Assessment of Hydrographic Surveying of a River Channel for Land Reclamation and Its Implication for Cost Estimate of Dredged Material (Case Study of Bakana Community in Rivers State)

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Abstract

Hydrographic surveying is one of the tools for measuring the horizontal coordinates and elevation of the sea bed and also very relevant for the estimation or determination of the quantum of dredged materials. In most of the dredging and reclamation projects, determination of quantum of material excavated from the seabed is often based on the pre and post topographic survey of the dumped site. However, it very important to determine the quantum of excavated material from the seabed based on the pre and post sounding of the river in other to give credence to the result obtained from the topographic survey of the site. Regrettably, this aspect is often ignored in most of the dredging or reclamation projects.

This study, therefore, attempt to determine the quantum of excavated material from the seabed using geospatial data obtained from the hydrographic survey of the sea bed and the topographic survey of the site to be reclaimed. To this end, pre and post hydrographic survey of the river channel was carried out along with the pre and post topographic survey of the dumped site.

Analysis of the data obtained revealed that the volume computed from the data obtained from the hydrographic survey of the sea bed was ***187,819.037 cubic meters;*** *while the result of the quantity of excavated material obtained from the topographic survey of the site was* ***218,823.776 cubic meters.*** *This gives a difference of* ***31,004.739 cubic metres.*** *The difference obtained was attributed to the time lag between the pre sounding data acquisition and the post sounding of the seabed.*

1.1 Introduction

Dredging, according to National Oceanic and Atmospheric Administration (NOAA) is the removal of sediments and debris from the bottom of lakes, rivers, and other water bodies. Dredging is a routine necessity in water ways around the world because, sedimentation, which is the natural process of sand and silts watching downstream gradually fills channels and harbours. Dredging activities have been going on from time to time for different reasons which include clearing of waterways for ease of navigation and for de-contamination of water bodies, while occasionally; governments at state and local level often give licences to company to remove sand from the seabed for economic purposes. In road construction, sand removed from the seabed form a major component before the laying of asphalts.

Land reclamation, especially in the Niger Delta Area is inevitable because of non-availability of land for development and other purposes. Government agencies, oil companies operating in the Niger Delta Area have continue to partner with the host communities in the area of dredging for reclamation so as to make more land available to the people.

However, determination of the quantum of material excavated from the seabed is a major factor that cannot be underestimated in all dredging activities as the process and cost of dredging is often based on the quantity of the dredged materials. Studies have shown that many companies or organisations embark on sand search and pre-sounding of the seabed before the commencement of dredging activities in order to determine the availability of sand materials and the extent of deposit. Regrettably, after the pre sounding and subsequent dredging exercise, post-sounding of the seabed is often neglected after the completion of the dredging process. The result of this anomaly is that the volume of materials removed from the seabed is computed from the site where the sand material is dumped, in the case of reclamation project.
In other to provide checks and balances, it is very essential that the post-sounding of the seabed be carried out so that the volume of materials excavated from the seabed can be related or compare with the volume computed from the dump site.

This study, therefore, emphasised on the need to embark on pre and post sounding of the seabed where the sand was removed or excavated along with the pre and post topographic survey of the dumped site for the computation of the volume of sand dredged for effective costing and project monitoring and evaluation. This will serve as a check against relying totally only on the result computed from the topographic survey of the site.

1.2 Study Area

The study area is Bakana Community in Degema Local Area in Rivers State, Nigeria. Geographically the community is located within 274100.881mE and 522903.293mN and 275283.456mE and 524435.118mN on the UTM (Zone 32 N) coordinate system. Naturally this location lies within a coastal region of the Niger Delta that is characterised by mangrove forests, swampy terrains with overlaying muds and silts deposits. Bakana people speak Kalabari as their local dialect and the predominant activities of the people include farming and fishing. The community is presently occupying a land mass of 46.403hectares. The study therefore is design to make more land available for developmental purposes and other ancillary activities.

