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GEOELECTRIC SURVEY FOR BOREHOLE SITING IN THE BASEMENT COMPLEX TERRAIN OF AJAOKUTA, SOUTHWESTERN NIGERIA.

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A R T I C L E I N F O

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Abstract

The location of a Steel Rolling Mill and a Gas Turbine Power Plant at Ajaokuta, Kogi State, has drastically increased the growing population of the area. The existing surface water facilities is to be complemented by groundwater resource in order to meet the water demand of the people. This study is aimed at determining the geoelectric sequence of the area, the overburden thickness, aquifer geoelectric characteristics and nature of the bedrock with a view to develop groundwater through borehole drilling. Horizontal resistivity profiling (HRP) was conducted along eight (8) traverses with station separation of 30 m using the Wenner array. The results of the HRP were presented as profiles and locations with lowest apparent resistivity value were further investigated with Vertical Electrical Sounding (VES) technique. Twenty-five (25) VES locations were occupied with the Schlumberger array of half current electrode spacing AB/2 ranging from 1 m to100 m. The data were acquired using PASI Digital Resistivity Meter (16 GL), presented as sounding curves and interpreted by partial curve matching and computer assisted 1D forward modelling using WinResist software. The results of the VES interpretation were used to generate three (3) geoelectric sections. The geoelectric sections revealed four major geoelectric layers which are the topsoil, weathered basement, partly weathered basement and fresh basement. The topsoil has resistivity value that varies from 6 ohm-m to 430 ohm-m and thickness of between 0.5 m and 4 m. The weathered basement has resistivity values that range from 16 ohm-m to 250 ohm-m and thickness of between 10 m and 30 m. The partly weathered layer has resistivity value of 32 to 410 ohm-m and thickness of between 5 to 55 m. The fresh basement has resistivity values that vary from 154 ohm-m to 30,000 ohm-m. The major aquifer is the weathered basement. Base on the results, one test borehole at VES 9 and two (2) observatory wells at VES 5 and 4 were drilled. The pumping test analysis conducted on the wells revealed a yield of 25 m^3/hr with recovery rate of 75 %. There was significant correlation between the geoelectric sections and the borehole logs.

1.0 Introduction

The location of a Steel Rolling Mill and a Gas Turbine Power Plant in Ajokuta the study area has drastically increased the growing population of the area. Presently, the water supply in the area has been from shallow wells in the overburden which dries out during the dry season and surface water supply from River Ohunene. However, River Ohunene is perennial and it remains the main source of domestic water for the community. The outlined sources are therefore considered inadequate for the water requirement of a growing community. In addition, because of the distance of the river to the communities and the inherent danger of pollution, there is urgent need to assess the groundwater potential of the area. Structural fissures such as faults, lithological contacts/boundaries and shear zones with thick weathered zones are important hydrogeological features in crystalline basement complex. These structural features create inhomogeneities which in turn enhance groundwater storage and flow. In delineating these features, geophysical methods play important role. The electrical resistivity method has routinely been used in delineating geological features that are suitable for groundwater accumulation. However, other geophysical methods such as electromagnetic (VLF) and seismic refraction can be used in combination with resistivity method to carry out comprehensive groundwater exploration in basement terrain. The electromagnetic (VLF) method has found useful applications in groundwater investigation in basement terrain, most especially as reconnaissance tool [1,2,3 & 4] applied the spontaneous potential (SP) and electrical resistivity to understand the nature and groundwater development feasibility of a suspected spring in Ajegunle-Igoba, Akure. In this paper, the electrical resistivity method involving Horizontal Resistivity Profiling (HRP) and Vertical Electrical Sounding (VES) was adopted for prospecting for groundwater resource in typical basement complex. The investigation was carried out to determine the geoelectric sequence of the area, the overburden thickness, aquifer characteristics, nature and topography of the bedrock for siting and drilling of productive borehole.

1.1 Description of the study area

The study area lies within latitudes 6^{o}30’50.15’’N and 7^{o}40’54.10’’N and longitudes 7^{o}00’19’’E and 7^{o} 30’ 22.5’’ E (Figure 1). It is located along Okene-Ajaokuta road about 20 km North-East of Adogo and 4 km North of Ajaokuta town in Kogi State.

The drainage within the study area is dendritic in pattern with two rivers (Osara and Uba) draining the area. The rivers flow eastwards to join the river Niger (Figure 1). The area falls within the tropical forest-savanah characterized by a mixture of trees, shrubs and grasses. The area has a peculiar climate of long dry season (October-April) and a short wet season (May-September). The annual rainfall is between 1000-1500 mm while the mean temperature is about 26.1^{o}C. [5]

1.2 Geology of the area

The study area is generally underlain by crystalline rocks of Basement Complex rocks of North central Nigeria which is classified into five (5) groups [7].

I. Migmatite gneiss complex which comprises of biotite and biotite hornblende gneisses, quartizite and quartz schist and small lenses of calcilicate rocks.
II. Slightly migmatised to

