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Geoelectric Investigation of the Suitability of a Proposed Foldot Ventures Potable Water Factory Site, Ipinsa, near Akure, Southwestern Nigeria

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ABSTRACT: This study is aim at determining the suitability of sitting a potable water factory within Chief Akin Omosebi layout off Ipinsa-Ilara road, near Akure, Ondo State, Nigeria by evaluating the groundwater potential, the aquifer overlying layer protective capacity and the foundation beds competence of the area. A total of twenty (20) vertical electrical soundings (VES) data were acquired along five (5) traverses using Schlumberger array with maximum half-current electrode separation of 150 m. Three curve types were delineated in the area (K, KH and KQ). The VES results delineated three to four geoelectric layers across the study area. The resistivity of the top soil, lateritic weathered layer, clayey sand weathered layer and weathered bedrock/fresh bedrock varies from 187 - 1212, 682 - 4164, 219 - 1157 and 77 - 3525 ohm-m respectively. This study reveals that the area is characterized by high groundwater potential and competent subsurface layers that can serve as foundation bed, but the aquifer layer must be well protected from pollution since the overlying layer(s) longitudinal conductance is less than 1.0 mhos which indicates that the underlying aquifer unit(s) are vulnerable to surface pollution.

Keywords*:* Groundwater potential, aquifer overlying layer, protective capacity, longitudinal conductance and foundation beds competence.

INTRODUCTION

Provision of potable water supply are not been given serious attention in many developing countries of the world, perhaps this is due to infrastructural deficits arising from poor economic state of such countries. Nigeria been a developing countries where commercial production of potable water is a fast growing industry, since most citizens who cannot afford boreholes results into purchase of sachet and bottled water for their daily water consumptions. However for potable water factory to be situated at a particular location two important criteria must be met: The area must have high groundwater potential (Mogaji *et al.,* 2011; Olayanju *et al.,* 2011 and Adeyemo *et. al.,* 2017a) and the aquifer layer must be well protected from pollution and contamination (Oladapo, 2004; Aweto, 2011 and Oni *et al.,* 2017). Presence of good competent subsurface layer(s) is also desirable for the construction of the potable water factory. This study was carried out to determine the suitability of the study area as a good location for sitting the proposed Foldot Ventures Nigeria enterprises' potable water factory. Groundwater potential evaluation have been carried out in crystalline basement complex terrain using different approaches such as isolated analyses of some hydrogeophysical significant parameters, such as overburden thickness, aquifer resistivity, aquifer thickness and bedrock relief (Amadi *et al.,* 2011; Mogaji *et al.,* 2011; Olayanju *et al.,* 2011; Akintorinwa and Olowolafe, 2013 and Adeyemo *et. al.,* 2017a) and application of multicriteria decision analysis (MCDA) method involving many hydrogeological parameters ranging from simple to complex parameters (Adiat et al., 2012; Adiat et al., 2013; Fashae et al., 2013). Similarly many approaches have been used to determine the aquifer protective capacity or aquifer vulnerability of an area. Overlay and index methods that combine specific physical characteristics that affect vulnerability, process-based methods consisting of mathematical models that approximate the behavior of substances in the subsurface environment (Adeyemo *et al*., 2015; Lathamani *et al*., 2015 and Javadi, *et.al.,* 2017) and statistical methods that draw associations with areas where contamination is known to have occurred (Chen *et. al.,* 2013 and Armengol, et. al., 2014). Geotechnical and geophysical methods have been used successfully for foundation beds competence investigations (Mesida, 1986, 1987; Adeyemo and Omosuyi, 2012).

