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Bathymetric Survey for Determination of Bottom Morphology at Niwa Dockyard Jetty, Warri, Delta State

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Abstract

Maintaining adequate depth at jetties involves periodic determination of the bottom morphology to ensure that the water capacity and depth around the jetty is sufficient for safe navigation of vessels. This study which was carried out at NIWA Dockyard Jetty, Warri, Delta State, Nigeria, was aimed at producing a chart showing the variation of bottom depth of the river bed. Acoustic method of depth determination was utilized. Positioning of the Echo Sounder was done using a Hemisphere V200s GNSS receiver for determining the geospatial position of the distributed depth values; a South SDE-28 Single-beam Echo Sounder was utilized in determining the depth. Hypack Navigation Software was used for previewing, analyzing and displaying depth data in relation to sounding lines. Further processing was carried out with ArcGIS 10.8 software, for creating map layers and evaluating relationships between mapped features and regions of the Surveyed area, Surfer 10,was used for creating the topographic profiles of the bottom of the river as well as dimensions. On completion of data analysis, contour map, Digital Elevation Model, and 3D surface map of the bottom morphology at the Jetty were produced. The result of the bathymetric survey showed that the lowest sounded depth was 0.30m and the highest was 15.80m. A total of 772 sounded depths were obtained. The result of analysis further showed that only limited areas within the Jetty had sufficient depth to provide enough clearance for vessels.

1. Introduction

Hydrography, the acquisition, analysis, visualization, and management of spatial information pertaining to all marine features and processes, is crucial for understanding their position in space with reference to time [1]. Hydrographic surveys are the applied science dealing with the measurement and description of the physical features and conditions of navigable waters and their shorelines [2]. This broad discipline involves the quantification of phenomena such as tides, tidal current analysis and prediction, waves, currents, chemical content, seabed depth, and more, all referenced to established geodetic controls for navigation purposes [3] A critical aspect of hydrographic surveys is the bathymetric survey, which focuses on determining the size, shape, and topography of the seabed through densely distributed depth measurements [4].

Accurate determination of seabed topography requires linking the positions of the depth values obtained within the survey area to an established control network. This ensures precise location of points with specific depths at later times, as depicted in the produced maps and profiles [5]

Bottom morphology, referring to the relief or depth differences of the riverbed over a predetermined area, it is a crucial factor in the continual maintenance of jetties. Accurate bathymetric surveys for bottom morphology determination are essential for scheduling timely dredging and maintenance operations, which are necessary to avoid grounding vessels and incurring significant revenue losses due to operational disruptions [6, 7]. The term "bathymetry" originally meant "ocean depth relative to sea level" but now encompasses "submarine topography" or "the depth and shape of underwater terrain" [1]. Bathymetric maps, which join points of equal depths, reveal seabed features like trenches and mid-ocean ridges [6]

Accurate depth measurements typically involve single or multi-beam echo sounders that use acoustic waves. The collected data is often integrated into Digital Elevation Models (DEMs), providing detailed and accurate digital representations of underwater topography compatible with various computer systems for on-site project execution and real-time operations [8, 9, 10], with the aim of demonstrating the efficacy of integrating ground survey data obtained from GNSS with bathymetric data obtained from Midas Echo-sounder in production of Seam Topo-bathymetric map, carried out a Topo-bathymetric survey operation in 2022.

The NIWA Dockyard Jetty in Warri, Delta State, Nigeria, has seen rapid economic growth, intensifying the need for accurate bottom morphology determination to support the safe navigation of larger vessels. Conducting a comprehensive bathymetric survey of this area will provide essential information on the current riverbed profile and topography, enabling informed decisions for dredging and maintenance activities. [11] (2017) carried out a bathymetric survey along the access route to Odidi well locations 10, 45, and 47 in Warri South Local Government Area, in Delta State, in order to investigate the volume of material to be dredged and to determine the dredged depth required for safe navigation of vessels. A post-dredge sounding operation was carried out by [12] (2014) on access route and slot to Opuama Location (1) in Warri North Delta State. Having critically reviewed literatures on works related to this project, the indirect method was concluded as the most suitable method for this project and the equipment's utilized included a South SDE-28 Single-beam Echo Sounder (for depth determination), a Hemisphere V200s GNSS receiver (for position determination) attached vertically to the Echo Sounder, as well as other necessary accessories and software applications which enabled satisfactory results for the project.

