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EFFECT OF DOWN-HOLE LITHOLOGICAL VARIATION ON WATER BEARING CAPACITY OF SOME BOREHOLES IN ILORIN, NIGERIA

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ABSTRACT. - Effect of Down-Hole Lithological Variation on Water Bearing Capacity of Some Boreholes in Ilorin, Nigeria. The paper attempts to explain the effect of downhole lithological variation on water bearing capacity of some boreholes in Ilorin Nigeria. Specifically, the study examined the lithological characteristics of the boreholes, assessed the variability in weathered overburden and analyzed the inter-relationships between lithology, hydrology and topography of the boreholes. Data used were extracted from twenty (20) borehole logs collected from the archive of Lower Niger Basin Development Authority in Ilorin. Information extracted from the borehole logs are: the number of lithological units intersected by each of the borehole and their depths, the nature of geological materials making up the lithological units and their moisture conditions. Information on coordinates and topographic heights of the boreholes are not given on the logs and those were collected from the field personally by the researcher using handheld GPS (Garmin GPS Channel 76 Model). The collected data were analyzed using descriptive statistics. Results reveal nine downhole lithological units with loamy and lateritic soil making up the first layer of lithology in 95% of the boreholes. Thickness of the top soil and the saprolite overlying the bedrock, has mean values of 4.2m and 11.3m respectively. Depth to water in the borehole ranged between 24.7 and 140m and with a mean value of 55.9m. Three (3) of the boreholes have two lenses of aquifer while the remaining seventeen (17) have one aquifer lens each. The three (3) boreholes with two aquifer lenses have their minor aquifers located within the saprolite. The main aquifer in most (65%) of the boreholes is located within the fractured basement while the remaining (35%) boreholes have their main aquifer located in the weathered basement. Correlation analysis revealed topographic elevation as one of the drivers of hydrology in the study area.

Keywords: *lithology, groundwater, saprolite, basement, topography*.

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INTRODUCTION

Groundwater is water existing in the voids of geological formations, in the pores and fissures of rocks below the surface of the Earth. It represents 0.58% of the total water resource available in nature and accounts for about 21% of global freshwater reservoirs (Monroe and Wicander, 2005). Okeola and Salami (2014) regard it as an important feature of the environment and an invisible part of the hydrological cycle. Groundwater remains the preferred source of drinking water globally (Guppy et al., 2018) and it makes a critical contribution to the progressive realization of the human right globally. According to Carrard et al. (2019), its development is considered a key strategy for addressing gaps in service delivery especially in developing countries where 2.1 billion people lack access to safely managed water and 844 million lack basic water (Velis et. al., 2017).

The importance of groundwater in meeting potable water demand in both rural and urban settlements in Nigeria cannot be over emphasized. This is due to its characteristics of high chemical and bacteriological quality at source, availability in-situ and its relatively low cost of development and maintenance of its equipment. Groundwater is often considered more reliable than surface water and more accessible because it can be directly exploited by users (Margat, 2013). According to Williams et al. (2014), groundwater could offer a potential source of water to supplement surface water sources or be used as a sole source supply for small communities and industries.

Apart from the aforementioned qualities of groundwater, the pathetic situation of public water supply through pipes in Nigeria has further endeared groundwater usage to many private individuals and some public agencies. Sule et al. (2016) observed that most settlements in Nigeria do not have access to improve water supply through pipe and where such facility exist according to them, they are either malfunctioning or broken down. The World Bank Group report as presented by Andres et. al. (2018) linked the non performance of water agencies in Nigeria to poor design, implementation and high cost. The report observed that the operating cost of most water agencies in Nigeria is too high because many of the agencies rely on diesel generators to power equipment since power supply in the country is erratic.

Although a number of studies such as Parameswari and Padmini (2018), Maity and Mandal (2019) and Pande et al. (2019) have reported the potential zones of groundwater as being generally determined by climate, landscape and environmental parameters of relief, slope, soil, land use/ land cover, etc., groundwater occurrence in any region is also influenced by geological and geomorphic conditions which ultimately control yields (Adimalla, 2020). Because of this, exploration for groundwater in regions underlain by crystalline basement rock such as Ilorin, the study area in this investigation, can be quite challenging. More than 90 percent of the area is underlain by crystalline basement rocks of Precambrian age (Oyegun, 1983).

