

EVALUATION OF THE GEOLOGY, WATER RESOURCES AND GEOTECHNICAL PROPERTIES OF SOILS IN UGA AREA, SOUTHEASTERN NIGERIA

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Abstract

Water is vital to life, ensures human survival and societal development. Its overdraft and harnessing can affect the environment adversely. This study evaluates the water resources and geotechnical properties of soils in Uga area, south-eastern Nigeria. The study area lies in the rainforest zone where rainfall is extreme and thus boasts of high water resources potential. Comprehensive data are lacking for effective water planning purposes. This research work contributes to existing data on the water resources potentials of Uga and environs. Surface waters (Obiada River and Agwura Stream), springs (Nwangene, Obizi and Ogbei Springs) abound in the area. Nanka Sands which is a prolific water-bearing unit defines the underlying geology of the area. Flow rates of surface waters are high due to annual precipitation of 2500mm a year. Springs are clear. Nwangene Spring has a flow rate of 0.39 m/sec while Obizi spring has a flow rate of 0.04 m/sec. Borehole depth at Nanka and Oko is 380 meters and 314 meters respectively while static water level is 42 meters and 69 meters respectively. Huge sand deposits abound in the area. This research work highlighted the geotechnical properties of soils from the area. Cobble, pebble and gravel sized grains are absent. CBR values ranged from 30% to 35%. Highest MDD gave a value of 1-824gcm⁻³ with an OMC of 11%. The lowest MDD recorded a value of 1.622gcm⁻³ with an OMC of 8%. LI test conducted on one of the samples yielded a value of 16%. PL and PI tests gave zero values for all the samples. The geotechnical results implied that soils from the area are excellent to good reserves for sub-grade and sub-base materials respectively.

Keywords: Geotechnical, Nanka Sands, Sub-base, Sub-grade, Uga, water resources.

INTRODUCTION

Water is critical and essential for human survival and consumption. Agriculture, industrialization, urbanization and improved socio-economic wellbeing of a people are heavily dependent on the availability of water resources (Okpoko, 2018b). Optimum economic development of water resources requires an integrated approach that coordinates the use of both surface and groundwater resources (Todd and May, 2005). Water is a natural resource. Water resources in the study area include surface waters (rivers, lakes, streams) and groundwater. The demand for water is ever increasing globally (Omonona, Ozobialu and Okogbue, 2017). Increase in population of Uga and the adjoining communities of Nanka, Nnewi, Oko, Ekwulobia, Agulu, Nkpologwu, Ekwulumili, Unubi with population growth rate of about 4.8% (National Population Commission, 2019) necessitated this study to evaluate the water resources potentials of the area. The present study is contributory to the data already existing on water resources potential of Uga and environs. Geotechnical properties of soils are influenced by climate, geology, drainage pattern, nature of parent rock material and even

degree of weathering and ferruginization (Aginam, Nwakaire, Nwajuaku, 2015). Various studies have been done in the area to characterize the lateritic soil as engineering geologic materials such as Aginam, Nwakaire, Nwajuaku, (2015) and Chinwuko, et al., (2016). The objective of this work is to evaluate the water resources potentials for domestic, agriculture and industry uses and characterize the geotechnical properties of soils for construction purposes. The area under study is bounded by latitudes $05^{\circ} 55' 1''$ N and $06^{\circ} 00' 1''$ N of the equator and Longitudes $007^{\circ} 00' 1''$ E and $007^{\circ} 07' 1''$ E of the Greenwich meridian and covers the following communities of Uga, Ekwulumili, Unubi, Ezinifite, Nkpologwu, Nanka, Oko and Ekwulobia (Figure 1).

Physiography and Drainage: The outstanding physiographic feature observed in the area is Abagana-Enugwu Ukwu-Oraukwu-Ichida-Orlu cuesta. The cuesta stretches from somewhere around Ukpo in the north, rises at Abagana swings eastwards through Oraukwu and Ichida and then changes direction in a southerly orientation towards Uga and thins out beyond Orlu area (Figure 2). The drainage pattern in the study area is controlled by physiography and underlying geology. Two water bodies (Obiada River and Agwura Stream) drain the area. They flow in a NE-SW direction creating a dendritic drainage pattern.

