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Hydrogeological and Groundwater Potential Studies Around Oke-Oyi Area, Sheet 202 Sw, South-Western Nigeria

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Abstract

Geology of an area can serve as a key factor in the understanding of its hydrogeology. The geologic and Hydrogeological studies of the Oke-Oyi area and its environs were carried out, aimed at analyzing the petrography of different lithologies encountered in the area as well as evaluating its groundwater potential. The study involves geological mapping through footpath traversing using appropriate mapping tools. Groundwater levels were measured from fifty hand-dug wells in the area using a weighted surveyor's tape, and employed to generate seasonal groundwater level maps. The hydraulic properties of aquifers which include hydraulic conductivity, transmissivity and storativity in the area were determined from their pumping test data using calculation methods with appropriate formulae. The lithologies observed in the area were biotite-granites and metasediments with open and infilled joints trending mostly in the NE-SW direction. The produced hydrogeological maps interpreted that groundwater flows through the relief pattern of the area and the flow is largely in a north-east direction. The hydraulic conductivity, transmissivity and storage coefficient ranged from 1.17×10^{-1} m/day to 8.60×10^{-2} m/day, 0.95 m^2/day to 3.16 m^2/day and 0.619 to 1.765 respectively. The crystalline rocks in the area can produce modest groundwater potential. Groundwater movement in the area is controlled by its hydraulic head and permeability of the material through which it flows. The declination in water levels indicates groundwater flow direction. The average value for the storage coefficient of the area indicated that the storage potential of the boreholes is low; hence, their recharge potential is low. Enhanced storage potential of the available boreholes through deepening of the borehole structure and artificial recharge should be encouraged.

Keywords: Aquifer, Conductivity, Granite-Gneiss, Hydrogeology, Transmissivity.

Introduction

The hydrogeology of an area may be influenced by factors such as geology, climate, and structural features. The type and nature of aquifers in an area are determined by subsurface geological formations and the associated structures, while the climate determines the amount and rate of recharge of the aquifers (Akiang et al., 2024, Tijani, 1994). Hydrogeology is concerned with the flow of water through aquifers and other shallow porous media. Foster and Shah, 2012 reported that about 40% of the world's irrigated area is flushed with groundwater. Groundwater allows 13% of total food production to be made and contributes to about 44% of irrigated food production (Villholth et al., 2013). Among the previous workers who have worked on the potability of groundwater in southwestern parts of Nigeria (Kwara State, inclusive) are Raji and Alagbe (2000), who observed a topo-geochemical sequence in the thick overburden aquifer of the Asa drainage basin in Kwara State. Forty groundwater samples were collected by the authors from wells in the area and chemically analyzed. Results of the analyses revealed that the PH value of the area was slightly acidic to slightly alkaline, the total dissolved solids average 555.33 and the major cations analyzed (Ca2+, Mg2+, K+, and Na+) were in decreasing order of abundance. On the other hand, the anions analyzed (HCO3-, SO42- and Cl-,) were in increasing order of abundance. According to the authors, the groundwater sequence observed based on the type of dominant ions in the study area were Ca-Mg bicarbonate waters, Ca-Mg bicarbonate-chloride water and Ca-Mg sulfate-chloride water. Also, Adeyemi et al. (2003) worked on the chemical characteristics of some well waters in Ikire, south-western Nigeria, aimed at determining the potability or otherwise of the well waters as well as the probable source(s) of the pollution of groundwater, if any. The concentration of ions in the majority of the samples is below the maximum permissible levels indicated in the World Health Organization (WHO) standards. This indicates that most of the waters in the area are potable. It is helpful when rock types in an area are well studied to give a better understanding of the area's water management and distribution. Hence, this study gives insights on the geology and hydrogeology of the study area.

The study area is bounded between latitudes 8030`N and 8045`N and longitudes 4040`E and 5000'E, covering an approximate area of about 513 km2 (Fig. 1). The vegetation zone of the study area is tropical savanna zone with a mean annual rainfall of 1,231mm (Ajibade, 2002), a mean annual temperature of 28oC (Ajibade, 2002), and a mean annual relative humidity of 56% (Olanrewaju, 2009). Oke-Oyi area and its environs being a Basement terrain comprise of rocks of the Basement Complex of south-western Nigeria, which is of Precambrian to Lower Palaeozoic age. This is in line with the report given by Jones and Hockey, 1964; Odeyemi, 1976; Rahaman, 1976. The relief of the area is rugged in nature, with mostly low, rounded hills and some flat-topped hills. The highest point in the area is 396 m, while the lowest point is 183m above the mean sea level. Rivers Oyi and Oshin with their tributaries are the main rivers draining the area where both rivers flow in a north-eastern direction and in a dendritic pattern.

