of Nigeria. It's tidal and connects both IkotAbasi and Opobocoastal towns to the Atlantic. Numerous creek and creek-lets connected the channel, including Jaja Creek, Fine Face Creek and Strong Face Creeks. Imo River-11 is the administrative boundary between Akwalbom and Rivers States of Nigeria. It's located between Latitude $04^{\circ} 33' 55.31''$ and $04^{\circ} 28' 30.04''$ North of Equator and Longitude $07^{\circ} 31' 31.63''$ and $07^{\circ} 35' 35.38''$ East of Greenwich.

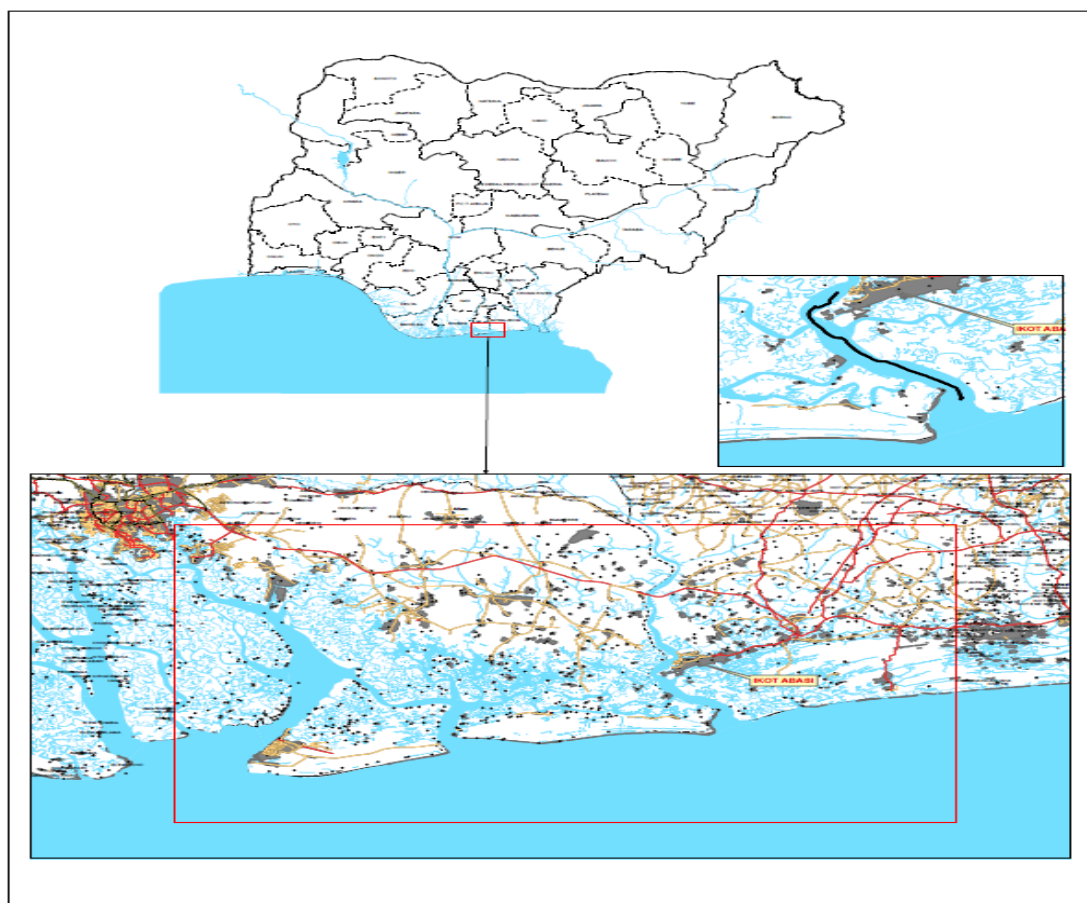


Figure 2 :- Map of Nigeria, Akwalbom and Rivers State, and Opobo Channel.

III. BATHYMETRIC DATA AQUISITION

(I) Bathymetric Measurements

Hydrography is an aspect systematic measurement in marine environment to determine the topographic status of the bed for many purposes including water depth, which amongst other uses, informs the navigability of the surveyed area. During bathymetric survey, water depth and position measurements were conducted simultaneously to provide spatial definition of each survey point in both horizontal and vertical planes.