Crystalline rocks belong to the category of hard rocks that are virtually devoid of any primary porosity. The occurrence of groundwater in this rock type according to Wijesekera (1984) is dependent on the development of secondary porosity which might have resulted from structural deformations, weathering dissolution and mass movements. According to Gustafon and Krasny (1994), hydraulic conductivity in the fractured zone of the basement complex rock is spatially variable as the nature of the fractures and faults within the rock can make borehole yields differ by several orders of magnitude within the same rock unit and often within short distances.

A detailed study of the effect of lithological characteristics on the occurrence of groundwater is crucial to the development and management of water resources; this especially germane in basement complex area where groundwater occurrence exhibits great variability. Specifically, the study examined the lithological characteristics of some boreholes, assessed the variability in weathered overburden and analyzed the inter-relationship between lithologic, hydrologic and topographic parameters in the study area.

THE STUDY AREA

Ilorin, the capital city of Kwara State, Nigeria (fig. 1), is the study area in this investigation. The city was chosen for investigation for two reasons. The first reason is due to the increasing reliance on groundwater by residents of the city for various activities because of the failure of the public water supply agency in meeting demand. The second reason is due to the high failure rate of boreholes constructed in the city. Studies such as Ifabiyi and Ashaolu (2013), Aderibigbe et al. (2008) and Ijaiya (2000) have earlier investigated the problem of water supply in the city. Ilorin is situated in the north-central part of Nigeria and located between latitudes 8°23' and 8°34' North of the Equator and between longitudes 4°29' and 4°42' East of the Greenwich Meridian. Wet season is usually experienced in the region between the months of May and October while dry season is between November and April. The annual mean rainfall for the area is 1,200mm (Olaniran, 2002) and this exhibits double maximal pattern with peak periods in the months of July and September. Average relative humidity in the area is 79.7% and this varies seasonally.

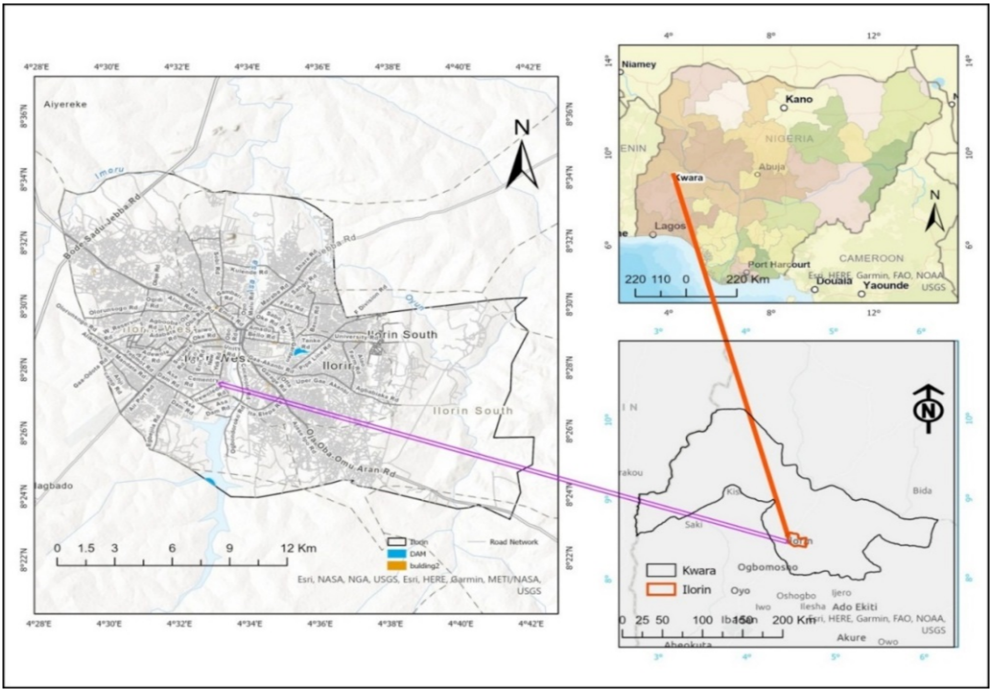

Fig. 1. Map of Ilorin with Kwara State and Nigeria as Insets.
Source: Kwara State Town Planning Authority (2021)