Figure 1: Topographical map of the study area, showing its relief Source: NGSA, 2006

Materials and Methods

The geological mapping of the study area was carried out through footpath traversing method using a topographic map on an appropriate scale of 1:100,000 as a base map and other appropriate field mapping equipment. Repeated water levels' measurements were undertaken in 50 hand-dug wells using a surveyor's weighted tape at the end of raining season (October, 2011) and at the peak of dry season (February, 2012). The measurements were used to produce groundwater contour maps for the end of the rainy season and the peak of the dry season. The hydraulic properties of aquifers determined from the available seven boreholes in the area were hydraulic conductivity, transmissivity, and storativity and they were estimated from pumping test data of the available boreholes by graphical plotting of drawdown of water level against the time interval using appropriate formulae. The hydraulic conductivity (K) was calculated as:

$$K = \frac{T}{b} \qquad (1)$$

Where K= hydraulic conductivity, T= transmissivity and b= aquifer thickness,

Transmissivity was calculated using the equation 2:

$$T = \frac{2.30Q}{4\pi\,\Delta s} \times \log_{10}\frac{t_2}{t_1} \qquad (2)$$

Where T = transmissivity (m^2/day), Q= discharge rate, Δs = change in drawdown, t_2 and t_1 = time (days) since pumping started and

Storativity was calculated using the equation 3:

$$S = \frac{2.25Tt_0}{r^2} \qquad (3)$$

Where: S= storage coefficient, T = transmissivity (m^2/day), t_o = time intercept on zero draw-down axis, r = distance of the borehole.

Results and Discussions

Geology of the study area

The rock types mapped in the area comprise of igneous and metamorphic rocks, which include biotite granite of three varieties (medium to coarse grained, fine grained, and coarse to porphyritic grained), granite gneiss, and metasediments, which are mainly quartz mica-schist and quartzite as presented in figure 2.

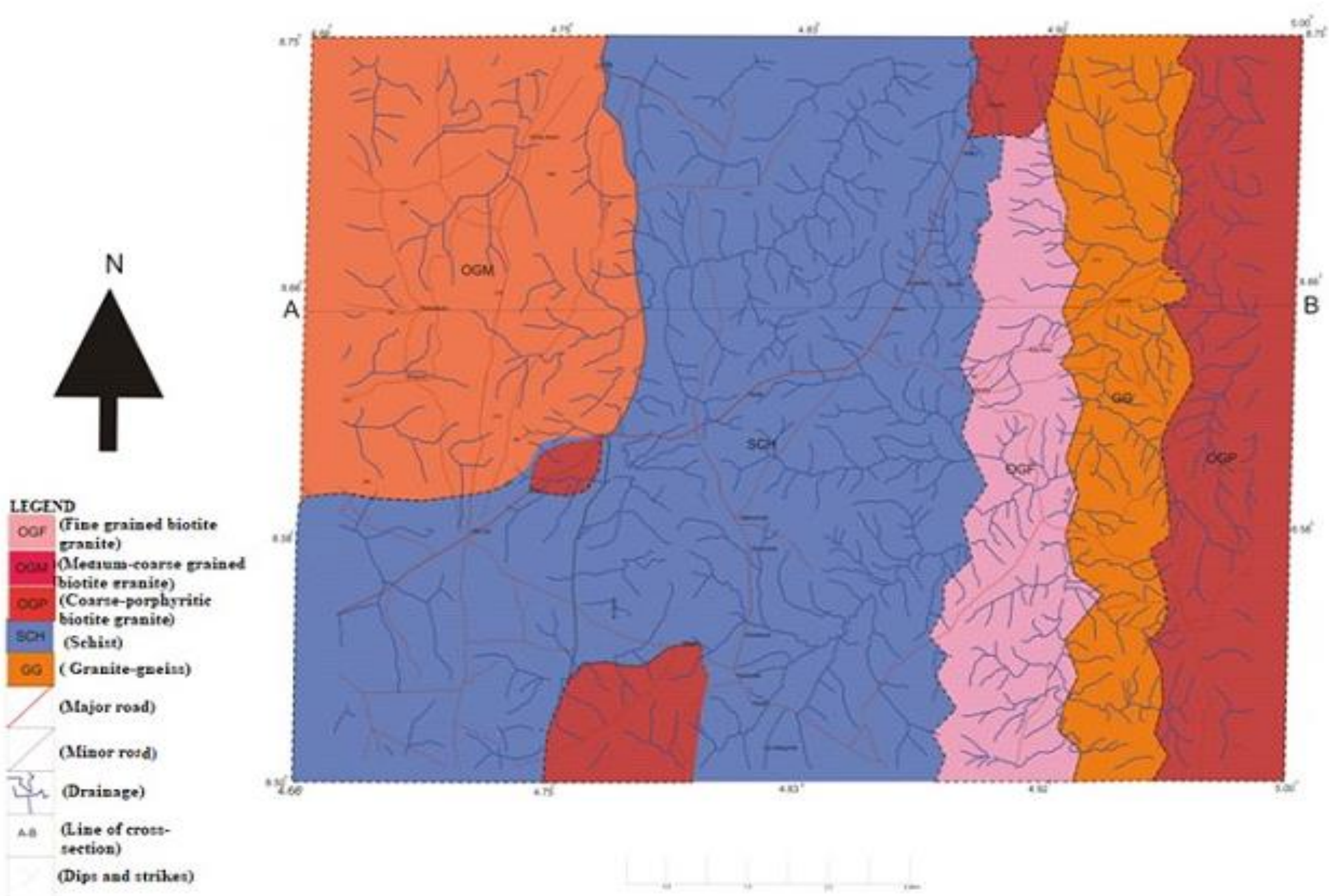
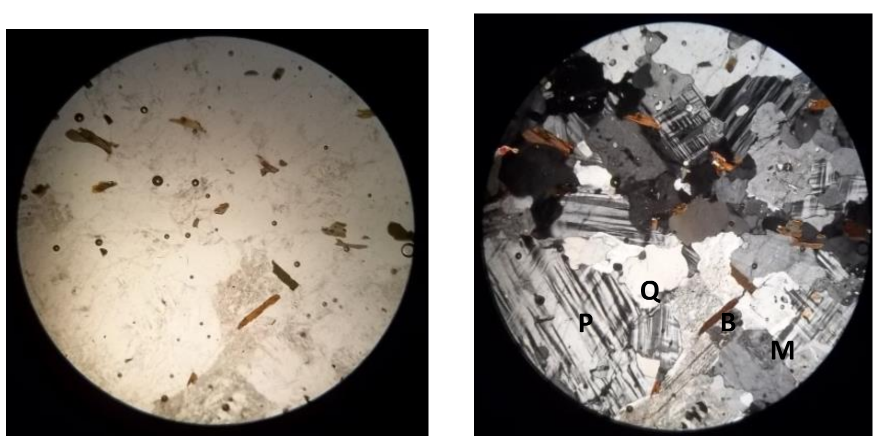


