Geoelectrical and Drill Hole Techniques for Ground Water Investigation at Projects Development Institute (Proda) Permanent Site, Emene Enugu, South-Eastern Nigeria

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Abstract: ***Geoelectrical Soundings and exploratory Drill holes have been carried out at Projects Development Institute (PRODA) permanent site Emene, Enugu. Schlumberger electrode configuration was employed in the spacing of the electrodes. The success of geophysical methods depends essentially on the presence of significant contrasts in the earth's physical properties. In this study area, good contrasts in electrical conductivity were expected between shale and sandy layers and between dry and water-bearing layers. A reliable interpretation of Vertical Electric Soundings (VES) and Drill Hole data was achieved. Three borehole locations 3, 4 and 5 were recommended which have sand thickness of more than 7meters and water-bearing sand of more than 3meters.***

Keywords: Electrical Sounding, Resistivity, borehole, Schlumberger array, water-bearing, drill hole, Enugu

1. Introduction

Projects Development Institute (PRODA), Emene Enugu is a research centre established by the Federal Government of Nigeria. The mandate of PRODA upon adoption by the Federal Government of Nigeria may be summarized as involving research and development of machinery and equipment, particularly pertaining to industrial consumer appliances and devices, including engineering design and fabrication of prototypes. PRODA also researches in materials science and process technology, including metallurgy and foundry work. PRODA therefore requires large volume of water daily to maintain these research and other activities. It became necessary to find permanent solution to water requirements of the Institute, hence this investigation. A number of techniques are available for investigating subsurface geology. Electrical resistivity is commonly used in engineering site investigation to determine depth to bedrock, the nature of the superficial deposit and structural mapping. Electrical resistivity method also is essentially employed for groundwater investigation and for determination of structural trends (Olorunfemi and Okhme, 1992). Thicknesses and apparent resistivity of various layers are obtained. This work is intended to apply combined geophysical, geological and Drill Hole methods involving Vertical Electrical Soundings (VES) to determine the ground water potential and locate sites for construction of prolific water boreholes.

The study area lies approximately within Latitudes 6^0 27'05N - 6^0 27'35N and Longitudes 07^0 .34'04 - 7^0 34'55E - 07^0 35' 20E, (part of Nkalagu NW sheet), Fig 1.

2. Geology

The area surveyed lies within Nkporo Group but is divided into two Geologic Formations with the Ekulu River acting as the boundary, Figure 1.The Enugu shale lies in the west while the Awgu/Ndeabor Shale Formation lies in east. The Enugu Shale underlies the plains of the Enugu Escarpment. It consists of soft, greyish-blue or dark grey mudstone and shale (Egboka, 1985). The age is Lower Santonian. The Agwu/Ndeaboh Shale Formation overlies the Ezeaku shale conformably. The lithology is a bluish-grey, fine grained yellow calcareous shaly limestone. The thickness is about 900m.The age ranges from Turonian to Santonian.

Figure 1: Location map of the Study area (PRODA) and Drill-Hole/VES Sounding Points

Hydrogeology

The occurrence of ground water is essentially a function of geologic setting (Offodile, 2002). Ideally, shales as geology formation are not good for groundwater development except under special conditions. That is, if they are badly weathered, fractured or contain sand/sandstone lenses. However, Alluvium that forms and underlies stream channels, as well as forming adjacent flood plains is known to provide good aquifers for groundwater development. Hence, the idea is to drill boreholes at the alluvial sands near the stream channel. The stream supplies water by influent seepage to the groundwater storage. The sands are only loosely consolidated. In Enugu area, the wet season rainfall averages 71.4'' a high recharge potential is assumed and the flat topography and vegetation assure limited runoff.

Field Geophysical Investigation:

Resistivity soundings are usually carried out using a Schlumberger array. With this configuration a current 'J' is fed into the ground using two current electrodes A and B placed at a distance 'L' apart. At the centre of the two electrodes, the voltage V is measured between two potential electrodes M and N placed at a distance 'B' apart. Current and potential electrodes were made of non-polarisable copper electrodes. If the resistivity of the soil surrounding the current electrodes does not vary appreciably from measurement to measurement, the apparent resistivity and thickness of the various electrical layers can be obtained. The ABEM terrameter300 was used for taking the readings. It has a high resolution and gives a direct readout of the apparent resistivity of the ground in ohms and milliohms digitally. This is converted to apparent resistivity value (Sa) by using the relation:

$$Sa = \pi \left(\frac{a2}{b} -- \frac{b}{4} \right) R$$

Where

a = half the distance between the current electrodes ($\frac{AB}{2}$)

b = distance between potential electrodes (MN)