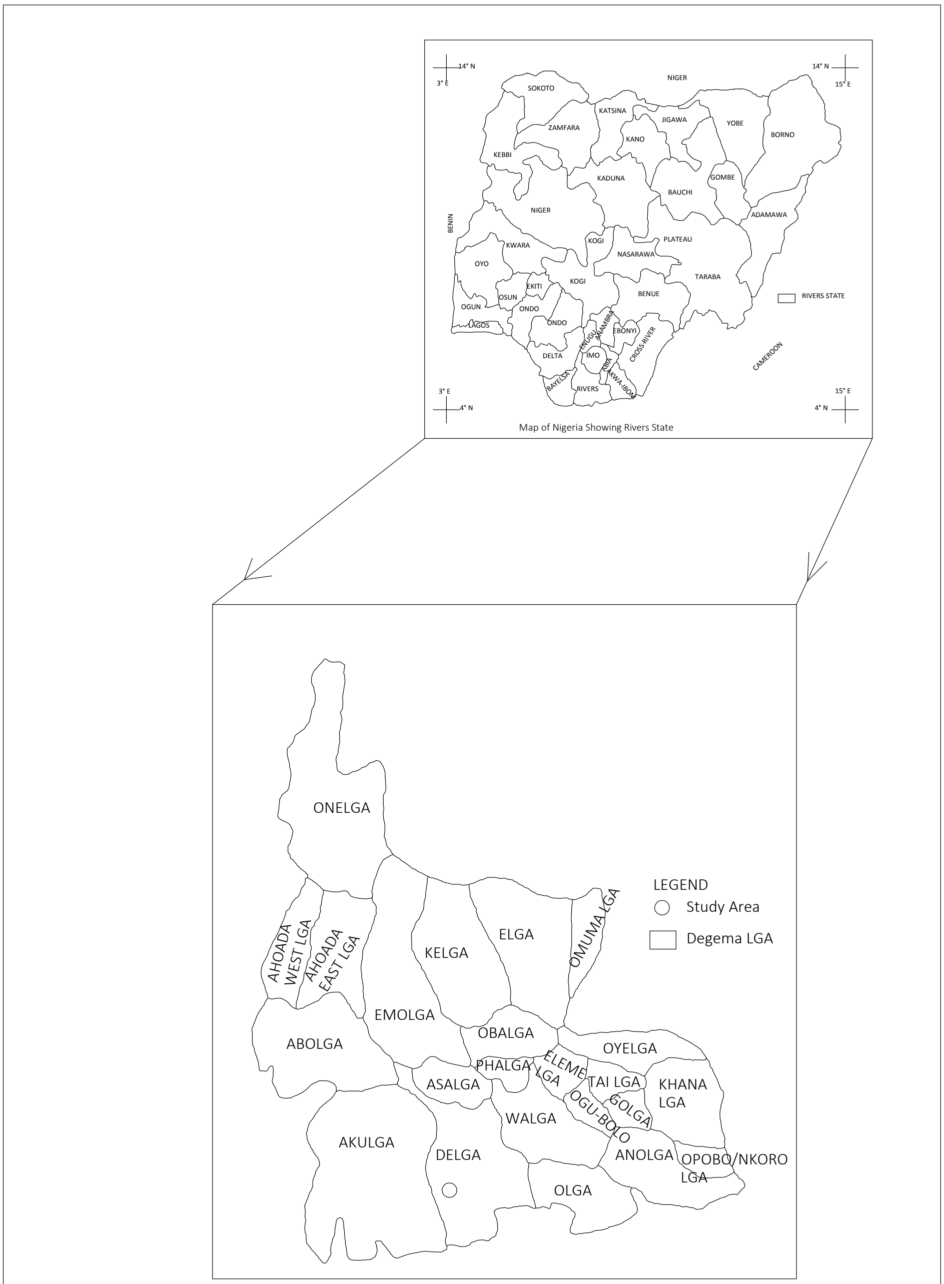

Fig. 1: Map of Rivers State Showing the Study Area

1.3 Significance of the Study

Dredging activities have been going on for several decades with little or no reference to the quantum of material that was or has to be excavated from the sea bed and also the extent of the dredging. Quantity estimation is very essential in dredging projects since it has a direct impact on the project and cost estimate. Available information revealed that computation of the volume of dredged material is based heavily on the pre and post topographic survey of the dumped site. However, it is also important to have an insight into the actual volume of material removed from the seabed based on the pre and post hydrographic survey of the river channel.This study is therefore an attempt to looks into the problems associated or may lead to the disparity in volume computation and also provide baseline information for further investigation into the determination of the quantum of dredged material.

1.4 Aim of the Study

The aim of the study is to assess the variation in the quantum of dredged material base on the hydrographic survey of the river channel and the topographic survey of the dumped site and the corresponding implication for cost evaluation.

1.5 Objectives of the Study

The objectives of the study include:

1. To determine the availability of sand material along the river channel and at economically viable distance from the project site.

