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Integrated Approach for the Assessment of Ihale Damsite for Reservoir Water Storage, Kogi, Nigeria

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ABSTRACT

Aim of the Study: Ihale damsite was evaluated for the purpose of constructing a dam for water storage and irrigation of farmland in the area.

Methodology: The location of the proposed dam axis lies on the Universal Transverse Mercator (UTM) coordinates 187872mE, 916118mN and 187634mE, 915603mN and to harness river Afun which is about 2.5km to Kabba-Bunu area. 10 trial/test pits for soil sampling and 2 deep borings into the basement rock were conducted on both sides of the river channel and DCP were conducted to the point of refusal. The number of blows per 10cm for the overburden soils ranges from 1 to 50 between depths of 0 – 2.0meters. DCP test involved driving a solid cone of 60^0 into the ground, using repeated blows of a hammer with a fixed mass of 10Kg falling through a distance of 550mm having maximum diameter of 20mm.

Findings & Conclusion: Findings revealed Clayey top soil, laterite, weathered basement and fresh basement rocks were the main geologic material obtained from the area with 4 geo-electric layers recorded. Resistivity values along the dam axis ranges from 29.1 to 2857.6 Ωm which is the third layer of VES 1 and 7. This layer was inferred to be weathered basement rock. In essence; placing the dam structure on the fourth layer of fresh basement rock will be more desirable to minimize seepages and enhance the foundational footing of the structure. Geotechnical analysis revealed bulk density varied from 1320 to 2830 kg/m^2. Specific Gravity ranges from 2.56 to 2.76 Ga. Natural moisture content Nmc varied between 1.73 and 24.49 % with optimum dry density and dry density desirable for the support of dam construction in the area. Unit Cone Resistance (KN/m^2) that varies from 95 to 520 KN/m^2 across the depths is desirable to support the dam area structure. Average DCP Bearing Capacity increased from 120 to 500 as depth of investigation increased from 0.5 to 2.0 m. The integrated approach has revealed the Ihale damsite is good for dam construction.

Keywords: Geotechnical Analysis, Specific Gravity, Electrical Resistivity Sounding, Unit Cone Resistance and Resistivity.

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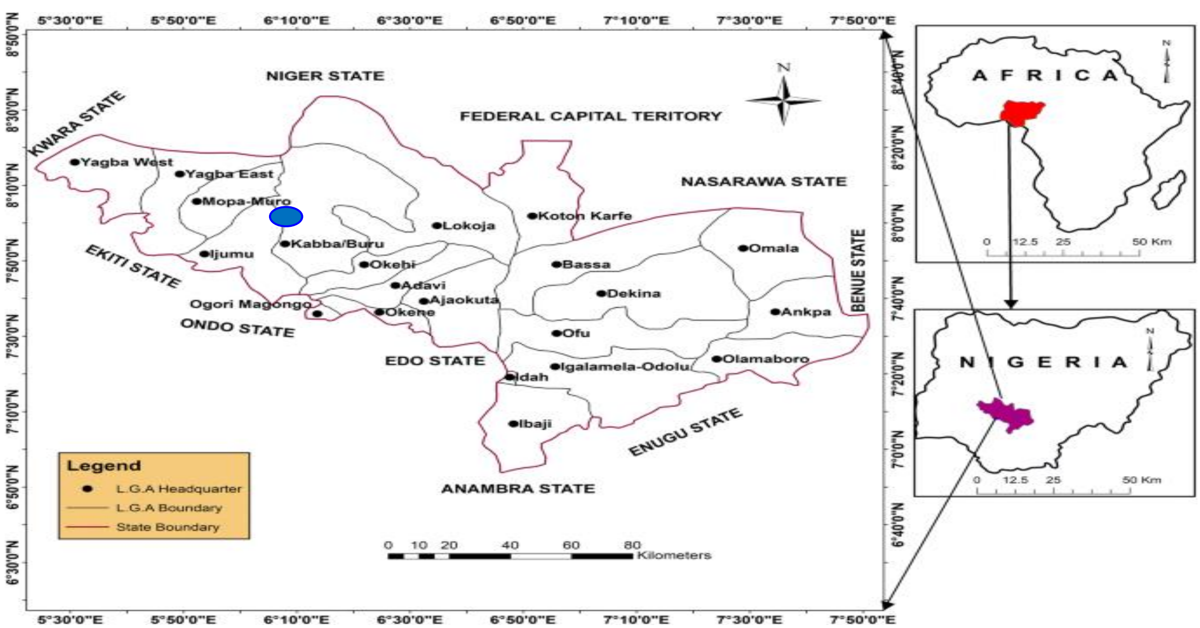
Introduction

It is important to carry out sub-surface exploration for the proposed dam axis, reservoir area and geologic structures to appropriate depths in order to determine the extent and properties of all soil and rock strata that could affect the performance of the proposed dam. This proposed dam is meant to exploit the irrigation potential of Afun river water. This will be of tremendous assistance to the people in the community that are largely farmers and will contribute to the growth and scio-economic development of the area, the state and nation at large. The study area was explored to understand the nature of the site for the Ihale earth dam, including its soil and rock composition, its area extent, the capacity and capability of these geologic materials to withstand the Engineering design and construction of the dam. It is worthy of note that geologic structures like folds, faults, joints, lineaments, dykes, uncomformities etc and their fluid contents that may be present are better analysed prior to Engineering design and construction. Ihale dam site investigation and interpretation was thus done to reveal buried Geologic mystery that will enhance the construction of the dam for the people of the area. In essence the use of test/trial pits, borrow and deep borings are crucial to understand the lithological facies of any area for damsite assessment and bearing capacity of anticipated structural loads. Ibrahim et al (2019, 2020 and 2023). Aeromagnetic and geophysical data were used by Aina (1996) for damsite investigation.