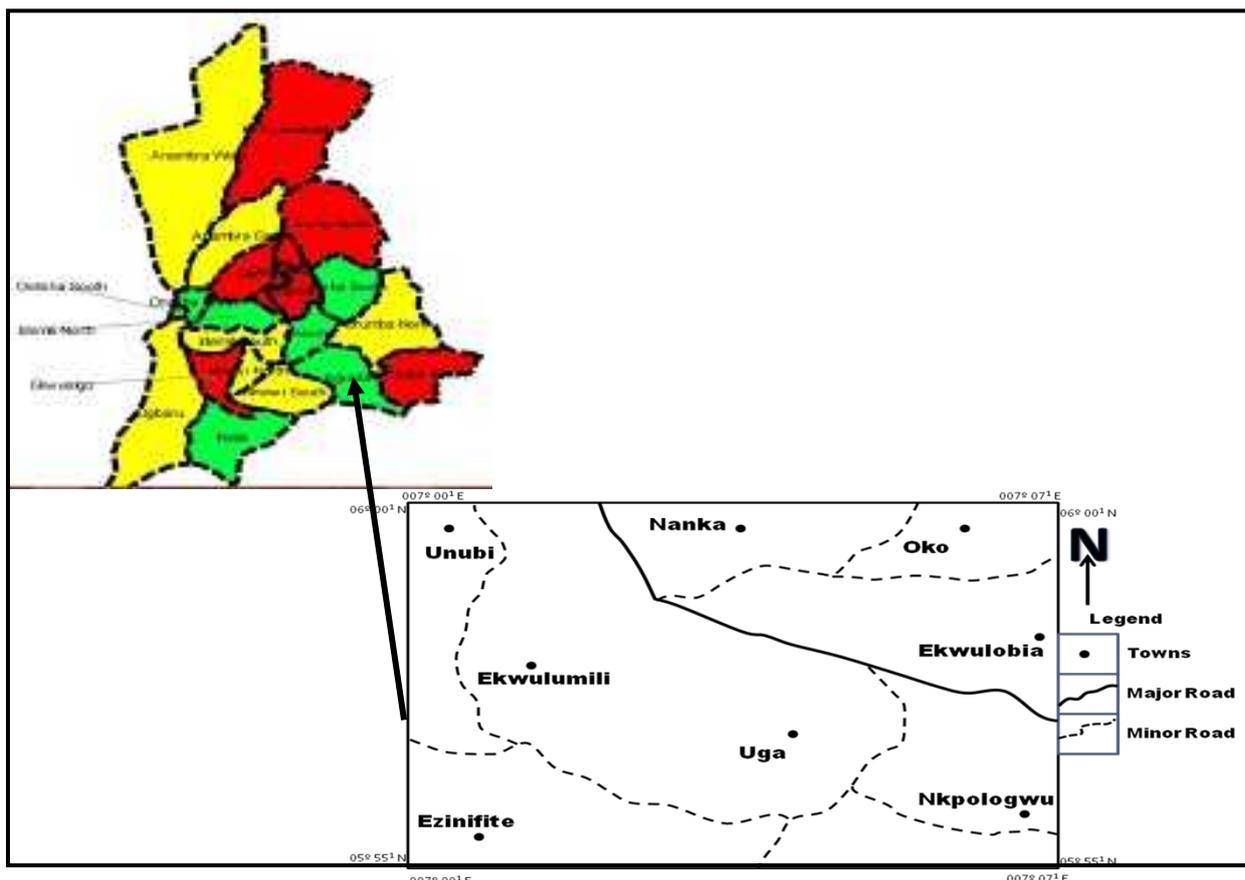


Figure 1: Location map of the study area with arrow showing position in Anambra State Nigeria.

Source: (Federal Surveys of Nigeria, 1981)

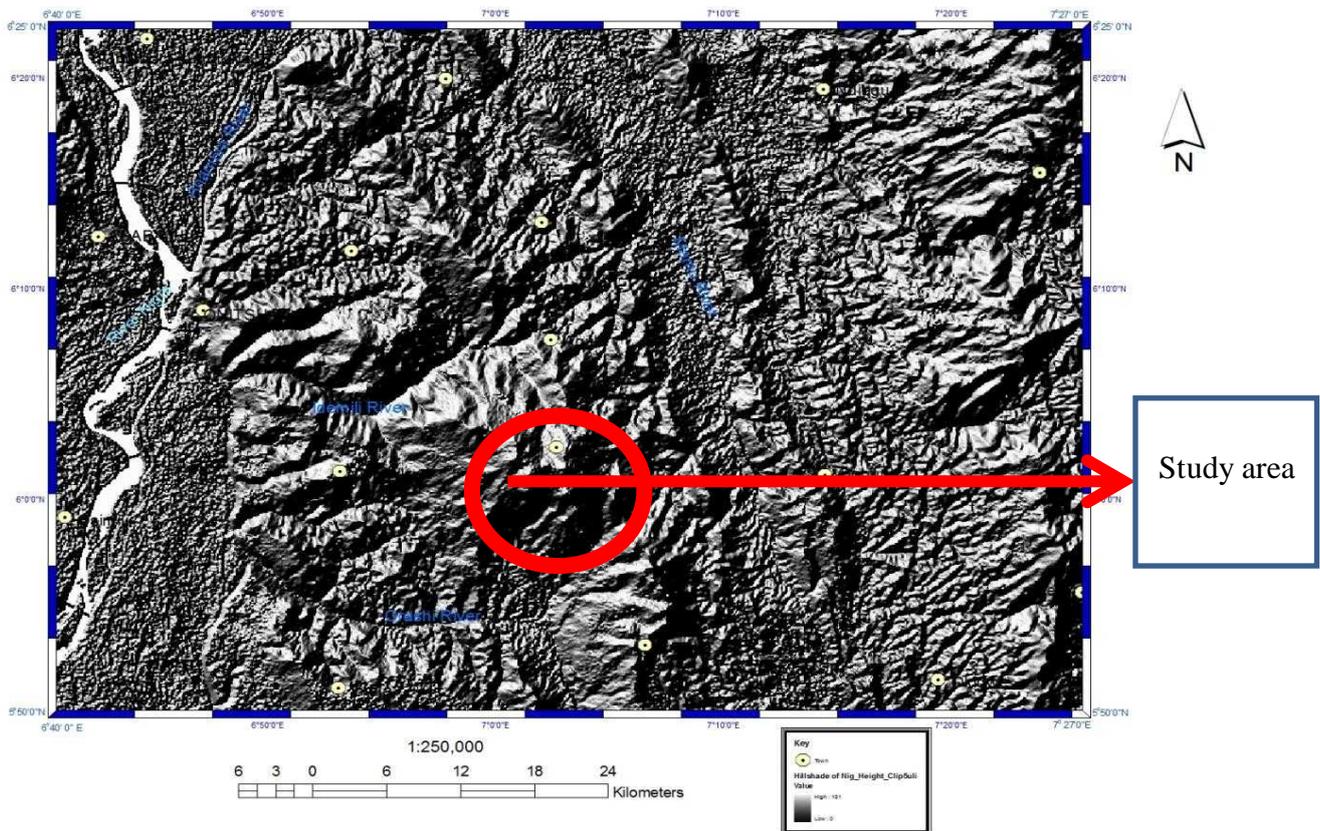


Figure 2: 3-D Physiographic map of part of southeastern Nigeria with the study area encircled.