Ilorin is underlain by Precambrian basement complex, comprising mostly gneiss granite, schist and undifferentiated metasediment rock (Azeez, 1972). The overburden is composed mainly of clay, sand and silt (Areola, 1978). Substantial area of the city is also underlain by sedimentary rocks which contain laterites and alluvial deposits (Oyegun, 1983). Precambrian igneous and metamorphic rocks of basement complex are neither porous nor permeable except in places where they are deeply weathered or fractured (Clark, 1985). Lithological logs for the region as analyzed by Adelana and Olasehinde (2004) revealed that weathering is fairly deep and rocks have been jointed and fractured severely at between 30-68m below the surface. In some parts of the study area groundwater is difficult to access, especially during the dry season (Aderigbe et al., 2008). The city is drained mainly by River Asa which flows from South to North. Tributaries of River Asa in Ilorin are rivers Aluko, Okun, Osere, Agba, Atikeke and Amule. These rivers exhibit a seasonal flow pattern, with the minor streams drying up during the dry season (Oyegun, 1983).

METHODS

Data used in this study were obtained from lithological logs of twenty (20) drilled boreholes obtained from the Lower Niger Basin Development Authority Office in Ilorin. The locational positions of the boreholes are fairly distributed in the study area (fig. 2). Information obtained from the borehole logs include the number of lithological units intersected by the boreholes and their depth, the nature of geological material making up each lithological unit and their moisture condition. Information on coordinates and topographic height of the boreholes are not given on the logs and these were collected from the field personally by the researcher using hand held GPS (Garmin GPS Channel 76 Model).

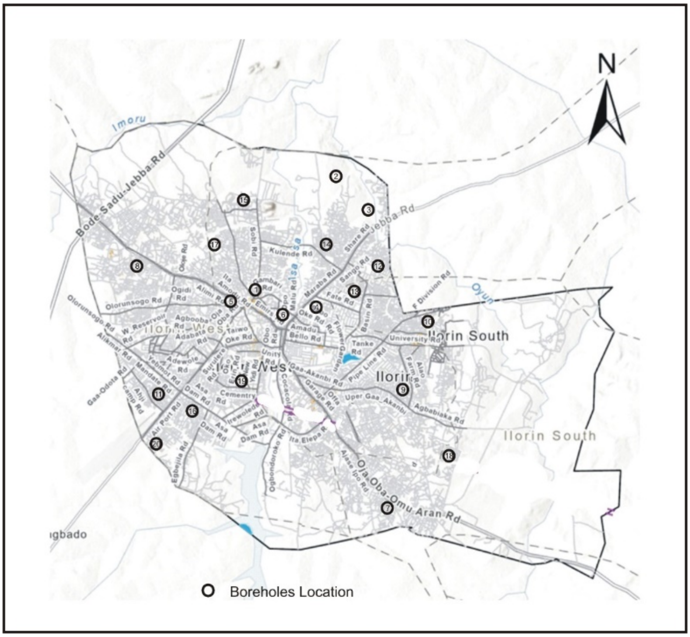

Fig. 2. Map of Ilorin showing Location of Studied Boreholes.
Source: author's fieldwork (2021)

Descriptive statistics were used to analyze the data. The means were used to measure the central location while the range, standard deviation, coefficient of variation were used to measure the degree to which the data collected deviate from average. Correlation matrix was generated to establish the inter-relationship between the hydrology (depth to water and borehole depth), lithology (number of lithological units and depth of regolith) and topography (elevation) of the study area.

RESULTS AND PRESENTATION

Location and Hydrogeological Characteristics of the Studied Boreholes

Table 1 presents the locational position of the studied boreholes, their elevations, depths and number of lithological units penetrated.