R = Resistance of the ground

Sa = Apparent resistivity

Π = constant

The observed field data were used to produce depth soundings curves. Curves are made of $\frac{AB}{2}$ (half the distance between current electrodes) and Sa (Apparent resistivity).These methods provided the layer thicknesses and resistivity which served as input data for computer modeling (Henker, 1985), hence a final step in the interpretation. Site localities were recorded and geo-referenced using a standard Garmin e-Trex global positioning system (GPS) instrument. The electrical and Drill Hole coordinates are presented in Table 1. Thicknesses and apparent resistivity values for the different geoelectric sections are then interpreted from the curves by appropriate software package and partial curve-matching techniques. The curves are given in figures 3, 5, 7 and 9.

Drill Hole Investigation

Four exploratory Drill Holes were drilled at locations near the sounding points using the Minute Man Drilling machine. The Drill Holes were geologically logged as shown In Figures 2, 4, 6 and 8. The logs were correlated with the geophysical results. A good correlation was obtained.

Table 1: Electrical and Drill hole locations

Drill hole (DH) points/ Electrical Sound points	Latitudes N (Degrees)	Longitudes E (Degrees)
DH-1	06 27 346	07 34 996
DH-2	06 27 428	07 35 120
DH-3	06 27 342	07 35 155
DH-4	06 27 228	07 35 200

Table 2: Vertical Electrical Sounding (VES—I)

Geoelectric layer	Apparent Resistivity ohm-m	Thickness meters	Remarks
Layer 1	2700.0	0.0 - 1.5	Top sandy soil
Layer 2	24300.0	1.5 - 2.7	Sand
Layer 3	1278.9	2.7 – 5.7	Greyish mud
Layer 4	63.3	5.7- 13.5	Sandy clay
Layer 5	1346.3	---	Shale

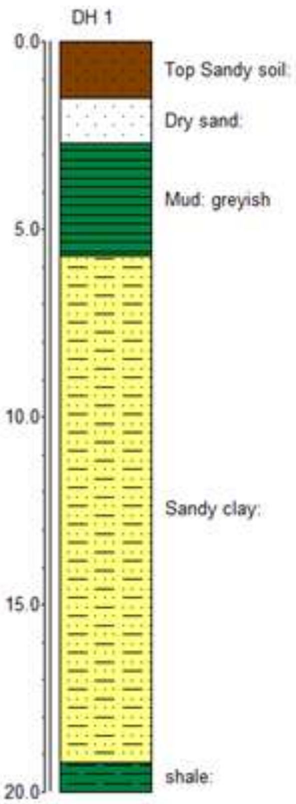

Figure 2: Lithologic Log of Drill Hole 1

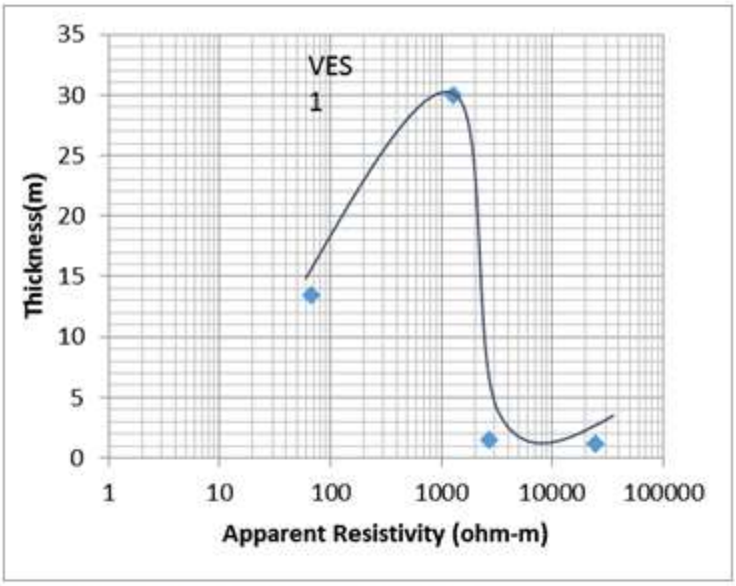

Figure 3: Graphic Plot of VES – 1 Soundings

Table 3: Vertical Electrical Sounding (VES–2)

Geoelectric Layer	Apparent Resistivity ohm-m	Thickness meters	Remarks
Layer 1	1000.0	0.0 - 1.5	Top sandy soil
Layer 2	9000.0	1.5 – 3.3	Very dry sand
Layer 3	3000.0	3.3 – 11.6	Dry sand
Layer 4	157.9	---	Loose sand

