Estimation of Volume of Sand Using Vertical Electrical Resistivity Imaging: A Case Study in Tombia, Yenagoa, Bayelsa State, Nigeria

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***Abstract*—** The electrical resistivity survey using the Schlumberger electrode configuration was conducted in parts of the Yenagoa local government area, Bayelsa State, Nigeria. The survey was aimed at estimating the volume of sand in a piece of land measuring 60 m by 30 m known as the study area. Nine 1D Vertical Electrical Sounding Points were acquired in the study area. ABEM Terrameter SAS 1000 was the instrument used with IPI2win and ZONDIP software for processing. The result obtained reveals that the area contains three layers within the depth of investigation. Lateritic sand with resistivity ranging from 42 Ωm to 1029 Ωm and thickness varying from 1.3 m to 3.0 m made up the first layer. The second layer is sand with resistivity values ranging from 476 Ωm to 3089 Ωm with thickness varying from 10.8 m to 23.2 m. The third layer is sandy clay with resistivity values ranging from 24 to 1024 Ωm. The survey shows that a considerable quantity of sand can be dredged from the area. The estimated volume of sand within the area of study is estimated to be approximately 550,767.60 tonnes. The result shows that sand deposits can be mined economically for domestic and building purposes and are also suitable for other engineering and construction work due to their inherent water permeability and storage ability.

***Keywords*—** VES, 1D Resistivity, Volume of Sand, Tombia, Yenagoa.

1. INTRODUCTION

Geo-electric methods are widely used in engineering research such as estimation of the volume of dredgeable sand, Hydrolysis, site investigation, etc. Sand is a substance that consists of very small grains of rock [9]. It occurs naturally as granular materials composed of finely divided rock and mineral particles. It is pertinent to note that sand deposits often serve as good groundwater and hydrocarbon reservoirs [10]. Sand is an important ingredient in the construction of major civil engineering works such as airports, bridges, roads, factories, etc. Therefore, the importance of sand cannot be overemphasized [11]. Sand mining is done to extract sand mainly from an open pit, beaches, inland dunes, and dredged from ocean beds and rivers beds [17]. This brings to bear the importance of sand exploration. The most common type of sand, found in non-tropical coast and continental areas in the silica which usually takes the form of quartz [8]. This type of sand is extremely resistant to weathering due to its chemical composition (SiO2), which makes the grain very hard [7]. It is used in manufacturing as an abrasive used to make concrete. Also, sand has industrial use as a raw material in glassmaking. Due to its increasing effective demands, sand is over-extracted at different depths varying from one to twenty meters, from different pits, streams, rivers, and basins [12]. As sand is extracted rapidly, groundwater evaporates fast, reducing groundwater recharge, increasing the failure of irrigation, wells, and the associated predicament in farming [18]. Sand mining is a direct cause of erosion which destroys farmland and local wildlife. Building sand is pit sand that can only be used for building or filling. It has no chemical associated with it. It can also be used as a filler for concrete [12].

The concept of electrical resistivity imaging techniques is arguably the most useful and successful techniques in hydrological, environmental investigation and the exploration of shallow alluvial aquifer all over the world [16]. This technique has a long history of success and to a large extent, dependable in the quest for subsurface investigation. Electrical methods of prospecting are more diversified compared to other known methods of exploration in geophysics [15]. Some of these electrical methods include Spontaneous (or Self) Potential, Electromagnetic Techniques, Telluric current and Magnetotelluric method, induced polarization method, and resistivity method [14].

As population increases in Bayelsa state, Niger Delta, the need to reclaim swampy areas for infrastructural development becomes necessary. The increasing demand for sand for domestic and industrial purposes makes in Niger Delta makes it necessary that detailed geological information of any site mapped for dredging should be carried out before dredging. This study is aimed at estimating the volume of sand in a borrow pit in Tombia, Yenagoa, Bayelsa State that can be used for filling and other engineering work. This study was carried out using the electrical resistivity method.

2. MATERIALS AND METHOD

The Study Area

The area under investigation is Tombia which is located in Yenagoa, the capital city of Bayelsa State, Nigeria, which covers an area of 170km with a good road network that links to parts of the study area. This area lies within longitudes 0060 14'30" and 0060 21'30" East of the prime meridian and Latitudes 040 55'0" and 050 0'30" North of the equator within the coastal area of the recent Niger Delta. (Figure. 1).