Source: (Okpoko, 2018a)

Climate and Vegetation: Two main climatic conditions are experienced: the dry and rainy seasons. The dry season spans the months of November to March with precipitation rate of about 60cm (Monanu and Inyang, 1975). The rainy season begins in April and ends in October attaining peak levels in June through July and a short break in August referred to as “August break”, thereafter gears up again in September. The mean annual rainfall of the area is between 1755mm to 2250mm (Iloeje, 1985). The study area falls under the evergreen rainforest vegetation type (Balogun, (2009). The vegetation is composed of tall trees with thick undergrowths of creepers and climbers resulting in a canopy forming pattern.

Regional Tectonic and Stratigraphic Setting: The area under investigation lies within Anambra Basin of Benue Trough mega structure. Sedimentation in the trough started in the Aptian-Albian times and continued until the Santonian where a major tectonic event accompanied with folding, faulting, uplifting and magmatism have been recorded (Figure 3) (Nwachukwu, 1972; Petters, 1978; Nwajide, 1990, 2013). The Santonian movements led to the folding and uplifting of the northeast trending Abakaliki Anticlinorium. Two depressions emerged after the uplift episode flanking the Abakaliki Anticlinorium: the wide Anambra Basin to the northwest and narrow Afikpo syncline to the southeast (Figure 4) (Hoque and Nwajide, 1985). The anticlinorium became a major sediment dispersal centre during the Santonian from where the Anambra Basin and Afikpo Synclinorium were fed with clastic sediments (Figure 4). Sedimentation in Anambra Basin started in the Campanian period with

the deposition Nkporo Group comprising Nkporo Formation, Enugu Formation and Owelli Sandstone (Obi, 2000; Obi, Okagbue & Nwajide, 2001). The second set of sediments (Mamu Formation, Ajali Sandstone and Nsukka Formation) was deposited during the Maastrichtian times (Murat, 1972; Kogbe, 1976; Nwajide, 1980; Agagu, Fayose and Petters, 1985). The third sequence were deposited during the Paleogene and Neogene times consisting of the Paleocene Imo Formation, Eocene Ameki Group comprising of Ameki Formation, Nanka Sands and Nsugbe Formation, Oligocene Ogwashi-Asaba Formation and the prograding Miocene Benin Formation (Nwajide, 2013; Odumodu, 2014).

In the study area, only one geologic formation was encountered (Figure 5). Surface outcrop and borehole lithologs reveal lithologies belonging to Nanka Sands of the Ameki Group. A total of 2 outcrops and 2 boreholes were systematically logged. The Lithology is characterized by thick sand layers (Figures 6b, 6c) with intercalation of siltstones, clay and ironstone (Figures 6a, 6d).

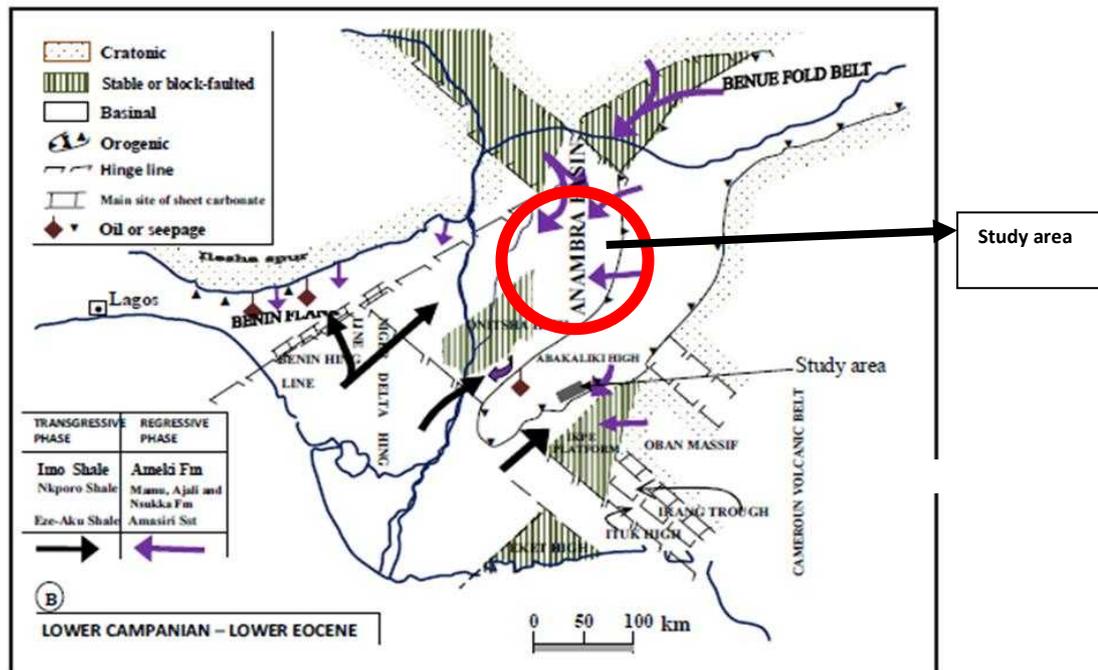


Figure 3: Tectonic framework of the Benue Trough. Study area encircled
 Source: (Nwajide, 1990)