Location and Geology of Study Area

The location of the proposed dam axis lies on the Universal Transverse Mercator (UTM) coordinates 32P; 187872mE, 916118mN and 187634mE, 915603mN covering a distance of 570 meters. The proposed dam axisis to be located across river Afun which is about 2.5km from Ihale-BunuVillage in Kabba-Bunu area of Kogi State (Fig. 1).



Ihale damsite study area

Fig. 1: *Location map of Ihale damsite study area*

The Geology of the area as at the time of our investigation showed the river was flowing at its lowest ebb level while farming activities were noticed to be ongoing around the proposed dam site with gross insufficient water for irrigation activities. The river bed surface was full of disintegrated rock boulders.

Vegetation within the dam axis/area include; growing grasses, shrubs and various trees. The overburden soil within the project area is predominantly brownish micaceous silty fine grained sand, reddish micaceous silty lateritic clay, brownish sandstones/gavels with boulders and reddish silty lateritic clay in varying combinations. It is underlain by rock of the Precambrian crystalline basement complex. Oyawoye (1972). The basement rocks comprises of the migmatitic and granitic gneisses, slightly migmatised to unmgmatised parashist and metaigneous rocks, Floggy quartzite, older Granite, gneiss, quartzite unmetamorphosed dolerite dykes, quartz-muscovite schist and granites are all contained in the area. (Fig. 2). The topography of the area as observed can be described as rolling and medium-steep slopes terrain and it slope towards the river bank.

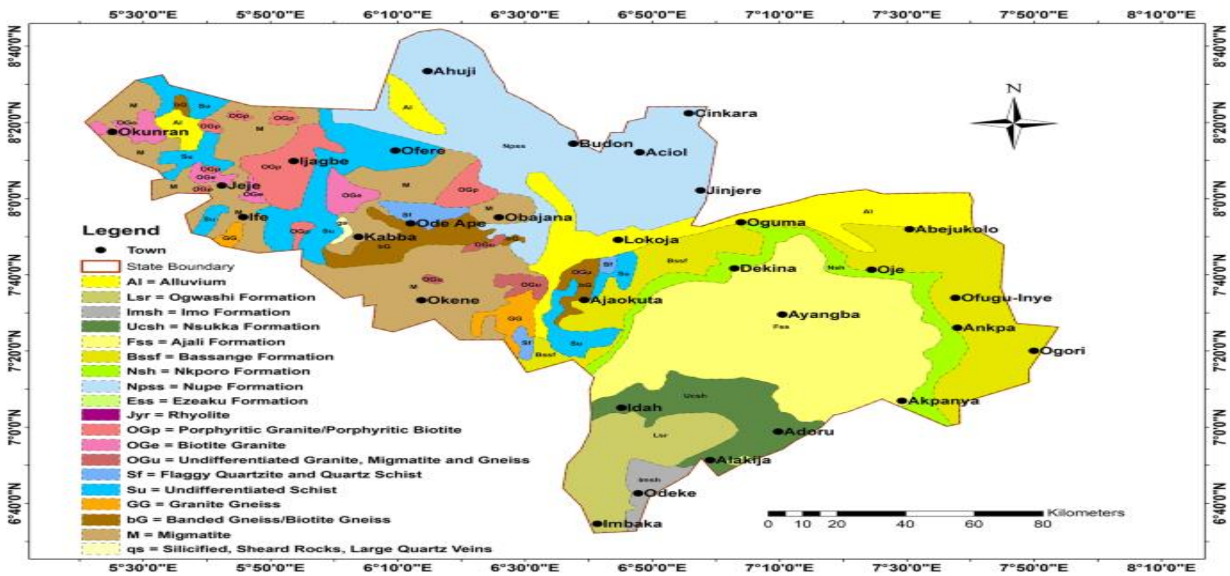


Fig. 2: *Geologic map of the area showing rock types present.*

Materials and Methodology

Posthole hand auger, geophysical survey terrameter (PetrozenithTerameter), Dynamic Cone Penetrometer, detachable manually operated boring rig, water pump, E-trex Handheld GPS, Measuring tapes and other hand tools were materials available on site for the assessment (Figs. 3 and 4). All field work including geophysical, geotechnical investigation and sampling along the proposed dam axis and construction materials sourcing were concluded on 10^{th} of March 2020. Furthermore, A total of seven (7) numbers of standard test pits complemented with posthole auger, two (2) number deep wash boring were executed on site and DCP sounding were conducted along the proposed dam axis. The borings were conducted at established beacons axis L1 and axis R1 on either side of the river while trial/test pits were excavated at same points where VES had been conducted. The soils encountered in the boreholes were carefully logged, packed and preserved on site and conveyed to laboratory for testing (Fig. 4).

The number of blows required to drive 100mm into ground was recorded and the test terminated at depths where hammer blows is greater than 50 or caused less than 100mm penetration. The Vertical Electrical Sounding conducted allowed a better penetration of the current to investigate the rock composition of the area.

Fig. 3: *DCP and Geophysical survey of the Ihale damsite area*

Eight (8) numbers of DCP were conducted to depth of refusal. The number of blows per 10cm for the overburden soils ranges from 1 to 50 between depths of 0 – 2.0meters. DCP Test involves driving a solid cone of 60^0 into the ground, using repeated blows of a hammer with a fixed mass of 10Kg falling through a distance of 550mm having maximum diameter of 20mm. The hammer strikes an anvil which is rigidly fixed to the rods which are of smaller diameters than the cone and transmit the hammer energy to it. As the cone was being driven into the ground, the number of blows required to drive each increment (typically 100 mm) was recorded.

