GROUNDWATER DEVELOPMENT, USE AND MANAGEMENT IN NIGER STATE.

BY

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BEING A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF POST GRADUATE DIPLOMA IN AGRIC ENGINEERING.

JUNE 2002

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any other University or Institution.

Information derived from published or un published work of others has been acknowledged in the text.

Signature of Candidate

CERTIFICATION

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DEDICATION

This work is dedicated to my wives and children, parents, of blessed memory, and all those in the business of uniting man with water.

ACKNOWLEDGEMENT

I hereby wish to acknowledge the contribution of my supervisor Eng. Dr. E. S. Ajisegiri, whose valuable contribution and suggestions made this work what it is today. My Head of Department, Dr. A. Adgidzi for his support and untiring effort in ensuring a smooth academic session, my esteem lectures Eng. Mohammed Bashir and others in the Department of Agric. Engineering.

My family for the care and understanding throughout the period of study, my Hon. Commissioner, Perm. Sec. and others for their encouragement each step of the way. And for all others that contributed in one way or the other to the success of this work, I say a big thank you.

Above all I am most grateful to Almighty Allah for the life, health, and opportunity and wherewithal to see to the completion of this work.

ABSTRACT

Groundwater, which occurs in structural units, known as aquifers have been an important source of water throughout the ages. Various methods have been used to exploit groundwater potentials of an area and also various methods have been developed for its extraction. Its use is diverse, ranging from domestic to industrial and agricultural uses.

This vital resource, if not properly managed may become exhausted, contaminated or polluted. Wells are drilled without due consideration to the local geology of the area, as such proliferation of wells eventually leads to dewatering of the aquifer and contamination.

Conservation of groundwater resources include avoiding drilling near contamination sources, a resource that should be used wisely and avoiding of waste. Groundwater laws should be enforced to protect this resource and community mobilization should be embarked upon to mobilize and sensitise beneficiaries of groundwater sources.

Hand-pumps and other abstraction methods should be designed to avoid contaminating the water and all efforts should not be spared in ensuring the safety and reliability of groundwater resources.

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CHAPTER ONE

1.1 INTRODUCTION

The late Gen. Murtala Muhammad created Niger State in 1976, it formed part of the then 19 States of Nigeria.

Groundwater development is all the processes that are involved in exploiting the groundwater potentials of an area.

Groundwater or surface water is water which occurs within the rocks that make up the geology of an area. Groundwater is commonly extracted for use by means of wells, boreholes and other excavations. Groundwater recharge is mostly through precipitation (rainfall). However not all rain that falls reaches the groundwater system, some are lost to streams and rivers through surface runoff, while others are lost to the atmosphere through evaporation and transpiration by plants. The climate of Niger State puts it in the semi-arid areas of Nigeria, such areas are characterized by long periods of dry season in which there is virtually no rainfall. The geology of the area generally favours a high rate of runoff with lesser percolation of water to the groundwater system.

In such areas where urbanization has put a lot of pressure on surface water sources and scourge of diseases like guinea-worm has limited water use in some areas, attention is being shifted to groundwater as alternative source of water. This has consequently put a lot of pressure on the wells and consequently on the aquifers. This situation if left unchecked may eventually lead to a permanent damage to the aquifer systems.

Groundwater must be properly developed to avoid contamination of the aquifer, properly used and managed, to avoid depletion of the aquifer and to protect and preserve this essential resource.

1.2 AIMS AND OBJECTIVES

This work is aimed at examining the various methods available for groundwater development in Niger State.

The specific objectives are;

i. - To examine how safe and reliable is the water.

ii. - To find out ways it can be protected and preserved.

iii. - To suggest ways in which present groundwater development methods can be improved.

1.3 SCOPE OF STUDY

The scope of work covers the whole of Niger State, which is located in central Nigeria with a landmass of about 80,000 km^2 and lies along longitudes $4^o 00^I$ to $7^o 15^I$ E and latitudes $8^o 15^I$ to $11^o 15^I$ N.

1.4 METHOD OF STUDY

The method of study involved visit to actual drilling sites and well construction areas to get a first-hand information on the processes involved in the construction. The major towns and villages in all parts of the state were visited and information on borehole/well used was gathered through the use of questionnaires, these were distributed to the inhabitants of such areas and the information gathered was used to arrive at major conclusions.

Accessibility is good all year round, except for some interior villages where accessibility is only by footpaths, and some areas are not accessible during the rainy season.

This study was conducted mainly in the dry season, when borehole/well use is greater and when most inhabitants of the areas visited were at home, free from farm work.

1.4 PREVIOUS WORK

Previous work carried out in this area was mainly extensive groundwater development programmes by state, federal and local governments and also by other donor agencies.

The first major comprehensive work was the groundwater development programme initiated by the then President, Alhaji Shehu Shagari, through the Bi-water Scheme in the early 1980's.

This was followed by that carried out by the state's water and sanitation board, closely followed by the extensive and sustained UNICEF assisted Rural Water and Sanitation Project (RUWATSAN). Other programmes like the defunct Directorate for Foods, Roads and Rural Infrastructures (DFRRI) also worked extensively in the area.

Apart from the drilling and other reports of these areas, this represents the first attempt at looking into the groundwater use and management in the state.

1.5 DURATION

The study lasted for six months, from December 2001 to June 2002, and within this period over 100 communities and settlements were visited.

1.6 GEOGRAPHICAL SETTING

Niger State lies between longitudes 4^{O} 00^{I} - 7^{O} 15^{I} E and latitudes 8^{O} 15^{I} - 11^{O} 15^{I} N. It is bordered in the north by Kaduna and Kebbi states, in the south by Kogi state. It shares boundary in the west with Kwara state and Benin republic and in the east with the Federal Capital Territory and Kaduna State. It is divided into Twenty seven local government areas with a land mass of about 80,000.00 square kilometers.

The climate of Niger State is like much of West Africa. The daylight temperatures vary from about 24^{o}C at the middle of the wet season to above 35^{o}C at the peak of the dry season. The seasonal rainfall regime gives rise to a longer wet season of about seven months with an average rainfall of 250mm, and a dry season of about five months with little or no rains at all.

1.7 GEOLOGICAL SETTING

About one half of the land mass of Niger state is underlained by the basement complex rocks, while the other is occupied by the cretaceous sedimentary rocks of the Bida basin. The boundary between these, runs in a Northwest – Southeast direction, within the basement rocks to the North and the sedimentary formation to the south.

The basement rocks consist of a suite of Precambrian gneisses, migmatites and meta-sedimentary schist crosscut by intrusive granitoids (Oyawoye 1972 and McCurry 1976). The gneisses and the metasedimentary schist which constitute the host rocks to the granitoids and are found mostly as flat-lying outcrops, are often ill exposed except along river channels and road cuttings.

The sedimentary formation on the other hand consists of loosely cemented sandstone of varying grain sizes, siltstones, clay and shale and are often capped by lateritic and/or ironstone concretions, particularly in upland areas (Shekwolo 1992).

A typical weathered profile of the basement rocks consists of two main zones, firstly the surficial zone, which is usually about one or two meters thick, and secondly, the fractured or fissured rock zone, which may range from a few meters to over 20 meters in places. Products of weathered granites and gneisses are usually loose aggregates of medium to coarse sand, while the weathered product of schist is generally made up of clayey sand.

CHAPTER TWO

2.0 LITERATURE REVIEW

The general pattern of groundwater occurrence is dependent upon the physical framework in which groundwater occurs and the hydrologic balance that results from recharge and discharge mechanisms.

Much of groundwater can be said to be meteoric in origin that is originating from the surface and the atmosphere. Also, a small percentage is known to enter the hydrologic cycle from subterranean sources and is described as Juvenile waters. Juvenile water includes water of magmatic and volcanic sources some contribution is also obtained from connate sources which contain water entrapped in the interstices of sedimentary formations.

The local occurrence of groundwater is the consequence of a finite combination of climatic, hydrologic, geologic, topographic and soil forming factors which together form an integral dynamic system.

Groundwater can be visualized as occurring in a subsurface reservoirs, known as aquifers. The boundaries of the reservoir are formed by adjacent less permeable or impermeable rocks. Where the reservoir is open everywhere to the land surface, we have an unconfined aquifer, when it is capped in large part by impermeable or relatively impermeable rocks, we have a confined aquifer. Materials forming the aquifer may be composed largely of unconsolidated sediments or of bedrock.

2.1 AQUIFERS

An aquifer can be defined as a saturated permeable geological bed, formation or group of formations which yields water to wells in sufficient quantities to be economically useful. The most common aquifers are unconsolidated sands and gravels, but permeable sedimentary rocks such as sandstone and limestone and heavily fractured or weathered volcanic and crystalline rocks can also be classified as aquifers.

2.1.1 SEDIMENTARY AQUIFERS

Sedimentary rocks are those rocks that were formed as a result of weathering, erosion and consolidation of a pre-existing rock. Common sedimentary rocks include sandstones, clays, shale, limestone, gravel, siltstones, mudstones and conglomerates.

The clays, mudstones and siltstones are very poor aquifers, and in most cases are aquicludes. This is so because porosity is an important factor in the hydrological characteristic of a consolidated formation. The fine grained sediments, while storing a lot of water, only allow limited water movement through them and therefore behave more as barriers, both laterally and vertically.

Sandstones, conglomerates and gravels form generally good aquifers in this area, this is on account of their high porosity and permeability. Factors controlling the porosity and permeability and specific yield of the aquifers in this area include; particle size, particle distribution, particle shape and the state of cementation of the particles.

The sandstone that form the aquifer in this area are often poorly cemented with the cementing materials being mostly quartz and clay. While in some cases cementation is so poor that the sandstone occurs in a very loose state. Where gravels form the aquifer, the cementing material is often clay and in cases where the gravel is clay-free, the yields of the aquifer tends to be very high (Idris-nda, 1999).

2.1.2 BASEMENT COMPLEX AQUIFERS

The basement complex system comprises of hard (crystalline) rocks and are mainly granitic in composition, they include gneisses, migmatites, schists, phyllites and quartzite.

These rocks are hard, with low permeability and generally not water bearing. Most of these rocks are located in areas of high relief, as a result run-off is high and infiltration rates very low. The groundwater storage, which is already limited by geological factors, is further reduced by adverse climatic conditions.

The porosity of rocks determines their hydro-geological properties, and this depends on the texture and mineralogy of the rocks. Invariably porosity and permeability is improved by joints and fractures in the rock system, the interconnection of these joints and the extent of the fracturing determines the hydro-geological potential of these rocks as potential aquifers.

The extent of weathering also improves the hydro-geological properties of these rocks, however this depends on the mineral composition of the parent rock. Overburden thickness in some parts of the state may be as high as 40m or more and in other places may be even less than 3m.

2.2 GROUNDWATER RECHARGE

Groundwater recharge in this area is limited to direct recharge by infiltration processes and influent seepage from the stream, which is limited to areas not far from perennial streams.

In the sedimentary portions direct recharge is favoured by the loose and fairly cemented nature of the sandstone, while the loose top soil in the basement area generally favours direct recharge. Where extensive fracturing occurs just below the regolith, rainwater infiltration recharges these fractures directly and the reservoir capacity can be quite extensive, this accounts for the rise in water level in boreholes drilled in these areas to a level of 2 meters at the peak of the rainy season and to as low as 20 meters at the peak of the dry season. During the dry season those areas located 2-3Km away from perennial streams, receive recharge by subsurface flow of water from these streams, this is especially the case in the sedimentary rock portions where the alluvium, coupled with the loose nature of the sandstone, favour a steady depletion of water in the streams through gravity flow into the aquifers, when groundwater level falls below the water level in the stream. In the hard rock terrain, this only happens where near-surface fractures are connected to the stream or lie just below the stream level. This results into the stream water being drained into the fracture system, depending on the depth, extent and degree of interconnection of the fractures. This has been found to be very important source of recharge for groundwater in this area.

2.3 GROUNDWATER HYDRAULICS

2.3.1 POROSITY

The porosity of a rock is it's property of containing pores or voids i.e. the spaces in-between individual particles that make up the rock.