Table 1: Location and Hydrogeological Characteristics of the Studied Boreholes

S/N	Location Site	Longitude (O⁰)	Latitude (O⁰)	Ground surface elevation (m)	Depth of wells (m)	Depth to water table (m)	Lithological Units Penetrated
1	**Ojaoba**	8⁰29'13"	4⁰29'39"	297	53.00	45.0	ll,hl,bsfwb,wb,bs
2	**Budo Fulani**	8⁰28'19"	4⁰36'56"	354	100.00	85.0	ll,hl,sc,s,bs,fb
3	**Apata Yakuba**	8⁰32'55"	4⁰39'04"	365	96.60	74.4	ls,l,c,bs,wb
4	**Alalubosa**	8⁰29'35"	4⁰34'18"	287	58.00	50.0	ll,hl,bs,fwb,wb
5	**New Market**	8⁰29'24"	4⁰32'16"	294	30.70	24.0	ls,l,c,bs,wb
6	**Maternity**	8⁰26'05"	4⁰35'38"	348	89.00	79.0	ls,hl,bs,wb
7	**Ganmo**	8⁰25'08"	4⁰36'03"	360	150.00	140.0	ls,l,s,bs,fb
8	**Okaka**	8⁰28'22"	4⁰35'26"	329	70.00	61.0	ls,l,sc,bs,fb
9	**Gaa-Akanbi**	8⁰27'47"	4⁰34'48"	324	31.00	25.0	ls,l,s,bs,fb
10	**Tanke Bubu**	8⁰28'35"	4⁰36'53"	346	40.70	35.7	l,c,s,wb,bs,fb
11	**Mandate**	8⁰28'18"	4⁰30'07"	355	40.00	31.5	c,sc,c,s,fb
12	**Oke Andi**	8⁰31'06"	4⁰36'20"	284	64.40	57.2	ls,bs,fb
13	**Fate**	8⁰29'16"	4⁰36'02"	340	65.00	55.0	ls,c,bs,fb,bs,fb
14	**Zango**	8⁰30'44"	4⁰34'28"	275	38.00	31.0	ll,hl,bs,wb
15	**Sobi**	8⁰32'30"	4⁰33'25"	303	85.00	75.0	ls,ll,hl,bs,fb
16	**Odota**	8⁰27'19"	4⁰31'03"	319	55.00	50.6	l,sc,bs,fb,bs
17	**Balogun Fulani**	8⁰29'49"	4⁰33'11"	311	42.00	35.0	ls,sc,bs,wb,fb
18	**Fufu**	8⁰29'35"	4⁰34'17"	286	48.70	41.0	ls,cs,bs,fb
19	**Osere**	8⁰28'01"	4⁰32'14"	310	35.00	33.5	ls,c,wb,br
20	**Airport**	8⁰26'38"	4⁰30'28"	331	100.00	91.0	ls,l,s,bs,fb,bs
	Sum			6418	2030	1118	
	$\bar{x}$			320.9	101.5	55.9	
	SD			24.04	68.58	27.72	
	CV			7.49	67.6	40.64	

Lithological units: ll = Loose laterite, hl = Hard laterite, fwb = Fairly weathered basement, wb = Weathered basement, bs = Basement rock, sc = Sandy clay, s = Silt, l = Laterite, ls = Loamy Soil, c = clay

Source: Author's Fieldwork, 2021.

The topographical height of the studied boreholes range between 294 and 365m and with mean value of 320.9m. The coefficient of variation of 7.6% reveals no great disparity in topographical heights of the studied boreholes. Borehole depth range between 31 and 150m with a mean value of 101.5m and a coefficient of variation of 67.6%. This result shows that well depth is highly variable in the study area. Reason for this may not be unconnected with the nature of fracturing and weathering of the rock in the area.

Although the weathering profile of the study area can broadly be classified into three layers of top soil, saprolite and bedrock (Oluyide et al., 1998), a total of nine (9) different lithological units were penetrated by the twenty (20) boreholes investigated. These lithological units are loose laterite, hard laterite, fairly weathered basement, weathered basement and basement rock. Others include sandy-clay, silt, loamy soil and clay. The number of lithological units penetrated by each of the boreholes however ranged between three and six. While boreholes located in areas such as Tanke Bubu, Oja Oba, Budo Fulani, Balogun Fulani and Airport intersected the highest number of lithological units of six, boreholes located in Apata Yakuba, New Market, Ganmo, Okaka, Gaa-Akanbi, Mandate, Sobi, Odota and Balogun Fulani areas intersected five lithological units. Areas such as Zango, Fufu, Osere, and Maternity intersected four units and the borehole located in Oke Andi intersected the lowest number of lithological units of three.

The lithological succession in the study area as obtained from the borehole logs shows that loamy soil make up the first layer of the lithology in twelve (60%) of the boreholes, lateritic material in seven (35%) and clay in the remaining one (5%). Nature of top soil is very important in influencing infiltration process. Surface water is lost to the underground aquifers through the top soil (direct recharge) especially in places where the overburden has been weathered. The thickness of the top soil which has a mean value of 4.2m, is greater than 5m in four (20%) of the boreholes while it is less than 5m in seven (35%) of the boreholes.

