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VERTICAL ELECTRICAL RESISTIVITY SOUNDING FOR GROUNDWATER IN BISHINI AREA OF KADUNA STATE

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ABSTRACT

Groundwater occurrence in Bishini area of Kaduna state was investigated using Electrical resistivity method for the purpose of sitting viable borehole. A total of twenty-seven (27) vertical electrical soundings (VES) using Schlumberger electrode array were acquired with a maximum electrode separation of AB/2=150 m, using the ABEM Terrameter SAS 300C.

Interpreted sounding curves revealed predominant of Three to five electro-stratigraphic units were delineated in the study area, namely: the topsoil (indurated laterite), lateritic clay, weathered basement rock, fractured basement rock and fresh basement. The weathered and / fractured basement rocks constitute the aquiferous zones with the weathered layer aquifer (63%) predominant while the weathered/fractured (unconfined) aquifer (7.4%) was least represented. The first two layers have variable resistivity of between 76 and 22938Ω-m. Weathered basement with average resistivity and thickness values of 211.52Ω-m and 16.4m respectively was encountered in all the sounding locations with exception of VES 23 and VES 26. Weathered/fractured basement was encountered in six locations with resistivity and depth to the top of fracture basement ranging from 77 - 977Ω-m and 5 -14m respectively. The weathered layer (5 – 37m overburden thickness) and weathered/fractured basement (20 – 62m overburden thickness) found within basement depressions constitutes the main aquiferous units. The geo-electric sections in the N-S, NW- SE and NE-SW directions revealed VES 9, VES13, VES 19 and VES 21 as sounding locations that could be drilled. VES 21 that was fractured with resistivity of 977Ω-m and overburden thickness of 62m was considered most suitable for borehole drilling provided there is no drop in volume of water as drilling progresses.

KEYWORDS: Vertical Electrical Sounding, Sounding Curves, Electro-Stratigraphic Units, Basement Depressions, Aquiferous Units

INTRODUCTION

Water is a key ingredient supporting food production, sanitation, rural livelihoods as well as ensuring continuity and functioning of ecosystem. It dictates the pace of settlement, agricultural and industrial development of any society and even in recent time, establishment of any human settlement was usually centered on available source of water supply and in modern time, issue of water has taken prominences in global matters (Humaira and Jose, 2009). Chunk of available World water in the oceans (97.5%) are salty and not useful for domestic and industrial applications. The remaining 2.5% constitutes fresh water, out of this; surface water and groundwater have 0.4% and 30.1% respectively while the remaining 69.50% are locked up in ice caps and glaciers (Gleick, 1996). Apart from the quantity advantage of groundwater over surface water, common knowledge shows that groundwater is of better quality as it is naturally filtered while percolating through the subsurface layers of the earth. In addition, the distributory problem associated with surface water is of no consequence with respect to groundwater as it is available virtually anywhere below the ground surface though with variable quantity.

Nigeria as a whole is rich in surface water about (224 trillion Litres per year) and that of groundwater is about (50 million trillion Litres per year) for a population of about 128 million with domestic consumption need of 6.0 billion Litres per year (Akujieze *et al.,* 2003). Despite the enormous water resources in the country, groundwater resources are considered deficient. Extensive area of the country i.e. about 50% is covered by the crystalline rocks of the Basement Complex which are poor aquifers and contribute little to the groundwater supply of Nigeria. The Basement Complex rocks made up mainly of igneous and metamorphic rocks are neither porous nor permeable except in areas where the rocks are shattered, jointed or fissured. Solid rocks of the Basement Complex have porosities ranging from 1 to 3 per cent. Permeability is also small because the pores are small and disconnected (Azeez, 1972). Although folds, faults, joints and shear zones are common, they are too localized to be of significant importance as reservoirs of water. Apart from the fracture systems that control basement aquifers, the thickness of the weathered regolith overlying the crystalline rocks is another important factor. Weathering may therefore render the normally impermeable crystalline rocks suitable for ingress and storage of water. Electrical resistivity survey has been found useful in delineating the lateral and vertical limits of the diastrophic features like faults, fractures, joints and shears and delimit the extent and thickness of the weathered mantle (Olorunfemi and Oloruniwo, 1985, Olorunfemi and Olayinka, 1992, Bala and Ike, 2001). Despite the problems associated with basement aquifers, Azeez (1972) has pointed out that large number of hand-dug wells in the rural areas not supplied with pipe-borne water was an indication that considerable water was available underground though occurrence was erratic because of the discontinuous nature of the groundwater source area. Low success ratio of previous borehole programmes in the Nigeria's Basement Complex was attributable to well sites by intuition (Azeez, 1972, Oyinloye and Ademilua, 2005). What is needed is a scientific method of locating well sites by means of sophisticated geophysical instruments. Hence, the vertical electrical sounding survey was aimed at investigating the hydrogeological conditions of Bishini area for locating water potentially viable to sustain people in the area for domestic purposes. This was to be accomplished by taking adequate number of resisitivity soundings suitably distributed over the area.