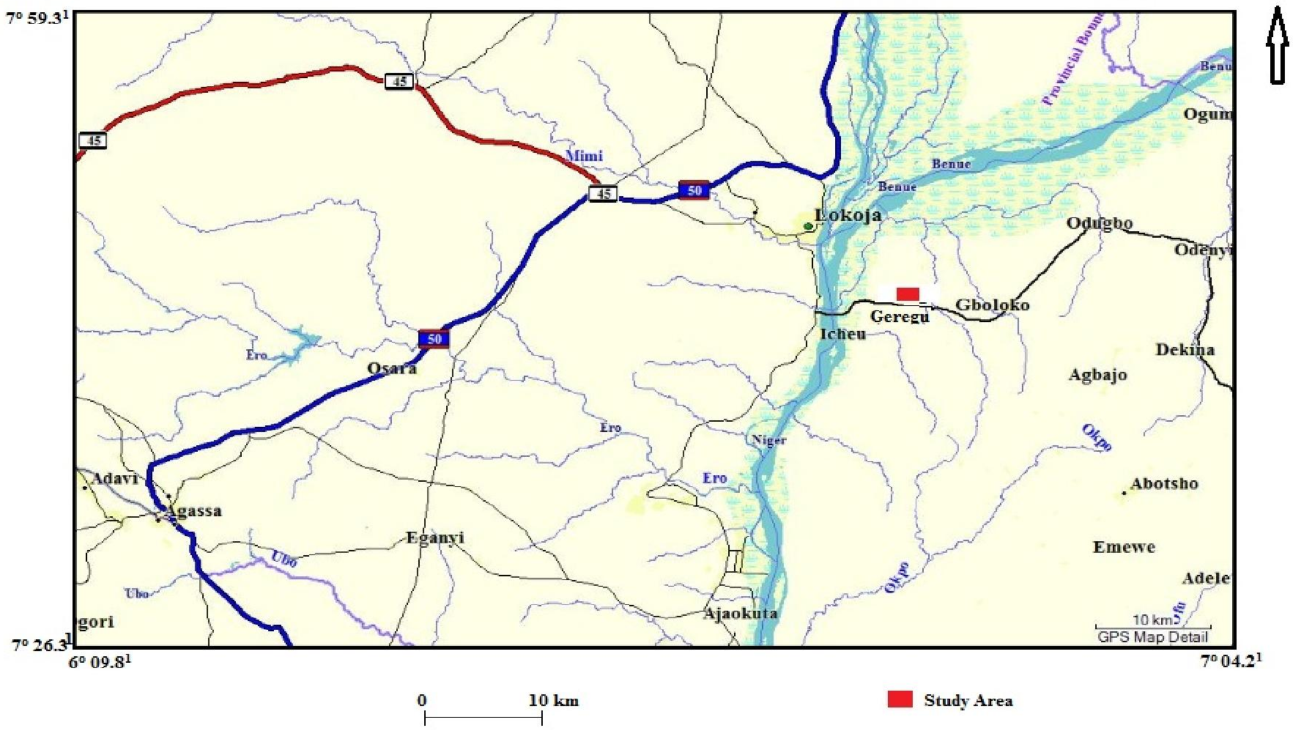

Figure 1: Location map of the study area

III unmigmatised paraschists and meta-igneous rocks
IV Charnokitics rocks
V, Older granite which comprise of rock varying in composition from granodiorite to granite and potassic synite
III. Unmetamorphosed dolerite dykes

The quartzite, migmatite gneiss and phyllite/schist are very exposed in most part of the area. The phyllite/schist is the metaconglomerates which occur at the bank of River Niger. The rocks strike in the north-south direction from the outcrops at the study area. The relics of quartzite comprises of many joints through which water could penetrate. The geologic map of the area is shown in Figure 2.

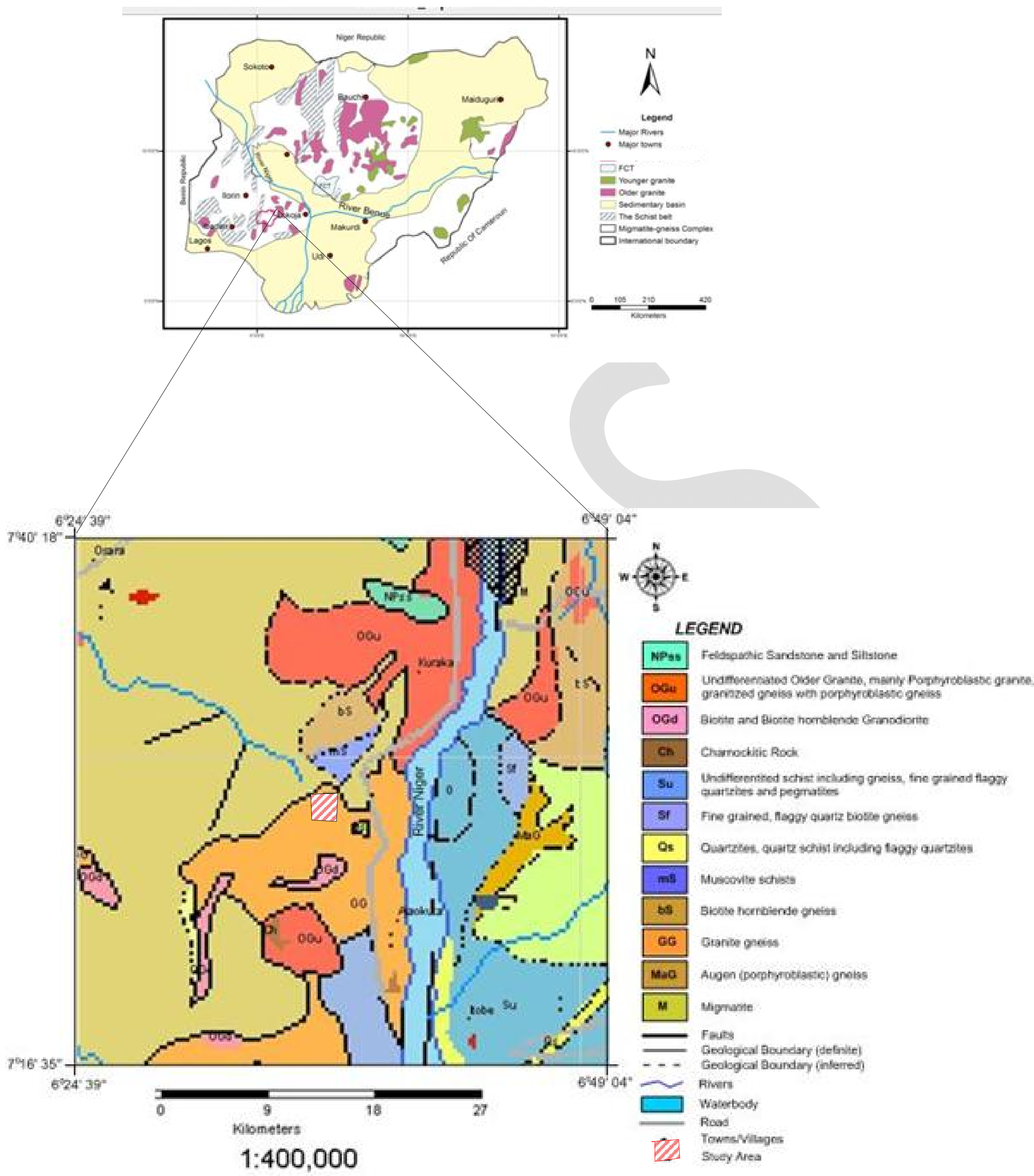

Figure 2: Geological Map of the Central part of Kogi State showing the Study Area [8]