Fig. 4: *Collected samples and Posthole hand auger operation of Ihale damsite area*

Results and Discussions

With a detail field and laboratory work carried out on collected field samples of Ihale damsite area to investigate the carrying capacity of the proposed dam in the area, the following assessment were adopted and used to probe the area including the dam axis for proper diagnosis of the site for the eventual construction of the dam. Salient assessment included Geophysical survey, Geotechnical evaluation that included lithological facies mapping, bulk density, specific density, Compaction, natural moisture content and Dynamic Cone Penetrometer (DCP) Test.

Geophysical Assessment

Vertical Electrical soundings conducted along the dam axis of the study area has revealed 4-5 layer earth model from the VES 1-8. In VES 1, recorded 4 layers with resistivity values of 696.5, 1482.7, 2857.6 and 458.3 Ωm have thicknesses of 0.6, 2.3, 5.5 and 21.6m respectively. The described geologic material inferred from the investigation included clayey top soil, laterite, weathered basement rock and fresh basement rock (Table 1). VES 2 displayed a similar configuration of 4 layers that included clayey top soil, laterite, weathered basement rock and fresh basement rock. The varying resistivity values included 1008, 85.1, 281.8 and 544.1 Ωm with thickness of 0.5, 2.7, 7.1 and 19.7m respectively (Table 1).

Resistivity values of 885.2, 40.8, 92.6, 1144.0 Ωm were recorded for the top soil, lateritic, weathered basement and fresh basement layers respectively and as advanced by Olorunfemi et al (2000).

Table 1: *Summary of Vertical Electrical Sounding conducted at Ihale damsite*

VES Location	Material Description	Depth (m)	Layer Thickness (m)	Resistivity Value p(Ωm)	Corresponding DCP/BH/TP Number
VES 1 32P 0187693 UTM 0916033	Top soil/ Clay Laterite. Weathered basement Fresh Basement	0 – 0.6 0.6 – 2.9 2.9 – 8.4 8.4 - 30	0.6 2.3 5.5 21.6	696.5 1482.7 2857.6 458.3	DCP 1 BH 1
VES 2 32P 0187716 UTM 0916074	Top soil/ Clay Laterite Weathered basement Fresh Basement	0 – 0.5 0.5 – 3.2 3.2 – 10.3 10.3 - 30	0.5 2.7 7.1 19.7	1008.0 85.1 281.8 544.1	DCP 2 TP 1
VES 3 32P 0187742 UTM 0916127	Top soil/ Clay Laterite Weathered basement Fresh Basement	0 – 1.0 1.0 – 3.1 3.1 – 5.8 5.8 - 30	1.0 2.1 2.7 24.2	885.2 40.8 92.6 1144.0	DCP 3 TP 2
VES 4 32P 0187771 UTM 0916179	Top soil/ Clay Laterite Weathered basement Fresh Basement	0 – 0.3 0.3 – 0.8 0.8 – 6.1 6.1 –30	0.3 0.5 5.3 23.9	235.5 2071.4 68.0 463.3	DCP 4 TP 3
VES 5 32P 0187647 UTM 0915927	Top soil/ Clay Laterite Weathered basement Fresh Basement	0 – 1.0 1.0 – 2.9 2.9 – 12.1 12.1 - 30	1.0 1.9 9.2 17.9	1715.1 1548.7 595.3 1383.0	DCP 5 BH 2 TP 4
VES 6 32P 0187631 UTM 0915894	Top soil/ Clay Laterite Weathered basement Fresh Basement	0 – 1.3 1.3 – 3.5 3.5 – 7.0 7.0 – 30	1.3 2.2 3.5 23	102.4 40.5 422.8 2064.8	DCP 6 TP 5
VES 7 32P 0187605 UTM 0915838	Top soil/ Clay Laterite Weathered basement Fresh Basement	0 – 1.5 1.5 – 2.3 2.3 – 8.8 8.8 - 30	1.5 0.8 6.5 21.2	554.4 242.9 29.1 394.4	DCP 7 TP 6
VES 8 32P 0187568 UTM 0915752	Top soil/ Clay Laterite Weathered basement Slightly weathered basement Fresh Basement	0 – 1.3 1.3 – 3.1 3.1 – 7.5 7.5 – 18.2 18.2 - 30	1.3 1.8 4.4 10.7 11.8	1283.2 922.4 103.2 43.4 114.0	DCP 8 TP 7

VES 4 displayed 235.5, 2071.4, 68.0 and 463.3 Ωm across top soil clayey layer 1, lateritic layer 2, weathered basement layer 3 and fresh basement layer 4 of varying thickness respectively. The study in summary has revealed that all the VES points ie VES 1-7 possess 4 layers of geo-electric sections with thickness ranging from 0.3-24.2 meters, resistivity values ranging from 29.1-2857.6 Ωm with the only exception of VES 8 with 5 layers in the area, in essence, the 5 layers from the VES 8 included clayey topsoil, laterite, weathered, slightly weathered and fresh weathered basement rock. They have their thicknesses to be 1.3, 1.8, 4.4, 10.7 and 11.8 with corresponding resistivity values recorded to be 1283.2, 922.4, 103.2, 43.4 and 114 Ωm respectively.(Table 1). From the geo-resistivity curves obtained for the investigated area, this has shown that Ihale damsite area is having few fracture trends that could allow seepages of water.

