THE HYDROGEOLOGY OF CHIKUN AND ENVIRONS (KAKURI SHEET 144 NW) NORTH CENTRAL- NIGERIA

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By

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DEPARTMENT OF GEOLOGY,
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ZARIA, NIGERIA

SEPTEMBER, 2017

DEDICATION

This dissertation is dedicated to the loving memory of my late brother, Mr Sunday OgarOdey, may the almighty God grant him eternal rest in His bosom Amen.

DECLARATION

I declare that the work in this dissertation entitled "The Hydrogeology of Chikun and Environs (Kakuri Sheet 144 NW) North Central-Nigeria" has been carried out by me and is a record of my own research work under the supervision of Dr. M. L Garba and Dr. T. Najime. All the information derived from literature had been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

_____	_____	_____
Name of Student	Signature	Date

CERTIFICATION

This dissertation entitled "The Hydrogeology of Chikun and Environs (Kakuri Sheet 144 NW) North Central- Nigeria" by Odey, Bernard Ogbor meets the regulations governing the award of master's degree in Geology (Hydrogeology) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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Dean, School of Postgraduate Studies	Signature	Date

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ABSTRACT

The Hydrogeology of Chikun and Environs (Kakuri Sheet 144 NW) North Central-Nigeriawas studied using geological, hydrogeological and geophysical methods. The major rock mapped within the study area include; mica schist, granitic gneiss and porphyritic granite. The petrographic analyses carried out reveals the presence of quartz, muscovite, microcline, perthite, biotite, plagioclase, and orthoclase. Results of VES interpretation reveal four to six geoelectric layers, thicknesses and their respective resistivity values that include; Top soil having the thickness and resistivity of 0 m and 391.0 Ω , sandy clay: 7.51 m and 291.0 Ω, consolidated sand: 22.12 m and 204.1 Ω , highly weathered basement: 27.57 m and 262.6 Ω, partially weathered basement: 30.85 m and 427.0 Ω, and the fresh basement: 87.50 m and 604.4 Ω. Based on hydraulic head measurements from 38 hand-dug wells, the groundwater configuration map for both dry and wet seasons were drawn to show the groundwater flow direction of the study area. The borehole performance was examined using information on hydraulic characteristics of the aquifer that include yield ranging from (15.552-88.128 m^3/day), Transmissivity, T (1.779 x 10^0- 8.96 x 10^{-1} m^2/day) and Storativity, S (1.03 x 10^{-1}-3.706 x 10^{-3}) as computed from the pumping test result. The geochemical results show Total Dissolved Solids (TDS) ranging from 8-365 mg/l having a median value of 14 mg/l with an average of 70.1mg/l, Electrical conductivity (EC) ranges from 13-522 µS/cm having a median value of 69 µS/cm with an average of 100.1 µS/cm, Temperature ranges from 6-30.75°C having a median value of 13.35 $^{\circ}$C with an average of 22°C and pH ranges from 5.26-6.8 having a median value of 5.89 with an average of 6. The major and minor elements concentrations are mostly within the permissible limit of NIS (2007) and WHO (2011). The results show that the groundwater in the study area is

potable and suitable for domestic, industrial and agricultural uses, except in some locations like Gwogofe, Damba 2, Gwagwada 3, AngwanTurai, GudunGuya and Angwan Alkali 2 where the concentration of Pb and Crare slightly above permissible limits. Based on the VES interpretation, VES 1, 2, 5, 8, 9, 13 and 15 can be considered for citing a borehole because of their relatively lower resistivities (between 195.3-215.1 ohm meters). Similarly, VES 3, 4, 6, 7, 10, 11, 12 and 14 are considered suitable for citing boreholes (between 213.3-259.0 ohm meters). The groundwater potential for the study area is rated low having a coefficient of T (m^2/d) ranging from 10-1 within the class of T magnitude of IV when compared with Krasny's Classification of Transmissivity of Magnitude and Variation, this classification suggests that the volume of groundwater within the study area is for smaller withdrawals for local water supply (Private consumption).

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CHAPTER ONE

INTRODUCTION

1.1Background to the study

Water is central to the survival of human beings as it is neededin all aspects of life (Tiwari and Ranga, 2012; Deshpande and Aher, 2012; Ranjan, 2012). Several boreholes installed with hand pumps have been drilled by various government agencies in Nigeria such as the National Water Resources Institute (NWRI) to provide potable water in order to improve the quality of life for many rural communities.Nigeria is blessed with large quantity of groundwater resources. The potential annual groundwater resources are estimated at 51.93 x 10^9 m^3, out of which the sedimentary basins account for 67% (FMWRRD, 1995). Regulations like Nigeria Integrated Water Resources Management Commission (NIWRMC, 2016) have been put in place to protect water resources in Nigeria to effectively control the indiscriminate dumping of effluents into open water bodies. These effluents come/originate from different sources like domestic, industrial and agricultural sources.As a result of this, different heavy metals have been found in concentrations well above acceptable and permissible levels and these include: lead, copper, zinc, nickel, chromium, cadmium and iron (Olayinka and Alo 2004; Esoka and Umaru 2006, Eniola*et al*., 2010). Degradation of water quality is most severe in the four states that contain eighty (80%) percent of the nations industries; Lagos, Rivers, Kano and Kaduna States, this has continued to pose a threat to health and economic development in Nigeria (Ajibade 2004; Olayinka and Alo 2004; Adekunle*et al*., 2007; Adeyemi*et al*., 2008; Mustapha, 2008; Adewolu*et al*., 2009).However, a large part of the Nigerian population still does not have access to water of adequate quantity and quality as some individuals tend to make

provision for potable water in form of hand dug wells in order to cushion the impacts felt from scarcity or non availability of boreholes or pipe borne water provided by government. According to the 2008 report of the WHO/UNICEF JMP (Joint Monitoring Programme for water supply and sanitation) the proportion of the population using water from improved sources has decreased by 3% from 1990 to 2006 (WHO/UNICEF, 2008). This research is an attempt to contribute to the knowledge of the Regional hydrogeology of Nigeria in the area of water quality.

1.2Statement of Research Problem

Over the years, the quality of water used for domestic purpose in Nigeria has not been given adequate attention in terms of the physico-chemical constituents, whether it is adequate, moderate or too high before consumption. This may lead to the outbreak of diseases such as cholera, typhoid, etc.

The water quality assessment in the study area becomes imperative in order to determine localities with good water quality in line with WHO standards. This becomes even more pertinent in view of the fact that the study area is located on River Kaduna downstream of Kaduna Refinery and Petrochemical Company (KRPC) plant.

1.3 Justification

Most of the previous research works was carried out onthenortheastern part of Sheet 144 as captured in the literature review of this dissertation. No contribution on the hydrogeologyofChikun and environs, KakuriSheet 144 NW has been done. Therefore, this research work became pertinent, in view of the location of the study area and the activities ongoing upstream Kaduna River before it traverses the study area.

1.4 Aim of the Study

The aim of this work is tostudy the hydrogeology of Chikun and environs, KakuriSheet144NW on a scale of 1:50,000.

1.5 Objectives of the Study

The specific objectives of this study are as follows:

i) To produce the geological and hydrogeological maps of the study area.

ii) Determine the groundwater flow direction at the peak of wet season and at the peak of dry season.

iii) Determine the water quality of the study area for domestic, industrial and agricultural purposes.

iv) Delineating groundwater potential of the study area using aquifer characteristics with a view to determine if it is low, medium or high for better management of water resources in the study area.

1.6 Location and Accessibility

The study area is located in Chikun Local Government Area of Kaduna State and lies between Longitudes$7^0$00'- 7^0 15'E and Latitudes 10^0 15'- 10^0 30' N. The area is withinKakuriSheet144NW. It covers an area of about 733.86 $km^2$and is accessible through Kaduna-Abuja road which traversed the area from the north, and through Buruku-BirninGwari-Lagos road from the south. The study area has boundary with Niger State to the west.There is also a dense network of footpaths and cattle tracks that make the study area quite accessible by foot and by vehicles.

(Fig. 1).

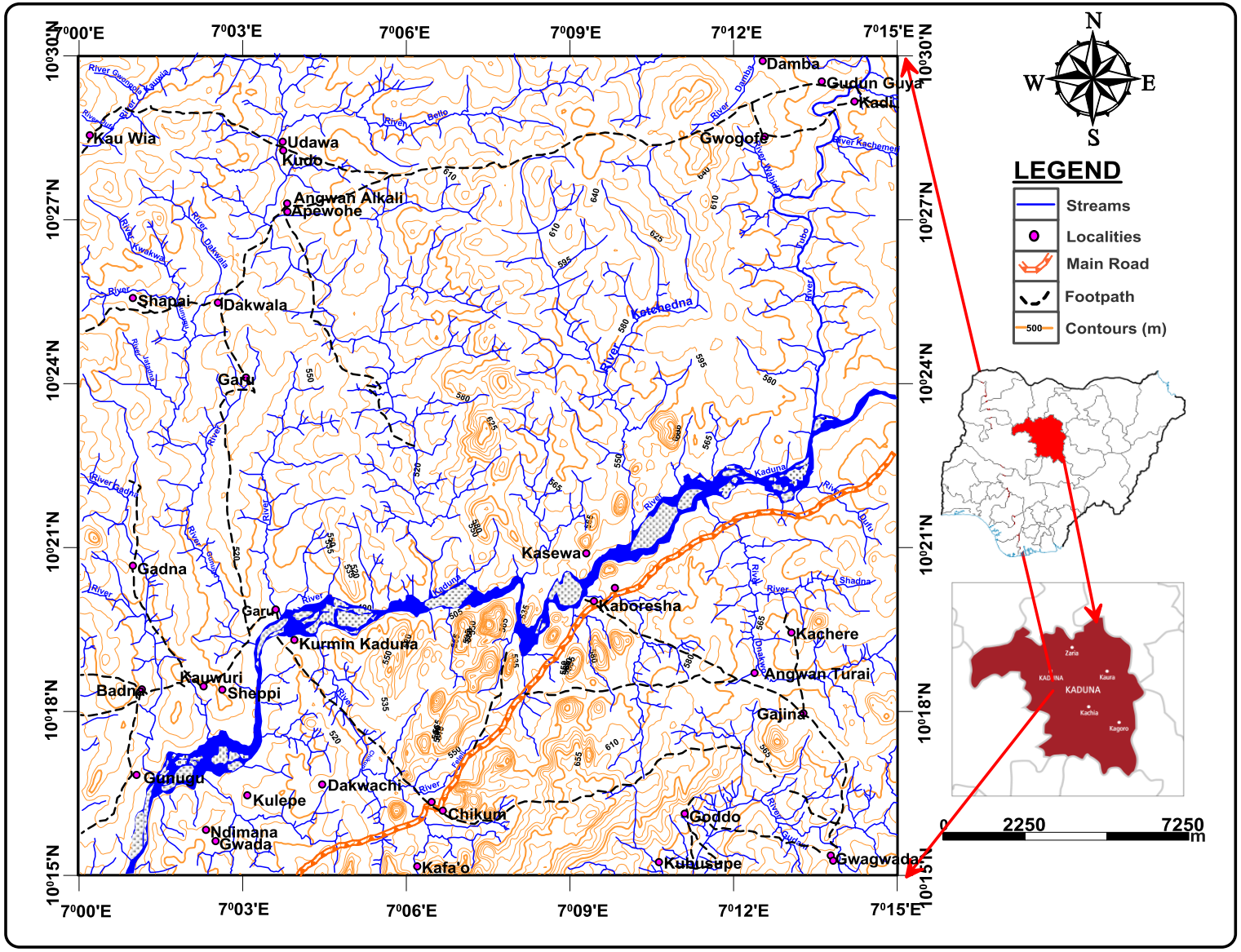


Figure 1.1:Locationand accessibility Map of the study area (Sheet 144 NW)

1.7 Climate and Vegetation

The study area lies within the sub-equatorial and guinea climatic regions with distinct wet and dry seasons. It has a short wet season of about six months. The wet season begins in April and ends in October when it becomes intensely hot. The dry season in which there is no rainfall occurs from October to April. The average temperature during the dry season is 36°C.

The area generally, lies within the Guinea Savannah zone of the northern Nigeria (Du Preez and Barber, 1965). The vegetation is characterized with scattered trees, mostly thorny shrubs with few tall trees. The grasses are thin but rarely tall and the vegetation tends to be partially dense, luxuriant and green along river courses due to prevailing soil moisture condition there. Anthropogenic activities like tree felling for firewood and annual bush burning have significantly reduced the vegetation density.

Groundwater systems tend to respond more slowly to variability in climatic conditions than do surface water systems. As a result, assessments and models of groundwater resources are commonly based on long-term average climate conditions (e.g., average annual recharge) and potentially underestimate the importance of variations from the norm. Droughts are the most widely recognized climate perturbation relative to groundwater (William, 2001).

Water storage is critical in dealing with climate variability. As surface water storage becomes more limited, use of groundwater storage to modulate the effect of droughts increases in importance as do potential enhancements by artificial recharge. If groundwater storage is large, droughts will have a small, if any, effect on long-term water storage in an aquifer system. In contrast, where groundwater storage has been substantially reduced by

long term withdrawals from wells, it may be more limited as a source of water to help cope with droughts.

Among the most important link between climate and groundwater are the effects of surface water and the land. For example, groundwater development may significantly affect more flows in streams, minimum levels in lakes and the hydro period of wetlands. Likewise, reduced heads in responds to increase in pumping during droughts can land subsidence as a result of compaction of aquifer materials. The quality of groundwater is also affected in many ways by climate. Changes in recharge in response to climate variability can affect contaminant transport, and lack of proper consideration of the lack of climate variability can lead to erroneous conclusion about temporal trends in groundwater quality, particularly if only a few samples have been collected. The study area experiences a tropical continental climate with two distinct seasonal climates, dry and rainy seasons. The wet season (May to October) and dry season (November to April). Mean annual rainfall ranged from 1,016mm to 1,524mm (Omotosho*et al.* 2013). The climatic pattern of Kaduna which is in Northern Guinea Savanna vegetation zone of Nigeria is suitable for the cultivation of subsistence and cash crops round the year, although dry season farming often needs to be complemented by irrigation.

Below is a climatic data consisting of daily rainfall depth in Kaduna state for 15 consecutive years (1991–2005).Fig. 1.2.

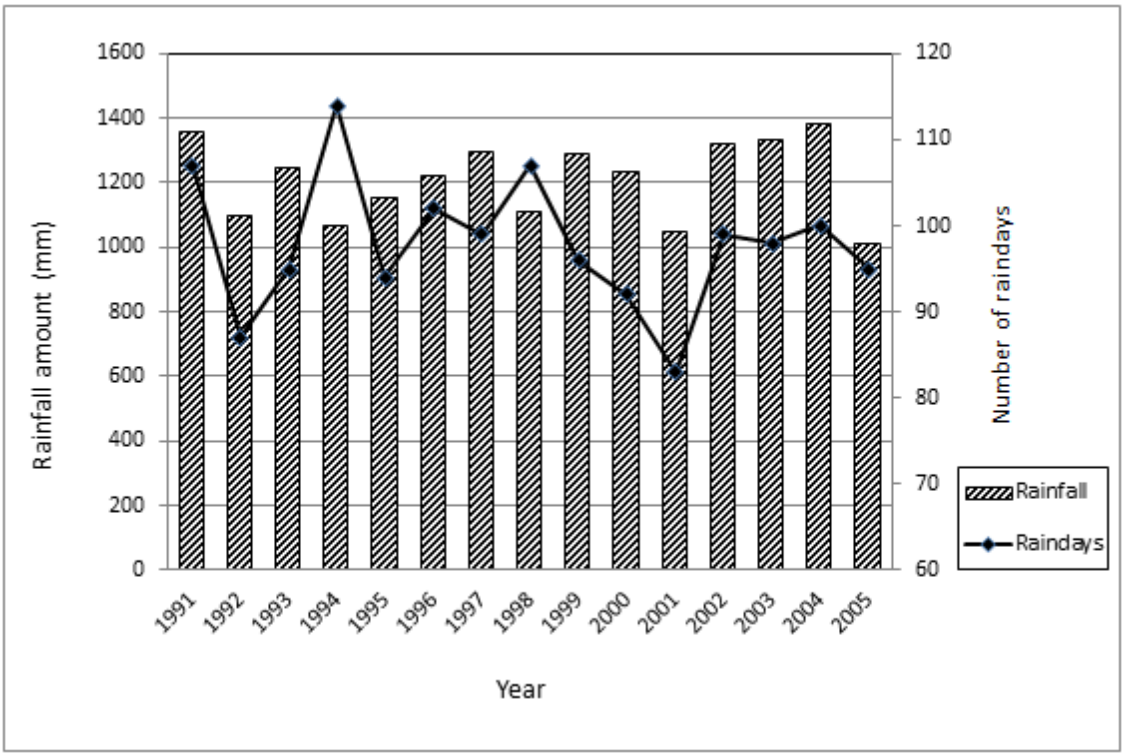


Figure 1.2: Rainfall Depth in Kaduna state from 1991-2005 (After, Nigerian Meteorological Agency)

1.8 Geomorphology and Drainage

Natural drainage systems are defined by the topography of an area. The largest feature of a natural drainage system is the drainage basin, or watershed. The watershed consists of a network of streams, rivers and tributaries which collectively convey all the surface water from a geographic region to one particular place. This place is called the major drainage feature or receiving body and it may be a river, lake or bay. The boundary of a basin is called the basin

divide. In the study area, the major rivers that drain the area are river Kaduna and river Udawa and flow east-western direction as shown in the drainage map of the study area. The study area is a rugged to gently undulating terrain, the undulation favoursthe formation of gully erosion that is so prominent in the study area.The area is drained by a

network of rivers, the drainage pattern is dendritic and the streams are all subjected to seasonal water level fluctuations (Nassef and Olugboye, 1979; FMI, 2000). The most conspicuous high relief features in the study area are the mountainous and highly weathered exposures of granitic rocks with elevation up to 701 m at Gajina hill, southeastern part of the study area.Fig. 1.3.

Kaduna is rapidly undergoing physical development and expansion, with remarkable changes in its land-use and urban landscape. These changes may be largely adduced to its proximity to the federal Capital Territory, Abuja (Abbas, *et al.*, 2010), better job opportunities and raising standard of living (Adewuyi&Baduku, 2012). These situations were derived largely from human activities such as agriculture, mining, construction, industrialization, deforestation, urbanization and so on. Even though, Kaduna was planned, but just as it is common with most developing cities, poor land management has often marred land-use planning with adverse consequences (Ndabula*et al.*, 2012). The land use/ settlement pattern in the study area is such that settlements are up to 20 – 22 km apart because of the acquisition of land for farming as evident in the study area.

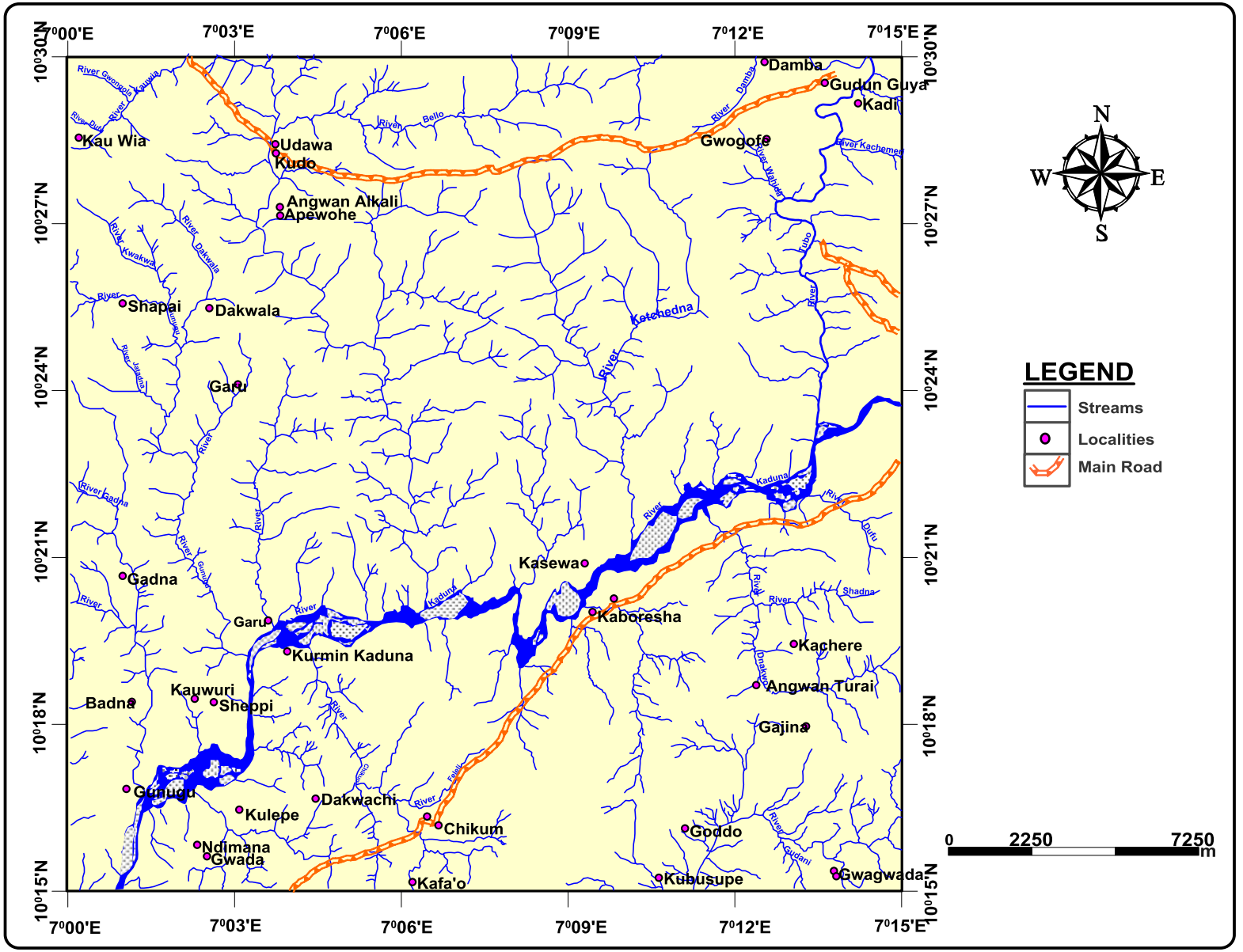


Figure 1.3: Drainage pattern of the study area

1.9Literature Review

The study area lies within the crystalline hydrogeological province of Nigeria (Basement Complex). Several hydrogeology and hydrogeology related research works had been conducted within Kaduna South Local Government Area of Kaduna State, among which include;

Akano*et al.,* (2016) studied the geology and hydrogeology of part of Suleja North Central Nigeria using Electrical Resistivity method of geophysical surveys. Two major rock types were identified in the area and they are Gneiss and Granite. The water chemistry test result showed little dissolution of the rock constituent in the water but rather the effect of sewage, pit latrines and wastewater sources around the wells in some areas. In their conclusion, it was observed that Groundwater occurrence and flow in the area is generally controlled by the topography.

Aliyu*et al.,* (*2015*) carried out a research on heavy metals pollution on surface water sources in Kaduna metropolis along River Kaduna and Kakuri – Makera drains which is at the North Eastern part of Federal Survey Sheet 144. X – Ray Florescence (XRF) as an analytical technique was used for the detection of heavy metals such as (Lead {Pb}, Arsenic {As}, Iron {Fe}, Chromium {Cr}, Copper {Cu} and Zinc {Zn}). The result shows the concentration of most of the heavy metals were higher than WHO (1997) acceptable limits.

Ugya*et al.,* (2015) carried out a research on assessment of well water quality in some major settlements of theKadunaand their findings indicated that all water samples analyzed were polluted with respect to Iron (Fe^{+2}) and magnesium (Mg^{+2}) while one of the samples is polluted with respect to chloride, the pH of another was slightly too acidic.

Isaac and Johnson (2014) researched on the appraisal of certain characteristics of aquifer in Chikun Local Government area of Kaduna State. They studied some hydraulic characteristics of aquifers with respect to the supply of potable water for semi-urban inhabitants in Chikun Local Government Area of the State. Data obtained from 19 boreholes in the study area showed that the aquifer has average specific capacity of 2.78 m^3/d, with an average yield of 32.32 l/min, with higher yields occurring mainly in fractured zones.

Muhammad (2012) conducted a research on the assessment of groundwater quality in low income high density areas of Kaduna metropolis by studying the physico-chemical and bacteriological parameters of the area using Garmin GPSmap 60CSx receiver, the depth of wells were obtained using intellimeasure laser made by Stanley. Generally, physical analysis of borehole and shallow well water samples in Kaduna Metropolis showed that most samples were colourless, odourless and tasteless. The author concluded that the microbial analyses showed that most samples from both boreholes and shallow wells are contaminated with potential pathogens with serious consequences on public health and safety.

Mohammed, (2013) researched on the current quality status of river Kaduna.In that work, important parameters like acidity, conductivity, Chemical Oxygen Demand, Biochemical Oxygen Demand, Dissolved Oxygen, Dissolved Sulphur, and heavy metals of mercury, lead, cadmium, rubidium, Wereanalyzed from samples obtained along strategic locations of the river and analyzed for their present values in the river. Most of these parameters have recorded higher values than the WHO (1993) acceptable standards. It was also observed that the higher concentrations were traceable to sampling locations in which

industrial and domestic wastes are being discharged. The author concluded by saying that there is an urgent need by the environmental agency to mount a serious pollution control measure to check the identified sources that are responsible for the disposal of untreated waste into the river.

Amadi*et al* (2012), conducted a research in River Chachanga and the study revealed that the soil and the groundwater are slightly polluted with heavy metals in the order of Fe > As > Zn > Cu >Pb> Cr > Cd >Mn, which they attributed to the natural enrichment of groundwater through weathering of bedrock in the course of groundwater migration and anthropogenic activities through dumping of untreated effluents from Kaduna refinery and petrochemical into the nearby soil and surface water.

Samaila*et al*., (2011) worked on the influence of waste water on soil chemical properties on irrigated fields in Kaduna South township, part of Federal survey sheet 144 NW, using soil and water samples that were subjected to laboratory analyses.The result of the analyses showed that the greatest problem faced with most soils in the area is that of salinity built up (121 – 1273 micro-ohms) which in turn affects negatively their productive capacity for plant development.

Aboh, (2009) worked on aquifers assessment in some selected villages in chikun local government area of Kaduna State. The author used The Vertical Electrical Sounding (VES) technique to investigate the sub-surface layering in some selected villages in Chikun LGA of Kaduna State with the aim of determining the configuration of the aquifer underlying the region. The result of the interpreted VES data suggests that the area under investigation is underlain by three to five layers. The geologic sections derived from the analyzed geoelectric section suggest that the alluvial deposits of sand, silt and sandy clay as well as

the weathered and fractured basement rocks constitute the aquifer in the areas. The average thickness of the aquifer was found to be 25m. Results obtained for the pumping tests and transmissivity values of boreholes drilled shows that the aquifer in the study area is capable of producing at least 0.75l/s of potable water. He concluded that the feature observed correlates with basement depressions found in that area as discovered from earlier works (Aboh and Osazuwa, 2000). Similarly, this observed phenomenon seem to suggest that the geometry of the underlying weathered basement are most likely serving as a form of structural control on the flow of rivers and streams within the area.

Jatau and Bajeh (2007) investigated the groundwater potential, quantity and quality of parts of Jema'a Local Government Area in the basement complex of southern part of Kaduna State using surface geophysical, hydrogeological and hydro-chemical analysis. The results of the surface geophysical survey, using the resistivity techniques, Horizontal Electrical Profiling (HEP) and Vertical Electrical Sounding (VES) proved effective in locating and assessing the thickness of regolith aquifers. The tri-linear diagram revealed that the groundwater in the study area is more with the earth alkaline water with higher alkaline proportion predominantly rich in HCO_3^-.

Mahre*et al*., (2007) conducted a research on pollution indicators in River Kaduna using water and sediment samples that were analyzed for pH, Temperature, Total Dissolved Solid, Phosphate, Nitrate, Sulphate and the organic pollution indicators that include Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) content of the water samples and Total Organic Carbon (TOC) of the sediment samples. The results of the concentration of heavy metals in water and sediment samples, BOD and COD were found to be above the recommended permissible limits set

by Federal Environmental Protection Agency of Nigeria, World Health Organization (WHO)/ European Union (EU) and the NSWQ 2007 permissible limit.

Jatau and Ajodo (2005) also worked on the appraisal of the groundwater potential of part of Kaduna South which include, UngwanRimi, Kakuri and Goningora using Vertical Electrical Sounding (VES) and their result revealed four to six geoelectric layers, consisting of topsoil (laterite, sand and clay), lateritic clay, sand and clay), (sandy clay) highly weathered basement, partially weathered/fractured basement rocks units and fresh basement rock or bedrock. The highly weathered basement/partially weathered and fractured layers constitute the main aquifer unit and with varied potentials in the study area.

Eduvie (2004) worked on exploration, evaluation and development of groundwater in southern Kaduna State, using EM and resistivity techniques and came up with a finding that the groundwater potential of the basement complex area of southern Kaduna which Kakuri NW is part of, had an area of 24,500km^2. The average catchments yield as estimated by the correlation of runoff coefficient with depths of rainfall and the runoff curve number methods gave a value of 22.66 x 10^9 m^3/annum. Interpretation of the sounding curves obtained in the study area, suggests that the subsurface layering ranges from 3-5 layers.

Hazell*et al*. (1992) stated that the crystalline basement rocks of Northern Nigeria have areas of deeply weathered regoliths estimated at 10-30 m which constitute useful aquifers separated by larger areas of relatively barren shallow regolith.

Eduvie (1991) reported that the coefficients of discharge for the hand-dug wells of the adjoining sheet (Sheet 144 Kakuri NE) are generally higher than those of the boreholes, due to the higher rate of discharge in the weathered overburden aquifers, which the hand-dug wells tap.

Eduvie*et al* (1999) conducted a research on exploration, evaluation and development of groundwater in southern Kaduna and discovered that the quality of water within the area exhibits low total mineralization.

Mbonu (1988) also carried out a study on the hydrogeology of basement rocks in North-Central Nigeria. He reported that 91% of sampled water points both surface and groundwater sources have nitrates concentration less than 45 mg/l.

Du Preez and Barber (1965) who worked on the distribution and chemical quality of groundwater in northern Nigeria and concluded that the presence of groundwater in the basement complex is dependent on whether there is sufficient weathered material, to allow rain water percolation within fractures present in fresh rocks.

From the literature review so far, none of the authors employed the use of GIS to study the lineaments of the considered study areas, also none worked on the hydrogeology of Chikun and Environs, especially Kakuri Sheet 144 NW. Therefore, this study became imperative.

CHAPTER TWO

GENERAL GEOLOGY AND HYDROGEOLOGY

2.1 Introduction

The basement complex rocks of Nigeria occupy nearly half of the entire area of the country, it is part of an upper Proterozoic to lower Phanerozoic mobile belt. The complex according to Cooray (1970) shows evidence of at least three orogenic events, namely: the Eburnean (2200 - 2000 ma), Kibaran(1400 – 1000 ma) and the Pan-African orogenies (600 ma). The Nigerian basementis flanked in the west by the West African Craton and to the southeast by the Congo Craton.Evolutionaryprocesses that include plate tectonic regime have been proposed for the Nigerian basement (McCurry, 1976; Black *et al*., 1979; Ajibade*et al*., 1987).

2.1.1 Basement complex

The Nigerian Basement Complex is, on the basis of rock types, divided into four units (Fitches *et al*., 1985; Ajibade*et al*., 1987; McCurry, 1976).These are:

i) Migmatite-gneisscomplex
ii) The Younger Meta-sediments: Composed of meta-sedimentary rocks and meta-igneous rocks.
iii) Older Granite Suite: Composed of charnokitic, gabbroic and diorite rocks.
iv) Metamorphosed to non-metamorphosed volcanic dykes and hypabyssal rocks.

The Migmatite-gneiss complex

This is the most widespread group and comprises largely of a sedimentary series with associated minor igneous rocks which had been altered by metamorphic, igneous and migmatitic processes (Rahaman, 1988). These rocks are mainly quartzites, amphibolites,

calcareous rocks, biotite-hornblende gneisses, quartz schist and biotite hornblende schist (Wright *et al*., 1985). The poly-metamorphicmigmatite-gneiss complex is of ages ranging from Liberian (2800 ma) to Pan-African (600 ma), metamorphism within this complex is generally in the amphibolites-facies grade. Migmatite is a rock of both metamorphic and igneous origin that exhibits characteristics of both types. Carlos *et al*, (2008) defined migmatite as a composite rock body containing two types of rock (igneous and metamorphic rock) that have interacted with each other nevertheless still distinguishable.