2.0 Methodology

2.1 The Geophysical Investigation

The geophysical investigation involved the electrical resistivity method adopting the horizontal resistivity profiling (HRP) using Wenner array and the Vertical Electrical Sounding (VES) with Schlumberger electrode array. The data was acquired using Pasi resistivity meter. The HRP adopted inter electrode spacing of 30 m and was carried out along traverses in order to locate appropriate positions for VES points (Figure 3). The HRP data were presented as profiles (Fig.4) and interpreted qualitatively by visual inspection for locations with relatively low apparent resistivity values typical of areas with thick overburden and/or partly fractured basement. In Vertical Electrical Sounding (VES), the vertical variation in ground apparent resistivity values were measured with respect to a fixed centre of array. The survey was carried out by gradual increase in the electrode spacing (AB) with respect to the centre of the electrode array. Twenty-five (25) locations were occupied. The Schlumberger array was adopted with half current electrode spacing (AB/2) varying from 1 to 100 m. The apparent resistivity values (ρ_a) at each station were plotted against half current electrode spacing (AB/2) on a bi-logarithmic graph to generate sounding curves. Partial curve matching was carried out for the quantitative interpretation of the curves. The results of the curve matching (layer thickness and resistivity) were fed into the computer as starting model parameters in a 1D forward modelling using the WinResist software (Vander Velpen, 2004). From the interpreted results, geoelectric sections were generated to determine bedrock topography and aquifer thickness.

3.0 Results and discussion

The VES curves obtained from the study area vary from 3-layer (H and A) to 6-layer HAKH as shown in Table 1 with the HA type predominating. In order to evolve a geological model and bedrock topography of the subsurface, the VES interpretation results were used to generate 2-D geoelectric sections.

Table 1: Summary of VES interpretation results.

VES station	Resistivity (Ohm-meter) ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	Thickness(m) h_1	h_2	h_3	h_4	h_5	Curve Types
1	14	23	10000	---	---	----	4	12	---	----	----	A
2	16	6	20	30000	-----	------	1.8	3.5	3.7	----	----	HA
3	32	21	56	250	---	----	2.4	2.9	19.5	----	-----	HA
4	57	51	348	462	---	---	1.5	24	25	----	-----	HA
5	289	62	79	472	122	652	2.2	3.5	6.2	3	33.2	HAKH
6	12	60	10000	100	-----	------	2.7	14	32.3	----	-----	AK
7	9.6	15	560	180	640	----	2.9	4.9	1.2	13	----	HKH
8	11	55	40	740	-----	-------	2.4	1.4	24.2	------	-------	KH
9	76	60	100	4000	----	---	2.4	9.6	54	---	---	HA
10	16	40	10000	-----	-------	------	1.4	14	-----	------	-----	A
11	170	12	50	1760	----	-----	2.1	2.1	16.8	------	--------	HA
12	520	30	59	1200	21	---	1.1	7.9	28	3	----	HAK
13	340	40	10000	-----	-------	-------	1.2	21	----	------	-------	H
14	11	22	105	190	10000	-----	2.6	2.6	5.2	22.6	--------	AAA
15	6	22	240	4200	-----	------	1.9	4.8	27.3	------	------	AA
16	21	20	53	154	----	-----	2.1	1.7	15.6	-----	-----	HA
17	35	44	151	188	------	-------	1.8	5.9	14.7	------	-------	AA
18	76	38	140	680	-----	------	2.2	17.4	13.7	------	------	HA
19	17	60	700	-----	------	------	2.3	19.7	-----	-------	--------	A
20	20	16	170	140	----	-----	2.0	2.8	9.6	----	-----	HA
21	56	22	5000	----	------	-----	1.1	9.8	---	------	--------	H
22	430	43	250	8,800	----	-------	1.6	8	55.0	--------	--------	HA
23	250	25	70	2000	------	-----	1.3	3.5	9.5	---------	-------	HA
24	60	32	300	-------	--------	-------	2.0	12	----	-----	-----	H
25	52	65	51	87	410	----	1.8	3.8	3.9	24	-----	KHA

Figures 2 and 3 depict the base map of the study area and the horizontal resistivity profiles while figures 5, 6 and 7 show the geoelectric sections in the study area. TR1relates VES 4,5,7,9,17,18 and 23 (Figure 5); TR2 relates VES 6,8,10,19 and 24 (Figure 6) while TR3 relates VES 14,15,20 and 25 (Figure 7). The sections identified four geoelectric layers comprising of the topsoil, weathered basement, partly weathered layer and fresh basement rock. These sections give respective layer resistivity values and thickness. The geoelectric characteristics are as following:

(i) Topsoil: The topsoil varies in composition from clay to sand with resistivity values varying from 6 to

430 Ω-m but generally less than 200 Ω-m . The thickness of the topsoil varies from 1.1 to 4.0 m but are generally less than 2.0 m (Figures 5, 6 and 7).

(ii) Weathered Layer: The weathered layer varies in composition from clay to sandy clay with resistivity value varying from 20 to 65Ω-m(Figures 5, 6 and 7). The thickness of the weathered layer varies from 10 to 30 m. It is thickest beneath VES 9.

(iii) Partly Weathered Basement: The partly weathered layer varies in composition from sandy clay to sand with resistivity values varying from 32 Ω-m to 410 Ω-m. The thickness of the partly weathered layer varies from 5 m to 55 m.

