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Comparison of Thickness and Depth Resolution Power of Wenner and Schlumberger Arrays: A Case Study of Temidire Quarters, Akure, Nigeria

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Abstract

An electrical resistivity sounding investigation was carried out within the vicinity of some hand dug wells at Temidire Quarters in Akure, Ondo State, Nigeria. The aim of this study was to compare depth and thickness resolution power of Schlumberger and Wenner arrays. The investigation involved twenty-four vertical electrical soundings (VES) which consisted of twelve Schlumberger array VES and twelve Wenner array VES. The VES results delineated geoelectric layers beneath each VES locations, their layer resistivities, layer thicknesses and depth to aquifer layer(s). Depth to aquifer layer was also determined from static water level measurement and this aided the aquifer layer delineation from VES results. The geoelectric sounding results showed that the study area is dominated by a KH-curve type which consists of top soil, clay/weathered layer, fractured basement and fresh basement. Results from both Schlumberger and Wenner array data were correlated with the static water level measurement; Schlumberger array was found to have higher correlation value than Wenner array.

Keywords

Vertical Electrical Sounding (VES), Wenner Array, Schlumberger Array, Static Water Level, Correlation

1. Introduction

Many electrode configurations have been designed [1] [2]. Some of them are occasionally employed in specialized surveys but only two are in common use; Wenner and Schlumberger arrays. The Wenner configuration (**Figure 1**) was first proposed for geophysical prospecting by Wenner 1916 [3]. It involves the use of four electrodes that are placed at the surface of the ground along a straight line and all the electrodes (current and potential electrodes) are maintained at an equal distance to each other [3]. The Schlumberger configuration (**Figure 2**) is the second and it also involves the use of four electrodes placed along a straight line on the Earth's surface in the same order as in Wenner array, but the two inner potential electrodes have a smaller spacing than the two outer current electrodes. The Schlumberger and Wenner electrode arrays are the most widely used arrays in electrical resistivity prospecting.

There are two essential differences between these arrays: in Schlumberger array, the distance between the potential electrodes [P_1 and P_2] is small and is always kept equal to or smaller than one-fifth of the distance between the current electrodes while in the Wenner array the distance between the current electrodes [C_1 and C_2] is always equal to three times of the potential electrodes distance [1] [2] [3] [4]. In Schlumberger sounding, the potential electrodes are moved only occasionally, whereas in Wenner sounding, all the electrodes are moved after each measurement. Schlumberger sounding is believed to possess a slightly greater probing depth and resolving power than Wenner sounding curves for an equal current electrode spacing [2]. The manpower and time required for carrying out Schlumberger soundings are less than that required for Wenner soundings. Stray current in industrial areas and telluric current that are measured with long spread affect measurements made with the Wenner array more readily than those made with the Schlumberger array. The effects of lateral variations in resistivity are recognized and corrected more easily on a Schlumberger curve than on a Wenner curve [1] [2] [3] [4].

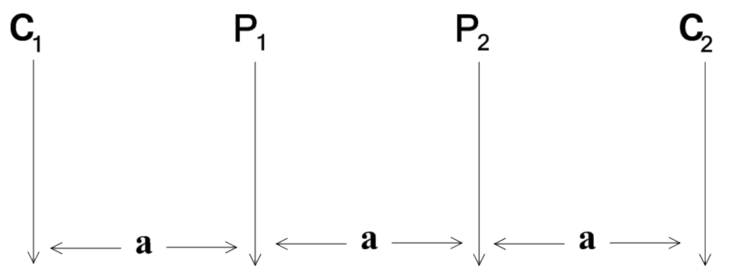

Figure 1. Wenner array layout.

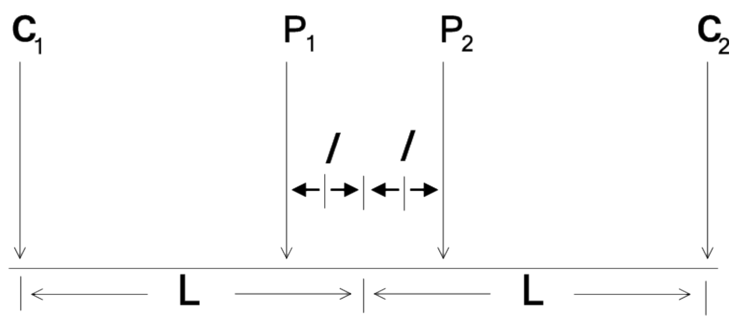

Figure 2. Schlumberger array layout.