Generally, migmatite is a heterogeneous silicate rock with properties of both igneous and metamorphic rocks believed to have been probably formed through the heating (but not melting) of rocks in the presence of abundant fluids (Olsen, 1983).

Typically the rock contains alternating lighter layer called leucosomes, which is made up of lighter colour minerals such as quartz, feldspar, muscovite and dark layer called melanosomes which is made up of dark-colour minerals such as amphibole and biotite (Anthony,1996). It can be formed through migmatization. Olarewaju (2002) reported that migmatization is the process whereby a rock undergoes partial melting during extreme metamorphism, producing new rock called migmatites. The final product of migmatization may be mixed granite, hence from the whole process, it is almost granitization synonym. Rahaman and Cooray(2004) reported that migmatite look very similar to a related rock called gneisses which also contains alternating light and dark layers which resulted under high pressure and temperature conditions.

According to Ogezi, (2004) these two rock types are certainly related in terms of deformation, in that when a gneiss experience slightly high temperatures, it may partially

melt and become a migmatite. Most migmatites probably were gneisses as they turn to true hybrid metamorphic-igneous rocks.

AccordingtoRahaman (1988), there are three petrological units that characterize the migmatite complex as follows:

i. A grey foliated biotite acid or biotite hornblende quartz feldspathic gneiss of tonalitic to granodioritic composition which is now known as the grey gneiss or early gneiss.

ii. Mafic to ultramafic components, which were present, often outcrop as discontinuous boudinaged lenses or concordant sheet of amphibolites with minor amount of biotite-rich ultramafite. Except where it constitutes thepaleosome to the migmatite, it is present in grossly subordinate amount in the grey gneiss.

iii. The felsic component which is composed of a varied group of rocks consisting of pegmatite, aplite, and quartz-oligoclase veins, fine grained granitic gneiss, and porphyritic granite.

Younger Metasediments

Rocks in this group constitute the Schist belts of Nigeria. They show litho structural similarities and are best developed in the western half of Nigeria. They are made up of pelitictosemi-pelitic schist and phyllites, quartzites, iron formations, marbles, calc-silicate rocks and subordinate meta-igneous rocks (Adekoya, 1996). They show lithologic similarities to schist belts from other parts of the world. McCurry (1976) and Rahaman*et al* (1981) have variously revealed the extent of this belt in Nigeria. These diverse rock types occur in varying proportions in the different belts. The schist belt of low-grade (mainly

green schist facies) supracrustal (and minor volcanic) assemblages, that occupy a general N-S trending synformal troughs infolded into the migmatite gneiss complex which are considered to be Late Proterozoic.

Based on structural and lithological associations, Grant (1978) suggested that some of the schist belts are of Kibaran (1100± 200 ma). Ajibade*et al*.,(1989) disagreed with the structural evidence and proposed a Pan-African age for all the schist belts. The schist belts are mostly developed in the western part of Nigeria though; smaller occurrences are found in the eastern part too (Obaje, 2009). They have been extensively studied in the western half of the nation coming up with the following groups: the Kusheriki Schist Group, the Karaukarau schist belt, the Kazaure schist belt, the maru schist belt, the Anka schist belt, the Zuru schist belt, the IseyOyan River schist belt, Ilesha schist belt and the Igara schist belt (Obaje, 2009).

The Older Granites

The Older Granites of Nigeria are related to Pan-African plutonism and occur in all parts of Nigerian Basement Complex, (Ajibade*et al*., 1987). They occur as distinct plutons and of limited composition and petrographic varieties.These plutons are products of magma genesis at levels substantially below the present exposure level. The plutons also exhibit a certain degree of foliation. This foliation in the Older Granites is regarded by Fitches *et al*. (1985) to be due to flow of magmatectonic processes rather than deformation. They are also generally regarded as late to post tectonic granites with respect to the main deformation of Pan-African tectonism. The older granites are the most obvious manifestation of the Pan African orogeny and they constitute about 40 to 50% of the basement complex rocks. Texturally they vary from strongly foliated gneiss varieties to

undeformed rocks. Rahaman (1988) described the following petrographic types: magmatic granitic gneiss, early pegmatite, aplites and quartz veins.

The Pan African granitoids in Nigeria are referred to as the older granites to distinguish them from Mesozoic anorogenic granite ring complexes (the younger granites). However, Ajibade*et al*.; (1987) used evidences from cross-cutting pegmatites and microgranites to show that the foliation is as a result of post emplacement deformation.The Older Granite of Nigeria includes a wide spectrum of rocks varying in composition from tonalite through granodiorite to granite, syenite and charnockite rocks (Trust-welland Cope 1963). The granitoids have been emplaced into both the migmatite-gneiss complex and the schist belts, and they occur in all parts of Nigeria (Ajibade, 1982). Recent work in different parts of the Nigerian Basement Complex has shown that the older granites are high level intrusions emplaced by stoping and diapiric process (Fitches *et. al*, 1985). The marked generally north-south linear aggregation of many of the large batholiths of the basement suggests that they may be related to deep-seated pre-existing plutonic episode controlled by major deep mantle structure (Ogezi, 1977*a*).

The intense regional deformation which accompanied and preceded the emplacement of the older granite resulted in the pronounced and wide spread of N-S trend. The granites termed the older granites in Nigeria have been dated severally at 500-750 ma (Van Breem*et. al* 1977, Rahaman*et. al,* 1983 and Kroner 1998). Granitic magma is commonly associated with several tectonic stages during evolution, and their structure, texture, and mineral composition can be of benefit and environmental impact (Pearce *et.al. 1984*, Pitcher 1983, 1989, Whalen *et al.*,1987, Frost *et. al.*, 1999).

It is good to note that the older granite occur intricately in association with the migmatite-gneiss complex and the schist belts into which they generally intruded. This means that the rocks occur in most places where rocks of the migmatite gneiss complex or of the schist belt occur (Obaje, 2009).

2.2Hydrogeology

The crystalline basement rocks possess little primary intergranular porosity or permeability and their hydrogeological properties are thus determined mainly by secondary effects such as fracturing and weathering that give rise to secondary porosity and permeability (Clark, 1985). In many communities of the world groundwater abstraction is from weathered and fractured zones through which wells/boreholes are cited (Clark, 1985; Olasehinde*et al*., 1998).

Basement aquifers are developed within the overburden and fractured bedrock of crystalline rocks of intrusive and or metamorphic origin which are mainly of Precambrian age. The climatic variables in rainfall and potential evapotranspiration are factors that determine run-off and groundwater recharge as far as the hydrogeology is concerned.

Du Preez and Barber (1965) had described the crystalline rock areas as poor groundwater regions, with recorded average yield of 3,960 litres/hr, average depth of 37.3m and over 30% failure rate in borehole drilling.

The localization of groundwater within the lithologic zones is controlled by a number of factors such as type of parent rock, depth, extent and pattern of weathering, thickness of the weathered materials, the sand/clay ratio and the degree of fracturing, fissuring and jointing (Amadi and Teme, 1987; Odusanya, 1990).However, recent experience has shown that, with selective siting of boreholes based on the different rock units of the basement

complex, adequate hydrogeophysical surveys, and improved drilling techniques, much better results can be achieved. The works done so far on groundwater of Sheet 144 include Exploration, evaluation and development of groundwater by Eduvie*et al*., (1999) and other workers like; Amadi*et al*., (2012) that worked on River Chachanga, Jatau and Ajodo (2005) worked on the groundwater potential of parts of Kaduna south, Goki*et al*., (2011) studied the structural geology of Sheet 144.

Results from VES show that the granitic gneiss terrain has higher aquifer thickness than the porphyritic granite terrain. Borehole data shows that the yield is higher in the Porphyritic granites terrain with 88.128m^3/day while the granitic gneiss yields an average of 48.216m^3/day These show that the Porphyritic granite provides a better aquifer than the Granitic gneiss in the study area.

2.2.1 Aquifer Type

In basement terrain, groundwater development is met with difficulties due to lack of primary porosity in the bedrock. The secondary porosities such as joints, faults and weathered zones are the sources of groundwater occurrence and movement (Chiton and Foster, 1995, Foster *et al* 2008, Srinivasa*et al.*, 2000, Wright and Burgess, 1992). Recharge is the proportion of rainwater that percolates to the water table. Groundwater recharge is mainly a function of rainfall, vegetation and soil characteristics (Eduvie 1991). The amount of recharge depends on the permeability of the material at the ground surface, vegetation cover and intensity of rainfall and the moisture content of the materials infiltrated (Umaru, 1987).Hence, the secondary porosity and weathered zones constitute the different aquifer systems. Olasehinde (1989) observed that elucidating structural fabrics, especially the fracture pattern in the Nigerian basement is a problem due to poor exposure. Beyond this,

elucidating them is useful in mineral and water exploration programs. Borehole lithologic logs in the area revealed two water bearing zones in the area; namely the highly fractured zone and the partially weathered basement rock.

2.2.2 Weathered Basement Aquifer

The secondary porosities such as joints, fault and weathered zones are the sources of groundwater occurrence and movement in the study area (Chiton and Foster, 1995, Foster et al 2008, Srinivasa, 2000, Wright and Burgess, 1992).

CHAPTER THREE

MATERIALS AND METHODS

The methodology employed for this study wasin five stages, consisting of desk study, field work, lineament extraction, laboratory work and evaluation of the field and laboratory data.Instrumentsused include; Geologic compass, Pasi automatic resistivity/Sp meter, geologic hammer, masking tape, polyethylene sample bottles, TDS meter, thermometer, nitric acid, pH meter, sample bag, measuring tape, field note book, marker pen, plastic drawing bucket attached with rope and GPS and topographic sheet 144 on a scale of 1:50,000.

3.1Desk Study

3.1.1 Preliminary studies

The preliminary study consisted of the assemblage and examination of all available information such as review of existing literaturefrom text books, journals, bulletins and conference papers.

3.1.2 Map compilation

This stage involved the production of topographic and geological maps required for field mapping.

3.1.3 Reconnaissance

Reconnaissance survey was carried out to seek for permits, appraise the area and acquire all the necessary materials and finally go for reconnaissance to the area to verify acquired informationand also the compilation of result and thesis.

3.2Field Work

3.2.1 Geological mapping

Geological mapping was carried out to locate the different rock types and their boundaries, petrographic description of outcropping rocks, and rock sampling. Geological mapping was conducted by locating with the GPS the study location and thereafter employing the traverse method of mapping by moving from one study location to another for a detailed mapping, by taking strike and dip of outcrop exposures, taking photographs of those outcrops, collecting representative samples and describing the rock samples in terms of their mineralogical composition, texture and colour with the aid of a hand lens when necessary.

3.2.2 Hydrogeological mapping

Hydrogeological mapping was also carried out by locating the water bearing units in the study area such as hand dug wells, boreholes, streams and rivers. The measurement of hydraulic head in wells during the dry and wet seasons of the year 2015/2016 was done with metric tape and subsequently taking the reading that is eventually used to compute the groundwater configuration maps for bothpeak of wet season and at peak of dry season.Fig. 4.4 andFig. 4.5 for Hydrogeological maps.

3.2.3 Water sampling

3.2.4Sample collection and preparation

Polyethylene bottles with screw rubber caps were used to collect the water samples. The bottles were thoroughly washed and rinsed with water to be sampled. Parameters such as temperature, pH, Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were determined insitu (at the point of sample collection) using thermometer, pH meter and

TDS and conductivity meter respectively and random sampling method of sample collection was adopted.

The samples were labeled in detail with their location name, those to be analyzed for cations were acidified and those for anions refrigerated and transported to the laboratory for analysis.

A total of twenty (20) water samples from wells were collected from different geologic units of the study area and tabulated as follows: (Table 3) for sampling points and well locations.

Table 3.1:Well Water Samples and Respective Geologic Units

S/NO	SAMPLE ID	GEOLOGIC UNITS	NO. OF SAMPLES
1	Gwogofe	Porphyritic granite	1
2	Damba 1	Porphyritic granite	1
3	Damba2	Porphyritic granite	1
4	Angwan Alkali 1	Porphyritic granite	1
5	Angwan Alkali 2	Porphyritic granite	1
6	Kudo	Porphyritic granite	1
7	Sabon Kau Wia	Porphyritic granite	1
8	Chikun 1	Granitic gneiss	1
9	Chikun 2	Granitic gneiss	1
10	Gwagwada 1	Granitic gneiss	1
11	Gwagwada 2	Granitic gneiss	1
12	Gwagwada 3	Granitic gneiss	1
13	Angwan Turai	Granitic gneiss	1
14	Gudun Guya	Granitic gneiss	1
15	Kurmin Kaduna	Granitic gneiss	1
16	Gajina 1	Granitic gneiss	1
17	Gajina 2	Granitic gneiss	1
18	Gajina 3	Granitic gneiss	1
19	Dakwachi	Mica schist	1
20	Kulepe	Mica schist	1

Plate 1 shows collection of water samples in Kurmin Kaduna.



Plate I: Measurement of depth to water table and collection of water samples in Kurmin Kaduna (one of the study locations). (N10^0 18' 45.5" and E007^0 04' 07.4")

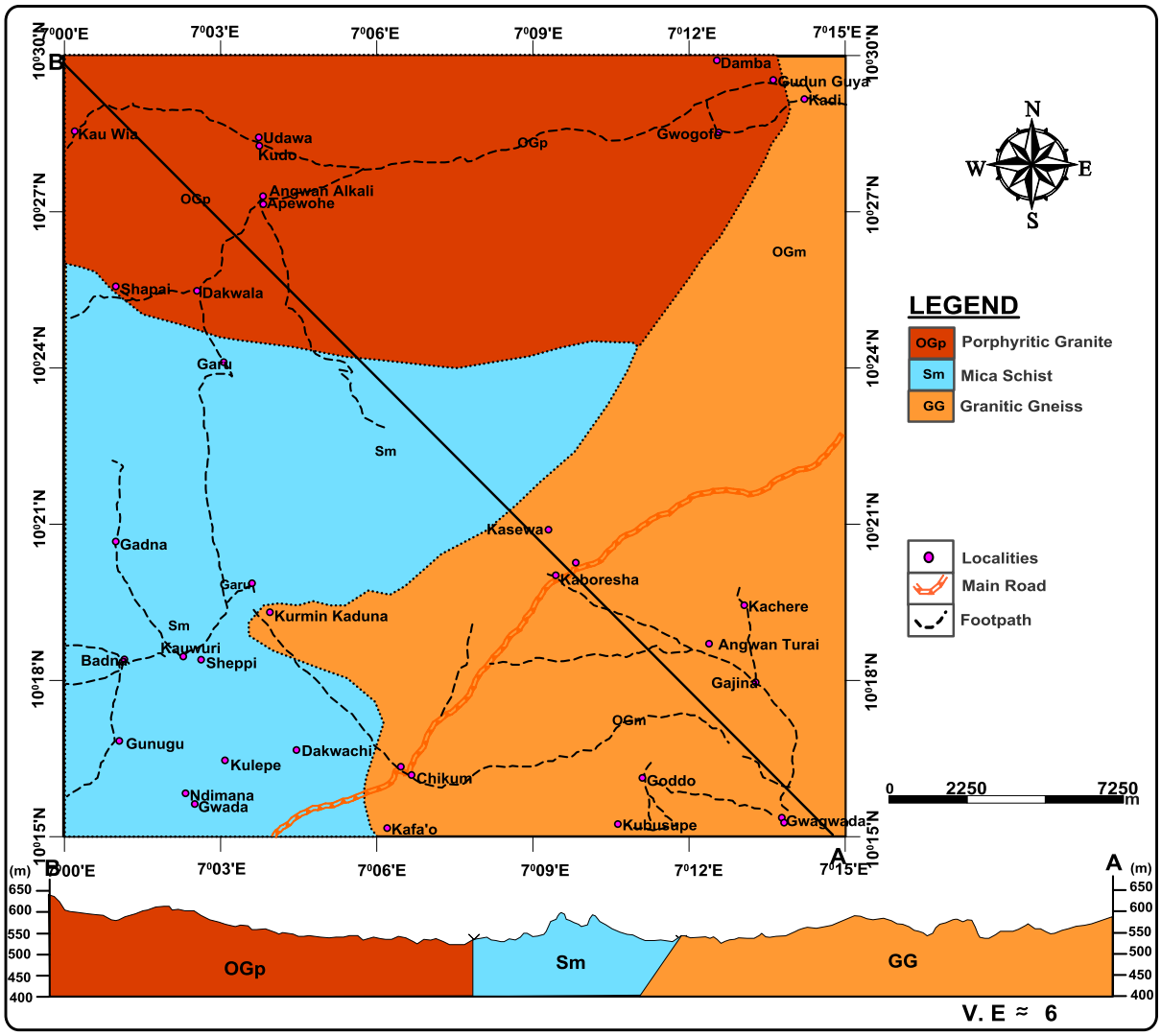


Figure 3.1: Water sampling Points and locations in the study area

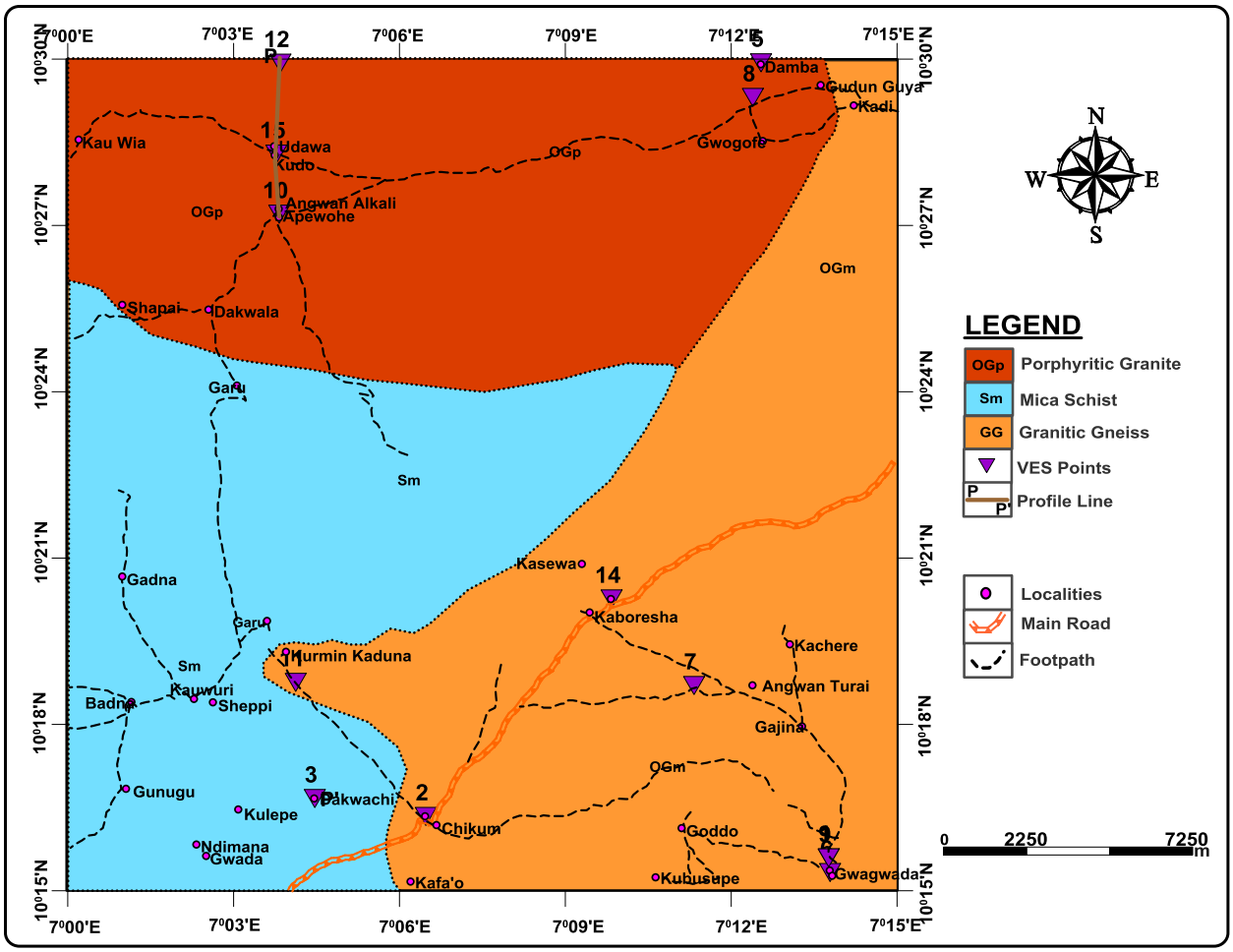


Figure 3.2: Geologic map with VES Points in the study area

3.3.Lineament Extraction

This was done in the PCI Geomatica GIS environment using the "Line: lineament extraction module" under geological and geophysical analysis. The lineament extraction in PCI extracts lineaments from any single 8-bit image in three steps namely: edge detection, thresholding and curve extraction respectively.

3.3.1 Data acquisition

A single scene of landsat enhanced thematic mapper plus (ETM+) 2005-10-19, path 189/ Row 052 acquired on 19th of October, 2005 was downloaded from the Global Land Cover Facility (GLCF) of the University of Maryland USA. The data has seven bands sensitive to different wavelength. Six of these bands detect visible (7,4,1), near infrared "NIR" (3) and short wave infrared "SWIR" (5). One thermal and one panchromatic. The area of study was subsetted from the single scene and was used in the present study.

3.3.2Principal component

The first principal component image (PC1) of land sat 7 pan sharpened reflected bands in 8-bit grayscale and 30m spatial resolution was used as it carries most information and is suitable for lineament extraction purposes. This was carried out using ENVI 4.5 software on a layer stacked image of the acquired landsat scene. The parameter settings used are shown in Table 3.1

Table 3.2: Software Setting for Lineament Extraction

Description	Values
Filter Radius (Pixels)	10
Edge Gradient Threshold	100
Curve Length Threshold (Pixels)	30
Line Fitting Error Threshold (Pixels)	3
Angular Difference Threshold (Degrees)	30
Linking Distance Threshold	20

3.3.3 Splitting compound lines into simple lines

This was done in the ArcMap 10.1 GIS environment. Compound lines were splitted at the vertices. The aim was so as to get the accurate endpoint of straight lines which is necessary for trend/orientation analysis. The length and endpoint of lines (X coordinate of line start (X1), Y

Coordinate of line start (Y1), X coordinate of line end (X2) and Y coordinate of line end (Y2) were also computed within the ArcMap 10.1 GIS environment.

3.4The laboratory work

Analysis of the collected water samples for their major cations, anionsand some heavy metal components was carried out in the Multi-user Science Research Laboratory, Department of Chemistry, Ahmadu Bello University and at the Soil Science Laboratory, Department of Soil Science,while the anions were analyzed at the Public Health Laboratory, Department of Water Resources and Environmental Engineering of Ahmadu Bello University, Zaria.

Major ions analyzed and the methods used in analyzing them are as follows; sodium (Na) and potassium (K) were analyzed by flame photometry, calcium (Ca), magnesium (Mg),

chromium (Cr), iron (Fe) and lead (Pb) were determined by fast sequential Atomic Absorption Spectrometry (AAS), variant product AA240FS. Turbidimetric method was used to determine sulphate ($S0_4$) using H18200 multiparameter Bench Photometer, chloride (Cl) was analyzed by the argentometric method, silver nitrate titration method was used to analyze bicarbonate (HCO_3) and nitrate (NO_3) was determined by chromotropic acid method using high range test 'N' tube.

3.4.1Principles and Descriptions of methods used in Analyzing the water samples

3.4.2 Analysis of Chemical Characteristics of Water Sample

3.4.3Determination of Sodium (Na^+) and (K^+) by flame photometry Method

Flame photometry is a method used in determining the concentration of some cations in group 1 and 11 (alkaline and alkaline earth metals) of the periodic table that have low ionization energy, of which sodium (Na^+) and Potassium (K^+) are among.

Principle of the method

The basic principle of flame emission is such that a sample in liquid form (water) is presented to a nebulizer which delivers a quantity of the sample as a fine aerosol on to a mixing chamber where it is combined and mixed with fuel. This mixture (aerosol and fuel) is directed to a burner for ignition and burning. The flame is positioned in a simple optical chamber where the emission from the flame is collected and directed through an optical filter system and on to a light detection device. The intensity of the light falling on the detector is measured and displayed on a meter.

Procedure for analysis

The fuel supply of the flame photometer was turned on at source and the "power" switched was depressed to switch on the 410. The "power on" LED started and an ignition cycle

wascommenced. If the “flame on” LED was not illuminated at the end of the ignition, the filter will be set to select the require element of interest. The nebulizer inlet-tube was inserted in a beaker containing approximately 100 ml of diluents and 15 minutes was allowed for the operating temperature to stabilize. This ensured a stable burner temperature when solutions were aspirated, after the warm up period. During the warm up period, a set calibration solutions was prepared to cover the required measurement range. 30 ppm for Sodium (Na^+) and 10 ppm for potassium (K^+) were used as the highest standard concentration in order to obtain maximum linearity corning recommend. The diluents were aspirated into the flame and the “blank” control of the instrument was adjusted so that the display reads zero while aspirating diluents. The highest concentration standard was aspirated and each of the remaining calibration standards was aspirated for 20 seconds (Starting with the lowest concentration to avoid carry over). 10 seconds was again allowed between measurement and 20 seconds was allowed for a stable reading than “coarse” and “five” controls were adjusted for a convenient reading. Example, 20 Na were set to read 20 Samples; standard and blank were aspirated at 20 seconds per sample to check the drift.

3.4.4Determination of Calcium (Ca^+), Magnesium (Mg^{2+}) Iron (Fe^{2+}) and Lead (Pb) by Atomic Absorption Spectrophotometer (AAS) method

Principle of the method

The principle is based on the absorption of radiant energy of various wavelengths by atoms present in the sample in their ground states. The atoms of elements strongly absorb radiation at certain characteristic wavelengths that coincide with the emission lines of spectral wavelengths of the particular element.

Procedure for analysis

Sample solution was aspirated through a nebulizer and sprayed as a fine aerosol into the mixing chamber where it was mixed, with fuel and oxidant gases. The mixture was carried to the head of a flame or burner for sample vaporization and atomization. The sample was passed through the light beam which is a hollow-Cathode lamp. These cathode lamps are designated to emit the atomic spectrum of a particular element and the specific lamps are designated to emit the atomic spectrum of a particular element and the specific lamps were selected for use depending on the element to be determined. For example, if mg was to be measured, a mg lamp would be selected for use. The atomic vapour of the sample absorbs some of the energy from a cathode lamp used as a radiant source. The energy absorbed and the remaining energy were passed into the monochromator which selected and isolated wavelengths of energy and of elements of interest. The wavelength of light isolated by the monochromator was directed to the detector, which serves as the eye of the instrument. This detector is a photo-multiplier tube; produces an electrical current dependent on the light intensity.

The electrical current was amplified and processed by the instrument electronics to produce a signal, which is a measure of the light attenuation occurring in the sample cell. This signal was further processed to produce instrument readout directly in concentration units.

3.4.5 Determination of Chloride (Cl^-) by Argentimetric Method

Principle of the method

The simplest and the most widely used method for the estimation of chlorides in water is Argentimetric method. This method is based on the titration of a halide Such as chloride (Cl^-) with standard Silver nitrate ($AgNO_3$) in the presence of Potassium chloride ($KCrO_4$)

as indicator. The end point of the titration was indicated when the solution changed from pure yellow to reddish brown. This was caused by the start of the precipitation of insoluble reddish brown silver chromate when all the chloride had reacted with Silver nitrate solution.

The reactions involved in the process are:

$$NaCl \quad x \quad AgNO_3 \longrightarrow AgCl_4 \; x \; NaNO_3$$

(In water) (Std Soln) (Insoluble white precipitate)

$$AgNO_3 \; x \; K_2CrO_4 \longrightarrow Ag_2CrO_4 \; x \; 2KNO_3$$ (Insoluble reddish brown ppt)

Procedure for analysis

A 100 ml of water sample: wass exactly measured in to a conical flask of 250 ml and 1.0 ml of potassium chromate indicator solution was added to it. The sample in the flask was titrated with a standard silver nitrate solution of 0.014 N until there was a perceptible colouration end point. The A concentration of chloride is, calculated from this below expression.

The expression goes thus:

$$Cl\ (Mg/l) = \frac{A \times N \times 35450}{Ml \text{ of sample taken for analysis}}$$

Where:

A = Ml of titration for sample

N = Normality of silver nitrate solution (N = 0141)

3.4.6 Determination of Carbonate and Bi-carbonate by Titrimetric Method

Principle of the method

This technique is based on titration of water sample with standard solution of Sulphuric acid (H_2SO_4) in the presence of phenolphthalein and methyl orange as indicators. The end point of the titration is indicated when the colour of the solution changed from orange – yellow to red.

Procedure for the analysis: Carbonate (CO_3^-) 0.0 ml of water sample was measured in a conical flask and 2-5 drops of phenolphthalein indicator was added to it. The solution was titrated with 0.02N H_2SO_4until the pink colour disappears. The volume of acid used was recorded and the concentration of CO_3^- was calculated as:

$$\frac{\textbf{2 x Normality of Acid x Volume of Water used x 100}}{\textbf{Aliquot taken (mls of acid used)}}$$

Bi-carbonate (HCO_3): To the same solution as above 2-5 drops of methyl – orange was added and then titrated until the colour changes which indicated the end point of the titration. The volume of acid used was recorded.

$$\frac{\textbf{2 x Normality of Acid x Volume of } \mathbf{H_2O} \textbf{ x 100}}{\textbf{Aliquot taken (mls of acid used)}}$$

N.B: 2 = Constant.

3.4.7Determination of Sulphate (SO_4^{2-}) and Nitrate (NO_3^-) by photometric methodDetermination of Sulphate (SO_4^{2-}) by precipitation method using photometer

Principle of the method:

This method is based on precipitation of Sulphate (SO_4^{2-}) with barium chloride crystals in which the light absorbance of the suspension is measured.

Procedure for the Analysis

A suitable sulphate method was selected. A cuvette was filled with 10 ml of unreacted sample and its cap was pressed and the display shows "O" when the meter was zeroed and ready for the measurement. The content of one packet of H193751-0 indicator reagent was added, the cap of the cuvette was replaced after the addition and it was inverted gently to mix for 1 minute (about 30 inversions). The cuvette was reinserted into the instrument (H18300 multiparameter Bench Photometer). The TIMER key was pressed and 5 minutes waiting was exercised and then READ key was pressed. When the timer ended, the meter performed the reading. Hence the instrument displayed concentration on mg/l of SO_4^{2-}.

3.4.8Determination of Nitrate (NO_3^-) by Cadmelium reduction method using Bench photometers

Principle of the method

This method is based on adaptation of the cadmium reduction method. This method explains the reaction between nitrate and the reagent which causes an amber tint in the sample

Procedure for analysis

A suitable nitrate method is selected. A cuvette is filled with 6 ml of the sample up to half of its height using the pipette and its cap is replaced after filling. The cuvette is then placed into the holder and the lid is closed. The ZERO key is pressed and ready for measurement. The cuvette is removed from the instrument and content of one packet of H193728-0 reagent is then added to it.

The cuvette's cap is replaced and immediately shaken vigorously up and down for exactly 10 seconds. The mixing continues by inverting the cuvette gently for 50 seconds, while taking care not to induce air bubbles.