The first lithological units in the boreholes are generally underlain either by clay or lateritic material. The nature of these two materials (clay and laterite) have resulted in the development of perched water table in four of the boreholes which are located in Gaa-Akanbi, Tanke Bubu, Adewole and Osere. Studies by Wright (1992) and Adelana and Olasehinde (2004) have earlier identified clay and laterite as the two main materials that can be found in the first two lithological sequences above crystalline basement rocks in tropical regions. The British Geological survey recognized these first two units in lithological sequences of weathering profile in crystalline basement rocks of tropical regions as the collapse zone (Gilespie et al., 2011).

The thickness of the saprolite in the studied boreholes ranged between 5 and 27.8m and with a mean value of 11.3m. Five (25%) of the studied boreholes have two aquifer lenses with the first (minor) lens located within the saprolite. This is understandable, because the saprolite is the weathered layer and one of the water bearing zones in basement area; according to Akanbi (2018), the saprolite is characterized by high porosity, and when the bedrocks are not fractured, it is the only alternative water bearing zones in basement area. LeGrand (1989) identified the saprolite as being characterized by low permeability and high porosity and thus functions as a reservoir that feeds water into fractures within the underlying bedrock.

According to Carrier et al. (2008), the most productive zone of groundwater, especially in basement complex area, is the lower part of the saprolite and the upper part of the fractured bedrock; with two parts generally complementing each other in terms of permeability and storage. The lower part of the saprolite is more productive in terms of groundwater because the upper part is usually more clayey and thus, have relatively low permeability and specific yield when saturated. Permeability in saprolite according to Wright (1992), commonly increases at lower levels because of lesser development of secondary clay minerals. For good ground water productivity, Akanbi (2018) observed that the saprolite should be more sandy to gravelly especially in areas underlain by unfractured and unweathered basement rock.

Depth to water in the studied boreholes range from the 24.7m observed in New Market to 140m observed in Ganmo. The mean depth to water is 55.9m. Adelana et al. (2008) have earlier observed that only few boreholes tap water below 60m in the study area. The 40.64% coefficient of variation on depth to water shows that the variability of water bearing capacity of the underlying geology in Ilorin is fairly high. Omoribola (1982) and Azeez (1972) have earlier identified crystalline basement rock which underlain the study area as poor aquifer because of its zero level of porosity and permeability.

The main aquifer in thirteen (65%) of the investigated boreholes is located within the fractured basement while the remaining seven boreholes (35%) have their main aquifers located within the weathered basement. Akanbi (2016) observed that sustainable groundwater supply is best guaranteed when the bedrock in basement region is fractured and there are good connections between the fractured rock and the weathered layer. According to Oladunjoye et al. (2019), groundwater yield in fractured basements is more productive than in weathered basements because they are more porous and permeable than weathered basements that consist of clay material.

Variability of Weathered Overburden and Implications on Groundwater Location

Table 2 shows the variability in lithology of the twenty (20) studied boreholes. The table revealed weathered and fractured rocks as the two main aquifer units in the study area. Studies such as Srinivasa et al. (2000), Chiton and Foster (1995), Wright (1992), Wright and Burgess (1992) have earlier identified joints, faults, fractures and weathered zones as sources of groundwater occurrence in areas underlain by basement complex rocks.

Table 2: Boreholes Logs for the Studied Wells

S/N	Borehole Location	No of Lithological Units Intersected	Nature of Lithological Units	Depth (m)	Colour	Remarks
1	Ojaoba	6	Loose Laterite Hard Laterite Basement Rock Fairly Weathered Rock Weathered Rock Basement Rock	5 6 29 5 5 3	Reddish Brown Reddish Brown	Dry Dry Dry Wet Water Zone
2	Budo Fulani	7	Loose Laterite Hard Laterite Sandy Clay Silt Basement Rock Basement Rock Fractured Basement	5 7 5 3 55 10 15	Reddish Brown Reddish Brown Yellow Ash Dry Wet Water Zone	Dry
3	Apata Yakuba	5	Loamy Soil Laterite Clay Basement Rock Weathered Basement	5 11 7 50.6 23.0	Brown Reddish Brown Yellow	Dry Dry Moist Dry Water Zone
4	Alalubosa	5	Loose Laterite Hard Laterite Basement Rock Fairly Weathered Basement Weathered Basement	5 5 30 10 8	Brownish Red	Dry Dry Dry Wet Water Zone
5	Ojatuntun	5	Loamy Soil Laterite Clay Hard Basement Weathered Basement	0.50 0.50 19.62 4.08 6	Brownish Red Red	Dry Dry Dry Dry Water Zone
6	Maternity	5	Top Loamy Soil Hard Laterite Hard Basement Rock	3 12 54	Brown Reddish Brown	Dry Dry Dry

