Original Research Article

EVALUATION OF GROUNDWATER LEVEL USING COMBINED ELECTRICAL RESISTIVITY LOG WITH GAMMA (ELGG) AROUND IKEJA, SOUTHWESTERN NIGERIA

Abstract

This study has been able to demarcate the subsurface geologic units based on the lithologic characters. The subsurface geology of Lagos Main land is made up of complex lithologies of an alternating sequence of clay and sand deposits. The borehole lithologic correlation shows that the subsurface geologic sequence is composed of alternations of sand and clay. Lenses of clayey sand and sandy clay occur in places. All the boreholes correlated were located within the Ikeja, Lagos State. The borehole depths vary from 119 m to 127 m and the sand and clay though variable show lateral continuity across the section. Four major fresh water sand aquifer layers were delineated within the upper 127 m of the subsurface sequence. The first aquifer layers were located at depth ranging from 61 m to 71 m below the ground level and thickness of 10 m with the resistivity varying from 190 Ωm to 320 Ωm. The second aquifer layers were located at depth ranging from 79 m to 87 m below the ground level and thickness of 8 m with the resistivity varying from 500 Ωm to 700 Ωm. The third aquifer layers were located at depth ranging from 85 m to 92 m below the ground level and thickness of 7 m with the resistivity varying from 300 Ωm to 590 Ωm while the fourth aquifer layers were located at depth ranging from 82 m to 89 m below the ground level. It has a thickness of 7 m with the resistivity varying from 300 Ωm to 610 Ωm. The aquifers were very heterogeneous as indicated by wide range of aquifer characteristics. Due to the occurrence of the sand formations in the study area, the aquifer level is between the depths of 61 m to 92 m. Hence, if there is a need for industrial purpose the aquifer should be tapped at the depth between 61 m to 89 m, and also screened for water supply. Relatively higher resistivity indicates significant formation fluid.

Keywords: Resistivity log, Gamma log, Lithology, Aquifer level

Introduction

Water is essential to humans and plays a major role virtually in every aspect of human life. Most rocks contain numerous open spaces called interstices in which water may be stored and through which water can move ref. Subsurface water above the zone of saturation is called vadose water, while subsurface water in interstices completely saturated with water is called Groundwater [1]. Groundwater is available only when the rocks in the zone of saturation are permeable enough to transmit sufficient water to wells, springs or streams [2]. Drilling of borehole comprises the action of breaking, crushing, cutting or dislodging the formation materials, clearing out the cuttings from the hole and stabilizing the wall of the hole for completion [3]. Geophysical well logging also called borehole geophysical log, includes all techniques of lowering sensing devices (Sonde or probe) in a borehole and recording physical parameter that may be interpreted in terms of the rock, that contained in the rocks and the construction of the well [4, 5, 6]. Geophysical logs can be interpreted to determine the lithology, geometry, resistivity, formation resistivity factor, bulk density, porosity, permeability, moisture content and specific water-bearing rocks, and to define the source, movement, chemical and physical characteristics of water [6, 7, 8]. Geophysical well logging can provide continuous and objective recording values that are consistent from well to well and from time to time, if the equipment is properly calibrated and standardized [9]. The most widespread uses of logs in groundwater hydrology are to define the lithology and geometry of aquifer systems and to estimate the quality of contained water [11]. The resistivity of a material is that property which characterizes its opposition to the electrical current ref. The electrical resistivity of a formation is directly related to the nature, quantity, quality, and distribution of the formation water ref. In as much as these factors vary appreciably from one formation to another, resistivity measurements made in a borehole can be used to determine formation boundaries and to obtain information on the nature of the beds traversed by the drill [12]. Resistivity logging devices measure the electrical resistivity of a known or assumed volume of earth materials under the direct application of an electric current or an induced electric current ref. The resistivity curve is obtained by lowering either one or several electrodes into the borehole and making appropriate electrical measurements [13]. These measurements are plotted in terms of depth and the resulting graph is called a resistivity curve ref. The gamma ray log (natural gamma ray log) is one of the radiation logs which involve the measurement of fundamental particles emitted from unstable radioactive isotopes ref. It is a measurement of the natural gamma radioactivity of the formations ref. In sedimentary formations, the gamma ray log normally reflects the shale (clay) content of the formations ref. The advantage of radiation logs over most others is that they may be recorded in either cased or open holes filled with any fluid, because the radioactive elements tend to concentrate in clays and shale ref. The main objective of carrying out this borehole logging was to optimize the performance of the borehole in a cost effective way by appreciably correlating the groundwater aquifer level in Ikeja. Also, in order to determine the quality of contained water by identifying the fresh water aquifers relative to depth using combined electrical resistivity log with gamma (ELGG).