2. To carry out pre and post topographic survey of the site and thepre and post hydrographic survey of the river channel.

3. To carry out a comparative analysis of the quantum of dredged material from the data obtained from the topographic survey and sounding exercise.

2.1 Seabed Mapping and Topographic Survey

Seabed mapping or Hydrographic Surveying is very essential during and after dredging operation. According to Ojinnaka (2007), Hydrographic Surveying is the survey which deals with mapping of large water bodies for the purpose of navigation, construction of harbour works, prediction of tides, and determination of mean sea level.

During dredging, Hydrographic Surveying is carried out by the Surveyor in other to determine the three dimensional coordinates which provides the basic geospatial data for the volume computation and vertical level of the seabed and therefore the quantum of materials to be excavated.

More so, Topographic Surveying is the survey carried out to depict the topography of the mountainous terrain, water bodies, wooded areas and other cultural details such as roads, railways, townships etc. (Moffitt, 1975).

A combination of Hydrographic Surveying of the seabed and topographic survey of the site to be reclaimed are essential components of dredging activities for the successful costing and project evaluation.

2.2 Area and Volume Computation: Without doubt, volume computation of the dredged material is the only way to monitor the dredging process, thereby comparing the amount of material planned to be dredged and the amount that was actually dredged. Consequently, accurate determination of the quantum of material is very essential and indispensable in every dredging activity. (Ekun et al. 2016).

A lot of dredging projects have been carried out specifically for navigational purposes where pre-dredge sounding and post-dredge sounding of the seabed were carried out. However, emphasis have been on the various techniques of determining the quantum of material dredged which in most cases depend on area of cross-sections, triangulated irregular network, and angular grids based on digital elevation models (Rabah, et al, 2015).

Ekun et al (2016) in a paper titled "Determination of Area and Volume from Dredged Geodata Set in Burutu Local Government Area of Delta State employed various techniques in the computation of the dredged materials. These include Simpson rule and trapezoidal rule for volume determination.

Also Aliyu et al (2013) carried out similar exercise in San Bartholomew River in Akukutoru Local Government Area of Rivers State. In this case, the method employed was the

Triangulated Irregular Network (TIN) because of the variation found between successive cross sections.

In these cases, the volume computation methods are reduced to that used in determining the area bounded by infinite group of data points and projecting this area over some length to obtain a primordial volume. The area can be projected vertically or horizontally as shown in the following equation.

i. The average end area technique for horizontal projection:

$V = \frac{1}{2}(A1+A2) \times L$ - - - (eqn. 1)

Where V = Volume;

A1 and A2 are the cross-section of the areas,

L = distance between A1 and A2.

ii. Bin/Grid techniques for vertical projection:

$V = H+A$ - - - - - (eqn. 2)

Where V =volume of the grid,

H= elevation of the depth above or below the reference surface;

A= cell area on the reference frame.

iii. TIN technique for vertical projection:

$V = 1/3(h_1 + h_2 + h_3) \times A_0$ - - - (eqn. 3)

Where h=height of vertices above designed (pay) prism;

A_0 = triangular area of primordial elements projected on design surface.

However the above studies emphasised on the use of different techniques of volume computation for the same project site which is at variant with the determination of volume of dredged material using data obtained from pre and post sounding along with the pre and post topographic survey of the dumped site, which is the focus of this study.

3.1 Site Visitation and Reconnaissance Survey

A site visitation and intensive reconnaissance survey was carried out. During this period, some areas were identified for exclusion from the area to be reclaimed. These included sacred forest, burial ground and some historical sites within and outside the community. Also, various sites were selected for reclamation. The sites were well distributed to cover different entries into the community.The second stage of the reconnaissance survey was the assessment of the various river bodies around the community for the subsequent sand search activities, hydrographic survey and the selection of borehole points. In all, six (6) points were selected for drilling at various distances and on both side of the selected rivers. (Fig. 3.1)