(II) Navigation and Positioning System

The navigation and positioning on the survey boat, fitted with the depth sounding equipment was with Hemisphere VS100 dual frequency DGPS system. These were setup on the survey vessel with offset measurements between the GPS antenna and echosound transducer positions, made and registered in the survey navigation software EivaNavipac. This enabled position co-ordinate determination of the E/S transducer position for every sounding point. The survey computer runs the EivaNavipac navigation software, which was configured to receive and log raw data in real-time from the interfaced DGPS, gyro compass and Echo Sounder systems. The software also transformed the logged raw GPS co-ordinate from WGS-84 format to local grid reference to Nigeria Mid Belt co-ordinate system using a set of 7 datum shift parameters. The real-time output data were local grid co-ordinate and uncorrected water depth at all annotated fix points, including screen display of the GPS data health statistics.

(III) Water Depth Measurements Process

A single beam, Dual Frequency E/S was used to measure the water depths along the channel center line. However, only the acquired high frequency data was used for the water depth reduction during post processing. The measured echo signal displayed digitally, while the digital raw depth data, logs automatically in the interfaced survey computer for every annotated fix-points.

Prior to commencement of the actual survey and measurements, a bar-check was conducted to calibrate the echo sounder and determine the sound speed in water. At reconciled water depth setting of 2 and 3m, the velocity of sound in water was noted and set as 1530m/s for the survey. Total Tide Software was used to simulate the predicted tide from Admiralty Tide Table for the nearest Opobo river entrance standard port. The simulated tidal difference against observed time was developed and used to correct all measured depths for tidal fluctuation, using LAT (Least Astronomical Tide) as Datum.

All acquired data were post-processed, resulting in the x,y,z coordinate listing of all bathymetric survey points. These were the primary data and used to plot the water depth profile using ArcGIS software.

Table of GPS/Echo Sounder Data point Quantity

Survey Date	Bathymetric Survey Method	Chart Datum	Port Ref for Tidal Correction.	Data Point Quantity
12 February 2015	GPS/Echo Sounder	LAT	Opobo River Entrance Port.	430

III. BATHYMETRIC DATA ANALYSES USING GEOGRAPHIC INFORMATION SYSTEMS (GIS)

GIS provides a stable platform with facilities for the data integration, sophisticated analysis, manipulation and cross-examination of data and its associated derivatives. It enhances display and visualization of data to a wider audience. According to Yomralioğlu, 2005, a geographical information system is an information system for the acquisition, preservation, analysis and presentation of graphical and non-graphical data, based on its spatial attributes. This also implies that GIS could be used for data analysis in a wide range of applications. In deriving attribute information required for the geographical information systems, reliable data acquisition process is one of the most important phases, requiring huge time and cost.

(I) Gathering Attribute Information

Attribute information for evaluating the water depth and river bed profile were derived from the result of the bathymetric survey of Opobo channel. The post processed co-ordinate listing and reduced water depth were the primary data. These were used to plot the water depth profile of Opobo Channel from Ikot Abasi to the Estuary. The initial water depth chart was produced from these primary data, which formed the bases for further data manipulations.

IV. RESULTS AND DISCUSSION

Within the scope of this study, digital water depth models and bathymetric chart of Opobo Channel was obtained using ArcGIS 10 software (Figure 3.1 and 3.2). The available water depth that will support safe navigation and possible dredging requirement, including dredged volumes were examined using the ArcGIS 10 utilities.

These results showed reduced water depth that will not support safe navigation within the channel. About 54% of the channel is shallower than 8m water depth and will require dredging. Due to high sediment dynamics of typical coastal rivers, a threshold of 12m was recommended as uniform dredge limit. Based on this water depth limit, the material volume to be dredged was computed using Cut-and-Fill utility in the GIS software. The volumetric model boundary for the computation was set for 200m width and 14km long. The derived volume of 29,000,000 cubic meters was compared with another computation method using Surface Difference. The correlation was more than 98%.

Unfortunately, it was not possible to get the bathymetric data of 1996 dredging works in the channel. This would have enabled the evaluation of rate of sedimentation. However, the current bathymetric works will serve as baseline for future assessment and determination of sedimentation rate. With this information, time for subsequent maintenance dredging could be predicted and planned for. Also the anticipated dredge volume will enable budgetary planning.