The objectives of this project are to carry out a detailed bathymetric survey of the river at the jetty, utilize GIS software in creating a Digital Elevation Model (DEM) that describes the riverbed morphology, and determine the highest and lowest bottom depths at the jetty. Achieving these objectives is vital for the design, construction, and maintenance of navigation channels at NIWA Dockyard Jetty. Accurate bathymetric surveys will provide comprehensive information about seabed depth and the necessary dredging operations. This will enable the jetty's management to plan dredging and channel maintenance effectively, reducing time and resources spent on inefficient operations and preventing accidents that could result in vessel grounding.

2. Materials and methods

2.1 Study Area

NIWA Dockyard Jetty, Warri, is one of the Dockyard Jetties owned, occupied, and operated by the National Inland Waterways Authority and it is, more precisely, located at Warri Dockyard, Warri-

Sapele road, Warri South Local Government Area of Delta State, lying between Latitudes 5°31'24.40"N and 5°31'03.35"N, and Longitudes 5°46'12.53"E and 5°46'09.56"E, which stretches over 1.5km. The Jetty is built along Udu River, which is a section of Warri River flowing past Udu Bridge. Warri, is renowned, primarily, for its immense economic outputs which has made it a major economic hub. Also, the surplus availability of means of water transport has led to increased use of navigation vessels on the surrounding rivers, especially Udu River, as a major means of transport. Hence, efforts by appropriate agencies to provide safe navigation channels along the river, especially around the NIWA Dockyard Jetty, are underway.