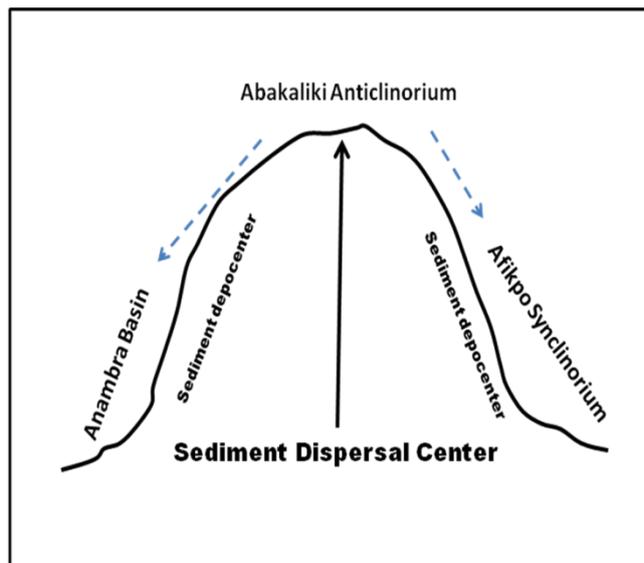


Figure 4: Santonian event model in Abakaliki region of Benue Trough

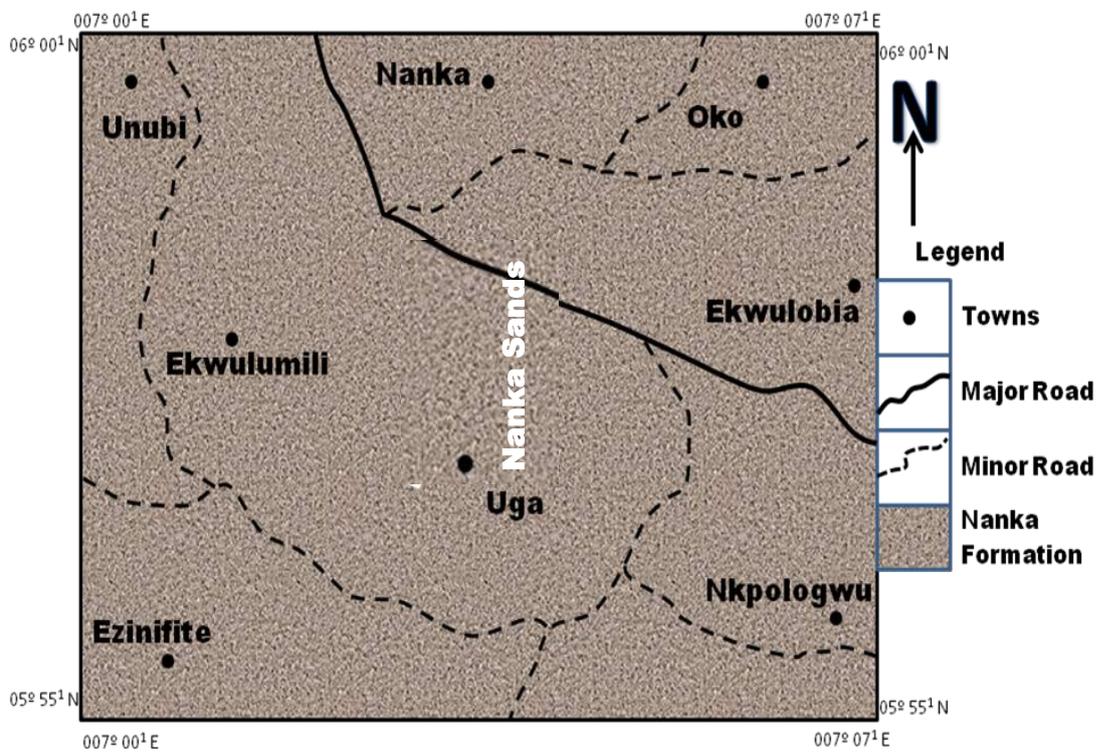


Figure 5: Geologic map of the study area

Source: (Federal Surveys of Nigeria, 1981)

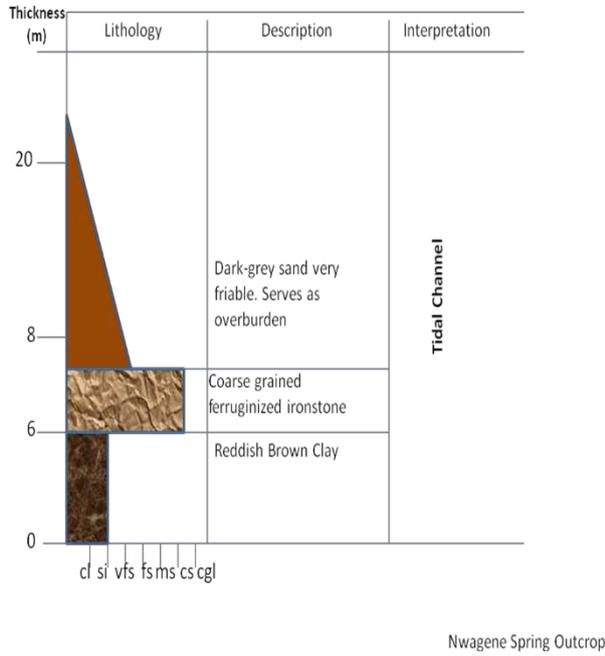


Figure 6a: Litholog of Nwagene Spring outcrop
Source: (Fieldwork, 2017)