The Niger Delta lies in the humid tropic region within the equatorial type climate belt. There are two (2) major seasons that defined this region. They are the dry and wet seasons. The wet season is characterized by high rainfall and a short duration of the dry season is observed around mid-August. The average rainfall here exceeds 300mm [3]. The dry season lasts from November to early March and the rainy season begins from late March to October. The temperature ranges between 200C and 300 and relative humidity of about 1524cm 1824cm [3]. This region supports luxuriant fast-growing swamp forests which include a palm tree, mangrove trees, and grasses. The organic debris which originates in these swamps, an important thing is that they assist in the sedimentation of this region climate vegetation root, types of trees, shrubs, etc occupation of the people, etc. [4].

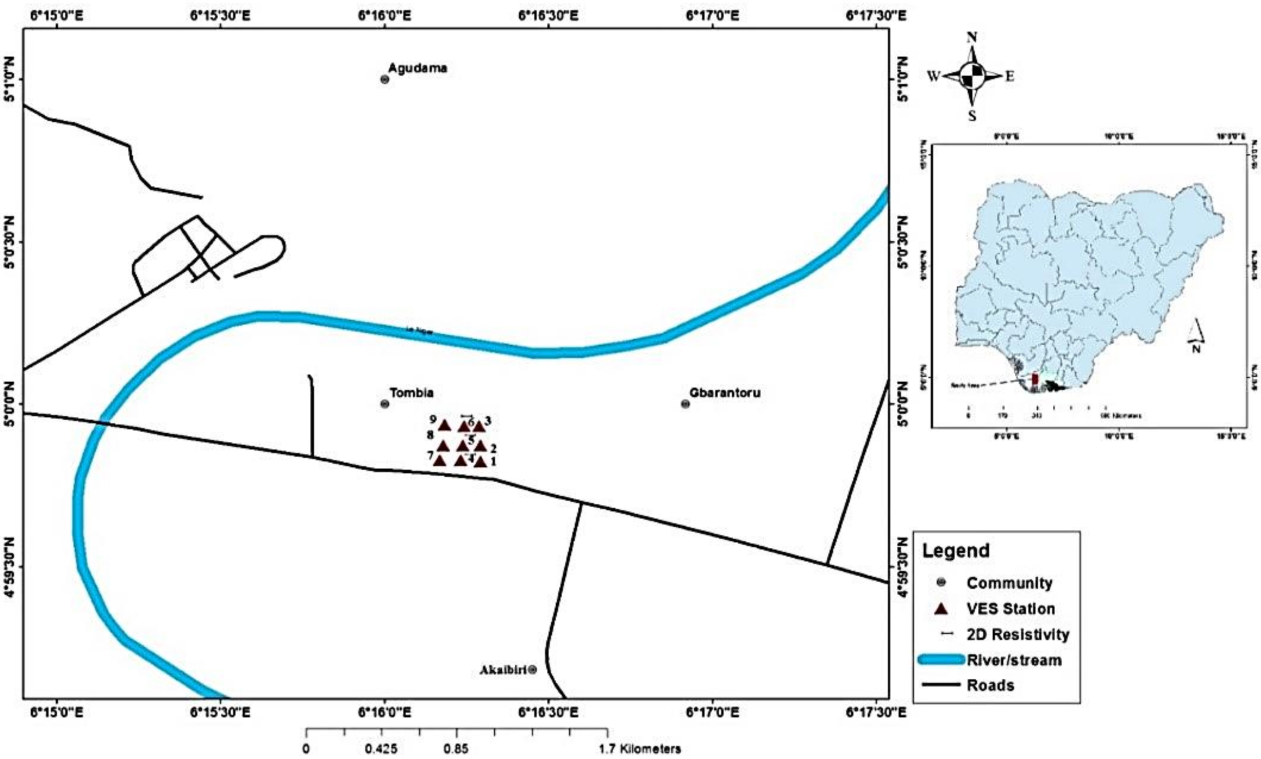

Figure 1: Map of the Study area showing VES points

The region is characterized by low lands with the topography of the area is low-lying with a maximum of 40m elevation. The areas are drained mainly by the nature of creeks example Epie creeks, Kolu creek and tend to slope gently into River Nun which in turn drains into the Atlantic Ocean. Due to the poor drainage of the area, it tends to flood during the rainy season [19].