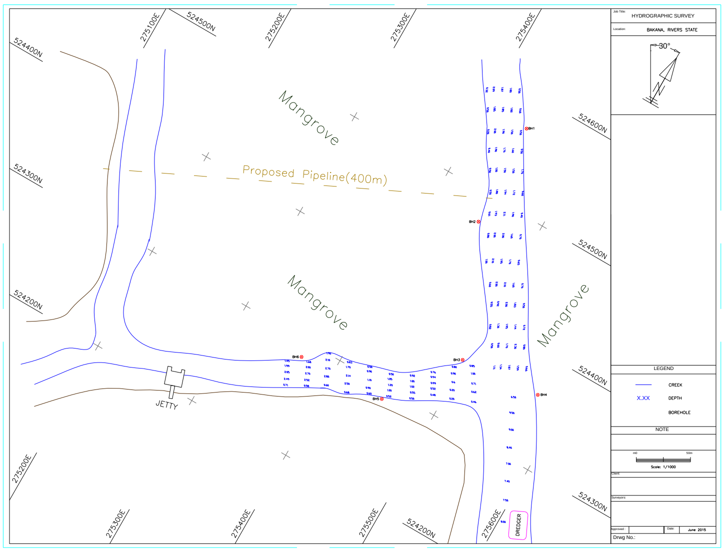

FIG. 3.1 : PRE-DREDGE HYDROGRAPHIC SURVEY OF THE SEABED

3.2 Instrument Selection and Calibration

Hydrographic surveying instruments including echo sounder and accessories, Global Positioning Systems (GPS) instrument, Speed boat were deployed for the seabed mapping, while Leica Total Station (TC 407), Reflector, and Tripod etc. were deployed for the topographic survey of the site. There instrument were properly calibrated before the commencement of field observation and measurement.In addition, an in-situ check was carried out on the three control pillars used for the survey. This was to ensure that the three control pillars were in their right position. The summary of the results obtained are as shown in table

Table 3.1: In-Situ Check Data Analysis

OBSERVED ANGLE	COMPUTED ANGLE	DIFFERENCE	OBSERVED DISTANCE	COMPUTED DISTANCE	DIFFERENCE
216^0 19’ 53”	216^0 19’ 45”	000^0 00’ 08”	176.790 m	176.783m	0.007 m

3.3 Field Observation and Measurement

Three major survey activities were carried out in the course of the study. These include the geotechnical survey along the identified river channel in search of sand availability, hydrographic survey of the river channel and topographic survey of the dumped site.

3.3.1 Geotechnics Survey

By means of a manually operated ***Rotational Drilling Rig***, six (6) boreholes were drilled by the creek at randomly selected spots. The logging was done as the strata formation varied from one layer to another. Drilling was done to a maximum depth of 15m. (See Fig. 3.4)

Table3.2: Boreholes Geospatial Data

FROMBH NO.	EASTING(m)	NORTHING(m)	DIST.(m)	TOBH NO.
1	275063.510	524571.654	65m	2
2	275091.112	524511.884	60m	3
3	275107.312	524453.570	60m	4
4	275115.116	524394.466	80m	5
5	275131.273	524315.884	70m	6
6	275185.772	524273.324		

3.3.2 Hydrographic Surveying of the River Channel

This is the determination of the depth of the river/creek bed by a technique known as ***echo sounding***. Hydrographic survey is also facilitated by carrying out a detailed survey of the water body and its adjoining man-made or natural features. In addition, topographic surveyemployed to obtain the spot heights of areas on land that are above water level, while the drilled/borehole positions were detailed in.Wherethe water level was considerably low, staff-sounding method was adopted.Sounding along the river body was carried out at 20m interval and 6metres interval across the river over a total distance of about 703.655metres.

3.3.3 Field Observation for Pre-Dredge Topographic Survey

As a necessity, the proposed site(s) to be reclaimed must be prepared and properly secured as a basis for the subsequent volume determination or computation of the dredged material.
Consequently, initial bush clearing of the sites were carried out, followed by the creation of bond-wall around the sites. This is necessary to prevent the sand being pumped from escaping back into the river.A perimetre survey of the entire sites was carried out, while existing natural and man-made features within the sites were noted in the course of the survey operation. Such details include jetties, river bodies, buildings etc.

Accurate spot heighting of the entire site was carried out at an interval of 10metres along the well-established grid lines right angle to the baseline. This procedure along with the method of radiation was employed more especially where terrain condition made measurement along the grid line impossible.The height of the instrument was determined and transferred to the tracking rod and where terrain condition imposed a limitation on this; new values were adopted and noted accordingly.