Figure 2: Geological map of Oke-Oyi area and its Environs

Biotite granite is late tectonic granite, which is part of the Nigerian Older Granites. It occupies the north-western portion of the mapped area. The rock is light grayish, and in some of its varieties, the light gray has pink tints as a result of the predominance of orthoclase. Three varieties of the rock, based on texture, were mapped in the area (medium to coarse-grained, coarse-porphyritic, and fine to coarse-porphyritic-grained). Figure 3a shows an outcrop of medium- to coarse-grained biotite being intruded by a pegmatite vein of 0.6 m thick with a lateral extent of 13.5 m. The Petrograhic study of the rock through a visual estimate showed that the biotite granite consists of plagioclase (35%), quartz (25%), microcline (20%), biotite (15%), and other accessories (5%). The biotite has moderate relief, is sub-heudral, pleichroic, and has a perfect cleavage in PPL. Plagioclase feldspar is the dominant mineral of all the constituents with a sub-heudral shape, while quartz is anhedral (Fig. 3b).

Figure 3a: Field photograph of an outcrop of medium to coarse grained biotite granite been intruded by pegmatite vein at 08.659^0 N and 04.696^0 E



PPL (Plane Polarized Light) XPL (Cross Polarized Light)

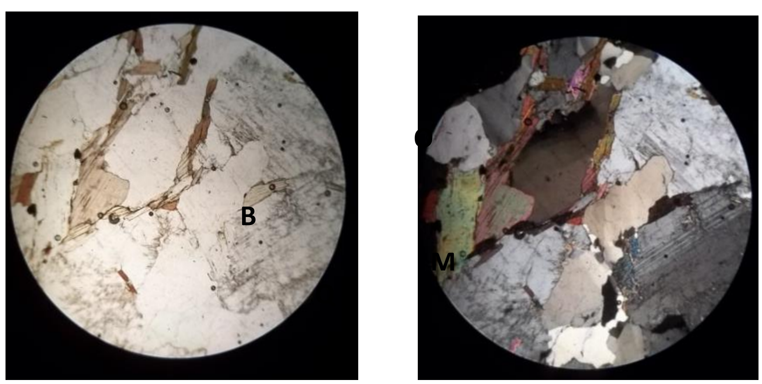
Figure 3b: Photomicrograph of Biotite granite in PPL and XPL

B= Biotite, **M**= microcline feldspar showing crosshatch twinning, **P**= plagioclase feldspar, **Q** = Quartz,

Granite Gneiss was observed along Adanda-Lajolo road at the eastern part of the mapped area. It is found being exposed along the river channel and being overlain by the superficial deposits of laterites.

The rock is grayish and coarse in texture (Figure 4a). The rock is foliated with strike and dip values of S240^{0}W and 54^{0}E, respectively (Figure 4a). The mineral constituents of the rock were identified from its petrographic study. The study revealed by visual estimate that the rock consists of quartz (40%), microcline (20%), biotite (20%), orthoclase (18%), and other accessories (2%). Quartz is xenoblastic in PPL; biotite is light brown but pleichroic from light to dark brown, sub-heudral, and has a perfect cleavage in PPL. Microcline and orthoclase are colorless but cloudy with low relief in PPL. Microcline is grayish in XPL with a crosshatch twinning pattern (Figure 4b).