The Study area

The study area is the proposed Foldot Ventures Nigeria Enterprises Potable Water Factory located at Chief Akin Omosebi layout off Ipinsa-Ilara road, near Akure, Ondo State, Nigeria (Figure 1). The area lies within 735840 - 735910 m (Easting) and 809925 - 809990 m (Northing) in (WGS 84) Universal Traverse Mercatum Coordinates and the total surface area is about 1520 m^2 (Figure 2). The surface elevation of the area varies between 415 and 416.5 m above sea level (Figure 2). The area falls within the tropical rainforest of the Southwestern Nigeria, which is characterized by wet and dry seasons with average rainfall of 1,000 - 1,400 mm (Adeyemo et al., 2017a) while the average daily temperature of the area range between 29 and 33 ^{0}C (Adeyemo *et. al.,* 2017a). Groundwater recharge in this environment is mostly through rainfall and lateral base flow. Generally the study area is underlain by Precambrian Basement complex rocks (Igneous and Metamorphic) of Southwestern Nigeria (Rahaman, 1989). In tropical and equatorial regions, weathering processes create superficial layers (Adeyemo *et al*., 2015 and Adeyemo *et al*., 2017a) which often constitute reliable aquifers if significantly thick. Also the concealed basement rock may contain faults and fracture systems which may house groundwater. The area is underlain by rocks of Migmatite-Gneiss-Quartzite Complex (Figure 3) of Southwestern Nigeria (Adeyemo *et. al.,* 2017a and Adeyemo *et. al.,* 2017b).

MATERIALS AND METHOD

This study adopted the vertical electrical sounding (VES) techniques of the electrical resistivity method. The Schlumberger electrode configuration was adopted for the data acquisition (Koefoed, 1979 and Zohdy, 1975) with half-current electrode spread varying from minimum of 1 m to maximum of 100 to 150 m. A total of 20 VES locations arrayed along five (5) traverses were occupied across the area (Figure 4). The field data were interpreted using the conventional partial curve matching techniques (Koefoed, 1979 and Zohdy, 1974) and the results were enhanced using Resist Version 1.0 software (Vander Velpen, 2005). A second order geoelectric parameter (longitudinal conductance) was also determined and the results were presented as a table and different maps.