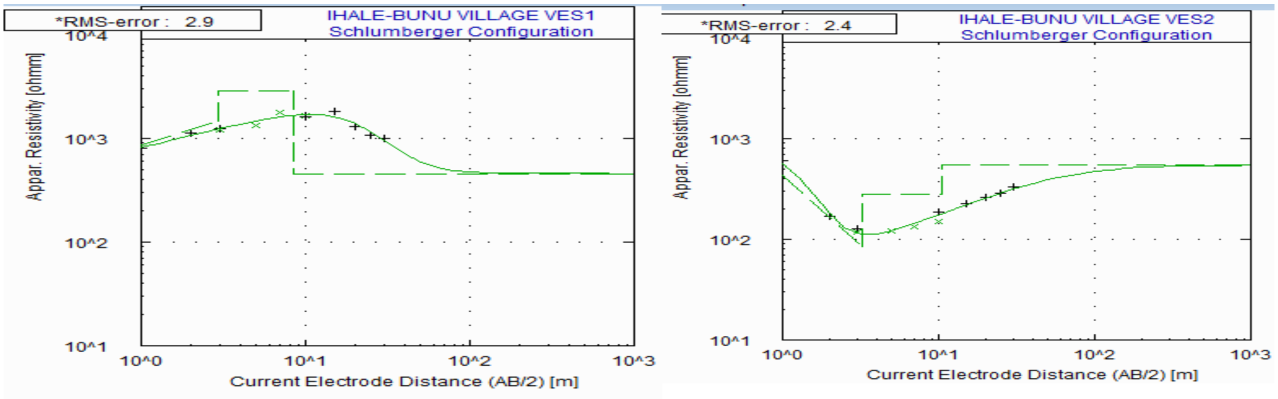


Fig. 5: *Selected resistivity VES 1 and 2 curves of the Ihale area investigated*

It is worthy of note that the Ihale, Kaaba-Bunu area is having its most desirable basement rock at about 11-21.6 meters depth (Table 1 and Figs 5 and 6). The stripping of the topsoil and other lithological facies on the fresh rock as enumerated (Table 1) and will have to be made by putting into consideration, that the essence of the dam is to have a water tight condition that will prevent or eliminate the anticipated water seepages of the proposed reservoir. The resistivity values recorded from this study are quite moderate and this reflects that more clay expected in the area will be absent. The conducted geophysical survey has equally revealed that the aquiferous underground water table is going to be shallow at about 12-19 meters during the dry season and will go deeper during the wet season.

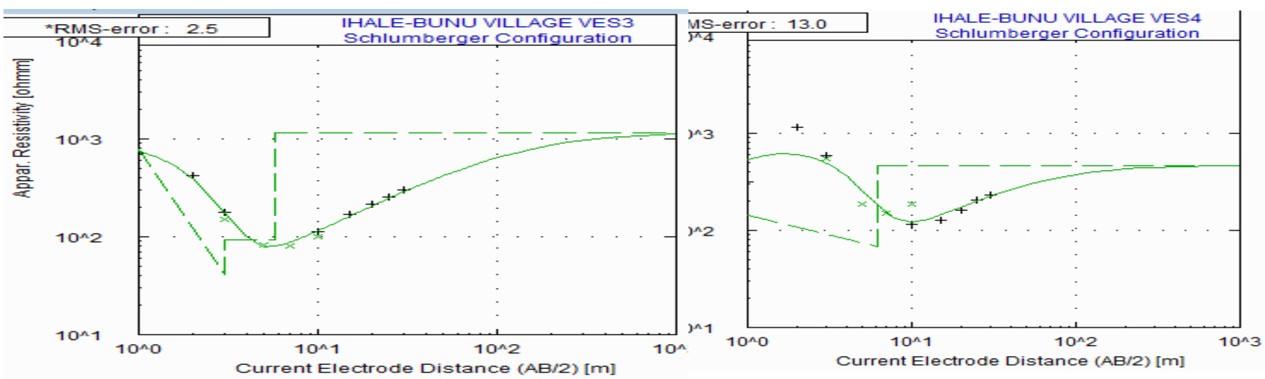


Fig. 6: *Selected resistivity VES 3 and 4 curves of the Ihale area investigated*

The Vertical Electrical Sounding obtained in the area has allowed the proper diagnosis of the fractural trend to know the likely areas of seepages, depth of excavation to expect in the area during construction and groundwater seasonal fluctuation of water table. In essence, the VES 1-8 have all shown that the topsoil of the area ranges from 0.8 in VES 4 to 3.5 in VES 6. (Table 1). With an envisaged 3.5 m depth of excavation, the lateral weathered rock that will be encountered can be treated with cement slurry, to prevent seepages ie loss of reservoir water. Bayowa et al (2019) investigated Oba earth fill dam and the geoelectric interpretation revealed that the area along the dam embankment is underlain by a maximum of 4 geoelectric layers.

Geotechnical Study

The geotechnical analysis of the area was done to evaluate the lithological facies, bulk density, specific gravity, natural moisture content, compaction and Depth Cone Penetration test of the soil along the dam axis and predict the capacity to carry such anticipated load of dam in the area.

Lithological Facies Mapping of the Area:

The collected lithological samples from the field work exercise facilitated the mapping of the lithological facies of the dam axis area. This prompted the design of the lithological log profile of all the collected samples in the test/trial pits of the area along the dam axis area. The encountered lithological profile of the area (Fig. 11) included brownish micaceous sands, brownish micaceous medium coarse sands, mottled silty-sandy clayey gravel, Brownish silty-gravel with boulders, greyish/mottled weathered micaceous clayey-silty gravel, mottled silty sandy clay-gravelly clay, mottled micaceous silty- sands, Brownish micaceous sandy gravel, reddish-brownish silty -sandy lateritic clay, reddish silty lateritic clay and greyish Impervious basement rock at 1.1 – 3.2 meters. This geotechnical mapping of the lithological facies has revealed that stripping of the loose topsoil will have to be done to 1.1 meters. Diagramatic details of the facies are well sketched and incorporated (Fig. 11).