Figure 4a: Field photograph of granite gneiss at Adanda-Lajolo road



PPL (Plane Polarized Light) **XPL (Cross Polarized Light)**

Figure 4b: Photomicrograph of granite gneiss in PPL and XPL
B= Biotite, **M** = microcline feldspar showing crosshatch twinning **O =** orthoclase, **Q**= Quartz,

Quartz-mica schist observed in the area is mostly weathered into grayish-brown coloration. The rock is coarse in texture and strongly foliated in the NW-SE direction. The foliation plane strikes N306^{o}W and dips 76^{o}E. In a road cut at Osin-Adelu, the schist was found occurring alternatively with pegmatite vein (Figure 5a). The photomicrograph of the rock showed that the rock consists of quartz (43%), muscovite (20%), biotite (25%), plagioclase feldspar (10%), and accessories (2%). Muscovite is colorless in PPL with perfect cleavage. The biotite is light brown but pleichroic. The muscovite displayed a pinkish interference color in XPL. The quartz is xenoblastic and inequigranular. The mica is prismatic to needle-like and pleichroic from light to dark brown (Figure 5b).

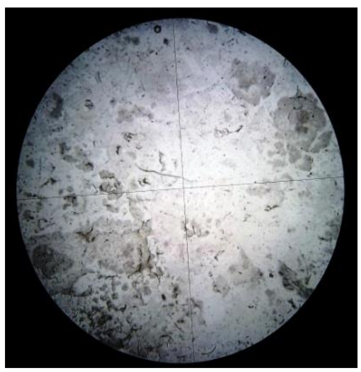
Figure 5a: Quartz-mica schist intruded by quartz and pegmatite veins with sharp contacts at 08.615^0 N and 04.783^0 E

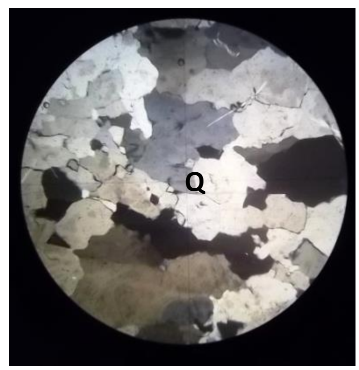
PPL (Plane Polarized Light) **XPL (Cross Polarized Light)**

Figure 5b: Photomicrograph of granite gneiss in PPL and XPL
B= biotite, **M=** muscovite, **P=** plagioclase feldspar and **Q=** Quartz,

Quartzite covers the north to southern portion of the mapped area. It trends as a dyke generally in the NW-SE direction in conformity with the schist as presented in figure 1. The rock also occurred as a ridge and as a block of boulders in some villages in the area, such as Ita-Alade and Panada, with joints (Fig. 6a) striking N86^{o}E and dipping 76^{o}E. The rock is mostly milky white or light brownish. The photomicrograph of the rock revealed that the only and dominant mineral in the rock was quartz (Fig. 6b).

Figure 6a: Field photograph of boulder of quartzite showing open joints at 08.618^0 N and 04.7990 E.





PPL (Plane Polarized Light) **XPL (Cross Polarized Light)**

Figure 6b: Photomicrograph of Quartzite in PPL and XPL
B= biotite, **M=** muscovite, **P=** plagioclase feldspar and **Q=** Quartz,

The general structural trends observed for joints in rocks of the area were NE-SW while others were NW-SE (Fig. 7).