S/N	Borehole Location	No of Lithological Units Intersected	Nature of Lithological Units	Depth (m)	Colour	Remarks
			Weathered Basement Weathered Basement	10 10		Dry Water Zone
7	Ganmo	5	Top Loamy Soil Laterite Silt Basement Rock Fractured Rock	5 7 3 1.25 10	Brownish Red Red Brownish	Dry Dry Dry Dry Water Zone
8	Okaka	5	Top Loamy Soil Laterite Sandy Clay Basement Rock Fractured Basement	3 6 2 50 9	Brown Brownish Yellow	Dry Dry Dry Dry Water Zone
9	Gaa-Akanbi	6	Laterite Silt Clay Hard Silty Rock Basement Rock Basement Rock Fracture Rock	3 2 1 9 9 6	Brownish Brownish Dark Brownish Brownish	Dry Dry Dry Moist Moist and Wet Water Zone
10	Tanke Bubu	6	Laterite Clay Silt Weathered Rock Basement Rock Fractured Rock	5.7 3 9 9 9 5	Brown Brown	Dry Moist Dry Dry Dry Water Zone
11	Mandate/ Adewole	6	Clay Silt Clay Clay Silt Basement Rock Fractured/Weathered Rock	7 1.63 2.9 8 11.47 9	Brownish Greenish Dark	Dry Dry Moist Moist Dry Water Zone
12	Oke-Andi	3	Top Loamy Soil Basement Rock Fractured Rock	9.6 47.6 7.2	Brownish Dry	Dry Dry Water Zone
13	Fate Basin	4	Loamy Soil Clay Basement Rock Fractured Rock	1 6 48 10	Dark Reddish	Dry Dry Dry Water Zone
14	Zango	5	Loose Laterite Hard Laterite Basement Rock Weathered Basement Weathered Basement	5 6 15 5 7	Brownish Brownish	Dry Dry Dry Wet Water Zone

S/N	Borehole Location	No of Lithological Units Intersected	Nature of Lithological Units	Depth (m)	Colour	Remarks
15	Sobi	5	Top loamy soil Loose Laterite Hard Laterite Basement Rock Fractured Basement	5 5 5 60 10	Brownish Red Red	Dry Dry Dry Dry Water Zone
16	Odota	6	Laterite Sandy Clay Weathered Basement Basement Rock Fracture Basement Fractured Basement	5 10 5 20 10 5	Reddish Brownish	Dry Dry Dry Dry Dry Water Zone
17	Balogun/ Fulani	5	Top Loamy Soil Sandy Clay Hard Basement Weathered Basement Fractured Basement	5 5 20 5 7	Brownish Brownish	Dry Dry Dry Wet Water Zone
18	Fufu	4	Laterite Clay Soil Basement Rock Fractured Basement	7.2 6.6 27.2 7.7	Brownish	Dry Dry Water Zone
19	Osere	4	Top Loamy Soil Clay Weathered Basement Basement Rock	0.50 27.8 5.2 1.50	Dark Reddish	Dry Moist Water Zone Water
20	Airport	5	Top Loamy Soil Laterite Silt Basement Rock Fractured Basement	1 4 1 85 9	Brownish Brownish Red Ash	Dry Dry Dry Dry Water Zone

Source: Archive of Lower Niger Basin Development Authority, Ilorin (2021)

The overburden in Oja Oba has a total depth of 11m with loose lateritic soil making up the first 5m depth followed by hard brownish red lateritic soil of 6m depth. Ground water in Oja Oba can only be accessed at a depth of 40m. Budo Fulani borehole has an overburden depth of 20m with loose lateritic soil making up the top 5m depth. Hard reddish brown laterite of 7m depth follows the lateritic layer before the occurrence of sandy clay and silt at the third and fourth layers of the lithology. Residents of Budo Fulani will need to dig more than 70m to access borehole water from fractured basement because of the nature of geology in the area.