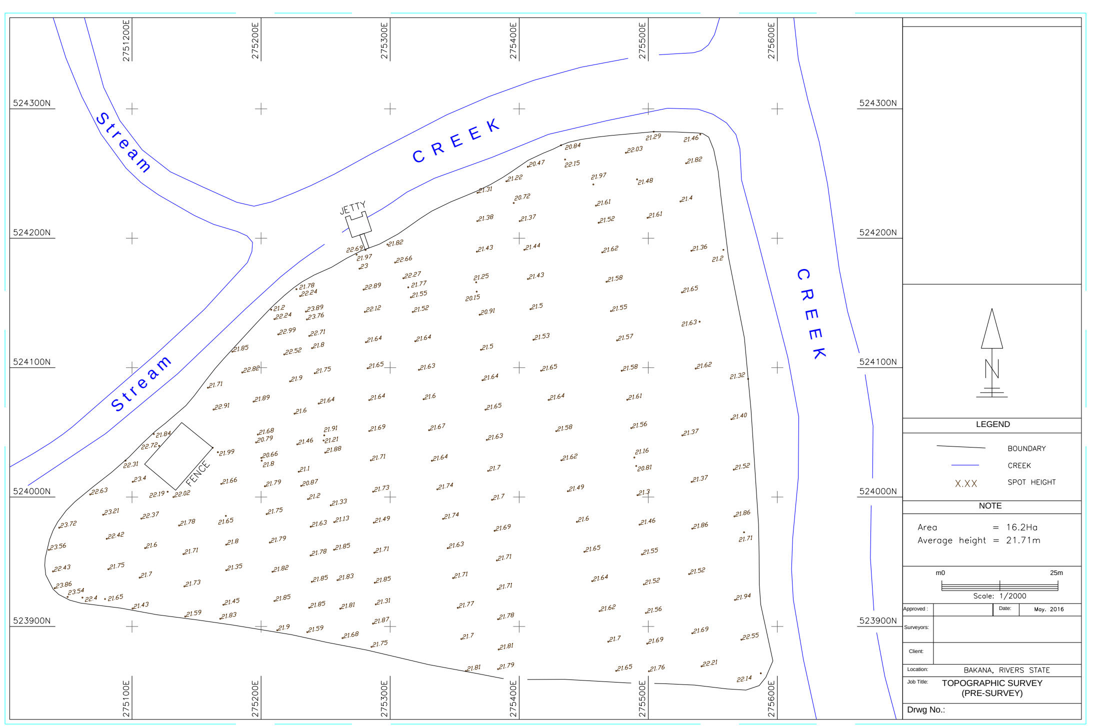

FIG. 3.1: TOPOGRAPHIC SURVEY OF THE SITE (PRE-SURVEY)

3.4 Post Topographic and Hydrographic Survey of the River

At the completion of the dredging exercise, a post topographic survey of the site was carried out in the same manner as the pre survey to determine the final spot heights of various points. However, the method of radiation was employed at every set-up of the instrument. Measurements were made randomly and not necessarily at 10metres so that more points are covered. Similarly, a post-sounding of the river was carried out at the end of the dredging exercise to determine the new topography of the sea bed and also to aid in the computation of the volume of materials removed from the river.

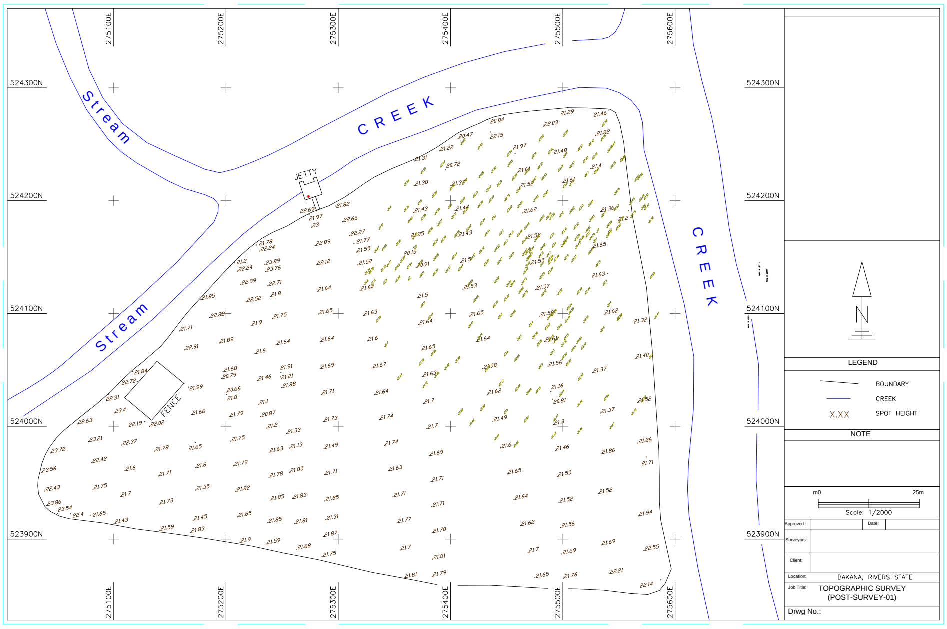

FIG. 3.3: TOPOGRAPHIC SURVEY OF THE SITE (POST-SURVEY)