Bulk Density

Most rocks and all soils can be regarded as containing voids between grains. These voids may be filled with water, air or both. Thus, three conditions are possible dry, partially saturated and saturated. The in situ or 'bulk' density of the material was determined by the relative proportions of mineral particles, water, and air in a given volume of material, and the specific gravity of the mineral particles. The bulk density is the amount of mass in a given volume and the units are Kg/m^3 (Table 1). The collected samples varied across the depth probe as such, BH1S1 sample collected at depth interval 0-2.8 recorded bulk density of $1640Kg/m^3$. BH1 S2 sample at 2.8 – 3.2 probe point depth interval recorded 1600 Kg/m^3. BH2 S1 and BH2S2 at 0-0.7 and 0.7-1.1 m probe depth recorded 1300 and 1910 kg/m^3 respectively (Table 1). TP1S1, TP1S2 and TP1S3 all had their bulk density as 1700, 1750 and 1530 kg/m^3 respectively at various depth interval of sample collection. Detail of sample analysis for their bulk density varied across the 2830 and 1340 kg/m^3. This revealed that the specific gravity of the area is good to support the construction of a dam in the area with anticipated minor or no leakage expectation.

Specific Gravity:

The specific gravity of the collected samples along the dam axis was analyzed to predict the potential to support the dam foundation and hold the anticipated load for proper placement of the footings of the dam and even the spillway structural design of the area. The BH1S1, BH1S2, BH2S1 and BH1S2 recorded a specific gravity of 2.61, 2.63, 2.60 and 2.65 respectively. Similarly, samples TP1S1, TP1S2, TP1S3 and TP2S1 all constitute recorded values that ranges from 2.70, 2.76, 2.68 and 2.56 respectively. TP2 S2, TP3 S1, TP4S1 and TP4S2 all recorded 2.77, 2.69, 2.60 and 2.65 respectively (Table 2).

Table 2: *Geotechnical properties recorded along the Ihale damsite area*

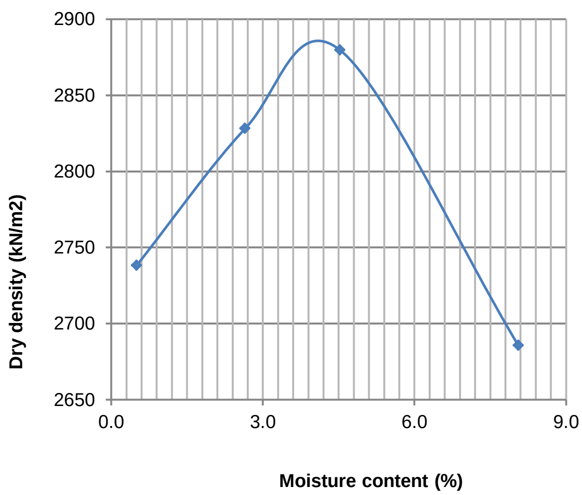
Probe point	**Depth (m)**	**Bulk Density kg/m^3**	**Specific Gravity Gs**	**Natural Moisture Content Nmc (%)**	**OMC (%)**	**MDD (kg/m^3)**
BH1 S1	0 – 2.8	1640	2.61	22.35	8.1	2686
BH1 S2	2.8 – 3.2	1600	2.63	24.49	-	-
BH2 S1	0 – 0.7	1300	2.60	10.04	12.1	3006
BH2 S2	0.7 – 1.1	1910	2.65	13.49	8.0	3148
TP1 S1	0 – 0.3	1700	2.70	2.22	7.0	3280
TP1 S2	0.3 – 0.7	1750	2.76	1.84	-	-
TP1 S3	0.7 – 0.95	1530	2.68	3.56	7.0	3182
TP2 S1	0 – 0.4	1490	2.56	3.27	8.97	3163
TP2 S2	0.4 – 0.9	2830	2.77	-	-	-
TP3 S1	0 – 0.6	1850	2.69	1.73	7.0	3209
TP4 S1	0 – 0.7	1320	2.60	10.04	12.1	3006
TP4 S2	0.7 – 1.1	1910	2.65	13.49	8.0	3148

TP5 S1	0 – 1.0	1360	2.62	7.5	-	-
TP6 S1	0 – 0.8	1350	2.58	8.71	12.2	2998
TP7 S1	0 – 0.7	1380	2.67	11.02	7.5	2782

TP5S1, TP6 S1and TP7S1 recorded 1360, 1350 and 1380 respectively. In essence, the recorded values across all study samples have revealed that the investigated dam axis area will be good for dam construction.

Compaction and Natural Moisture Content Test

Compaction strength test was conducted on selected study samples of BH1S1, BH2S2, TP1S1, TP1S3, TP2S1 and TP3 S1 with a value that ranges from about 3-14% moisture content. The curves were plotted for each sample as dry density (KN/m^2) against moisture content (%) of each sample. Inverted V curves were generated for all studied samples which was further interpreted as cohesive soils with fines in all study samples (Figs. 7-9). Maximum compaction of the mapped geologic material will be necessary as fill material for the construction of the Ihale damsite in the area.