Site Description and Geology of the Study Area

The study area falls entirely in the Dahomey Basin, ikeja, Lagos State. The geology of the area is underlain by sedimentary rocks with no basement outcrop (Figure 1). The Dahomey Basin was formed following the break-up of the African and South American Plates [14] and is partially separated from the Niger Delta and the Eastern Nigeria sedimentary basin by a Ridge of crystalline rocks. The earliest sediments in the area were deposited as a result of the first major marine transgression in South Western Nigeria [15]. The upper sediments in the Dahomey Basin are recent. This is underlain by Coastal Plain Sands of the Quaternary Age. Basically the geologic sequence in the Dahomey Basin extends from Precambrian to Recent. Three distinct sequences, which are closely related to the geology of the sediments, are identified from past studies of South-Western Nigeria [16]

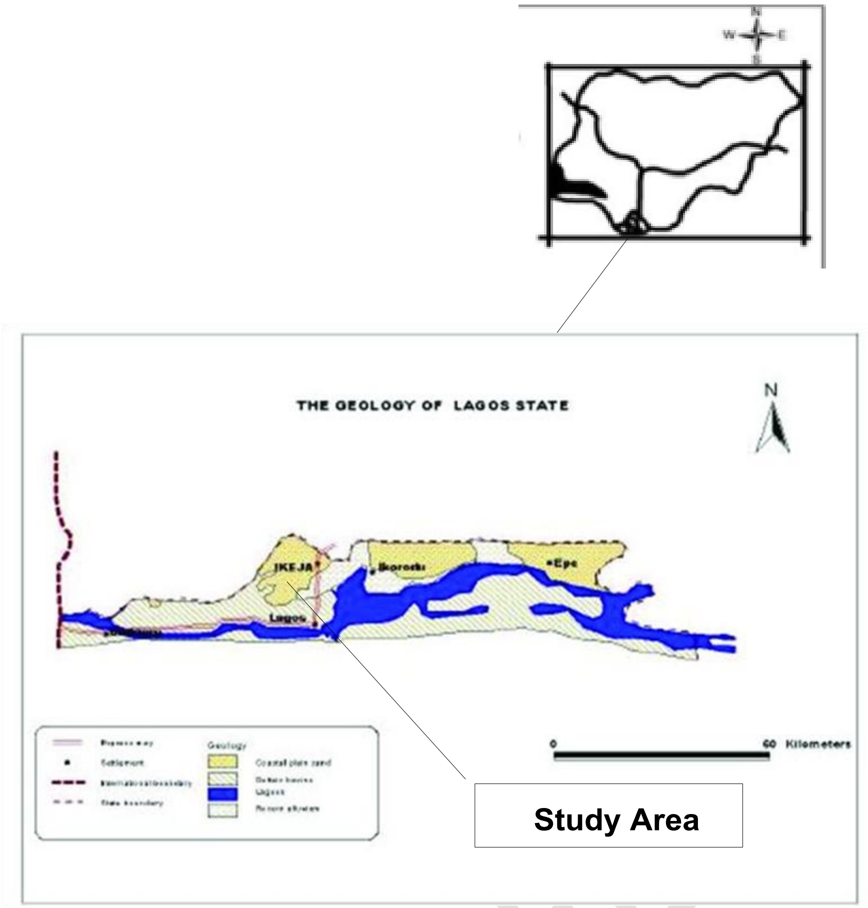

Figure 1. Geological Map of Lagos Showing the Study Area

Methodology

Four composite geophysical well logs were obtained from four borehole locations in Ikeja, Lagos state (Figure 2). The composite log consists of the resistivity and gamma ray measurements. The GPS coordinates were gotten in UTM units showing the northing, easting and elevation of the location above sea level. The cutting were collected at an interval of 3 meters in the well bore, washed and bagged. In this study, one lithology detection log (gamma ray log) and one fluid detection log (resistivity) were employed in interpreting the subsurface deposition of the wells. The subsurface layers (sand and clay) were delineated and correlated stratigraphically. Delineation into aquifer horizons was done from well to well by the use of lithologic logs and supplemented by geophysical logs. The interpretation of well logs involves choosing best models from the given data so as to obtain results which are geologically plausible. Well log interpretations are often quantitative and qualitative, but only the qualitative technique was employed for facies analysis. The qualitative interpretation involved the use of models which represent the characteristic log response to the formation parameters. The qualitative interpretations involve Identification of sand units from chosen top sand to the last water bearing sand using gamma ray log, Classification of the sand that contain aquifer of relevant geological formation that juxtaposed it, Identification of water-bearing sand from resistivity log and Identification of fresh water sand. A baseline is drawn on the gamma log, which is midway between the maximum and minimum gamma signals. All signals to the left of the baseline were regarded as sand while all signals to the right of the baseline are taken as clay. Based on the available data on the ditch cuttings, Lithology was prepared. The motive of the resistivity log was used to determine the sandy formation. Formation fluid of high resistivity indicates sand while low resistivity indicates clay. A deflection of the resistivity curve to the right indicates sand (fresh water). On the other hand, a deflection towards the resistivity curve to the left indicates clay. Resistivity of rock units and fluid are measured directly on the geophysical log [17]. Intervals of logs from different wells were matched for similarity or for characteristic log responses to lithological markers. The borehole lithologic logs of the study area were correlated along one direction. The subsurface layers were correlated and delineated stratigraphically along the aforementioned directions and aquifer levels were delineated.