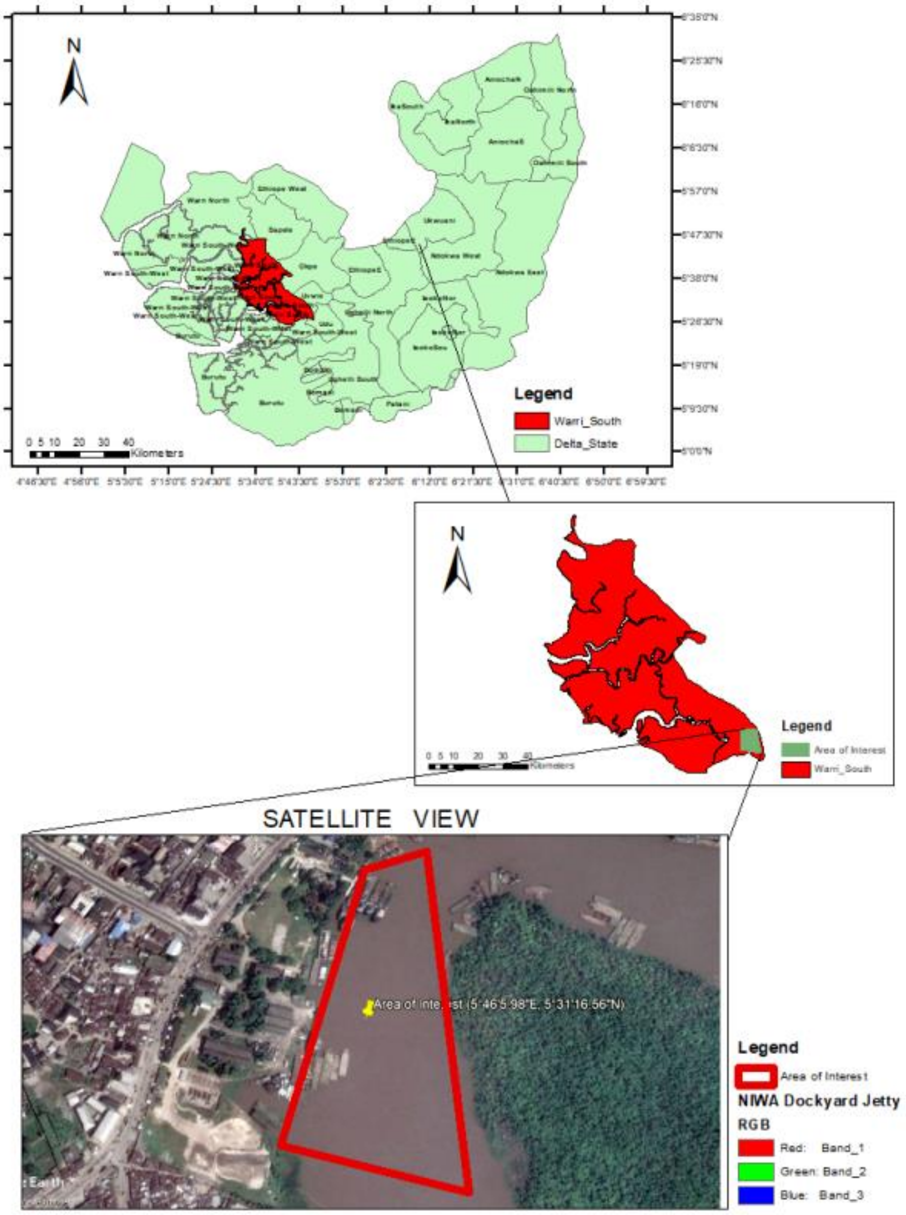

Figure 1: Study Area Map

2.2 Methods

This section enumerates the methods adopted for achieving the aim of this study. It includes the series of steps and the critical considerations involved in selecting the procedures to be applied. The flow chat of methodology is presented in Figure 3.1