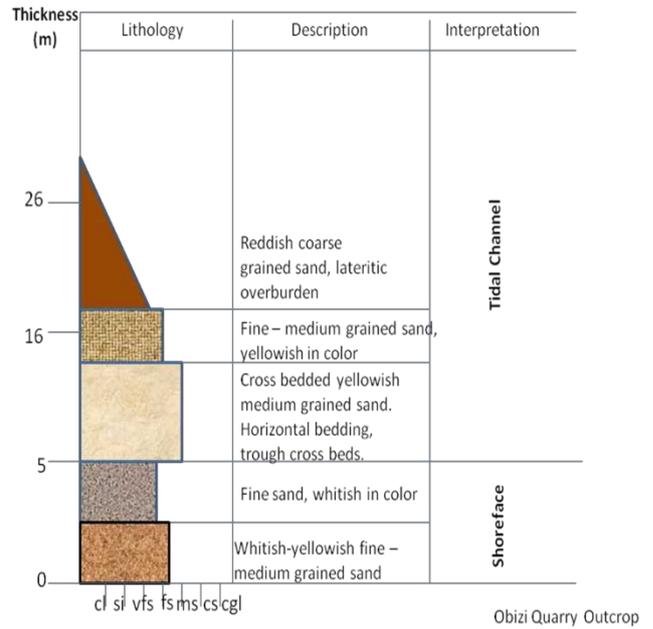


Figure 6b: Litholog of Obizi quarry outcrop
Source: (Fieldwork, 2017)

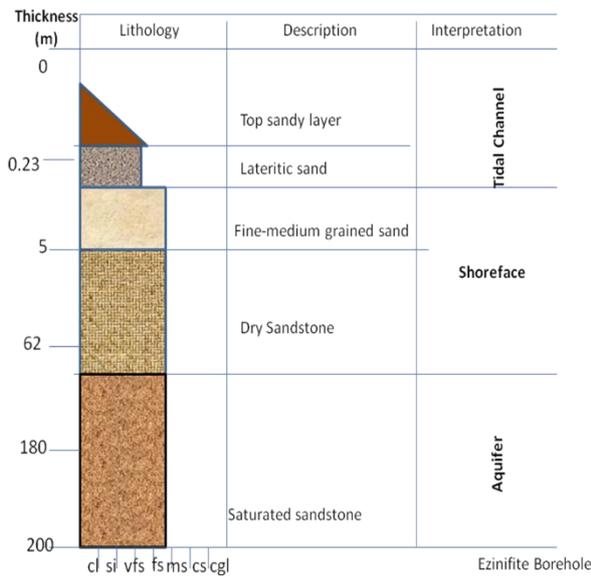


Figure: 6c. Litholog of Ezinifite borehole in Nanka Sands
Source: (Fieldwork, 2017)

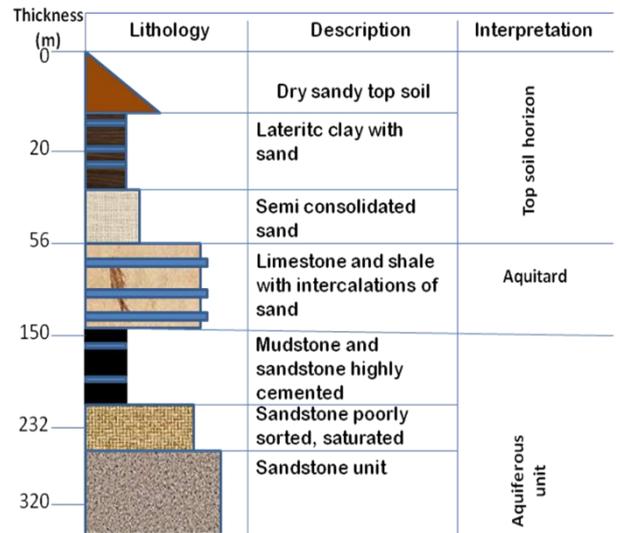


Figure: 6c. Litholog of Uga borehole in Nanka Sands
Source: (Fieldwork, 2017)

MATERIALS AND METHODS

Materials put in place for the study include: Global Positioning System (GPS), stop watch, Pencil, Biro, Notebook, Tape, Gum, Nylon polyethene sacks, Leather bags, Digital camera and water bottles. A field oriented approach was used as research methodology. All road networks, physiography and drainage patterns were drawn on the base map prepared from topographic sheet of OKIGWE 312 scale 1: 100,000 (Federal Surveys of Nigeria, 1981) Field observations were recorded in the notebook. Coordinates of the study area, outcrop locations, water bodies and borehole points were obtained using the GPS. Flow rates were measured using stop watch. Fresh sand samples were collected from Obizi Uga quarry site in Nylon polyethene and leather bags and taken to IDC construction company facilities in Awka, north of the study area for geotechnical analysis.

RESULTS AND DISCUSSION

Water Resources Evaluation: Water resources include surface water and groundwater. Water resources in the area are yet to be fully harnessed and exploited. Use of water in the area is mainly for domestic purposes. Small and medium scale industries are sustained mainly by water supplied from boreholes and a small percent from surface water in the study area. Rainwater is used for almost all agriculture activities (Okpoko, Egboka, Anike & Eliabeth, 2013).