Figure 2.Satellite imagery of the study area showing the point of Borehole logs

Results and Discussion

The data obtained from four representative wells of the study area were presented in a digitized form. Figure 3 displays the digitized logs borehole one (1) to four (4) with well drilled to the depth of 132 meters. The lithology of the borehole consists entirely of alternating layers of sand, clay, sandy clay and clayey sand. The sand layers are significantly thick, uniform and continuous with intercalations of clayey sand, sandy clay and clay layers. The lithology of the borehole was deduced from the Natural Gamma Log which goes along with the resistivity log

Geophysical Correlation of boreholes

Each of the boreholes is discussed based on their lithology and formation resistivity from the available logs (Figure 4 to 7). Generally the lithology of the boreholes formations consist of cylcothems of sand, clay, clayey sand and sandy clay. Sometimes, the sand occurs as lenses within the clay formation. Interpretation of gamma ray and resistivity logs of water wells in the study area also reveal the existence of aquifer bearing sand. Identification of the major aquifers for each of the wells of the study has been made. All the wells were made up of multilayer aquifer systems but were reduced to major ones. Lithology is derived from the gamma ray log and the corresponding saturating fluid is gotten from the resistivity log. Lithology of the formations is tabulated in respect to depth and corresponding formation description (Tables 1 to 4). Table 5 illustrates the summary of water bearing sands depth in the study area with Bh1 varies from 26 to 50 m, 55 to 57 m, 61 to 71 m and 77 to 83 m while Bh2 ranges from 15 to 23 m, 25.5 to 28 m, 33 to 36 m, 71 to 74 m, 79 to 87 m and 97 to 100m. Bh3 varies from 22 to 25 m, 64 to 68 m, 85 to 92 m, 98 to 102 m and 107 to 112 m while Bh4 ranges from 23 to 27 m, 30 to 34 m, 56 to 60.5 m, 71 to 74 m and 82 to 89 m.