Powder will not completely dissolve and time as well as way of shaking could sensitively affect the instrument. The cuvette is then reinserted in to the instrument taking care not to shake it. The TIMER key is pressed and 4 minutes and 30 seconds waiting is allowed after which the READ key is pressed.When the timer ends, the meter will perform the reading. The instrument displays the result in mg/l of nitrate-nitrogen. The key CHEM FRM is then pressed to convert the result in mg/l of nitrate (NO_3^-)

3.5 Formula Illustration for calculating Aquifer Characteristics such as T, S and K.

Transmissivity, T for BH Gwagwada (One of the boreholes in the study area)

$$\text{Using } T = \left[\frac{2.3Q}{4\pi\Delta s}\right] \times \left[\log 10\left(\frac{t_2}{t_1}\right)\right] \quad \text{--------- (i) (After Theis, 1935)}$$

$$= \frac{2.3 \times 46.656}{4 \times 3.142 \times 4.8}$$

$$= \frac{107.3088}{60.3264}$$

$$T = 1.779 \times 10^0 \, m^2/day$$

Where,

T = Transmissivity m^2/day

Q = Constant pumping rate m^3/sec

Δs = Change in Drawdown time

t_2, t_1 = time (days) since pumping started

Storativity, S for BH Gwagwada (one of the boreholes in the study area)

Using $S = \frac{2.25Tt_o}{r^2}$ ----------**(ii)** (After Theis, 1935)

$$= \frac{2.25 \times 1.77880331 \times 0.03}{(0.15)^2}$$

$$= \frac{0.12006922}{0.0225}$$

$$= 5.33640978$$

Note:

Since 1 day = (60 x 24) min

$$X = \frac{1\text{min}}{60 \times 24} \times \frac{2.25Tt_o}{r^2}$$

$$\therefore \quad S = \frac{1}{1440} \times \frac{0.12006922}{0.0225}$$

$$= 0.006944444 \times 5.33640978$$

$$= 0.00370584$$

$$S = 3.706 \times 10^{-3}$$

Where,

S = Storativity

T = Transmissivity

t_o = time intercept on zero drawdown axis

r = radius of the borehole

Hydraulic Conductivity, K for BH Gwagwada (One of the boreholes in the study area)

Using $T = KD$

$$K = \frac{T}{D} \quad \text{---------- (iii) (After Darcy, 1856)}$$

Where,

T = Transmissivity

K = Hydraulic Conductivity

D = Saturated thickness

= BH depth - SWL

= 50 - 6.3 (as read from the pumping test result for Gwagwada)

= 43.7 m

Substituting into $K = \frac{T}{D}$

$$K = \frac{1.7788033}{43.7}$$

$$= 0.04070488$$

$$K = 4.1 \times 10^{-2} \text{ m/day}$$

CHAPTER FOUR

RESULTS

4.1Introduction

The various field and laboratory data acquired are presented in this chapter. The data were assessed with respect to the geology, hydrogeology and groundwater quality and usability in the study area according to World Health Organization (WHO, 2011) and Nigeria Standard for Drinking Water Quality (NSDWQ) 2007 standards. The types of groundwater in the area were determined using piper Trilinear diagram (After Piper 1994).

4.2Geology of the study area

The study area is underlain by rocks of the basement complex. The distribution of the various rock types is as shown in the geological map of the area (Fig.4).Three main rock types were identified in the study area, they include; Granitic gneiss, porphyritic granite and mica schist. The rock units are distributed such that the porphyritic granite terrain is found at the northwestern part of the study area, the mica schist is found at the centre and towards the western part of the study area and the granitic gneiss appears at the southeastern part of the map and their field relationship is that they all have clear cut boundaries with each other without any interference by other minor outcrop exposures.

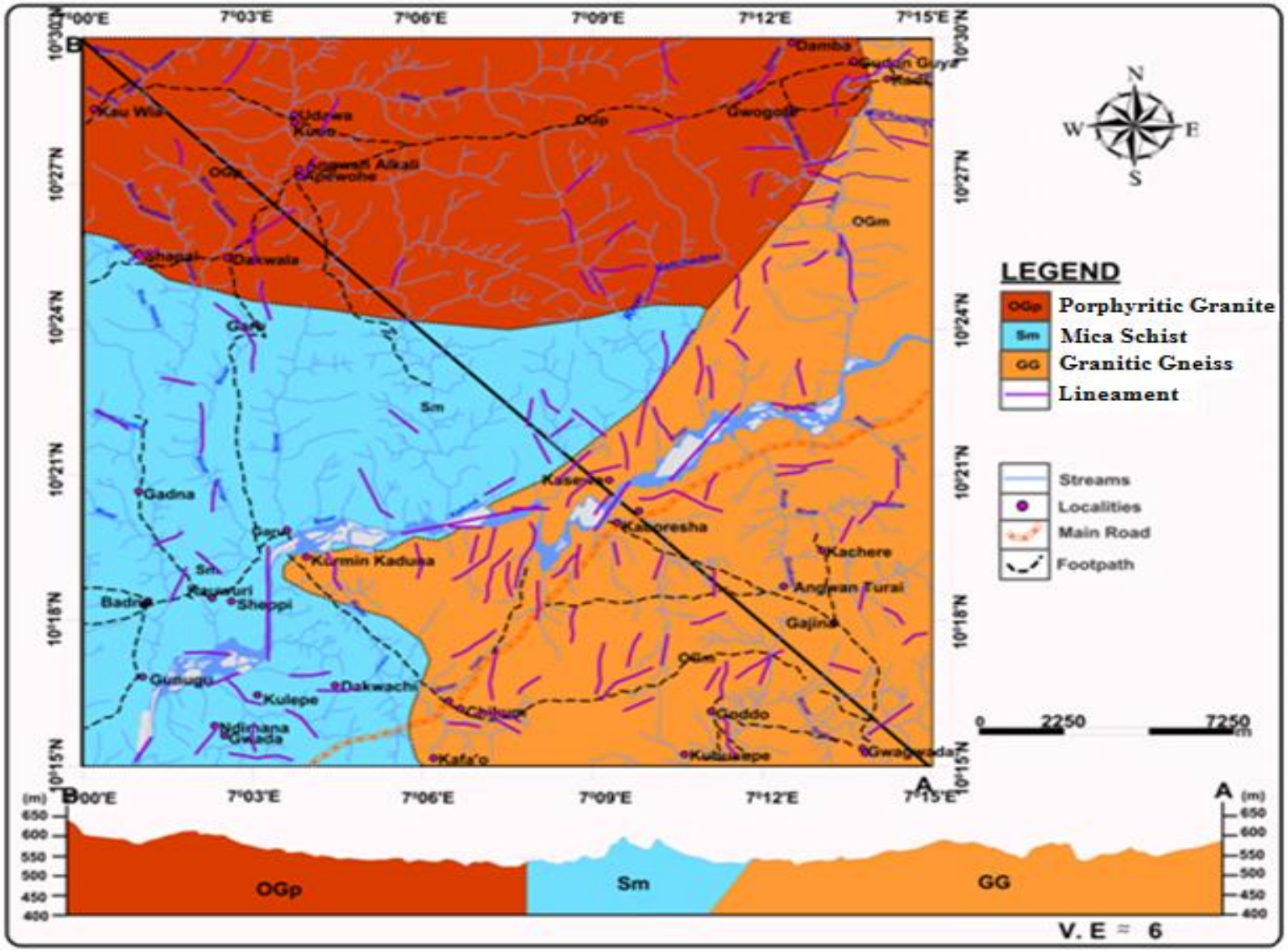


Figure 4.1: Geological map of Kakuri, Sheet 144 NW (Study Area) with sampling points on a scale of 1:50,000

4.2.1 Granitic Gneiss

In hand specimens, the rock is light to dark grey, it is medium to coarse grained. Its outcrop appears with prominent pegmatite vein and joints, table 4.1, that can be seen clearly from the surface (Plate IIa). The granitic gneiss strikes at an angle of 60^0 NNE – 240^0 SW with dip of 60^0 in 140^0 ESE direction.Fig. 4.2

Table 4.1: Joints of Granitic Gneiss in the study area

140^0	180^0	190^0	60^0	21^0	332^0	296^0
192^0	188^0	195^0	56^0	24^0	336^0	300^0
191^0	90^0	196^0	190^0	25^0	340^0	304^0
190^0	60^0	180^0	180^0	28^0	344^0	308^0
195^0	50^0	185^0	16^0	30^0	348^0	312^0
196^0	190^0	192^0	17^0	31^0	352^0	
180^0	180^0	193^0	17^0	32^0	356^0	
185^0	140^0	180^0	18^0	26^0	284^0	
192^0	192^0	188^0	18^0	27^0	288^0	
193^0	191^0	90^0	20^0	329^0	292^0	

According to McCurry, (1971) and Danbatta (1999), joints often result from contraction on cooling and are believed to be associated with a single episode of cooling and fracturing during epeirogenic uplift.

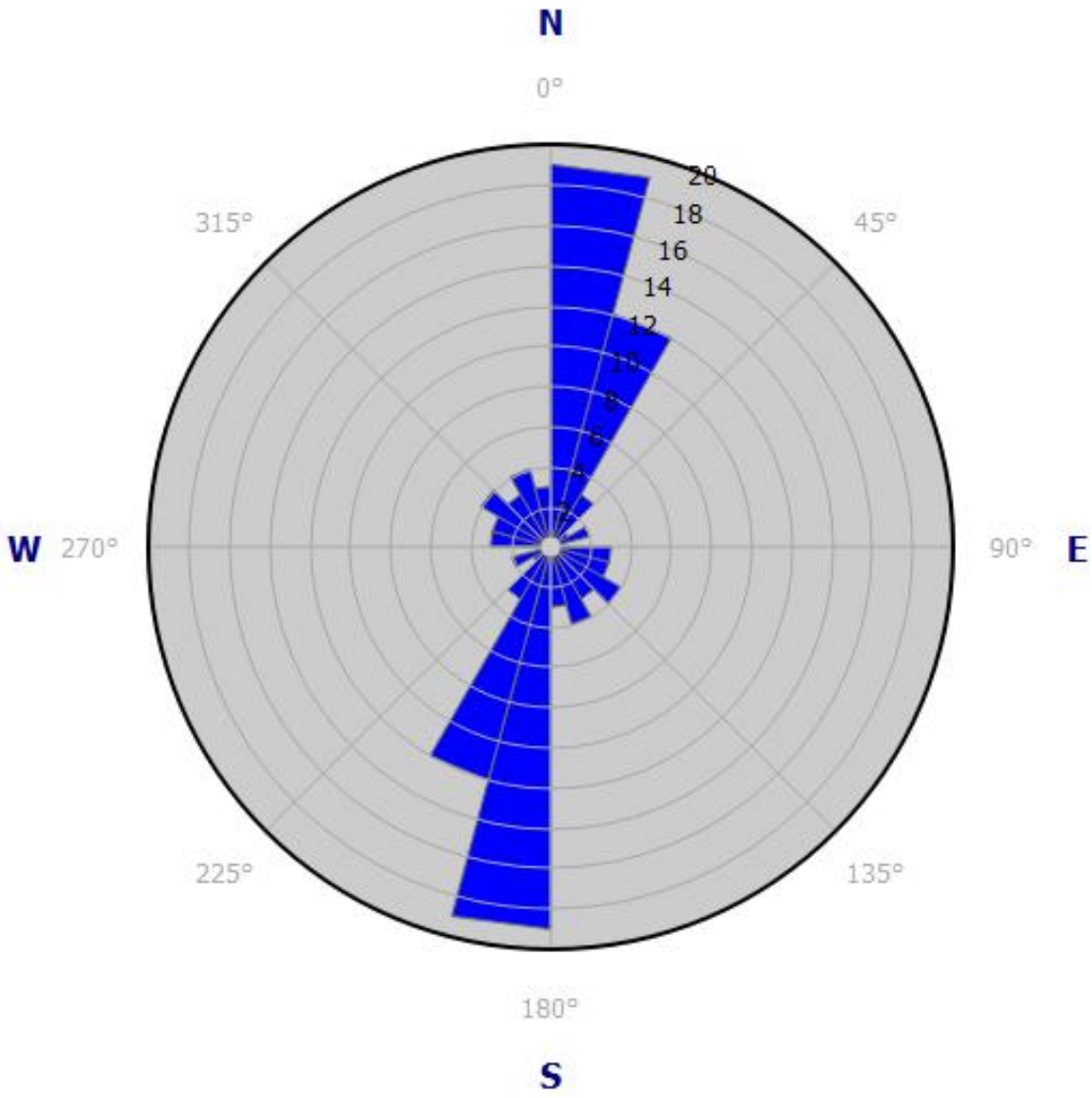


Figure 4.2: Rose Diagram of joints on Granitic gneiss in the study area showing a dominant NE-SW trend.



Plate IIa:Outcrop exposure of granitic gneiss east of GudunGuya(N10^0 29' 18.5" and E007^0 12' 42.3")

In thin section, it is composed of mainly quartz, microcline, orthoclase, biotite, muscovite and plagioclase. Quartz is the dominating mineral followed by plagioclase feldspar with muscovite as the least dominating mineral.

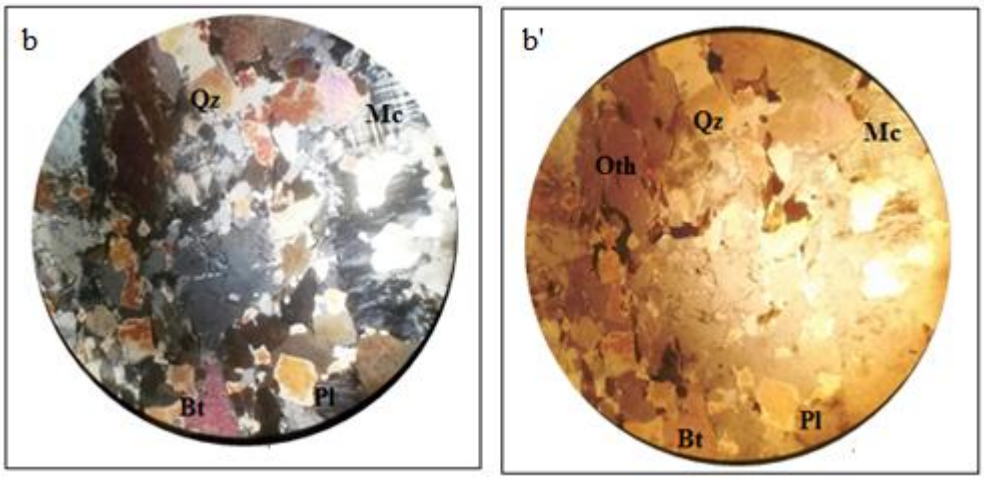


Plate IIb: Photomicrographs of granitic gneiss in XPL; (b') of granitic gneiss in PPL:
NOTE:Oth = Orthoclase, Mc = Microcline, Pl = Plagioclase, Bt = Biotite, Qz = Quartz.

The granitic gneiss consists of the following minerals in their ascending order of percentages; Quartz (35%), Plagioclase (25%), Biotite (20%), Microcline (10%), Muscovite (5%) and Orthoclase (5%).

4.2.2Porphyritic Granite

In hand specimen, it is composed of quartz and biotite. Quartz is the most abundant of these major minerals present. It strikes at an angle of 37^0 NE/217^0 SW and dips at 307^0 NW with dip amount of 19^0.



Plate IIIa: Porphyritic granite atDamba 2(N10^0 29' 26.1" and E007^0 12' 43.0")

In thin section, the rock is composed of quartz, microcline, perthite and biotite. It is porphyritic in texture and light coloured, there is myremekitic intergrowth texture in places. The main feldspar forming phenocrysts is the alkali feldspar (microcline).

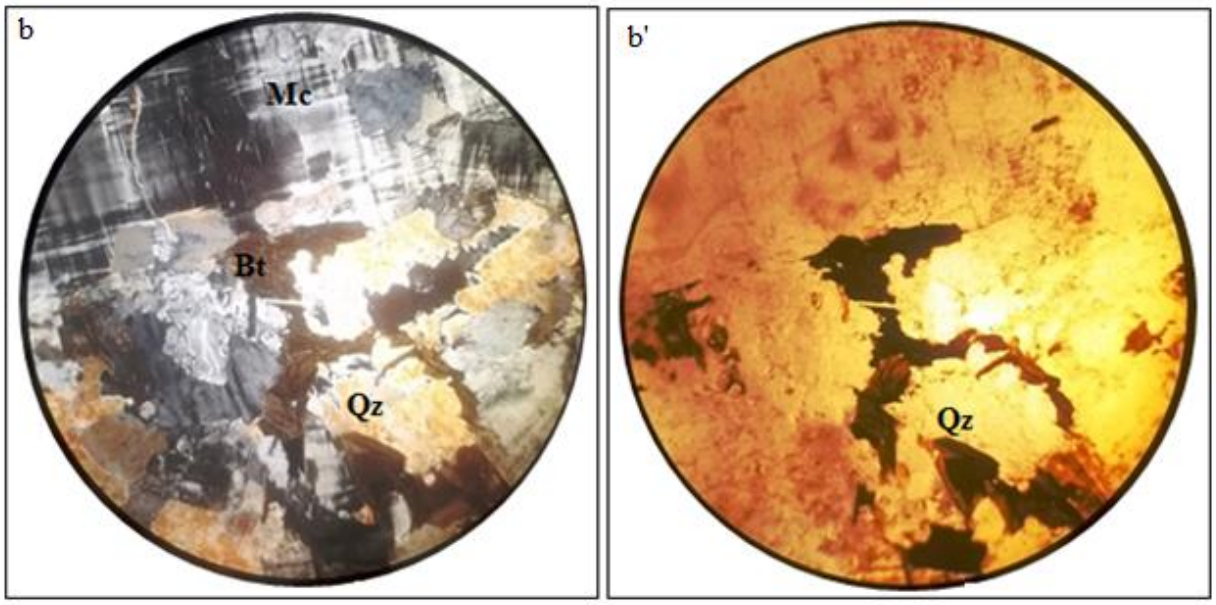


Plate IIIb: Photomicrographs of porphyritic granite in XPL (b') of porphyritic granite in PPL;

NOTE: **Qz** = Quartz, **Mc** = Microcline, **Bt** = Biotite.

The porphyritic granite consists of the following minerals in their ascending order of percentages; microcline (40%), quartz (35%), biotite (20%) and perthite (5%).

4.2.3 Mica Schist

In hand specimens, the rock is leucocratic (light in colour) to dark grey. It carries small porphyroblasts of quartz in the ground mass. The major mineral grains present are large enough to be recognized. It is seen to be rich in quartz and contains some feldspars and biotite. It trends NNE – SSW trending with dip of 40^0 to 110^0 ESE direction.



Plate IVa: Outcrop of mica schistatKulepe northeast of Ndimana (Fig. 4.1) ($N10^0$ 16' 39.3" and $E007^0$ 3' 00.5")

In thin section, the rock is composed of muscovite, biotite, quartz, plagioclase opaque and other accessories. The mineral alignment forms lineation of biotite and muscovite. Two phases are identified, the quartz veining being younger and undeformed.

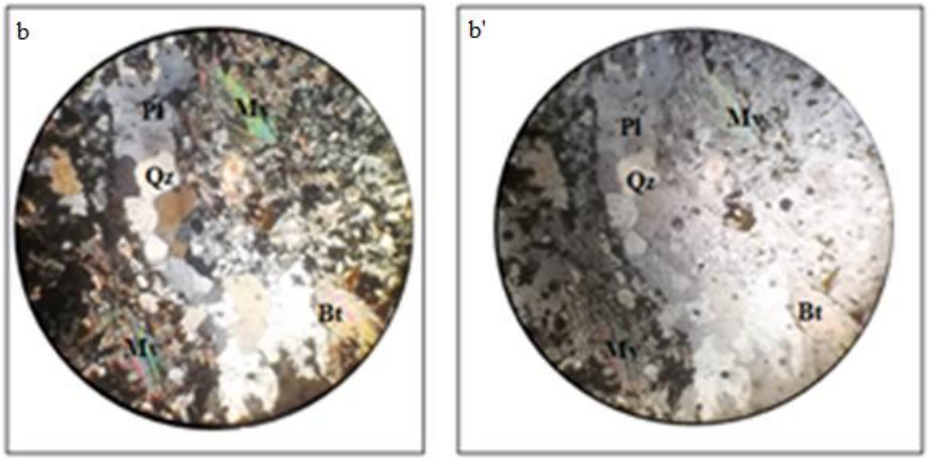


Plate IVb: Photomicrographs of mica schist in XPL (b') of mica schist in PPL.

NOTE: **Mv** = Muscovite,**Qz** = Quartz, **Pl** = Plagioclase, **Bt** = Biotite.

The Mica schists consist of the following minerals in their ascending order of percentages; Quartz (50%), muscovite (20%) biotite (15%) and (5%) accessories mineral.

4.3 Groundwater configuration in the study area (Hydrogeology)

4.3.1 Peak of Wet Season

The water table map at the end of wet season **(**Fig.4.3**)** was based on the static water level measured from hand-dug wells in October, 2015. The maximum depth to water table was 6.8 m (22.3 ft) while the minimum was 1.2 m (3.9ft) bgl.

4.3.2 Peak of Dry Season

The water table map at the peak of dry season (Fig.4.4) was based on the static water level in hand-dug wells measured in May, 2015.The maximum water level elevation was 11 m (36.1ft) while the minimum was 4.1 m (13.5ft).

4.3.3 Direction of Groundwater Flow

Direction of groundwater flow is also known as direction of groundwater movement which is indicated in the hydrogeological map of the study area by the arrows drawn perpendicular to the groundwater table contours (equipotential lines). Groundwater in the study area flows from the higher groundwater elevation contour to lower groundwater elevation contour and the flow is largely towards the NE direction.Fig. 4.3 and Fig.4.4.

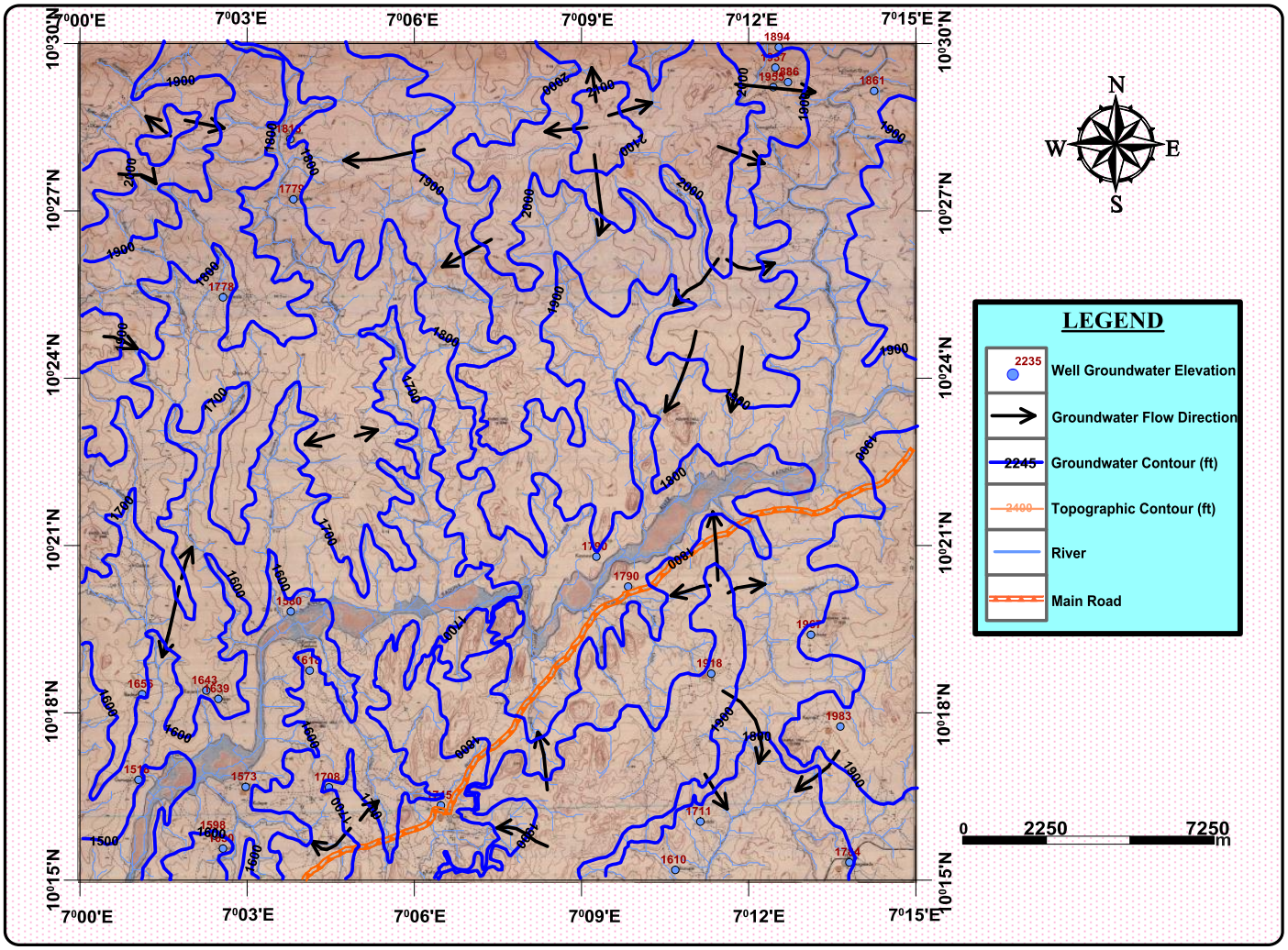


Figure 4.3: Hydrogeological map of the study area showing groundwater table configuration and direction of groundwater flow, at Peak of wet Season (October, 2015 Hydrogeologic year)

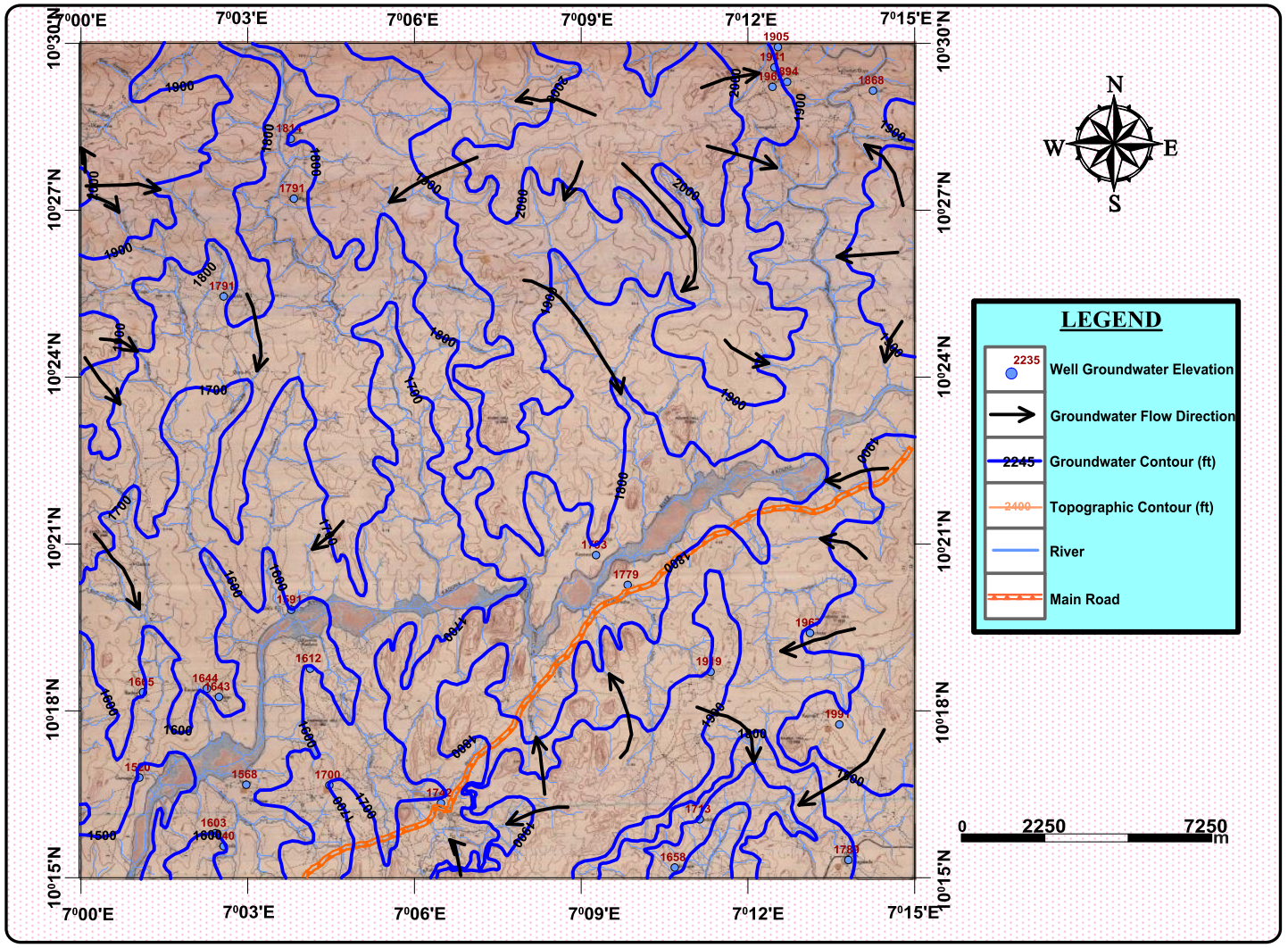


Figure 4.4: Hydrogeological map of the study area showing groundwater table configuration and direction of groundwater flow, at Peak of dry Season (May, 2016 Hydrogeologic year)

4.4 Hydrogeochemistry (Water Quality)

4.4.1 Chemical characteristics

Table 4.2: Concentration of major, minor and trace elements in the water samples

SAMPLE ID	LOCATION	pH	EC(µS/cm)	TDS (mg/l)	T (°C)	K^+ (mg/)	Na^+ (mg/l)	Mg^{2+} (mg/l)	Ca^{2+} (mg/l)	Fe^{2+} (mg/l)	Cr (mg/l)	Pb (mg/l)	Hg (mg/l)	NO_3^{3-} (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	HCO_3^- (mg/l)
1	Gwogofe	5.8	36	25	20.75	5.3	3.8	2.36	0.54	0.075	0.088	0.186	6.427	7	16	1.27	36
2	Damba 1	6.6	155	109	20.09	1.3	7.1	3.8	12.34	0.135	0.087	0.088	5.008	21	16	3.5	136
3	Damba 2	6.04	28	20	20.75	2.7	5.7	0.67	0.39	0.032	0.212	0.128	5.265	14	16	1.43	14
4	Chikun1	5.94	13	9	20.09	3.9	1.4	0.79	1.02	0.051	0.131	0.038	4.045	7	12	2.22	10
5	Chikun2	6.4	22	15	20.85	2.6	3.7	0	0	0.009	0.095	0.077	4.61	7	12	2.07	20
6	Gwagwada 1	6.56	522	365	20.75	3.2	4.9	15.6	60.29	0	0.05	0.054	2.246	14	99.97	2.22	40
7	Gwagwada 2	6.8	373	261	30.75	30.75	4.7	15.96	36.24	0	0.197	0.088	2.555	14	51.98	9.06	108
8	Gwagwada 3	6.58	246	172	20.75	2.9	1.5	13.21	17.7	0.023	0.208	0.251	2.505	21	75.98	2.38	72
9	AngwanTurai	5.95	123	86	20.75	5.3	2.6	3.68	6.43	0.048	0.052	0.1	5.631	14	21.99	2.22	32
10	GudunGuya	6.52	29	20	20.7	0.9	5.9	0.82	0.91	0.038	0.159	0.145	6.904	7	17.99	2.54	24
11	Angwan Alkali 1	5.26	109	08	6	1.3	1.5	1.71	0	0.005	0.12	0.009	3.282	7	10	3.5	36
12	Angwan Alkali 2	5.73	13	9	20.8	2.8	1.2	0	0	0	0.129	0.005	3.516	35	8	2.54	28
13	Kudo	6.17	53	37	20.7	2.6	1.3	1.34	1.91	0.031	0.093	0.13	5.45	21	19.99	2.38	28
14	Kurmin Kaduna	6.86	128	90	20.7	4.7	1.9	1.69	14.84	0.095	0.018	0.115	6.954	21	33.99	2.86	32
15	Gajina 1	5.85	34	24	20.8	6	5.9	2.33	0.57	0.072	0.113	0.077	3.128	7	12	2.86	32
16	Gajina 2	5.74	20	14	20.75	2.7	5.1	0.57	0	0.262	0.13	0.02	3.183	7	14	3.5	14
17	Gajina 3	5.79	20	14	20.8	2.4	4.5	1.16	0	0.675	0.149	0.036	3.348	7	19.99	2.86	36
18	Dakwachi	6.26	20	14	20.9	4	4.9	0.54	0	0.033	0.081	0.108	6.266	7	16	2.86	36
19	Kulepe	*6.75*	*38*	*27*	*20.9*	*2.6*	*7.9*	*0.79*	*4.61*	*0.114*	*0.143*	*0.083*	*6.427*	*7*	*12*	*2.07*	*52*
20	SabonKauWia	6.4	121	85	20.7	1.4	1.9	3.08	8.13	0	0.218	0.122	5.845	21	41.99	2.54	56
	AVERAGE	6	100.1	70.1	22	3	4	4	4	0	0.124	0.078	4.63	13.3	29.75	2.844	42.1

4.4 HYDROGEOCHEMISTRY (WATER QUALITY)

4.4.1 Physical characteristics of groundwater sample (Table 4.2)

Temperature: The temperature of the water sample was measured using digital thermometer and temperature in the following range was obtained and ranges from 20.09-30.75^{0}C with an average of 22^{0}C (Tables 4.2).

