Analyses of Pre-Dredged and Post-Dredged Sounding of Odidi Creek in Warri South, Delta State, Nigeria

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Abstract

This study examines the volume of materials dredged and the depth required for safe navigation of vessels along Odidi creek in Warri South, Delta State, Nigeria. Pre-dredging and Post-dredging bathymetric survey were carried out by obtaining the followings: Mean Tide Level (MTL) of the creek; sounded depths and positioning using Hydrostar Elac 4300 dual frequency Echo Sounder and C-NAV 3050 GNSS respectively. The sounded depths were reduced to MTL datum. The area of the project and volume of materials were 26792.542m² and 52800.018m³ respectively, and bathymetric uncertainty of ±0.512m was obtained. Analysis of the post-dredged results showed that the area was over dredged by 1.35m after comparing the expected and the reduced average depths obtained. Bathymetric chart, contour map, 3D surface and Triangulated Irregular Network of the two data sets were produced. The result further revealed that creation of Under Keel Clearance Management System (UKCMS) to enhance quick accessibility to depth information on Nigerian Inland Water Ways was a prerequisite for safety to navigation.

Keywords — *Sounded Depths, Bathymetry, Pre-Dredging, Post-Dredging, Tidal Rivers, Creek, Under Keel Clearance, Chart, Triangulated Irregular Network.*

I. INTRODUCTION

Dredging is the removal of sediments and debris from the bottom of lakes, rivers, harbors, and other water bodies. It is a routine necessary in waterways around the world because sedimentation is a natural process whereby sand and silt washing downstream gradually fills channels and harbors. Dredging often is focused on maintaining or increasing the depth of navigation channels, anchorages, or berthing areas to ensure the safe passage of boats and ships [5]. It is broadly classified into two categories; Capital and Maintenance Dredging. While capital dredging is a one-time dredging in port areas like harbour basin and navigational channel to create/increase depths to receive the ships in a one-time capital expenditure; maintenance dredging, on the other hand, is done periodically to maintain the depths so created by capital dredging at ports, as well as its expenditure [5]. For the purpose of this study, dredging was primarily performed to improve and maintain the depth of the waterway for easy and safe navigation of vessels.

The importance of pre-dredging and post-dredging bathymetric survey is indispensable in the dredging industry. It is used to collect data sets on navigable waters in order to guaranty safe and accurate navigational depths [3]. It is also employed in gathering data for capital and maintenance dredging where they help to determine the total volume of dredge materials, as well as the required water depths obtained over the entire study area. This later purpose is required by the mariners for safe navigation along the access route. In this study, pre-dredging bathymetry was performed to estimate the volume of dredge materials that would be required to attain the specified design level. While, post-dredging bathymetry was later performed to ascertain the water depths. On the whole, the nominal depth was achieved, which allow vessels with maximum draft of 3.18m and minimum under keel clearance of 0.32m to navigate safely. The results of the analysis and deliverables also sort to enlighten the mariners on the type of vessels that could sail successfully along the channel, as well as enabling the fishermen to identify areas that were safe for fishing. Lastly, the data sets obtained was useful to ascertain the cost for the volume of dredged materials without any dispute.

Gaining access into Odidi creek for the operations and maintenance of the oil wells situated within the region could only be achieved when the nominal depth of the well slots could sustain a loaded longitudinal centre floatation of a particular vessel navigating along the channel without running aground. Due to accumulation of sand and silts caused by siltation, vessels with maximum drafts ranging from 2.11m to 3.18m could not navigate safely along the channel without running aground. To proffer solutions to the above, pre-dredging bathymetry, navigational dredging and post-dredging bathymetry were carried out in Odidi well location. To this end, the study aimed at determining the required depth of water for safe navigation of vessels along the access route to Odidi Well Location. The objectives include: to investigate the volume of dredge materials; determining the safety clearance of vessels with respect to the nominal depth; to ascertain the dredged depth of the channel with respect to the formation level, and presentation of the pre- and post-dredged data sets.

service vessels were the two major types vessels taken into consideration that navigate the river.