(iv) Fresh Basement Bedrock: The resistivity of the fresh basement varies from 1200 to ∞Ω-m

The generated geoelectric sections (Figures 5, 6 and 7) revealed the presence of weathered layer/partly weathered basement aquifer with high hydrogeological significance as inferred from the thickness and the relative resistivity values.

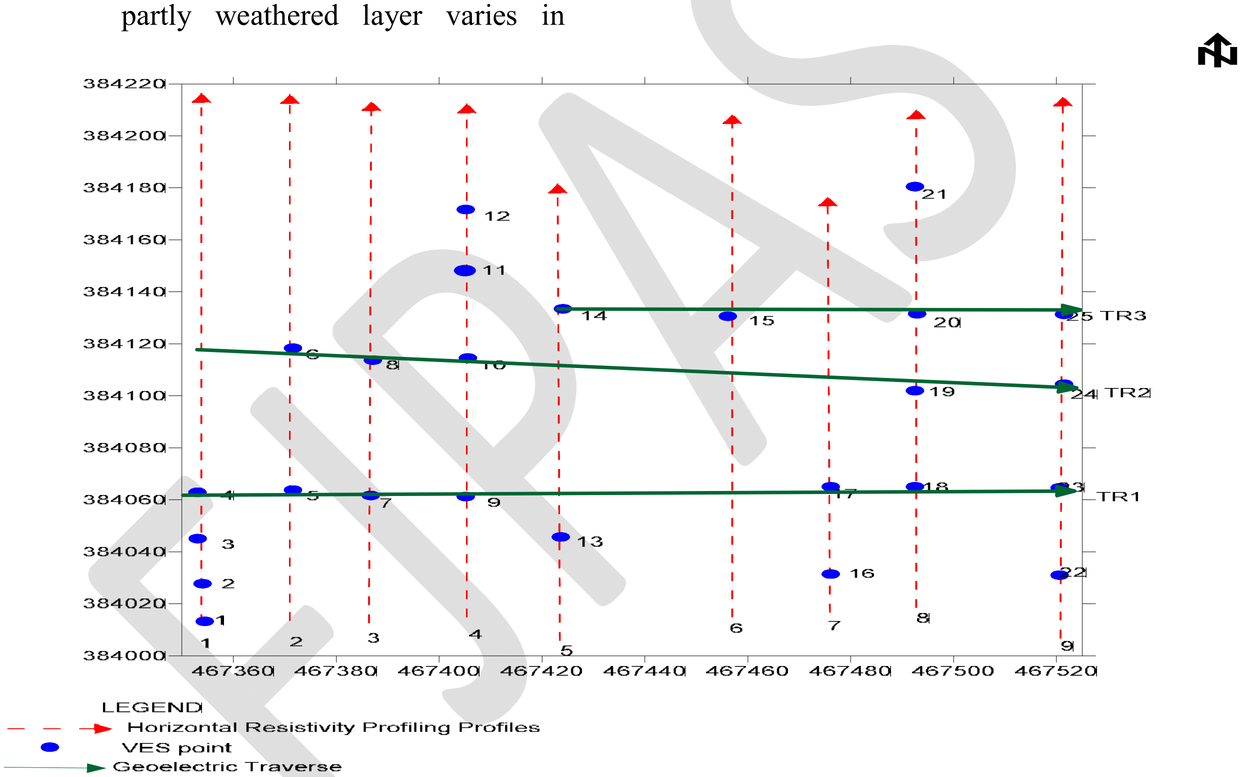

Figure 3: Base Map of the Study Area

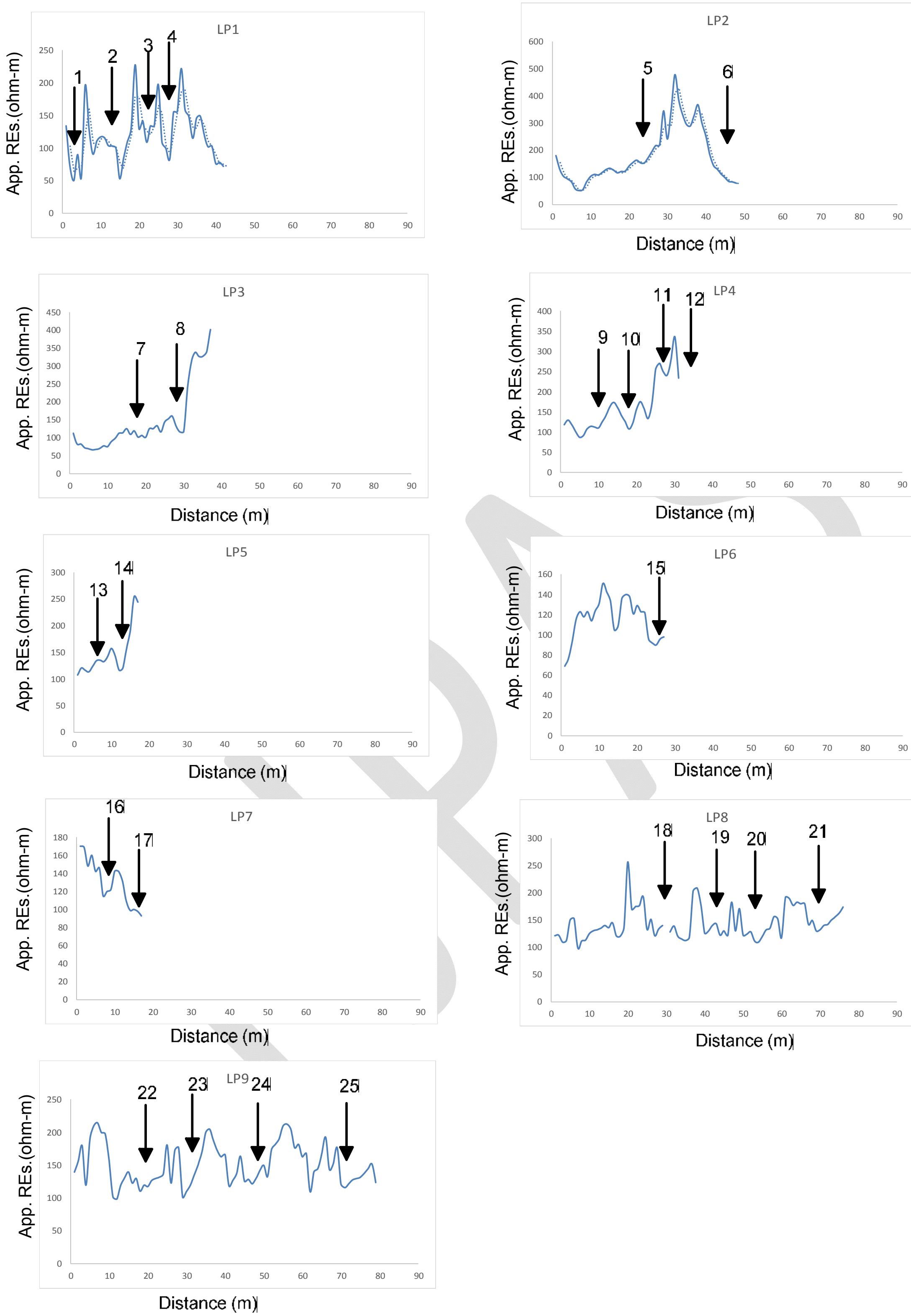

Figure 4: Horizontal Resistivity Profiles

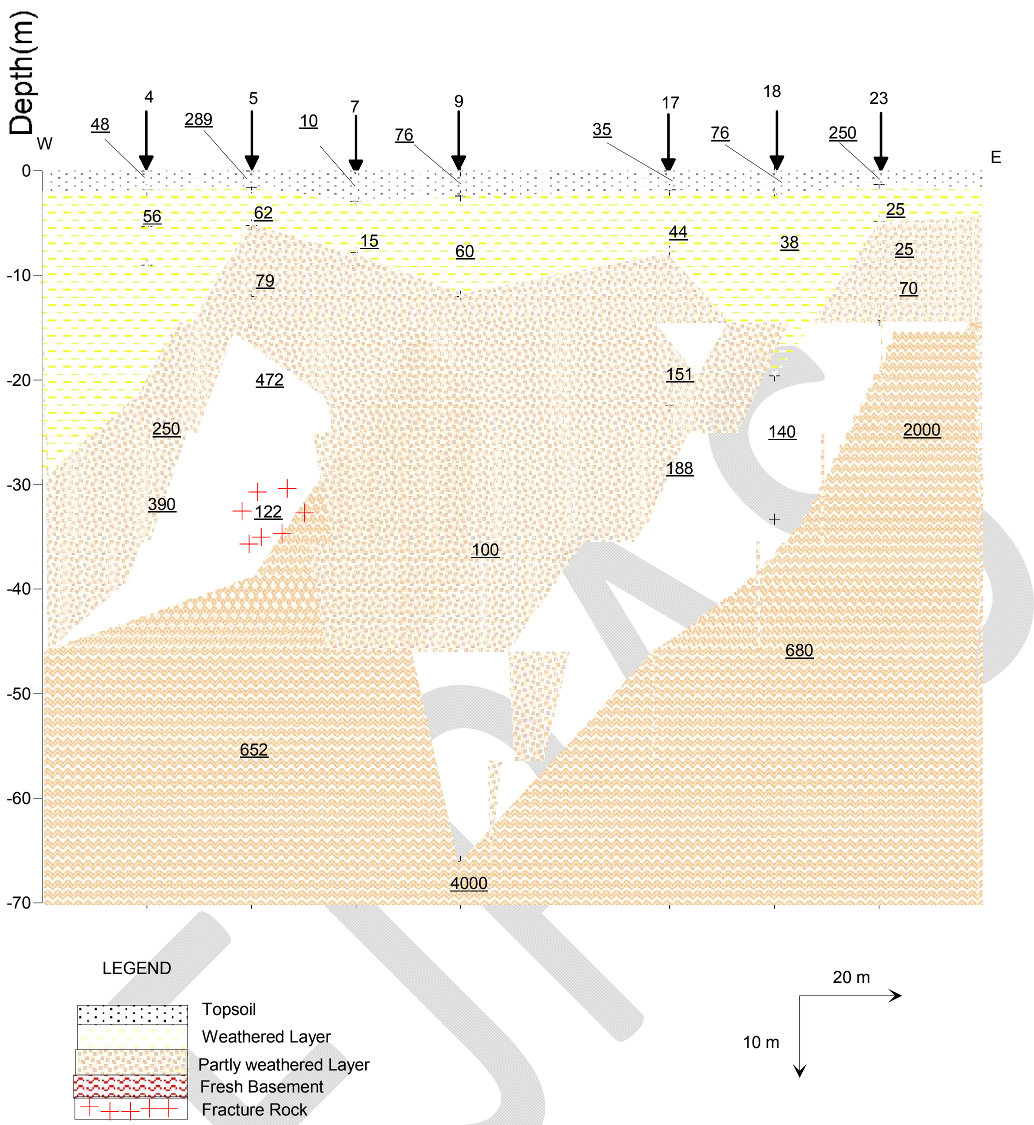

Figure 5: Geoelectric Section along TR1 (W-E of the study area).