While thickness of overburden of the borehole in Apata Yakuba represents almost a quarter (23.8%) of total borehole depth, substantial (82.8%) depth of the borehole in Alalubosa is made up of basement complex rock. The Alalubosa borehole contrast well with the borehole in New Market where depth of overburden represents almost 70% of the borehole depth. Groundwater from this particular borehole can be obtained from weathered basement lying at a depth of over 96m. The high depth of overburden in this particular borehole may be the reason why the aquifer is located within the weathered basement instead of the fractured basement.

Basement complex rocks make up 74m depth out of the 89m depth of the borehole in Maternity and 135m depth out of the 150m depth borehole in Ganmo. Residents of Ganmo may need to dig up to 140m to access groundwater because of the nature of lithology which is neither weathered nor fractured to a great depth. The depth of overburden and depth to water table at Okaka are 11 and 61m respectively. Two lenses of aquifer can be found in boreholes located in Apata Yakuba, Tanke Bubu and Adewole areas of the city with the first aquifer in all the three boreholes located in the saprolitic layer made up of clay material while the second aquifer in all the three wells can be found at deeper locations in the fractured bedrock.

Borehole in Oke Andi has the least number of lithological units of three. Water in this borehole can be accessed from the aquifer located at 57.2m depth in the fractured rock. Groundwater in Fate Basin can be accessed in fractured rock located at 48m depth below the 7m depth of overburden. Although the boreholes located in Zango and Sobi areas of the city intersected six lithological units each, the depth of overburden in Zango when compared to that of Sobi is shallow and the depth to water table in Sobi is more than twice the value of depth to water table in Zango.

Odota borehole intersected six lithological units with two layers of fractured zone. While the first fractured zone which is found between 41 and 50m depth is dry, the aquifer in this particular borehole can be found in the second fractured zone which commences at 51m depth.

Shapiro et al. (1999) have earlier revealed that water availability in fractured rock terrain can be spatially and vertically variable to the extent of ranging over several orders of magnitude among lithologies and over relatively short distances due to heterogeneous fracture distribution and variable degrees of interconnectivity between the structural features. Although the boreholes in Balogun Fulani and Fufu intersected five and four lithological units respectively, the aquifers in the two boreholes can be found within the fractured basements located at 31 and 41m depth respectively. While the presence of water can be felt at less than 1m depth in the borehole located at Osere, depth to water in the borehole located at the Airport is 91m. Fig. 3 shows the downhole lithological logs of the studied boreholes.

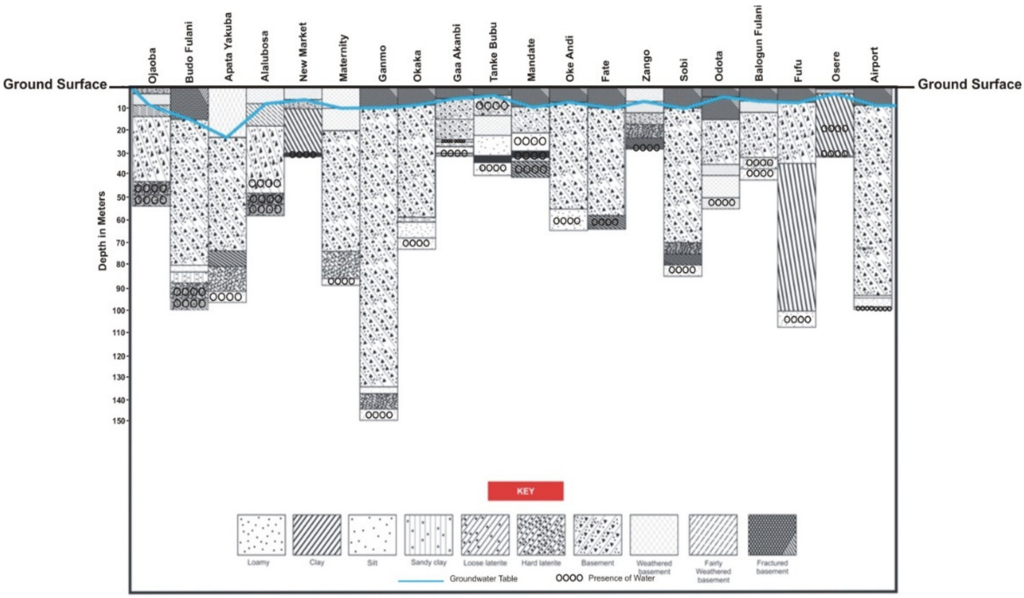

Fig. 3. Downhole Lithological Logs of Studied Boreholes**.**
Source: Author's Finding (2021)