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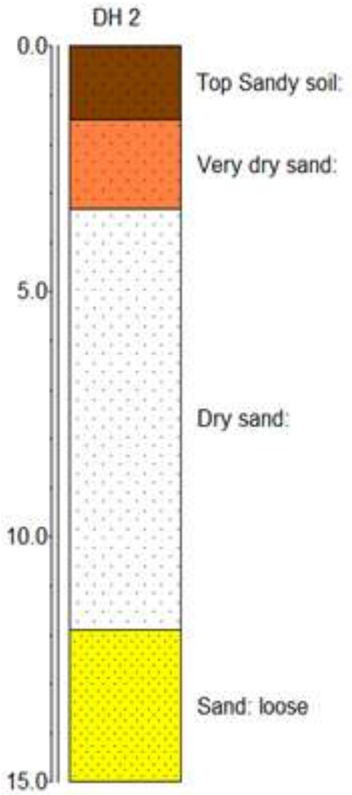

Figure 4: Lithologic Log of Drill Hole 2

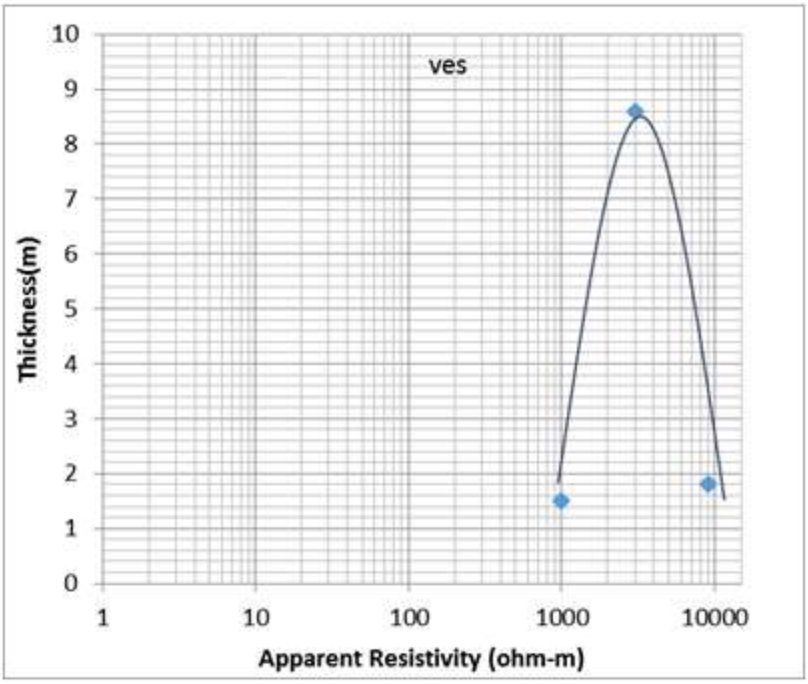

Figure 5: Graphic Plots of VES – 2 Soundings

Table 4: Vertical Electrical Sounding (VES -3)

Geoelectric Layer	Apparent Resistivity ohm-m	Thickness meters	Remarks
Layer 1	4100.0	0.0 - 1.5	Top sandy soil
Layer 2	23233.3	1.5 - 3.3	Dry sand
Layer 3	9957.1	3.3 - 5.8	Mud
Layer 4	29871.4	5.8 - 14.3	Dry sand/or shale
Layer 5	1572.2	--	Water-bearing sand