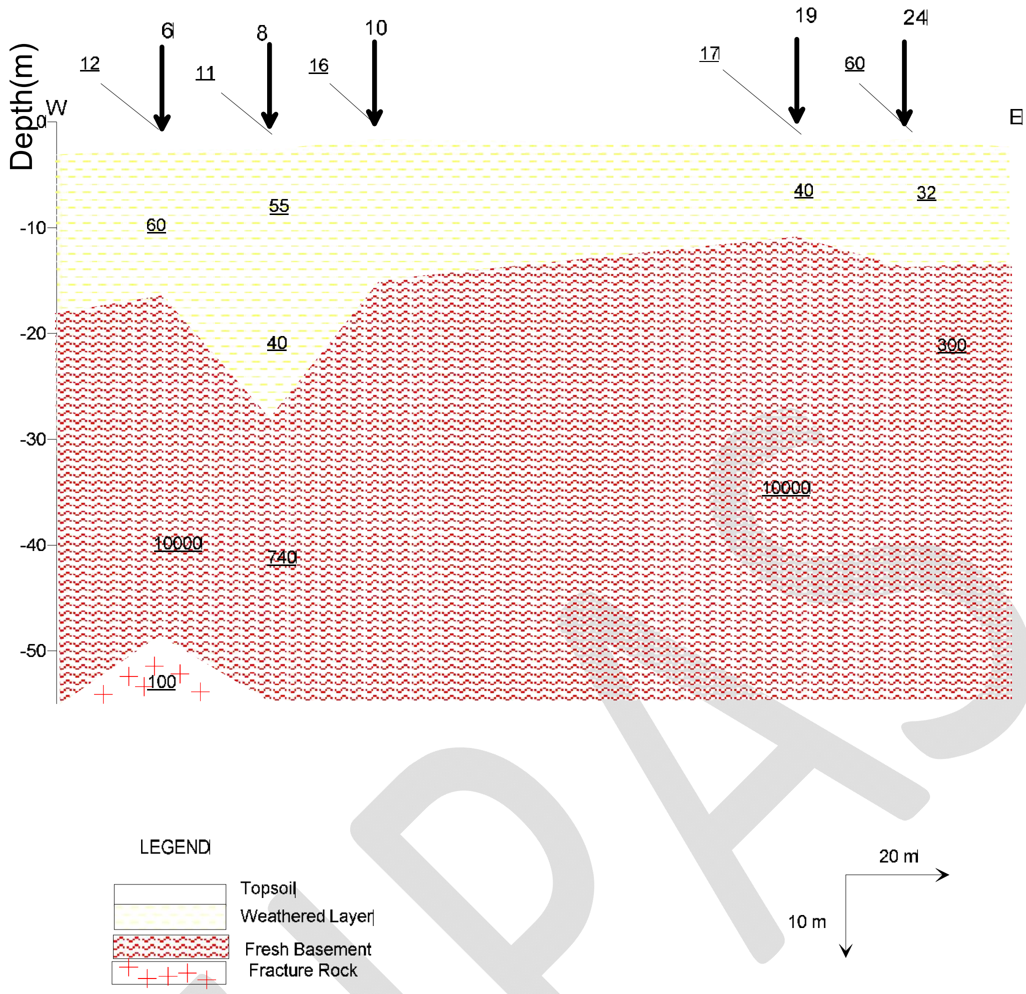

Figure 6: Geoelectric Section along TR2 (W-E) of the study area

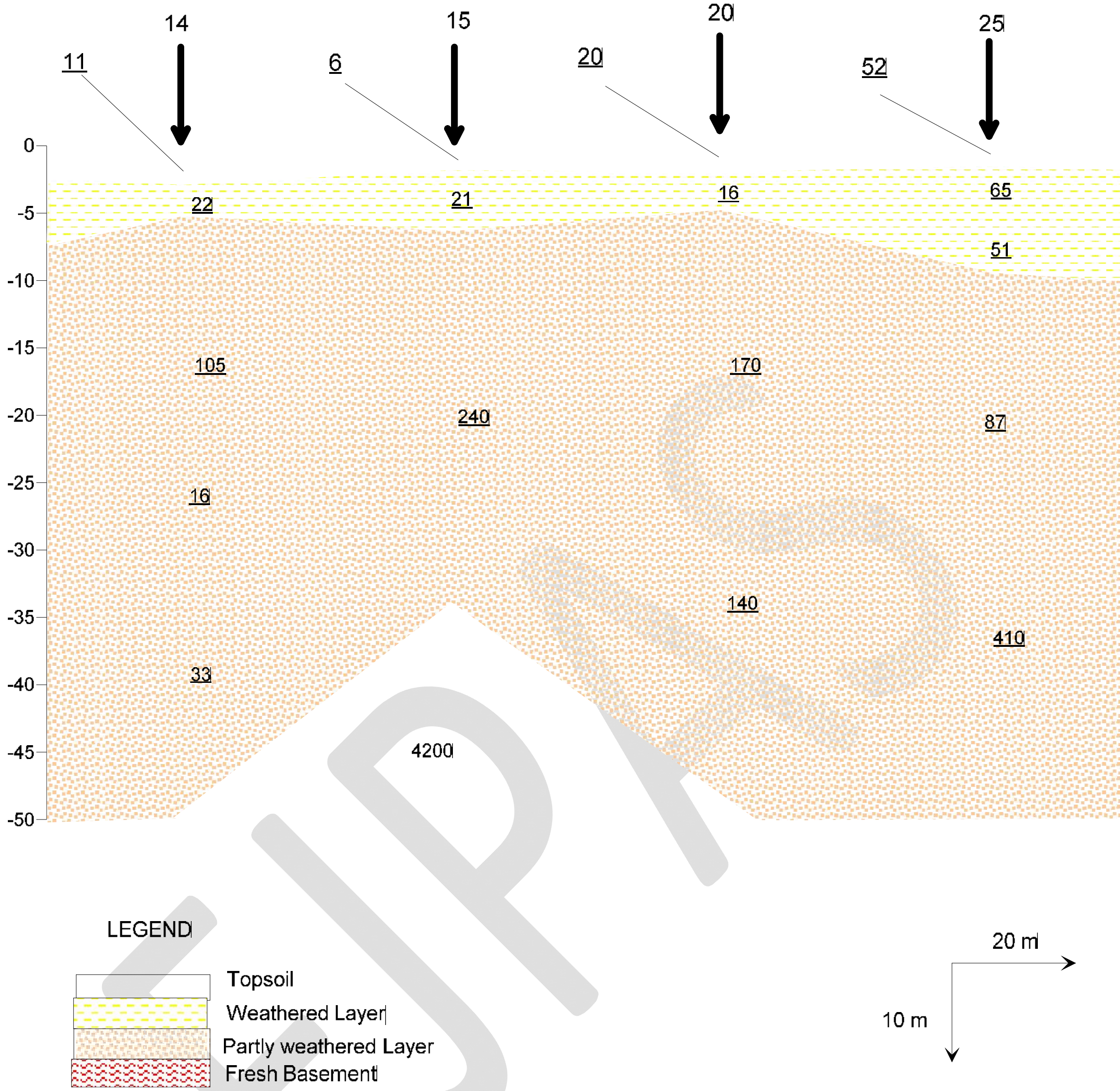

Figure 7: Geoelectric Section along TR3 (W-E) of the study area

The weathered basement unit is 10-30 m thick and extensive with tendency for large storage capacity and average groundwater yielding capacity. On the bases of our investigation, a test borehole was recommended for drilling at VES 9 and observatory boreholes at VES 4 and 5. The test hole and observatory boreholes were drilled and thetest hole was pump tested. The test borehole was productive with groundwater yield of 25 m^3/hr after pumping test analysis, which is an indicative of moderately high groundwater recharge. The static water level remains at about 10 m. The partly weathered basement encountered in the borehole log corroborates the prediction from both horizontal resistivity profiling (HRP) and VES interpretation results. Figures 8, 9 and 10 show good correlation of VES (4, 5 & 9) interpretation results with borehole lithological logs.