With consolidated and hard rocks, a distinction is usually made between primary porosity, which is present when the rock is formed and secondary porosity, which develops later as a result of solution or fracturing. Porosity plays a major role in groundwater storage, as it provides the spaces needed to create a reservoir potential in aquifers.

2.3.2 HYDRAULIC CONDUCTIVITY

The hydraulic conductivity is the constant of proportionality in Darcy's law. It is defined as the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow (Kruseman et al., 1991).

The hydraulic conductivity of fractured rocks depends largely on the density of the fractures and the width of their apertures. Fractures can increase the hydraulic conductivity of solid rocks by several orders or magnitude.

Permeability, which is the coefficient of hydraulic conductivity, and hydraulic conductivity are the chief determinants of groundwater movement. A rock may be very porous but with a low permeability or hydraulic conductivity, it may therefore store water but will not be capable of transmitting the water into wells placed in them, such as clay.

Hydraulic conductivity can have any unit length/time, for example m/d.

2.3.3 TRANSMISSIVITY

Transmissivity is the product of the average hydraulic conductivity and the saturated thickness of the aquifer. Consequently transmissivity is the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the whole saturated thickness of the aquifer. Transmissivity has the dimensions of $length^3/Time \times length$ or $length^2/time$ and is, for example, expressed as m^2/d or m^2/s.

2.3.4 SAFE YIELD

The safe yield of an aquifer is the rate at which groundwater can be withdrawn without causing a long-term decline of the water table or piezometric surface. Thus, the safe yield is equal to the average replacement rate of the aquifer (recharge).

In areas of limited water resources, for example, groundwater may be deliberately '*mined*' because it is the cheapest and most readily available water resource for economic development. Sooner or later, however, groundwater withdrawal in excess of the hydrological safe yield will produce undesirable effects. These effects may range from declining groundwater level and resulting increases in pumping lifts and costs and need for deepening wells, to deterioration of groundwater quality and eventual depletion of the groundwater resource (Bouwer, 1978).

2.3.5 GROUNDWATER DEVELOPMENT IN NIGER STATE

Groundwater studies have always held a certain fascination for people right from prehistoric times. People had always being forced to move from areas that lack water to areas nearer river channels. Water was indeed the chief determinant of the settlement patterns of early man. However with a more sedentary living style of man, it became necessary to explore alternative sources of water.

Groundwater development for rural, urban and industrial supplies currently takes many different forms.

The Niger State government embarked on various groundwater development programmes during various regimes. This is mostly as a result of the threat to health posed by such diseases like guinea worm, typhoid fever, dysentery etc., which were directly attributable to poor drinking water and hygienic conditions. These programmes range from the provision of hand dug wells to boreholes and large scale water supply using groundwater sources – such as the Biwater Scheme.

Groundwater development therefore involves all the stages involved in bringing groundwater to the surface for use by man. Reliance on groundwater as a cheaper and safer alternative to surface water is gradually becoming the norm rather than the exception, as almost all those that can afford them had one placed in their homes, office premises and the booming business of packaging borehole water as 'pure' water has become the vogue in recent times.

The provision of a reliable safe water supply to a village community may have social as well as economic benefits. If available in sufficient quantity it may be regarded as a resource not only for health benefits but also as a potential for small scale irrigation projects.

2.3.6 HAND DUG WELLS

Hand dug wells have been utilized for groundwater development from prehistoric times to the present time. In most parts of the state hand dug wells account for over 80% of the total sources of water, even in the more urbanized areas, like Minna, the state capital.

Due to the erratic and epileptic supply of water from the state's water board, many households had wells placed in them to augment the pipe borne water. In most areas this is the only source of water. However most of these wells are not dug with hygiene or sanitation in mind. These wells are often left unlined and in the same household you find pit latrines existing side by side with hand dug wells.

2.3.7 EXCAVATION METHODS

The implements that are required for excavating wells are shovels, diggers, digging rods, buckets, strings/ropes with a manpower of two people.

In the crudest form, one person does the digging while the other removes and dumps the dug material. As the well gets deeper a string is attached to a bucket handle for hauling out the dug material. Holes are created on the sides of the well to serve as foot and hand holds for descending into the well and ascending. Once water is struck or a hard formation, such as crystalline rock is encountered, the well is terminated cleaned and is ready for use.

The method of abstracting water from these wells is commonly by a piece of string attached to a bucket or a collapsible bucket made out of a tire tube. The wells are mostly uncovered and left unprotected. Sometimes toads, snakes and other reptiles fall into the wells and render them useless for sometime.

Because these wells are left open from all sides, the water seeping in tends to have a high TDS (Total Dissolved Solids), faecal pellets and other contaminants. The rate of TDS often impacts a kind of taste to the water which may not be tolerated by those not used to such kind of water.

When the wells are constructed in very soft formations, they often fall or cave-in, the collapse may form a very deep gash in the ground, which has to be refilled. The wells are also often cleaned to maintain a steady supply of water. This is done by climbing down the well and removing any material or debris that may collect inside.

In recent times the wells are plastered with cement, much as is done in buildings, to prevent collapse and improve the water quality.

These wells are found everywhere in the state as it is very cheap to dig (less than x5,000, five thousand Naira is some areas) and in favourable locations is capable of supplying water all year round. With a little improvement this may still represent the best way of groundwater development.

Some hand dug wells have been fitted with electrical lifting pumps to pump the water to an overhead reservoir for subsequent treatment and distribution.

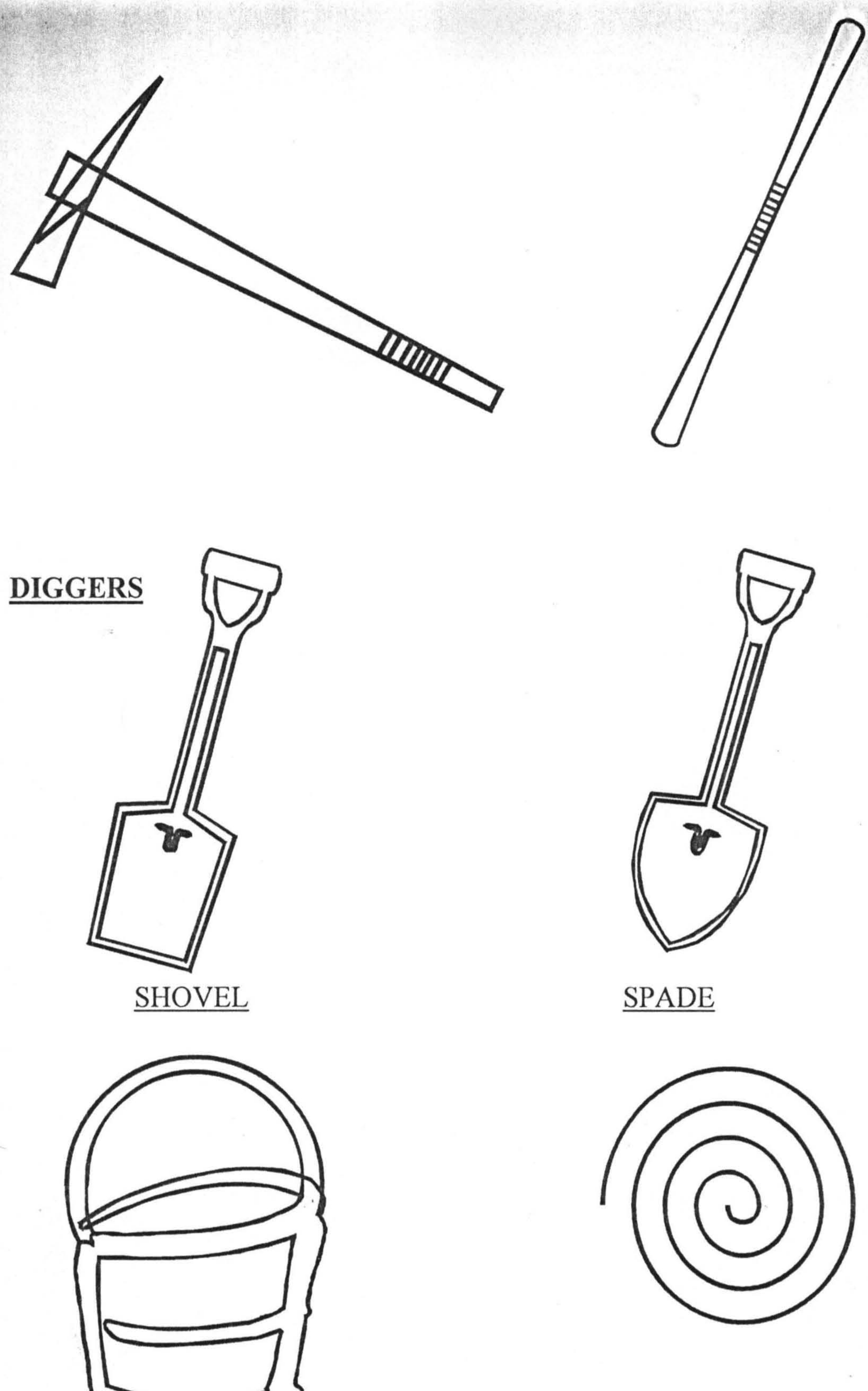


Figure 1: Tools for hand dug wells.

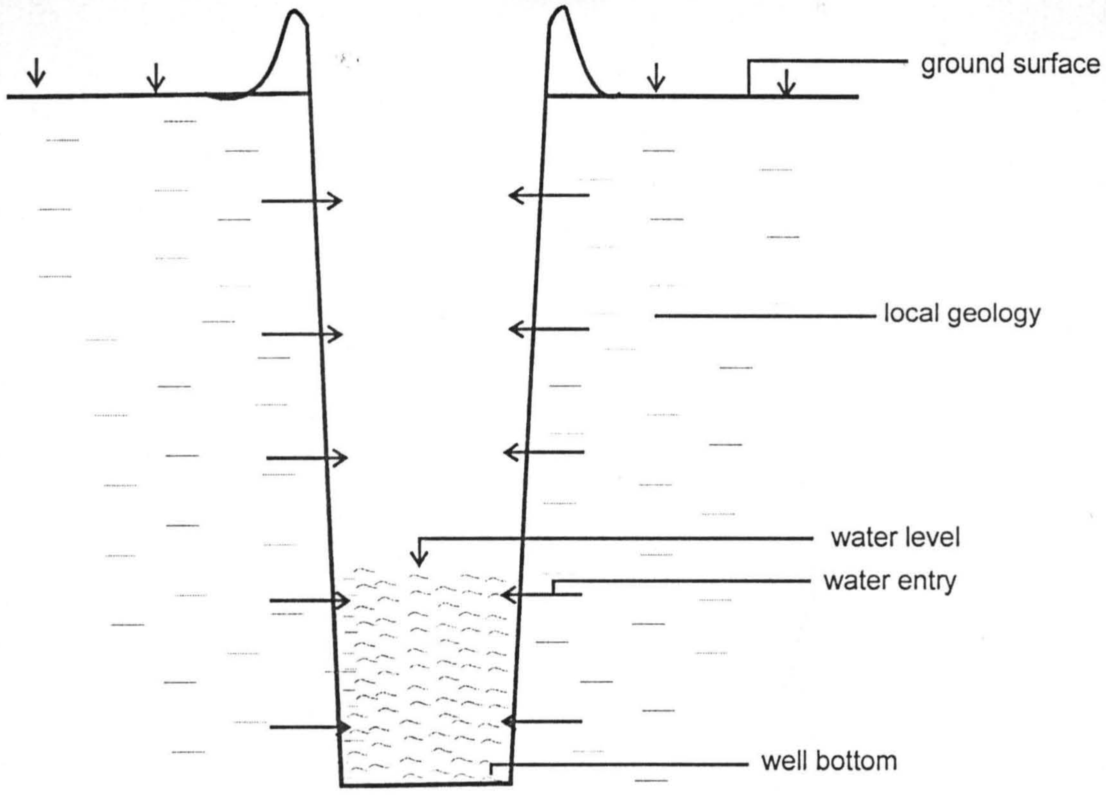


Figure 2: Sketch of a hand dug well

2.3.8 CONCRETE LINED HAND DUG WELL

Concrete lined wells are also hand dug wells that are otherwise known as '*Kwakwara*' wells in the local parlance. These are improvements over the traditional unlined wells. These are often dug to deeper levels and provide safer drinking water. All precautions were taken in digging these wells to make them hygienic and pollution free. They are often community wells, rather than individual wells. They are placed in central locations to serve as water points for the whole community, usually about one hundred or more people to one well.