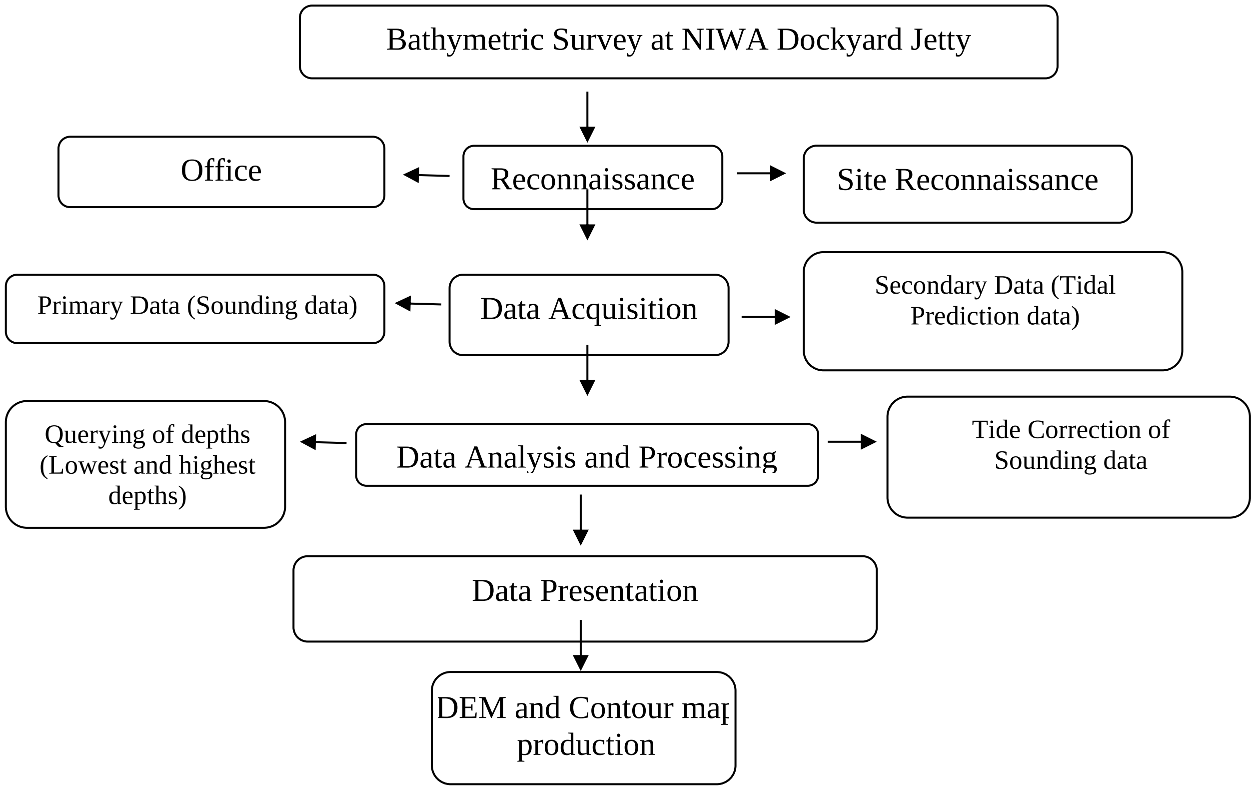

Figure. 2: Flow chart of workflow during bathymetric survey.

Office reconnaissance carried out basically involved the determination of the types of equipment suitable for the type of project at hand, as well as the availability of staff that could carry out the project within the given project constraints, including: duration of work, cost specification, accuracy requirements.

Site reconnaissance, on the other hand, involved physically evaluating the site before actual work, for estimation of its physical characteristics and features. Information obtained on site describes: the probable barriers to the project (for mitigation), the presence of man-made and natural structures within the area that have a certain effect on the success of the project, as well as to gain familiarity of the site terrain for planning purposes.

2.3 Instruments

In this bathymetric survey, instruments utilized for the acquisition of various data includes: Differential Global Positioning System – DGPS Base Station, the Hemisphere V200s GNSS receiver, GPS – Mobile Station, Single Beam Echo Sounder, Navigation System Laptop, Communication ports, Inverter system, 12 Amps car battery, Bar check plate and clamps, Fiber Plastic Boat.

2.4 Instrument Test

The bar check procedure for calibration of the acoustic sounding instrument was carried out to ascertain and control the quality of depth measurements obtained from the sounding operation. It primarily involved the determination of measured depth due to variance in a water column. To execute this calibration process, the depth between the water surface and the transducer of the Echo Sounder was first measured. Next, a bar check plate was submerged in the water via a calibrated rope of known length, making sure that the plate was guided under the transducer. Sounding from the transducer to the plate was then carried out. The difference between the value displayed by the

Echo Sounder and the depth given by the calibrated rope gave the correction applied to all depth values obtained by the Echo Sounder [1].

Position Verification was the second instrument test which involved the determination of the accuracy of quality of data gotten from the GNSS positioning system. It involves placing the receiver over a known point for a long period of time (usually 30 minutes) while it obtains positional data from satellites. The difference between the coordinates obtained by the GPS and the Coordinates of the known point shows the correction to be applied to all coordinates obtained within the vicinity (i.e. the project site) [13]

2.5 Software

The various software applications utilized for this project include: Google Earth Software, AutoCAD Software, Hypack Navigation Software, and Surfer 10 Software and ArcGIS Software.

2.6 Sounding Along Survey Run Lines

Sounding operation was carried out as the boat navigated on the X-axis (Run lines) from one side of the river to another (upstream to downstream) in sequential manner (i.e., X_1, X_2,...,X_n). On reaching the end of one Run line, the Survey boat navigated to the beginning of the next run line and commenced sounding towards the other direction. This process was carried out until the last Run line (X_n) was reached. With the Echo Sounder and GNSS receiver unit, the depths and positions along the Run lines were obtained and automatically stored. Navigation along the Sounding survey lines was carried out at a speed of about 5 knots throughout the entire survey period; this was done so as to ensure data quality and integrity which is highly necessary.

2.7 Data Acquisition & Downloading using Echo Sounder

To acquire data via the Echo Sounder, after successful equipment set up on the sounding vessel, the Echo Sounder was first turned on, after which, the Echo sounder data acquisition software (NAV380 software) was initiated. Data acquisition interval was then set to 5 seconds, the High and Low frequency pulse length, signal gate and gear setups were fixed to the "AUTO" option, while the HF (High Frequency) and LF (Low Frequency) were set to 200KHz and 15KHz respectively.