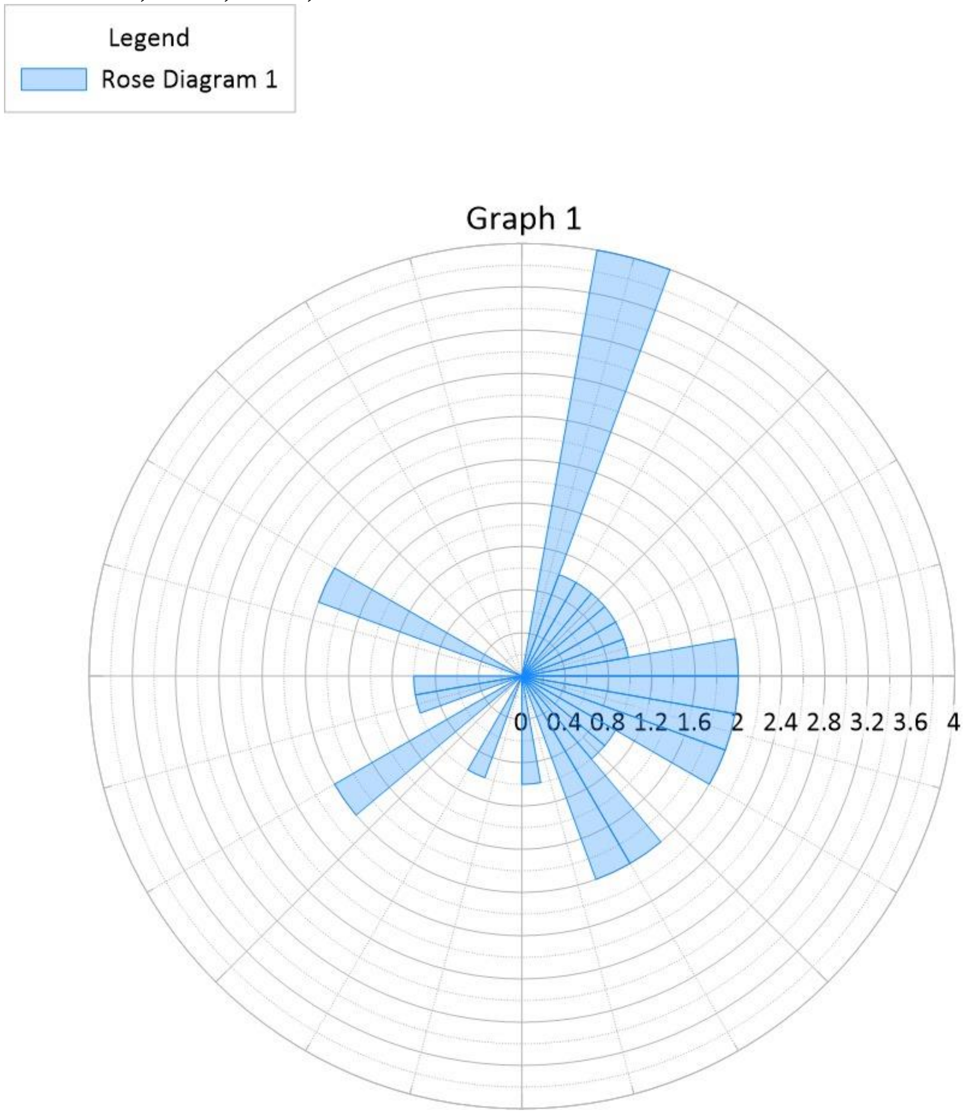


Figure 7: Rosette diagram showing strikes of joints in rocks of the area trending in NE-SW and NW-SE directions

Hydrogeology of the Area

Map of the configuration of water level in the study area

The data for the depth to water levels measured from the fifty hand-dug wells in the area with their coordinates and elevation above sea level is presented in Table 1. The groundwater contour maps in the study area have been drawn at a 15-meter interval for both seasons. The contours were produced by deducting the values of measured water level at each well location from the altitude of the well location in which lines were then drawn to join points of equal elevations (Figs. 8 and 9). The result of the calculated values for the aquifer parameters of the available boreholes in the area through graphical plotting of drawdown of water level against the time interval and application of appropriate formulae is presented in Table 2

Table 1: Measurements of hand-dug wells for depth to water level, coordinates and elevations above mean sea level at the end of rainy season and the peak of dry season

					END OF RAINY SEASON			**PEAK OF DRY SEASON**			
Locations	Settlements	Latitude (N)	Longitude (E)	Elevation a.m.s.l (m)	Depth to Water level (m)	Date of measurement	Elevation of Ground Water Level (m)	Depth to Water level (m)	Date of measur-ement	Elevation of Ground Water Level (m)	Ground water fluctuations
1	Loosa House Oke-Oyi	08.578^0	04.714^0	393	3.0	01-10-2011	390.0	3.95	27-3-12	389.05	0.95
2	Zango-Okeoyi	08.579^0	04.718^0	395	4.0	01-10-2011	391.0	6.40	27-3-12	388.60	2.40
3	Gaari Company	08.583^0	04.717^0	382	3.10	01-10-2011	378.90	4.60	27-3-12	377.40	1.50
4	Eleran Compound	08.584^0	04.716^0	369	3.55	01-10-2011	365.45	7.10	27-3-12	361.90	3.55
5	A.I.S.S.U.I.B.E	08.593^0	04.717^0	372	3.37	01-10-2011	368.63	5.10	27-3-12	366.90	1.73
6	Idiape	08.645^0	04.723^0	376	2.72	01-10-2011	373.28	5.50	27-3-12	370.50	2.78
7	Loosa Community	08.624^0	04.706^0	373	5.13	01-10-2011	367.87	5.14	27-3-12	367.86	0.01
8	Budo Alfa	08.634^0	04.697^0	347	13.2	01-10-2011	333.80	14.30	27-3-12	332.70	1.45
9	Babadudu	08.659^0	04.696^0	384	8.45	01-10-2011	375.55	9.90	27-3-12	374.10	1.10
10	Agodi House	08.583^0	04.686^0	389	4.27	01-10-2011	384.73	4.50	27-3-12	384.50	0.23
11	Lanwa Garage	08.583^0	04.686^0	355	3.26	01-10-2011	357.74	4.40	27-3-12	350.60	1.14
12	Badi Village	08.596^0	04.738^0	374	1.2	01-10-2011	372.80	2.45	27-3-12	371.55	1.25
13	Adelu Village	08.615^0	04.783^0	275	6.8	02-10-2011	368.20	9.00	28-3-12	266.00	2.20
14	Behind magajipanada	08.618^0	04.799^0	349	5.61	02-10-2011	343.39	5.90	28-3-12	343.10	0.29
15	Central well panada	08.619^0	04.797^0	366	7.2	02-10-2011	358.8	5.50	28-3-12	360.50	1.70