Inter-relationship between Lithology, Topography and Hydrology in the Studied Boreholes

Explanation of the hydrology of fractured rock terrains according to Bailey et al. (2018) remains one of the most challenging and complex problems in water resources management and development, and this is because of the structural complexities of aquifer in such regions (Moore et al., 2020). Attempt at explaining the hydrology of the study area towards ameliorating problems induced by increasing water demand calls for the understanding of the inter-relationships between lithology, topography and hydrology in the study area (table 3). This effort will not only help groundwater prospecting activity in the study area but will also assist in the promotion of sustainable groundwater development in similar geological regions.

Table 3. Inter-relationship between Hydrological, Topographical and Lithological Parameters

	No. of Lithological Units	Depth of Saprolite	Depth to Water table	Topographic Elevation	Borehole Depth
Number of Lithological Units	1				
Depth of Saprolite	0.065	1			
Depth to Water table	0.277	-0.069	1		
Topographic Elevation	-0.575	-0.310	0.498*	1	
Borehole Depth	0.296	-0.055	0.992	0.534*	1

*Correlation Significant at 0.05 Level
Source: Author's Finding (2021)

The matrix (table 3) revealed a strong correlation value (r > ± 0.7) only in one relationship i.e. between borehole depth and depth to water table (r= 0.992). However, two of the relationships, i.e. between topographic height and depth to water table (r= 0.498) and between topographic height and borehole depth (r= 0.534) are statistically significant at 0.05 confidence level. These two relationships thus show that the higher the topographic height, the deeper the depth to water and the deeper the borehole depth.

The positive relationship between topographic height and depth to water is understandable; topography affects groundwater through slope exposure (Grinevsky, 2014). Higher slope areas discourage infiltration process by generating quick runoff. High relief areas thus offer little volume of water for groundwater recharge; hence the statistically positive significant relationship between topographical height and depth to water table.

The positive relationship between topographic height and borehole depth is expected. Borehole depth in this study is strongly correlated positively with depth to water table. The fact that water table is positively correlated with topographic height, borehole depth is thus positively correlated with topographic height. Studies such as Akanbi (2018), Plummer and Carlson (2008), Marklund and Worman (2007), Condon and Maxwell (2015), Devito et al. (2005), Wolock et al. (2004) and Hatjema and Mitchell-Bruker (2005) have all identified topography as one of the factors that determine groundwater configuration.

The weak negative correlation (r = -0.069) between depth of regolith and depth to water table shows that depth to water table in areas with deep depth of regolith are high while depth to water table in thin regolith are low. This result is expected; the deeper the regolith, the greater is the ability to store water and the higher the water table. Studies such as Olaniyan et al.

(2010), Ifabiyi et al. (2016), Akanbi (2017), Adelana et al. (2008) and Wright (1992) have linked borehole productivity in basement complex regions to thickness of regolith.

The weak inverse relationship (r = -0.069) between depth of saprolite and depth to water table mean that the thicker the depth of weathered regolith, the lower the water table. This finding is understandable; though the weathered regolith is highly permeable, it is also highly porous. Thus infiltrated water into thick regolith will continue to percolate into either fractured or weathered rock below.

CONCLUSION

The study has related down-hole lithographic variation with water bearing capacity of some boreholes in Ilorin, Nigeria. Although the weathering profile of the studied area can broadly be classified into three layers of top soil, saprolite and bed rock, nine lithological units were identified in the studied boreholes. Three of the investigated boreholes have two aquifers lenses each (minor and major) while the remaining seventeen have one aquifer lens each. The minor lens in each of the three boreholes with two aquifer lenses are located in lithological units composed of clay material found within the saprolite. The main aquifer in most of the boreholes is located within the fractured basement while only few of the boreholes have their main aquifer located within the weathered basement. Statistical evaluation shows that topographic height is of great significance in influencing water table in the study area.

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