2.3.9 EXCAVATION AND EXTRACTION

The tools required for digging these kind of wells are essentially the same as those for hand dug wells. Digging is manually done, but a manpower of between four and five people with one person digging at a time.

The excavation tool also includes a tripod equipped with a wire string and a system of pulleys for hauling out the dug material as well as lowering and bringing up the person doing the digging. The tripod may be equipped with one or two handles for operation, depending on the depth and bucket size. The diameter of this well ranges from 1.5 to 2.5 meters. The well is dug up to the level at which an aquifer is encountered or in the basement complex area, all the overburden thickness is excavated up to the basement. This accounts for the depth of the wells, which is seldom less than 20 meters and in some cases may even exceed 40 meters.

Once the well has reached the required depth it is lined with concrete rings from the bottom to the top. The rings are about 1m in length and some are perforated to allow for entry of water into the well. Gravels are placed between the well wall and perforated ring to filter the water going into the well.

The completed well is built up to 1 meter above the surface and provided with collection points with spouts as well as wooden rollers in a steel rod embedded in the walls of the well. These rollers allow for easy pulling out of water from the well. Some of the wells are mounted with tripods equipped with pulleys, this is to ease the lowering and raising up of water from the wells.

These wells are capable of yielding a large volume of water, mostly with a very low TDS and low contamination/pollution level.

The only constraints imposed on this type of well is the cost of construction, which exceeds one hundred thousand Naira (x100, 000.00). Most communities in the state have benefited from these types of wells. They are virtually maintenance free and capable of yielding water all year round for a very long time.

A census of concrete lined hand dug wells show that none has been done in recent times, most of them are over 30 years old and still functional.

They are spread evenly across the state and most especially in basement complex areas.

Groundwater development through the use of '*Kwakwara*' wells has been very successful in meeting the water demands of the benefiting communities in the state.

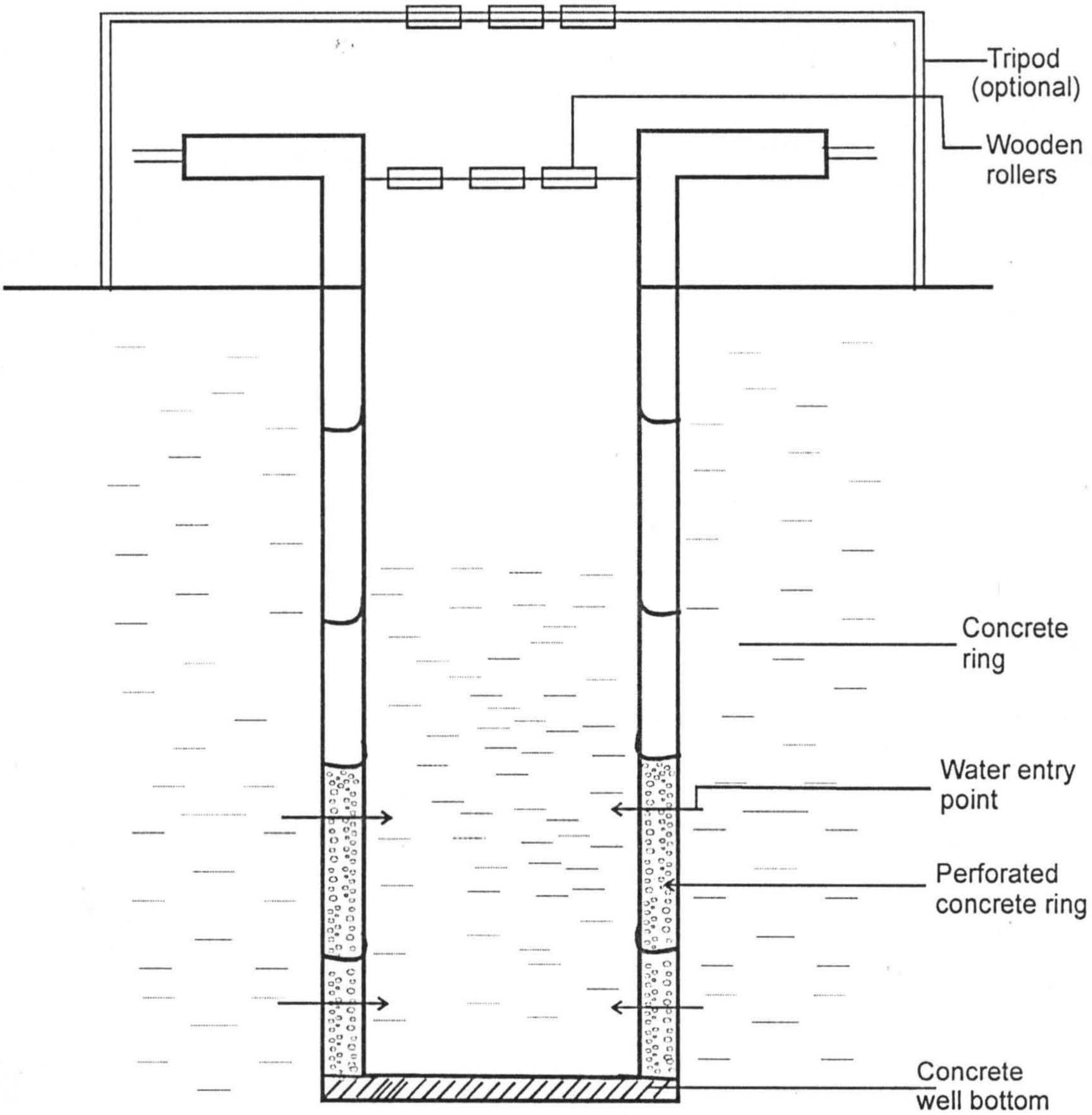


Figure 2a: Section through a '*Kwakwara*' well

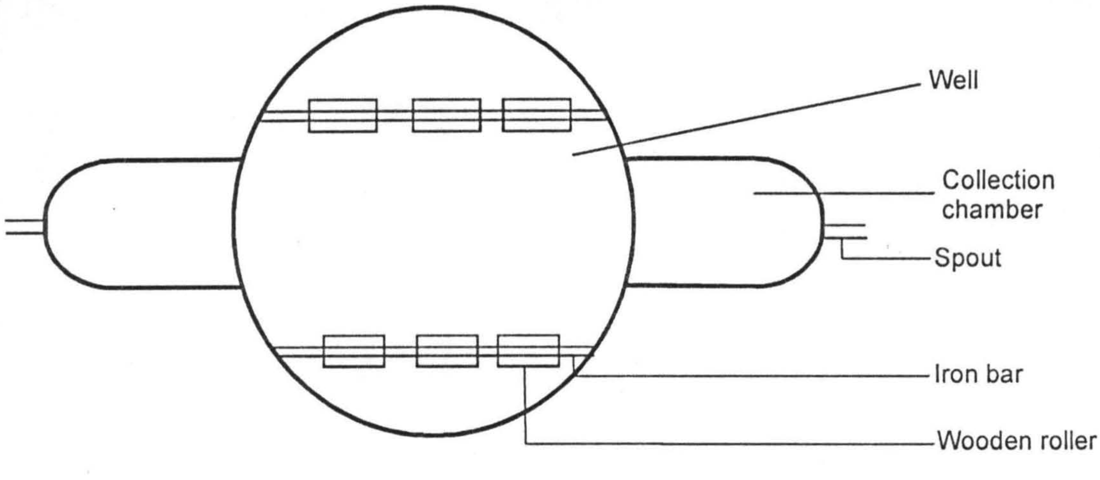


Figure 2b: Plan view of a '*Kwakwara*' well

2.4.0 BOREHOLES AND TUBEWELLS

Boreholes and tubewells are small diameter vertical shafts dug in the ground to provide water for use. Machines or various kinds of tools are required to drill the wells and various finishing methods are used to complete the wells depending on the use.

However before the wells are drilled a pre-drilling geophysical survey is conducted to determine the nature of the local geology and groundwater availability.

2.4.1 SURFACE GEOPHYSICAL INVESTIGATION

Geophysical investigation is essentially the interpretation of the variation in measured response at the surface to certain forces, either naturally or artificially generated within the earth crust. Such variations result from differences in physical characteristics such as density, elasticity, magnetism and electrical resistivity of the underlying materials. Measurements are usually made at predetermined distances or locations along a traverse or on a grid.

Four basic methods of geophysical surveying are available; seismic, electrical, gravimetric and magnetic. The first two depend on the introduction of mechanical or electrical energy into the earth crust and measurement of the effects of subsurface materials and condition on the transmission of this energy. The latter two methods depend on the measurement of the variations in the intensity and direction of the natural forces of gravity and magnetism.

The subsurface data of interest in groundwater investigation that can be produced by various geophysical methods include:-

1. Depth to aquifer
2. Thickness of aquifer
3. Horizontal changes in aquifer
4. Geological boundaries
5. Water quality (whether fresh or saline).

It should however be noted that no one single method can sufficiently determine the presence of water in a geological material, but it becomes possible through the data obtained to interpret anomalies as either indicative of the structures capable of holding and transmitting water or of geological materials which, except for the presence of water, might have given different results from those obtained. Some geologic materials also do exist which can 'mimic' or mask the presence of water in the formation.

Surface geophysical survey has been employed widely in groundwater prospecting and the number of successful boreholes, even in difficult areas, attest to the success of this method in groundwater development.

The survey method commonly employed is the electrical method, the equipment used is the Terrameter. A sample of typical resistivity survey data and curve for both sedimentary and basement terrain is given in figure 3.5 to 3.8.

2.4.2 TUBEWELLS

Tubewells are small diameter wells, ranging from 2 inches or 50.80mm to 4 inches or 101.60mm in diameter. These kinds of wells are mostly shallow, drilled to only a few meters, ranging from 6m to 30m and are mostly drilled in alluvial deposits.

They are constructed using various methods, ranging from the fully mechanized mono-rigs to hand augers. The wells are mostly used for small to large scale irrigation purposes.

The Niger State Agricultural Development Project (NSADP) has drilled these kinds of wells all over the state for agricultural purposes.

The wells are drilled to the required depth, cased screened, gravel packed and developed. The completed well is installed with surface lifting pumps, tubes are inserted into the well and water pumped out to irrigation fields. The wells are capable of high yields all year round, this is also coupled with the fact that the water being pumped out is also available for recharge. Due to the shallow and unconsolidated nature of the aquifer the pumped water immediately infiltrates into the ground to rejoin the water table, thus becoming available for re-use once more.

Immense success has been achieved by the NSADP in this regard, the wells are very cheap to drill, often less than forty thousand Naira (x40,000.00), average farmers were able to afford them and those that could not formed cooperative societies that put up money for its construction and the water circulated between the beneficiaries. Also lifting pumps are made available to the farmers at subsidized rate by the government.

Once properly used and maintained tubewells have very long life span, since they are mostly used during the dry season. The only constraint imposed on them is that an alluvial deposit is needed to place them.