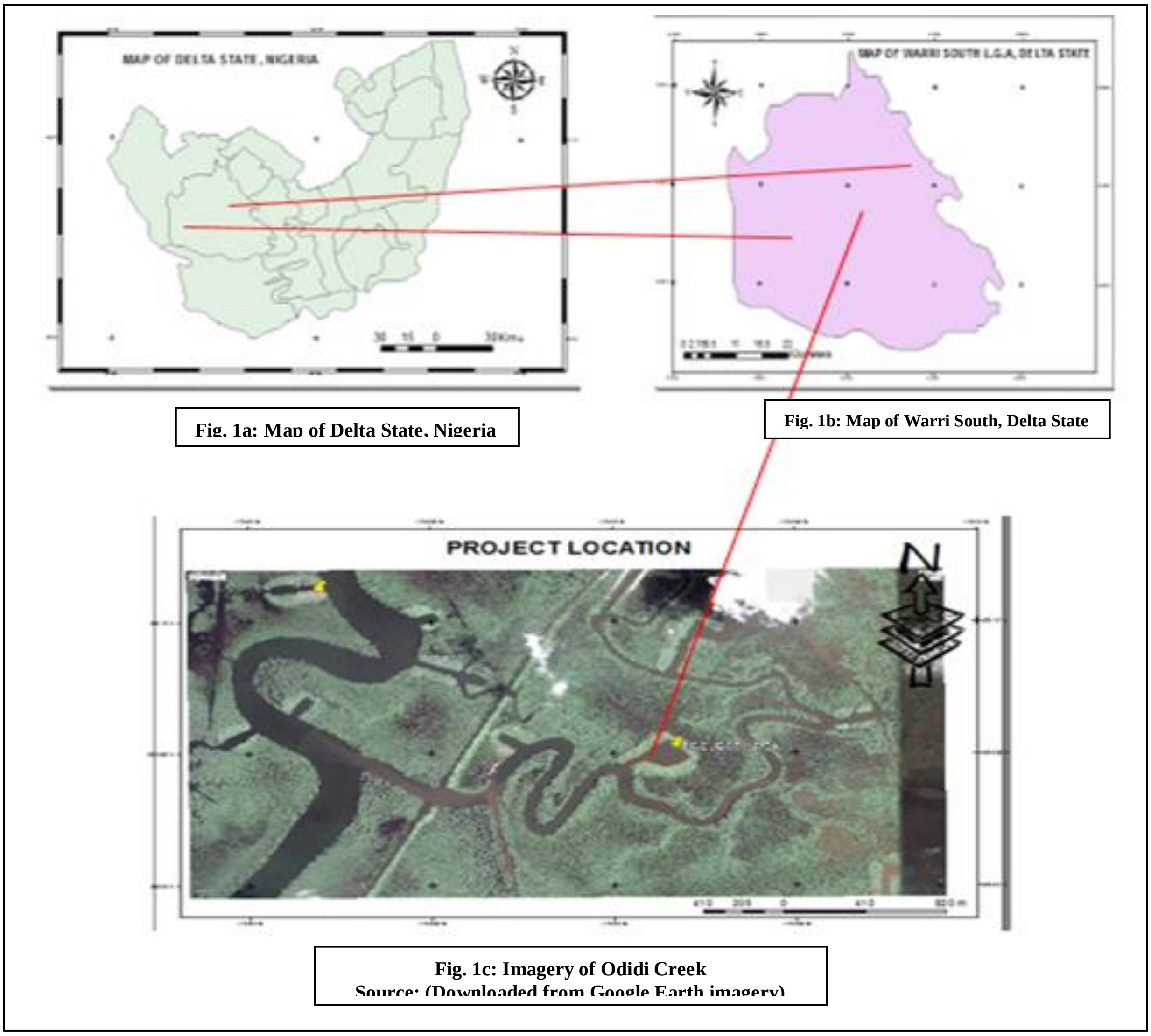

Fig. 1a: Map of Delta State, Nigeria

Fig. 1b: Map of Warri South, Delta State

Fig. 1c: Imagery of Odidi Creek
Source: (Downloaded from Google Earth imagery)

Fig. 1: Map of the Study Area

II. MATERIALS AND METHODS

A. *Study Area*

The study area was at Odidi Oil Field in Warri South Local Government Area of Delta State, Nigeria. Its geographic location lies between latitude 05^0 30’ 27.57’’ N & 05^0 30’ 30.45’’ N and between longitude 05^0 29’ 02.52’’ E and 05^0 29’ 09.99’’ E. The area is characterized by meandering creeks, mangrove swamp and mangrove forest on the land terrain. The tidal regime of Odidi Creek is semi-diurnal because of two (2) low water and two (2) high water levels occurrences in each day. In order to access the oil well situated within the area, special purpose vessels and