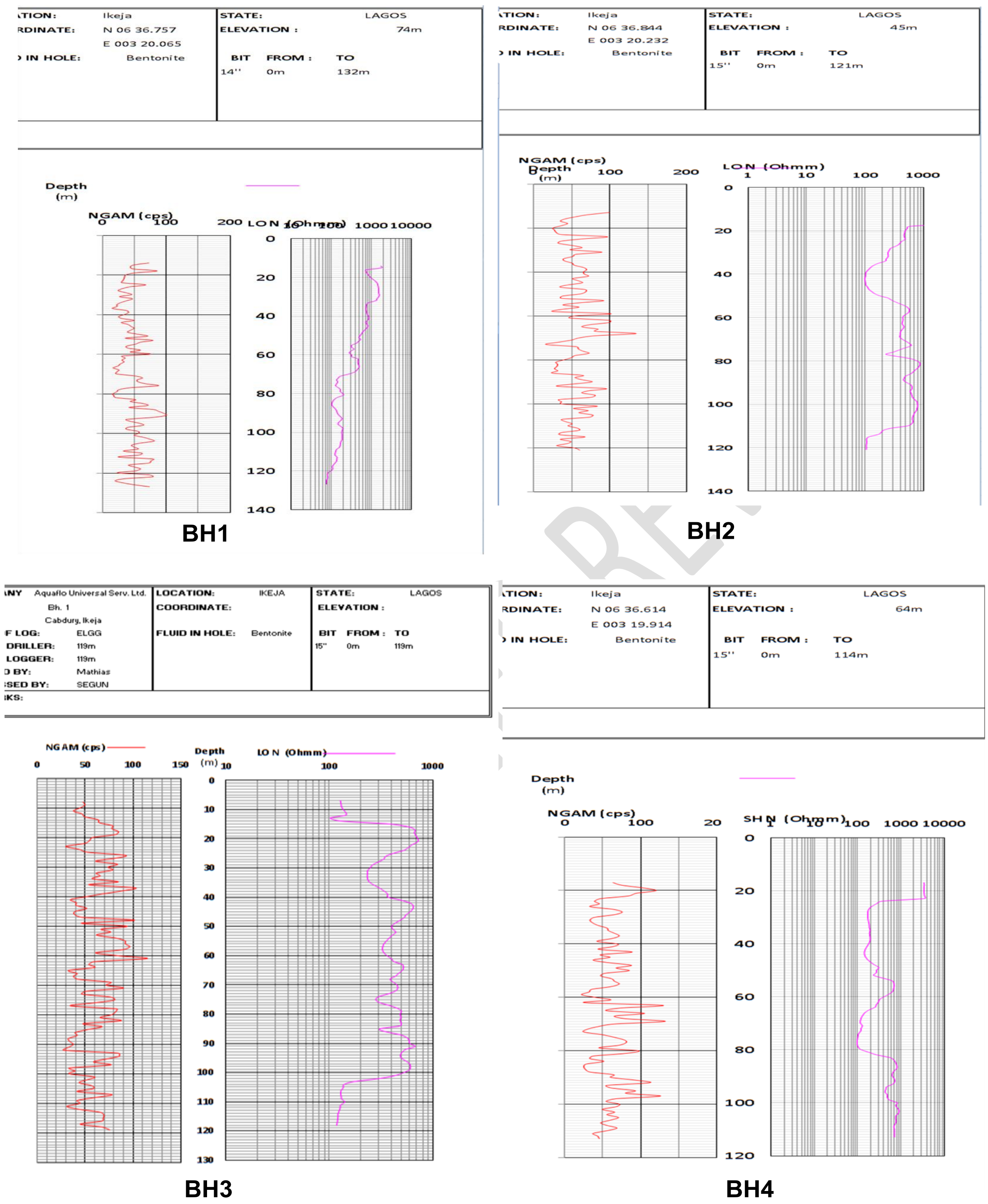

Figure 3. Digitized Logs of Borehole 1 to 4 of the Study Area

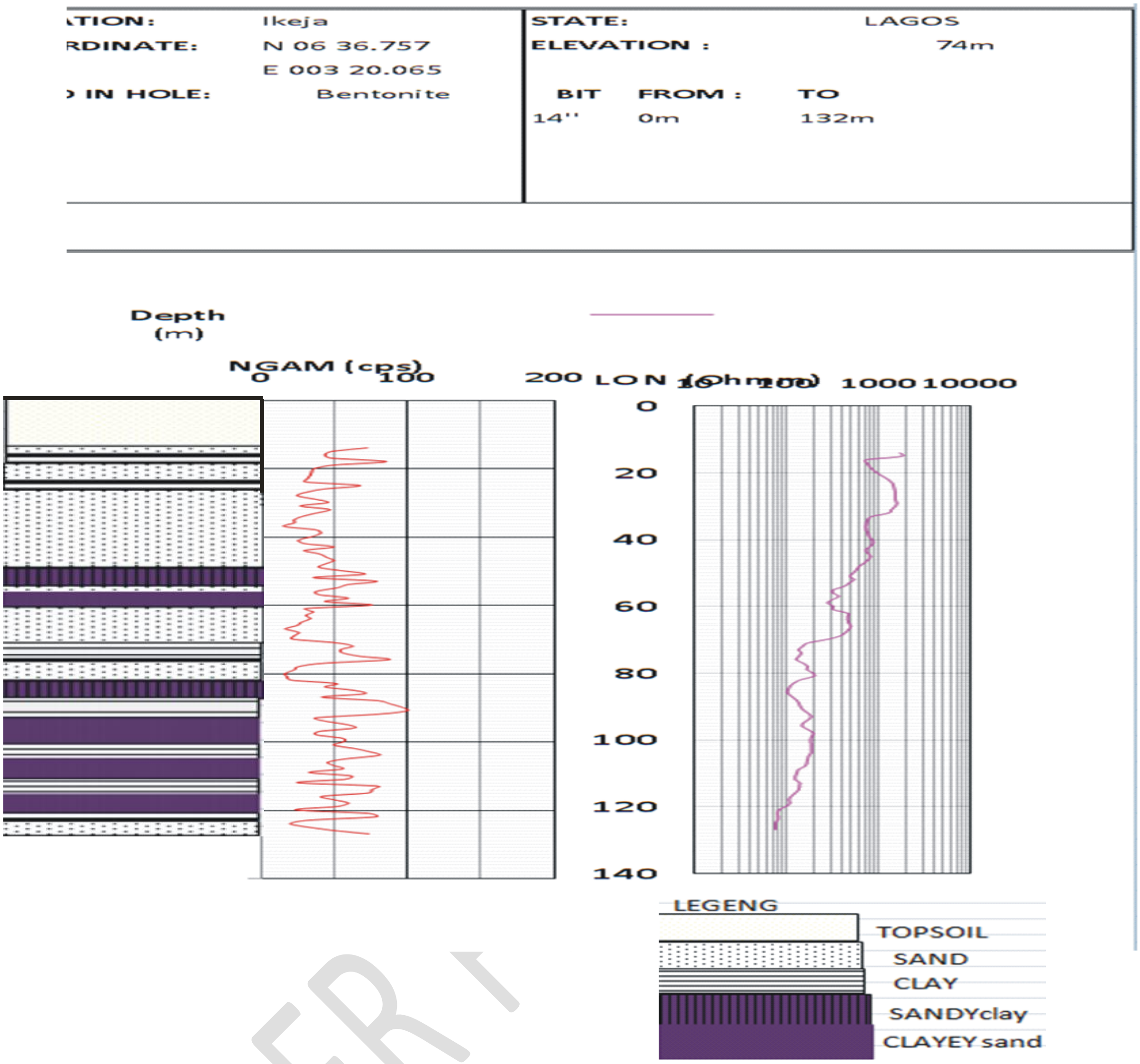

Figure 4 Geophysical Correlation of borehole1

Table 1.The lithology of Borehole 1 in respect to depth and corresponding formation description.

Depth(m)		Lithologic description
From	To	
15	17	Sand
17	19	Clay
19	25	Sand
25	26	Clay
26	50	Sand
50	55	Clay, sandy
55	57	Sand
57	61	Sand, clayey
61	71	Sand/medium
71	77	Clay
77	83	Sand
83	87	Clay, sandy
87	93	Clay
93	101	Sand, clayey
101	105	Clay
105	112	Sand, clayey
112	116	.Clay
116	121	Sand, clayey
121	122.5	Clay
122.5	126	Sand