Total Dissolved Solids (TDS): The total dissolved solids in the study area were found to range from 008-365 mg/l with an average of 70.1 mg/l from analyzed samples and is rated excellent when compared with NIS (2007) and WHO (2011) permissible limit of total dissolved solid.

Hydrogen ion exponent (pH): pH, measures the acidity of water or alkalinity of water. Hydrogen ion exponent depends on free carbon dioxide from the atmosphere absorbed by rain or on presence of sulphates. High pH is due to the presence of bicarbonates and hydroxides of calcium, magnesium and sodium. The pH of the water analyzed in the study area ranges from 5.26-6.86, with an average of 6, and rated good when compared with the NIS (2007) and WHO (2011) permissible limit guideline of pHTable 4.2

Electrical Conductivity (EC): The electrical conductivity in the study area ranges from 13 -522µS/cm with an average of 100.1µS/cm.

Calcium: Results show that the concentration of calcium range from 0.00- 60.29mg/l with an average of 4 mg/l, Ca^{2+} has low concentration when compared with the NIS (2007) and WHO (2011) permissible limit of calcium.

Potassium: Potassium concentration in the study area ranges from 0.9-30.75mg/l, with an average of 3mg/l and rated good when compared to NIS (2007) and WHO (2011) permissible limit of potassium.(Table 4.2).

Sodium: The concentration of sodium in the study area range from 1.2-7.9mg/l with an average of 4mg/l and it is rated good using the NIS (2007) and WHO (2011) permissible limit of sodium.

Magnesium: Magnesium has a concentration ranging from 0.00-15.95mg/l with an average concentration of 4mg/l and is considered low using the NIS (2007) and WHO (2011) permissible limit of magnesium.

Iron: The result of iron has a range of concentration from 0.00-0.678 mg/l with an average of 0.08 mg/l which is lower than the NIS (2007) and WHO (2011) permissible limit of iron.

Nitrate: Nitrate in the study area varies between 7.0-35.0 mg/l with an average of 13.3 mg/l with an excellent rating putting the NIS (2007) and WHO (2011) permissible limit into consideration with only one sample from Angwan Alkali having a high value above the margin of other samples collected probably due to a grazing reserve and the fertilizer application due to agricultural activities by the inhabitants of the host community within the study area.

Chloride: From the result, it shows that it varies from 8.00-99.97 mg/l with an average of 29.75 mg/l, this is relatively low when compared with the NIS (2007) and WHO (2011) permissible limit guideline for chloride.

Sulphate: The sulphate values from the analyzed water samples range from 1.27-9.06 mg/l with an average of 2.844 mg/l, which shows that all groundwater samples studied, had sulphate content below the WHO (2011) and NIS (2007) permissible limit.

Bi-Carbonate: The laboratory result show that Bi-carbonate from the water samples analyzed ranges from 10.0-136 mg/l with an average of 42.1 mg/l, and it shows to be below the NIS (2007) and WHO (2011) permissible limit.

Lead: Lead has a concentration ranging from 0.088-0.251 mg/l with an average of 0.078 and is slightly higher than the NIS (2007) and WHO (2011) permissible limit.

Chromium: The concentration of total chromium range from 0.018-0.218mg/l with an average of 0.124mg/l and is rated high when compared with the NIS (2007) and WHO (2011) permissible limit guideline value of 0.05 respectively(Table 4.2).

Table 4.3 below shows physicochemical parameters measured in hand dug wells during field work exercise (May, 2016). While table 4.4 shows comparison of field data (Present work) with NIS (2007) and WHO (2011) recommended values for physical and chemical parameters of water for drinking and domestic uses.

Table 4.3: Physicochemical parameters measured in the hand dug wells during field work exercise (May, 2016).

Sample ID	Locations	Well	Northing Decimal Degrees	Easting Decimal Degrees	pH	TDS(mg/l)	Temp.(°C)	EC(µS/cm)
1	Gwagwada 1	W	10.259889	7.229388	6.56	365	27.5	522
2	Gwagwada 2	W	10.255306	7.230583	6.8	261	37.5	373
3	Gwagwada 3	W	10.255307	7.230111	6.58	172	27	246
4	Gajina 1	W	10.255472	7.229806	5.85	24	28	34
5	Gajina 2	W	10.296056	7.225972	5.74	14	27.5	20
6	Gajina 3	W	10.295917	7.227417	5.79	14	28	20
7	Angwan Alkali1	W	10.453389	7.063750	5.73	06	28	08
8	Angwan Alkali 2	W	10.453472	7.063833	5.26	9	28	13
9	Chikun 1	W	10.272333	7.107944	5.94	9	29	13
10	Chikun 2	W	10.272306	7.106667	6.4	15	28.5	22
11	Damba 1	W	10.498889	7.209000	6.6	109	29	155
12	Damba 2	W	10.492806	7.207972	6.04	20	27.5	28
13	Kudo	W	10.471444	7.062889	6.17	37	27	53
14	AngwanTurai	W	10.311694	7.188806	5.93	86	27.5	123
15	SabonKauWia	W	10.501917	7.030806	6.4	121	85	121
16	Dakwachi	W	10.277722	7.074472	6.26	14	29	20
17	Kulepe	W	10.277861	7.049556	6.75	27	29	38
18	Gwogofe	W	10.488472	7.206528	5.8	25	27.5	36
19	GudunGuya	W	10.488472	7.211750	6.52	20	27	29
20	Kurmin Kaduna	W	10.312639	7.068722	6.86	90	27	128

Table 4.4: Comparison of Field Data (Present work) with NIS (2007) and WHO (2011) Recommended Values for Physical and Chemical Parameters of Water for Drinking and Domestic uses.

Parameters	Unit	WHO 2011	NIS 2007	Author's Result 2016 Range	Average	Remark
Water Temp.	°C	—	—	20.09 - 30.75	22	Good
pH	—	6.5 ?8.5	6.5 ?8.5	5.26 - 6.86	6	Good
TDS	mg/l	1000	500 ? 1500	8.00 – 365	70.1	Excellent
K?	mg/l	10-15	—	0.9 - 30.75	3	Good
Na?	mg/l	200	200	1.2 - 7.9	4	Good
Mg^{2}?	mg/l	50	0.2	0.00 - 15.95	4	Low
Ca^{2}?	mg/l	100	75-200	0.00 - 60.29	4	Low
Fe^{2}?	mg/l	0.3	0.3	0.00 - 0.675	0.08	Low
Cr	mg/l	0.05	0.05	0.018 - 0.218	0.124	High
Pb	mg/l	0.01	0.01	0.339	0.078	High
$NO3^{-}$	mg/l	50-100	50	7.0 - 35	13.3	Excellent
Cl	mg/l	250	250	8.0 - 99.97	29.75	Low
$SO4^{-}$	mg/l	250	100	1.27 - 9.06	2.844	Low
$HCO3^{-}$	mg/l	500-1000	—	10 – 136	42.1	Low
EC	µS/cm	—	1000	13-522	100.1	Excellent

4.4.2 Water type

Piper diagrams are produced based on the concentrations of ions determined from analysis of water samples. Plot of major elements (cations) obtained from the analysis are done on a triangle together with their respective anions and this can be projected in a diamond shape representing both thecations and the anions as well as their relationship. Fig. 4.5 shows the cationsconcentration while Fig. 4.6 shows the groundwater Type of Kakuri NW, Superimposed on the Geological Map.

4.4.4 Characteristics of the groundwater

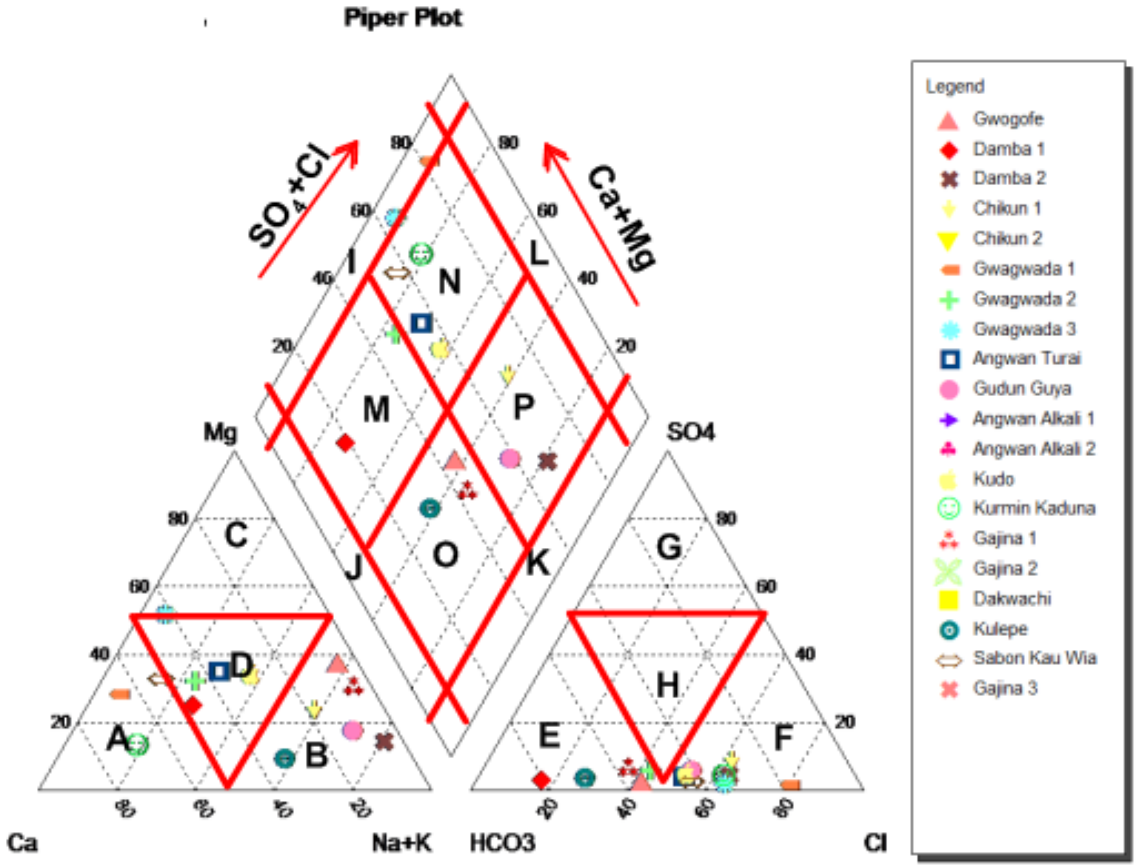


Figure 4.5: Piper Trilinear Diagram of the relative Cation and Anion composition of groundwater samples of Kakuri NW (After Piper 1994).

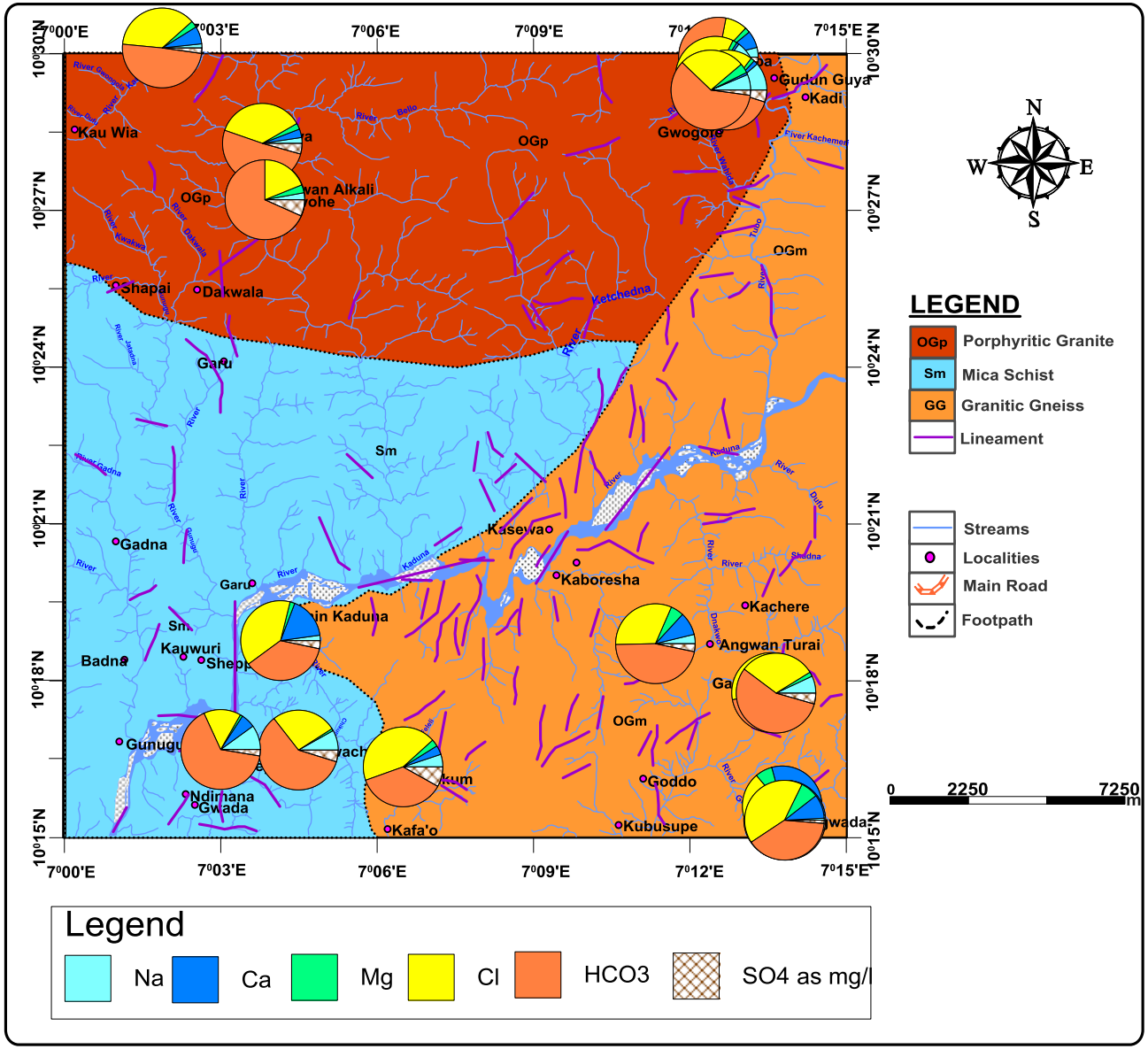


Figure 4.6: Groundwater Type of Kakuri NW, Superimposed on the Geological Map

The concentration of ions in milliequivalent per litre are represented on a Piper trilinear diagram, Fig. 4.5. The overall chemical character as shown in the trillinear diagram is that of a normal alkaline fresh water type. Out of the twenty (20) groundwater samples studied, two (2) samples fall within the Ca-K- HCO_3 water type corresponding to 10%,six (6) fall within the Ca-HCO_3 water type which corresponds to 30%, five (5) samples fall within the Na-HCO_3 water type which corresponds to 25%, three water samples fall within the Ca-Mg-HCO_3water type corresponding to 15%, two samples fall within the Na-Ca-HCO_3water types corresponding to 10% and two samples each falls within the K-HCO_3, and Na-Mg-HCO_3water type corresponding 10% of the total water samples analyzed.Distribution of hydrochemicalFacies of Groundwater from different Geological units of the study locations is analyzed. Table 4.5 and table 4.6.

From the Schoeller plot (Fig. 4.7) the dominant cation is in the order of Ca>Mg>Na while that of Anions is in the order of Cl>HCO_3>SO_4.

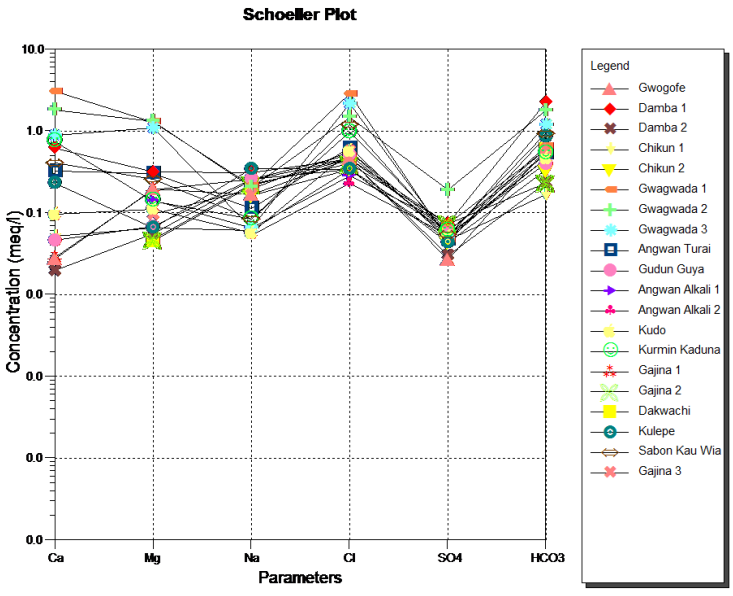


Figure 4.7: Schoeller plot showing the dominant cations and anions in the study area

Table 4.5:Distribution of hydrochemicalFacies of Groundwater from different Geological units of the study locations

Sample ID	Location	Geology	HydrochemicalFacies
1	Gwogofe	Porphyritic Granite	Ca^{2+}-HCO_3-Cl^-
2	Damba 1	Porphyritic Granite	Ca^{2+}-HCO_3-Cl^-
3	Damba 2	Porphyritic Granite	Ca^{+}-HCO_3- Cl^-
4	Chikun1	Granitic Gneiss	K^{+}-HCO3- Cl^-
5	Chikun2	Granitic Gneiss	Na^{+}-HCO3- Cl^-
6	Gwagwada 1	Granitic Gneiss	Ca^{2+}-Mg^{2+}-HCO3- Cl^-
7	Gwagwada 2	Granitic Gneiss	Ca^{2+}-Mg^{2+}-K^{+}-HCO3- Cl
8	Gwagwada 3	Granitic Gneiss	Mg^{2+}-Ca^{2+}-HCO3- Cl^-
9	AngwanTurai	Granitic Gneiss	Ca^{2+}-Mg^{2+}-HCO3- Cl^-
10	GudunGuya	Granitic Gneiss	Na^{+}-HCO3- Cl^-
11	Angwan Alkali 1	Porphyritic Granite	Ca^{2+}-HCO3- Cl^-
12	AngwanAlkali2	Porphyritic Granite	Ca^{+}-K^{+}-HCO3- Cl^-
13	Kudo	Porphyritic Granite	Ca^{+}-HCO3- Cl^-
14	KurminKaduna	Granitic Gneiss	Na^{2+}-HCO3- Cl^-
15	Gajina 1	Granitic Gneiss	Na^{+}-Mg^{2+}-HCO3-Cl
16	Gajina 2	Granitic Gneiss	Na^{+}-HCO3- Cl^-
17	Gajina 3	Granitic Gneiss	Na^{+}-HCO3- Cl^-
18	Dakwachi	Mica Schist	Na^{+}-Ca^{2+}-HCO3- Cl^-
19	Kulepe	Mica Schist	Na^{+}-Ca^{2+}HCO3- Cl^-
20	SabonKauWia	Porphyritic Granite	Ca^{2+}- HCO3- Cl^-

Table 4.6: Summary OfHydrogeochemicalFacies As Worked Out From Piper Diagram Of The Study Area (Fig. 4.6)

FACIES/WATER TYPE	SAMPLING LOCATION	NUMBER OF SAMPLES	PERCENTAGE (%)
Ca^{2+}-$HCO3^{-}$	Gwogofe, Damba 1&2, Angwan Alkali 1 SabonKauWia	6	30
K^{+}-$HCO3^{-}$	Chikun 1	1	5
Na^{+}-$HCO3^{-}$	Chikun 2, GudunGuya, Kurmin Kaduna, Gajina 1&3	5	25
Mixed-Ca2+-Mg2+-$HCO3^{-}$	Gwagwada 1&3, AngwanTurai	3	15
Mixed-Ca2+-Mg2+-K+$HCO3^{-}$	Gwagwada 2	1	5
Mixed-Na+-Mg2+-$HCO3^{-}$	Gajina 1	1	5
Mixed- Na+-Ca-$HCO3^{-}$	Dakwachi, Kulepe	2	10
Mixed-Ca2+-K+-$HCO3^{-}$	Angwan Alkali 2	1	5
Total		20	100

4.4.3 Classification of water type based on mineralization

According to Schoeneich (2001) water can be classified chemically based on mineralization; (prevailing mega-ions; and some trace elements or some dissolved gases). Based on this classification, all the water samples analyzed are oligomineral waters or simply put as fresh waters because they have mineralization < 1 g/l (1000 mg/l). Based on the conductivity of the water samples, fourteen (14) of the samples are excellent for irrigation (conductivity < 250 µS/cm); six (6) of the samples are good for irrigation (conductivity between 250-750 µS/cm).

Wilcox plot (Fig.4.8) shows the suitability of water for irrigation purposes. It is a plot of Sodium Hazard Sodium Adsorbtion Ratio (SAR) VS Salinity Hazard (Conductivity).

Wilcox plot has the following sections; Conductivity (µS/cm) C1: Low (0-249), C2: Medium (250-749), C3: High (750-2249),

C4: Very High (2250-5000). The values are divided into the following categories; S1: Low, S2: Medium, S3: High, S4: Very High.

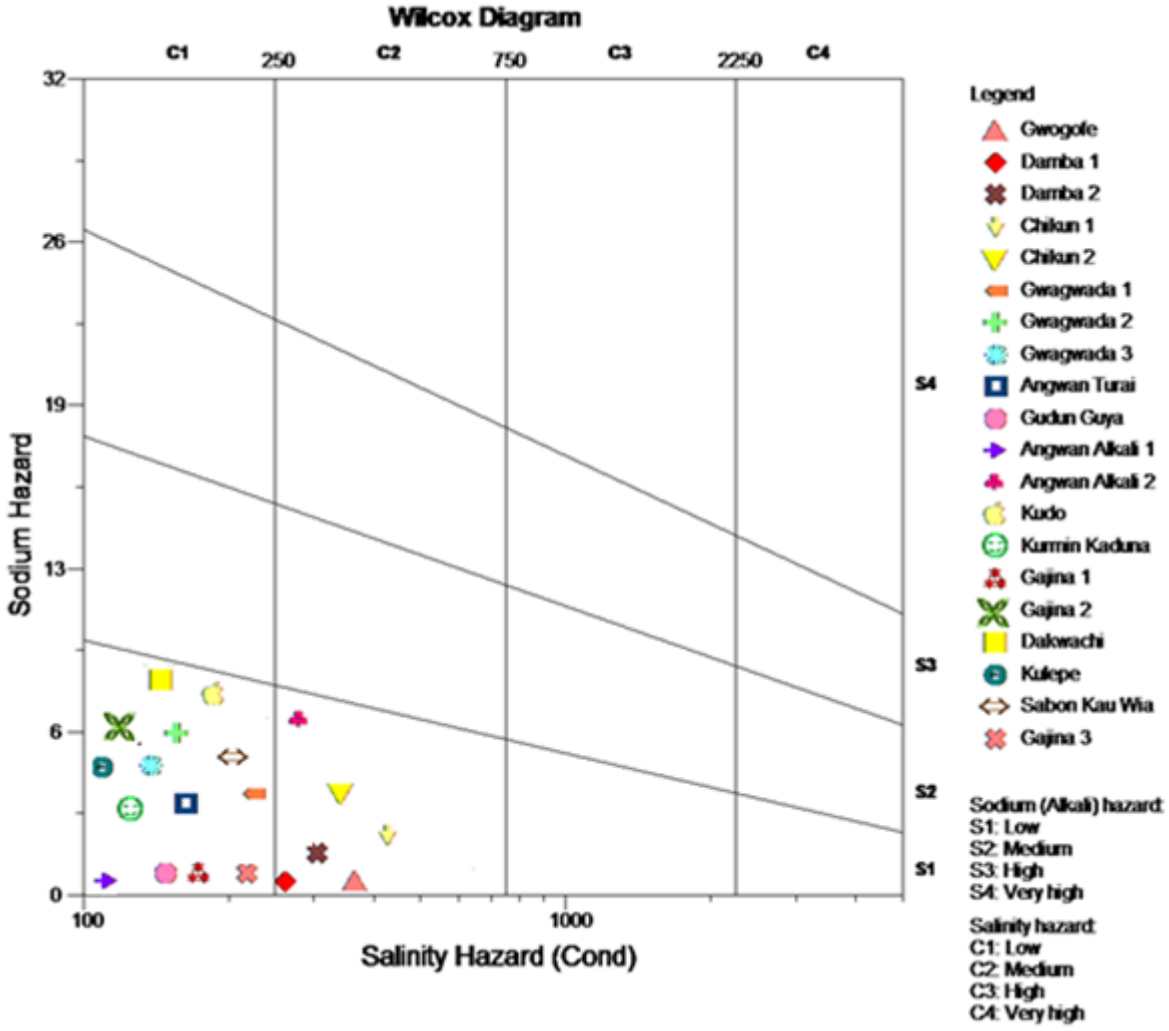


Figure 4.8: Wilcox plot for classification of irrigation water in the study area (after Wilcox, 1995).

The Wilcox plot (Fig.4.8) is a plot of sodium hazard (SAR) versus salinity hazard (Cond.), 14 out of the 20 water samples fall into C1-Low salinity hazard, 6 samples plotted into C2-Medium salinity hazard and the entire 20 samples plotted into the S1-Low sodium hazard class which means the water from the study area is excellent for irrigation purposes.

The relevance of Wilcox plot, Fig. 4.8 to this study is that if the value of SAR is in excess, it indicates that there is a medium or high sodium or low calcium plus magnesium content in groundwater. If this kind of water is used in irrigation, it can cause the dispersion of soil colloids, destroying soil texture and permeability.

Measured salinity hazard and Sodium Hazard Classification based on Sodium Absorption Ratio (After Wilcox, 1955) of the Study Area is summarized in table 4.7 and 4.8 showing C1-C4 class, electrical conductivity (μS/cm), remark on quality and hand dug wells sample number. While table 4.8 shows sodium hazard class ranging from S1-S4, Sodium Adsorption Ration (SAR), remark on quality and number of sampled hand dug wells.

Table 4.7: Measured Salinity Hazard of Groundwater Samples of the Study Area

Class	**EC (µS/cm)**	**Remark onQuality for Irrigation**	**Hand dug wells sample number**
C1	0 -250	Excellent	14
C2	250 – 750	Good	6
C3	750 – 2250	Doubtful	0
C4	> 2250	Unsuitable	0
Study sample average	**100.1**	**Excellent**	

Table 4.8: Sodium Hazard Classification based on Sodium Adsorbtion Ratio (After Wilcox, 1955) of the Study Area

Sodium Hazard Class	**Sodium Adsorbtion Ratio**	**Remark on Quality For Irrigation**	**Number of sampled Hand dug wells**
S1	10	Excellent	20
S2	10 - 18	Good	0
S3	18 – 26	Doubtful	0
S4	> 26	Unsuitable	0

4.4.4 Lineaments

Lineaments are usually linear features in a landscape which is an expression of an underlying geological structure such as faults. Typically a lineament will comprise a fault-aligned valley, a series of fault or fold-aligned hills, a straight coastline or a combination of these features. Bates and Jackson (1980), properly define a lineament as a "linear topographic feature that is believed to reflect crustal structure." Fig. 4.9.

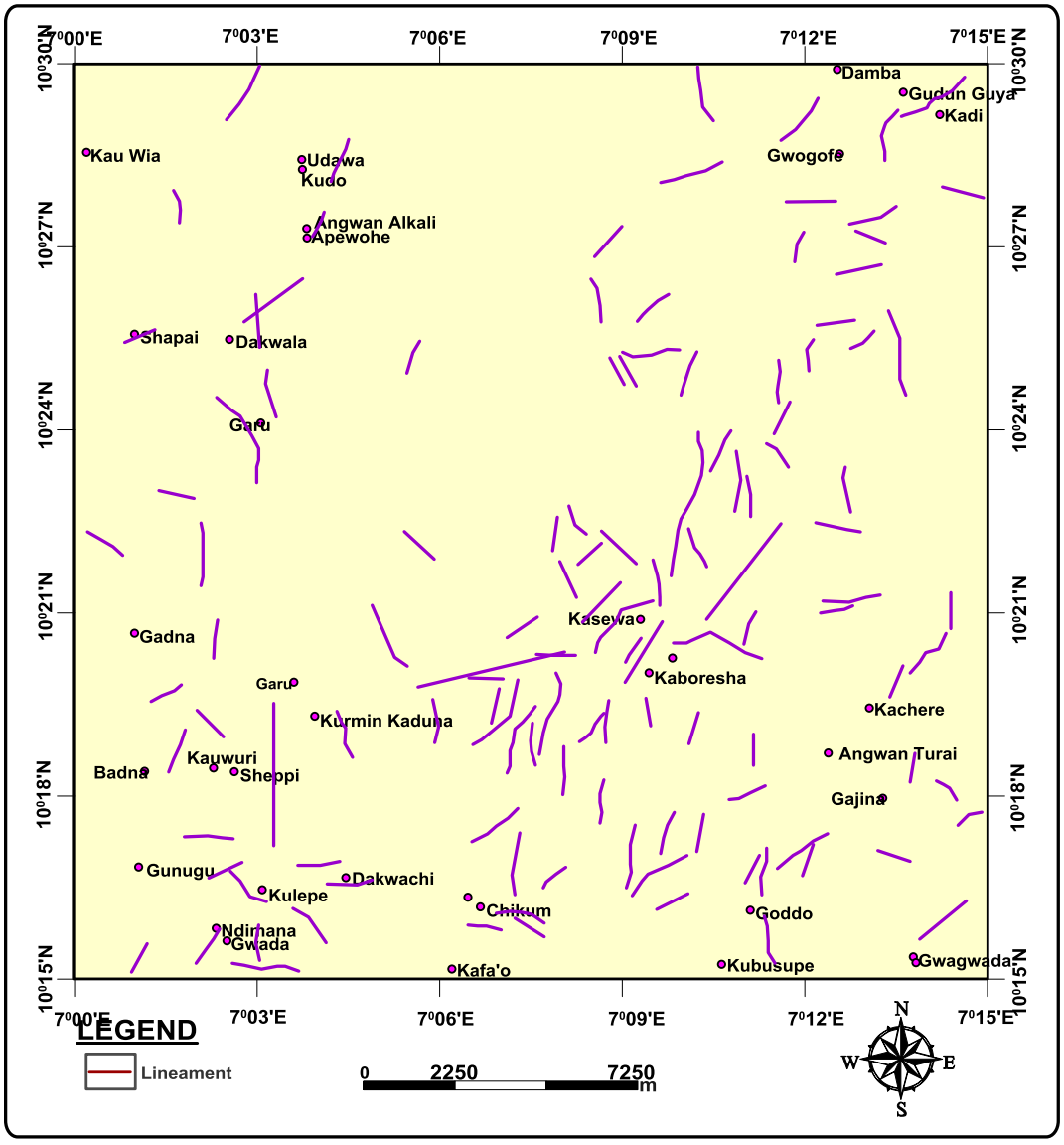


Figure 4.9: Lineament map of the study area

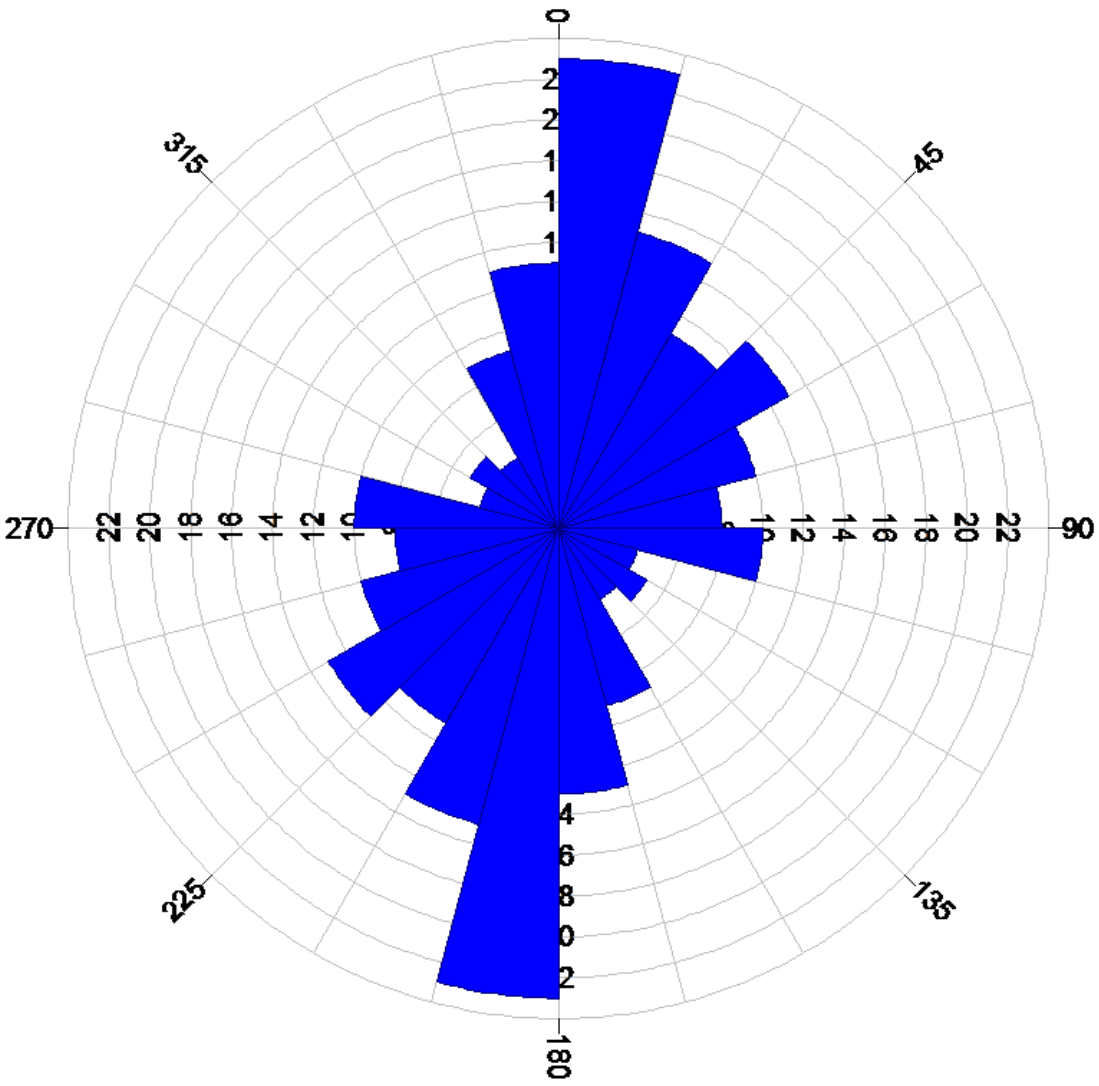


Figure 4.9.1: Rose diagram of lineament in the study area

4.4.5Geophysical assessment

Geophysical investigation data was collected for fifteen (15) locations where the survey was done.Vertical Electrical Sounding (VES) techniques was employed with full Schlumberger Electrode Array Configuration, using the Pasi Automatic Resistivity/Sp Meter. The half-current electrode separation AB/2 ranges between 1.0 and 70.0m and the target depth of investigation was between 50 – 58 m while half-potential electrode separation MN/2 was between 0.5 and 7.5m. The instrument and survey technique were geared towards good data resolution and subsurface investigation for proper delineation of the geo-electric layers and their geological equivalence.However the results show that the study area comprises of 4-6 geo-electric layers. The sequence of the layers is as follows: Top soil, sandy clay, consolidated sand, highly weathered basement, partially weathered/fractured basement and the fresh basement. Nevertheless, the thickness of the various layers for the study area as a whole could not be determined since the measurements were not carried out along a profile. The thickness of the layers for each VES point probed is as presented in Table 4.9.