Site Location and Geology

Bishini lies between co-ordinates 10˚26′ to the North and 7˚52′ to the East within the Basement Complex of Nigeria (Figure 1). The area is a little less than half square kilometer. Bishini falls within the geologic terrain underlain by the Precambrian basement complex rocks of Nigeria characterized by the Migmatite-gneiss complex, older granites, charnockites, quartzite and minor intrusive lithologies (Rahaman, 1988). The local geology showed that the area is underlain by rocks of the basement complex (migmatites, gneisses and granite). Outcrops are rare except for a few Laterite capping the bedrock. The Laterite consists of different horizons with distinct petrographic characteristics which may have significant influence on the shape of the VES curves. The surface terrain is fairly uniform permitting easy stretch of the Schlumberger array.

METHODOLOGY

The electrical resistivity method has been applied extensively in groundwater exploration because it can clarify the subsurface structure, delineate groundwater zone and is inexpensive (Mazae et al., 1985). The resistivity survey was carried out using ABEM, Tetrameter SAS 300C employing the collinear four electrode Schlumberger configuration array. The electrical sounding stations were sited on fairly long straight stretch of land to reduce error in both resistivity measurements and interpretation. The successive electrode positions were measured and marked on either side of the centre along a straight line. The current electrode separations [AB/2] varied from 1.0 to 150m while the potential electrodes were kept at an initial separation of 0.5m. The potential electrodes were increased only when it became too small for reliable readings to be obtained and the separation did not exceed 4m in any VES station. The data collection points of the study area are shown in figure 1.