V. CONCLUSIONS

The GIS utilities have shown to be a reliable tool for effective management of bathymetric data that will provide a realistic overview of water depth information for safe navigation in Opobo Channel. This is a key decision-making tool for planning the dredging works within the channel.

In addition, there is need for continuous study and update of hydro-morphological characteristics within the channel and especially around the estuary, which has more sedimentation dynamics. With this continuous information, an updated co-ordinate listing that defines safe route will be made available to mariners/vessels arriving the channel.

For proper budgetary planning and financial management, the availability of GIS enables a prediction tool, with information on time, volume and cost of future maintenance dredging works. This added value of the GIS will provide a prediction tool with high level of confidence for safe navigation, especially, when one considers the huge cost of vessel beachment.

Geographic Information Systems (GIS) technology has allowed Opobo Channel bathymetry to be two-dimensionally modelled, analyzed and displayed. By deploying such information manipulation tool, the efficiency and effectiveness of coastal river channel management may be considerably augmented for optimal effect. Once the channel is free for year-round safe navigation, other developmental processes can now key-in. This assures the realization of the ultimate goal of exploring and exploiting the socio-economic potential of Ikot Abasi and environs, including Nigeria as a country.

Due to multiple influent creeks and creek-lets along the channel, including the downstream estuarine sediment yield, there is need for a detailed morphological research on the evolution of sediment dynamics and characteristics of Opobo Channel. This will bring history to the fore and create a reliable baseline for management of the channel.

VI. Acknowledgements

The authors would like to thank the Managing Director of Sckopemate Konsult Limited, Chigbo Okeke (FNIS), for providing and authorizing the use of bathymetric data and charts of Opobo Channel. Also, Nweke Chukwuemeka, who, in addition to his very busy schedule, willingly made out time to assist in resourcing technical materials. We thank you all and may God reward you abundantly.

REFERENCES

- [1] **Lutz, E. and M. Munasinghe (1994)**, Environmental accounting and valuation in the marine sector. In *Ocean Governance: Sustainable development of the Seas*, edited by Payoyo, P.B., (Tokyo, New York, Paris: United Nations University Press).
- [2] **Eckert, R. D. (1979)**, *The Enclosure of Ocean Resources: Economics and the Law of the Sea*, (Stanford: Hoover Institution Press).
- [3] **Erkaya, H., Hoşbaş, R. G. (1998)**, "Hydrographic Surveying Course Notes", Yıldız Technical University, Geomatic Engineering department, İstanbul.
- [4] **Millett, G. N., Evans, S. (2009)**, "Hydrographic Data Management Using GIS Technologies.", Environmental Systems Research Institute, New York, USA.
- [5] **Burrough, P. and McDonnell, R. (1997)**, *Principles of Geographical Information Systems*, (Oxford: Oxford University Press). Carter, R.W.G., 1988, *Coastal Environments*,
- [6] **Durand H., et al. (1994)**, An example of GIS potentiality for coastal zone management: Pre-selection of submerged oyster culture areas near Marennes-Oléron (France). EARSEL Workshop on Remote Sensing and GIS for Coastal Zone Management. Delft, The Netherlands, 24 - 26 Oct.
- [7] **Populus J. and Loubersac L. (2000)**, *Geomatics and coastal environment*. (Brest: Éditions de l'Ifremer).
- [8] **Wright D. and Bartlett D. (2000)**, *Marine and Coastal Geographical Information Systems*. (London: Taylor and Francis). © 2005
- [9] **Yomraloğlu, T. (2005)**, "Geographic Information Systems: Basic Concepts and Applications." İBER Ofset Publisher, Trabzon, 32-148. Central Anatolian 12th. District Office of Mineral Research.
- [10] **Wheeler, P. (2005)**, 'Bathymetric Evolution at a Coastal Inlet after Channel-edge Groyne Emplacement'. *Applied GIS*, Vol. 1, No. 2, 2005, pp. 28.1–28.34. DOI: 10.2104/ag050028.
- [11] **Nnamah, P. (2005)**, *Baseline Data Determination for the Study of Dynamics of Sediment Redistribution over the Delta Formation at Bonny/Finima River Confluence, Bonny – Nigeria*. Unpublished, M.Phil. (Hydrographic Engineering), thesis, Institute of Geoscience and Space Technology, University of Science and Technology Port Harcourt. Nigeria.