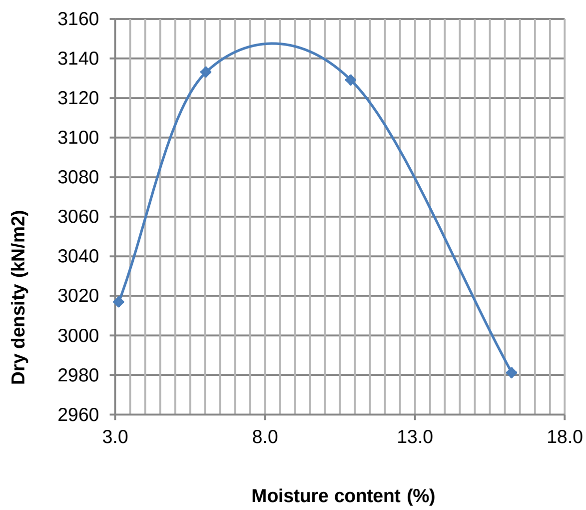


Fig. 7: *Compaction curve of BH1S1 and BH2S2 samples of Ihale study area.*

Table 3: *Geotechnical properties of BH1S1 and BH2S2*

		BH1S1		
Dry Density (KN/m^2)	**2743**	**2828**	**2879**	**2687**
Moisture Content (%)	**0.93**	**2.86**	**4.62**	**8.11**
		BH2S2		
Dry Density (KN/m^2)	**3016**	**3133**	**3630**	**2930**
Moisture Content (%)	**3.0**	**6.02**	**10.60**	**16.50**

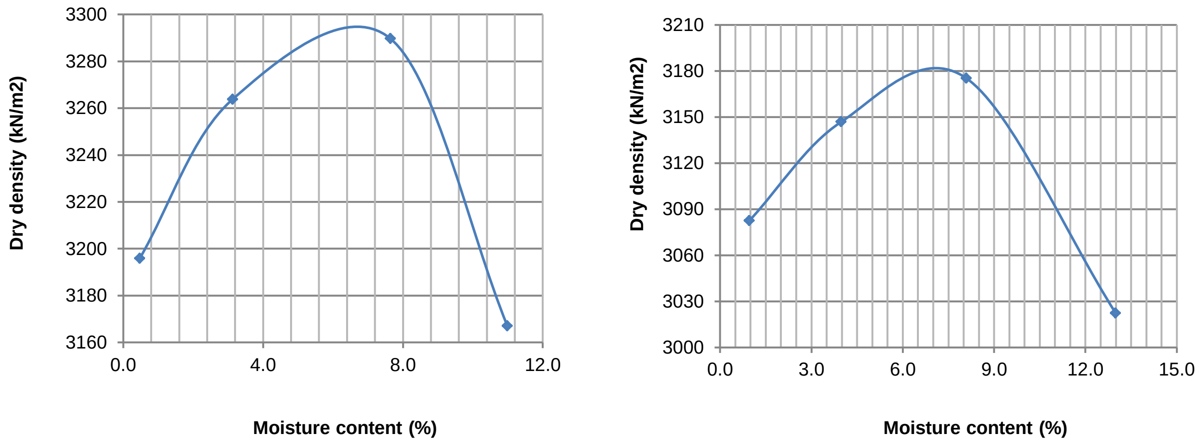


Fig. 8: *Compaction curve of TP1 S1 and TP1S3 samples of Ihale study area.*

Table 4: *Geotechnical properties of TP1S1 and TP1S2.*

		TP1S1		
Dry Density (KN/m^2)	**3194**	**3266**	**3290**	**3164**
Moisture Content (%)	**0.81**	**3.21**	**7.37**	**11.21**
		TP1S2		
Dry Density (KN/m^2)	**3081**	**3148**	**3178**	**3025**
Moisture Content (%)	**1.23**	**4.00**	**8.01**	**12.98**

The compaction geotechnical strength test conducted on the study samples has revealed that, as water was gradually added to the dry samples, the particles became closer with void reducing across the samples and this was reflected in the dry density mass that increased before slightly dropping. As the moisture content also increases, the soil particles developed larger water film around the particles as protective layer, as such, water seepages, which is almost totally inevitable in the proposed dam construction from the groundwater and rainwater infiltration that will have less effects on the dam foundation property to conserve water. The test has thus revealed very cohesive soil property with fines in the voids that constitute the matrix of the studied samples. The maximum dry density of all study samples were equally obtained at the optimum water content to reveal its property of highly cohesive nature which is desirably good in dam construction. In essence, the tested soil samples for the construction of a dam/weir in Ihale area will be supportive with very little issue of liquefaction and seepage expected in the soil profile of the area. Proper compaction of the geologic materials will needed to prevent wash-out especially during rainy season period.