Advantages of the Wenner array are limited to the following: relatively small current values sufficient to produce measurable potential differences and availability of large album of theoretical master curves for two, three and four layer earth models [3] [5] [6]. The above comparison indicates that it is advantageous to use the Schlumberger array rather than the Wenner array in conducting electrical resistivity soundings. The interpretation techniques are well developed and more diversified for Schlumberger sounding curves than Wenner curves. This study is focused on comparing the thickness and depth resolution power of Wenner and Schlumberger in atypical basement complex environment especially since no known previous work have ever touched this aspect.

2. Location and Geomorphology of the Study Area

The study area is Temidire Quarters, Ita Oniyan, off Ilesha-Akure Road, Akure Ondo State, Nigeria (**Figure 3**). The area lies within 737,900 - 738,800 m Eastings and 806,000 - 810,600 m Northings (UTM-Minna Datum).

The study area has a climate which is characterized by dry and wet seasons and dusty north-eastern trade wind called harmattan with temperature of 30˚C.

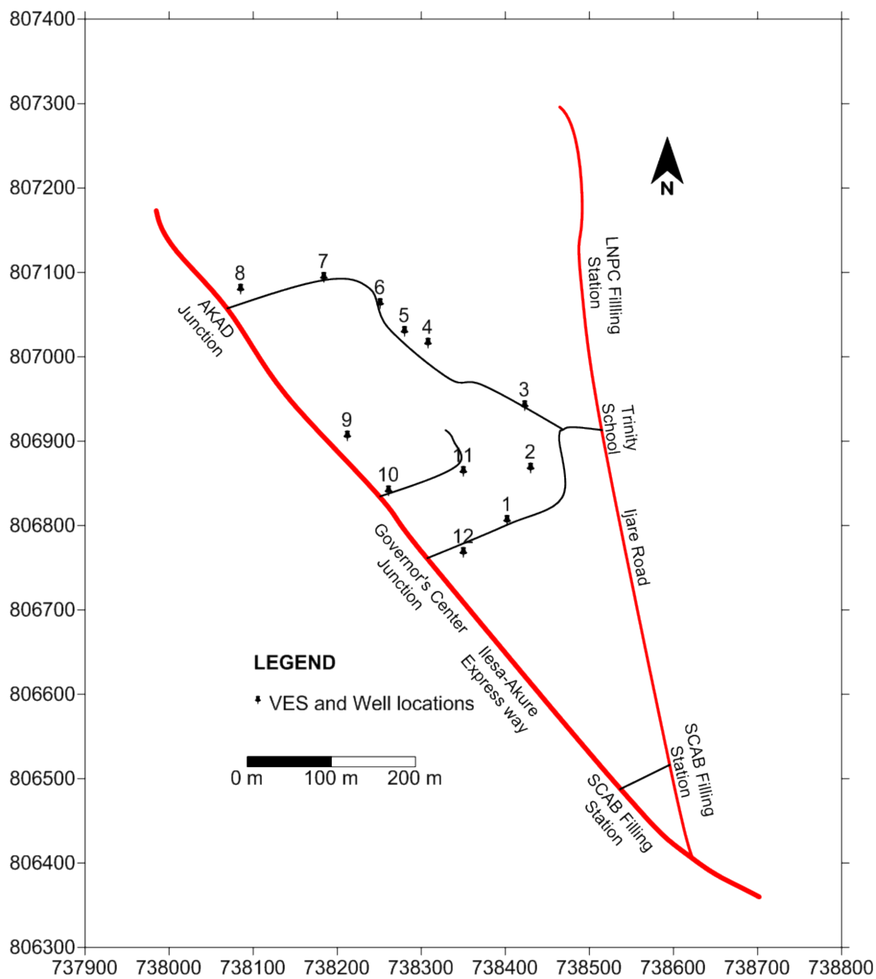

Figure 3. Location map of the study area, showing the VES and Well locations.

The Annual rainfall within the study area ranges between 100 and 1500 mm [7]. The annual temperature varies between 18˚C to 34˚C [7]. The warmer dry season stretches from late October to April with the peak period occurring between December and late February and the raining season stretches from May to early October, about two weeks break in the month of August, this known as August break or drought.

3. Methodology

This study combined static water level measurement and geoelectric sounding. The study consisted of twelve Schlumberger array soundings and twelve Wenner array soundings.