Table 4.9: VES Location, Layer resistivity, Layer thickness, total depth to basement, Geoelectric Layers and Coordinates

S/No	VES LOCATION	Layer Average Resistivity (Ohm-m)							Layer Thickness (m)						Total Depth to Basement	No of Geoelectric Layers	Coordinates
		1	2	3	4	5	6	7	1	2	3	4	5	6			
1	Gwagwada	391.0	291.0	204.1	262.6	402.2	-	-	0	7.51	22.12	27.57	87.50	-	30	5	$N10^0$ 15' 35.6" $E7^0$ 13' 45.8"
2	Chikun	384.9	196.3	274.8	355.5	524.5	-	-	0	5.68	18.51	26.12	87.50	-	30	5	$N10^0$ 16' 20.4" $E7^0$ 6' 28.6"
3	Dakwachi	296.3	238.6	287.0	300.0	479.5	-	-	0	6.68	18.51	26.12	30.57	87.50	40	5	$N10^0$ 16' 39.8" $E7^0$ 4' 28.1"
4	Kulepe	333.1	230.9	276.6	321.9	437.0	604.4	-	0	7.24	21.37	30.85	87.50	-	40	6	$N10^0$ 16' 40.3" $E7^0$ 2' 58.4"
5	Damba	310.4	306.5	203.0	278.8	331.2	481.6	-	0	5.42	21.39	30.85	38.40	87.50	40	6	$N10^0$ 29' 56" $E7^0$ 12' 32.4"
6	Gajina	322.0	259.0	274.3	310.4	480.6	-	-	0	6.68	20.51	28.12	33.57	87.50	40	5	$N10^0$ 15' 19.7" $E7^0$ 13' 47.3"
7	AngwaTurai	329.8	306.2	283.2	232.2	240.3	679.8	-	0	3.42	9.24	23.39	32.85	87.50	45	6	$N10^0$ 18' 42.1" $E7^0$ 11' 19.7"
8	Gwogofe	309.7	211.5	302.9	514.7	-	-	-	0	5.31	16.10	19.47	87.50	-	30	4	$N10^0$ 29' 18.5" $E7^0$ 12' 23.5"
9	GudunGuya	330.0	317.7	258.3	215.1	352.1	378.8	577.1	0	6.46	20.04	30.62	87.50	-	35	6	$N10^0$ 15' 35.6" $E7^0$ 13' 45.8"
10	Angwa Alkali	406.3	261.1	249.1	328.7	541.5	-	-	0	6.64	21.87	32.14	44.31	-	50	5	$N10^0$ 27' 12.2" $E7^0$ 03' 49.5"
11	Kurmin Kaduna	353.6	298.7	277.8	227.8	600.3	-	-	0	6.68	19.51	27.12	47.57	87.50	50	5	$N10^0$ 18' 45.5" $E7^0$ 04' 7.4"
12	Udawa	366.3	246.6	309.5	787.0	-	-	-	0	5.82	26.92	87.50	-	-	58	4	$N10^0$ 29' 55.6" $E7^0$ 03' 50.8"
13	SabonKauwia	396.8	305.2	315.7	210.9	265.9	314.9	511.6	0	6.07	16.87	22.59	32.92	87.50	40	5	$N10^0$ 30' 6.9" $E7^0$ 1' 50.9"
14	Kaburesha	318.7	213.3	279.4	328.3	490.2	-	-	0	7.68	20.51	28.12	48.57	87.50	50	5	$N10^0$ 20' 15.8" $E7^0$ 09' 50.2"
15	Kudo	373.8	195.3	238.0	571.1	-	-	-	0	7.15	22.40	40.44	87.50	-	45	4	$N10^0$ 28' 17.2" $E7^0$ 03' 46.4"

Top soils and laterites constitute the first layer and it consists mainly of unsaturated materials above the water table which has relatively high resistivity.

Sandy clay (regolith): This is the second layer in the geo-electric section made up of sands and clayey materials.

The third layer in the geo-electric section consists of mainly coarse sand.

Highly weatheredrock: This layer is composed of saturated material. It has relatively low to moderate resistivity valueanditis the main aquiferous zone in the study area.

The sixth layer in the geo-electric section is unsaturated and contains sizeable amount of clay. And the last layer which is the fresh basement comprises mainly ofunweathered and unfractured rock as shown on a generalized geo-electric profile from VES 1 to VES 15.Fig. 4.9.2, while Fig. 4.9.3 shows lithologic logs of boreholes in the study area.

Plots of the data obtained from the various VES points in the study area are presented in Appendix 1. It was observed that 3 out of the 15 VES points in the study area are made up of 4 layers, 7 VES Points have 5 layers and 4 VES point has 6 layers and 1 has 7 layers, all with different ranges of resistivity values and layer thickness as shown in Table 4.9. The percentage correlation between the water well and the VES points in the study area as shown in Fig. 4.9.4, is 78.8%.

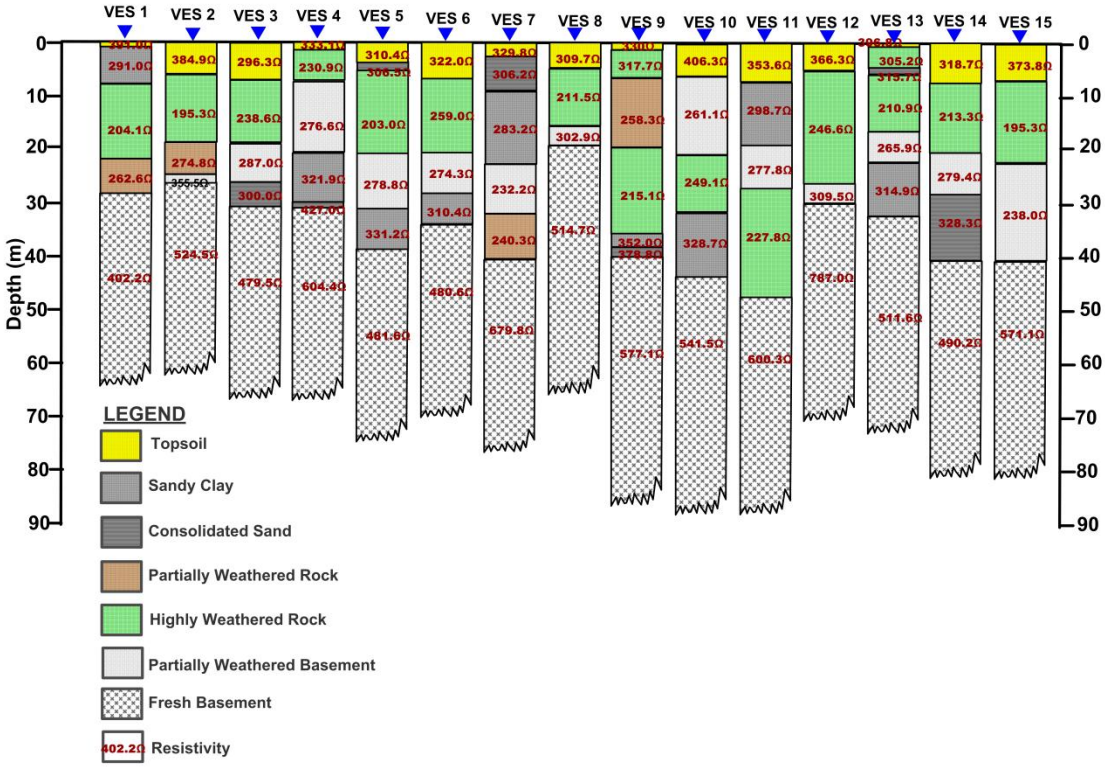


Figure 4.9.2: Generalized Geo-electric section across the three lithologic units of the study area showing the probable aquiferous zones

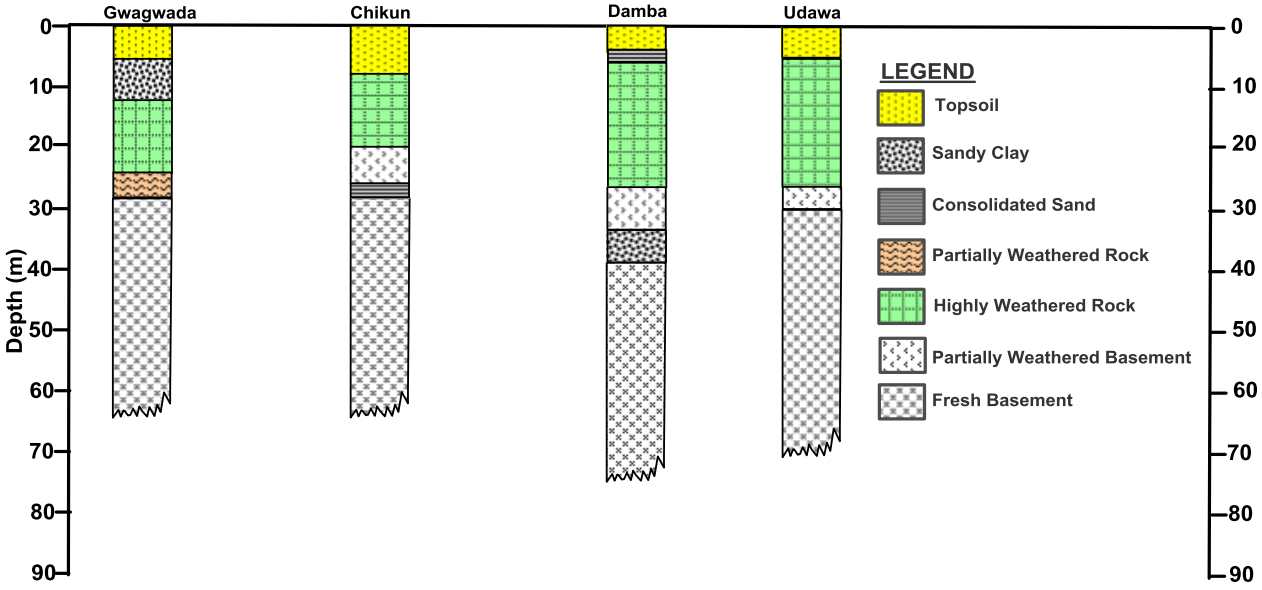


Figure 4.9.3: Lithologic logs of boreholes in the study area

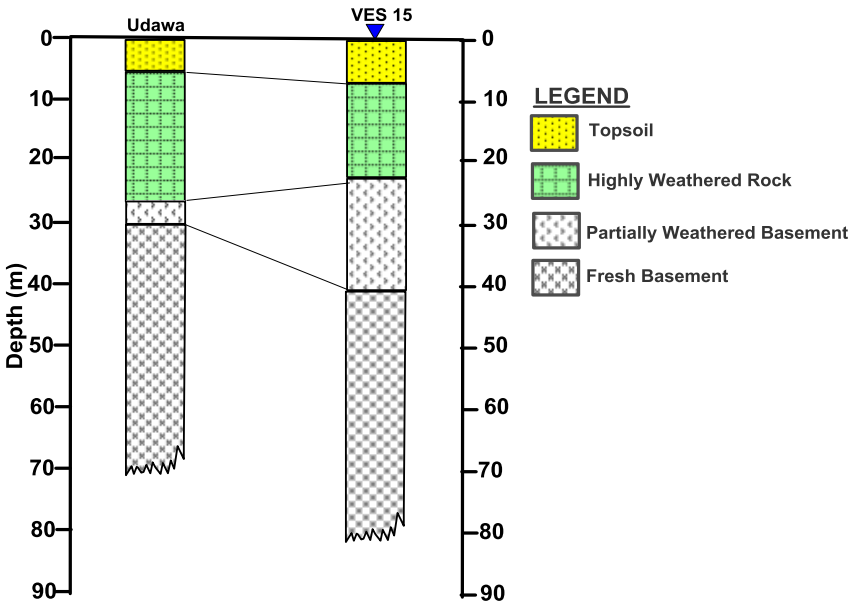


Figure 4.9.4: Correlation of VESwith lithology in the study area

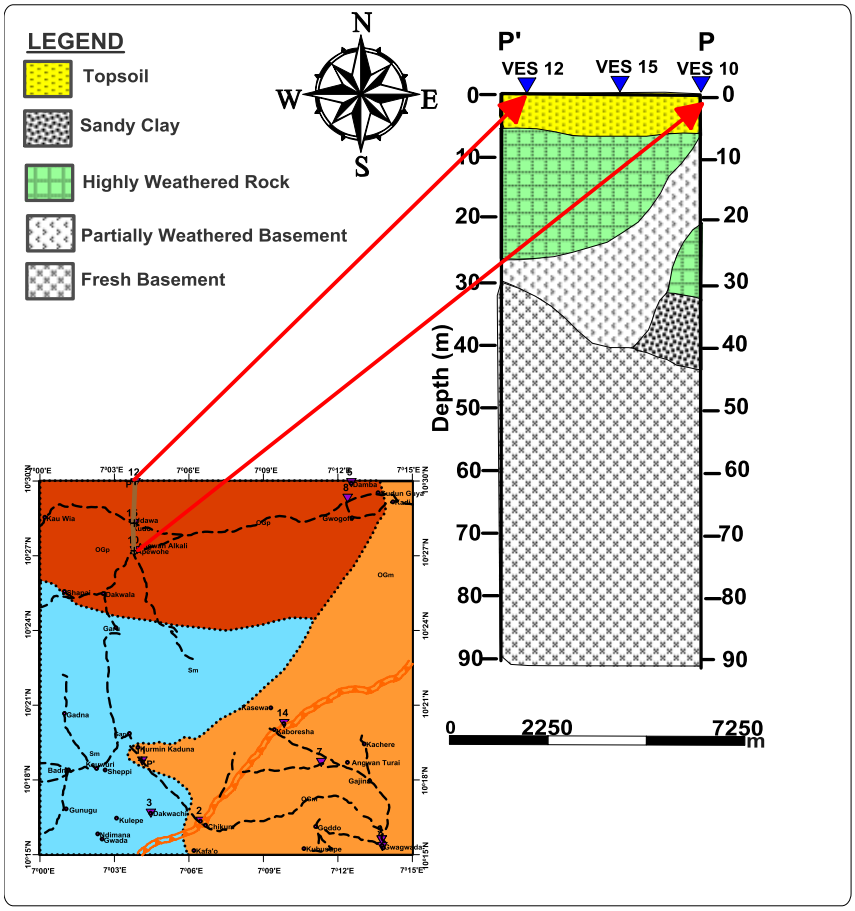


Figure 4.9.5: Geo-electric cross section across P' to P

Table 4.9.1:Krasny's Classification of TransmissivityofMagnitude and Variation (After Krasny, 1993)

Coefficient of transmissivity (m^2/d)	Class of transmissivity magnitude	Designation of transmissivity magnitude	Nonlogrithmic Specific capacity q in l/s m	Logarithmic Index Y	Groundwater supply potential	Very approximate expected discharge in l/s of a single well at 5 m drawdown
	I	Very high			Withdrawals of great regional importance	>50
1,000			10	7.0		
	II	High			Withdrawals of lesser regional importance	5 - 50
100			1	6.0		
	III	Intermediate			Withdrawals for local water supply (small communities, plants, etc.)	0.5 - 5
10			0.1	5.0		
	IV	Low			Smaller withdrawals for local water supply (private consumption, etc.)	0.05 - 0.5
1			0.01	4.0		
	V	Very low			Withdrawals for local water supply with limited consumption	0.005 - 0.05
0.1			0.001	3.0		
	VI	Imperceptible			Sources of local water supply are difficult (if possible) to ensure	<0.005

The hydraulic characteristics were compared with Krasny'sclassification of transmissivityofmagnitude and Variationand it show that transmissivityof the boreholes in the studylocation falls within the 10-1 coefficient of T (m^2/day), Class IV of T magnitude corresponding to lowdesignation of T magnitude whose groundwater supply potential is for smaller withdrawals for local water supply (private consumption). See table 4.9.5 and Appendix 3.

4.5 Borehole Data in the Study Area

Data of existing boreholes were acquired for four boreholes drilled by Kaduna State Ministry of water Resources, under the Kaduna State Agricultural Development Project (KADP) on Rural Water Supply Borehole Project (1992-1994) in collaboration with Geoplus Engineering Nig. Ltd. Information acquired from the four boreholes in the study area includes location of the boreholes, completion date, lithology, and the aquifer properties of each borehole (Appendix 2).

4.5.1Aquifer characteristics

The depth of the four boreholes namely; BH Gwagwada, BH Damba, BH Chikun and BH Udawa in the study area ranged from 50-58 m with an average of 54 m as observed from the information on the boreholes. The boreholes tap the highly weathered basement aquifer. The yield ranges from 46.7-82.9 m^3/day in the granitic gneiss terrain and 88.128 m^3/day in the Porphyritic granite terrain, transmissivity, T ranges from 1.779 x 10^0– 5.929 x 10^{-1} m^2/day in the granitic gneiss terrain and 8.960 x 10^{-1} m^2/day in the porphyritic granite terrain, Storativity, S ranges from 1.029 x 10^{-1} – 3.706 x 10^{-3} in the granitic gneiss terrain and 2.987 x 10^{-2} in the Porphyritic granite terrain and Hydraulic conductivity, K ranges from 1.3 x 10^{-2} – 5.7 x 10^{-2} m/day in the granitic gneiss terrain and 1.6 x 10^{-2}m/day in the porphyritic granite terrain.Table 4.9.6.

Table 4.9.2:Borehole Data in the Study Area (Source: Geoplus Engineering Nig. Ltd.)

S/No	BH Name	Coordinates	Depth of BH (m)	Lithology	Pump Setting (m)	Static water Level (m)	Yield (m^3/day)	Transmissivity, T (m^2/day)	Storativity, S	Hydraulic Conductivity, K (m/day)
1	Gwagwada	$N10^0$ 15' 35.6'' $E7^0$ 13' 45.8''	50	Granitic Gneiss	27.5	6.3	46.656	1.779×10^{0}	3.706×10^{-3}	4.1×10^{-2}
2	Chikun	$N10^0$ 16' 20.4'' $E7^0$ 6' 28.6''	50	Granitic Gneiss	27	4	15.552	5.929×10^{-1}	1.029×10^{-1}	1.3×10^{-2}
3	Damba	$N10^0$ 29' 56'' $E7^0$ 12' 32.4''	58	Granitic Gneiss	50	3	82.944	3.162×10^{-0}	1.208×10^{-1}	5.7×10^{-2}
4	Udawa	$N10^0$ 29' 55.6'' $E7^0$ 03' 50.8''	58	Porphyritic Granite	50	2	88.128	8.96×10^{-1}	2.987×10^{-2}	1.6×10^{-2}

CHAPTER FIVE

5.1Discussion

5.2Geology and Structures

The geology of the study area consisting of granitic gneiss, porphyritic granite and the mica schist which is characteristic of the schist belt of Nigeria.

Several outcrops of granitic gneiss were mapped in the study area, in most places, the granitic gneiss is well foliated,it varies in texture from medium to coarse grain and has granophyricintergrowthtexture on orthoclase feldspar. The granitic gneiss is a massive outcrop with an approximate N-S trend.

Outcrops of porphyritic granite were observed in the northern part of the study area (Plate IIIa). The porphyritic granite is leucocratic and coarse grained. It has prominent joints as structures and has an approximate NW trend striking 280^0 with an elevation of approximately 518 m. Towards the eastern part of river Damba in the study area (Fig. 3.1), Aplite dyke occurs within the porphyritic granite and appears to be younger in age but as a small unit.

Mica schist is one of the three rock types mapped and it occurs at Kulepe northeast of Ndimana (Fig. 3.1). It is light coloured and varies from medium to coarse grain texture. It is a massive outcrop with thin quartz veins(Plate IVA).Mica schist in the study area is a well-developed medium grade metamorphic rock that has parallelism of minerals such as mica and quartz.

The components forming the lineaments in the study area include; ridges, rivers, streams,faults, and valleys. The degree of lineament intersection determines the degree of anisotropy of groundwater flow in the fracture network, as in environments with a high degree of interconnection where groundwater flow is smoother and more uniform (Mabee*et al.,* 1994).(Fig.4.9).

Joints were clearly seen and mapped on certain outcrops in the study area showing a dominant NE-SW trend which validatesthe report of Goki et al., (2011) that the structural trend of the adjoining sheet (Sheet 144, Kakuri NE) of the study area shows a NE-SWtrend(Fig. 4.2).

5.3 Hydrogeology of the Study Area

Depth to groundwater table was measured at both peak of wet and dry season respectively and the groundwater configuration map of the study area shows that, during the wet season groundwater flows from the high groundwater elevation contours of 617 m (2024ft) in the Porphyritic granite province at the north eastern part of the study area around Gwogofe, GudunGuya, Kadi, Kaboresha and Kachere to an elevation of 457 m (1500 ft) around the granitic gneiss province at the southeastern part of the study area (Gajina, Godo, Kubusupe and Gwagwada) because of the elevation difference.

The groundwater configuration map of the study area shows that, during the dry season (May, 2016) there is a slight change in the flow direction because the drop in the water table level was not much except for some few water wells around Chikun village that went dry completely maybe due to the fact that some wells have their base flow below the depth of the well and due to the dynamic nature of groundwater(Fig. 4.3 and Fig. 4.4).

5.4 Interpretation of Hydrogeochemical Results

The chemical composition of groundwater in the study area has been assessed in order to determine its suitability for domestic, industrial and agricultural uses. The major elements compositions in the three rock units are within permissible limit. Results also indicate low levels of heavy metals with the exceptions of lead (Pb) and (Cr) that is found to be relatively high after inter-laboratory comparison. These findings agree with the report of Amadi et al (2012) that the soil and the groundwater is polluted with heavy metals. The presence of anions in the groundwater of the study area appears to be low with the exception of a well atAngwan Alkali 2 where nitrate concentration was found to be up to 35 mg/l indicating possible pollution. The high level of nitrate concentration may be attributed to the presence of a mini grazing field/reserve at close proximity to the groundwater well in question and also to the indiscriminate application of fertilizer by the farmers in the area (Uma, 1993). Other factors responsible for high nitrate concentrations in the area include soil leaching and nitrogenous organic waste (Ozoko, 2004), poor well completion (Edet and Okereke, 2005), improper waste disposal (Alagbe, 2006).

The total dissolved solids in the study area indicate low total mineralization which agrees with the report of Eduvie (1999). The chemical properties of groundwater in the study area mostly are withinpermissible limits of NIS (2007) and WHO (2011) guidelines for domestic and industrial purposes, (Table 4.4). From the chemical characteristics, the groundwater of the area is potable and suitable for domestic and industrial uses except the Pb and Cr content which appear to be well above the permissible limit(Table 4.2).

5.5 Assessment of Groundwater for Irrigation Purpose

The sodium or alkali hazards in the use of water for irrigation is determined by the absolute and relative concentrations of cations and is expressed as the Sodium Adsorption Ratio (SAR) using this method as expressed in the following equation.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{ca^{2+} + Mg^{2+}}{2}}} \quad \text{.....} \quad (1)$$

Where ionic concentration of Sodium (Na), Calcium (Ca) and Mg are in milliequivalent per litre.

The SAR was computed using the expression developed above by the US salinity laboratory staff (1954).

5.6Interpretation of Geophysical Assessment

Results of geophysical assessment of groundwater in the area using the Vertical Electric Sounding (VES) for borehole sitting indicate areas with relatively low resistivity values suggests presence of water.In such areas, the depth ranges from 16.87-30.62 m. The VES points with high resistivity values indicate lack of water suggesting fresh basement rock in the study area.Based on the VES results the drilled depth on the granitic gneiss is 50-58 m.The water level decreased with pumping throughout the pumping phase but increased relatively during the recovery phase. (See Appendix 2). However, the yield may increase during the rainy season as a result of recharge from infiltration, while during the dry season, the yield tend to decrease due to constant withdrawal for domestic and other purposes. Basically, a geo-electric section is drawn across point P' to P indicating a straight profile line connecting VES points in the study area whose result revealed four to six geoelectric layers with highly weathered rock forming the main aquiferous zone in the

study area which agrees with the report of Jatau and Ajodo (2005) and that of Aboh (2009).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1Conclusion

The study area is within the crystalline hydrogeological province and is underlain by rocks of the basement complex predominantly mica schist, granitic gneiss and porphyritic granite as shown on the geological map. From the fieldwork and geophysical data acquired, it is observed that the groundwater potential is controlled by the nature of the rock types forming the aquifer and the degree of weathering and fracturing of the rocks. Two major aquifer units are present in Kakuri sheet 144 NW and these are the partially weathered aquifer and the highly weathered aquifer with the highly weathered aquifer forming the major aquifer unit in the study area. The VES interpreted have revealed that the area consists of four-six geoelectriclayers;Top soil, Sandy clay, consolidated sand, highly weathered basement, partially weathered basement and the fresh basement.

Beneath the weathered zone is the fractured basement aquifer. Fractured aquifer underlies the study area and is regarded as source of groundwater because of its thickness. The permeability and storativity of the groundwater system are dependent on the volume and extent of the joints and fractures in the aquifer (Clark, 1985). Therefore groundwater in the crystalline basement rocks occurs in the fracture system in unweathered rocks; these types of aquifers are generally restricted and have limited groundwater resources. However, some fractured aquifers are highly prolific, especially when these fractures are extensively interconnected and linked to the surface for recharge. Fractures in the crystalline Basement of Northern Nigeria extend to a depth of not more than 90 m (Du-Preez and Barber, 1965).

Offodile (1992) observed that the distance between fractures increases rapidly with depth. Therefore, as the depth of a borehole increases, the frequency of interception of fractures decreases.

It is observed that most of the rivers and streams in the study area dry up completely by dry season with the exception of few rivers likeriverUdawaand river Chidu near Kaboresha.

Its configuration which is similar in both seasons resembles that of the ground surface contour lines except where interrupted by the outcrops of the basement rocks.

Results of water analyses show that the chemical quality of groundwater in the study areas is within the permissible limit by WHO (2011) and NSDWQ (2007) of the analyzed elements, except for Pb, and NO_3 at a well in Angwan alkali. Calcium (Ca) is found to be below detectable limit from the Atomic Adsorbtion Spectrometry result in areas such as Chikun 2, Angwan Alkali1, Angwan Alkali 2, Gajina 2, Gajina 3 and Dakwachi. However, the quality of water from data in the study area reveals that the water is fresh and has low mineralization. The highest TDS value is 365 mg/l and the lowest is 9 mg/l. The groundwater is slightly acidic (pH varies between 6.86 - 5.26 with an average of 6); therefore, water in the study area is good for domestic and industrial uses. Based on electrical conductivity, the groundwater is low – medium salinity hazard, $C_1 – C_2$ and low sodium hazard, S_1. Generally, groundwater samples from the study area is classified as being excellent for irrigation purpose.

6.2 Recommendations

i) Management of factors that bring about higher concentration of lead and chromium in some parts of the study area.

ii) The groundwater potential of the study area is low based on Krasny'sclassification, modalities should be put in place to sustainably manage the situation for future use.

iii) Analysis for microbial concentration of the groundwater in the study area should also be carried out as a routine process.

iv) Surface water inform of overhead tanks should be built to enhance rural water supply in the study area in general.