Surface water Hydrology: Surface water resources include streams, rivers, lakes and rivulets. Surface waters are generally uncommon in the study area due to topography and lithologies. The study area is situated on the Awka-Orlu Uplands where it serves as a water divide hence surface waters tend to run-off on opposite sides of the divide (Figure 7). Coupled with the sandy geology of the area, infiltration is relatively high thus resulting to scarcity of surface waters in the area. The flow rates are high due to high rainfall experienced in the area (about 2500mm). The waters are usually grey to brown in colour due to presence of suspended particles. Two major rivers were however encountered in the study area. They are Obiada River at Ekwulumili (Figure 8a) and Agwura Stream at Unubi (Figure 8b).

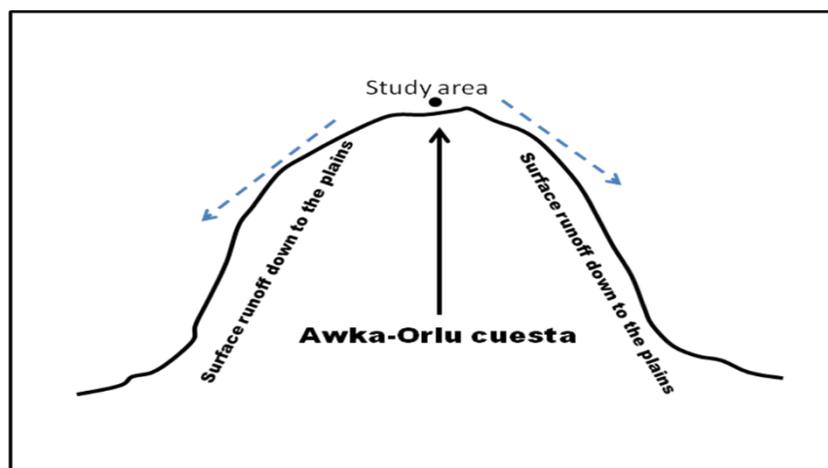


Figure 7: Water divide model for Awka-Orlu cuesta



Figure 8a: Obiada River at Ekwulumili
Source: (Fieldwork, 2017)



Figure 8b: Agwuru Stream at Unubi
Source: (Fieldwork, 2017)

Spring water Hydrology: The Awka-Orlu cuesta consists of sandstone and clay lithologic units. They are veritable sources for the emergence of springs from the basal contact areas between aquiferous sands and aquitard clays and shales. The reason for the small number of springs is explained by favourable combination of factors not being met namely large diameter area and desired geologic structures (Davis and Dewiest, 1996). Springs encountered in the area include Nwagene Spring, Obizi Spring and Ogbei Spring.

1. Nwagene Spring (Long. 007° 01¹E, Lat. 05° 57¹N, Elev. 86m)

This spring is the source of Obiada River in Ekwulumili. The water is clear and flows down the channel at the rate of 0.39m/sec (Figure 9a). The source of the water is from a contact between reddish brown clay unit and coarse grained ferruginized ironstone (Figure 7a).

2. Obizi Spring (Long. 007° 03¹E, Lat. 05° 56¹N, Elev. 68m)

The water is clear with low aquatic life (Figure 9b). It has a width of 2.8m and depth of 3.58m. A flow rate of 0.04m/sec was recorded. The slow movement of the spring channel acts as a recreational centre for the people of Uga and neighbouring towns. The Obizi Spring flows out under pressure at the foothill of the Awka-Orlu cuesta. It is a large spring of fourth order magnitude. The spring discharges from an aquifer of large storage in Nanka Sands with high permeability and is used as a mini water scheme to provide water for the entire people of Uga and its catchment area.

3. Ogbei Spring (Long. 007° 06¹E, Lat. 05° 59¹N, Elev. 127m)

The water is clear with low aquatic life having a width of 2.4m and a depth of 0.15m. It has a flow rate of 0.3m/sec (Figure 9c). The people of Nkpologwu and adjoining communities use the water for their domestic use mostly for drinking.



Figure 9a: Nwagene Spring at Ekwulumili
Source: (Fieldwork, 2017)



Figure 9b: Obizi Spring at Uga
Source: (Fieldwork, 2017)



Figure 9c: Ogbei Spring at Nkpologwu
Source: (Fieldwork, 2017)

Groundwater Hydrology: Groundwater in the area is exploited by boreholes and/or water wells. They are water bodies occurring naturally beneath the earth surface. Two physical properties (porosity and permeability) of a rock largely control the amount and movement of groundwater. (Fetter, 2001; Todd and Mays, 2005; Scwartz and Zhang, 2003). Three major rock materials make up groundwater bearing units. They include unconsolidated sands and gravels, permeable sedimentary rocks (sandstone and limestone) and heavily fractured volcanic and crystalline rocks. Only unconsolidated sands, gravels and permeable sandstone occur in the area. The study area is underlain by Nanka Sands consisting of numerous thick series of aquiferous sands (Figures 6b, 6c, 6d). It is an excellent and prolific groundwater reservoir with high permeability and porosity. The sandy units of the formation occur mostly

as deep aquifers as revealed by borehole logs from the area (Figure 6c, 6d). In deep aquifers the water table is at great depth. Depth of boreholes at Ezinifite and Uga are 200 and 320 meters respectively. There is paucity of Hydrogeologic data in the area. Record of borehole at Nanka gave depth of borehole at 380 meters, static water level (SWL) of 46.2 meters, dynamic water level (DWL) of 50.9 meters and yield value of 26.6 m³/hr. Borehole drilled at Oko gave total depth of 314 meters. SWL of 69 meters, DWL of 199.2 meters, drawdown of 30.2 meters and yield value of 10m³/hr was obtained.