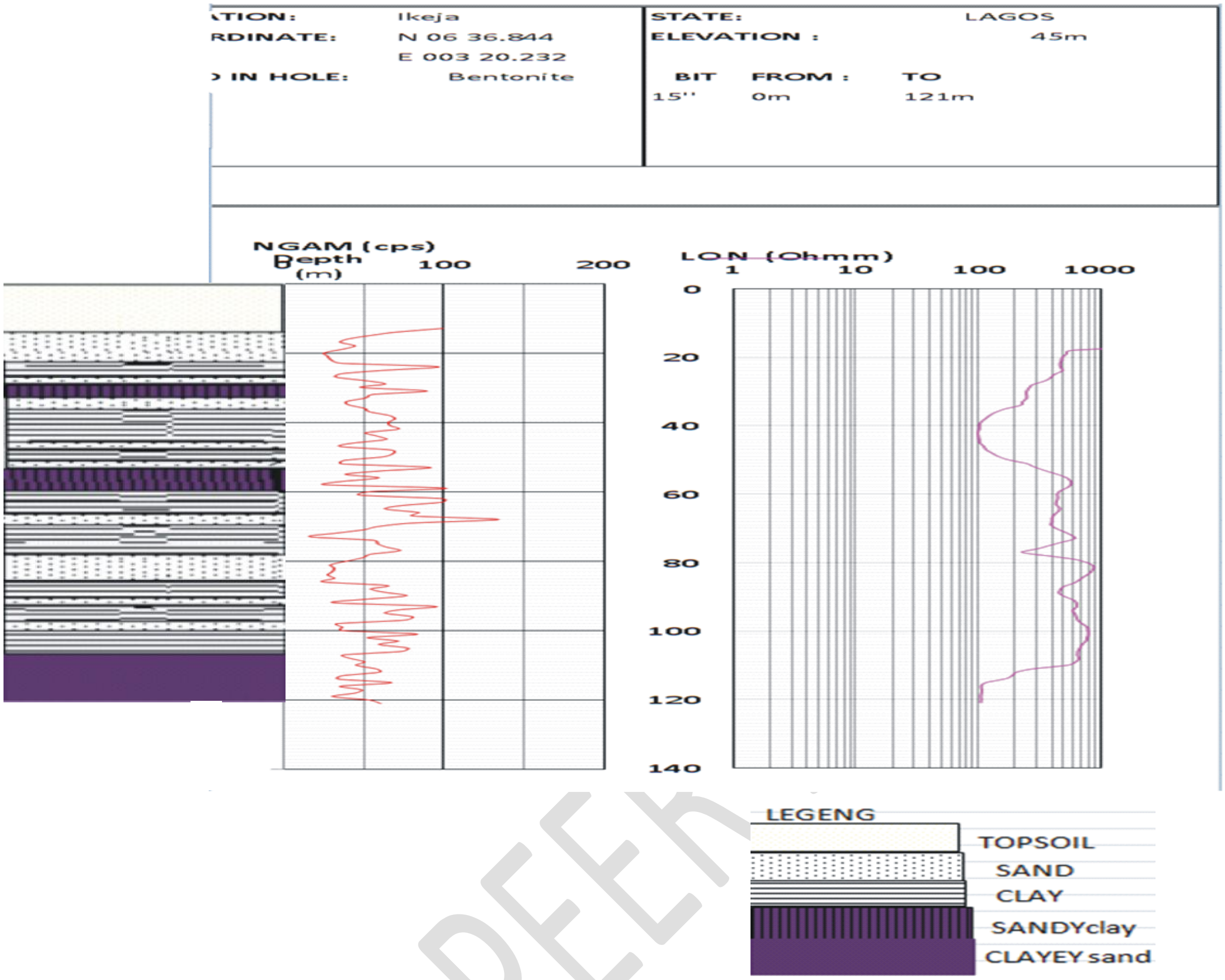

Figure 5. Geophysical correlation of borehole 2

Table 2. The lithology of Bh2 in respect to depth and corresponding formation description.

Depth (m)		Lithologic description
From	To	
13	15	Clay
15	23	Sand
23	25.5	Clay
25.5	28	Sand
28	33	Clay sandy
33	36	Sand
36	46	Clay
46	47.5	Sand
47.5	51	Clay
51	52	Sand
52	61	Clay Sandy
61	71	Clay
71	74	Sand
74	79	Clay
79	87	Sand
87	91	Clay
91	92	Sand
92	97.5	Clay
97.5	100	Sand
100	107	Clay
107	121	Sand clayey