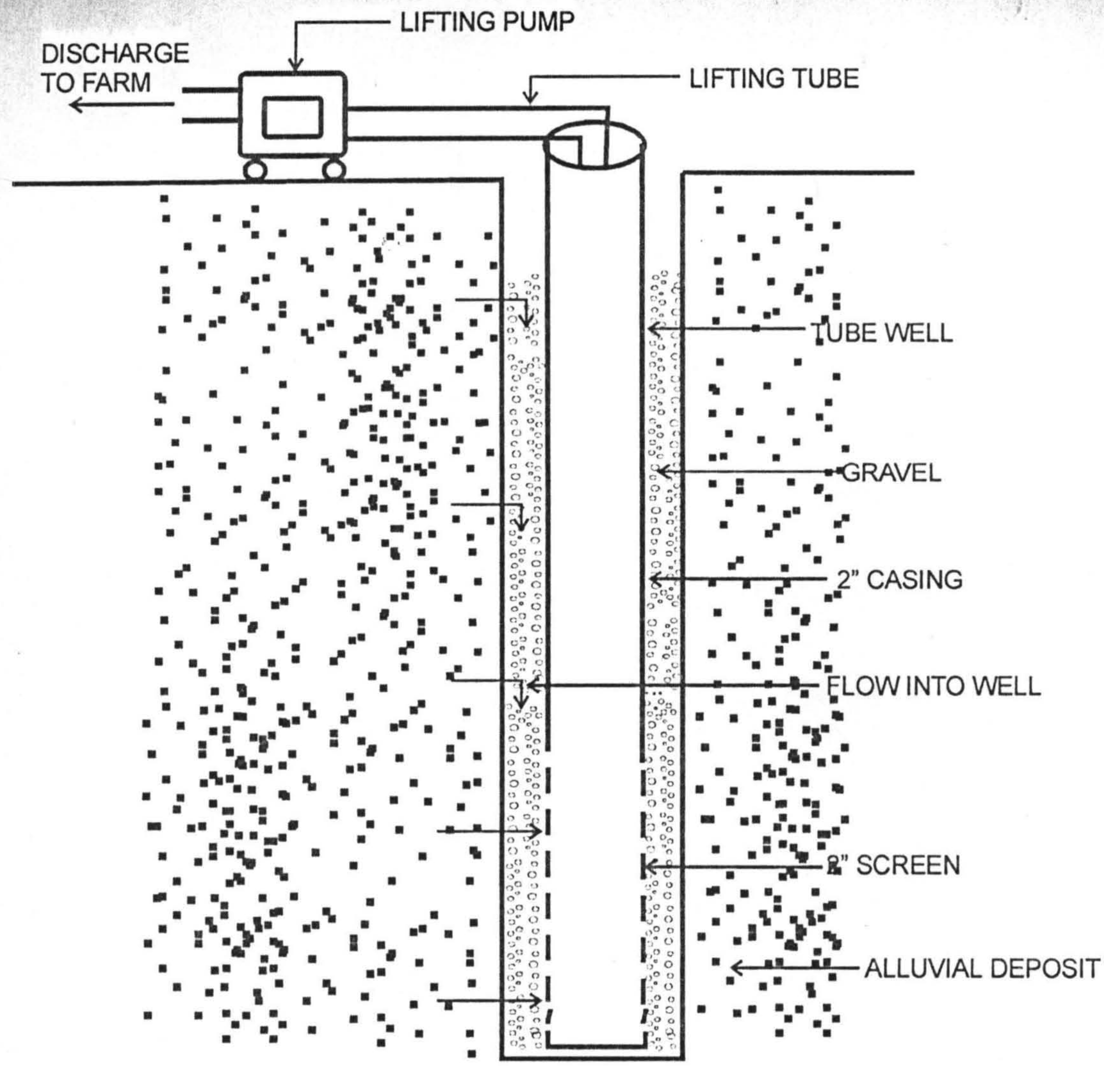


Figure 5: Section through a pumped tubewells

2.4.3 BOREHOLES

Boreholes are vertical small diameter pumped wells. The diameter of the well must be large enough to permit entry of groundwater without undue head loss and to accommodate a pump. The following relation between expected well yield and optimum well diameter (Internal diameter of casing), may be used as a guide in selecting well diameters, adapted from Johnson (1972) in Bouwer (1978).

Expected well yield, m^3/day	Well diameter	
	Inches	Millimeter
<500	6	150
400-1000	8	200
800-2000	10	250
2000-3500	12	300
3000-5000	14	350
4500-7000	16	400
6500-10,000	20	500
8500-17,000	24	600

Depths of wells range from a few meters to more than 300m. A common range for production wells is 20m to 500m. Small, shallow wells for individual residences or farms (domestic wells) may be driven, jetted, or hand-augered down if the underground material is unconsolidated and relatively free from stones. Deeper wells and wells in gravelly or consolidated materials are mechanically drilled using cable-tool or rotary drilling techniques.

In unconsolidated materials, the borehole must be lined with pipes called casings to prevent the well walls from caving in. Special screen sections or perforated casings are used where groundwater is to enter the well. If the aquifer consists of relatively fine, uniform material, entry of sand into the well may cause excessive wear on pump impellers and bearings, and fill the lower portion of the well (silting). To avoid this situation, an oversized hole is drilled and the annular space between well screen and hole wall is filled with gravel or coarse sand. Such gravel packs or gravel envelope then effectively prevents sand from moving into the well. Casing the top of the well and placing a cement slurry between the well wall and casing (grouting) is also necessary to allow proper sealing to prevent entry of polluted surface water into the well.

The average borehole diameter in Niger State is between 102mm (4 inches) to 200mm (8 inches) and commonly 150mm (6 inches). The depth range from 30 meters in basement areas to 50 meters in sedimentary areas and 100 meters in some other areas, like Mokwa, Mashegu, Matane etc. The average well depth seldom exceeds 60m, except in some difficult areas. Borehole yield are high in those basement areas with thick overburden and highly fractured areas, low in basement areas with shallow overburden and low fracturing. The sedimentary areas generally produce high yields except in some difficult areas with very deep aquifers, in which case the borehole may not be deep enough to tap the full potential of the aquifer, like in some parts of Kontagora (NTA area) to Kaboji and Matane.

DRILLING METHODS

The equipment and method of drilling depends largely on the local geology of the area. Cable tool (percussion) and rotary drilling are the two most common methods for drilling boreholes, while other techniques like jetting, driving, or augering are used only in selected, shallow situations.

The commonest method employed in groundwater development in Niger State, through the use of boreholes, is the rotary method, and to a very limited extent hand augering.

ROTARY METHOD

Rotary drilling is the standard method for drilling oil wells and is increasingly used for water-well drilling. Drilling bits may consist of several conical roller gears (roller bits), drag bits (flexible carbide fingers) or systematically placed buttons in the bit face. The bit is fastened to the bottom of a hollow drill pipe (rods), which is rotated at a rate of 30 to 60 rpm in the borehole. Drilling is obtained by the grinding, clipping, and crushing action of the gears, fingers, or buttons as they roll or scrape over the formation material under the weight of the entire drill stem and rotary head which also supplies the pull-down pressure.

Drilling fluid consisting of a carefully formulated suspension of bentonite clay in water- plus various additives, if necessary – is pumped down the drill pipes. The fluid leaves the drill pipe through the bit, where it cools and lubricates the abrading surface and picks up drill cuttings. The drill cuttings are transported upwards as the fluid returns to the ground surface through the annular space between drill pipe and hole wall. The fluid then flows into a pit or settling basin where the cuttings settle out, after which the drilling fluid is pumped back into the drill pipe. The fluid itself forms a mud lining or filter cake on the hole wall, thereby stabilizing the hole and preventing collapse or caving in.

The rate of drilling depends on numerous factors, including hardness of rock: size, type, and condition of bit; rotation rate of bit; total weight on bit; properties of drilling fluid; fluid pressure on hole bottom; and circulation rate of drilling fluid.

This is the method of drilling that has been employed in drilling of boreholes in the sedimentary areas of the state, and also in basement complex area with thick overburden, and also in contact zones, whose upper parts are essentially sedimentary overlying crystalline rock, like in some part of Lapai, Borgu, Magama, Rijau and Kontagora.

The main complications that may be encountered with rotary drilling are borehole instability and circulation loss (like in Mokwa area). Instability of the hole wall, such as caving in, sloughing, heaving, or washout, is normally caused by swelling deformation, or other reactions between formation material and water that has entered the formation through the mudcake. Damage by borehole instability can be minimized by reducing the rate of circulation of the drilling fluid to minimise erosion of the bad section(s). Pressure surges inside the hole should also be avoided.

Another rotary technique used for drilling borehole in the state is the rotary-air method. Here the drilling fluid consists of dry air-generated by a compressor. In this case the air pressure must be high enough to produce upward velocities of up to 10 to 30m/s in the annular space between drill pipe and hole wall to evacuate the cuttings. This is the method commonly used to open up the overburden in crystalline rock areas and in consolidated sandstones, foam is added to water and other surfactants lighter than water to bring up the cuttings. This method was used to drill boreholes in areas like Mokwa with loss circulation zones.

ROTARY-PERCUSSION

This is another direct rotary method using air and is otherwise known as "down-the-hole" drilling system. A pneumatic drill operated at the end of the drill pipe rapidly strikes the rock while the drill pipe is rapidly rotated.

The hammer is constructed from alloy steel with heavy tungsten-carbide inserts that provide the cutting or chipping surfaces. Rotation of the bit helps to assure even penetration and, therefore, straighter holes even in extremely abrasive or resistant rock types. The rates of penetration in several rock types are higher than those obtained by other drilling methods or other types of tools. Six-inches (152mm) and 6½ inches (165mm) hammer bits are commonly used.

Cuttings are removed continuously by the air used to drive the hammer.

Compressed air must be supplied to the hammer at a pressure of 100 to 110 psi (690 – 758 kpa). Some tools require as much as 200 psi (1,300 kpa). To remove cuttings effectively, the upward velocity in the space outside the drill pipe should be about 3000ft/min (915m/min) or more for drilling 4 inches (102cm) holes, the air supply must be at least 100cfm (0.047 m^3/sec), for 6 inches (152m) holes at least 330 cfm (0.156 m^3/sec) is needed.

Proper rotation speed is from 10-30 rpm: reduced speed is best in harder and more abrasive rock.

Down-the-hole hammers have been used extensively for drilling in the basement complex areas. Once the overburden has been opened, surface temporary casings are installed, after which the hammer is lowered and operated using the compressed air till completion of drilling. Drilling using this method has been very successful. The commonly used bit is the 6 inches (152mm) and 4 inches (102mm) common hammers is use are Ingersoll-Rand, Halco, Tone, Mission and Atlas Copco.

A down-the-hole Hammer

BOREHOLE DESIGN AND DEVELOPMENT

BOREHOLE DESIGN:

Borehole design is the sum total of events that take place from mobilizing of equipment and manpower to site to completion of well, and most importantly positioning of the screen and gravel pack.

Once the well has been successfully drilled to the designed depth, the casings and screens are then installed. It should be noted that improper positioning of the screen may lead to a reduced borehole yield and even a complete borehole failure.

In Cased wells, groundwater enters the well through screens or perforated sections of pipe. The main function of the well screen or perforations is to let water through without undue head loss and risk of encrustation, while keeping sand and other formation material out. Casings and screens normally are not necessary for wells in consolidated materials, where water enters the well through natural pores (interstices), cracks, fissures, solution channels, or other stable openings in the formation. Most boreholes in the basement complex areas with shallow overburden are mostly left as open boreholes, with only the overburden part cased, while the stable bedrock is left uncased. In some cases the overburden may be screened and gravel packed, while the bedrock is left open.

The major type of screen used is the continuous slot screen type using the same material as the casing – commonly UPVC or steel. In some cases, like the Biwater Scheme, the Johnson perforated screens were used. The screen slot size depends on the average size of the aquifer material and the gravel pack material.

GRAVEL PACK

Gravel packs are used in relatively fine textured aquifers (including poorly cemented sandstones), where the effective particle size is less than 0.25mm and the uniformity coefficient less than 3. Gravel pack material effectively prevents the entry of sand into the well and it also enables the use of large slot sizes for the screens or perforated sections, thus reducing well losses. Gravel packs improves the hydraulic conductivity/permeability of the area surrounding the screen and also increases the effective radius of the well.

Gravel pack may consist of uniform or graded material. Uniform gravel can be poured into the borehole from ground surface, as long as bridging between screen and hole wall is avoided. Coarse sand may also be used as gravel pack material. But quarried rock and granite should be avoided as gravel pack material.