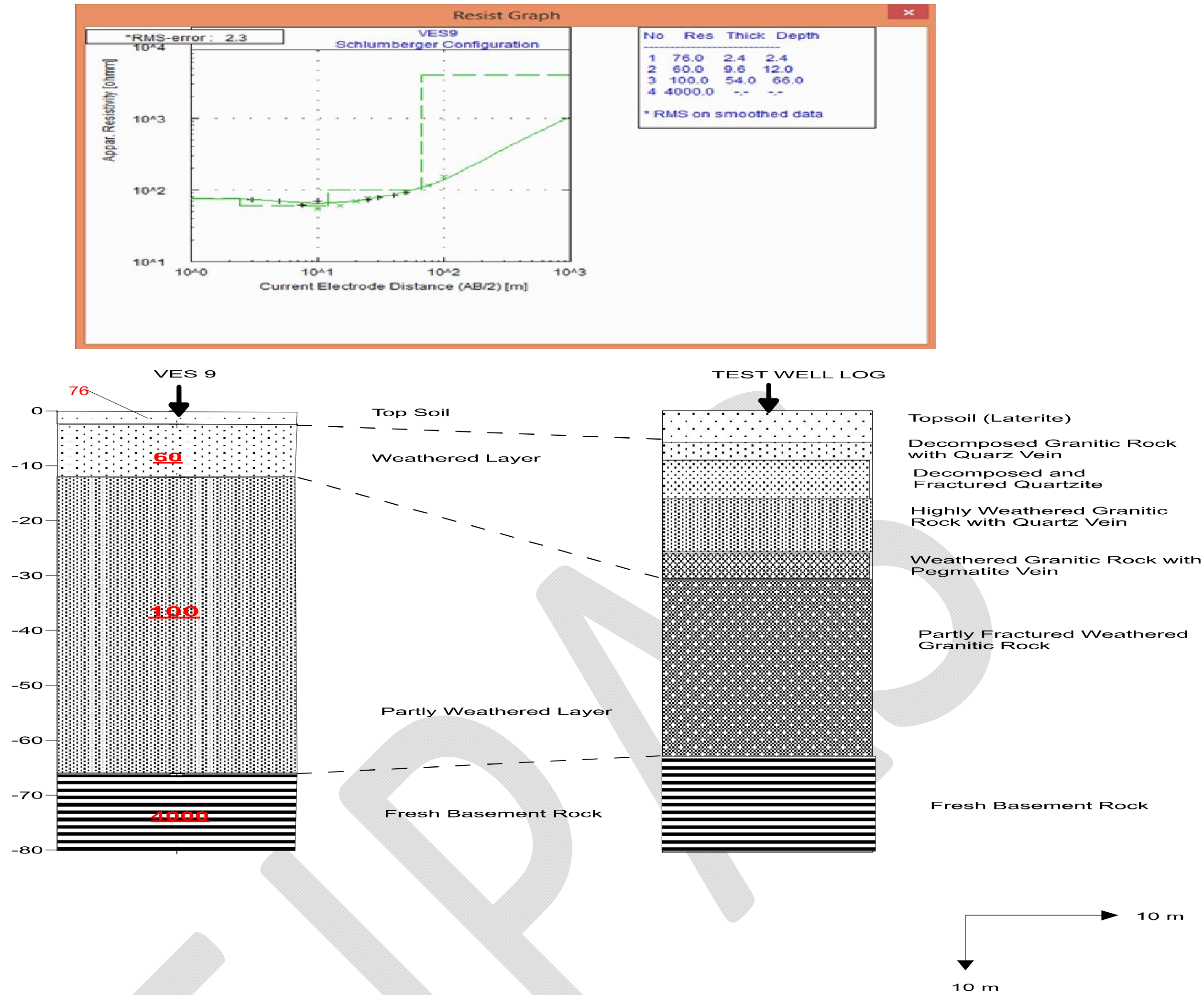

Figure 8: Correlation of VES9 with Lithological log

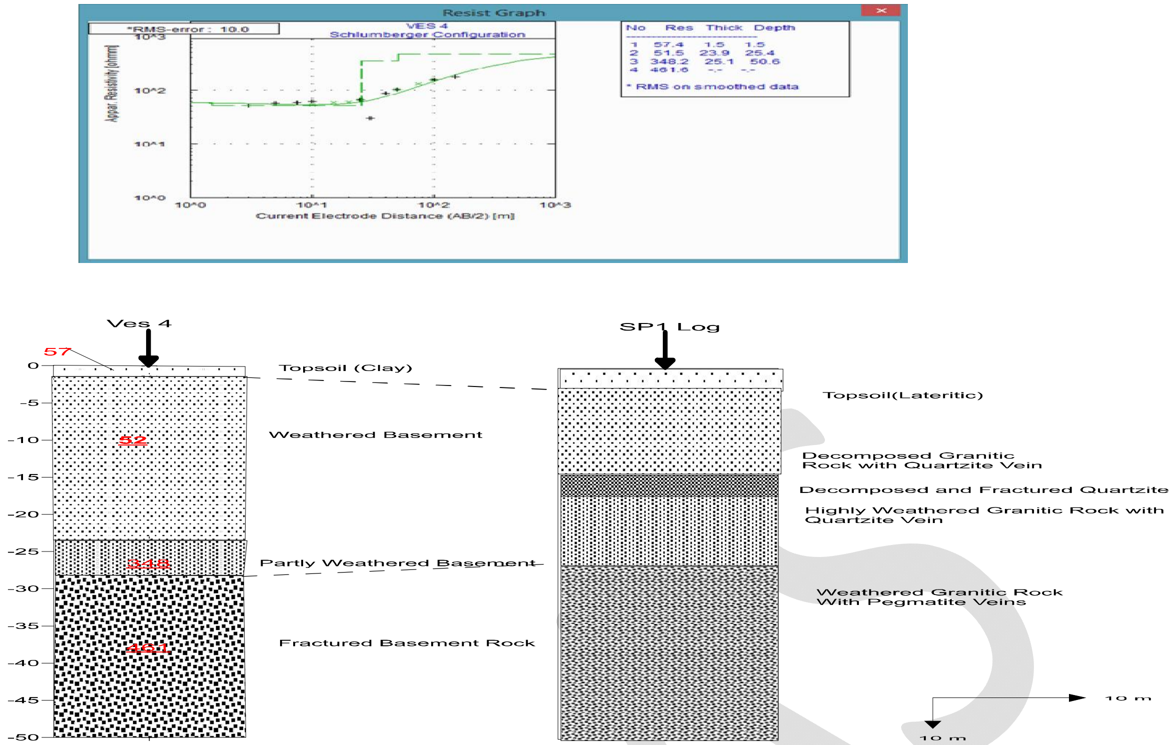

Figure 9: Correlation of VES4 with Lithological logs

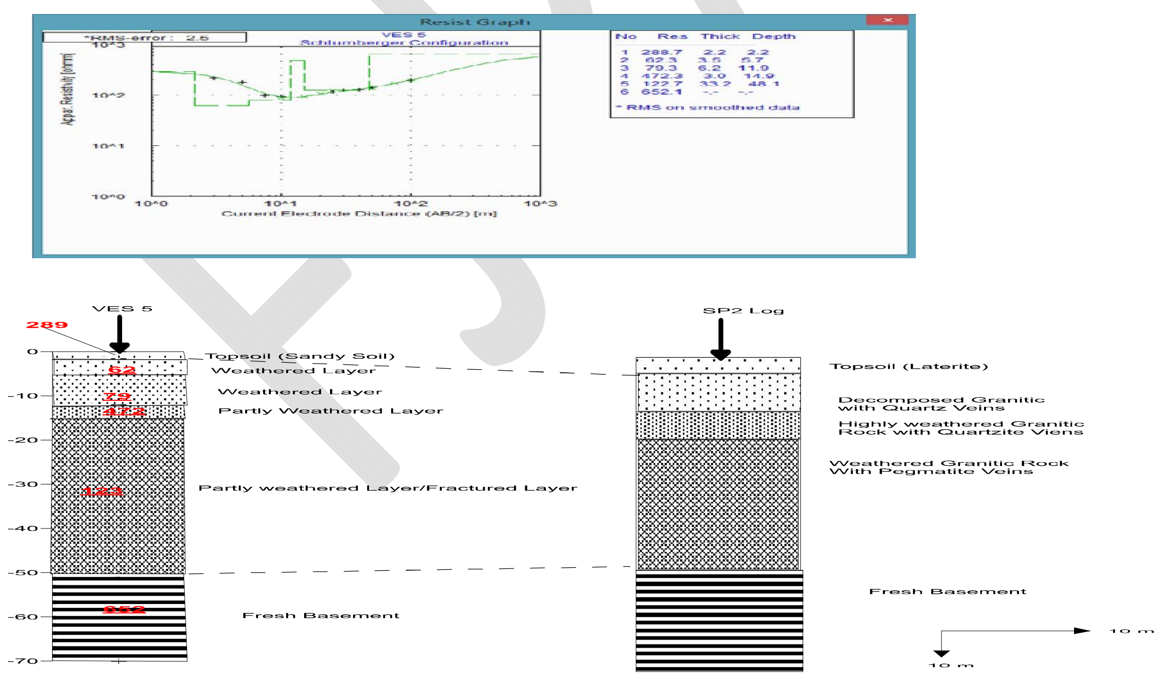

Figure 10: Correlation of VES5 with lithological results

4.0 Conclusion

Geoelectric survey, using Wenner Horizontal Profiling and Schlumberger Vertical Electrical Sounding was carried out at Geregu Power Plant site in Kogi State for groundwater development. The geoelectric section generated from the interpretation of the VES results revealed the presence of four major geoelectric layers comprising topsoil, weathered layer, partly weathered basement and fresh basement. The weathered layer and partly weathered basement with average resistivity value of 120 ohm-m and thickness of 60 m constitute the major aquifer units. The partly weathered basement unit is thick and extensive with tendency for large storage capacity and significant groundwater yielding capacity. Based on the results, the VES 9 was recommended and test drilled with two other observatory wells (VES 4 and 5) for the pump testing activity. There was significant correlation between geoelectric sections and borehole logs. Pumping test analysis conducted on the recommended VES 9 station revealed a yield of 25 m^2/hr with a recovery rate of 75 %.

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