6.3 Contribution to Knowledge

i) Geological map of Kakuri, sheet 144 NW on a scale of 1: 50,000 has been updated.

ii) Groundwater configuration maps showing the direction of groundwater flow for both wet and dry season have been produced which gave an insight of the direction of recharge and discharge of groundwater in the study area.

iii) The groundwater quality in terms of chemical concentration in the study area has been determined and documented, such that areas with suitable water quality can be developed for use.

iv) The groundwater yield of the study area has been tied up to the rock types in the study area

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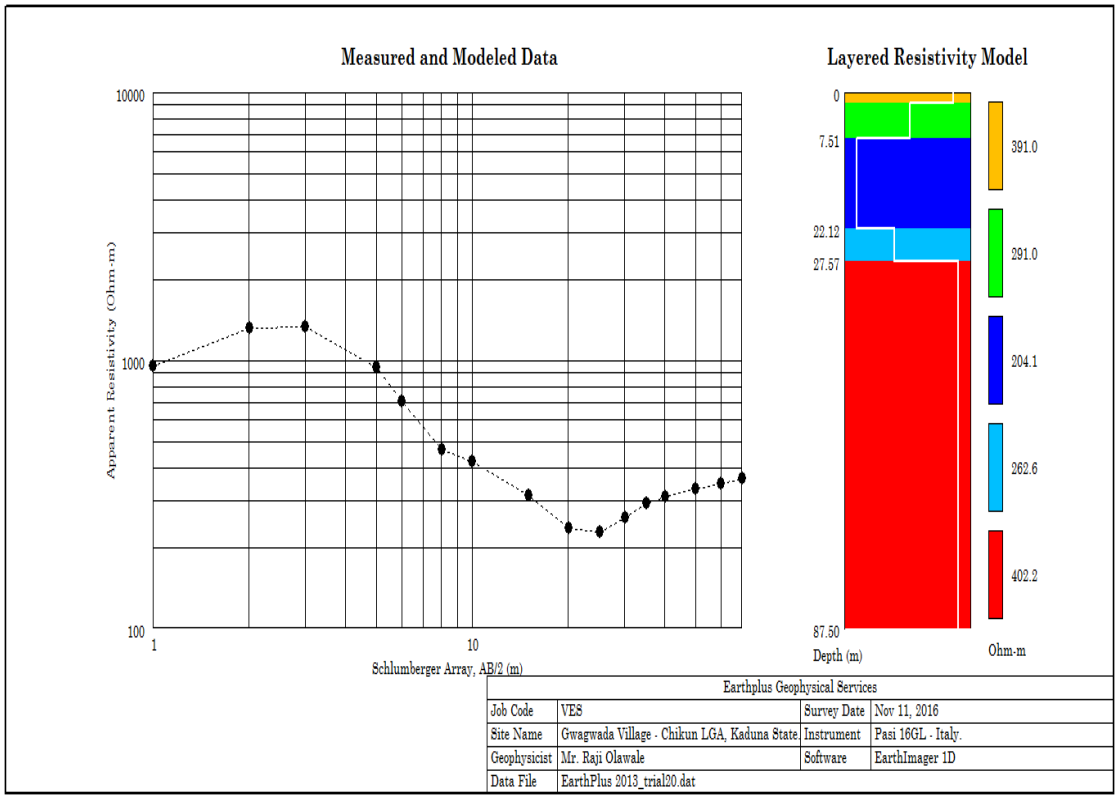
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APPENDICES

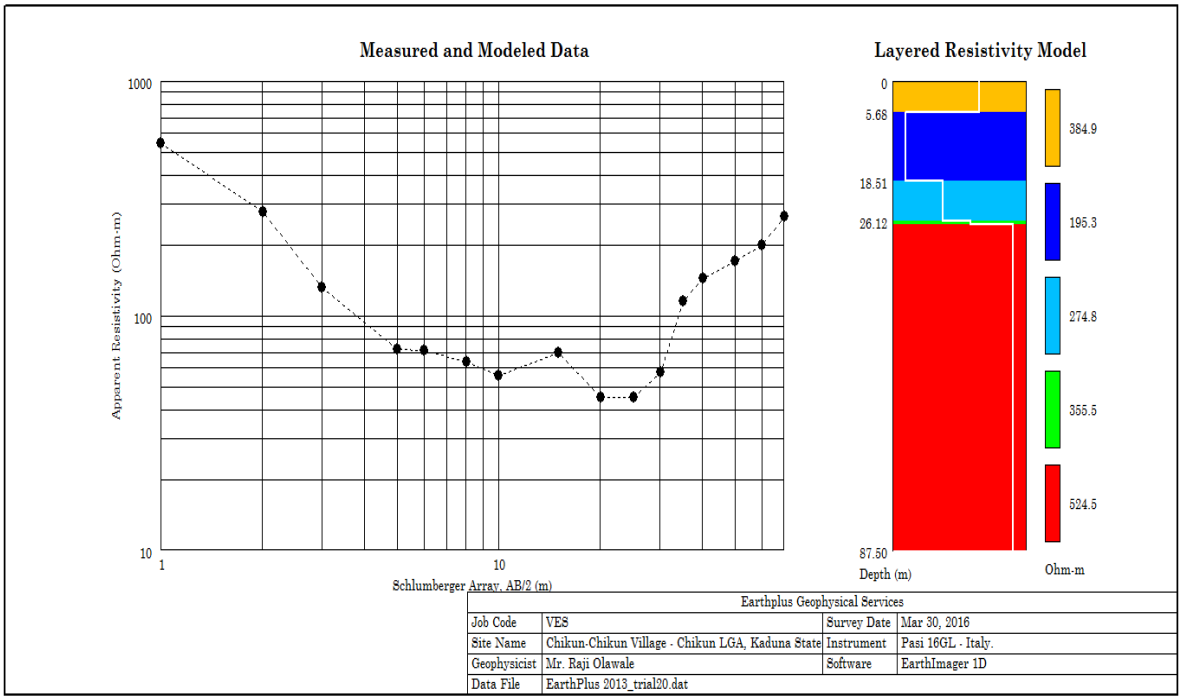
Appendix I: Vertical Electrical Sounding For Fifteen (15) Locations In The Study Area

Title: Field Measurements @ Gwagwada Village - Chikun LGA

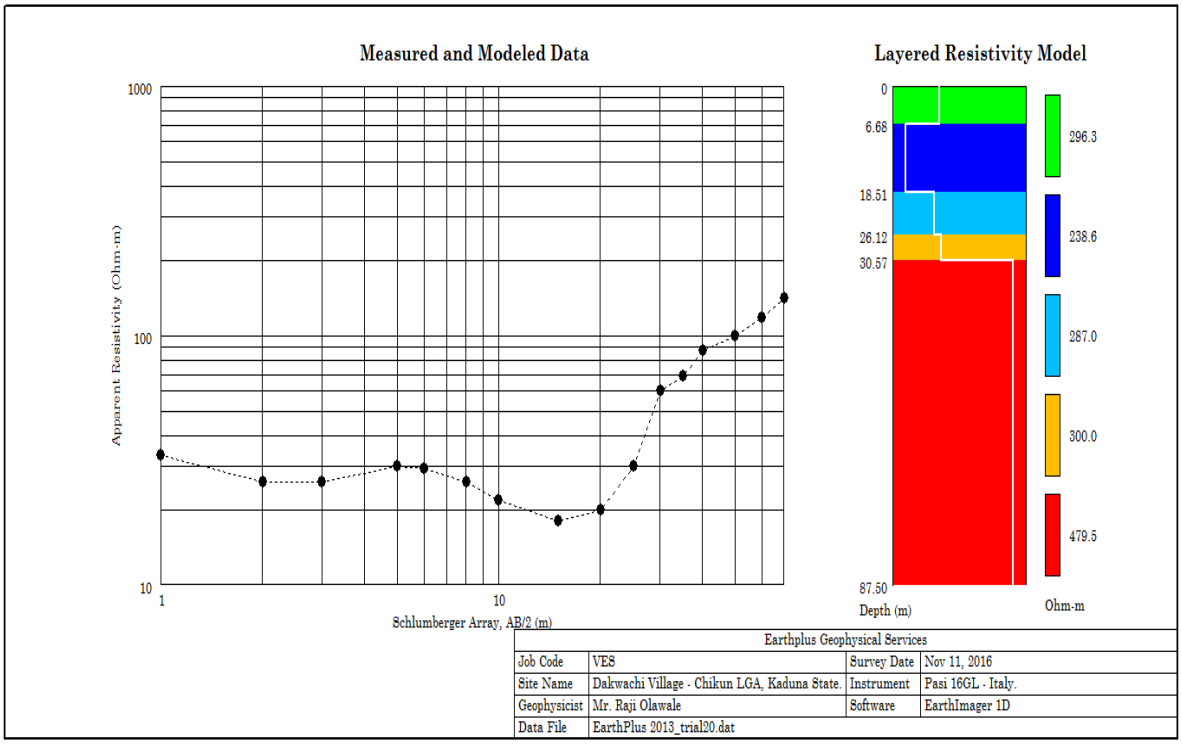
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	40616.300	100	1.000	1.000	957.00
2	11272.400	100	1.000	2.000	1328.00
3	4860.100	100	1.000	3.000	1335.99
4	1220.500	100	1.000	5.000	948.99
5	624.032	100	1.000	6.000	700.86
6	1274.809	100	2.000	6.000	700.86
7	469.900	100	2.000	8.000	465.01
8	270.585	100	2.000	10.000	420.78
9	714.346	100	5.000	10.000	420.78
10	228.500	100	5.000	15.000	314.06
11	96.200	100	5.000	20.000	238.00
12	58.900	100	5.000	25.000	228.99
13	45.900	100	5.000	30.000	257.76
14	38.100	100	5.000	35.000	291.76
15	31.129	100	5.000	40.000	311.72
16	96.411	100	15.000	40.000	311.72
17	64.500	100	15.000	50.000	330.12
18	46.900	100	15.000	60.000	348.09
19	35.700	100	15.000	70.000	362.17



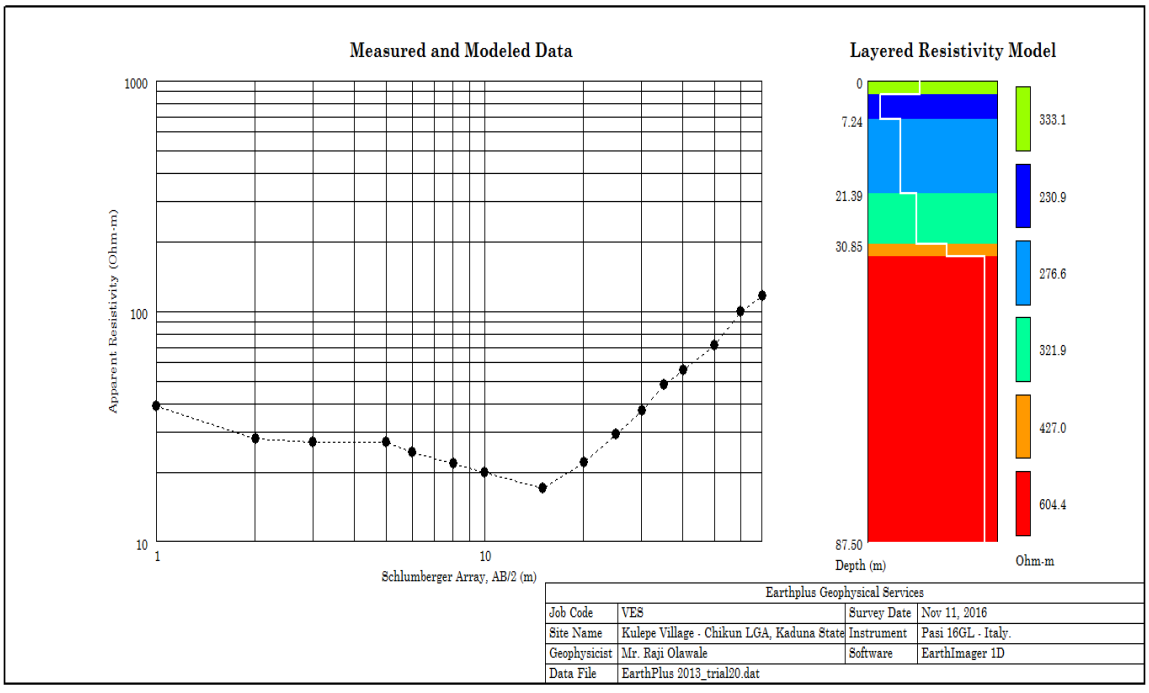
Title	Field Measurements @ Chikun Village - Chikun LGA, Kaduna				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	23130.500	100	1.000	1.000	545.00
2	2368.200	100	1.000	2.000	279.00
3	483.800	100	1.000	3.000	132.99
4	92.600	100	1.000	5.000	72.00
5	63.661	100	1.000	6.000	71.50
6	130.051	100	2.000	6.000	71.50
7	64.700	100	2.000	8.000	64.03
8	35.931	100	2.000	10.000	55.88
9	94.857	100	5.000	10.000	55.88
10	50.900	100	5.000	15.000	69.96
11	18.200	100	5.000	20.000	45.03
12	11.600	100	5.000	25.000	45.10
13	10.200	100	5.000	30.000	57.28
14	15.100	100	5.000	35.000	115.63
15	14.494	100	5.000	40.000	145.14
16	44.891	100	15.000	40.000	145.14
17	33.600	100	15.000	50.000	171.97
18	27.100	100	15.000	60.000	201.14
19	26.200	100	15.000	70.000	265.79



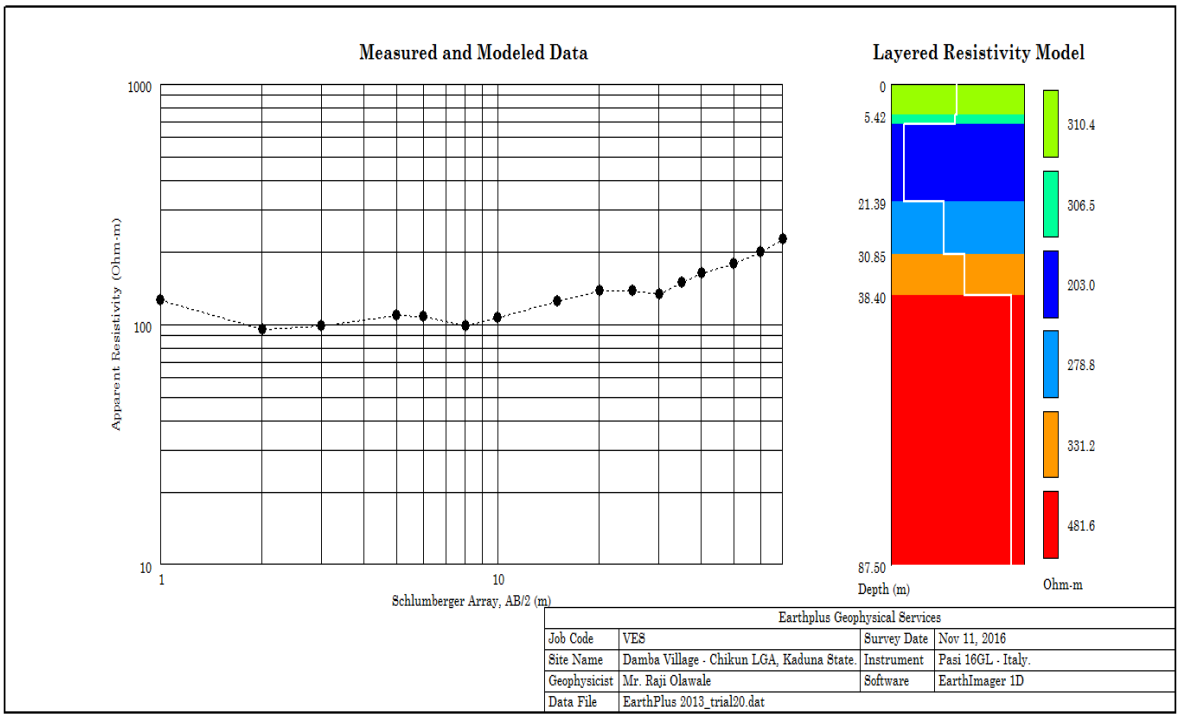
Title	Field Measurements @ Dakwachi Village - Chikun LGA				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	1400.600	100	1.000	1.000	33.00
2	220.700	100	1.000	2.000	26.00
3	94.600	100	1.000	3.000	26.00
4	38.600	100	1.000	5.000	30.01
5	26.172	100	1.000	6.000	29.39
6	53.467	100	2.000	6.000	29.39
7	26.300	100	2.000	8.000	26.03
8	14.083	100	2.000	10.000	21.90
9	37.179	100	5.000	10.000	21.90
10	13.100	100	5.000	15.000	18.01
11	8.100	100	5.000	20.000	20.04
12	7.700	100	5.000	25.000	29.94
13	10.700	100	5.000	30.000	60.09
14	9.000	100	5.000	35.000	68.92
15	8.741	100	5.000	40.000	87.53
16	27.072	100	15.000	40.000	87.53
17	19.500	100	15.000	50.000	99.80
18	16.000	100	15.000	60.000	118.75
19	14.000	100	15.000	70.000	142.03



Title	Field Measurements @ Kulepe Village - Chikun LGA				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	1655.200	100	1.000	1.000	39.00
2	237.700	100	1.000	2.000	28.00
3	98.200	100	1.000	3.000	26.99
4	34.700	100	1.000	5.000	26.98
5	21.741	100	1.000	6.000	24.42
6	44.413	100	2.000	6.000	24.42
7	22.200	100	2.000	8.000	21.97
8	12.852	100	2.000	10.000	19.99
9	33.929	100	5.000	10.000	19.99
10	12.400	100	5.000	15.000	17.04
11	8.900	100	5.000	20.000	22.02
12	7.500	100	5.000	25.000	29.16
13	6.600	100	5.000	30.000	37.06
14	6.300	100	5.000	35.000	48.24
15	5.543	100	5.000	40.000	55.50
16	17.167	100	15.000	40.000	55.50
17	13.900	100	15.000	50.000	71.14
18	13.500	100	15.000	60.000	100.20
19	11.500	100	15.000	70.000	116.66

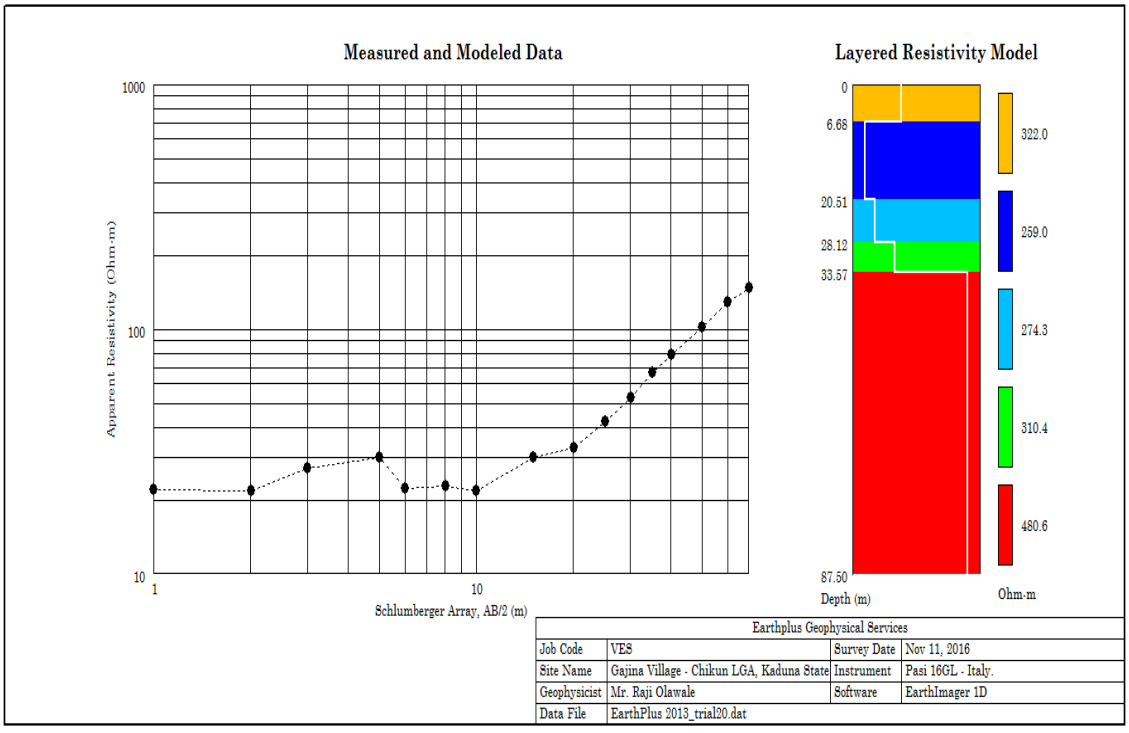


Title	Field Measurements @ Damba Village - Chikun LGA				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	5390.000	100	1.000	1.000	127.00
2	814.900	100	1.000	2.000	96.00
3	360.100	100	1.000	3.000	98.99
4	140.200	100	1.000	5.000	109.01
5	96.616	100	1.000	6.000	108.51
6	197.374	100	2.000	6.000	108.51
7	100.000	100	2.000	8.000	98.96
8	68.490	100	2.000	10.000	106.51
9	180.814	100	5.000	10.000	106.51
10	90.900	100	5.000	15.000	124.94
11	56.200	100	5.000	20.000	139.04
12	35.500	100	5.000	25.000	138.01
13	23.700	100	5.000	30.000	133.09
14	19.600	100	5.000	35.000	150.09
15	16.339	100	5.000	40.000	163.61
16	50.604	100	15.000	40.000	163.61
17	35.200	100	15.000	50.000	180.16
18	27.100	100	15.000	60.000	201.14
19	22.300	100	15.000	70.000	226.23

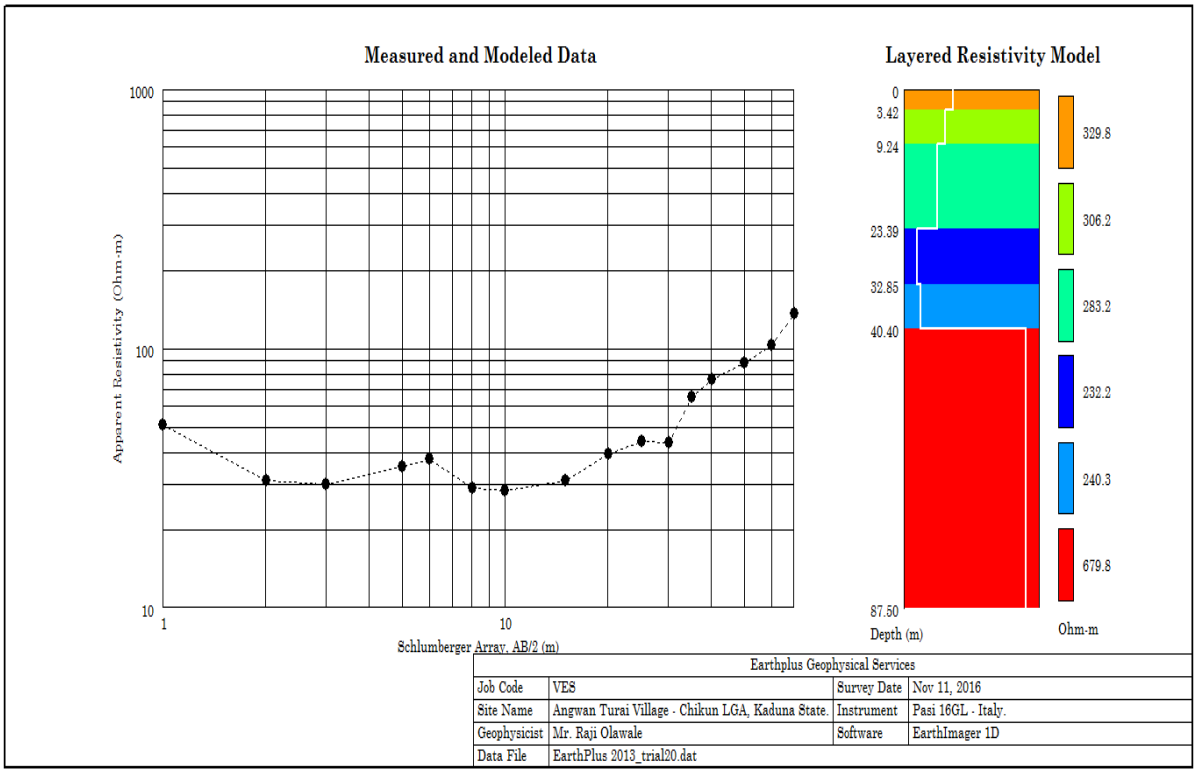


Title Field Measurements @ Gajina Village - Chikun LGA

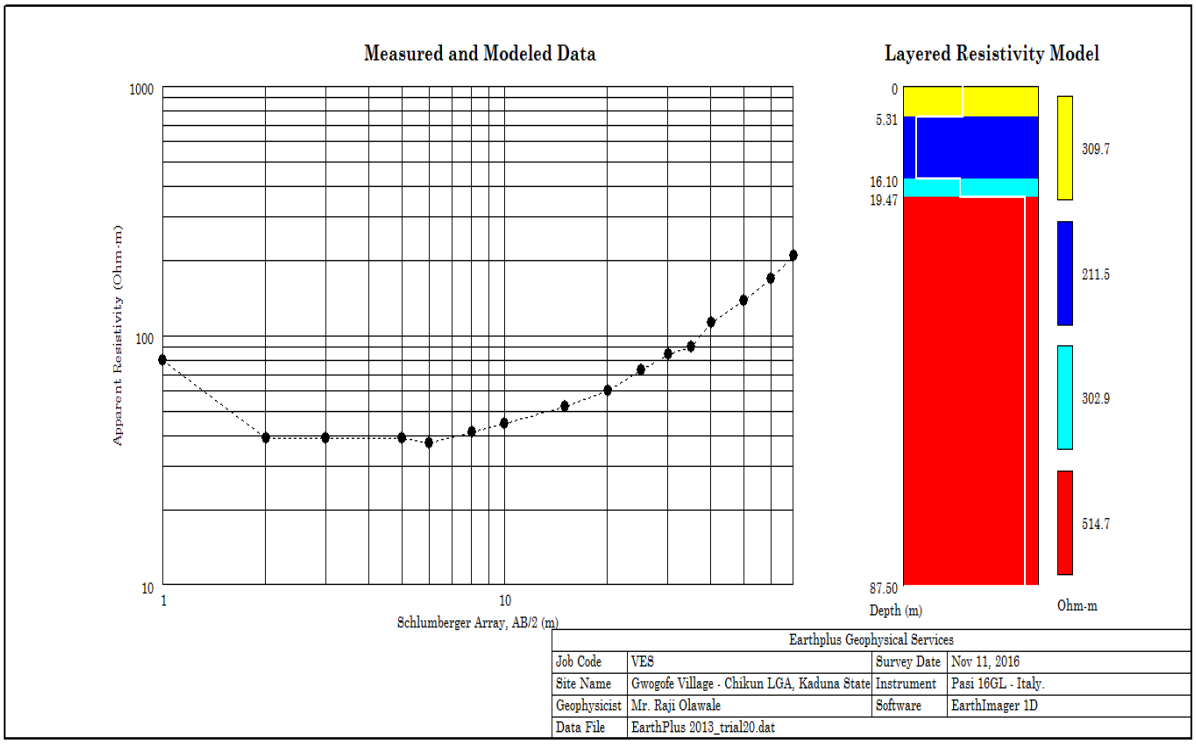
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	933.700	100	1.000	1.000	22.00
2	186.700	100	1.000	2.000	22.00
3	98.200	100	1.000	3.000	26.99
4	38.600	100	1.000	5.000	30.01
5	20.026	100	1.000	6.000	22.49
6	40.911	100	2.000	6.000	22.49
7	23.200	100	2.000	8.000	22.96
8	14.122	100	2.000	10.000	21.96
9	37.282	100	5.000	10.000	21.96
10	21.800	100	5.000	15.000	29.96
11	13.300	100	5.000	20.000	32.90
12	10.800	100	5.000	25.000	41.99
13	9.400	100	5.000	30.000	52.79
14	8.700	100	5.000	35.000	66.62
15	7.836	100	5.000	40.000	78.47
16	24.270	100	15.000	40.000	78.47
17	19.900	100	15.000	50.000	101.85
18	17.500	100	15.000	60.000	129.89
19	14.600	100	15.000	70.000	148.11



Title	Field Measurements @ Angwa Turai Village - Chikun LGA				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	2164.500	100	1.000	1.000	51.00
2	263.100	100	1.000	2.000	31.00
3	109.100	100	1.000	3.000	29.99
4	45.000	100	1.000	5.000	34.99
5	33.369	100	1.000	6.000	37.48
6	68.169	100	2.000	6.000	37.48
7	29.300	100	2.000	8.000	29.00
8	18.298	100	2.000	10.000	28.46
9	48.307	100	5.000	10.000	28.46
10	22.600	100	5.000	15.000	31.06
11	15.800	100	5.000	20.000	39.09
12	11.300	100	5.000	25.000	43.93
13	7.737	100	5.000	30.000	43.45
14	8.500	100	5.000	35.000	65.09
15	7.635	100	5.000	40.000	76.46
16	23.648	100	15.000	40.000	76.46
17	17.200	100	15.000	50.000	88.03
18	13.900	100	15.000	60.000	103.17
19	13.500	100	15.000	70.000	136.95

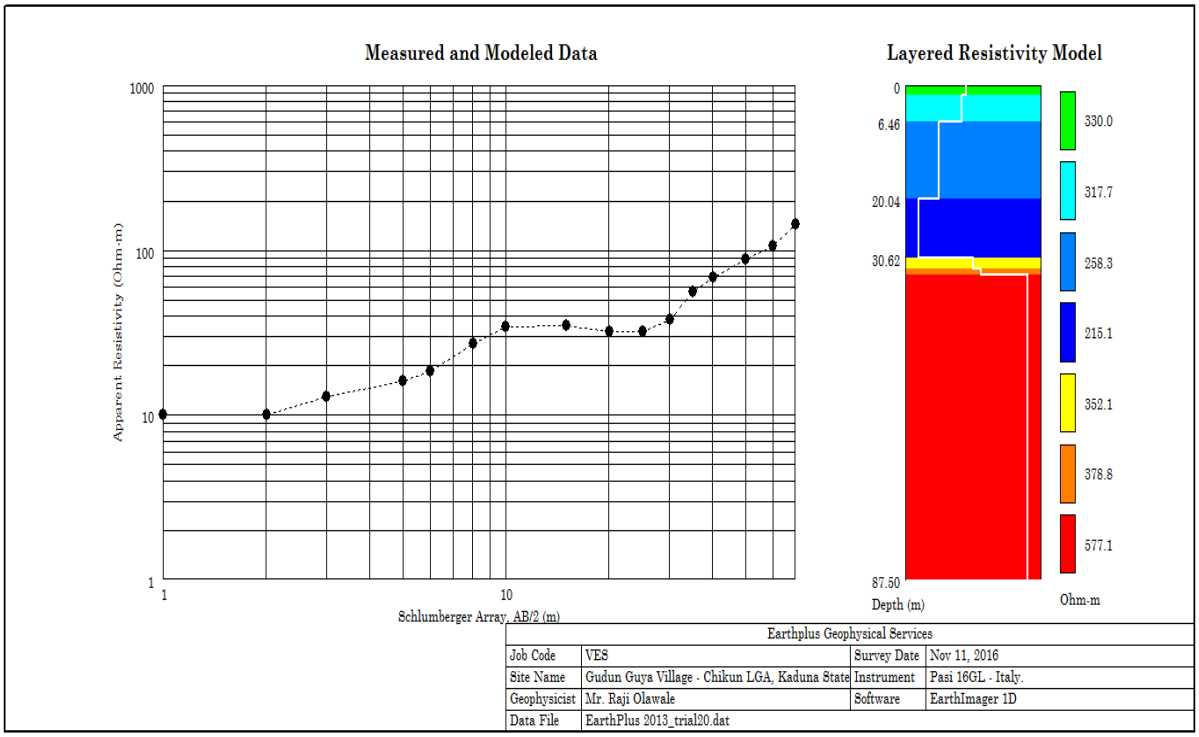


Title	Field Measurements @ Gwogofe Village - Chikun LGA				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	3395.300	100	1.000	1.000	80.00
2	331.000	100	1.000	2.000	39.00
3	141.900	100	1.000	3.000	39.01
4	50.200	100	1.000	5.000	39.03
5	32.922	100	1.000	6.000	36.98
6	67.255	100	2.000	6.000	36.98
7	41.400	100	2.000	8.000	40.97
8	28.596	100	2.000	10.000	44.47
9	75.494	100	5.000	10.000	44.47
10	37.800	100	5.000	15.000	51.95
11	24.300	100	5.000	20.000	60.12
12	18.800	100	5.000	25.000	73.09
13	15.100	100	5.000	30.000	84.80
14	11.800	100	5.000	35.000	90.36
15	11.282	100	5.000	40.000	112.97
16	34.941	100	15.000	40.000	112.97
17	27.000	100	15.000	50.000	138.19
18	22.900	100	15.000	60.000	169.96
19	20.600	100	15.000	70.000	208.98