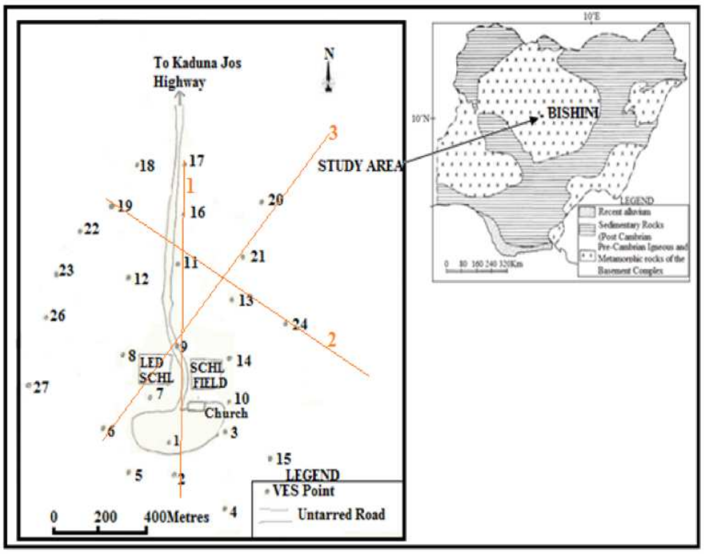

Figure 1: Location of the Study Area

RESULTS AND DISCUSSIONS

Twenty seven VES locations were occupied in the study area. Results obtained from the interpreted data are presented in form of geoelectric curves (Figure 2) and sections (Figure 3) while comparative details of the various geoelectric parameters are presented in Table 1. Interpretation could be qualitative or quantitative. In basement terrain, groundwater occurrence is in the porous and permeable weathered basement rocks and in the fractured/jointed basement columns. Olorunfemi and Fasuyi, (1993), identified five different combinations of the weathered basement aquifer and the fractured/jointed aquiferous zone in the basement complex of Nigeria. The combinations include weathered layer aquifer, weathered/fractured (unconfined) aquifer, weathered/fractured (confined) aquifer, weathered/fractured (unconfined)/fractured (confined) aquifer and fractured (confined) aquifer. Furthermore, it was established that the highest groundwater yield is often obtained from weathered/fractured (unconfined)/fractured (confined) aquifer. In this research, qualitative interpretation revealed predominant of the weathered layer aquifer (63%) typified H and QH curves while the weathered/fractured (unconfined) aquifer with QHA and HA curve signatures (7.4%) was least represented. Other types of aquifers include weathered/fractured confined (11%) and fractured confined (18.52%) with HKH and KH curve signatures respectively. Furthermore, maximum of five different subsurface lithologic units which include topsoil, lateritic-clay, weathered basement, fractured basement and fresh basement were established. The thickness of the first layer varied between 1 and 9m while the resistivity ranged from 212 - 11048Ω-m. Similarly, the second layer has thickness that ranged from 2 – 10m and resistivity of 76 - 22938Ω-m. The low resistivity values in some VES locations were consequent of varied lithology and water retention capacity of the soils as water percolates through the sub surface. High resistivity up to 22938Ω-m, typified the hard indurated red laterite common to tropical regions of Nigeria. The water bearing layer has thickness of 4 – 42m and resistivity that ranged between 30 and 552Ω-m. VES locations (1, 9, 11, 12 and 13) with low resistivity values and high overburden thickness (overburden thickness; 21 – 45m, resistivity; 87 - 248Ω-m) and the fractured layers VES 3 and VES 7 are viewed as likely locations for borehole sitting. Figure 3a shows the resistivity cross-section constructed for VES points 2, 1, 9, 11, 16 and 17 in the N – S direction. The figure delineates three to four layers along this profile. The resistivity values of the third layer (aquifer) vary from 84Ω-m to 552Ω-m while the thickness ranged between 14 and 25m. VES 9 with maximum thickness of 25m and resistivity of 134Ω-m is most favourable for borehole sitting along this profile. Fresh basement rocks with resistivity values ranging from 1930Ω-m to 68711Ω-m and of infinite thickness are found beneath the aquiferous layer. As for the resistivity cross section in the NW-SE direction (Figure 3b) (Profile 2) across VES24, VES 13, VES 11 and VES 19, four to five layers were encountered with the maximum five layers restricted to VES 19. VES 19 with aquifrous layer (85 Ω-m, 8m thick) and a pre-basement horizon (234 Ω-m, 9m thick) representing a fractured bedrock sequence could constitute viable groundwater source. All the layers are underlain by basement rock of infinite thickness and resistivity of 1095 - 65416Ω-m. The third geo-electric section (Figure 3c) cutting across VES 6 VES 9, VES 21 and VES 20 in the NE-SW direction has maximum of four lithologic units. VES 21 that is characterized by very thin overburden and with significantly thick column of the basement that is densely fractured with layer resistivity of 977Ω-m and thickness of 57m typified by geoelectric curve HA is considered favourable for borehole sitting. The fresh basement rocks of infinite thickness and resistivity value of 67829Ω-m underlying the horizon showed wide contrast. The depth to basement (Figure 4) varies from 6m at VES 25 representing the basement high to 62m at VES 21, the deepest points in the study area which corresponds to basement depression (Figures 3c and 4). VES 21 constitutes the most suitable layer for groundwater occurrence and preferred point for drilling.