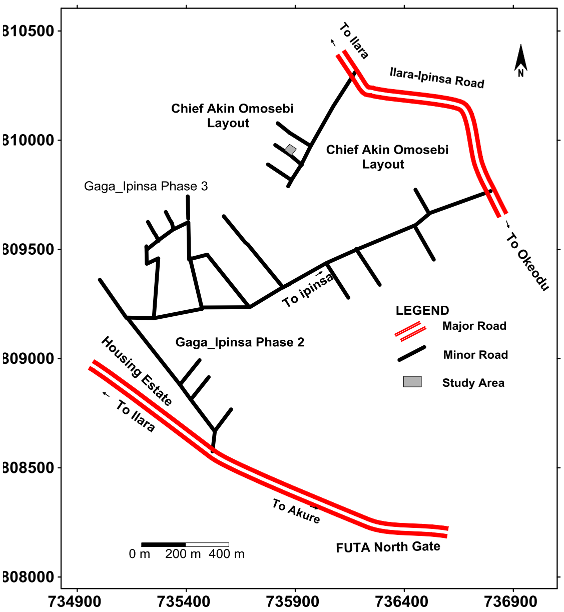


Figure 1: Layout map of Chief Akin Omosebi layout, Ipinsa Ondo State, Nigeria

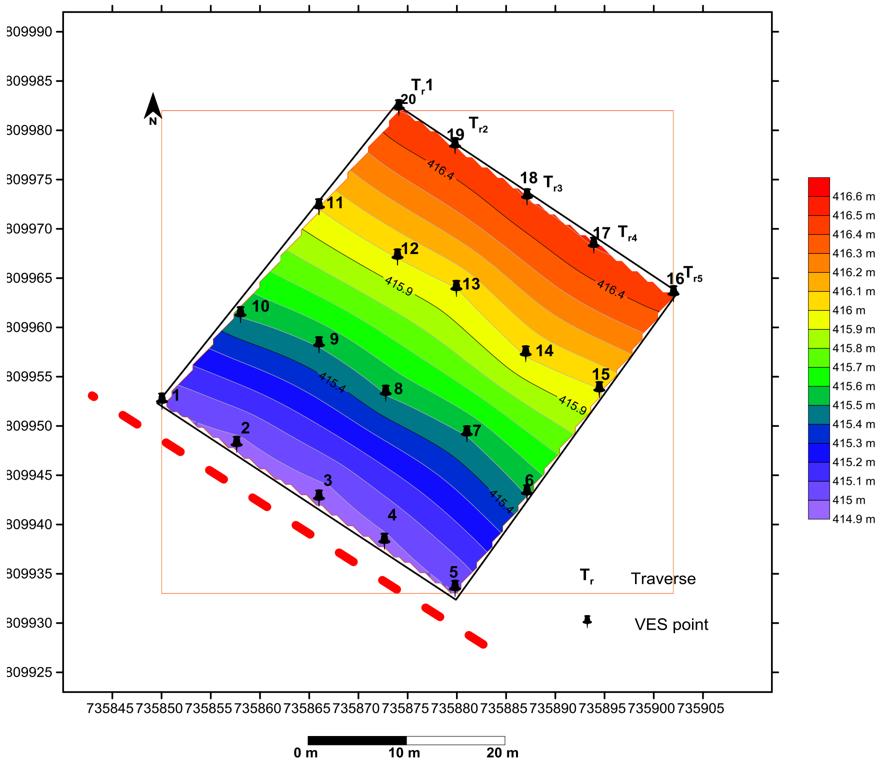


Figure 2: Topographic map of the study area (Foldot ventures site, Ipinsa Ondo State, Nigeria)

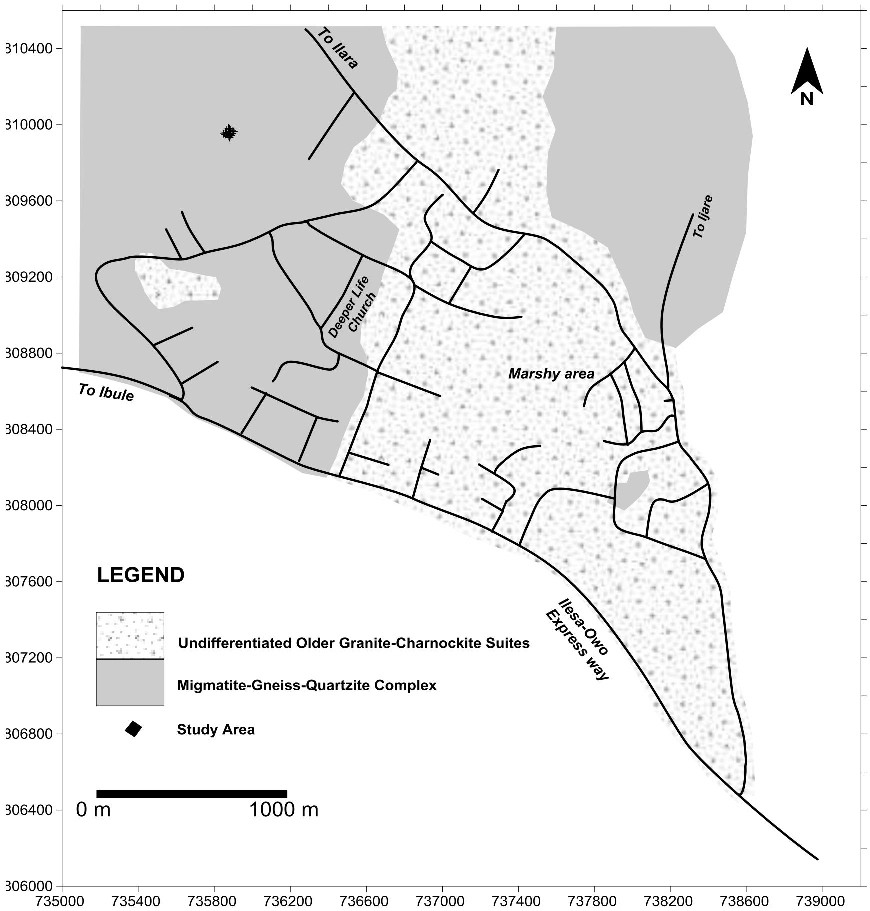


Figure 3: Simplified geological map of the area (Source: Adeyemo *et. al.,* 2017a and 2017b)