GROUNTING

Cementing or grouting of wells, is accomplished by pumping or otherwise placing a cement slurry between casing and hole wall,it is done to prevent polluted surface water or low-quality water from other aquifers from seeping along the outside of the casing and contaminating the well or aquifer. Grouting also anchors the casing inside the borehole, prevents the caving in of the land around the well in unstable materials and enables better development of the productive aquifer section around the well screen because the rest of the well is sealed off.

The cement slurry normally used for grouting is a mix of about 45 to 55 litres of water per 100kg of cement.

BOREHOLE DEVELOPMENT

The final phases of well construction are development and sterilization of the well to produce water free from pathogenic organisms, and also well stimulation, if well yields should be increased.

Well development is the removal of sand and other fines (including drilling mud) from the aquifer around the well by surging, jetting, intermittent pumping, backwashing, and other actions which move the fines into the well so that they may be baited or pumped out. The objective of well development is to create a 'developed' or natural filter zone around the well screen or gravel pack that prevents further movement of aquifer particles into the well and that is more permeable than the aquifer itself. The developed zone is coarsest at the screen or envelope surface and grades back gradually to the original aquifer material.

The common techniques used for borehole development in the state are the backwashing method, and air jetting.

In backwashing water is pumped through the well casings, out through the screens and come to the surface through the annular space between the casings and borehole wall, this effectively removes the chemical used and any fine particle. The process is continued till the water becomes clean, at which stage the pressure is reduced and gravel added gradually till completely filled up.

In air jetting, compressed air is introduced into the hole at high pressure. The air forces out all the water and fines in the well to the surface. When the water has become clean and sand free, the compressor is shut down and the flushing pipes pulled out.

WELL STERILISATION

The last step in well construction is disinfection to kill bacteria and viruses that invariably have entered the well. Drilling equipment, casing, screens etc. collect micro-organisms from contact with the ground, handling by humans, animal droppings etc. Also bacteria and viruses enter the hole with soil and other materials that fall in during construction, and with surface water that runs into the hole.

Disinfection is normally done with chlorine solution of about 50 to 200 mg/l, obtained by adding a solution of sodium hypochlorite or by dissolving calcium hypochlorite or chlorine gas in the water.'

For any drilling chemical that might be left unremoved from the borehole, Barafos® may be added, this loosens up any remaining chemical and allows them to settle in the sand pipe.

The sterilised borehole is then sealed and opened only for pumping tests and installation of pump.

PUMPING TESTS

The principle of a pumping test is that if we pump water from a well and measure the discharge of the well and the drawdown in the well and in piezometers at known distances from the well, we can substitute these measurements into an appropriate well-flow equation and can calculate the hydraulic characteristics of the aquifer.

A pump has to be installed to lift out the water, the pump and power unit should be capable of operating continuously at a constant discharge for a period of at least a few days. The capacity of the pump and the rate of discharge should be high enough to produce good measurable drawdown.

The water delivered by the well should be prevented from returning to the aquifer. This can be done by conveying the water through a large diameter pipe, say over a distance of 100 or 200m, and then discharging it into a canal or natural channel.

The measurements to be taken during a pumping test are of two kinds:

- Measurement of water in the well and piezometers
- Measurement of the discharge rate of the well.

Pumping test have been conducted for most boreholes drilled in the state, the most comprehensive was that done by Biwater, NSADP on tubewells, PTF rural water scheme and most motorized boreholes. However it must be stated that pumping test data for the state is not comprehensive and as such is not immediately available to this author.

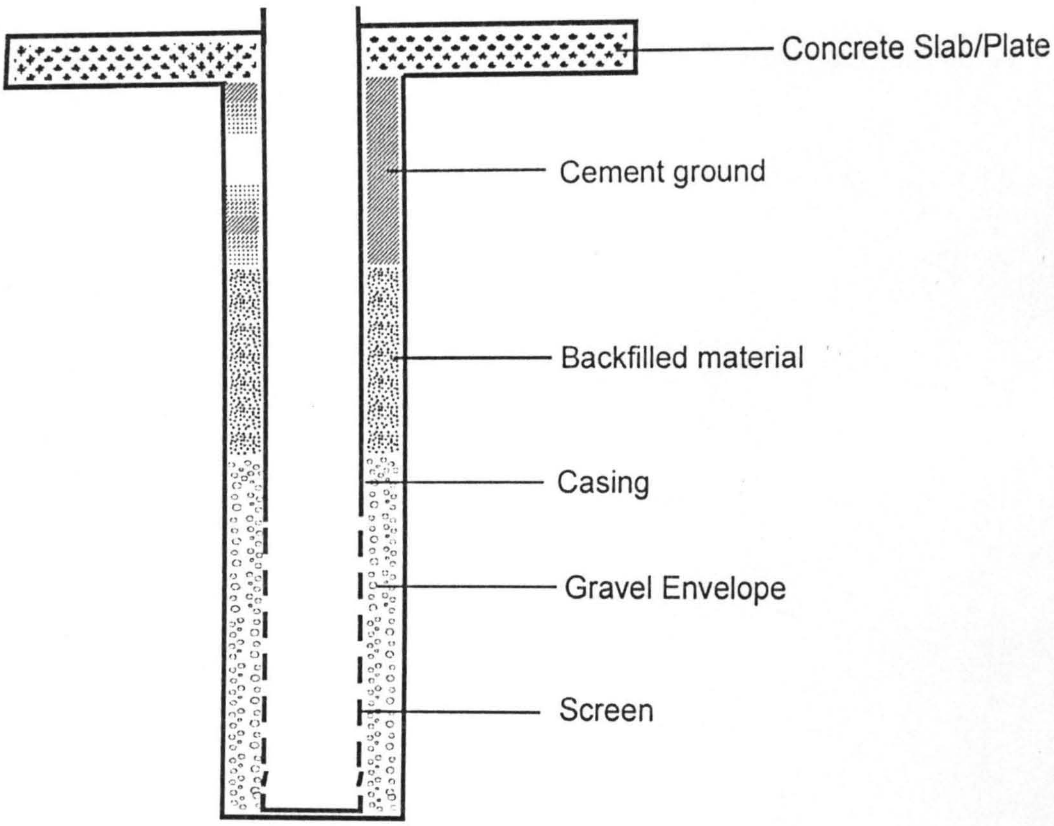
Pumping tests are necessary to determine the hydraulic characteristics of the borehole, such as specific yield, storativity, transmissivity etc. This helps in making water budgets and determining the type and capacity of pump to be installed.

PUMPS

The commonest kinds of pumps in use are electrical submersible pumps and manual hand pumps. About 80% of the boreholes drilled in the state, especially in the rural and semi-urban areas are fitted with India mark II hand-pumps while the remaining are installed with submersible pumps, a few are installed with powered pumps in rural areas.

The India mark II pumps have been found to be very reliable and efficient. Installation, operation and maintenance are very easy, parts are affordable and locally available and personnel are trained at village level to carry out maintenance.

Submersible pumps are mostly installed by individuals and industries and are mostly confined to the urban areas. The Biwater Scheme comprises of a number of wells installed with submersible pumps and all connected to central reservoir (Tower) from where it is distributed. The scheme was a complete package comprising of wells, pumps, pump stations, generator houses, water treatment plants and reticulation networks. The Biwater towers can be seen dotting the skyline of the various parts of the state and was a very successful programme.



SECTION THROUGH A COMPLETED BOREHOLE

CHAPTER THREE

3.0 GROUNDWATER USE AND MANAGEMENT

3.1 GROUNDWATER USE

Groundwater has been an important water resource throughout the ages. Today, groundwater is a major source of water for many municipalities and farms. In Niger State, groundwater is estimated to supply water for over 70% of the population. About half of the public water supply systems use groundwater, and groundwater is essentially the only water source for the over 2 million people in the rural areas of the state. As with any natural resource, groundwater supplies are not unlimited. They must be wisely managed and protected against undue exploitation and contamination by pollutants.

3.1.1 DOMESTIC USES

The greatest use of groundwater in rural, suburban and urban areas is for domestic purposes. It is chiefly used for drinking, washing, laundry, cooking and other household utility.

It is estimated that an average adult uses about 148 litres or 37 gallons for this purpose daily, with an average population of three (3) million people depending on groundwater for their water needs, it is estimated that an average 5 million litres or 1.2 billion gallons of water is required daily.

All the water projects initiated by the state are geared towards satisfying this need. The healthcare delivery of the populace is also hinged directly to the kind of water they drink. A scourge of guineaworm hit the state some years back, rendering thousands of farmers and able bodied young men useless and unproductive, this greatly affected the agricultural output of the state, since agricultural is the mainstay of the state's economy. This scourge resulted into an adverse effect on the state's economy. Guinea-worm is directly caused by infected drinking water. This prompted UNICEF in conjunction with the Niger State government to initiate a wide borehole programme, starting with the affected areas and spreading to the rest part of the state. This programme led to the formation of the Rural Water Supply and Sanitation Agency (RUWATSAN) which was charged with the provision of boreholes and other ground-water development sources.

3.1.2 INDUSTRIAL USES

Though Niger State is mostly an agrarian state, the few industries in the state depend to a large extent on groundwater for their water needs.

The MInna Pharmaceutical Company and Dana Pharmaceuticals all use groundwater for processing and manufacturing their drugs, all major hospitals, especially the general hospital in Minna depend on groundwater for producing dextrose saline and other drugs. Imurat International, manufacturers of plastic products depend also largely on groundwater for their production, IBB Specialised Hospital also utilizes groundwater for their various water requirements.

Apart from these, light packaging industries using borehole water have sprang up all over the state. With NAFDAC's stringent rule on packaged water – otherwise known as '*pure water*' – many had to utilize borehole water that has been chemically certified fit for human consumption. The booming pure water business has created a lot of job opportunities for the producers and the vendors alike, it has been used widely for various purposes including ceremonial occasions.

Others that have found jobs through the use of groundwater are water vendors, these load barrows with jerry cans of water for sale to the public. These vendors can be found virtually in every part of the country, especially at periods where water scarcity is being experienced, they have greatly alleviated the stress involved in search for water, while at the same time creating employment for themselves.

Also light industries for the production of such local drinks like *sobo*, yogurt, *kunun zaki* etc. to a great extent depend on groundwater sources.

3.1.3 IRRIGATION

Dry season farming has been practiced since ancient times, using various irrigation methods: most commonly farms are located near streams and rivers where water is lifted by a system known as '*Shaduf*' from the stream to channels created throughout the farm. In areas such as ancient Egypt, apart from the *shaduf*, Tunnels or '*foggaras*' are dug into slopes until groundwater is reached, *Tamburs* were also used to draw water from wells to the catchment basin. The Persian wheel or *Sakya* was used to draw water from very deep wells for irrigation purposes using farm animals like oxen.

Niger State has also practiced its own kind of dry season farming through various irrigation programmes. This ranges from small scale household garden, individual irrigated farms to large community farms. The Upper Niger River Basin Development Authority (UNRBDA), Niger State Agricultural Development Project (NSADP) and the defunct Directorate for Foods, Roads and Rural Infrastructures (DFFRI) have all contributed immensely towards dry season farming. River Basin provided dams, such as the Swashi dam, while the NSADP exploited the use of groundwater for irrigation through the provision of boreholes and tubewells. Most other individuals have also had boreholes placed in their farms for irrigation and animal drinks. Notable among such farms are Abdulsalam Farms, Nasko Farms, Kure Farms, Garba Duba Farms to mention but a few. These are all large scale agricultural and poultry farms that have come to depend entirely on groundwater for their farming requirements. Most Abattoirs, like the

Mokwa Ranch and Abattoir also depend mostly on the use of groundwater for their water requirements.

However the average farmer has not benefited from the use of groundwater for irrigation purposes, this is mostly attributable to the high cost of drilling a borehole, installing of pumps and power plants and also overhead reservoirs, and this is beyond the income of the average farmer. The use of groundwater in various aspects of a man's life cannot be overemphasised. The current trend in drilling of boreholes by individuals and organisations all over the country, especially in Abuja and its environs, testify to the popularity the use of groundwater is gaining.