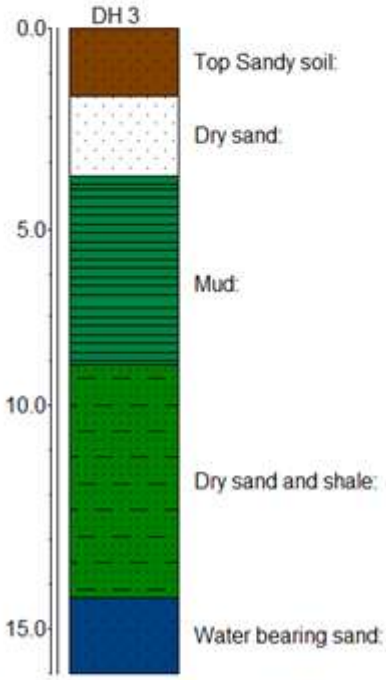

Figure 6: Lithologic Log of Drill Hole 3

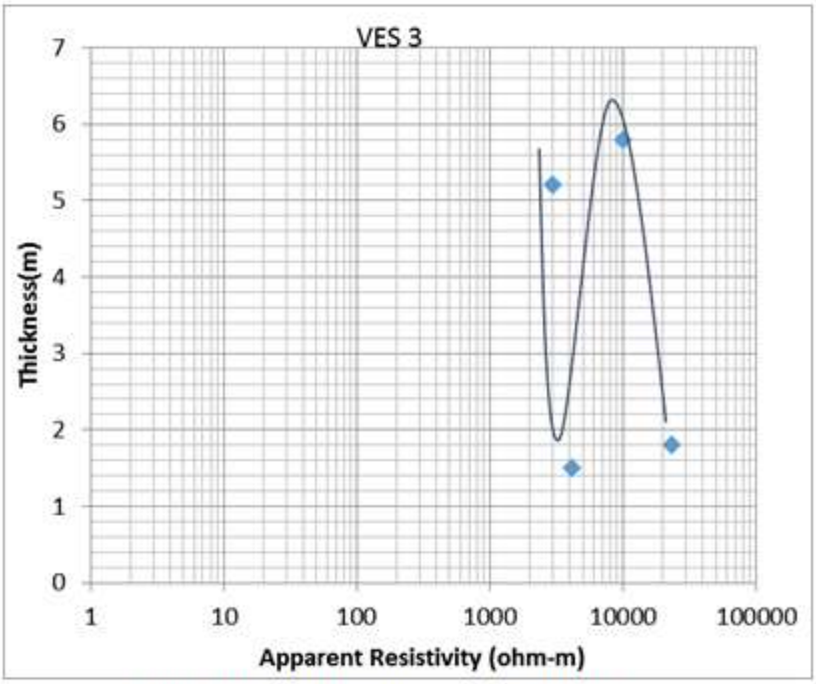

Figure 7: Graphic Plots of VES – 3 Soundings

Table 5: Vertical Electrical Sounding (VES -4)

Geoelectric Layer	Apparent Resistivity Ohm-m	Thickness meters	Remarks
Layer 1	2100.0	0.0 - 1.5	Top sandy soil
Layer 2	8400.0	1.5 - 2.3	Dry sand
Layer 3	2800.0	2.3 – 3.1	Moist sand
Layer 4	147.4	3.1 – 6.5	Water saturated sand
Layer 5	2947.4	6.5 –28.3	Shale
Layer 6	155.1	--	Water-bearing sand