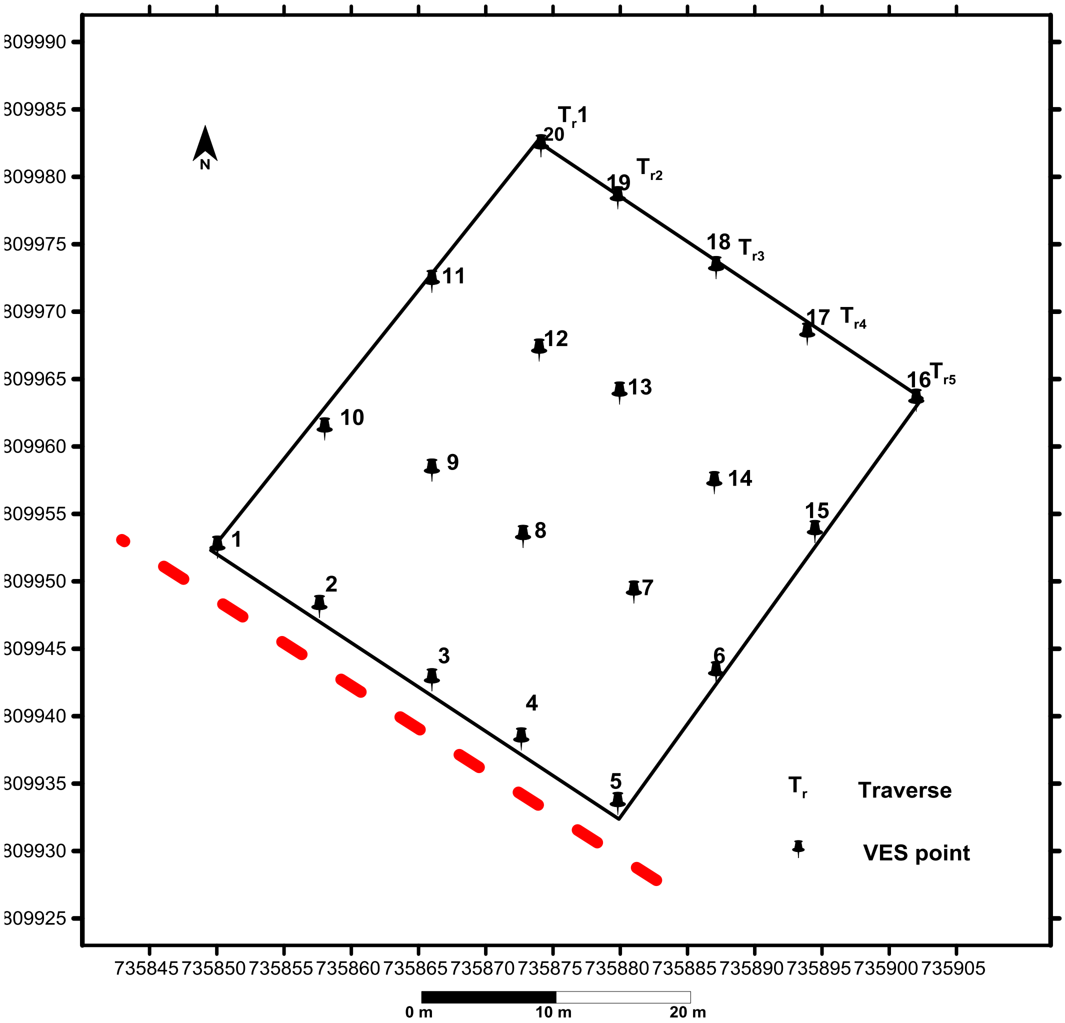


Figure 4: Basemap of the study area showing the VES locations

RESULTS AND DISCUSSION

The vertical electrical sounding (VES) results delineated three to four geoelectric layers across the study area. The K, KH and KQ are the three sounding curve types delineated in the area (Table 1). The K and KQ curves are the predominant curve types in the area, their percentage of occurrence is 40% each, while the KH curve has 20% occurrence. The resistivity of the top soil, lateritic weathered layer, clayey sand weathered layer and weathered bedrock/fresh bedrock varies from 187 - 1212, 682 - 4164, 219 -1157 and 77 - 3525 ohm-m respectively.