Groundwater has been discovered to be clean, reliable – water when you need it, how you need it and where you need it. It can virtually be used without further treatment, except in contaminated areas, it is also cheap and reliable. Various public water corporations across the country have failed in their public water supply, with water supply being mostly erratic and epileptic. This led to the focusing of attention, by those who can afford them and state and federal governments, to the use of groundwater as an alternative source of water supply. In some other areas, like Borno State, water supply is solely based on groundwater, where deep wells are needed to reach the aquifers. In Niger State the whole of the rural areas, where over 80% of the population live rely on groundwater and perennial streams for their water supply.

3.2 GROUNDWATER MANAGEMENT

Groundwater is a resource that must be properly utilised and managed. Though seemingly groundwater is considered by some as inexhaustible, this is far from the truth. Groundwater can be exhausted if not properly managed.

Groundwater like any other natural resource, needs the right geological environment to collect, and it takes a long time for the aquifer to be completely saturated and even a longer time for the depleted aquifer to be recharged. Once an aquifer is penetrated by a well, discharge and lowering of the water table begins, once forces of discharge and recharge do not eventually balance out groundwater mining begins. Mining, it should be recalled, is a process whereby a material is removed without being replaced. Groundwater mining eventually leads to complete exhaustion of the aquifer and wells placed in that aquifer would no longer be capable of being productive.

3.3 GEOLOGICAL CONSTRAINTS

Nature is so designed that conditions may be favourable for one resource in one area and unfavourable for that same resource in a different area. This accounts for the reason why there is oil in the Niger Delta and none in the North, this also accounts for the reason why the water in the Niger Delta is mostly brackish water and salty. In the Northern part of the country groundwater situation is more promising as it is mostly fresh and none saline.

The geological constraint imposed on groundwater flow is that of reservoir potential. The right condition must exist for groundwater to be stored and transmitted in a geological medium. In some areas this condition exists, while in some other areas this condition does not exist.

In the sedimentary terrain groundwater flow is slow and laminal, through the pore spaces or voids in between the particles that make up the aquifer. Thus it takes several years for groundwater to move for a distance of just one meter, while in some others, like cohesionless or loose sand, like in alluvial deposits, groundwater flow is faster.

In crystalline rock terrain on the other hand, groundwater flows through fracturing, joints and fissures in the rock, for groundwater to exist in such fractures, they must have a hydraulic contact with recharge zones, else they will remain empty.

In some areas, the right conditions may exist for the storage and transmission of groundwater, but the rock may be devoid of any water or is unsaturated like the case in Mashegu and Matane areas of the state and some parts of Kontagora.

In such areas, the little water that is available must be properly managed and utilized, in view of the geological constraint imposed on the area, borehole proliferation should also be avoided. In some cases the situation may be so bad as to preclude any groundwater use in the area.

3.4 RECHARGE POTENTIAL

Niger State falls within the semi-arid area of Nigeria. This area experience periods of rainfall and dry season. Rain falls for about seven months in a year, while the remaining five months is a period with no rains at all.

Groundwater recharge is commonly through rainfall and streams or rivers that have a hydraulic contact with the groundwater system. The streams and rivers are also mostly perennial, they flow in the rainy season and dry up at the peak of the dry season. This is also the period in which there is marked drop in water levels in wells and boreholes. Coincidentally, the dry season is also a period in which water demand is higher. Because of the rise in temperature, people sweat a lot, takes a lot of water and wash more often than in the rainy season.

Dry season is a period in which water conservation and management should be given more attention. Because of the drop in water level in streams which are used for public water supply, pumping of water to the public becomes more erratic due to the low water level and more reliance will be on groundwater supply. This accounts for the reason why most people prefer boreholes to be drilled in the dry season, because of the general belief that some boreholes will only encounter rainy season water tables and tend to dry up in the dry season, thus defeating the aim of drilling them in the first place.

It should also be noted that due to the slow movement of groundwater, it will take the whole of the rainy season for the aquifer to be charged to its saturation point, in cases where discharge from boreholes is very high with a corresponding high demand the aquifer may not be able to be replenished to its full saturation point. This may eventually lead to a drop in borehole yield and eventual drying up of the well before the peak of the dry season.

3.5 PROLIFERATION OF WELLS AND BOREHOLES

Proliferation of wells and boreholes in any given area place a high demand on the aquifer. The aquifer is not allowed enough time to be recharged before water is withdrawn, this has led to the drying up of some aquifers, and therefore rendering boreholes put in them unproductive. The case is even more pronounced in boreholes, as hand dug wells are mostly shallow and utilise water contained in the saturated zones. Boreholes however tap their water from aquifers some of which are deep seated.

The current trend of uncontrolled drilling of boreholes in most urban areas of the state is causing a lot of harm on the aquifer.

Borehole proliferation in an area may eventually lead to contamination of the aquifer, which may lead to groundwater pollution contaminated aquifers are very difficult to clean, and it takes a long period of time to restore an aquifer to its original form.

In the rural areas the case is somewhat different, most boreholes in rural areas seldom exceed one or two and are fitted with hand-pumps, with only very few fitted with solar powered pumps. The rate of discharge of a hand-pump is low, and recharge is allowed to take place before further discharge. In motorised wells on the other hand discharge is very high and drawdown very fast. Motorised boreholes therefore causes the most harm on the aquifer, as sufficient time is not allowed for aquifer recharge before being extracted.

3.6 GROUNDWATER CONTAMINATION

Groundwater is one of the purest sources of water, it is used mostly in its natural form without recourse to further treatment. It is thus the cheapest and purest source of water available to mankind.

Groundwater can also become contaminated. Due to the slow moving nature of groundwater, the contamination plume does not spread quickly, and in some cases may become dissipated before it gets too far from the source of contamination.

Groundwater contamination can be as a result of natural factors, like saline water, or water coming in contact with a geological material which it can dissolve easily. It can also occur artificially through the activity of man. Various human activities that lead to groundwater contamination includes mining, where groundwater is exposed to various chemicals and mining tools; Agriculture, this involves the application of fertilisers, herbicides and pesticides to farmland and eventually joins the water table; oil spillages; uncontrolled and unplanned refuse disposal systems; decaying human corpses in cemeteries and a host of others.

Moderate amounts of these contaminants does not however cause much damage to the aquifer, due to natural filtration that takes place as the water makes its way painstakingly through pores and voids in the rock. However care should be taken in siting the wells, to avoid areas where these pollutants occur such as close to septic tanks, or digging wells close to pit latrines, graveyards and so on.

3.7 GROUNDWATER CONSERVATION

Groundwater is one of the greatest gifts God has bestowed on mankind, as such efforts should not be spared in the protection and conservation of this essential natural resource. Groundwater is the least resource that mankind depends on o satisfy his water needs. In fact water is often the first thing considered in siting new villages and settlements.

All contamination sources should be avoided or reduced to the barest minimum, chemicals compatible to the soil type and climatic conditions should be used in farms, good refusal disposal methods should be adopted and water sources not located near pit latrines and septic tanks or soak-away.

Groundwater should be used wisely and avoid waste of water. Once water is used economically it will reduce demand for water and consequently demand on the aquifer.

Groundwater and other mining laws should be made available to the general public and these laws should be seen to be implemented, as groundwater is considered part of the countries natural resources, as such laws have being made to conserve and protect this vital resource.

CHAPTER FOUR

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

Groundwater has been extensively developed in all parts of Niger State through individuals, local government, state and federal government efforts since its creation in 1976. Individuals have had hand dug wells placed within homes and farms and concrete lined hand dug wells or '*kwakwara*' wells were also provided as community water points.

Extensive geophysical surveys for groundwater conducted in various parts of the state showed a great potential for groundwater in some areas and low potential for some others. The basement complex areas generally have a low to medium groundwater potential, while the sedimentary areas have a higher potential. Since the state is divided almost sub-equally by these two geological terrains, it follows that groundwater development is higher in some areas and lower in other areas.

Rainfall distribution is almost the same all year round all over the state, with peak rainfalls experienced In September and October. These are periods of groundwater recharge, which tend to be higher in the sedimentary areas and lower in the basement complex areas, except In areas with a high overburden, due to the crystalline nature of the rock which precludes rainfall percolation.

Active drilling for boreholes was commenced during the Alh. Shehu Shagari/Awwal Ibrahim's administration with the provision of water through multiple borehole schemes, these were the popular Biwater towers. The spread of guinea-worn led to the creation of the RUWATSAN project by UNICEF and Niger State government, the duty of the project was to eradicate guinea-worm through the provision of boreholes. The programme became highly successful and today guinea-worn has virtually being eradicated.

Groundwater has been used extensively in the state for domestic, industrial, commercial and agricultural purposes. A groundwater recharge period of about seven months is followed by a five months period of no rainfall at all. This is a period in which water use increases sharply, as urban water supplies experience drop in water levels, and shallow wells dry up. Reliance on boreholes increases with a corresponding decline in the water table due to gradual depletion of water in the aquifer. Groundwater, like any other resource, becomes completely depleted and exhausted if not properly used and managed. Groundwater is one of the purest forms of water, its mode of occurrence ensures proper filtration and purification and is also the cheapest and most reliable form of water supply. It is our collective responsibility to protect and preserve this essential resource, as it may end up becoming the only resource we may eventually al rely on.

4.2 RECOMMENDATIONS

The local geology of Niger State is generally favourable for groundwater development through the use of wells, tubewells and boreholes. It is therefore recommended that;

4.2.1 First of all the government should, through the necessary agency, ministry or parastatal take a census of all boreholes, wells, tubewells and springs in the state, including their locations on a generalised map of the state. This will go a long way in determining the hydrogeological parameters of the state and general water use.

4.2.2 Borehole drilling programmes should be well coordinated and controlled, this will reduce the incidence of proliferation of boreholes in one area and over dependence on a particular aquifer.

4.2.3 People living in areas to be supplied with boreholes or close to water points should be educated on basic hygiene and excreta disposal methods to protect groundwater sources. Also the urban development board should wake up to their task of safe sewage disposal methods to protect our groundwater from contamination.

4.2.4 Government should mobilise the public, through the necessary agency, on ways of groundwater use and management, especially in the dry season, this will lead to less water wastage and conservation of our water resources.

4.2.5 Finally, government should endeavour to educate the public and enforce water laws. These laws, though very much a part of our constitution, has being virtually neglected, enforcing the laws will ensure the protection and conservation of our groundwater resources.

The results of the questionnaires are summarised in the following table.

House -hold No.	Famil y Size	WATER USE (Gallons)/Individual						Total
		Washin g	Laund ry	Cookin g	Drinki ng	Animal s	Other s	
1	14	5	12	4	1	3	12	37
2	4	5	4	2	1	-	3	15
3	7	12	10	3	1	4	-	30
4	6	7	6	3	1	4	3	30
5	9	10	12	3	2	4	20	51
6	14	4	12	4	2	3	12	37

From this table, which is just a representative set from various locations, it could be seen that an average daily consumption of water by an individual is about 30 gallons. Considering the water requirements of some households, which comprise of over 10 individuals, water need is quite enormous. As such all efforts should be made to conserve and protect the water resources of an area by proper planning and water budget. The beneficiaries should be educated on ways of managing available water resources and conservation.