Resistivity Theory

The purpose of an electrical survey is to ascertain the condition and nature of the subsurface resistivity distribution by effecting measurements on the surface using the appropriate equipment for such purpose. From these measurements, the researcher will be able to ascertain the true resistivity of the subsurface geological sequence.

Electrical resistivity survey has shown to be the most successful as applied by several researchers in the detection of pollution, obtaining information about the sub-strata of the earth and also used for many decades in mining, geotechnical and hydro-geological investigations [2]. With today's technological improvement and advancement, the electrical resistivity techniques in recent times have been employed for environmental surveys, which has further expanded the scope of the Electrical Resistivity method [5]. Variations in electrical resistivity mainly indicate a change in the composition, layer thickness, or contamination level.

In the electrical resistivity method, electric currents are injected into the subsurface via two current electrodes, normally marked C1 and C2, and measuring the resulting voltage difference at another two potential electrodes, labeled P1 and P2 [6]. Figure 2, gives the common array used in resistivity surveys together with the geometric factors of each of the arrays. The Terrameter gives the resistance (R) value of the subsurface.

$$R = \frac{V}{I} \qquad (1)$$

In practice, the apparent resistivity value is calculated using the formula

$$\rho_a \; \alpha \; \frac{V}{I} \qquad (2)$$

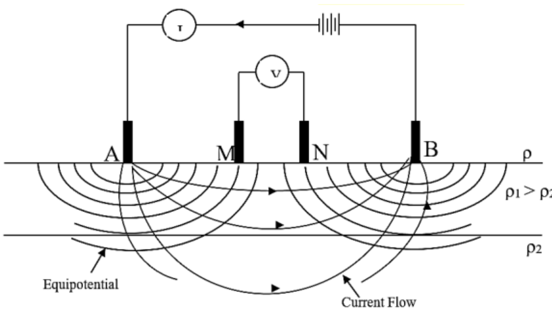

Fig. 2: Schlumberger Array

However, it is interesting to note that, the apparent resistivity value(s) calculated is not the true resistivity of the subsurface [6]. To determine the true resistivity, it is necessary to use a computer program for the inversion of the apparent resistivity values. The relationship that exists between the apparent resistivity and that of the true resistivity is complex. The geophysical survey was carried out at a borrow pit in Tombia to estimate the volume of sand in the area. 1D electrical resistivity soundings were carried out using Schlumberger

$$\rho_a = k\frac{V}{I} \qquad (3)$$

Where ρ_a is apparent resistivity and K represents the geometric factor, which is a function of the arrangement of the four electrodes expressed as

$$K = \frac{\pi a^2}{b}\left(1 - \frac{b^2}{4a^2}\right) \qquad (4)$$

Where K is the Geometric Factor, a is half the distance between the current electrode and b is the distance between the potential electrode.

Substituting Equation 1 into 3 we have

$$\rho_a = KR \qquad (5)$$

configuration with an electrode spacing of AB/2 = 80m that is, the largest current electrode spacing AB used was 160m. Nine VES profile was taken to ascertain the volume of sand deposits in a 60m by 30 m pieces of land in the area (Figure 3). The Abem Terrameter SAS 1000 with an inbuilt booster for greater current injection into the subsurface was used for exploring the field [20]. The apparent resistivity values were calculated using the formula as expressed in equation 5.

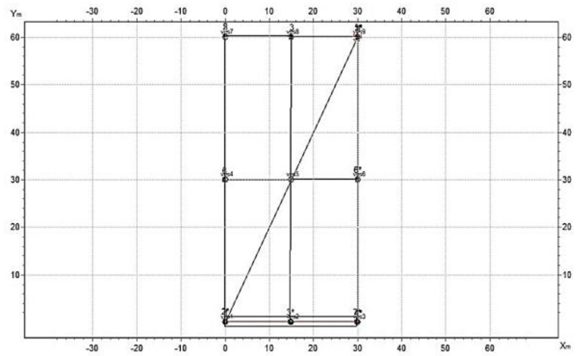

Figure 3: Survey plot measuring 60 m by 30 m.