Groundwater Potential Evaluation

The groundwater potential evaluation of the area was done by synthesizing the generated aquifer layer resistivity and thickness maps. These two parameters; aquifer resistivity and thickness were considered to be sufficient for evaluating the groundwater potential of the area, because the area extent is small, they are within the same lithologic units and the elevation difference is very negligible (about 1.5 m). The aquifer layers are essentially the clayey sand weathered layer (third geoelectric layer) and weathered bedrock (fourth geoelectric layer) and their resistivity vary from 77 - 457 ohm-m across the study area (Table 1). The aquifer layer resistivity map (Figure 5a) shows that the western part of the area are characterized by higher resistivity indicating lesser water saturation (above 250 ohm-m), while the eastern part of the area is characterized by lower resistivity which is indicative of moderate to high water saturation (80 - 250 ohm-m) based on earlier classification

(Adeyemo *et. al.*, 2017a). The aquifer layer thickness map (Figure 5b) indicates that the whole area have thick aquifer layer (above 40 m) capable of yielding appreciable water quantities (Adeyemo *et. al.,* 2017a). In order to synthesize the two maps, the groundwater potential map (Figure 5c) was generated using additive model first used by Chachadi (2005) and adapted by Adeyemo et al. (2017a). The contributions of the two parameters (aquifer resistivity and thickness) to groundwater potential were weighed as presented in table 2.

Table1: Vertical Electrical Sounding (VES) Results

VES No	Resistivity (Ω-m) $\rho_1/\rho_2/\rho_3\ldots\ldots\ldots\rho_n$	Thickness (m) $d_1/d_2/d_3/\ldots\ldots\ldots d_n$	Curve Type	Depth to Aquifer Layer (m)
1	426/ 2087/ ***219***/ 1808	1.0/ 9.9/ 93.1	KH	10.9
2	387/ 2168/ ***439***/ 3525	1.0/ 8.3/ 60.5	KH	9.3
3	393/ 2303/ ***459***/ 1357	1.0/ 7.5/48.5	KH	8.5
4	1212/ 2010/ ***406***/ 1061	1.5/ 7.7/ 52.0	KH	9.2
5	631/ 2972/ 664/ ***108***	0.8/ 7.9/ 46.8	KQ	55.5
6	286/ 1386/ ***226***	0.8/ 16.9	K	17.7
7	187/ 2163/ ***349***/ ***77***	0.7/ 3.4/ 42.1	KQ	46.2
8	838/ 4164/ 1157/ ***234***	0.7/ 2.6/ 28.5	KQ	31.8
9	399/ 1902/ ***457***	0.5/ 9.8	K	10.3
10	432/ 1322/ ***351***	0.7/ 16.7	K	17.4
11	334/ 1591/ ***356***	0.8/ 13.3	K	14.1
12	373/ 1169/ ***355***	0.9/ 16.5	K	17.4
13	471/ 2381/ 1042/ ***229***	0.6/ 2.9/ 26.8	KQ	30.3
14	272/ 2896/ 846/ ***142***	0.5/ 3.1/ 29.1	KQ	32.7
15	402/ 3304/ 601/ ***143***	0.8/ 3.9/ 31.4	KQ	36.1
16	661/ 2989/ 891/ ***203***	1.3/ 6.2/ 18.1	KQ	25.6
17	357/ 682/ 843/ ***164***	0.8/ 2.7/ 23.2	KQ	26.7
18	526/ 999/ ***298***	1.1/ 23.8	K	24.9
19	606/ 989/ ***373***	0.8/ 12.8	K	13.6
20	408/ 805/ ***400***	1.2/ 10.0	K	11.2

Note: the bold and italicized figures are the aquifer layers resistivity values.

Table 2: Indicators Relative Weights

S/N	Indicators	Normalized Weights
1	Aquifer Layer Resistivity (ohm-m)	5.5
2	Aquifer Layer Thickness (m)	4.5

The two (2) parameters were synthesized using the following relationship;

RT value = $\{[Wt_{resistivity} * Rt_{resistivity}]\ [Wt_{thickhness} * Rt_{thickness}]\}$ (equation 1)

Where,

Wt = Normalized Weight

Rt = Rating

The groundwater potential map (Figure 5c) shows that the western part of the area is of high potential while the eastern part has very high potential. This indicates that boreholes meant for the purpose of commercial potable water supply in the study area should be sited within the eastern part of the area.