Geotechnical Evaluation

Soil samples from Obizi Uga Quarry was collected from surface level to a depth of 1m and stored in airtight bags. The determination of some geotechnical parameters was done after air drying all the samples. The geotechnical variables determined were particle size distribution, Atterberg's limits, California Bearing Ratio (CBR), Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). All samples from the quarry (Uga 1, 2 and 3) have similar characteristics. They are slightly moist, less cohesive with little or no proportion of fines. Texturally, they are equigranular, well rounded, moderately to well sorted. They appear white to yellow in colour.

Particle Size Analysis: The particle size analysis unveils curves of samples across the quarry to have similar size distribution as shown in Figure 10. The particle size analysis shows that the quarry is sand dominated with little or no amount of gravels and fines. Based on the particle size analysis, it is expected that the quarry samples would exhibit characteristics such as non-cohesiveness, non-plasticity and no water retention capacity which are all peculiar to sandy and gravelly deposits.

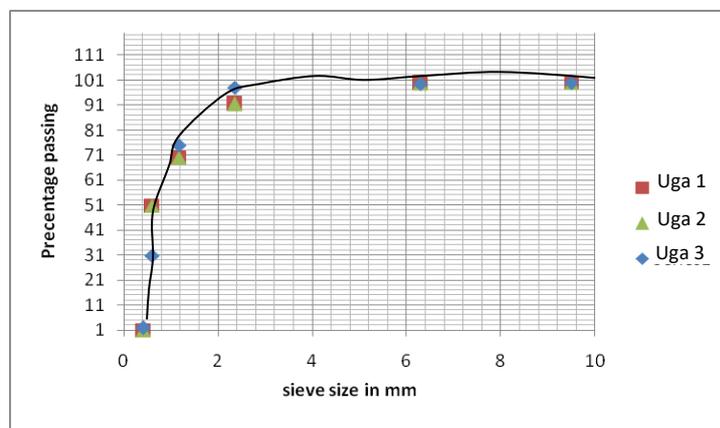


Figure 10: Particle size distribution curve for all samples

Atterberg's Consistency Test: The Atterberg's limit tests show also similar characteristics for all the samples. Table 1 shows the summary of the Atterberg's consistency limit parameters for the quarry samples. At a moisture content of 16, Uga 1 is expected to behave like a liquid material (Figure 11). Uga 2 and 3 being entirely composed of granular material yielded no plastic limit (PL) value and thus plasticity index (PI) was zero. The PI suggests no evidence of fines and hence no plastic behaviours. The implication of the Atterberg's consistency test is that the samples are not susceptible to any volume change in form of swelling or shrinkage (Zolfaghari, Mosaddeghi & Ayoubi, 2015). However, the fact that Atterberg's limit analysis was performed on Uga 1 suggests the soil sample not to be entirely

sandy (Ameh, Ogbonnaya & Bemadette, 2016; Ameh, Ogbonnaya, Abdulateef, Mustapha, & Isa, 2018). This shows that the sample contains negligible amount of fines. In relating the result of the above test to the specification, it could be seen that Uga 1 with liquid limit (LI) of 16% falls below the specification liquid limit of $\leq 35\%$ (Table 2). Therefore the sample is good and together with Uga 2 and 3 is fit for engineering construction purposes.

Table 1: Summary of Atterberg’s Consistency limit for the samples

Test	Sample Identity		
	Uga 1	Uga 2	Uga 3
LL(%)	16	0	0
PL(%)	0	0	0
PI(%)	0	0	0

Table 2: Specification limits for Atterberg’s Test

Test	Specification
Liquid Limit (LL)	$\leq 35\%$
Plasticity Index	$\leq 12\%$

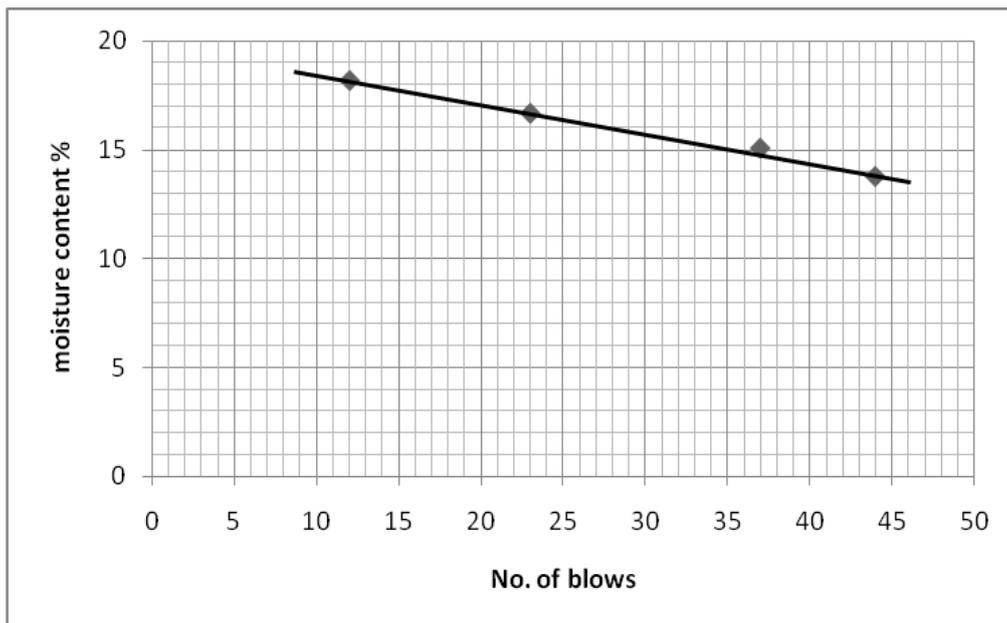


Figure 11: Liquid limit plot of moisture content against no. of blows for Uga 1

Compaction Test: The compaction test result obtained from an AASHTO compaction test apparatus is presented in Figure 12. Uga 1 shows the highest MDD of 1.824gcm⁻³ with an OMC of 11%, while Uga 2 shows the lowest MDD of 1.622gcm⁻³ with an OMC of 8%. The implication of the compaction test is that continued addition of water will result in volume change if the samples are not compacted in place. Therefore the samples should be compacted with greater compaction energy so as to obtain better compaction values and improved geotechnical properties.