The VES survey results delineated different geologic sequence/geoelectric layers beneath each VES locations, their layer resistivities and thicknesses; from which depth to aquifer layer(s) were determined. Depth to aquifer layer was also inferred from static water level measurement. The depths to aquifer layer delineated from VES results were subsequently compared with the corresponding static water level measurement and this was done for both the Wenner and Schlumberger array. Their level of correlation were then determined using standard deviation method.

4. Discussion of Results

The results of the twenty-four VES data were as presented in Table 1 and Table 2. The typical curve types delineated from the geoelectric models are A, AA, KH and QH.

4.1. Schlumberger Array

The Schlumberger array sounding (Table 1) delineated 3 to 4 layers which correspond to the following lithologic units: the topsoil, lateritic/clay layer, wea-

Table 1. Summary of the Schlumberger VES results.

VES No	Apparent resistivity ρ_a (ohm-m) $\rho_1/\rho_2/\rho_3/\rho_4/\rho_5/\rho_{n-1}\cdots\cdots\rho_n$	Thickness (m) $h_1/h_2/h_3/h_4/h_5/h_{n-1}\cdots\cdots h_n$	Curve types
1	2568/4942/12851/16605	0.7/2.9/8.0	AA
2	1337/4300/2182/12741	0.6/3.0/4.6	KH
3	1415/3415/1487/79836	0.6/4.7/11.6	KH
4	1260/2815/1100/4704	0.9/5.4/17.8	KH
5	1130/5451/2244/5964	1.1/5.9/26.9	KH
6	668/6889/2887/5258	0.5/5.0/42.5	KH
7	761/4890/2074/2918	0.4/5.1/32.3	KH
8	1437/5445/771/1567	0.8/4.5/21.8	KH
9	400/1737/283/6954	1.3/5.5/13.8	KH
10	1620/1045/175/1048	0.5/10.4/21.2	QH
11	213/605/1782	0.8/5.9	A
12	386/1046/40/1200	0.7/2.6/11.7	KH

Table 2. Summary of the Wenner VES results.

VES No	Apparent resistivity ρ_a (ohm-m) $\rho_1/\rho_2/\rho_3/\rho_4/\rho_{n-1}\ldots\ldots\rho_n$	Thickness (m) $h_1/h_2/h_3/h_4//h_{n-1}\ldots\ldots h_n$	Curve types
1	2678/11505/2173/17236	0.6/0.6/4.5	KH
2	1650/15103/2733/7795	0.9/0.3/8.8	KH
3	814/1863/1108/1876	0.9/0.9/10.5	KH
4	1219/3934/1193/2677	1.2/2.4/27.6	KH
5	1117/17535/1736/2597	1.2/1.6/20.3	KH
6	454/3606/1047/1211	0.9/3.0/43.3	KH
7	1386/7020/2063/5612	1.1/5.6/39.4	KH
8	1474/ 6538/712/1145	1.0/3.9/35.0	KH
9	451/4324/503/1399	1.9/1.8/12.1	KH
10	495/1003/203/1365	2.0/2.0/16.0	KH
11	226/597/1617	1.0/2.8	A
12	406/1633/50/1210	1.1/1.5/8.8	KH

thered layer and fractured/fresh basement. The topsoil resistivity ranges from 213 to 2568 Ω-m and its thickness varies from 0.4 to 1.2 m, the lateritic/clay layer resistivity value ranges from 605 to 6889 Ω-m and its thickness varies from 2.8 to 10.4 m, the clay/weathered layer resistivity value ranges from 40 to 175 Ω-m, while its thickness varies from 4.6 to 37.0 m, the fresh basement resistivity value ranges from 1048 to 79,836 Ω-m.

4.2. Wenner Array

The Wenner array sounding technique identified 3 to 4 layers (Table 2) which correspond to the topsoil, lateritic/clay layer, weathered layer and fractured/fresh basement. The topsoil resistivity ranges from 226 to 2678 Ω-m and its thickness varies from 0.6 to 1.2 m, the lateritic/clay layer resistivity value ranges from 597 to 15,103 Ω-m and its thickness varies from 0.3 to 5.6 m, the clay/weathered layer resistivity value ranges from 50 to 2733 Ω-m and its thickness varies from 4.5 to 43.3 m, the fresh basement resistivity value ranges from 1145 to 17,236 Ω-m.

4.3. Correlation between Static Water Level and VES Results

The difference between the static water level measurements across all the wells and the corresponding depth to aquifer layer from Schlumberger and Wenner array soundings results were determined (Table 3). These were subsequently used to calculate correlation coefficient of each electrode configuration to the static water level measurement.