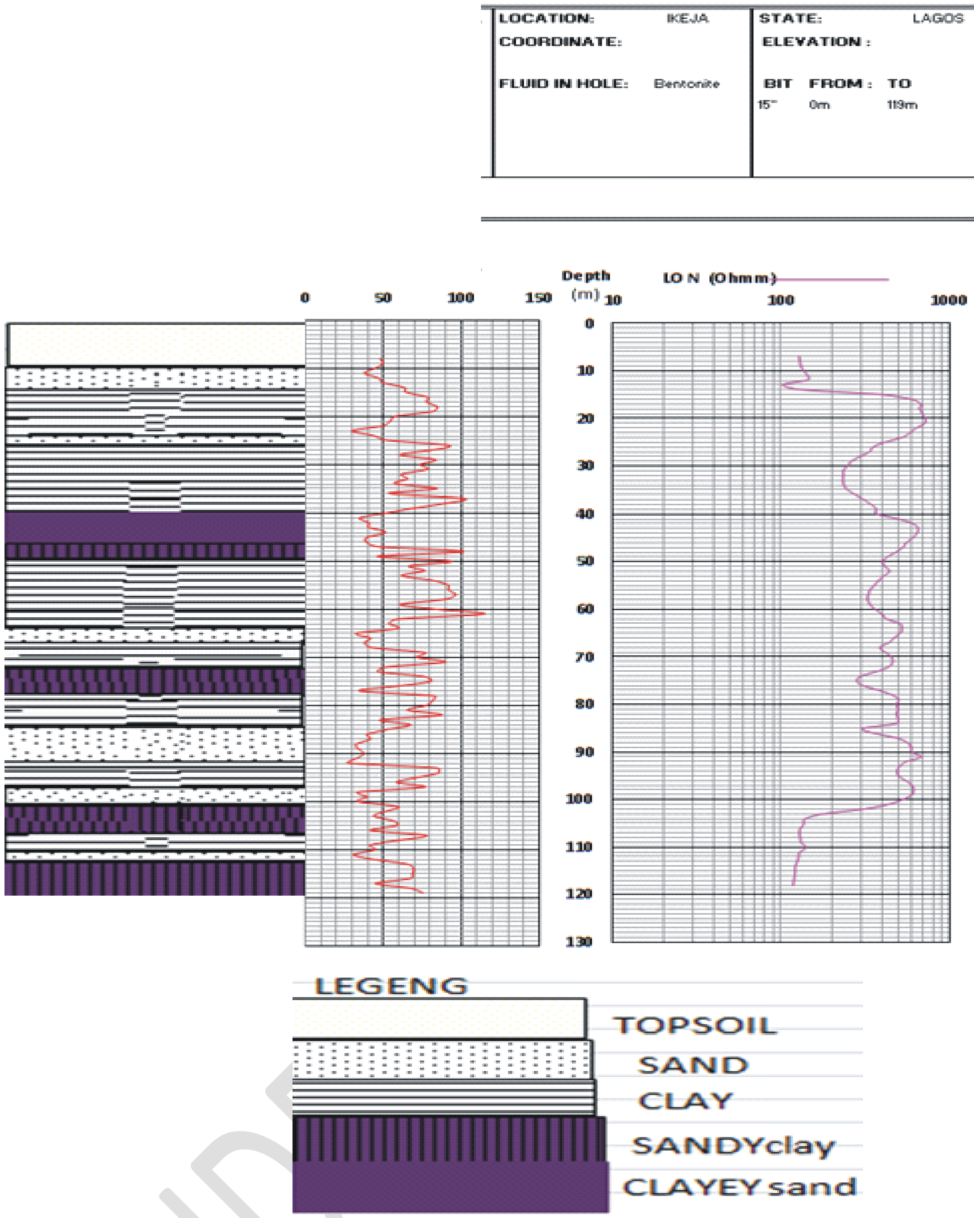

Figure 6. Geophysical Correlation of borehole3

Table 3. The lithology of Bh3 in respect to depth and corresponding formation description.

Depth (m)		Lithologic description
From	To	
8	12	Sand
12	22	Clay
22	25	Sand
25	40	Clay
40	47	Sand, clayey
47	49	Clay, sandy
49	64	Clay
64	68	Sand
68	72	Clay
72	78	Clay, sandy
78	85	Clay
85	92	Sand
92	98	Clay
98	101	Sand
101	106	Clay, sandy
106	109	Clay
109	112	Sand
112	119	Clay, sandy