16	OkutalaPanada	08.618^0	04.799^0	376	4.32	02-10-2011	371.68	5.50	28-3-12	370.5	1.18
17	OdofunfunAgbeyangi	08.590^0	04.810^0	386	1.36	02-10-2011	384.64	1.80	28-3-12	384.20	0.44
18	Ayi House Agbeyangi	08.588^0	04.814^0	381	3.64	02-10-2011	377.36	5.20	28-3-12	375.80	1.56
19	Atanda well Agbeyangi	08.588^0	04.815^0	392	2.36	02-10-2011	389.64	3.20	28-3-12	388.80	0.84
20	Oloruntele	08.562^0	04.819^0	320	3.1	02-10-2011	316.9	7.50	28-3-12	312.50	4.40
21	Oduntaye Mosque.	08.530^0	04.816^0	343	5.13	02-10-2011	337.87	9.05	28-3-12	333.95	3.92
22	Bale oduntaye	08.529^0	04.816^0	342	4.10	02-10-2011	337.90	6.40	28-3-12	335.60	2.00
23	MagajiAlaroIlupeju's House	08.527^0	04.817^0	345	2.35	02-10-2011	342.65	8.20	28-3-12	336.80	5.85
24	IfayabaleIlupeu	08.533^0	04.814^0	341	5.10	02-10-2011	335.9	10.20	28-3-12	330.80	5.10
25	Olala House Ilupeju	08.532^0	04.816^0	339	2.66	02-10-2011	336.34	5.47	28-3-12	333.53	2.81
26	MagajiOloko's House	08.523^0	04.819^0	314	4.50	02-10-2011	309.50	5.05	28-3-12	308.95	0.55
27	Bale Idiape's House	08.543^0	04.796^0	358.0	2.50	02-10-2011	355.5	5.10	28-3-12	352.90	2.60
28	Okepoko well Idiapa	08.543^0	04.795^0	380.0	4.42	02-10-2011	375.8	6.65	28-3-12	373.35	2.23
29	Abanbgewell,Jolasun	08.559^0	04.752^0	369	2.78	02-10-2011	366.2	3.45	28-3-12	365.55	0.65
30	Jolasun Mosque well	08.558^0	04.751^0	382	2.11	02-10-2011	379.89	5.50	28-3-12	376.50	3.39
31	Kaaelesin Jolasun	08.559^0	04.753^0	389	3.88	02-10-2011	385.12	8.10	28-3-12	380.9	4.22
32	Eleran's House,Lanwa	08.748^0	04.756^0	278	1.30	02-10-2011	276.7	2.50	28-3-12	275.50	1.20
33	Kanajogun House ,Lanwa	08.745^0	04.758^0	282	2.30	02-10-2011	279.70	5.20	28-3-12	276.80	2.90
34	Alapa House Ita-alade	08.632^0	04.817^0	394	4.30	03-10-2011	389.70	7.30	29-3-12	386.70	3.00
35	Arinle's Well Ita-Alade	08.632^0	04.816^0	400	8.60	03-10-2011	391.40	13.20	29-3-12	386.80	4.60
36	AlokoLaaroIponrin	08.638^0	04.838^0	362	2.45	03-10-2011	359.55	4.60	29-3-12	357.40	2.15
37	Budo Alfa (2)	08.639^0	04.844^0	330	2.10	03-10-2011	327.90	3.15	29-3-12	326.85	1.05
38	IponrinOke-Ajia	08.639^0	04.851^0	335	2.50	03-10-2011	332.50	12.18	29-3-12	322.82	9.68

39	Sado's House Iponrin	08.641^0	04.853^0	332	4.20	03-10-2011	327.8	14.20	29-3-12	317.80	10.00
40	Kure Oja	08.659^0	04.869^0	307	1.54	03-10-2011	305.46	6.17	29-3-12	300.83	4.63
41	MagajiOnikoko's House	08.668^0	04.871^0	292	0.65	03-10-2011	291.35	4.54	29-3-12	287.46	3.89
42	Ifesowapo House Onikoko	08.668^0	04.870^0	294	1.60	03-10-2011	292.4	3.48	29-3-12	290.52	1.88
43	Baale's House Apado	08.669^0	04.886^0	299	2.46	03-10-2011	296.54	6.90	29-3-12	292.10	4.44
44	Isale Tapa WoruOja	08.715^0	04.889^0	330	4.15	04-10-2011	325.85	14.70	**30-3-12**	315.30	10.55
45	Olomopupo House Woru	08.717^0	04.891^0	326	3.21	04-10-2011	322.79	6.15	30-3-12	319.85	2.94
46	AfaSuberu's House Woru	08.717^0	04.891^0	329	2.20	04-10-2011	326.8	4.64	30-3-12	324.36	2.44
47	Magaji Yoruba's House Woru	08.713^0	04.889^0	321	5.20	04-10-2011	315.8	14.60	30-3-12	306.40	9.40
48	MagajiAbudu's House	08.731^0	04.899^0	297	2.80	04-10-2011	294.2	6.30	30-3-12	290.70	3.50
49	Opposite Abudu Compound	08.733^0	04.900^0	286	2.50	04-10-2011	283.5	4.20	30-3-12	281.80	1.70
50	Aloko Compound	08.743^0	04.907^0	288	2.80	04-10-2011	285.2	9.20	30-3-12	278.80	6.40