The software used for analyzing the data is ZONDIP. The goal of the ZONDIP program is to determine the resistivity of a rectangular block and create a pseudo-section that corresponds to the actual measurement. ZONDIP also can create pseudo-partitions as desire

3 RESULT AND DISCUSSION

A geophysical survey was carried out at a borrow pit in Tombia in other to study and estimate the volume of sand to ascertain whether it could be dredge commercially. Nine geo-electrical profile was acquired. Vertical electrical sounding models made at VES stations were used to obtain geo-electric sections of different profiles in a rectangle shape of 60m by 30m. The result of the Nine (9) vertical electrical soundings (VES) conducted are presented in Table 1. The area shows that three geological layers are present at each

VES profile in the study area. The result shows that the topsoil is lateritic with resistivity ranging from 42 Ωm to 1029 Ωm with thickness varying from 1.3 m to 3.0 m. The second layer is sand with resistivity ranging from 476 Ωm to 3089 Ωm with a thickness varying from 10.8 m to 23.2 m. The third layer is sandy clay with resistivity values ranges from 24 to 1024 Ωm. The thickness of the third layer cannot be determined as the current electrodes terminated in this layer in most of the profiles. In essence, the "K" resistivity curve type was predominantly obtained in the study areas (Figure 4a-i). The resistivity, thickness, and depth of each profile are summarized in Table 1. The survey result shows that the first and second layer consists mostly of sand indicating a considerable quantity of sand which can be dredged from the area of study and it has an average total depth of 19.1 m.

Table 1: Summary of VES model results and their corresponding thicknesses and depth for Tombia

	Layer 1 (Top soil)			**Layer 2 (Sand)**			**Layer 3 (clayey sand)**			**Layer 4 (water Saturated Sand)**			
VES	**ρ**	**h**	**d**	**ρ**	**h**	**d**	**P**	**h**	**d**	**ρ**	**h**	**d**	**RMS Error**
No	*(Ωm)*	*(m)*	*(m)*	*(Ωm)*	*(m)*	*(m)*	*(Ωm)*	*(m)*	*(m)*	*(Ωm)*	*(m)*	*(m)*	*(%)*
VES 1	45	2.2	2.2	590	17.1	19.3	198	-	-	-	-	-	2.035
VES 2	102	2.0	2.0	1206	17.2	19.2	445	-	-	-	-	-	1.348
VES 3	95	1.8	1.8	897	15.5	17.3	457	-	-	-	-	-	1.552
VES 4	42	2.1	2.1	583	16.1	18.2	92	4.3	22.5	1.224	-	-	1.856
VES 5	83	3.0	3.0	1420	23.2	26.2	361	-	-	-	-	-	1.910
VES 6	97	2.2	2.2	1245	17.9	20.1	352	-	-	-	-	-	1.327
VES 7	57	2.0	2.0	476	16.0	18.0	24	-	-	-	-	-	1.232
VES 8	1029	1.3	1.3	3089	10.8	12.1	1024	6.0	18.1	203	-	-	1.366
VES 9	399	2.5	2.5	1763	18.9	21.4	647	-	-	-	-	-	1.327

Where ρ is bulk resistivity, h is thickness and d is the depth.