The correlation coefficient of 0.74 (Figure 4) was obtained between static water levels measured from wells and the depths to aquifer layer in the Schlumberger array sounding results indicating strong correlation, while correlation coefficient of 0.58 was obtained between static water levels measurements observed from wells and the depths to aquifer layer obtained from the Wenner array sounding results (Figure 5) suggesting a weak correlation.

Table 3. Static water level and depth to aquifer layer (Wenner and Schlumberger array).

Well/VES No	Static water level (m)	Depth to aquifer (m) (Schlumberger)	Depth to aquifer (m) (Wenner)
1	2.7	2.9	1.2
2	2.5	2.1	1.2
3	3.6	5.2	1.8
4	5.6	6.3	3.6
5	5.1	5.9	2.9
6	6.3	5.6	3.9
7	6.2	5.6	6.7
8	5.1	4.9	5.0
9	6.9	6.9	3.7
10	7.2	9.8	4.1
11	5.2	5.3	3.8
12	4.4	3.3	2.5

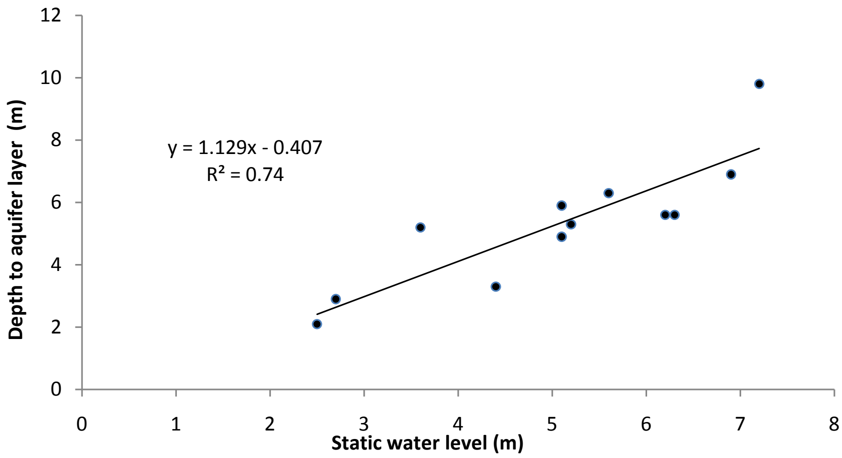

Figure 4. Correlations between static water level measurement and depth to aquifer layer (Schlumberger array).

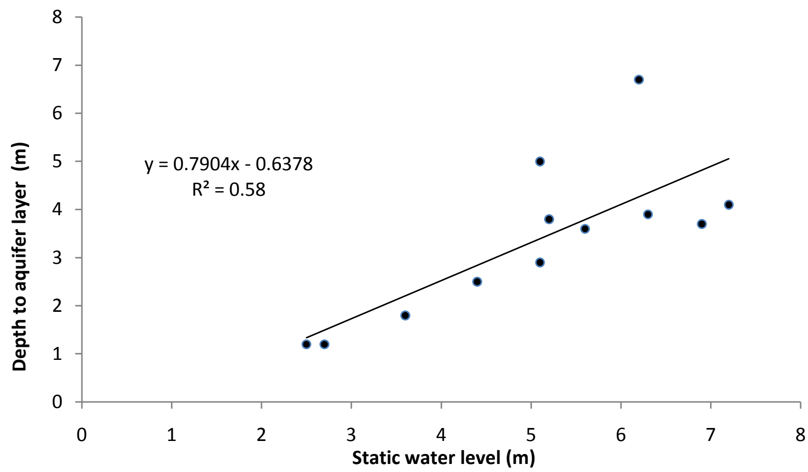

Figure 5. Correlations between static water level measurement and depth to aquifer layer (Wenner array).

5. Conclusion

A surface electrical resistivity survey was conducted at Temidire quarters, Akure with the aim of highlighting the difference between Wenner and Schlumberger arrays ability to resolve layer thickness and depth. From the correlation chart, it was shown that there is a strong correlation between the static water level measurements from the hand dug wells and the depths to aquifer layer obtained in the Schlumberger array sounding results (0.74) while there is a weak correlation between the static water level measurements from wells and depths to aquifer layer from Wenner array sounding results (0.58). The results showed that Schlumberger array has stronger correlation than Wenner array. Therefore, Schlumberger array has a better thickness and depth resolution power than Wenner configuration.

6. Recommendation

It can therefore be suggested that Schlumberger array be considered ahead of Wenner array for any VES survey where accurate depth determination is required.

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