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QUESTIONNAIRE

GROUND WATER USE AND MANAGEMENT

NAME: Musa Karbau

OCCUPATION: Farming

ADDRESS / VILLAGE: Mariga

STATUS: (A) ✓ Landlord (B) Tenant *(please tick)*

If Landlord number of Tenant in household: 13

If Family head number of Wives/Children 3 wives, 10 children

Source of Water: (a) Pipe borne (b) Borehole (c) Well (d) Others (Please Specify) Borehole and Well

Amount of water used by individual for

			lt	Gal
(a)	Washing (Bathing)	1 Bucket	20	4
(b)	Ablution (if Muslim)		4	1
(c)	Washing (Laundry)	3 Buckets	60	12
(d)	Cooking		20	4
(e)	Drinking		4	1
(f)	Animal Drinks (Specify)	Goats		3
(g)	Others (Specify)	Irrigation of garden		12

Total daily water consumption by individual 148 lt 37 Gal

Total daily consumption of household 1976 lt 494 Gal

Average daily consumption 2000 lt 500 Gal

Signed

Musa

QUESTIONNAIRE

GROUND WATER USE AND MANAGEMENT

NAME:--ADAMU MAAJI--------------------

OCCUPATION: --CIVIL SERVANT--------------

ADDRESS / VILLAGE: --MAIKUNKELE BOSSO LOCAL GOVT.--

STATUS: (A) ✓ Landlord (B) Tenant *(please tick)*

If Landlord number of Tenant in household: --15 PEOPLE--

If Family head number of Wives/Children--ONE WIFE 14 CHILDREN--

Source of Water: (a) Pipe borne (b) Borehole (c) Well (d) Others (Please Specify)-

----

Amount of water used by individual for

(a) Washing (Bathing) ------5000------ ----------lt--------------- -Gal--------------

(b) Ablution (if Muslim) ------100------ -------lt --------------- Gal--------------

(c) Washing (Laundry)------2000------ lt --------------- --Gal--------------

(d) Cooking ------2000------ ---------- lt ------------ -- Gal--------------

(e) Drinking ------2000------ -------- lt ------------ ----Gal--------------

(f) Animal Drinks (Specify) ---2500--- ---- lt ------------- --Gal--------------

(g) Others (Specify) ----2000---- ----- ----- --- lt ----------------Gal--------------

Total daily water consumption by individual-1000 lt ------------ Gal-------------

Total daily consumption of household 3000---- lt ---------- ---Gal-------------

Average daily consumption---5000----------------- lt ----------- -Gal--------------

Signed

--(signature)------------------

QUESTIONNAIRE

GROUND WATER USE AND MANAGEMENT

NAME:----------BALA ISAH---

OCCUPATION: ----FARMER---

ADDRESS / VILLAGE: ----------KATCHA------------------------------------

STATUS: (A) Landlord (B) Tenant *(please tick)* ✓ (B)

If Landlord number of Tenant in household: ----------Tenant----------------

If Family head number of Wives/Children----------1/4-----------------------

Source of Water: (a) Pipe borne (b) Borehole (c) Well (d) Others (Please Specify) ✓ (b)

Amount of water used by individual for

(a)	**Washing (Bathing)** ----------3----------	----60---lt	---------------	-Gal-------------
(b)	**Ablution (if Muslim)** ----------------------	10-----lt	----------------	Gal----------
(c)	**Washing (Laundry)**-------------------------	60---- lt	-------------	--Gal----------
(d)	**Cooking** ---------------------------------	40---- lt	------------ --	Gal----------
(e)	**Drinking** ---------------------------------	40---- lt	------------	----Gal------------
(f)	**Animal Drinks (Specify)** ------------ -	50---- lt	-------------	--Gal-------------
(g)	**Others (Specify)** ---------------	------ 100 --- lt	---------------	Gal-------------

Total daily water consumption by individual------- lt ------------ Gal-------------

Total daily consumption of household --------------- lt ----------- ---Gal-------------

Average daily consumption----------------------------- lt ----------- -Gal-----------

Signed

QUESTIONNAIRE

GROUND WATER USE AND MANAGEMENT

NAME:---- HAROUNA ABUYALI ----

OCCUPATION: ---- C/SERVANT ----

ADDRESS / VILLAGE: ---- RUWATSAN PROJECT MINNA ----

STATUS: (A) Landlord (B) Tenant *(please tick)*

If Landlord number of Tenant in household: ---- — ----

If Family head number of Wives/Children---- One wife, two children

Source of Water: (a) Pipe borne (b) Borehole (c) Well (d) Others (Please Specify)-

----

Amount of water used by individual for

(a)	Washing (Bathing)	15	lt	Gal
(b)	Ablution (if Muslim)	10	lt	Gal
(c)	Washing (Laundry)	20	lt	Gal
(d)	Cooking	10	lt	Gal
(e)	Drinking	8	lt	Gal
(f)	Animal Drinks (Specify)	—	lt	Gal
(g)	Others (Specify) Toilet	15	lt	Gal

Total daily water consumption by individual	78	lt	Gal
Total daily consumption of household	312	lt	Gal
Average daily consumption	280	lt	Gal

Signed

[signature]

QUESTIONNAIRE

GROUND WATER USE AND MANAGEMENT

NAME: IBRAHIM INUWA

OCCUPATION: TRADER

ADDRESS / VILLAGE: DIKO

STATUS: (A) Landlord (B) Tenant *(please tick)*

If Landlord number of Tenant in household: SIX 6

If Family head number of Wives/Children 1 wife and two childe

Source of Water: (a) Pipe borne (b) Borehole (c) Well (d) Others (Please Specify)

Amount of water used by individual for

			lt	Gal
(a)	Washing (Bathing)	Twaise a day	2 boket	10
(b)	Ablution (if Muslim)	Five daily	10 litre	2
(c)	Washing (Laundry)	Once a day	40 litre	10
(d)	Cooking	three times a day	12 "	3
(e)	Drinking		20 "	4
(f)	Animal Drinks (Specify)		20 "	4
(g)	Others (Specify)			

Total daily water consumption by individual ------- lt ------------ Gal-------------

Total daily consumption of household --------------- lt ----------- ---Gal-------------

Average daily consumption------------------------------ lt ----------- -Gal------------

Signed

QUESTIONNAIRE

GROUND WATER USE AND MANAGEMENT

NAME: Mal: Abubakar Ibrahim Suleja

OCCUPATION: Farmer

ADDRESS / VILLAGE: Angwan kayi / Suleja

STATUS: (A) Landlord (B) Tenant (please tick)

If Landlord number of Tenant in household: —

If Family head number of Wives/Children 1 / 4

Source of Water: (a) Pipe borne (b) Borehole (c) Well (d) Others (Please Specify)

Amount of water used by individual for

(a)	Washing (Bathing)	lt 84	Gal
(b)	Ablution (if Muslim)	lt 20	Gal
(c)	Washing (Laundry)	lt 64	Gal
(d)	Cooking	lt 30	Gal
(e)	Drinking	lt 10	Gal
(f)	Animal Drinks (Specify)	lt 20	Gal
(g)	Others (Specify)	lt –	Gal

Total daily water consumption by individual ------- lt ------------ Gal

Total daily consumption of household -------------- lt ---------- Gal

Average daily consumption ------------------------ lt ----------- Gal

Signed

QUESTIONNAIRE

GROUND WATER USE AND MANAGEMENT

NAME:---ABUBAKAR SIADIQ IBRAHIM KHALIFA ISLAMI---------
OCCUPATION: ---------FARMER---------------------------------
ADDRESS / VILLAGE: ---MOKWA RAILWAY STATION---------------------
STATUS: (A) Landlord (B) Tenant *(please tick)*
If Landlord number of Tenant in household: --------9---------------------------
If Family head number of Wives/Children-------------3/6------------------------
Source of Water: (a) Pipe borne (b) Borehole (c) Well (d) Others (Please Specify)-

----

Amount of water used by individual for

(a)	Washing (Bathing)	lt 56	Gal
(b)	Ablution (if Muslim)	lt 20	Gal
(c)	Washing (Laundry)	lt 45	Gal
(d)	Cooking	lt 30	Gal
(e)	Drinking	lt 10	Gal
(f)	Animal Drinks (Specify)	lt 40	Gal
(g)	Others (Specify) watering of flowers.	lt 100	Gal

Total daily water consumption by individual------- lt ---301---- Gal-------------
Total daily consumption of household -------------- lt ---------- ---Gal-------------
Average daily consumption----------------------------- lt ----------- -Gal-------------

Signed

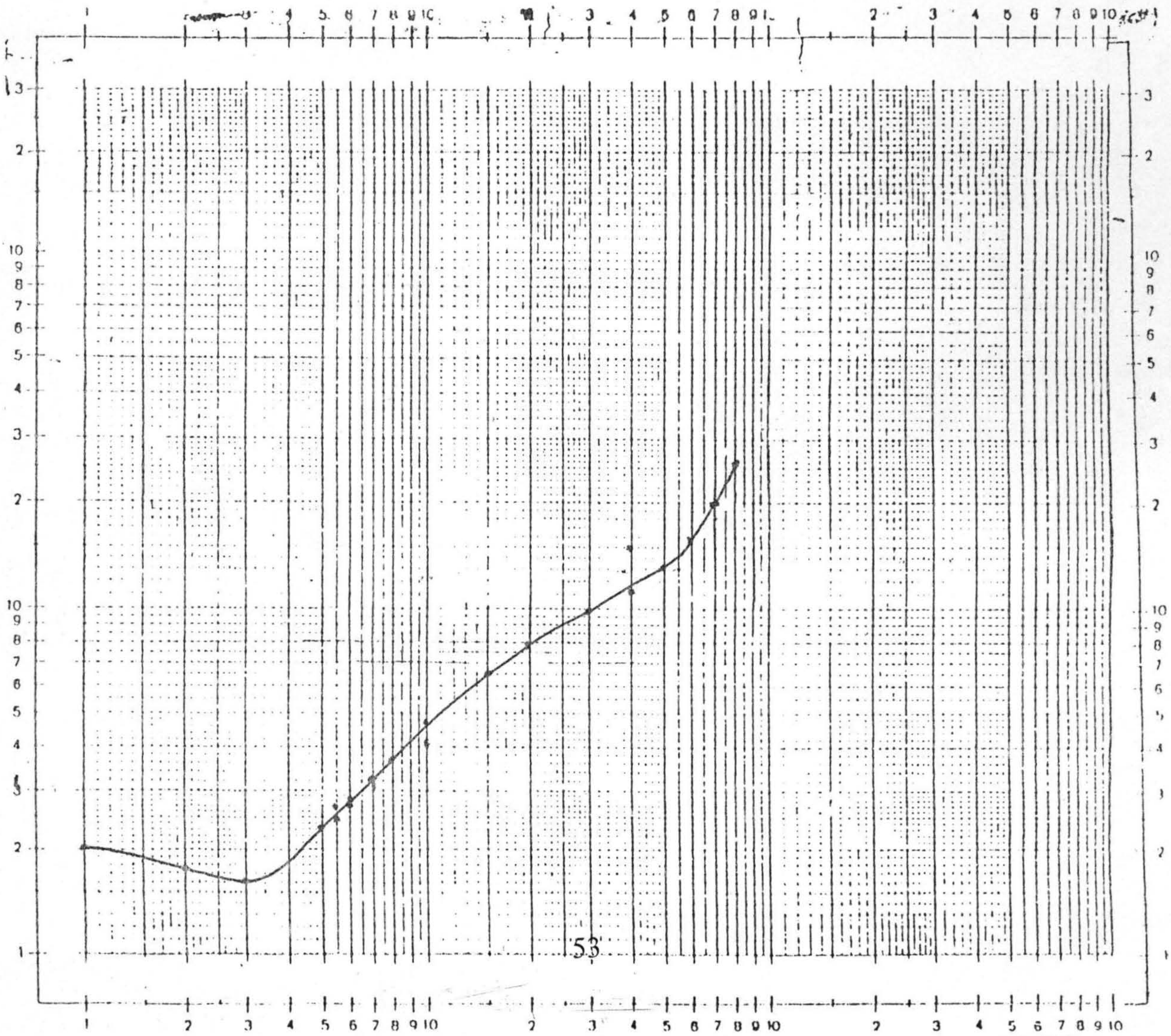
VERTICAL ELECTRICAL SOUNDING DATA ENTRY FORM

Locality: NEW BUSSA LGA: BORGU State: NIGER
Surveyed By: A. IDRIS Date: 18/05/02 VES No.: BRG/009/05/02
ALT ______ Latitude ______ Longitude ______ Azimuth ______