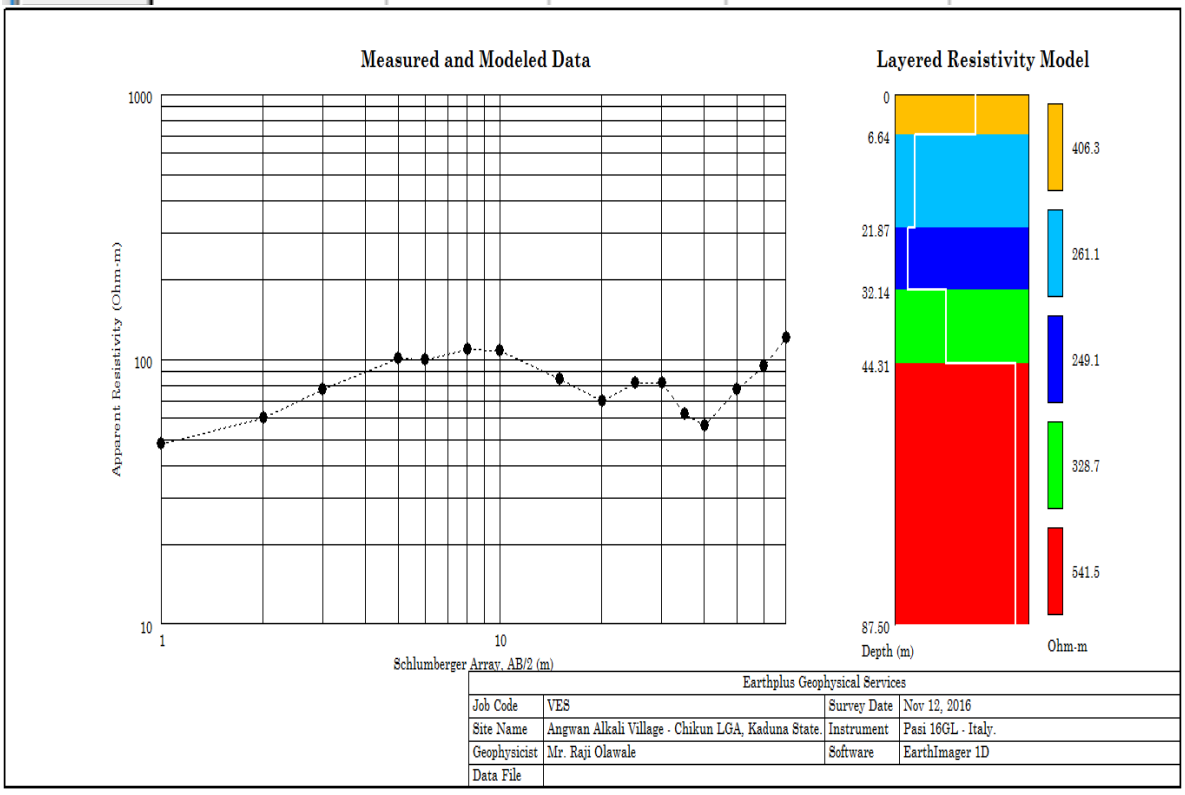
Earthplus Geophysical Services			
Job Code	VES	Survey Date	Nov 11, 2016
Site Name	Gwogofe Village - Chikun LGA, Kaduna State	Instrument	Pasi 16GL - Italy.
Geophysicist	Mr. Raji Olawale	Software	EarthImager 1D
Data File	EarthPlus 2013_trial20.dat		

Title	Field Measurements @ Gudun Guya Village - Chikun LGA				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	424.400	100	1.000	1.000	10.00
2	84.900	100	1.000	2.000	10.00
3	47.300	100	1.000	3.000	13.00
4	20.600	100	1.000	5.000	16.02
5	16.462	100	1.000	6.000	18.49
6	33.629	100	2.000	6.000	18.49
7	27.300	100	2.000	8.000	27.02
8	21.999	100	2.000	10.000	34.21
9	58.078	100	5.000	10.000	34.21
10	25.500	100	5.000	15.000	35.05
11	12.900	100	5.000	20.000	31.91
12	8.200	100	5.000	25.000	31.88
13	6.800	100	5.000	30.000	38.19
14	7.300	100	5.000	35.000	55.90
15	6.840	100	5.000	40.000	68.49
16	21.184	100	15.000	40.000	68.49
17	17.400	100	15.000	50.000	89.06
18	14.400	100	15.000	60.000	106.88
19	14.200	100	15.000	70.000	144.06



Title: Field Measurements @ Angwan Alkali - Chikun LGA

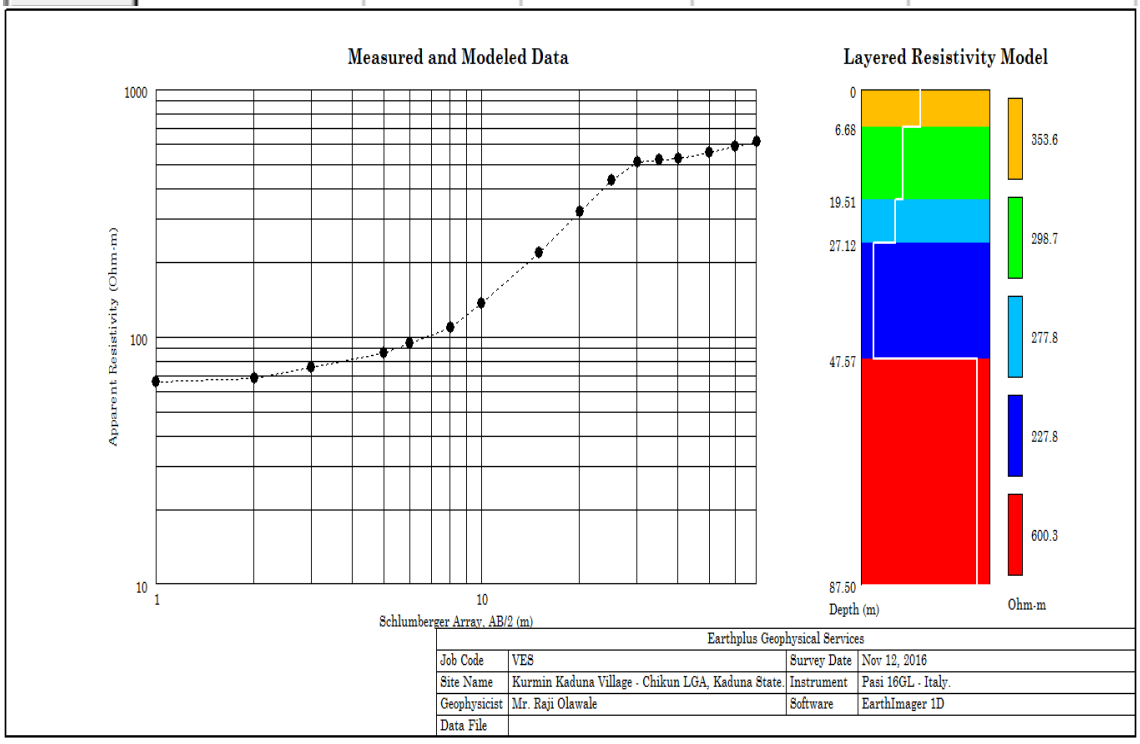
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	2037.200	100	1.000	1.000	48.00
2	509.300	100	1.000	2.000	60.00
3	280.100	100	1.000	3.000	77.00
4	129.900	100	1.000	5.000	101.00
5	88.579	100	1.000	6.000	99.49
6	180.955	100	2.000	6.000	99.49
7	110.100	100	2.000	8.000	108.96
8	69.717	100	2.000	10.000	108.42
9	184.054	100	5.000	10.000	108.42
10	61.100	100	5.000	15.000	83.98
11	28.300	100	5.000	20.000	70.01
12	21.100	100	5.000	25.000	82.03
13	14.600	100	5.000	30.000	81.99
14	8.100	100	5.000	35.000	62.03
15	5.641	100	5.000	40.000	56.49
16	17.472	100	15.000	40.000	56.49
17	15.000	100	15.000	50.000	76.77
18	12.700	100	15.000	60.000	94.26
19	11.900	100	15.000	70.000	120.72



Earthplus Geophysical Services			
Job Code	VES	Survey Date	Nov 12, 2016
Site Name	Angwan Alkali Village - Chikun LGA, Kaduna State.	Instrument	Pasi 16GL - Italy.
Geophysicist	Mr. Raji Olawale	Software	EarthImager 1D
Data File			

Title	Field Measurements @ Kurmin Kaduna - Chikun LGA

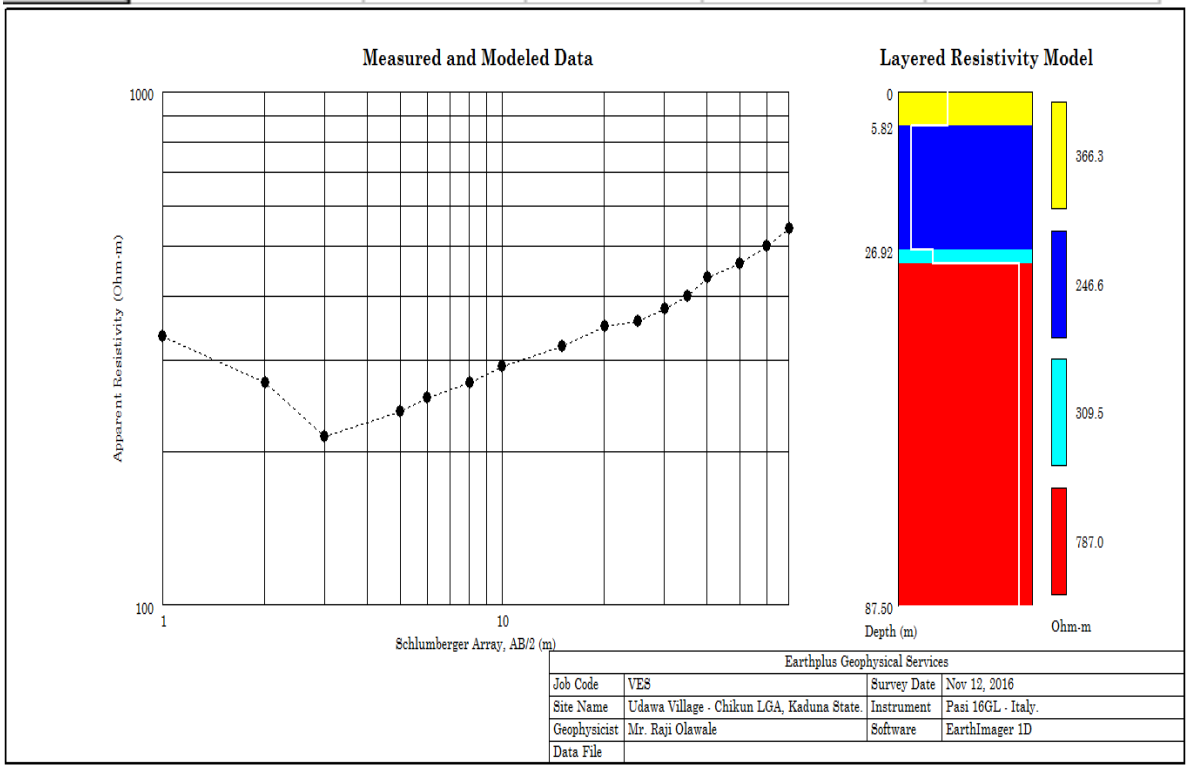
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	2801.100	100	1.000	1.000	66.00
2	577.200	100	1.000	2.000	68.00
3	272.800	100	1.000	3.000	74.99
4	110.600	100	1.000	5.000	86.00
5	83.703	100	1.000	6.000	94.01
6	170.994	100	2.000	6.000	94.01
7	110.100	100	2.000	8.000	108.96
8	87.780	100	2.000	10.000	136.51
9	231.740	100	5.000	10.000	136.51
10	160.100	100	5.000	15.000	220.05
11	129.700	100	5.000	20.000	320.88
12	111.100	100	5.000	25.000	431.93
13	91.400	100	5.000	30.000	513.27
14	67.900	100	5.000	35.000	519.95
15	52.508	100	5.000	40.000	525.81
16	162.626	100	15.000	40.000	525.81
17	109.400	100	15.000	50.000	559.93
18	80.000	100	15.000	60.000	593.76
19	61.100	100	15.000	70.000	619.84



Earthplus Geophysical Services			
Job Code	VES	Survey Date	Nov 12, 2016
Site Name	Kurmin Kaduna Village - Chikun LGA, Kaduna State.	Instrument	Pasi 16GL - Italy.
Geophysicist	Mr. Raji Olawale	Software	EarthImager 1D
Data File			

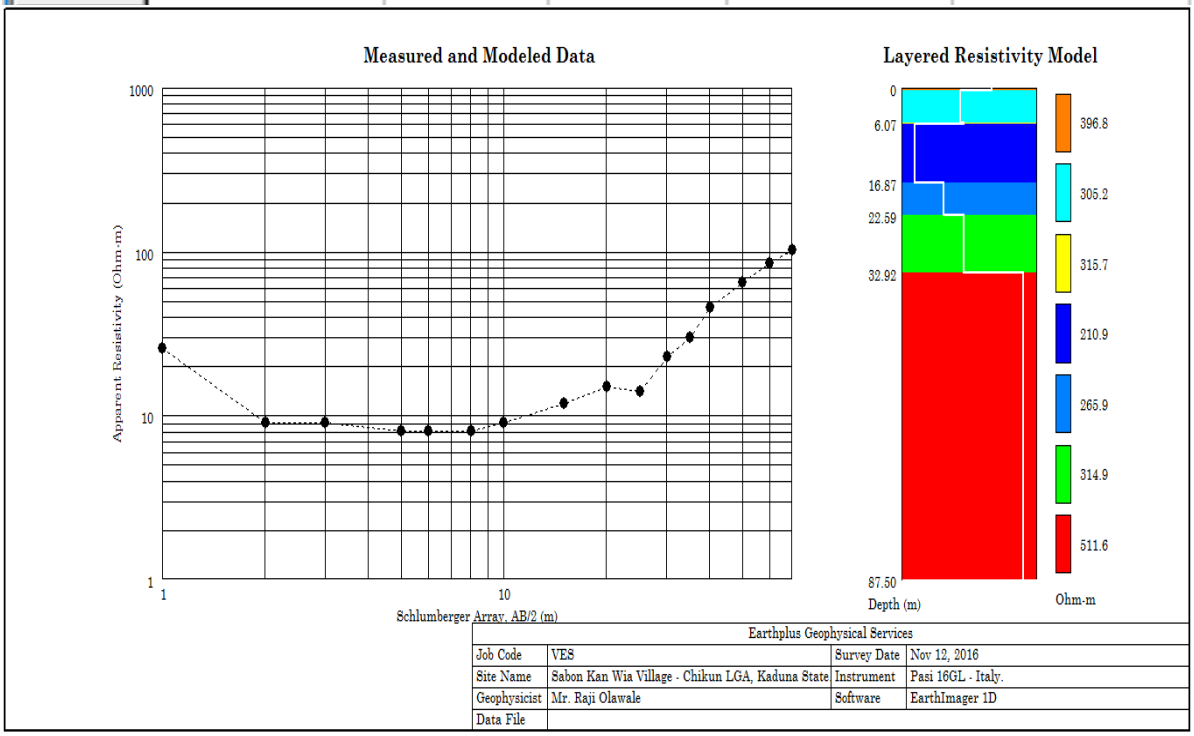
Title	Field Measurements @ Udawa - Chikun LGA

Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	14175.400	100	1.000	1.000	334.00
2	2304.719	100	1.000	2.000	271.52
3	774.900	100	1.000	3.000	213.01
4	306.100	100	1.000	5.000	238.01
5	226.166	100	1.000	6.000	254.01
6	462.024	100	2.000	6.000	254.01
7	274.900	100	2.000	8.000	272.04
8	188.375	100	2.000	10.000	292.94
9	497.309	100	5.000	10.000	292.94
10	232.100	100	5.000	15.000	319.01
11	141.500	100	5.000	20.000	350.07
12	92.100	100	5.000	25.000	358.06
13	67.500	100	5.000	30.000	379.05
14	52.400	100	5.000	35.000	401.26
15	43.570	100	5.000	40.000	436.30
16	134.944	100	15.000	40.000	436.30
17	90.300	100	15.000	50.000	462.17
18	67.400	100	15.000	60.000	500.24
19	53.600	100	15.000	70.000	543.76



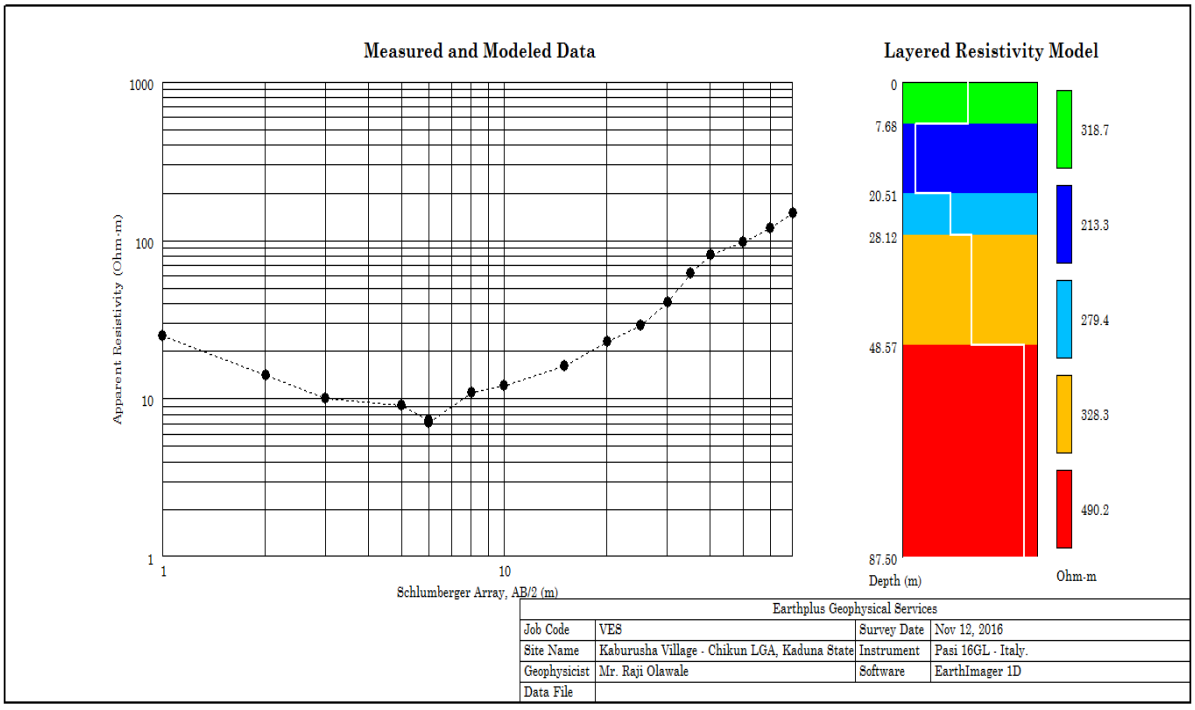
Earthplus Geophysical Services			
Job Code	VES	Survey Date	Nov 12, 2016
Site Name	Udawa Village - Chikun LGA, Kaduna State.	Instrument	Pasi 16GL - Italy.
Geophysicist	Mr. Raji Olawale	Software	EarthImager 1D
Data File			

Title	Field Measurements @ Sabon Kan Wia - Chikun LGA				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	1103.500	100	1.000	1.000	26.00
2	76.400	100	1.000	2.000	9.00
3	32.700	100	1.000	3.000	8.99
4	10.300	100	1.000	5.000	8.01
5	7.123	100	1.000	6.000	8.00
6	14.552	100	2.000	6.000	8.00
7	8.100	100	2.000	8.000	8.02
8	5.798	100	2.000	10.000	9.02
9	15.306	100	5.000	10.000	9.02
10	8.700	100	5.000	15.000	11.96
11	6.100	100	5.000	20.000	15.09
12	3.600	100	5.000	25.000	14.00
13	4.100	100	5.000	30.000	23.02
14	3.900	100	5.000	35.000	29.86
15	4.594	100	5.000	40.000	46.00
16	14.228	100	15.000	40.000	46.00
17	12.700	100	15.000	50.000	65.00
18	11.500	100	15.000	60.000	85.35
19	10.200	100	15.000	70.000	103.48

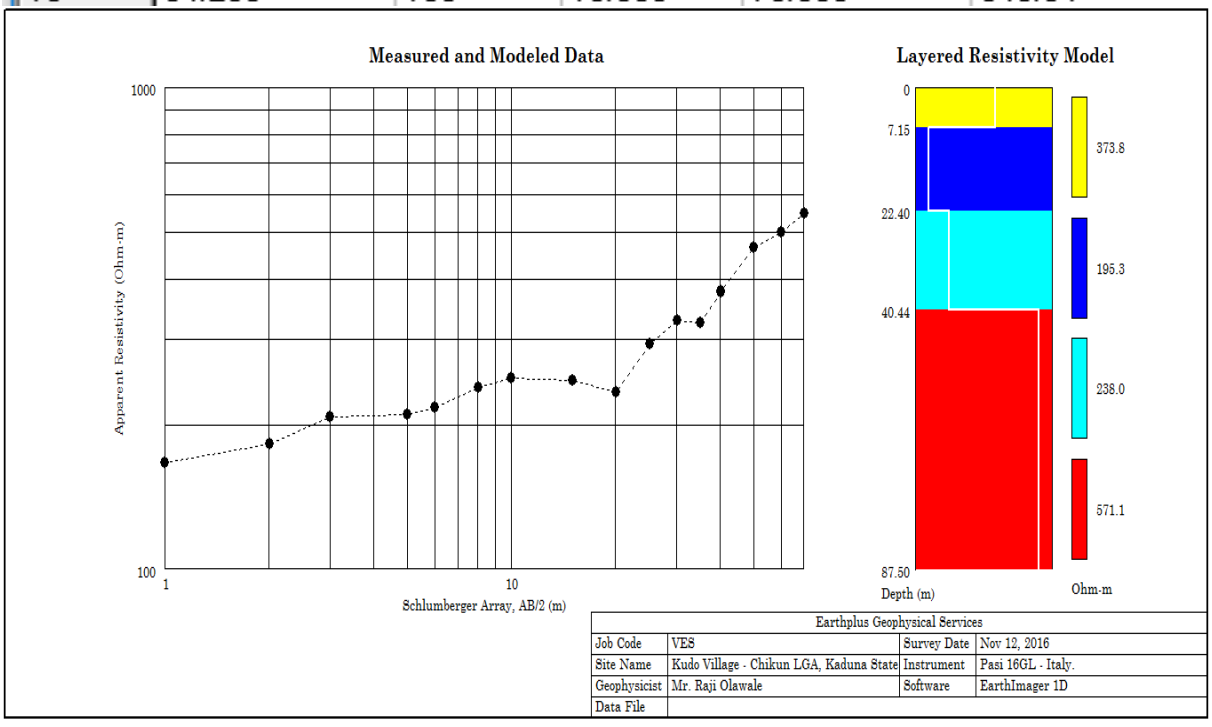


Earthplus Geophysical Services			
Job Code	VES	Survey Date	Nov 12, 2016
Site Name	Sabon Kan Wia Village - Chikun LGA, Kaduna State	Instrument	Pasi 16GL - Italy.
Geophysicist	Mr. Raji Olawale	Software	EarthImager 1D
Data File			

Title	Field Measurements @ Kaburusha - Chikun LGA				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	1061.000	100	1.000	1.000	25.00
2	118.800	100	1.000	2.000	14.00
3	36.400	100	1.000	3.000	10.01
4	11.600	100	1.000	5.000	9.02
5	6.475	100	1.000	6.000	7.27
6	12.789	100	2.000	6.000	7.03
7	11.100	100	2.000	8.000	10.98
8	7.714	100	2.000	10.000	12.00
9	20.364	100	5.000	10.000	12.00
10	11.600	100	5.000	15.000	15.94
11	9.300	100	5.000	20.000	23.01
12	7.500	100	5.000	25.000	29.16
13	7.300	100	5.000	30.000	40.99
14	8.100	100	5.000	35.000	62.03
15	8.097	100	5.000	40.000	81.08
16	25.076	100	15.000	40.000	81.08
17	19.100	100	15.000	50.000	97.76
18	16.000	100	15.000	60.000	118.75
19	14.800	100	15.000	70.000	150.14



Title	Field Measurements @ Kudo - Chikun LGA				
Data#	V (mV)	I (mA)	MN (m)	AB/2 (m)	Ohm-m
1	7045.300	100	1.000	1.000	166.00
2	1544.900	100	1.000	2.000	182.00
3	753.000	100	1.000	3.000	206.99
4	270.100	100	1.000	5.000	210.01
5	192.792	100	1.000	6.000	216.53
6	393.846	100	2.000	6.000	216.53
7	240.500	100	2.000	8.000	238.00
8	160.133	100	2.000	10.000	249.02
9	422.752	100	5.000	10.000	249.02
10	179.700	100	5.000	15.000	246.99
11	94.200	100	5.000	20.000	233.05
12	75.400	100	5.000	25.000	293.13
13	58.600	100	5.000	30.000	329.07
14	42.400	100	5.000	35.000	324.68
15	37.574	100	5.000	40.000	376.26
16	117.028	100	15.000	40.000	378.38
17	91.000	100	15.000	50.000	465.75
18	67.600	100	15.000	60.000	501.73
19	54.200	100	15.000	70.000	549.84



Earthplus Geophysical Services			
Job Code	VES	Survey Date	Nov 12, 2016
Site Name	Kudo Village - Chikun LGA, Kaduna State	Instrument	Pasi 16GL - Italy.
Geophysicist	Mr. Raji Olawale	Software	EarthImager 1D
Data File			

Appendix II: Pumping Test Result Of Four (4) Boreholes In The Study Area

PUMPING TEST RESULTS

LOCATION: Gwagwada
L.G.A: Chikun
STATIC WATER LEVEL: 6.30 m
STATE: Kaduna
BH DEPTH: 50 m
PUMP SETTING: 27.5 m
LITHOLOGY: Granite Gneiss
DATE: 28-02-1992
PUMP TYPE/CAPACITY: 1 Hp
CASING SIZE: 6 Inches

PUMPING PHASE				RECOVERY PHASE			
Time (min) Since Pumping started	Elapsed Time (min)	Pumping Water Level (m)	Drawdown (m)	Pumping Rate (l/min)	Time (min) Since Recovery started	Water Level (m)	Residual Drawdown (m)
	0	6.30	0	"	0	22.83	16.53
	1	10.01	3.71	"	1	22.40	16.10
	2	14.21	7.91	"	2	21.61	15.31
	3	15.02	8.72	"	3	21.07	14.77
	4	15.97	9.67	"	4	20.48	14.18
	5	16.15	9.85	"	5	19.75	13.45
	6	16.40	10.10	"	6	19.21	12.91
	7	16.66	10.36	"	7	18.70	12.40
	8	16.80	10.50	"	8	18.10	11.80
	9	17.12	10.82	0.54 l/sec	9	17.60	11.30
	10	17.15	10.85	"	10	17.09	10.79
	12	18.20	11.90	"	12	16.10	9.80
	14	18.60	12.30	"	14	15.27	8.97
	16	18.90	12.60	"	16	14.40	8.10
	18	19.10	12.80	"	18	13.55	7.20
	20	19.22	12.92	"	20	12.83	6.53
	25	19.66	13.36	"	25	11.37	5.07
	30	20.12	13.82	"	30	10.33	4.03
	35	20.37	14.07	"	35	9.55	3.25
	40	20.66	14.36	"	40	8.91	2.61
	45	20.84	14.54	"	45	8.54	2.24
	50	21.02	14.72	"	50	8.20	1.9
	55	21.16	14.86	"	55	8.01	1.71
	60	21.27	14.97	"	60	7.85	1.55
	70	21.47	15.17	"	70	7.85	1.55
	80	21.52	15.22	"	80	7.85	1.55
	90	21.71	15.41	"	90	7.85	1.55
	120	22.30	16.00	"	120	7.85	1.55
	150	22.64	16.34	"	150	7.85	1.55
	180	22.83	16.53	"	180	7.85	1.55

LOCATION: Chikun-Chikun
L.G.A: Chikun
STATIC WATER LEVEL (SWL):4.00 m
STATE: Kaduna
BH DEPTH: 50 m
PUMP SETTING: 27.00 m
LITHOLOGY: Granite Gneiss
DATE: 13-03-1992
PUMP TYPE/CAPACITY: Allegro/0.75 HP
Time Started: 8.40am
Time Stopped: 10.30am

PUMPING PHASE				RECOVERY PHASE			
Elapsed Time (min)	Dynamic Water Level (m)	Drawdown (m)	Pumping Rate (l/Sec)	Time (min) Since Recovery started	Pumping Rate (l/Sec)	Dynamic Water Level (m)	Residual Drawdown (m)
0	4.00	0.00	0.18	0	Nil	15.71	11.71
1	4.05	0.05	"	1	"	14.47	10.47
2	4.92	0.92	"	2	"	14.17	10.17
3	5.20	1.20	"	3	"	13.64	9.64
4	5.42	1.42	"	4	"	12.29	8.29
5	5.63	1.63	"	5	"	10.70	6.70
6	5.82	1.82	"	6	"	9.31	5.31
7	5.92	1.92	"	7	"	9.00	5.00
8	6.12	2.12	"	8	"	8.85	4.85
9	6.28	2.28	"	9	"	8.39	4.39
10	6.38	2.38	0.16	10	"	7.12	3.12
12	6.98	2.98	"	12	"	6.80	2.80
14	7.23	3.23	"	14	"	6.68	2.68
16	7.57	3.57	"	16	"	6.53	2.53
18	7.71	3.71	"	18	"	5.50	1.50
20	7.95	3.95	"	20	"	5.47	1.47
25	8.18	4.18	"	25	"	5.30	1.30
30	8.67	4.67	"	30	"	5.00	1.00
35	9.09	5.09	"	35	"	4.74	0.74
40	9.39	5.39	"	40	"	4.60	0.60
45	9.64	5.64	"	45			
50	9.85	5.85	"	50			
55	10.03	6.03	"	55			
60	10.20	6.20	"	60			
70	12.31	8.31	"	70			
80	12.42	8.42	"	80			
90	13.55	9.55	"	90			
100	14.65	10.65	"	100			
110	15.71	11.71	"	110			
120				120			
150				150			
180				180			
210				210			
240				240			
270				270			

LOCATION: Damba
STATIC WATER LEVEL (SWL):3.00 m
BH DEPTH: 58 m
LITHOLOGY: Granite Gneis
PUMP TYPE/CAPACITY: 1HP

L.G.A: Chikun
STATE: Kaduna
PUMP SETTING: 50 m
DATE: 12-10-1993

PUMPING PHASE				RECOVERY PHASE			
Elapsed Time (min)	Dynamic Water Level (m)	Drawdown (m)	Pumping Rate (l/Sec)	Time (min) Since Recovery started	Pumping Rate (L/Sec)	Dynamic Water Level (m)	Residual Drawdown (m)
0	3.00	0	"	0	"	14.00	11.00
1	4.70	1.70	"	1	"	12.00	9.00
2	5.70	2.70	"	2	"	10.40	7.40
3	6.60	3.60	"	3	"	9.30	6.30
4	7.20	4.20	"	4	"	8.80	5.80
5	7.70	4.70	"	5	"	7.80	4.80
6	8.15	5.15	0.96	6	"	7.20	4.20
7	8.50	5.50	"	7	"	6.90	3.90
8	8.70	5.70	"	8	"	6.40	3.40
9	9.10	6.10	"	9	"	6.00	3.00
10	9.35	6.35	"	10	"	5.00	2.00
12	9.70	6.70	"	12	"	4.40	1.40
14	9.90	6.90	"	14	"	3.90	0.90
16	9.10	7.10	1.24	16	"	3.40	0.40
18	10.40	7.40	"	18	"	3.15	0.15
20	11.90	8.90	"	20	"	3.00	0.00
25	12.80	9.80	"	25	"	3.00	0.00
30	13.60	10.60	"	30	"	3.00	0.00
35	14.00	11.00	"	35	"	3.00	0.00
40	14.00	11.00	1.30	40	"	3.00	0.00
45	14.00	11.00	"	45	"	3.00	0.00
50	14.00	11.00	"	50	"	3.00	0.00
55	14.00	11.00	"	55	"	3.00	0.00
60	14.00	11.00	"	60	"	3.00	0.00
70	14.00	11.00	"	70	"	3.00	0.00
80	14.00	11.00	"	80	"	3.00	0.00
90	14.00	11.00	"	90	"	3.00	0.00
100	14.00	11.00	"	100	"	3.00	0.00
110	14.00	11.00	"	110	"	3.00	0.00
120	14.00	11.00	"	120	"	3.00	0.00
150	14.00	11.00	"	150	"	3.00	0.00
180	14.00	11.00	"	180	"	3.00	0.00
210	14.00	11.00	"	210	"	3.00	0.00
240	14.00	11.00	"	240	"	3.00	0.00
270	14.00	11.00	"	270	"	3.00	0.00

LOCATION: Udawa
STATIC WATER LEVEL (SWL):2.00 m
BH DEPTH: 58 m
LITHOLOGY: Porphyritic Granite
PUMP TYPE/CAPACITY: 1HP

L.G.A: Chikun
STATE: Kaduna
PUMP SETTING: 50 m
DATE: 12-10-1994

PUMPING PHASE				RECOVERY PHASE			
Elapsed Time (min)	Dynamic Water Level (m)	Drawdown (m)	Pumping Rate (l/Sec)	Time (min) Since Recovery started	Pumping Rate (l/Sec)	Dynamic Water Level (m)	Residual Drawdown (m)
0	2.00	0	"	0	"	19.00	17.00
1	3.10	1.10	"	1	"	16.90	14.90
2	4.50	2.50	"	2	"	15.05	13.05
3	5.80	3.80	"	3	"	13.65	11.65
4	7.30	5.30	1.02	4	"	12.20	10.20
5	8.70	6.70	"	5	"	10.60	8.60
6	10.05	8.05	"	6	"	9.04	7.04
7	11.25	9.25	"	7	"	7.54	5.54
8	12.40	10.40	"	8	"	6.34	4.34
9	13.30	11.30	"	9	"	5.30	3.30
10	14.30	12.30	"	10	"	4.14	2.14
12	15.80	13.80	1.20	12	"	3.24	1.24
14	17.00	15.00	"	14	"	2.44	0.44
16	17.80	15.80	"	16	"	2.04	0.04
18	18.40	16.40	"	18	"	2.00	0.00
20	18.80	16.80	"	20	"	2.00	0.00
25	19.00	17.00	"	25	"	2.00	0.00
30	19.00	17.00	1.10	30	"	2.00	0.00
35	19.00	17.00	"	35	"	2.00	0.00
40	19.00	17.00	"	40	"	2.00	0.00
45	19.00	17.00	"	45	"	2.00	0.00
50	19.00	17.00	"	50	"	2.00	0.00
55	19.00	17.00	"	55	"	2.00	0.00
60	19.00	17.00	"	60	"	2.00	0.00
70	19.00	17.00	"	70	"	2.00	0.00
80	19.00	17.00	"	80	"	2.00	0.00
90	19.00	17.00	"	90	"	2.00	0.00
100	19.00	17.00	"	100	"	2.00	0.00
110	19.00	17.00	"	110	"	2.00	0.00
120	19.00	17.00	"	120	"	2.00	0.00
150	19.00	17.00		150	"	2.00	0.00
180	19.00	17.00		180	"	2.00	0.00
210	19.00	17.00		210	"	2.00	0.00
240	19.00	17.00		240	"	2.00	0.00
	19.00	17.00		270	"	2.00	0.00

SOURCE: Kaduna State Agricultural Development Project on Rural Water Supply (KADP), (1994).