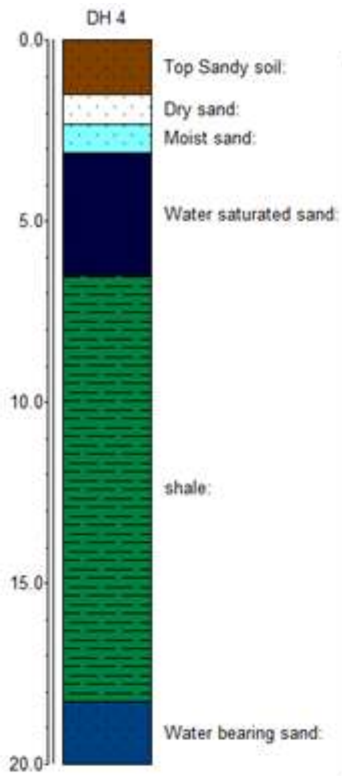

Figure 8: Lithologic Log of Drill Hole 4

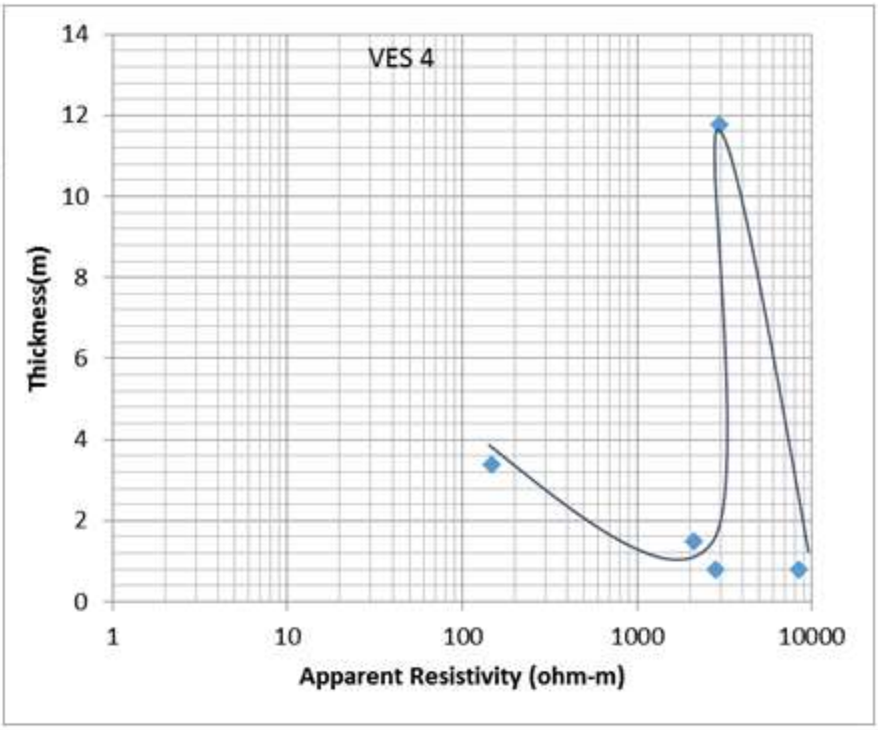

Figure 9: Graphic Plot of VES – 4 Soundings of Drill Hole 4

3. Result and Interpretation

The results are presented in form of tables and cross-sections. Tables 2 -5 show summary of electrical resistivity results. The tables show geoelectric layers, apparent resistivity in ohm-m, thicknesses of various layers in meters and field observations. The curves generally show 4 and 6 layer sections. Combining the interpreted information from the vertical electrical soundings (VES) with the lithological logs from exploratory drill holes (Figs 2, 4, 6 and 8), drilled close to the sounding points, we arrive at the conclusion that the first two geoelectric layers correspond to sandy dry soil. The upper part of this overburden sandy soil is weathered top soil. The soil formation changes from mud to sandy shale, to water bearing sand and to shale proper. Thickness of these soil types varies from 1.2m in DH-1, 1.8m in DH-2 and 3m to 11.8m in DH-3 and DH-4 in water bearing sand.

The resistivity distribution and the subsurface stratigraphy are as follows:-
Layer 1 consists of top sandy soil with the resistivity variation of 1000 ohm-m to 4100 ohm-m
Layer 2 comprises dry sand with the resistivity variation of 8400 ohm-m to 24300 ohm-m
Layer 3 consists of muddy sand with the resistivity variation of 1278.9 ohm-m to 9957.4 ohm-m
Layer 4 comprises sandy clay in VES-1, sand in VES-2 and 4 and water saturated sand in VES-4.
Layer 5 consists of shale in VES-1 and 3 and water bearing sand in VES-4
Layer 6 comprises water bearing sand as in VES-4.

4. Conclusions and Recommendations

Geoelectrical equivalence is a major problem in the interpretation of electrical sounding curves. Equivalence was virtually eliminated by mutual correlation of the Drill Hole logs obtained from test drill holes drilled at the sounding locations. However, this was not completely achieved in VES-4 as the drill could not get to the geoelectric layer 6. The results of a Vertical Electrical Sounding (VES) are represented in the form of graphs (Figs: 3, 5, 7 and 9) which the half-length of AB in (meters) is plotted on the abscissa, and the corresponding apparent resistivity in ohm-m is plotted on the ordinate. The abscissa axis is also used conventionally to position the thicknesses and a depth of the different terrains surveyed although no simple relationship exists between depths and transmission lines AB. The use of logarithmic coordinates is based on the fact that in electrical prospecting, the effect of strata decreases with depth. It is rarely possible to achieve a quantitative interpretation on the basis of isolated Vertical Electrical Sounding (VES) data only. Thus relying on available geological data and existing Drill Holes give reliable interpretation of VES investigation. In general, a reliable interpretation was achieved.

We recommend that boreholes will be drilled at PRODA western side of Ekulu River on the alluvial flood plain sands at locations 3, 4 and 5 (Fig 1). These locations have sand thickness of more than 7meters and water-saturated sand of more than 3meters.The thicknesses were obtained in location 4 when the exploratory drilling was done. The geophysical results indicate that a sand-body exist after the shale in locations 3 and 4.This could not be confirmed by the drilling information as the drill could not intercept the shale. If this can be confirmed by actual borehole drilling, an artesian well will be obtained as the water will be under pressure compressed by the shale. We therefore recommend a borehole depth of 20m to 25m. We also recommend double screening in case of locations 4 and 5. The borehole should be screened in the first saturated sand and then the sand after the shale. We strongly favour location 5 as recharge of the aquifer will be assured by the infiltration from Ekulu River.

5. Accuracy of Measurement

The measurements were made with great care and precautions. However, we attach an accuracy of ± 10% to the interpreted depths because of the complex nature of the earth and its physical parameters.

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