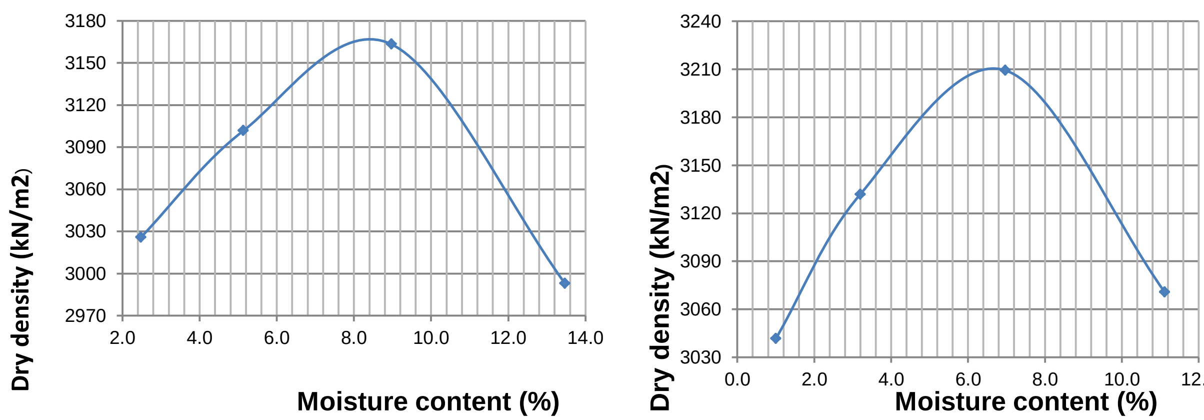


Fig. 9: *Compaction curve of TP2S1 and TP3 S1 samples of Ihale study area.*

Table 5: *Geotechnical properties of TP2S1 and TP2S3*

		TP2S1		
Dry Density (KN/m^2)	**3028**	**3103**	**3176**	**3991**
Moisture Content (%)	**2.61**	**7.93**	**9.03**	**13.51**
		TP2S3		
Dry Density (KN/m^2)	**3038**	**3128**	**3210**	**3068**
Moisture Content (%)	**1.00**	**3.21**	**7.00**	**11.2**

Natural Moisture Content of the tested soil samples vary from the lowest among investigated samples of Ihale dam axis to be 2.22% and this was recorded by sample TP1S1. On the other hand BH1S2 sample of the area recorded the highest natural moisture content of 24.49%. This indicates a moderate moisture value that can hold the foundation of a proposed dam in the area. More importantly, with excessive rainfall pattern in the area the recorded values have shown the soil will not loose its strength to perform the function of supporting the foundational footing of the proposed dam in the area. The highest dry density recorded at the Ihale damsite area was 3991 KN/m^2 and this was for TP2S1 sample with a corresponding 13.51% moisture content. This is desirable and will withstand excessive rainfall water content in the area. Conversely, the lowest dry density recorded across the investigated area was 2687 KN/m^2 with a corresponding 8.11% moisture content. An average moisture content of 29.53% was recorded by Umoren et al (2016) at the Nkari damsite, Southeastern Nigeria.

Dynamic Cone Penetrometer (DCP) Test

Eight (8) numbers of DCP were conducted to the point of refusal. The number of blows per 10cm for the overburden soils ranges from 1 to 50 between depths of 0 – 2.0meters. DCP Test involves driving a solid cone of 60^0 into the ground, using repeated blows of a hammer with a fixed mass of 10Kg falling through a distance of 550mm having maximum diameter of 20mm. The hammer strikes an anvil which is rigidly fixed to the rods which are of smaller diameters than the cone, and transmit the hammer energy to it. As the cone was being driven into the ground, the number of blows required to drive each increment (typically 100 mm) was being recorded. The number of blows required to drive 100mm into ground was recorded and the test terminated at depths where hammer blows is greater than 50 or caused less than 100mm penetration. The blow count was inputted into appropriate excel software to provide a more-or-less continuous profile of penetration resistance with depth and consequent determination of the bearing capacity usually at 0.5m depth interval.

The Dutch formula for Dynamic Penetrometer was used for the computation of the unit cone resistance. The outcome was further employed for the estimation of allowable soil bearing pressure based on penetrometer theory/application. Dynamic formula for unit cone resistance, (Rd);

$$\mathrm{R_d} = \frac{\mathrm{M^2H}}{\mathrm{Ae(M+\rho)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

$$\mathrm{q_{ad}} = \frac{\mathrm{R_d}}{20} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where; M = weight of hammer (kg)
H = Height of fall (cm)
A = Sectional area of cone at base (cm^2)
e = Penetration / blow (cm)
ρ = Weight of cone accessories (kg)
$\mathrm{R_d}$ = Unit cone resistance (kg/cm^2)
$\mathrm{q_{ad}}$ = Allowable bearing pressure. (kg/cm^2 or kN/m^2)

The computed unit cone resistance values at 0.5m intervals for depth up to 2meters below the ground surface is presented in Table 6 while the resistance profile is presented in . Several sounding curves were obtained with selected ones of the Dynamics Cone Penetrometer (DCP) sounding curves incorporated (Fig. 10)

Table 6: *DCP Unit Cone Resistance Values*

Depth (m)	Unit Cone Resistance (KN/m^2)								Average DCP Bearing Capacity Values (KN/m^2)
	DCP1	DCP 2	DCP 3	DCP 4	DCP 5	DCP 6	DCP 7	DCP 8	
0.5	95	145	115	145	95	160	130	145	130
1.0	150	205	175	215	205	205	260	270	210
1.5	175	260	260	320	155	295	330	295	260
2.0	520	460	520	520	520	415	520	520	500