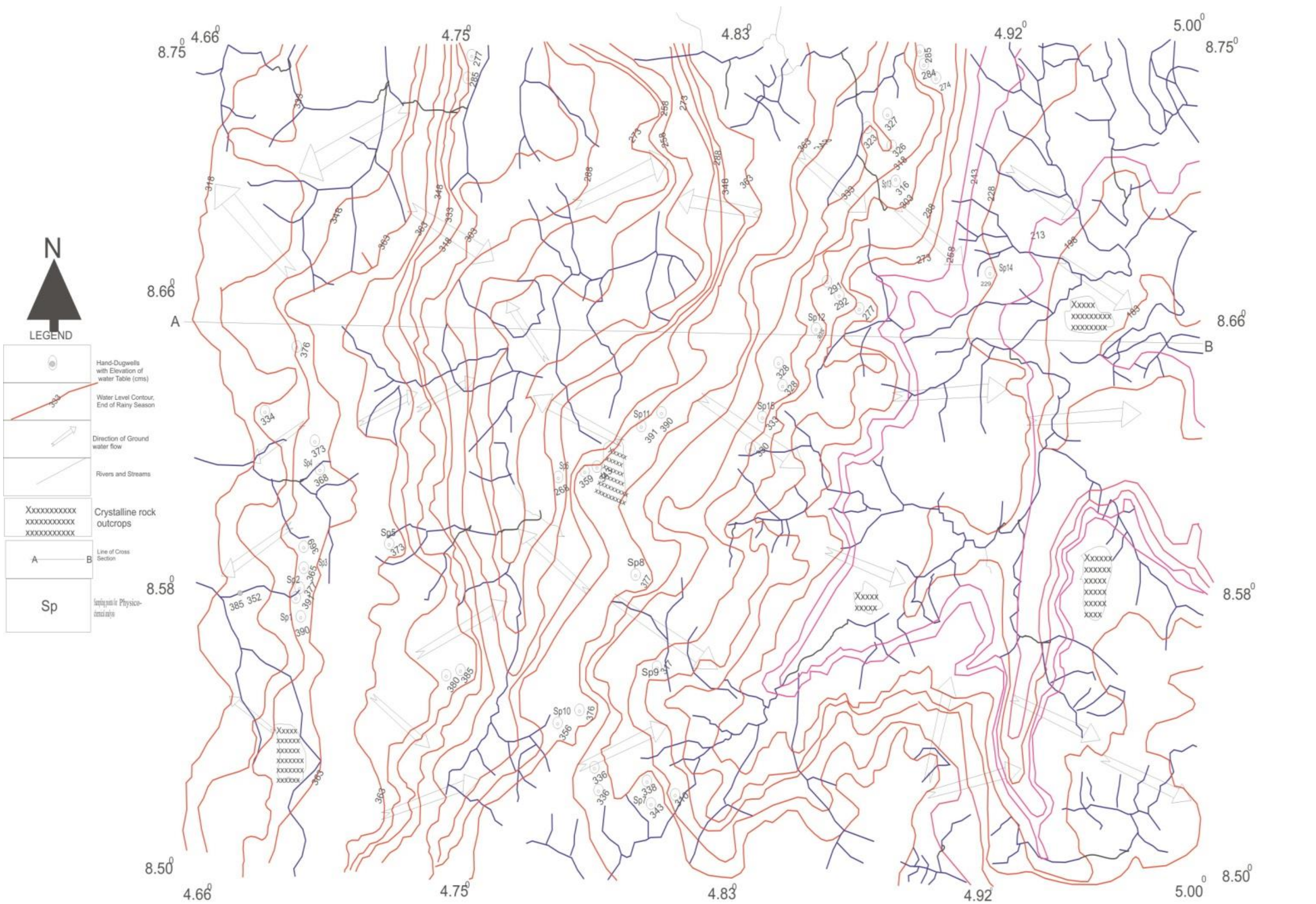


FIGURE 8: HYDROGEOLOGICAL MAP OF OKE OYI AND ITS ENVIRONS SHOWING WATER LEVEL CONTOURS AND DIRECTION OF GROUND WATER FLOW, END OF RAINY SEASON