B. *Methodology*

The systematic approach adopted at various stages to achieve the aim of the study include the followings:

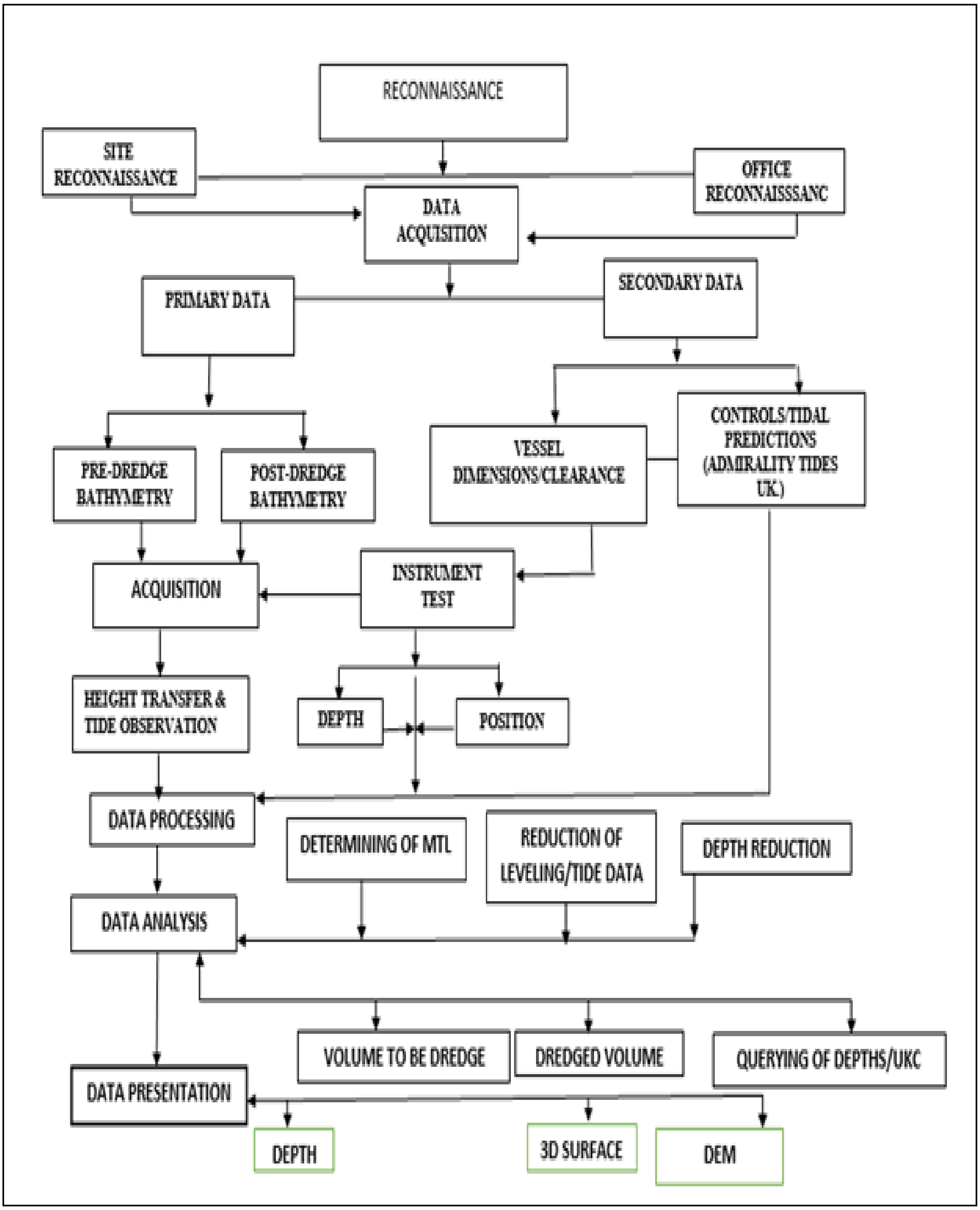

Fig. 2: Flowchart of Methodology

Reconnaissance, Pre-Analysis, Data acquisition, Data processing, Data analysis and Presentation. Below is the flowchart that shows systematic methods adopted for the study.