To calculate depth, the Echo Sounder employed the formula for the two way travel of the acoustic waves in water as given in Equation 1 [1]

$$D = \frac{C \times t}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where D, c, and t represent the acoustic depth, speed of sound in water, and the two way time of travel of acoustic pulse to the river bed.

2.8 Computation of Bathymetric Uncertainty

To ensure that the data acquired during the Sounding operation had a high level of precision, the depth uncertainty (bathymetric uncertainty) at the 95% confidence level was computed from the standard method. This method involved the use of the equation: [1]

$$S = \pm\sqrt{a^2 + (b \times d)^2} \quad \ldots\ldots\ldots\ldots \quad (2)$$

Where:
S = Bathymetric Uncertainty
a = constant depth error = 0.25m (constant)
b = factor of depth dependent error = 0.0075m (constant)
d = maximum depth
The maximum depth (tide corrected) obtained for this project was 15.80m

Applying equation (2) above, the value of bathymetric uncertainty was gotten as follows:

$$S = \pm\sqrt{0.25^2 + (0.0075 \text{ x } 15.80)^2}$$

S = ± 0.277

The above value is in accordance with the International Hydrographic Organization (2008) recommendation which requires that the bathymetric uncertainty for a special order survey be ≤ 0.39. Also, tide prediction values were used in correcting measured depth with respect to time. The measurement was done in line with the following mathematical relationship in equation 3

Reduced depth = Chart Datum value (L.A.T.) – Measured Depth (Raw Depth) ….. (3)

2.9 Processing of Bathymetric Data and Analysis

Hypack Software was the principal software utilized for the analysis of bathymetric data. This was due to its flexibility in analysis, data presentation, and data query features. Data acquired were analyzed using the Hypack Single Beam Editor feature. This feature allowed for the removal of spikes and outliers (random errors) thereby improving the integrity of the data being analyzed.

2.10 Tide Prediction Table for Depth Reduction (Tide Correction)

To analyze depths obtained from the site, a reference tide level had to be adopted to aid tide correction for all sounded depths obtained. The reference utilized was the Lowest Astronomical Tide (L.A.T.) and Tide prediction table was used to obtain predicted tidal values for the river.

3.0 Results and Discussion

This section presents and discusses the final results as well as the implication of these results to the objectives of the study. It includes the series of steps, calculations and considerations involved in the achievement of these results.

After removing outliers, tide correction was carried out on the data to correct for tide changes. Thereafter, plotting of the various files required for mapping the river bed was carried out. These files included Contours and Digital Elevation Models. (DEM)