Aquifer Overlying Layer Protective Capacity

Another very important parameter to be considered before sitting a commercial borehole is the protective capacity of the aquifer overlying layer(s). The depth to the aquifer layers range from 9.2 – 55.5 m and all things been equal the thicker the overlying layer the more the protective capacity. The overlying protective capacity was determined using the aquifer overlying layer(s) longitudinal conductance as done in previous works (Oladapo, 2004; Aweto, 2011 and Oni *et al.,* 2017). The aquifer overlying layer(s) longitudinal conductance was determined using the following relationship;

$$S = \sum_{i=1}^{n} \left(\frac{hi}{pi}\right) \quad \text{(equation 2)}$$

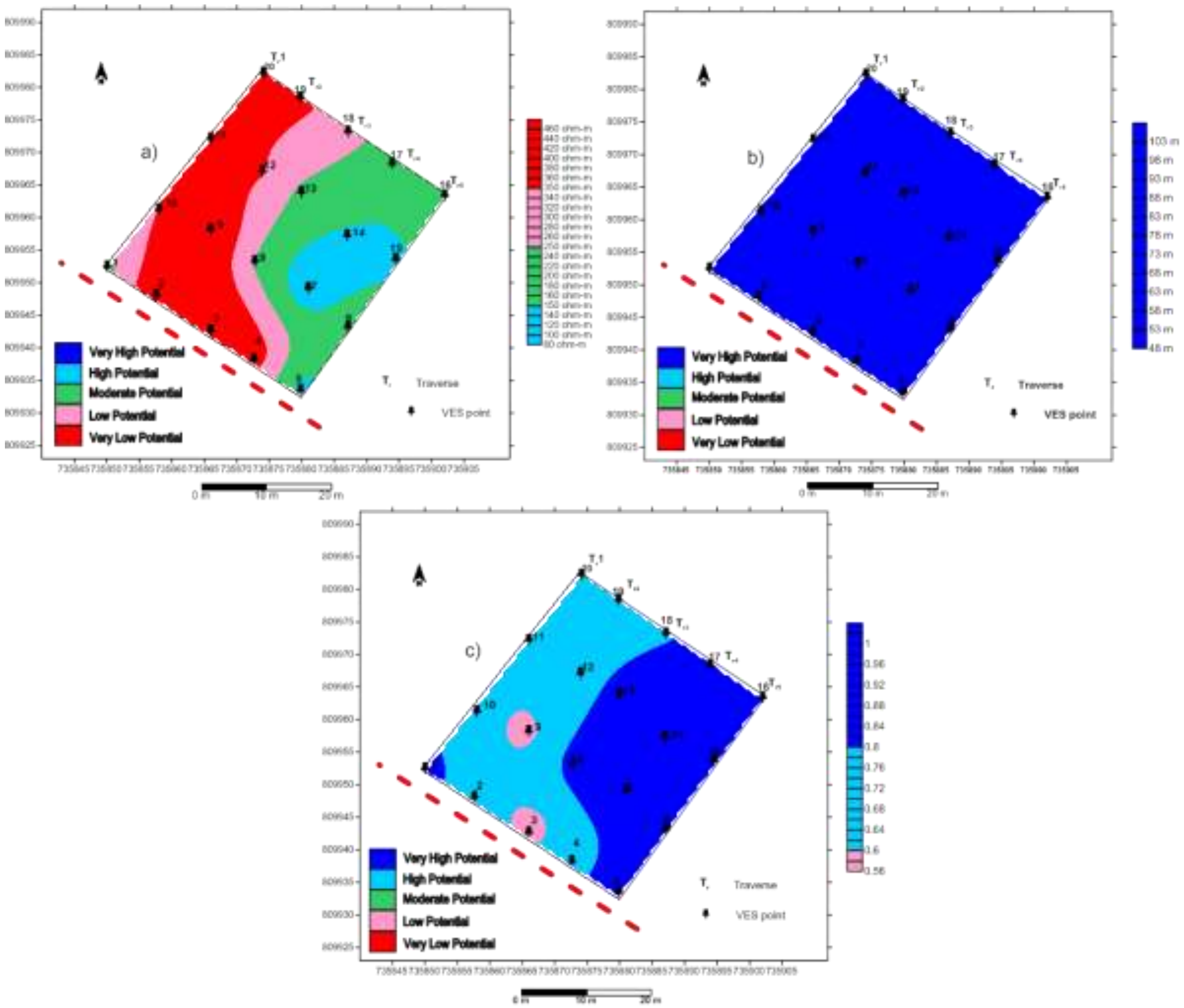
Where,
h_i = layer thickness (m)
ρ_i = layer resistivity (ohm-m)
While, for n layers the total longitudinal conductance (mhos) is:

$$S = \sum_{i=1}^{n} \frac{hi}{\rho i} = \frac{h1}{\rho 1} + \frac{h2}{\rho 2} + \frac{h3}{\rho 3} + \cdots + \frac{hn}{\rho n}$$ (Zhody, *et. al.*, 1974) (equation 3)

The aquifer overlying layer(s) longitudinal conductance map (Figure 6) reveals that the aquifer layer(s) in most part of the study area are overlained by materials of very low to moderate protective capacity (less than 0.1 mhos). This suggest that the the aquifer layer(s) in the area are susceptible to pollution (Oladapo, 2004; Aweto, 2011; Adeyemo *et. al.,* 2015 and Oni *et. al.,* 2017). Therefore standard practice must be followed in carring out borehole completion in this area. Any borehole constructed in the area must be properly grouted and about 5 m radius of the surface around the borehole should be covered with concrete to prevent percolation of possible pollution from the surface.

Foundation Beds Competence

The VES results (Table 1) shows that the second geoelectric layer (lateritic weathered layer) with resistivity range of 682 - 4164 ohm-m is geotechnically competent (Habeeb *et al.,* 2012) and hence can serve as appropriate foundation bed in the study area, however depth to this layer varies from one VES location to the other. The VES result was therefore presented as depth slice maps at three different surfaces (0.5, 0.75 and 1.0 m). As expected the depth slice maps (Figures 7a-c) shows improvement in the subsurface competence with increase in depth, and that the appropriate depth for foundation in the study area is minimum of 1.0 m.



Figures 5: (a) Aquifer layer resistivity map (b) Aquifer layer thickness map and (c) Groundwater potential map of the area