a). Reconnaissance

Reconnaissance involves data search to obtain relevant information required about the area. To achieve this, the following data were obtained:

i. Working map covering the study area;
ii. Google earth imagery of the project site to aid in design of the sounding lines;
iii. Geodetic parameters for the study area were also obtained.

b). Instrumentation

Equipment (hardware and software) deployed for the study were: Hydrostar ELAC 4300 Dual Frequency Echo Sounder, C-NAC 3050 GNSS, Kolida KL 32 Automatic Level, Tide Gauge, Google Earth imagery, ArcGIS 10.1, Golden Surfer 12, and AutoCAD CIVIL3D 2017.

As a prerequisite, specific tests of instruments were carried out to ascertain that they were in good working condition before being deployed for the field operations. These included Bar check and two-peg-test on the Echo sounder and Level instrument respectively. The results of the Bar Check are as shown in Table 1 below.

Table I: Results of Bar Check

S/N	Plate Depth (M)	Echo Sounder Depth (m)	Diff.
1	0.5	0.51	0.01
2	1	1.02	0.02
3	1.5	1.49	0.01
4	2	2.02	0.02
5	2.5	2.52	0.02

c). ***Field Observations***

Measurements carried out during the process included the followings:

i. Height transfer to the water surface,
ii. Tidal observation at 30-minute intervals to obtain Mean Tide Level (MTL),
iii. Sounding to obtain water depths.

II. RESULTS AND DISCUSSIONS

A. Results And Analyses

After all the field data acquisition, both the pre-sounding and post-sounding data were managed, processed, analyzed. The processes undertaken were as follows;

i. Leveling Reduction was carried out using SAT 16 as the reference datum with height 2.247m above chart datum,
ii. Mean Tide Level (MTL) was determined from mean of the High-Water Levels (HWL) and Low Water Levels (LWL), as 1.008m. This value was also related to the height of SAT 16, to aid in depicting the seabed topography,
iii. The Reduced Sounded Depths were computed using Microsoft excel 2016 software as shown.

Reduced Sounded depths
= (MTL) –Sounded Depths *(2.1)*

iv. Analysis of Volume of Materials to be dredged was done after careful reduction of sounded depths. The data set was loaded into surfer 12 and the value of the required depth (3.5m) was keyed in. The Grid Volume computation report was generated which shows the estimated volume of materials to be dredged as shown in Fig. 3.

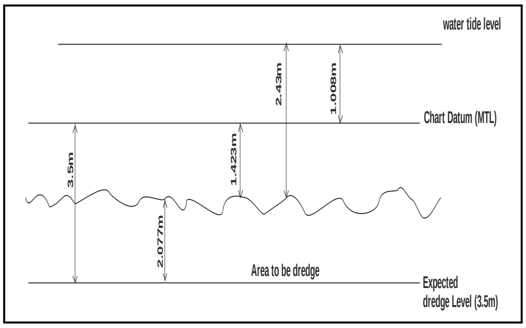

Fig. 3: Showing Volume of Materials to be Dredged

The diagram above shows a position fix at 12.09GMT with horizontal coordinate of 340078.334mE, 166803.653mN and sounded depth of 2.43m.
Mean Tide Level (MTL) = 1.008m
Required depth = 3.5m

Reduced depth = MTL – Sounded depths
= 1.0085-2.43 = -1.422m

Depth to be dredged =
Reduced depth +Required depth
= -1.422+3.5 = 2.077m

v. Analysis of Dredged Volume Material revealed that the area was over dredged by 1.35m after comparing the expected average dredged depths obtained from the client and the reduced average depth obtained after field operations as shown in Fig. 4.