3.1 Generation of Dem Map for the Project using Arcgis Software

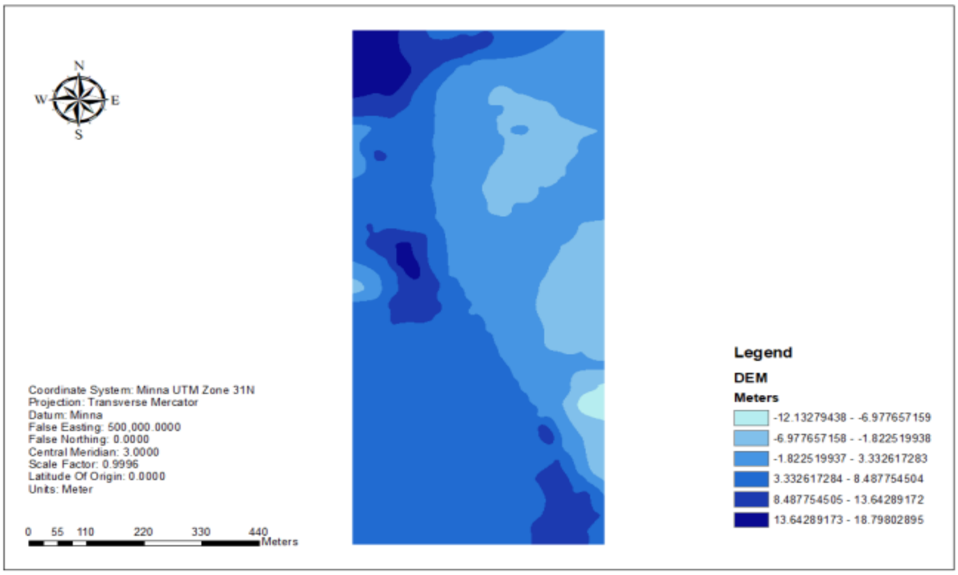

Fig. 1: DEM Map of Bottom Morphology of NIWA Dockyard Jetty, Warri

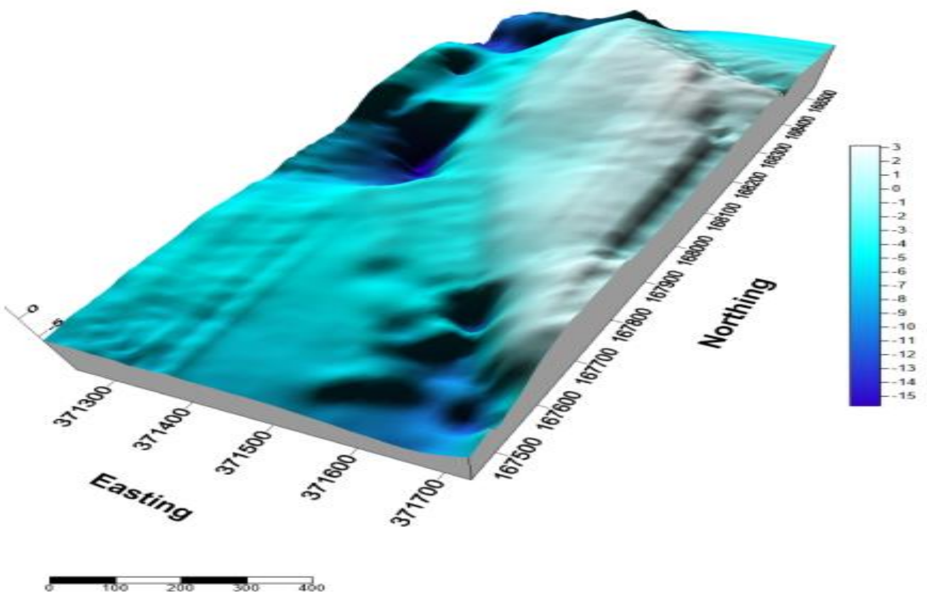

Fig. 2: 3D DEM Map of Bottom Morphology of NIWA Dockyard Jetty, Warri, produced from Surfer Software