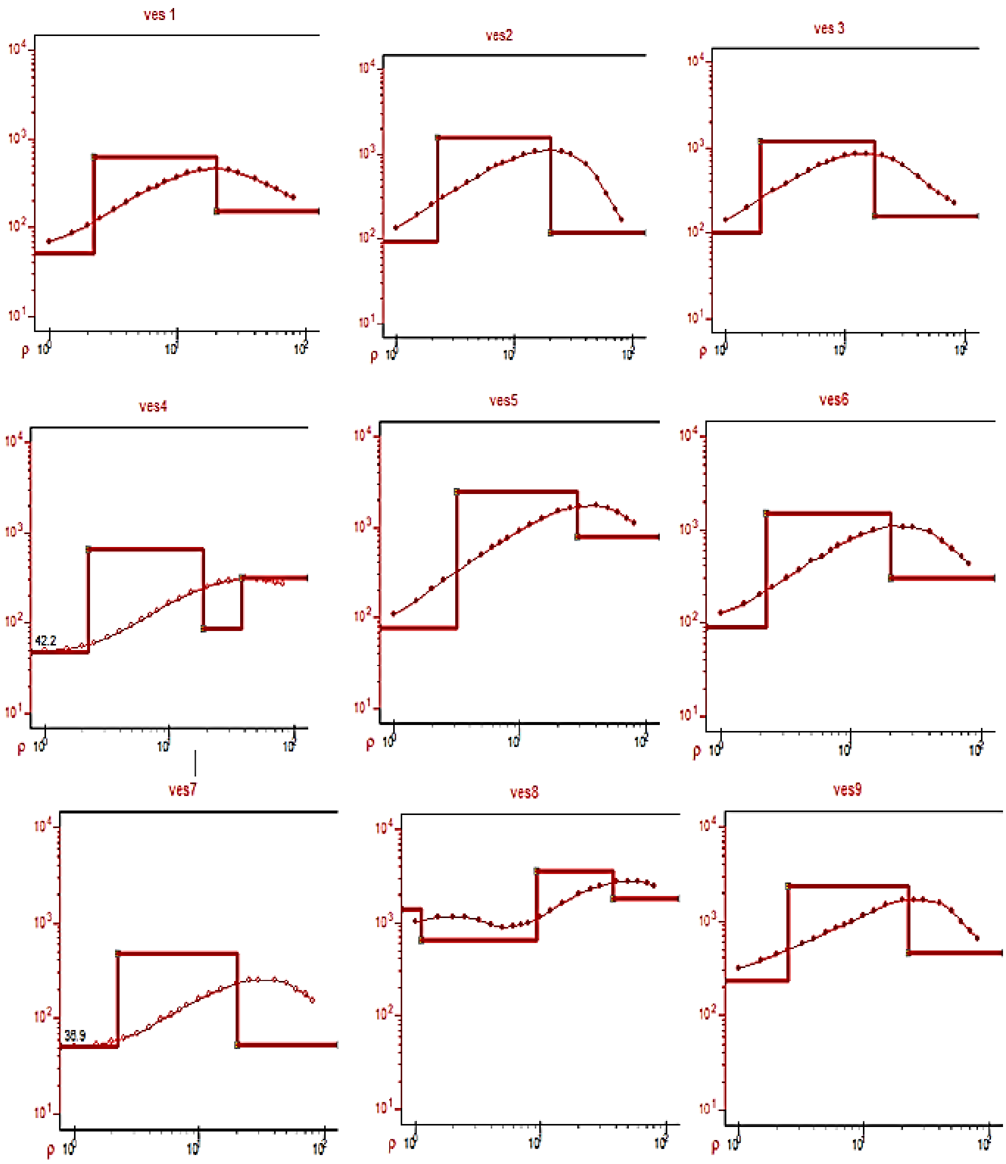

Figure 4: Resistivity sounding curves at Yenagoa – Tombia.

Calculation of Sand Quantification

The shape of the study area is a rectangle.
The Area of a rectangle = Length x Width.
The Depth of the layer is taken as the total thickness.
The volume of the rectangle = Area x thickness
The mass of sand occupying the area = Density x volume
Average depth or thickness of the nine VES =

$$\frac{19.3 + 19.2 + 17.3 + 18.2 + 26.3 + 20.1 + 18.0 + 12.1 + 21.4}{9} = \frac{171.8}{9} = 19.1\text{m}$$

Therefore, the volume of the rectangle = Area x thickness
= 1800 x 19.1 = 34,380 m^3
The Mass of sand occupying the study area = Density x volume
Density of sand = 1.602gcm^{-3}
Density = 1.602 x 1000 = 1602kgm^{-3}

Volume of sand estimation from VES values for Tombia

Area = Length x Width
Where L=60m, W=30m
Therefore, the Area of the study area = 60 x 30 = Area = 1800m

Mass = 1602 x 34,380 kg
= 55,076,760 kg
= 550,767.60 tonnes
Hence the quantity of sand present in the mapped area is 550,767.60 tonnes.