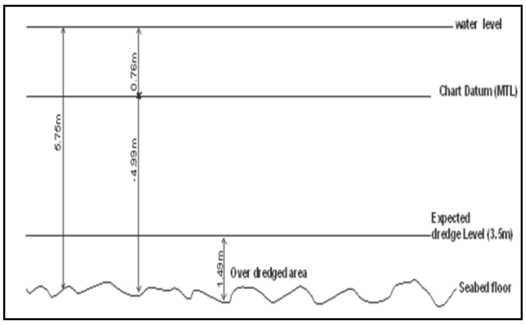

Fig. 4: Volume of Materials over dredged

Similarly, the diagram above shows a position fix at 14:40GMT with horizontal coordinate of 339954.521mE,166819.362.653mN and sounded depth of 5.75m.

Mean Tide Level (MTL) = 0.76m

Required depth = 3.5m

Reduced depth = MTL – Sounded depths
= 0.76-5.75 = -4.99m

Over dredged depth =
Reduced depth +Required depth
= -4.99+3.5 = 0.99m

vi. Querying of Pre- and Post-Dredging Depths. An attribute query is defined as the process of searching and retrieving records of features in a database based on desired attribute values [3]. In this study, queries of the attribute values were done in two phases, Pre- and Post-dredging. The data set for the pre-dredging was queried using the select by attribute tool in ArcGIS to show the area below various depth. Also, data set for post-dredging was also queried to show the depths above the expected depth. Figs. 5 and 6 show the results of both queries.

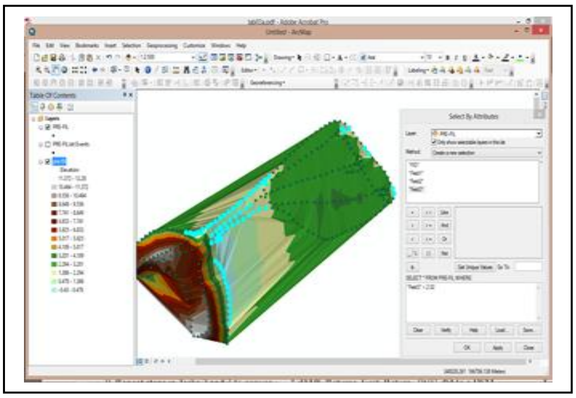

Fig 5: Query showing depths below 2.02m before dredging

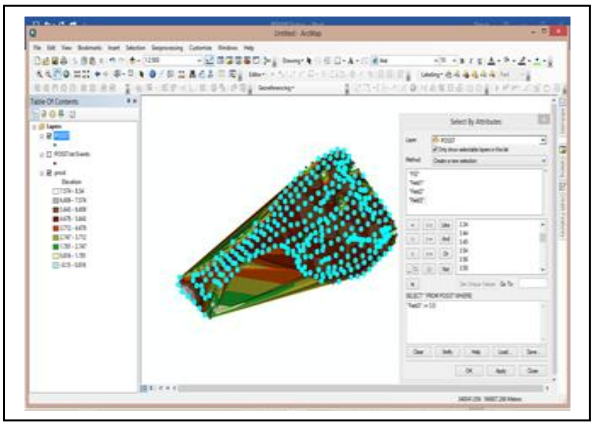

Fig. 6: Query showing depths above 3.50m after dredging

vii. Determination of Under Keel Clearance (UKC) for Vessels. Under keel clearance is a vertical distance between the deepest underwater point of the ship's hull and the water area bottom or ground [6]. The safe under keel clearance should enable the ship to maneuver within an area so that no damage to the hull occurs due to the hull impact on the ground. To determine the safety clearance for vessels navigating the channel, the recommended safe clearance UKC for port approaches, harbor and well slots in dynamic condition is 10% of the static draft.

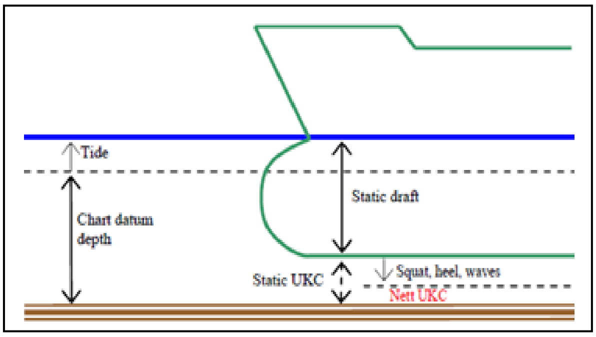

Fig. 7: Components of under Keel Clearance (source: https://www.researchgate.net/figure/Components-of-underkeel-clearance)

From the diagram above, using operating draft of the vessel as 3.20m, the minimum clearance will be:

Safety clearance required = 10% of 3.20m
= 0.32m

Therefore, nominal depth is the sum of operating draft and safety clearance.