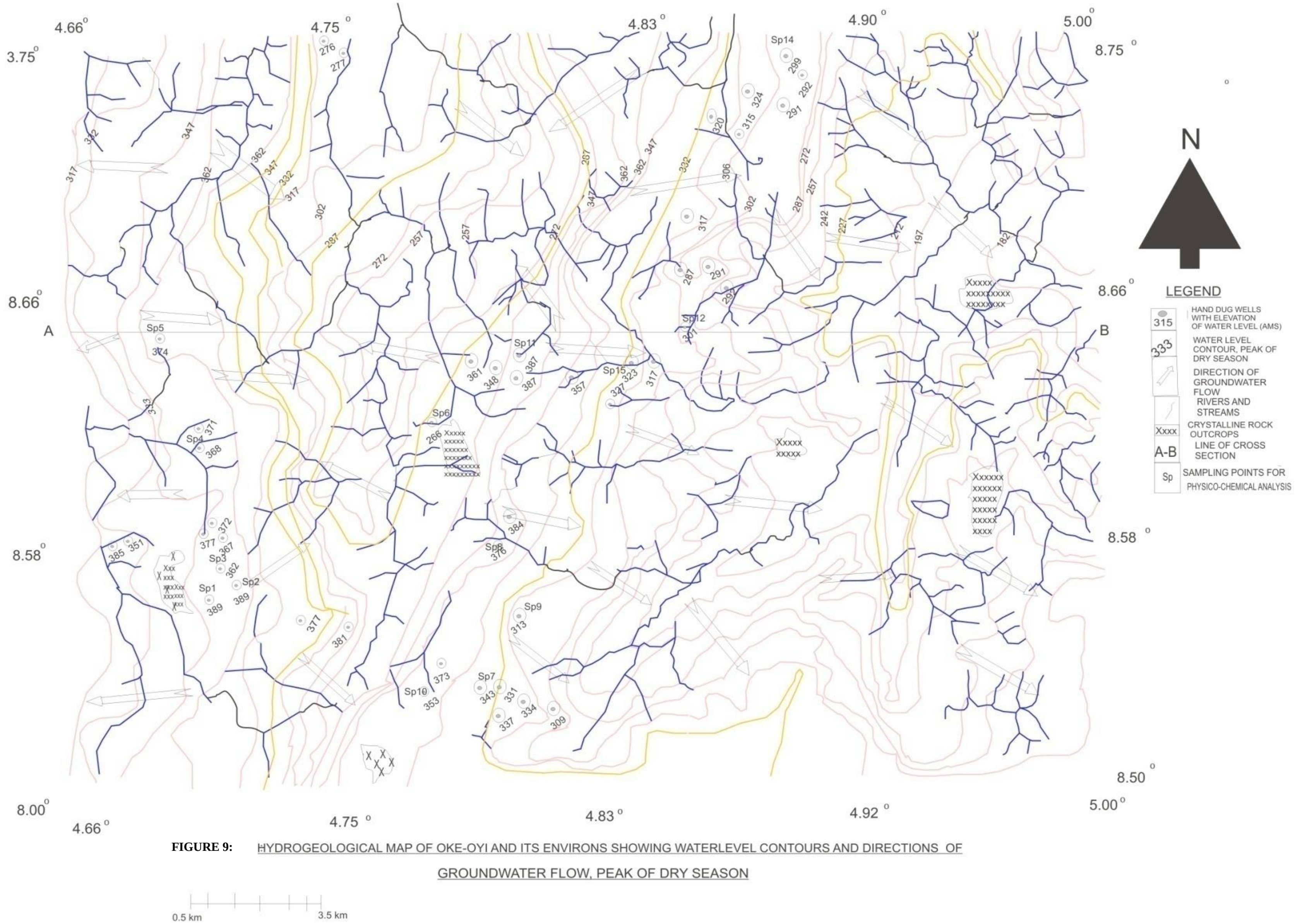


FIGURE 9: HYDROGEOLOGICAL MAP OF OKE-OYI AND ITS ENVIRONS SHOWING WATERLEVEL CONTOURS AND DIRECTIONS OF GROUNDWATER FLOW, PEAK OF DRY SEASON

Table 2: Calculated Values of Hydraulic Conductivity, Transmissivity and Storage Coefficient obtained from the seven boreholes**.**

Names of the boreholes	Hydraulic Conductivity(m/day)	Transmissivity (m^2/day)	Storage coefficient	Bedrock types
Jolasun borehole	1.17×10^{-1} m/day	3.16 m^2/day	1.322	Granite-gneiss
Sentu borehole	5.08×10^{-2} m/day	1.22 m^2/day	1.418	Granite-gneiss
Budo-Oyo borehole	3.51×10^{-2} m/day	1.26 m^2/day	1.756	Granite gneiss
Aramonu borehole	8.6×10^{-2} m/day	2.53 m^2/day	1.765	Granite-gneiss
Panada borehole	6.1×10^{-2} m/day	1.72 m^2/day	1.079	Granite-gneiss
Apado borehole	5.3×10^{-2} m/day	1.52 m^2/day	0.707	Granite
Alokolaro borehole	3.61×10^{-2} m/day	0.95 m^2/day	0.619	Granite

Conclusion

The findings obtained from this study have drawn out the following conclusions:

i. Two main rock types which are igneous and metamorphic rocks have been identified present in the study area with their petrographic analyses. The rocks can produce modest water resources.
ii. Groundwater movement in the area is controlled by its hydraulic head and permeability of the material through which it flows.
iii. The declination in water levels indicates groundwater flow direction.
iv. The average value for the storage coefficient of the area indicated that the storage potential of the boreholes is low; hence, their recharge potential is low.

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