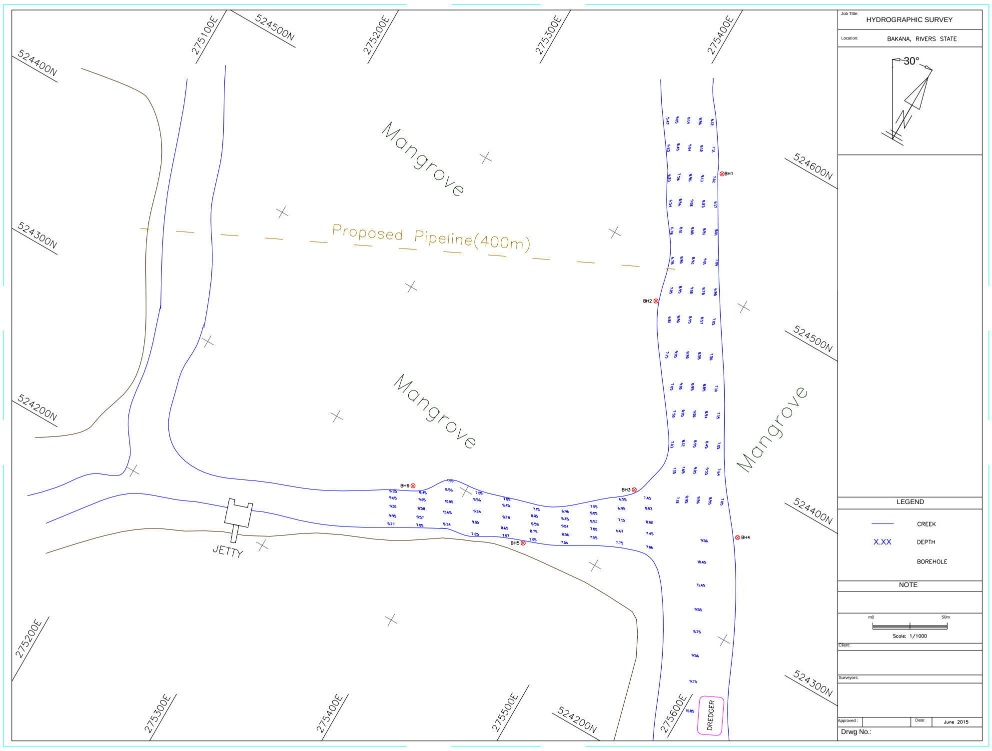

FIG. 3.4: POST-DREDGE HYDROGRAPHIC SURVEY OF THE SEABED

4.1 Data Reduction and Processing

Reduction of field data was simplified because data capture was done digitally and recorded in terms of X, Y and Z coordinates in the instrument. All the field data were downloaded from the instrument to the computer in Notepad format. This was further simplified by editing and removal of unnecessary data components.The new data was later saved as an Excel file format for easy manipulation and subsequent calculations.

4.1.1 Geotechnical and Hydrographic Data Reduction and Processing

The sand search investigation was viewed with the aim of determining the dimensions (length and breadth) of the intended *borrow pit*, the depth of water, volume of material (sand) and as well as the quality (physical characteristics).

The sounding covered a total distance of about 700m while the average width of the river was about 30m. The Sand Search was conducted within a stretch limit of about 350m.

4.1.2 Data Analysis

Data analysis entails reducing the observed field data the format that is amenable to the computer manipulation and processes and analysis of the result obtained from the sand search.The results from the drill logs, shows the various layers of deposits which make it easy for the volume of material to be calculated by simple geometry and arithmetic.