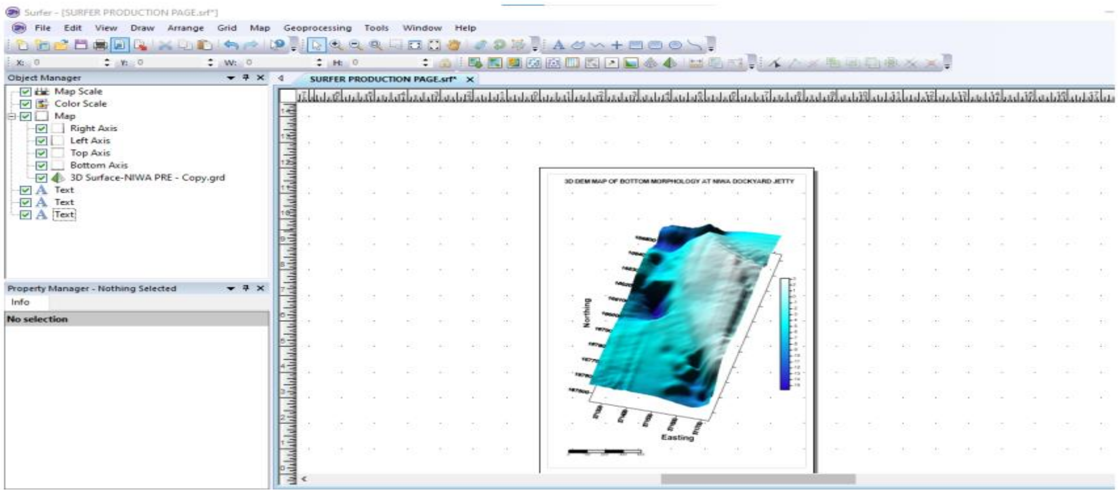

Fig. 3: 3D DEM Map of Bottom Morphology of NIWA Dockyard Jetty, Warri

The DEM map for NIWA Dockyard Jetty, via ArcGIS software, obtained from the Echo Sounder files, after application of tide reduction, was converted to excel (.CSV) format. This file was imported into ArcGIS environment by using the "Add XY data" option, with the appropriate elevation column indicated. Next, the "properties" option was selected for the added elevation data layer and under the "label" property, "label layer" was selected at the top with the "Z" field selected. Placement of the labels (i.e., contour values) was selected to be parallel. The result was the above DEM map. The negative values arose from the interpolation of the software which, from the study area map, shows relative accuracy in determining the location of dry ground away from the river.

3.2 Generation of Contour for the Project

The contours describing the bottom morphology, based on the final depth data, were generated using both ArcGIS and Surfer Software. This procedure was adopted in order to allow for comparison of the precision of the results. The Contour map for NIWA Dockyard Jetty was prepared, via Surfer software.

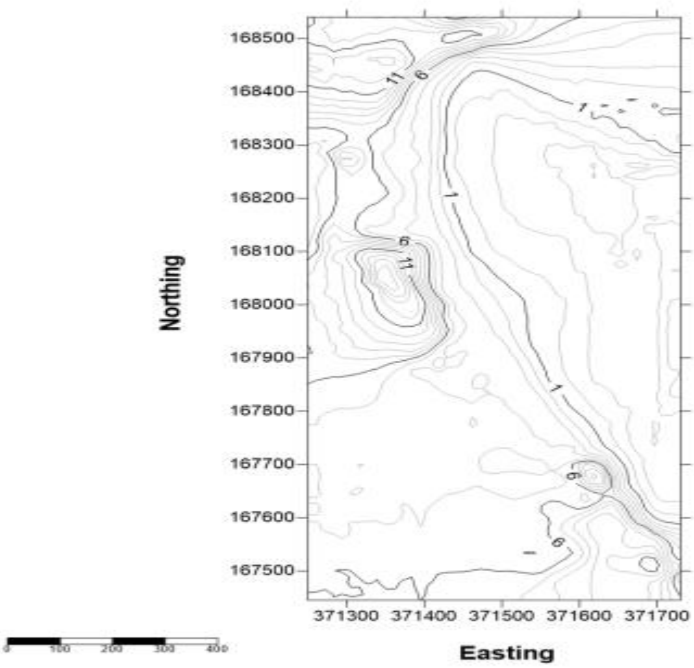

Fig. 4: Contour Map of Bottom Morphology of NIWA Dockyard Jetty, Warri.

The datasets required for meeting the project objectives have been clearly shown in the figures presented. These datasets were the River bed contour map and Digital Elevation Model (DEM) using both Surfer and ArcGIS software. These maps obtained were then compared to understand the level of precision with which they define the same location for application purpose

4. Conclusion

In this study, bathymetric survey for determination of bottom morphology at NIWA Dockyard Jetty, Warri, Delta State, was carried out. In order to achieve the expected results of the project, the project was carried out by determining the depths along the river by means of sounding operation with the depths subsequently reduced via predicted tidal values as obtained from a tide prediction table utilized around the area. The data obtained were then analyzed and utilized in the production of River bed Contour and Digital Elevation Model (DEM). The main aim of this project was to map out the bottom morphology (also referred to as topography) at NIWA Dockyard Jetty, Warri, Delta State, via a properly conducted bathymetric survey operation. From the resulting Digital Elevation Models generated, the sea bed was accurately depicted and information for possible dredging or maintenance works, to aid navigation of vessels, clearly indicated. The variation of depth on the sea bed was well represented. The project result showed that reduced depth ranged from 0.3m to 15.8m. This showed that certain areas around the Dockyard Jetty required urgent dredging to prevent accidents that might occur. This would enable vessels with higher draft to navigate freely and safely within and around the Jetty.