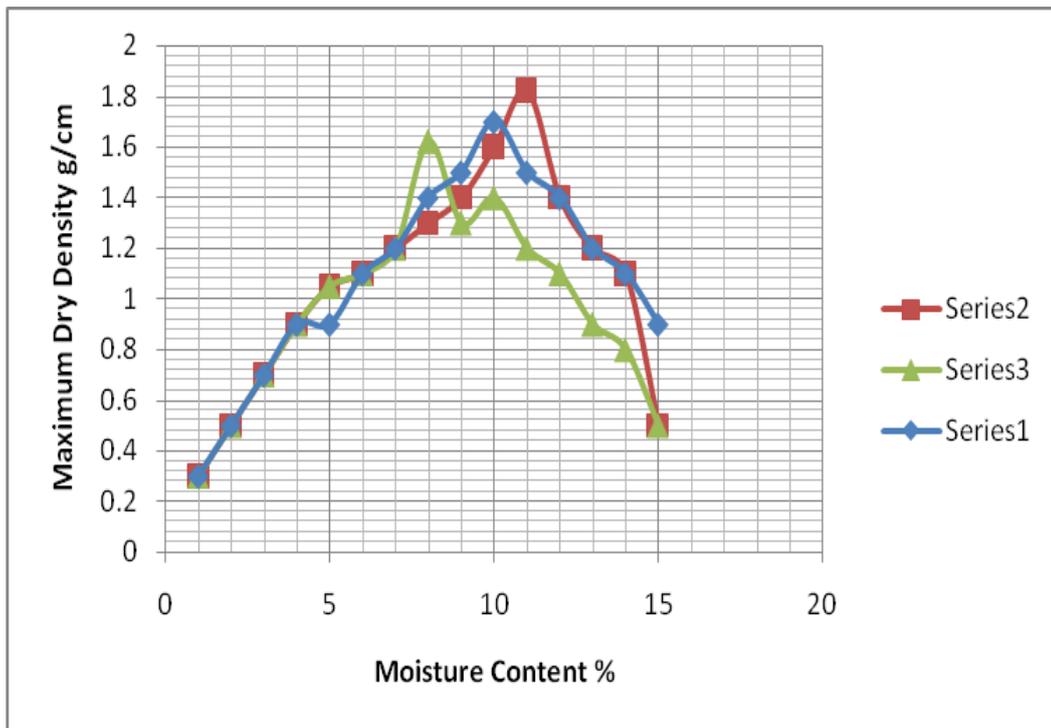


Figure 12: Stacked plot of MDD against OMC for all the samples

California Bearing Ratio (CBR): This is defined as the percentage of soil bearing capacity at a certain penetration with reference to a specific soil obtained for California testing. The penetrations most necessary are at 2.5mm and 5.0mm. To calculate the CBR, read off the force at 2.5 mm penetration divide it by the standard force at 2.5mm and then multiply by 100. Do the same for 5.0mm penetration and take the highest value as your CBR (Table 3). The CBR test result for the samples is presented in Table 4. The CBR test suggests that the samples are excellent sub grade and good sub base materials (Table 5).

Table 3: CBR standard force for 2.5mm and 5.0mm penetration

CBR STANDARD FORCE (KN)	
2.5 Penetration	13.24
5.0 Penetration	19.96

Table 4: CBR Test result summary for all samples

Sample	Penetrations (mm)	Corrected CBR%		CBR Values
		Top	Bottom	
Uga 1	2.5	4.5	3.8	34%
	5.0	3.5	3.5	
Uga 2	2.5	4.0	3.7	30%
	5.0	3.6	3.6	
Uga 3	2.5	4.7	3.8	35%
	5.0	3.4	3.4	

Table 5: Specification limits for CBR Test

MATERIAL	CBR %
Sub Grade	≥ 10%
Sub Base	≥ 30%
Base Course	≥ 80%

CONCLUSION

This research work analysed the water resources and geotechnical properties of soils in Uga area in south-eastern Nigeria. Surface water, springs and groundwater abound in the study area. The surface waters include Obiada River and Agwura Stream.. Nwagene, Obizi and Ogbei constitute the springs found in the area. The study area is underlain by Nanka Sands which consists of thick sequence of sands with intercalation of mudrocks, and is an excellent groundwater reservoir. Groundwater exploitation is feasible in the area. Surface waters and springs serve the locals for drinking, agricultural and other domestic purposes. Geotechnical analyses carried out indicate sands to be moderately to well sorted, well rounded and texturally matured. Atterberg's limit test results suggest that all samples are fit for engineering construction purposes. Compaction test carried out suggest that there is need to compact the

soils to attain maximum densification. The CBR test result shows samples to be excellent sub grade material and good sub base material but not as base course materials.

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