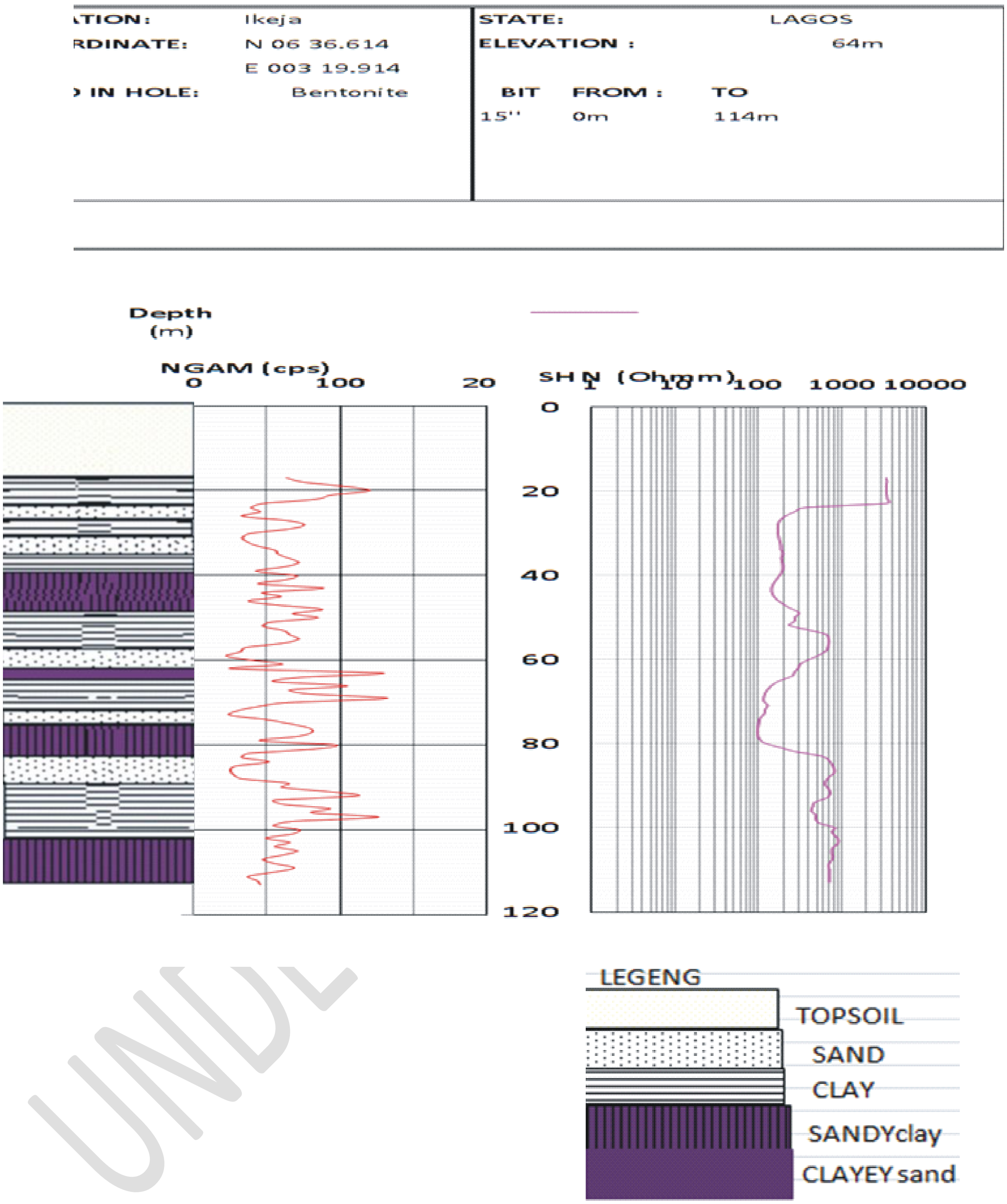

Figure 7. Geophysical correlation of borehole4

Table 4. The lithology of Bh4 in respect to depth and corresponding formation description.

Depth(m) From	To	Lithologic description
17	23	Clay
23	27	Sand
27	30	Clay
30	34	Sand
34	38	Clay
38	47	Clay, sandy
47	56	Clay
56	60.5	Sand
60.5	62	Sand/medium, clayey
62	71	Clay
71	74	Sand
74	82	Clay, sandy
82	89	Sand
89	102	Clay
102	113	Clay, sandy

Table 5. Summary of the water bearing sands depth in the study area.

WATER BEARING SANDS							
S/N	LOCATION/AREA	WATER BEARING SANDS DEPTH (m)					
1	Bh1	26-50	55-57	61-71	77-83		
2	Bh2	15-23	25.5-28	33-36	71-74	79-87	97-100
3	Bh3	22-25	64-68	85-92	98-102	107-112	
4	Bh4	23-27	30-34	56-60.5	71-74	82-89	

Correlation of Lithological Logs

Lithostratigraphic sections and resistivity correlations are relevant in aquifer development because they give us an insight into the general subsurface stratification and fluid characteristics. Table 6 shows the lithostratigraphic and resistivity correlations of the main land region studied in the aforementioned directions. Figure 8 illustrates the correlation of lithological logs showing the fresh water bearing sand of each well in the study area. All the boreholes correlated are located within the coastal plain sands. The borehole depths vary from 119m to 127m**.** The stratigraphic section is composed of alternations of sands and clays. The sands and clays, though variable, show lateral continuity across the section. Table 7 show the four major fresh water sand aquifer layers that were delineated within the upper 127m of the subsurface sequence. The first aquifer layers were located at depth ranging from 61m to 71m below the ground level. It has a thickness of 10m with the resistivity varying from 190Ωm to 320Ωm. The second aquifer layers were located at depth ranging from 79m to 87m below the ground level. It has a thickness of 8m with the resistivity varying from 500Ωm to 700Ωm. The third aquifer layers were located at depth ranging from 85m to 92m below the ground level. It has a thickness of 7m with the resistivity varying from 300Ωm to 590Ωm while the fourth aquifer layers were located at depth ranging from 82m to 89m below the ground level. It has a thickness of 7m with the resistivity varying from 300Ωm to 610Ωm

Table 6. showing fresh water saturated and their resistivity values

S/N	AQUIFERS	DEPTH [M]	THICKNESS [M]	RESISTIVITY [ΩM]
BOREHOLE1	A	26-50	24	500-1700
	B	55-57	2	320-380
	C	61-71	10	190-320
	D	73-83	10	130-150
BOREHOLE2	A	15-23	8	500-1000
	B	25.5-28	2.5	280-450
	C	33-36	3	180-220
	D	71-74	3	400-600
	E	79-87	8	500-700
	F	97-100	3	790-800
BOREHOLE3	A	22-25	3	410-600
	B	64-68	4	390-500
	C	85-92	7	300-590
	D	98-102	4	300-600
	E	107-112		130-600
BOREHOLE4	A	23-27	4	190-1100
	B	30-34	4	180-190
	C	56-60.5	4.5	400-700
	D	71-74	3	110-140
	E	82-89	7	300-610