Given the dimensions of length, breadth and depth as shown below, a ***theoretical*** estimation can be made as follows:

BH NO. 1: Length = 70m; Width = 30m; Depth = 7m

Therefore, volume = 70m x 30m x 7m = **14,700m^3**

BH NO. 4: Length = 70m; Width = 30m; Depth = 2m

Volume = 70m x 30m x 2m = **4,200m^3**

BOREHOLE NO. 1

Project: Sand Search Height of water (m) = 0m
Location: Bakana Depth of Borehole = 15.0m

SOIL PROFILE		
DEPTH (m)	**DESCRIPTION**	**CODE**
0	Earth Surface	
1	Mud	
2	CREEK BED	
3		
4		
5		
6	Sand	
7	(Brownish)	
8		
9		
10		
11		
12		
13	Mud	
14		
15	End of Logging	
16		
17		
18		
19		
20		

Fig. 4.1a: Analysis of the Sand Search for Borehole 1

BOREHOLE NO. 4

Project: Sand Search — Height of water (m) = 0m

Location: Bakana — Depth of Borehole = 15.0m

SOIL PROFILE		
DEPTH (m)	**DESCRIPTION**	**CODE**
0	Earth Surface	
1	Mud	
2	← CREEK BED →	
3	Sand (Brownish)	
4		
5		
6		
7		
8		
9		
10	Clay	
11		
12		
13		
14		
15	End of Logging	
16		
17		
18		
19		
20		

Fig. 4.1b: Analysis of the Sand Search for Borehole 4

Pre-Dredged and Post-Dredged Data Analysis

Based on the result obtained after the necessary data reduction, the total area of the site along with the average height before and after sand filling were computed using a combination of the in-built module in the AutoCAD software and Excel software. The volume computation was based on the principle of simple geometry.

That is, Volume = Area of Site X Average Height.

The results obtained are as stated below:

Area of the site before dredging = 16.4211 Hectares

Average height before dredging = 21.314 Metres
Area after dredging = 13.9500 Hectares
Average height after dredging = 22.755 Metres
Height Difference 22.755m - 21.314m = 1.441 Metres
Post-dredged Volume = **218,823.776 Cubic metres**

Pre and Post Sounding Data Analysis

Area covered during sounding (Pre) = 703.655 square metres
Average depth of the river (pre-sounding) = 1.235 metres
Area covered during post sounding = 703.655 square metres
Average depth (post) = 6.83 metres
Volume = **187,819.037 cubic metres**

Results Presentation

Table 4.1 shows the results of the field observation and measurements.

Table 4.1: Results Analysis

VOLUME COMPUTUED FROM THE SITE	VOLUME EXCAVATED FROM THE SEABED	DIFFEERENCE
218,823.776 Cubic metres	**187,819.037 Cubic metres**	**31,004.739 Cubic metres**

Discussion

From the foregoing tables, it is very clear that the volume computed based on the data obtained from the pre and post topographic survey slightly different from the results of the pre and post sounding exercise. The variation in the results could be attributed to several factors. These include:

1. **Time lag:** One important consideration is the time lag between the period of Pre-sounding and post-sounding and also between the times the pre-topographic survey and the post topographic survey were carried out. In the case of a tidal river, sand deposit is a continuous exercise or occurrence and if the post sounding was not done on time, the result will be badly influenced as can be seen in the result analysis table.

2. **Site Condition:** If the area to be reclaimed is muddy as in the case of mangrove area, sufficient time must be allowed for the site to stabilize or else some of the sand may be buried in the mud.

3. **Securing the bond wall**: For the dredged site, the bond wall must be sufficiently secured and monitored especially during the rainy season the collapse of the bond wall may lead to loss of material as some of the sand might find their way back into the river.

Recommendation

To ensure good service delivery and to maintain harmonious relationship among the various parties involved in dredging exercise, the following recommendations are hereby proposed.

i. The use of settlement plates must be emphasized before the commencement of dredging exercise, while little consideration must also be given to settlement factor.

ii. The time lag between pre dredging and post dredging exercise must be kept at minimum. Also between pre sounding and post sounding.

iii. Bond wall must be properly formed and protected from leakage so that the material dredged may not find their way back into the river.

iv. After bush clearing, the site must be given sufficient time to settle or stabilized especially if the area is swampy or muddy.

Conclusion

As earlier mentioned, volume determination is a critical factor in any dredging project as in most cases, the cost of the project is to a large extent depend on this singular factor. As such, the need to compute the volume of sand using different approaches cannot be under-estimated. Apart from providing checks and balances, it also gives credence to the technique of data acquisition and processing adopted in the course of the exercise.

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