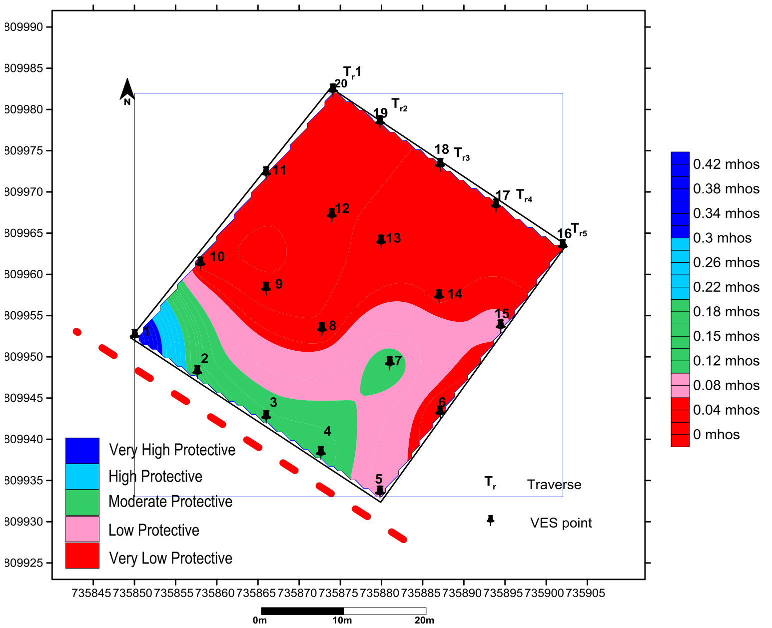
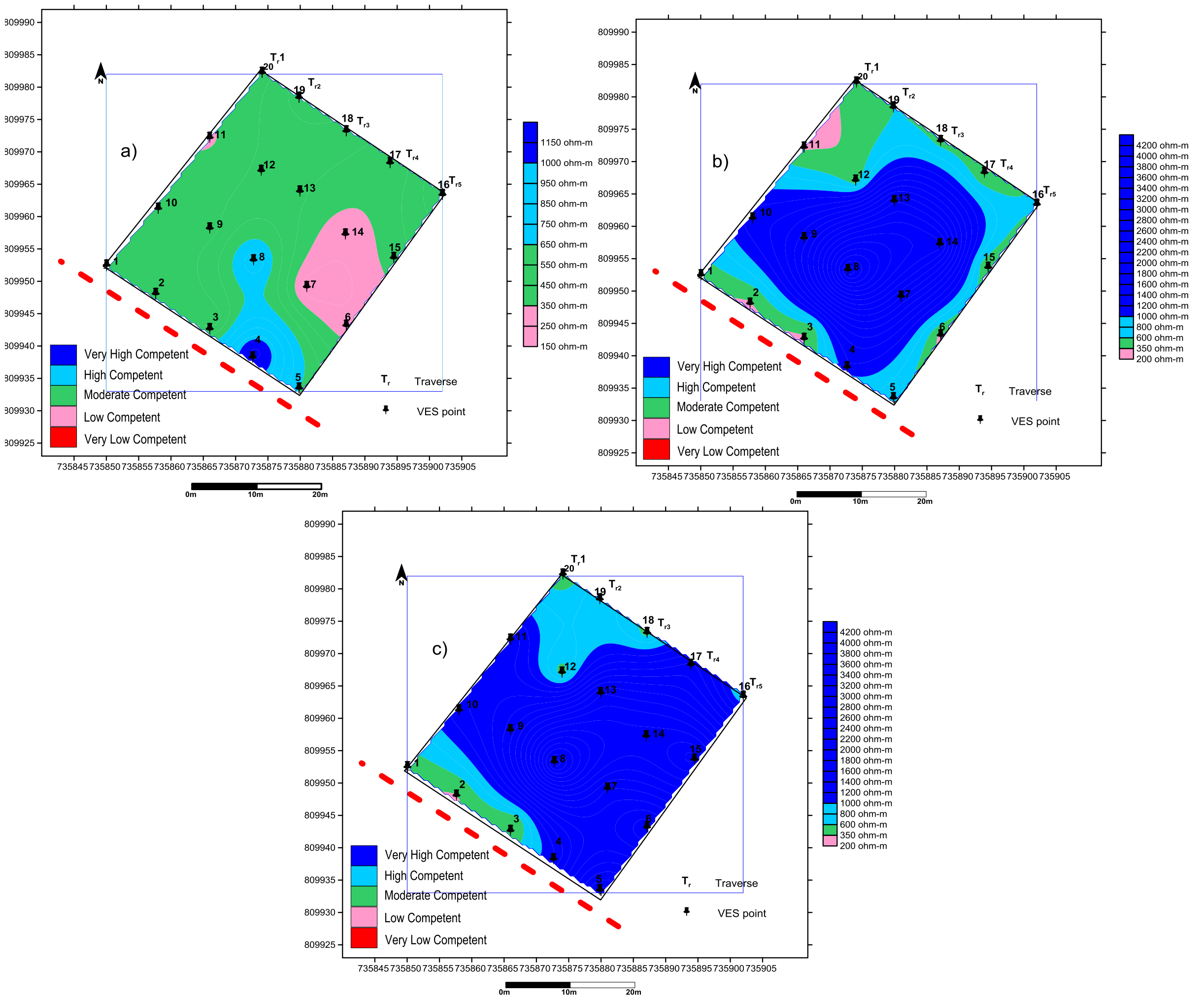


Figure 6: Aquifer protective capacity map of the area



Figures 7: Isoresistivity maps (a) at depth slice of 0.5 m, (b) at depth slice of 0.75 m and (c) at depth slice of 1.0 m

CONCLUSION

The work was carried out to determine the suitability of the study area as a good location for sitting the proposed Foldot Ventures Nigeria Enterprises Potable Water factory. The results discussion showed that the study area is characterized by high groundwater potential and competent subsurface layers that can serve as foundation bed. However the aquifer layer must be well protected from pollution and contamination since the overlying layer(s) longitudinal conductance is less than 1.0 mhos which indicates that aquifer units in the study area are vulnerable to surface pollution. Therefore any borehole constructed in the area must be properly grouted and about 5 m radius of the surface around the borehole should be covered with concrete to prevent possible pollution from the surface.

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