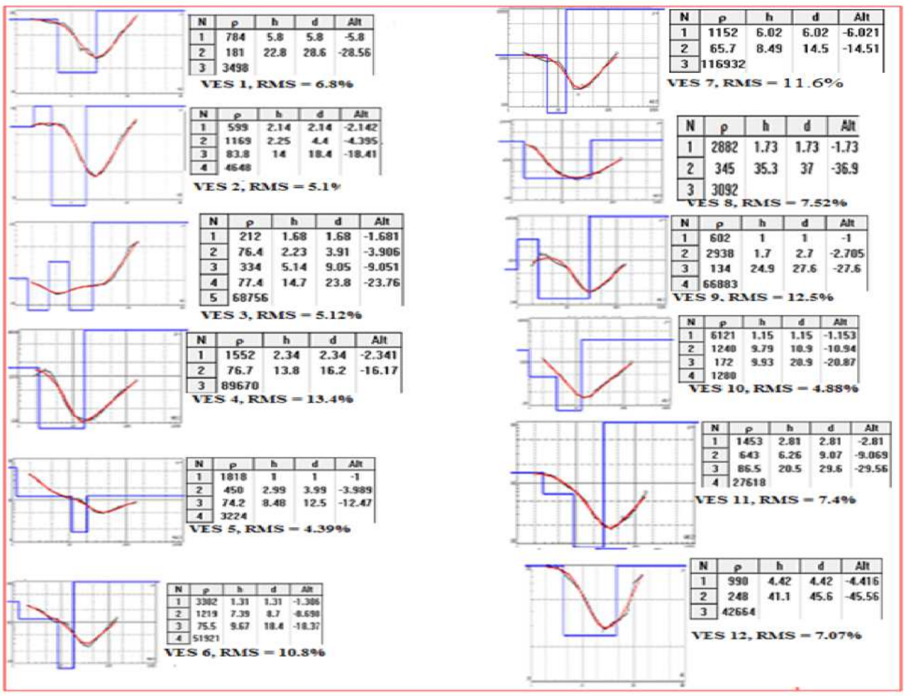

Figure 2: Sounding Curves from the Study Area Continued

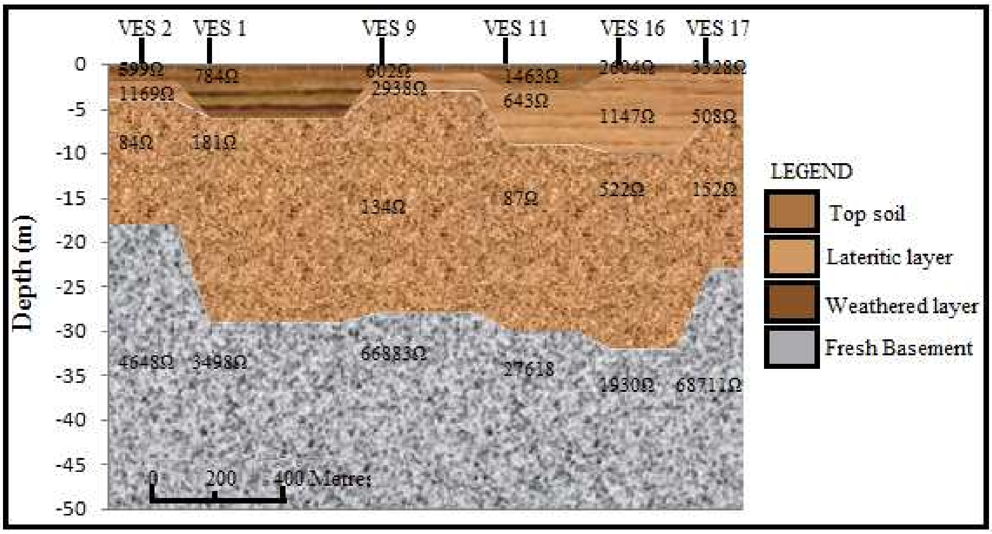

Figure 3a: Geoelectric Section across N-S Direction (Profile 1)

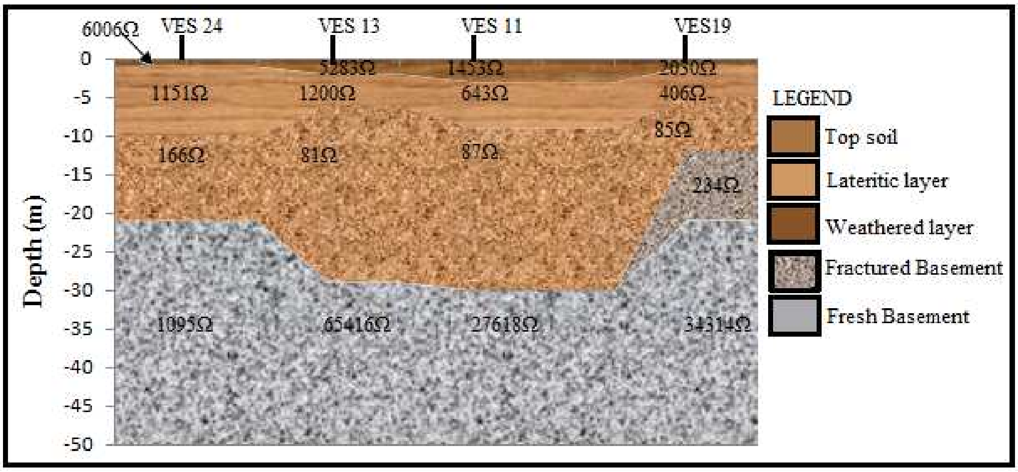

Figure 3b: Geoelectric Section across NW-SE Direction (Profile 2)