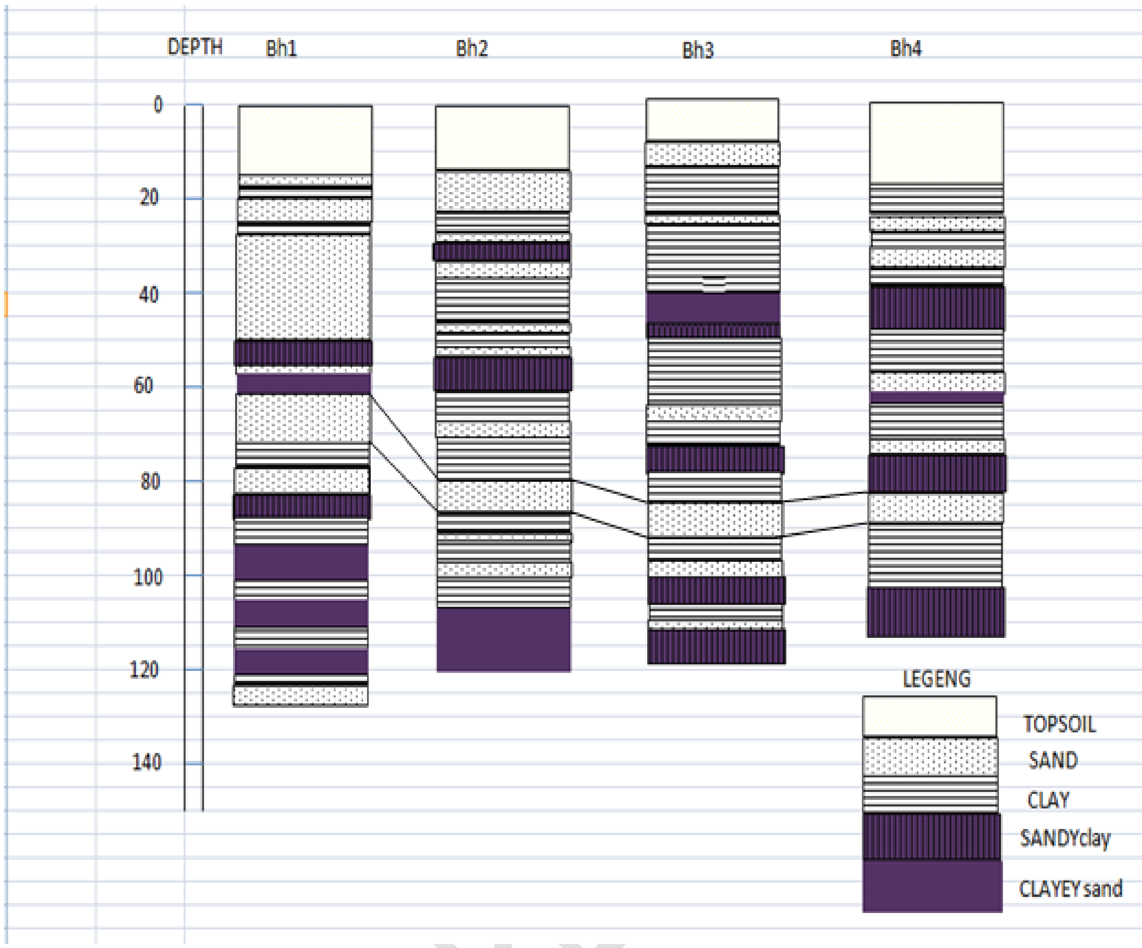

Figure 8. lithological log correlation of the aquifer

Table 7 Show the major depth of aquifers in the four boreholes

S/N	AQUIFERS	DEPTH [M]	THICKNESS [M]	RESISTIVITY [ΩM]
BOREHOLE1	C	61-71	10	190-320
BOREHOLE2	E	79-87	8	500-700
BOREHOLE3	D	85-92	7	300-590
BOREHOLE4	E	82-89	7	300-610

CONCLUSION

The subsurface geologic units have been demarcated in this study based on the lithologic characters. The borehole lithologic correlation shows that the subsurface geologic sequence is composed of alternations of sands and clays. Lenses of clayey sand, sandy clay and silty clay occur in places. The geophysical log and Lithology log were correlated from the Bh1, Bh2, Bh3 and Bh4. All the boreholes correlated were located within the coastal plain sands. The borehole depths vary from 119m to 127m**.** The stratigraphic section is composed of alternations of sands and clays. Four major fresh water sand aquifer layers that were delineated within the upper 127m of the subsurface sequence. The first aquifer layers were located at depth ranging from 61m to 71m below the ground level. It has a thickness of 10m with the resistivity varying from 190Ωm to 320Ωm. The second aquifer layers were located at depth ranging from 79m to 87m below the ground level. It has a thickness of 8m with the resistivity varying from 500Ωm to 700Ωm. The third aquifer layers were located at depth ranging from 85m to 92m below the ground level. It has a thickness of 7m with the resistivity varying from 300Ωm to 590Ωm while the fourth aquifer layers were located at depth ranging from 82m to 89m below the ground level. It has a thickness of 7m with the resistivity varying from 300Ωm to 610Ωm. The subsurface geology of Lagos Main land is made up of complex lithologies of an alternatisng sequence of clay and sand deposits. The data available allows for delineation of subsurface into four aquifer horizons. Sand and gravel constitute the materials in the aquifer of recent sediments and Coastal Plain Sands. Four major fresh water bearing sand aquifer layers suggesting that the deposits could be of fluvial usually estuarine deposits. The aquifers are very heterogeneous, as indicated by wide range of aquifer characteristics. In light of this information, it is recommended that due to the occurrence of the coastal plain sand in the study area the aquifer level is between the depths of 61m to 92m. Hence, if there is a need for industrial purpose, the aquifer should be tapped at the depth between 61m to 89m, and also screened for water supply. Relatively higher resistivity indicates significant formation fluid.

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