Nominal depth = 3.20+0.32 = 3.52m

B. Results Presentation

The results sets were presented in various forms. Bathymetric chart for pre-dredging and post-dredging was produced using AutoCAD Civil3D software as shown in Figs. 8 and 9. The two charts were also presented in 3D surface using Surfer 12 software (Figs. 12 and 13). While Digital Elevation Model (DEM) to depict the surfaces was produced using ArcGIS as shown in Figs. 10 and 11.

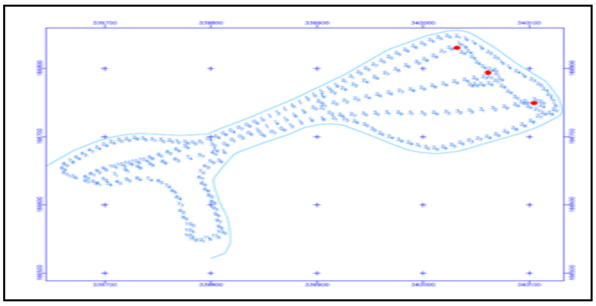

Fig. 8: Bathymetric Chart for Pre-Dredging

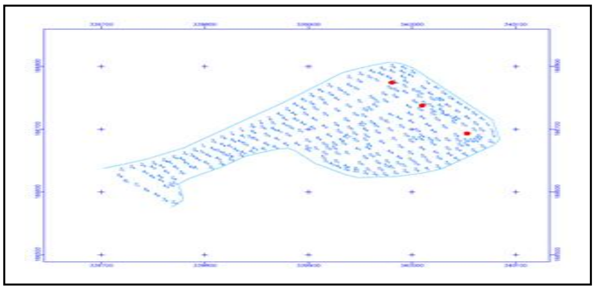

Fig. 9: Bathymetric Chart for Post-Dredging

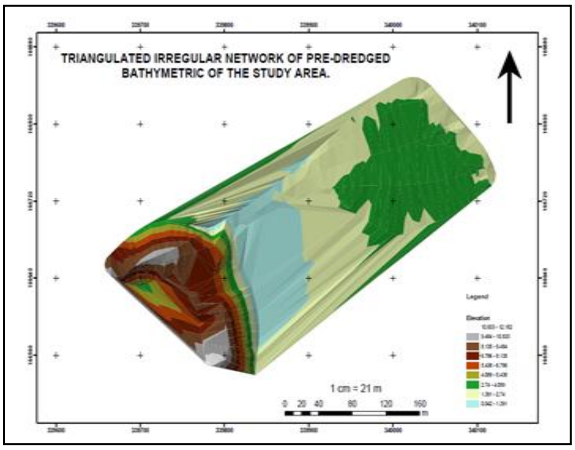

Fig. 10: Triangulated Irregular Network of Pre-Dredging

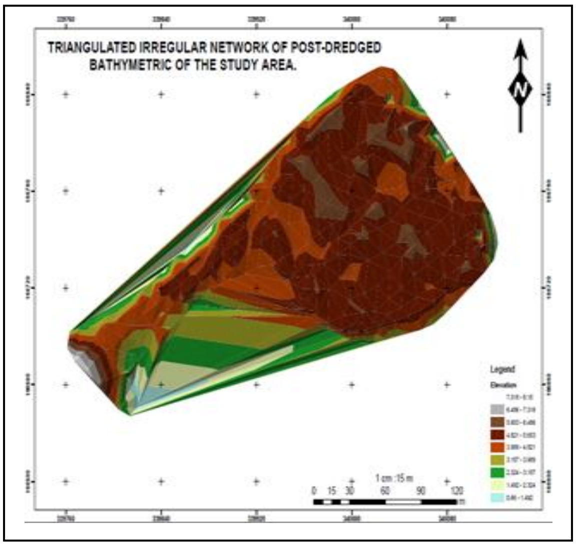

Fig. 11: Triangulated Irregular Network of Post-Dredging

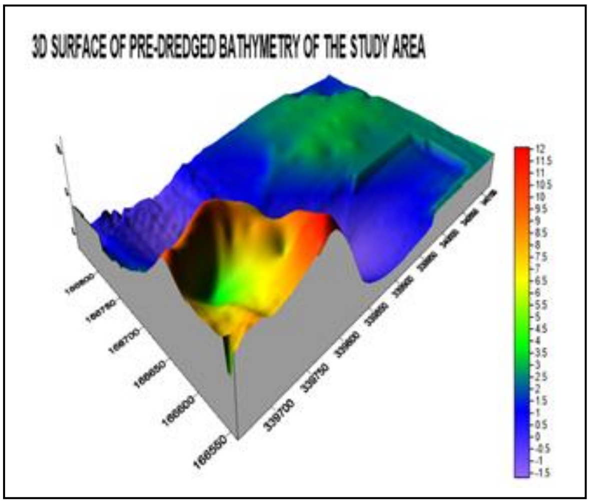

Fig. 12: 3D Surface of Pre-Dredged Bathymetry

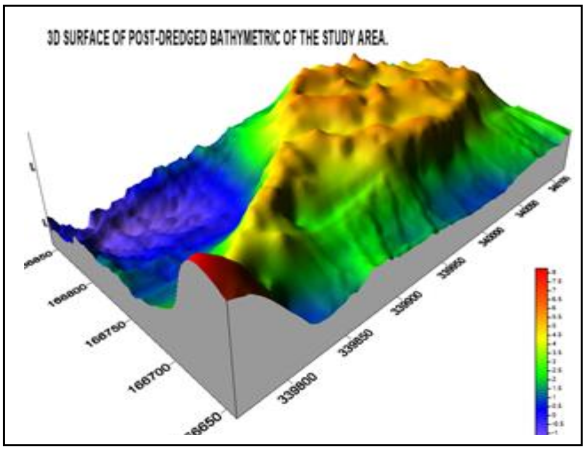

Fig. 13: 3D Surface of Post-Dredged Bathymetry

C. Discussion

Based on the analysis of the post-dredged dataset, it was observed that the area was over dredged by 1.35m when compared with the expected average dredge depth given by the client. "Reference [2] observed that one of the factors that influenced the final result from the expected result was the time lag between the period of Pre-bathymetric and post-bathymetric survey as there was continuous sedimentation of sand". It was observed that in tidal rivers, accumulation of the stockpile materials increases due to the fact that the post- bathymetric surveys were not done on time. Thus, in this study, the two main factors that caused the over dredged depth was linked to failure of accurate positioning system employed and automatic tide gauge. First, there was seemingly inefficiency in the positioning system to monitor the progress of work during the process of dredging. Secondly, real-time tide gauge that could transmit real-time tidal values was not employed during the dredging operation. Investigation further revealed that the cost of