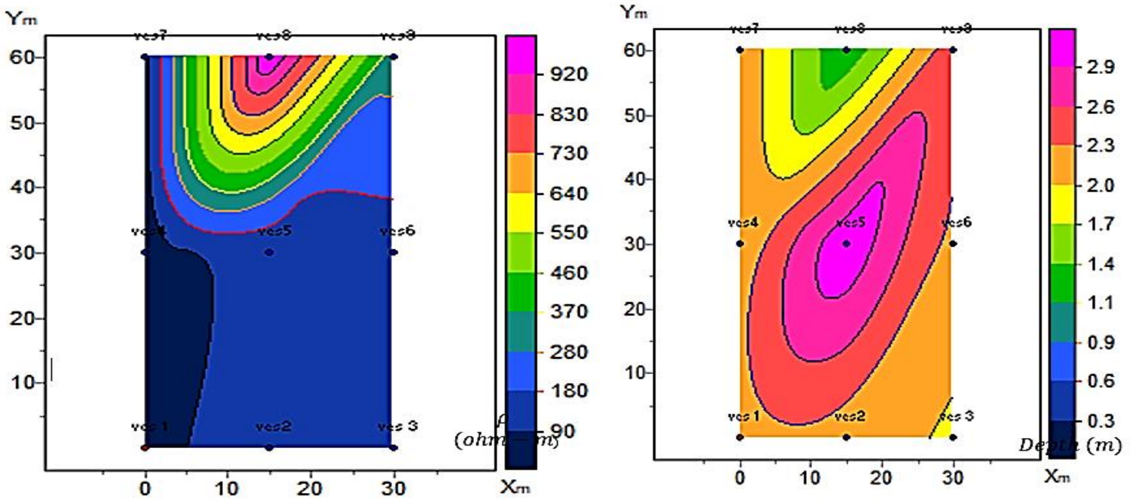

Figure 5: (a) Apparent resistivity distribution in a rectangular block for layer 1. (b) Layer thickness.

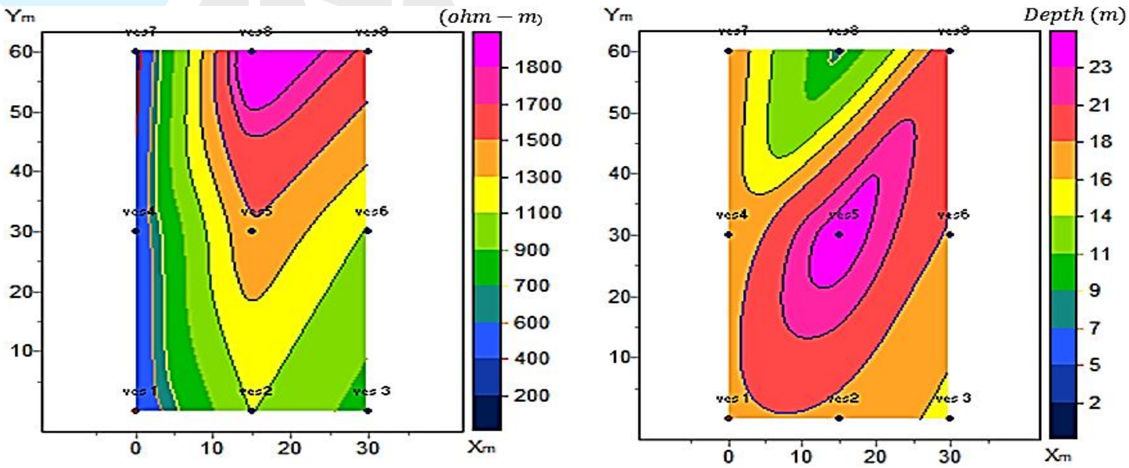

Figure 6: (a) Apparent resistivity distribution in a rectangular block for layer 2. (b) Layer thickness.

4. CONCLUSION

A geophysical survey has been conducted in Tombia to estimate the volume of sand. Nine VES were carried out with resistivity curves obtained showing three geoelectric layers. The resistivity distribution for the rectangular plane of the study area as well as the thickness for layers 1 and 2 is shown in figure 5a-b and figure 6a-b respectively. The survey shows that the first and the second layer is sand indicating that a considerable quantity of sand can be dredged in the area. The estimated volume of sand within the area of study is approximately 550,767.60 tonnes. This result shows that sand deposits can be dredged economically for domestic and construction purposes. Its water quality is could be good due to the large content of fine sand in its aquifer. Further investigation is highly recommended to study construction sand deposits beyond the surveyed areas.

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