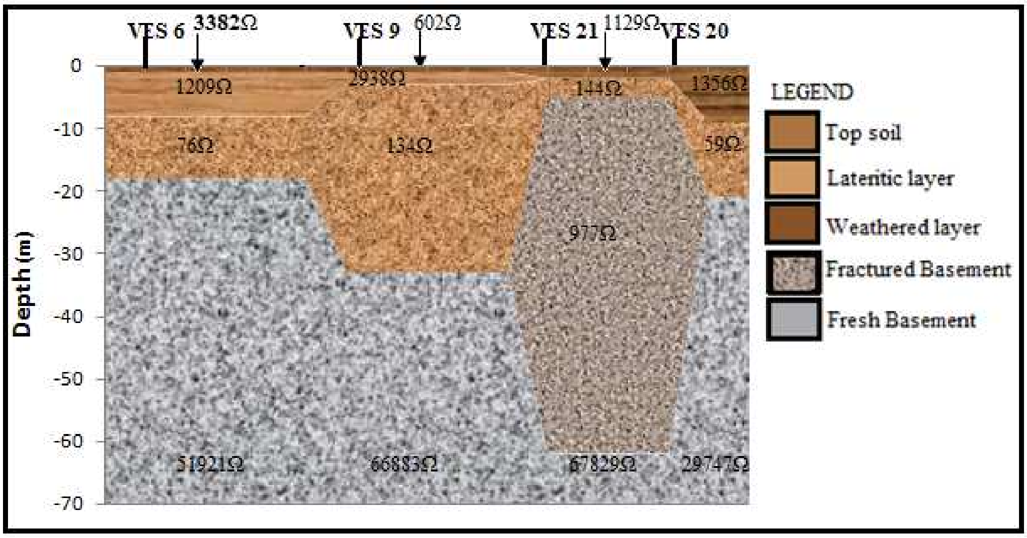

Figure 3c: Geoelectric Section across NE-SW Direction (Profile 3)

Table 1: Correlation Table

Ves Point		1	2	3	4	5	6	7	8	9	10	11	12	13	14
CURVE TYPE		H	KH	HKH	H	HA	QH	HKH	H	KH	QH	QH	H	QH	H
LTIHOLOGY															
TOP SOIL	TOP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	BASE	6	2	2	2	1	1	1	2	1	1	3	4	2	2
	THICKNESS	6	2	2	2	1	1	1	2	1	1	3	4	2	2
	Ωm	784	599	212	1552	1818	3382	1587	2882	605	6121	1453	990	5283	614
LATERITIC-CLAY	TOP	-	2	2	-	1	1	1	-	1	1	3	-	2	-
	BASE	-	6	2	-	4	8	3	-	3	11	9	-	6	-
	THICKNESS	-	4	2	-	3	7	2	-	2	10	6	-	4	-
	Ωm	-	1169	76	-	450	1219	531	-	22938	1240	643	-	1200	-
WATER BEARING SANDY &GRAVEL	TOP	6	6	4	2	4	8	3	2	3	11	9	4	6	2
	BASE	29	20	9	16	16	13	11	37	28	21	30	46	29	22
	THICKNESS	23	14	5	14	12	10	8	35	25	10	21	42	23	20
	Ωm	181	84	334	77	74	76	66	345	134	172	87	248	83	109
FRACTURED BASEMENT	TOP	-	-	9	-	-	-	7	-	-	-	-	-	-	-
	BASE	-	-	24	-	-	-	20	-	-	-	-	-	-	-
	THICKNESS	-	-	15	-	-	-	13	-	-	-	-	-	-	-
	Ωm	-	-	77	-	-	-	80	-	-	-	-	-	-	-
BASEMENT	TOP	29	20	24	16	16	13	20	37	28	21	30	42	29	22
	BASE	-	-	-	-	-	-	-	-	-	-	-		-	-
	THICKNESS	-	-	-	-	-	-	-	-	-	-	-		-	-
	Ωm	3498	4648	68756	89670	3224	51921	1899	3092	66883	1280	2761	42664	65416	43775