References

[1] Ojinnaka O.C. (2007). *Principles of Hydrographic Surveying – From Sextant to Satellite*. Department of Geoinformatics and surveying, University of Nigeria, Enugu Campus

[2] Chukwu, F.N., & Badejo O.T. (2013). *Bathymetric Survey Investigation for Lagos Lagoon Seabed Topographical Changes.* Journal of Geosciences and Geomatics, 2015; 3(2): 37-43.

[3] Bannister, A., & Raymond, S. (1981) *"Surveying."* Pearson education Ltd, Edinburgh Gate Harlow, Essex CM20 2JE England, Fifth Edition.

[4] Elhassan I. (2015). *Ba thymetric Techniques.* Paper presented at the International Federation of Surveyors (FIG), FIG Working Week 2015, Sofia, Bulgaria

[5] Archibong, E. (2017). *Bathymetric Survey of Part of Nwaniba River, Uyo, Akwa Ibom State*. Published B.Sc. project of Department of Geoinformatics & Surveying, University of Uyo, Uyo.

[6] Brookes, A., Gregory, K.J., & Dawson, F.H. (1983). *An Assessment of River Channelization in England and Wales.* Science of the Total Environment 27 (2-3), 97-111.

[7] Idhoko, K.E., Omorogie J., & Agaba, P. (2016). *Bathymetric Assessment of Sedimentation Levels of Jebba Dam Reservoir, Niger State, Nigeria.* International Journal of Scientific Research and Engineering Studies, Vol. 3, Issue 5, May 2016. ISSN: 2349-8862

[8] Samaila-Ija, H.A., Oluibukun, G.A., Nanpon, Z., Kuta, A.A., Adesina, E.A., & Ibrahim, P. (2014). *Bathymetric Survey and Volumetric Analysis for Sustainable Management Case Study of Suleja Dam, Niger State, Nigeria.* Journal of Environment and Earth Science, 2014.

[9] Olushola, S.O., & Ehigiator-Irughe, R. (2017). *Determination of University of Benin GNSS Calibration Base Accuracy Standard.* Journal of the Nigerian Association of Mathematical Physics 40, 307-314

[10] Oladosu, S.O., Alademomi, A.S., & Salami, T.J. (2017). *Integrated Hydrographic Survey for Proposed Jetty Location along Benin River at Oghara Delta State, Nigeria.* Arabian Journal of Geosciences 16 (4), 284.

[11] Effiong, V. (2017). *Analysis of pre dredged and post dredged sounding of Odidi Creek, in Warri South, Delta state*. Published B.SC project of Department of Geoinformatics & Surveying, University of Uyo, Uyo

[12] Adejare, Q.A., Olusina, J.O., & Olaleye, J.B. (2017). *Empirically Determined Passenger Ferry Navigable Routes within Lagos Lagoon.* Nigerian Journal of Technological Development 14 (2), 74-79,2017.

[13] Ehighiator, M.O., Oladosu, O.S., & Ehigiator-Irughe, I.R. (2017). *Determination of Volumme and Direction of Flow of Kainji Reservoir using Hydro-Geomatics Techniques.* Nigerian Journal of Technology 36 (4), 1010-1015, 2017.

Elhassan I. (2015). *Ba thymetric Techniques.* Paper presented at the International Federation of Surveyors (FIG), FIG Working Week 2015, Sofia, Bulgaria.

Effiong, V. (2017). *Analysis of pre dredged and post dredged sounding of Odidi Creek, in Warri South, Delta state*. Published B.SC project of Department of Geoinformatics & Surveying, University of Uyo, Uyo.