transporting the debris for disposal will increase with respect to the excess volume of the dredged materials. Dredged materials were to be properly managed and disposed of in order to prevent its adverse effects on the environment as well as on humans. This was often approved and regulated by the governments at Federal, States, and Local Governments, as well as by Corporate Bodies such as Port Authorities [1]. Distance from the study area to the approved site for disposal of the debris was far away, hence, would affect the initial cost as the additional stockpile needed to be transported. Also, personnel, time and other logistics were wasted as the dredging activity was not properly monitored. It is therefore pertinent to employ real-time input technologies which could be connected to the HYPACK software to aid in displaying dredging accuracies in real time [4]. This could display the dredging tools in 3D, design depths, profile view for current and required depths, color-coded digital terrain model (DTM), and also to integrate an alarm device to trigger-on whenever the design depth was exceeded.

IV. CONCLUSION

The primary purpose of this project was achieved in view of the fact that the required depth of water for safe navigation of vessels was attained.

Pre-dredging sounded datasets was used to compute the volume of materials to be dredged, while post-dredge sounding datasets was used to compute the dredged volume of materials by triangulated irregular network using surfer software.

The results of the pre- and post-dredging datasets presented in different formats revealed the true terrain situation of the Odidi Creek. However, though the systems employed in this study were not on real-time values, there is need to adopt these technologies so as to eliminate unwarranted wastages and to save costs. With the availability of real-time datasets, database for Under Keel Clearance Management System could be developed for the Odidi Creek to aid vessels navigating through water.

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