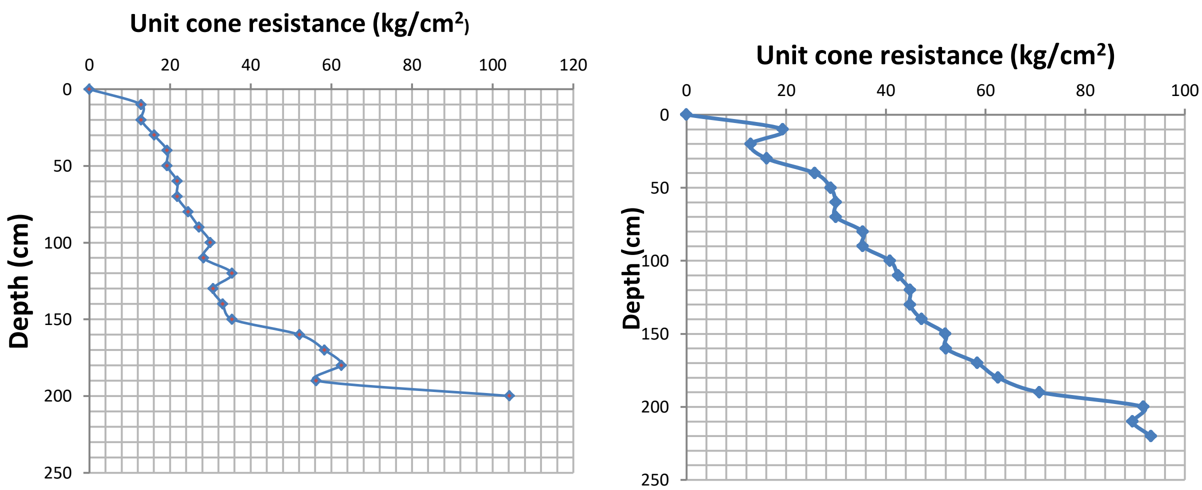


Fig. 10: *Selected DCP 1 and 2 damsite curve of Ihale investigated area*.

Conclusions and Recommendations

Clayey top soil, laterite, weathered basement rock and fresh basement rock were the main geologic material obtained from the area with 4 geo-electric layers recorded except VES 8 with 5 layers. Resistivity values along the dam axis ranges from 29.1 which is the third layer of VES 7 to 2857.6 Ωm that represent third layer of VES 1. The third layer of VES 1-7 was inferred to be weathered basement rock. Dam placement footing on this layer could be hazardous as the weathered rocks are commonly weak to support the foundational footings of the dam structure. In essence placing the dam structure to rest on the fourth layer of fresh basement rock will be more desirable to minimize seepages and enhance the foundational footing of the structure. Geotechnical analysis revealed bulk density varied from 1320 to 2830 kg/m^2. Specific Gravity ranges from 2.56 to 2.76 Ga. Natural moisture content Nmc varied between 1.73 and 24.49 % with optimum dry density and dry density desirable for the support of dam construction in the area. Washout of the geologic material will be very minimal. Fill materials for the embankment could be sourced from identified borrow area around the project area or at existing borrow pits along Ofere - Ihale – Bunu road. Unit Cone Resistance (KN/m^2) that varies from 95 to 520 KN/m^2 across the depths is desirable to support the dam area structure. Average DCP Bearing Capacity Values (KN/m^2) increases from 120 to 500 as depth of investigation increases from 0.5 to 2.0 m.

It is recommended that a clay core or concrete wall is recommended for the central portion of the earth embankment while riprap or boulder blanket/toe drains are recommended for the upstream and downstream face of the embankment portion of the dam respectively. Lastly, water for concrete works can be sourced from the Afun river due to its perennial nature.

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BOREHOLE LOG ALONG PROPOSED DAM AXIS

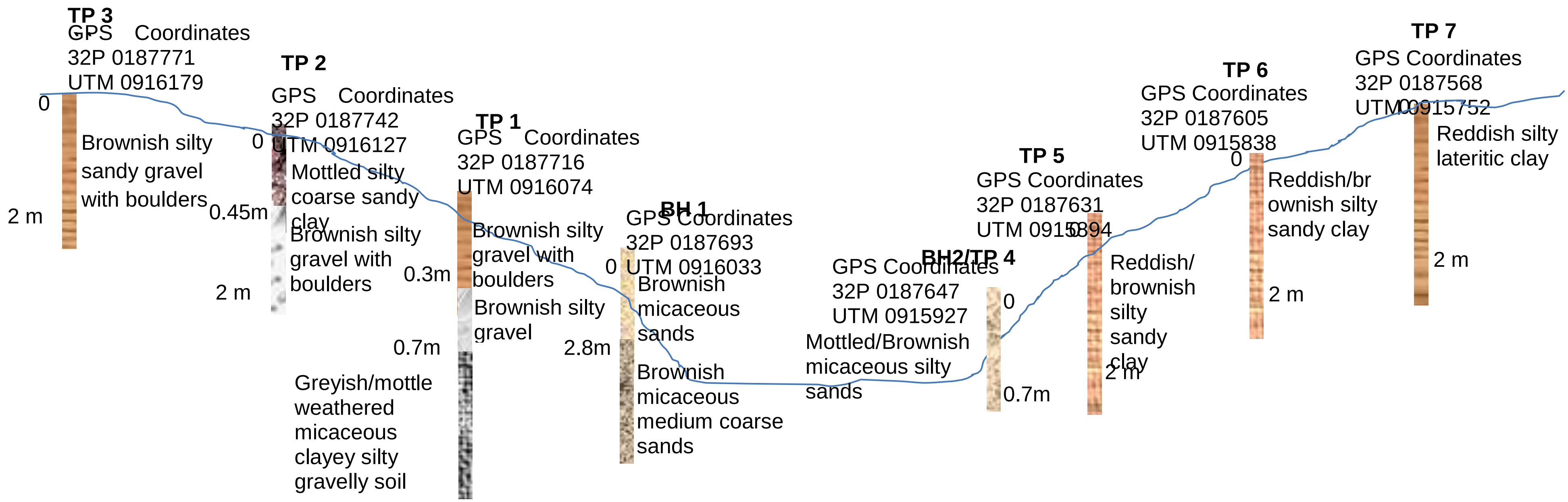

Fig. 11: Borehole and Test pits log of the Ihale dam site area, showing its lithological facies