Ves Point		15	16	17	18	19	20	21	22	23	24	25	26	27
CURVE YPE		QH	QH	QH	KH	QHA	H	HA	KH	QH	QH	H	KH	H
LTIHOLOGY														
TOP SOIL	TOP	0	0	0	0	0	0	0	0	0	0	0	0	0
	BASE	1	1	1	1	1	9	2	1	1	1	3	3	5
	THICKNESS	1	1	1	1	1	9	2	1	1	1	3	3	5
	Ωm	11048	2684	2328	643	2030	1356	1120	588	2869	6006	1498	1122	1710
LATERITIC-CLAY	TOP	1	1	1	1	1	-	-	1	1	1	-	3	-
	BASE	4	6	6	3	6	-	-	3	10	10	-	10	-
	THICKNESS	3	5	5	2	5	-	-	2	9	9	-	7	-
	Ωm	487	1147	508	3025	486	-	-	3254	1769	1151	-	1578	-
WATER BEARING SANDY &GRAVEL	TOP	4	6	6	3	6	9	2	3	-	10	3	-	5
	BASE	12	28	23	25	14	21	5	32	-	21	6	-	22
	THICKNESS	8	22	17	22	8	12	3	29	-	11	3	-	17
	Ωm	106	522	152	173	85	59	144	47	-	166	30	-	233
FRACTURED BASEMENT	TOP	-	-	-	-	14	-	5	-	10	-	-	10	-
	BASE	-	-	-	-	23	-	62	-	32	-	-	32	-
	THICKNESS	-	-	-	-	9	-	57	-	22	-	-	22	-
	Ωm	-	-	-	-	234	-	977	-	915	-	-	931	-
BASEMENT	TOP	12	28	23	25	23	21	62	29	32	21	6	32	22
	BASE	-	-	-	-	-	-		-	-	-	-	-	-
	THICKNESS	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ωm	7976	1998	68711	5224	34314	29742	67829	2057	1926	1095	1254	1924	96281

CONCLUSIONS

This present work presents the results of vertical electrical sounding for groundwater occurrence in the crystalline basement terrain at Bishini area in Kaduna state, North Central Nigeria. Interpreted sounding curves revealed predominant of the weathered layer aquifer (63%) while the weathered/fractured (unconfined) aquifer (7.4%) was least represented. Three to five electro-stratigraphic units were delineated in the study area, namely: the topsoil (indurated laterite), lateritic clay, weathered basement rock, fractured basement rock and fresh basement. The weathered and / fractured basement rocks constitute the aquiferous zones in the area. The depth to basement varies from 6m at VES 25 representing the basement high to 62m at VES 21, the deepest points in the study area which corresponds to basement depression. VES 8, 11, 12 and 21 could be considered for drilling with an average depth of 40 – 60m depending on sounding point.

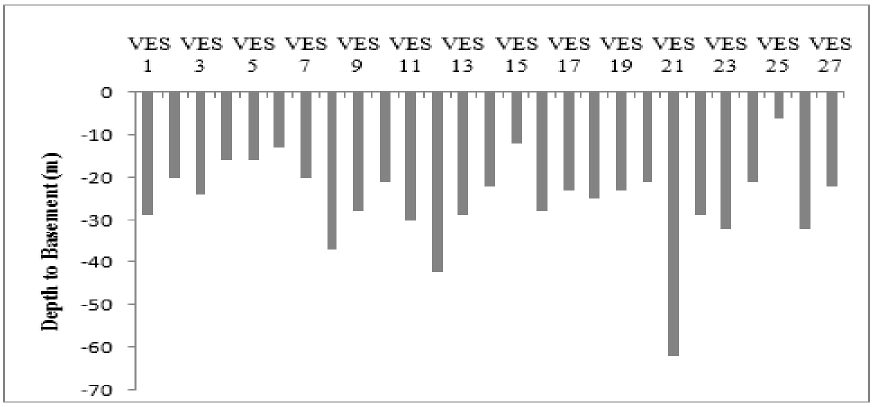

Figure 4: Depth to Basement Rock

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