Appendix III: BOREHOLE DATA AS CALCULATED FROM PUMPING TEST RESULT IN APPENDIX 2

S/No	BH Name	Q(l/sec)	Q(m3/day)	S_1	S_2	$\triangle s$	t_0	r	Transmissivity (m^2/day)	Storativity	Hydraulic Conductivity (m/day)	Yield(l/sec)	Yield(m^3/day)
1	Gwagwada	0.54	46.656	6.4	11	4.8	0.03	0.15	1.778803	0.003706	0.040705	0.54	46.656
2	Chikun	0.18	15.552	2	6.8	4.8	2.5	0.15	0.592934	0.10294	0.012899	0.18	15.552
3	Damba	0.96	82.944	2.8	7.6	4.8	0.55	0.15	3.162317	0.120783	0.057497	0.96	82.944
4	Udawa	1.02	88.128	3	21	18	0.48	0.15	0.89599	0.029866	0.015999	1.02	88.128

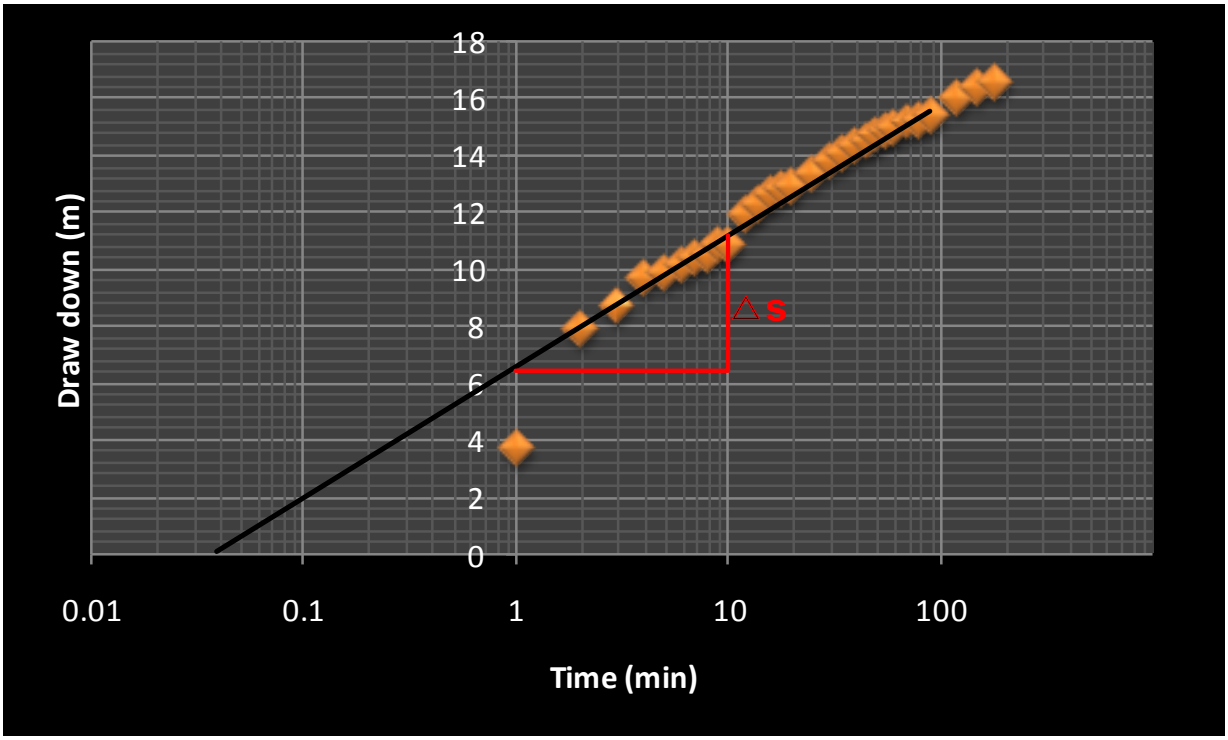
Where T, S and K were determined using;

$$T = \left[\frac{2.3Q}{4\pi\triangle s}\right] \times \left[\log 10\left(\frac{t_2}{t_1}\right)\right] \text{----------(i)}$$

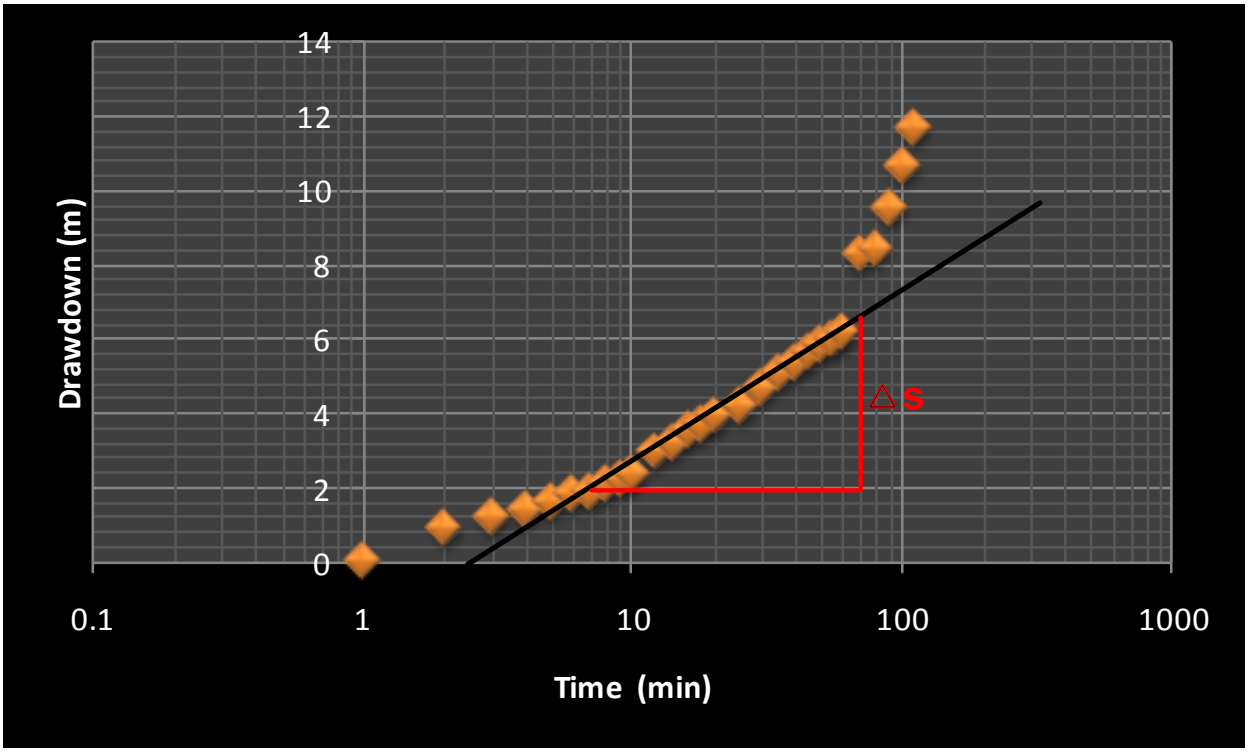
$$S = \frac{2.25Tt_o}{r^2} \text{----------(ii)}$$

$$T = KD$$

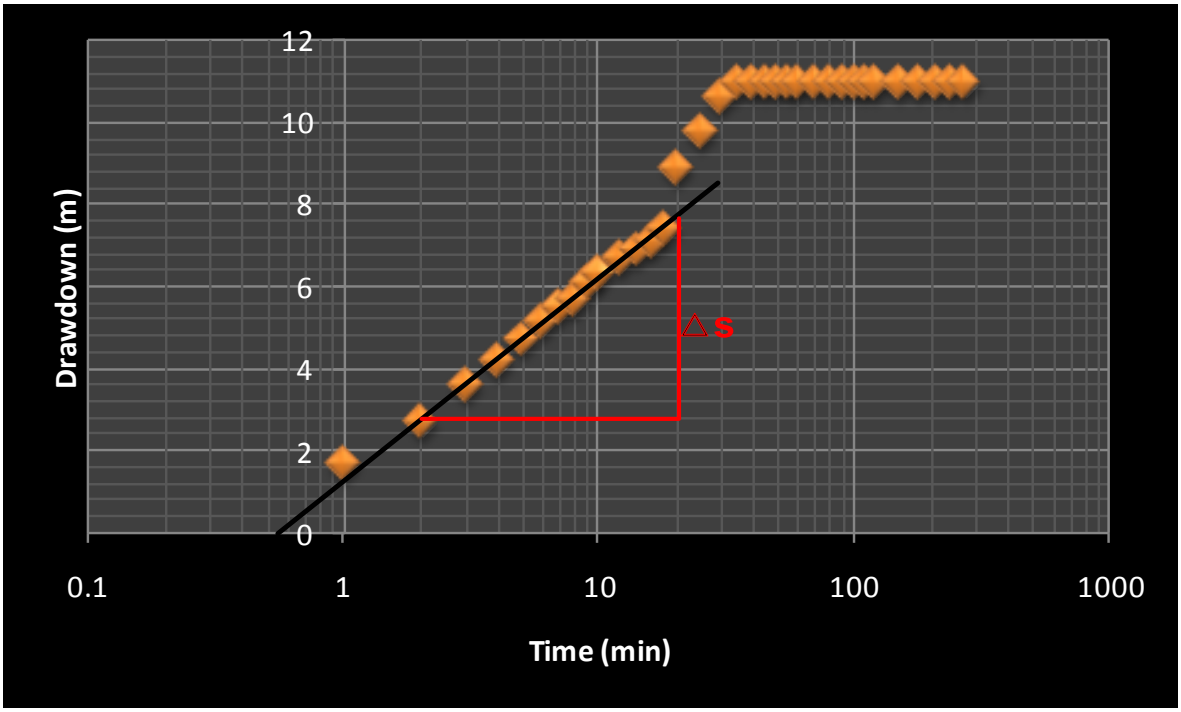
$$K = \frac{T}{D} \text{----------(iii)}$$



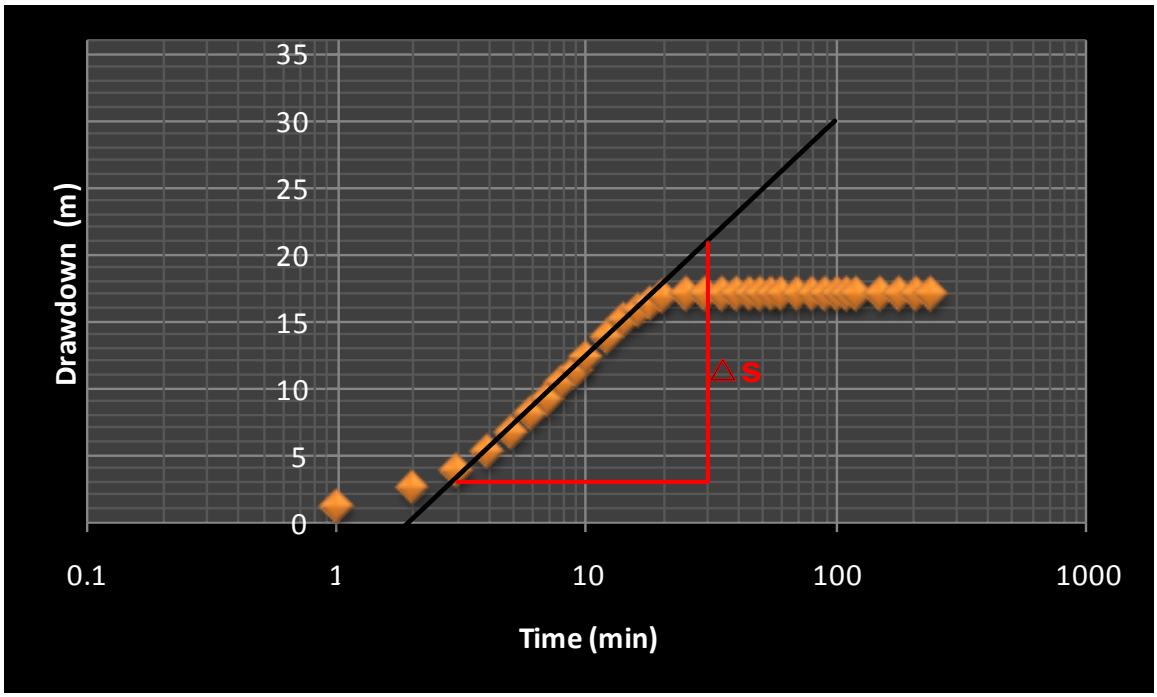
BH- Gwagwada



BH- Chikun



BH- Damba



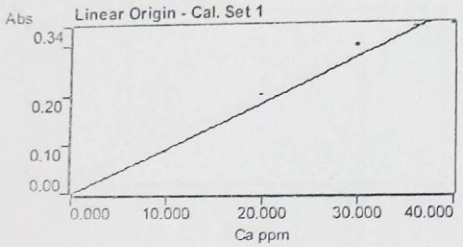
BH- Udawa

Appendix IV: Laboratory Result For Concentration Of Elements

SpectrAA Report 12:43 PM 6/9/2016 Page 1 of 1

Analyst	MUSRL/ABU Zaria
Date Started	12:22 PM 6/9/2016
Worksheet	Calcium 001 72
Comment	Odey Bernard Ogbor
Methods	Ca
Computer name	MUSRL-PC
Serial Number:	AA0904M046

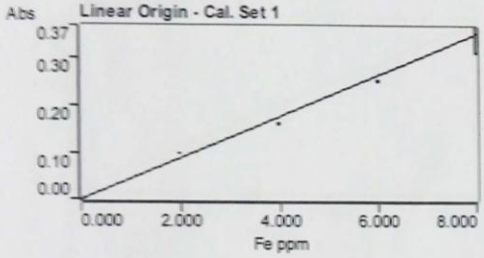
Method: Ca Water (Flame)



Sample ID	Conc ppm	SD	Mean Abs
Sample 2	36.242	0.0028	0.3306
Sample 3	17.698	0.0006	0.1614
Sample 4	0.567	0.0006	0.0052
Sample 5	0.000	0.0005	-0.0012
Sample 6	0.000	0.0008	-0.0012
Sample 7	0.000	0.0005	-0.0018
Sample 8	0.000	0.0004	-0.0027
Sample 9	1.018	0.0003	0.0093
Sample 10	0.000	0.0006	-0.0033
Sample 11	12.338	0.0006	0.1125
Sample 12	0.390	0.0004	0.0036
Sample 13	1.912	0.0002	0.0174
Sample 14	6.426	0.0006	0.0586
Sample 15	8.132	0.0007	0.0742
Sample 16	0.000	0.0003	-0.0020
Sample 17	4.612	0.0009	0.0421
Sample 18	0.542	0.0008	0.0049
Sample 19	0.905	0.0002	0.0083
Sample 20	14.844	0.0014	0.1354
Sample 1	60.290m	0.0004	0.1100

Analyst	MUSRL/ABU Zaria
Date Started	12:59 PM 6/9/2016
Worksheet	Iron 001 001 33
Comment	Odey Bernard Ogbor
Methods	Fe
Computer name	MUSRL-PC
Serial Number:	AA0904M046

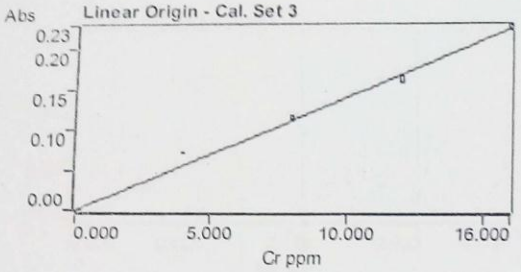
Method: Fe Water (Flame)



Sample ID	Conc ppm	SD	Mean Abs
Sample 1	0.000	0.0008	-0.0006
Sample 2	0.000	0.0007	-0.0004
Sample 3	0.023	0.0007	0.0010
Sample 4	0.072	0.0009	0.0031
Sample 5	0.262	0.0005	0.0115
Sample 6	0.675	0.0010	0.0296
Sample 7	0.005	0.0003	0.0002
Sample 8	0.000	0.0006	-0.0005
Sample 9	0.051	0.0001	0.0022
Sample 10	0.009	0.0005	0.0004
Sample 11	0.135	0.0005	0.0059
Sample 12	0.032	0.0009	0.0014
Sample 13	0.031	0.0012	0.0014
Sample 14	0.048	0.0005	0.0021
Sample 15	0.000	0.0004	-0.0006
Sample 16	0.033	0.0012	0.0015
Sample 17	0.114	0.0002	0.0050
Sample 18	0.075	0.0009	0.0033
Sample 19	0.038	0.0003	0.0016
Sample 20	0.095	0.0028	0.0042

Analyst	MUSRL/ABU Zaria
Date Started	11:21 AM 6/13/2016
Worksheet	Chromium 001 001 20
Comment	Odey Bernard Ogbor
Methods	Cr
Computer name	MUSRL-PC
Serial Number:	AA0904M046

Method: Cr Water (Flame)

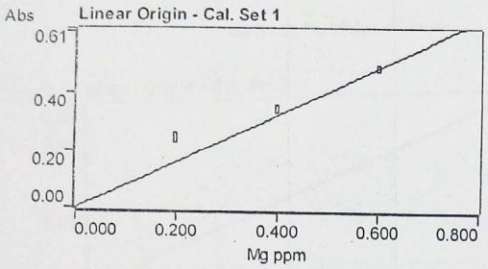


Sample ID	Conc ppm	SD	Mean Abs
Sample 1	0.050	0.0018	0.0007
Sample 2	0.197	0.0003	0.0028
Sample 3	0.208	0.0013	0.0029
Sample 4	0.113	0.0010	0.0016
Sample 5	0.130	0.0017	0.0018
Sample 6	0.149	0.0021	0.0021
Sample 7	0.120	0.0002	0.0017
Sample 8	0.129	0.0007	0.0018
Sample 9	0.131	0.0011	0.0018
Sample 10	0.095	0.0015	0.0013
Sample 11	0.087	0.0008	0.0012
Sample 12	0.212	0.0011	0.0030
Sample 13	0.093	0.0006	0.0013
Sample 14	0.052	0.0001	0.0007
Sample 15	0.218	0.0009	0.0031
Sample 16	0.081	0.0010	0.0011
Sample 17	0.143	0.0005	0.0020
Sample 18	0.088	0.0004	0.0012
Sample 19	0.159	0.0017	0.0022
Sample 20	0.018	0.0002	0.0002

SpectrAA Report. 12:03 PM 6/13/2016 Page 1 of 1

Analyst	MUSRL/ABU Zaria
Date Started	11:43 AM 6/13/2016
Worksheet	Magnesium 001 63
Comment	Odey Bernard Ogbor
Methods	Mg
Computer name	MUSRL-PC
Serial Number:	AA0904M046

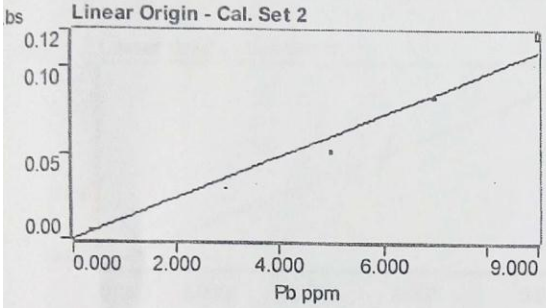
Method: Mg Water (Flame)



Sample ID	Conc ppm	SD	Mean Abs
Sample 1	15.595	0.0000	0.6258
Sample 2	15.959	0.0022	0.2562
Sample 3	13.209	0.0004	0.2120
Sample 4	2.326	0.0010	0.0373
Sample 5	0.569	0.0017	0.0091
Sample 6	1.156	0.0029	0.0186
Sample 7	1.705	0.0020	0.0274
Sample 9	0.791	0.0023	0.0318
Sample 11	3.802	0.0102	0.3051
Sample 12	0.669	0.0021	0.0537
Sample 13	1.344	0.0065	0.1079
Sample 14	3.680	0.0033	0.2954
Sample 15	3.078	0.0101	0.2471
Sample 16	0.541	0.0031	0.0434
Sample 17	0.790	0.0050	0.0634
Sample 18	2.361	0.0031	0.1895
Sample 19	0.821	0.0007	0.0659
Sample 20	1.687	0.0044	0.1354
Sample 8	0.000m	0.0040	-0.0179
Sample 10	0.000m	0.0056	-0.0252

Analyst	MUSRL/ABU Zaria
Date Started	10:30 AM 6/9/2016
Worksheet	Lead 001 00 1 68
Comment	Odey Bernard Ogbor
Methods	Pb
Computer name	MUSRL-PC
Serial Number:	AA0904M046

Method: Pb Water (Flame)

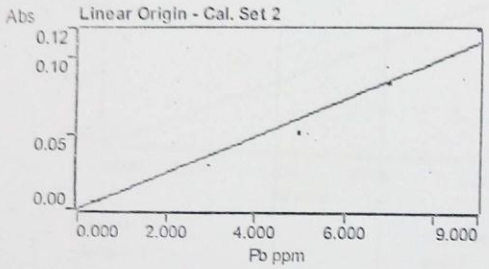


Sample ID	Conc ppm	SD	Mean Abs
Sample 1	0.421	0.0001	0.0051
Sample 2	0.387	0.0004	0.0047
Sample 3	0.726	0.0024	0.0088
Sample 4	0.552	0.0007	0.0067
Sample 5	0.495	0.0003	0.0060
Sample 6	0.511	0.0001	0.0062
Sample 7	0.466	0.0006	0.0057
Sample 8	0.480	0.0003	0.0058
Sample 9	0.513	0.0002	0.0062
Sample 10	0.552	0.0003	0.0067
Sample 11	0.563	0.0002	0.0068
Sample 12	0.603	0.0002	0.0073
Sample 13	0.605	0.0004	0.0074
Sample 14	0.575	0.0000	0.0070
Sample 15	0.597	0.0004	0.0073
Sample 16	0.583	0.0008	0.0071
Sample 17	0.558	0.0001	0.0068
Sample 18	0.661	0.0007	0.0080
Sample 19	0.620	0.0001	0.0075
Sample 20	0.590	0.0005	0.0072

SpectrAA Report. 11:01 AM 7/14/2016 Page 1 of 1

Analyst	MUSRL/ABU Zaria
Date Started	10:30 AM 6/9/2016
Worksheet	Lead 001 00 1 68
Comment	Odey Bernard Ogbor
Methods	Pb
Computer name	MUSRL-PC
Serial Number:	AA0904M046

Method: Pb Water (Flame)



Sample ID	Conc ppm	SD	Mean Abs
Sample 1	0.421	0.0001	0.0051
Sample 2	0.387	0.0004	0.0047
Sample 3	0.726	0.0024	0.0088
Sample 4	0.552	0.0007	0.0067
Sample 5	0.495	0.0003	0.0060
Sample 6	0.511	0.0001	0.0062
Sample 7	0.466	0.0006	0.0057
Sample 8	0.480	0.0003	0.0058
Sample 9	0.513	0.0002	0.0062
Sample 10	0.552	0.0003	0.0067
Sample 11	0.563	0.0002	0.0068
Sample 12	0.603	0.0002	0.0073
Sample 13	0.605	0.0004	0.0074
Sample 14	0.575	0.0000	0.0070
Sample 15	0.597	0.0004	0.0073
Sample 16	0.583	0.0008	0.0071
Sample 17	0.558	0.0001	0.0068
Sample 18	0.661	0.0007	0.0080
Sample 19	0.620	0.0001	0.0075
Sample 20	0.590	0.0005	0.0072
LANK → Sample 21	0.475	0.0007	0.0056

DEPARTMENT OF SOIL SCIENCE

FACULTY OF AGRICULTURE/INT. FOR AGRICULTURAL RESEARCH

AHMADU BELLO UNIVERSITY, ZARIA

WATER ANALYSIS

CLIENT'S NAME ODEY BERNARD OGBOR

S/N	DILUTION FACTOR	Potassium K (mg/l)	DILUTION FACTOR	Sodium Na (mg/l)
1	NIL	3.2	x20	4.9
2	"	3.2	x20	4.7
3	"	2.9	x20	1.5
4	"	6.0	NIL	5.9
5	"	2.7	"	5.1
6	"	2.4	"	4.5
7	"	1.3	"	1.5
8	"	2.8	"	1.2
9	"	3.9	"	1.4
10	"	2.6	"	3.7
11	x10	1.3	"	7.1
12	NIL	2.7	"	5.7
13	"	2.6	x10	1.3
14	"	5.3	x10	2.6
15	"	1.4	x10	1.6
16	"	4.0	NIL	4.9
17	"	2.6	"	7.9
18	"	5.3	"	3.8
19	"	0.9	"	5.9
20	"	4.7	x10	1.4

Thank you for your patronage

Name of Analyst B.H. Jatau

07-05-16

Sign/Date

PUBLIC HEALTH LABORATORY, DEPARTMENT OF WATER RESOURCES AND ENVIRONMENTAL ENGINEERING, AHMADU BELLO UNIVERSITY, ZARIA.

RESULTS OF SAMPLE ANALYSIS COLLECTED FROM ..... Otey Bernard O. .....

SAMPLE/NO	LABEL	PARAMETER NITRATE	UNIT (Mg/l)	TYPE OF SAMPLE
1	Gwagwada 1	,,	14.0	Liquid
2	Gwagwada 2	,,	14.0	,,
3	Gwagwada 3	,,	21.0	,,
4	Gajina 1	,,	7.0	,,
5	Gajina 2	,,	7.0	,,
6	Gajina 3	,,	7.0	,,
7	Agwan Alkali 1	,,	7.0	,,
8	Angwan Alkali 2	,,	35	,,
9	Chikun 1	,,	7.0	,,
10	Chikun 2	,,	7.0	,,
11	Damba 1	,,	21.0	,,
12	Damba 2	,,	14.0	,,
13	Kudo	,,	21.0	,,
14	Angwan Turai	,,	14.0	,,
15	Sabon Kau Wia	,,	21.0	,,
16	Dakwachi	,,	7.0	,,
17	Kulepe	,,	7.0	,,
18	Gwogofe	,,	7.0	,,
19	Gudun Guya	,,	7.0	,,
20	Kurmin Kaduna	,,	21.0	,,

Thank you for your patronage.

Name of Analyst ..... Mr. G. Ameh ..... Sign/ Date 31/5/16

(Technologist I)

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RESULTS OF SAMPLE ANALYSIS COLLECTED FROM ..... Odey Benard O. .....

SAMPLE/NO	LABEL	PARAMETER CHLORIDE	UNIT (Mg/l)	TYPE OF SAMPLE
1	Gwagwada 1	,,	99.97	Liquid
2	Gwagwada 2	,,	51.98	,,
3	Gwagwada 3	,,	75.98	,,
4	Gajina 1	,,	12.00	,,
5	Gajina 2	,,	14.00	,,
6	Gajina 3	,,	19.99	,,
7	Agwan Alkali 1	,,	10.00	,,
8	Angwan Alkali 2	,,	8.00	,,
9	Chikun 1	,,	12.00	,,
10	Chikun 2	,,	12.00	,,
11	Damba 1	,,	16.00	,,
12	Damba 2	,,	16.00	,,
13	Kudo	,,	19.99	,,
14	Angwan Turai	,,	21.99	,,
15	Sabon Kau Wia	,,	41.99	,,
16	Dakwachi	,,	16.00	,,
17	Kulepe	,,	12.00	,,
18	Gwogofe	,,	16.00	,,
19	Gudun Guya	,,	17.99	,,
20	Kurmin Kaduna	,,	33.99	,,

Thank you for your patronage.

Name of Analyst... Mr. G. Aneh ..... Sign/ Date.....

(Technologist I)

31/5/16

PUBLIC HEALTH LABORATORY, DEPARTMENT OF WATER RESOURCES AND ENVIRONMENTAL ENGINEERING, AHMADU BELLO UNIVERSITY, ZARIA.

RESULTS OF SAMPLE ANALYSIS COLLECTED FROM Odey Benard O.

SAMPLE/NO	LABEL	PARAMETER SULPHATE	UNIT (Mg/l)	TYPE OF SAMPLE
1	Gwagwada 1	,,	2.22	Liquid
2	Gwagwada 2	,,	9.06	,,
3	Gwagwada 3	,,	2.38	,,
4	Gajina 1	,,	2.86	,,
5	Gajina 2	,,	3.50	,,
6	Gajina 3	,,	2.86	,,
7	Agwan Alkali 1	,,	3.50	,,
8	Angwan Alkali 2	,,	2.54	,,
9	Chikun 1	,,	2.22	,,
10	Chikun 2	,,	2.07	,,
11	Damba 1	,,	3.50	,,
12	Damba 2	,,	1.43	,,
13	Kudo	,,	2.38	,,
14	Angwan Turai	,,	2.22	,,
15	Sabon Kau Wia	,,	2.54	,,
16	Dakwachi	,,	2.86	,,
17	Kulepe	,,	2.07	,,
18	Gwogofe	,,	1.27	,,
19	Gudun Guya	,,	2.54	,,
20	Kurmin Kaduna	,,	2.86	,,

Thank you for your patronage.

Name of Analyst Mr G. Ameh (Technologist I)

Sign/ Date 31/5/16

PUBLIC HEALTH LABORATORY, DEPARTMENT OF WATER RESOURCES AND ENVIRONMENTAL ENGINEERING, AHMADU BELLO UNIVERSITY, ZARIA.

RESULTS OF SAMPLE ANALYSIS COLLECTED FROM ..... Odey Benard O. .....

SAMPLE/NO	LABEL	PARAMETER BI-CARBONATE	UNIT (Mg/l)	TYPE OF SAMPLE
1	Gwagwada 1	,,	40.0	Liquid
2	Gwagwada 2	,,	108.0	,,
3	Gwagwada 3	,,	72.0	,,
4	Gajina 1	,,	32.0	,,
5	Gajina 2	,,	14.0	,,
6	Gajina 3	,,	36.0	,,
7	Agwan Alkali 1	,,	36.0	,,
8	Angwan Alkali 2	,,	28.0	,,
9	Chikun 1	,,	10.0	,,
10	Chikun 2	,,	20.0	,,
11	Damba 1	,,	136.0	,,
12	Damba 2	,,	14.0	,,
13	Kudo	,,	28.0	,,
14	Angwan Turai	,,	32.0	,,
15	Sabon Kau Wia	,,	56.0	,,
16	Dakwachi	,,	36.0	,,
17	Kulepe	,,	52.0	,,
18	Gwogofe	,,	36.0	,,
19	Gudun Guya	,,	24.0	,,
20	Kurmin Kaduna	,,	32.0	,,

Thank you for your patronage.

Name of Analyst. Mr. G. Awuh (Technologist I)

Sign/ Date..... 31/5/16