$K = (AB/2)^2 - (MN/2)^2\ 3.1415/MN$

$\rho a = KR\ R = V/I$

Electrode Spacing (m) AB/2	MN/2	Geometric Factor (k)	Resistivity (ρ) Ω	Apparent Resistivity (ρa) Ω-m	Interpretation: Layer res. Ω-m	Interpretation: Geoelectric Layer	Well Design
1	0.50	2.36	8.898	21			
2	"	11.8	1.441	17			
3	"	27.5	0.582	16			
5	"	77.8	0.295	23			
6	"	112	0.223	25			
6	1.00	55	0.509	28			
8	"	99	0.363	36			
10	"	156	0.288	45			
10	2.50	58.9	0.679	40			
15	"	137	0.477	65			
20	"	247	0.319	79			
30	"	562	0.174	98			
40	"	1001	0.110	110			
40	7.50	323	0.464	150			
50	"	512	0.238	122			
60	"	742	0.215	.160			
70	"	1014	0.197	200			
80	"	1329	0.189	251			
80	15	647					
90	"	825					
100	"	1024					
110	"	1244					
120	"	1488					
130	"	1746					



VERTICAL ELECTRICAL SOUNDING DATA ENTRY FORM

Locality SULEJA LGA SULEJA State NIGER

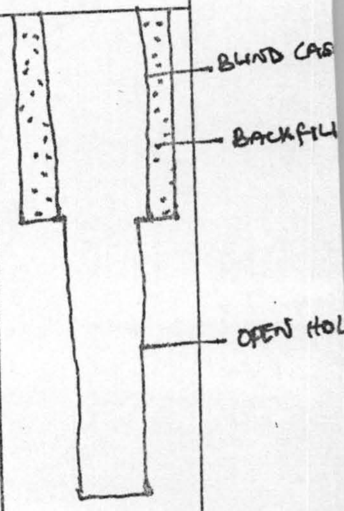
Surveyed By A. IDRIS Date 28/04/02 VES No. SUL/003/04/02

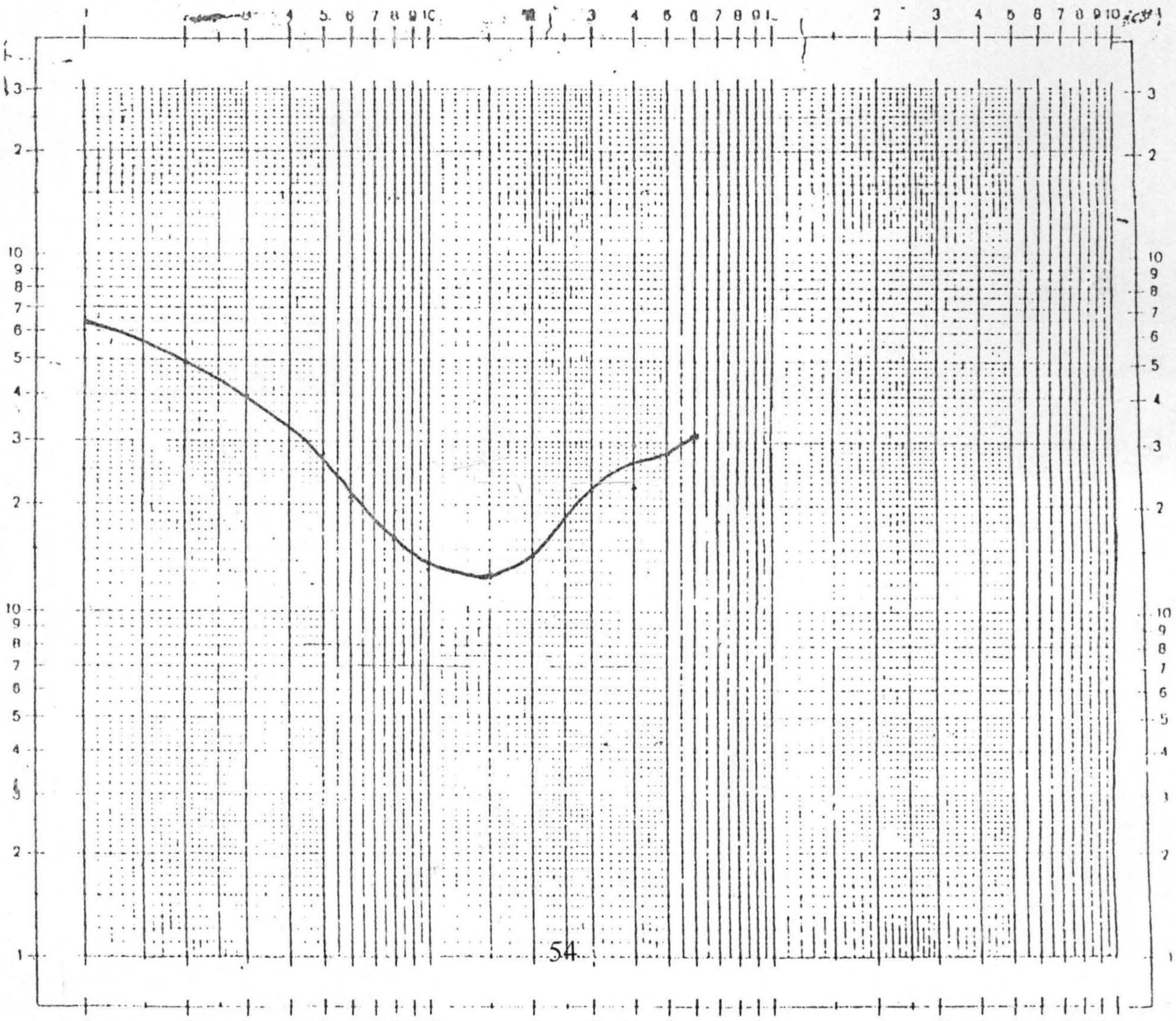
ALT 554m Latitude E006.99762° Longitude N09.46397° Azimuth 015°N

$K = (AB/2)^2 - (MN/2)^2\ 3.1415/MN$ $\rho a = KR\ R = V/I$

Electrode Spacing (m) AB/2	MN/2	Geometric Factor (k)	Resistivity (ρ) Ω	Apparent Resistivity (ρa) Ω-m	Interpretation: Layer res. Ω-m	Geoelectric Layer
1	0.50	2.36	268	632	600	
2	"	11.8	41.81	493		
3	"	27.5	14.51	399		
5	"	77.8	3.553	276		
6	"	112	1.877	210		
6	1.00	55	3.726	204		
8	"	99	1.637	162		
10	"	156	0.863	134		
10	2.50	58.9	2.372	139		
15	"	137	0.937	128		
20	"	247	0.589	145		
30	"	562	0.390	219	130	
40	"	1001	0.293	293		
40	7.50	323	0.712	229		
50	"	512	0.540	276		
60	"	742	0.430	319		
70	"	1014				
80	"	1329				
80	15	647			300	
90	"	825				
100	"	1024				
110	"	1244				
120	"	1488				
130	"	1746				

Well Design





VERTICAL ELECTRICAL SOUNDING DATA ENTRY FORM

Locality: LAPAI LGA: LAPAI State: NIGER

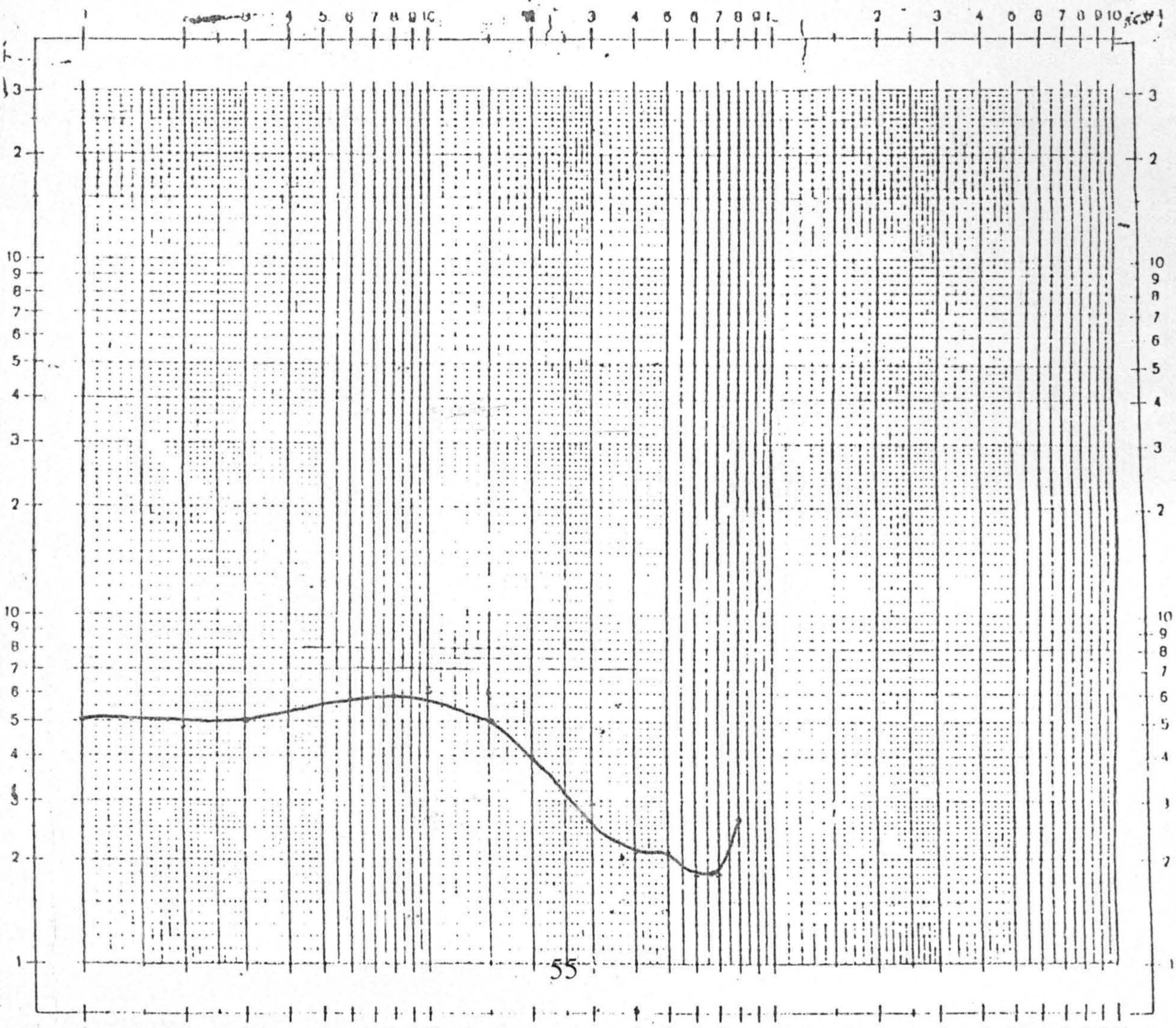
Surveyed By: A. IDRIS Date: 13/04/02 VES No.: LAP/008/04/02

ALT: 187m Latitude: E006. 37201° Longitude: N09. 03882° Azimuth: 240°SW

$K = (AB/2)^2 - (MN/2)^2$ 3.1415/MN

ρa=KR R = V/I

Electrode Spacing (m) AB/2	MN/2	Geometric Factor (k)	Resistivity (ρ) Ω	Apparent Resistivity (ρa) Ω-m	Interpretation: Layer res. Ω-m	Geoelectric Layer	Well Design
1	0.50	2.36	22.91	51	50		
2	"	11.8	4.067	48			
3	"	27.5	1.812	50			
5	"	77.8	0.716	56			
6	"	112	0.518	58			
6	1.00	55	1.048	58	50		
8	"	99	0.595	59			
10	"	156	0.323	50			
10	2.50	58.9	0.902	53			
15	"	137	0.374	51			
20	"	247	0.163	40			
30	"	562	0.051	29			
40	"	1001	0.021	21			
40	7.50	323	0.114	37	25		
50	"	512	0.042	21			
60	"	742	0.025	18			
70	"	1014	0.018	18			
80	"	1329	0.020	27			
80	15	647					
90	"	825					
100	"	1024			30		
110	"	1244					
120	"	1488					
130	"	1746					



VERTICAL ELECTRICAL SOUNDING DATA ENTRY FORM

Locality ODUOYE QTRS LGA MINNA State NIGER

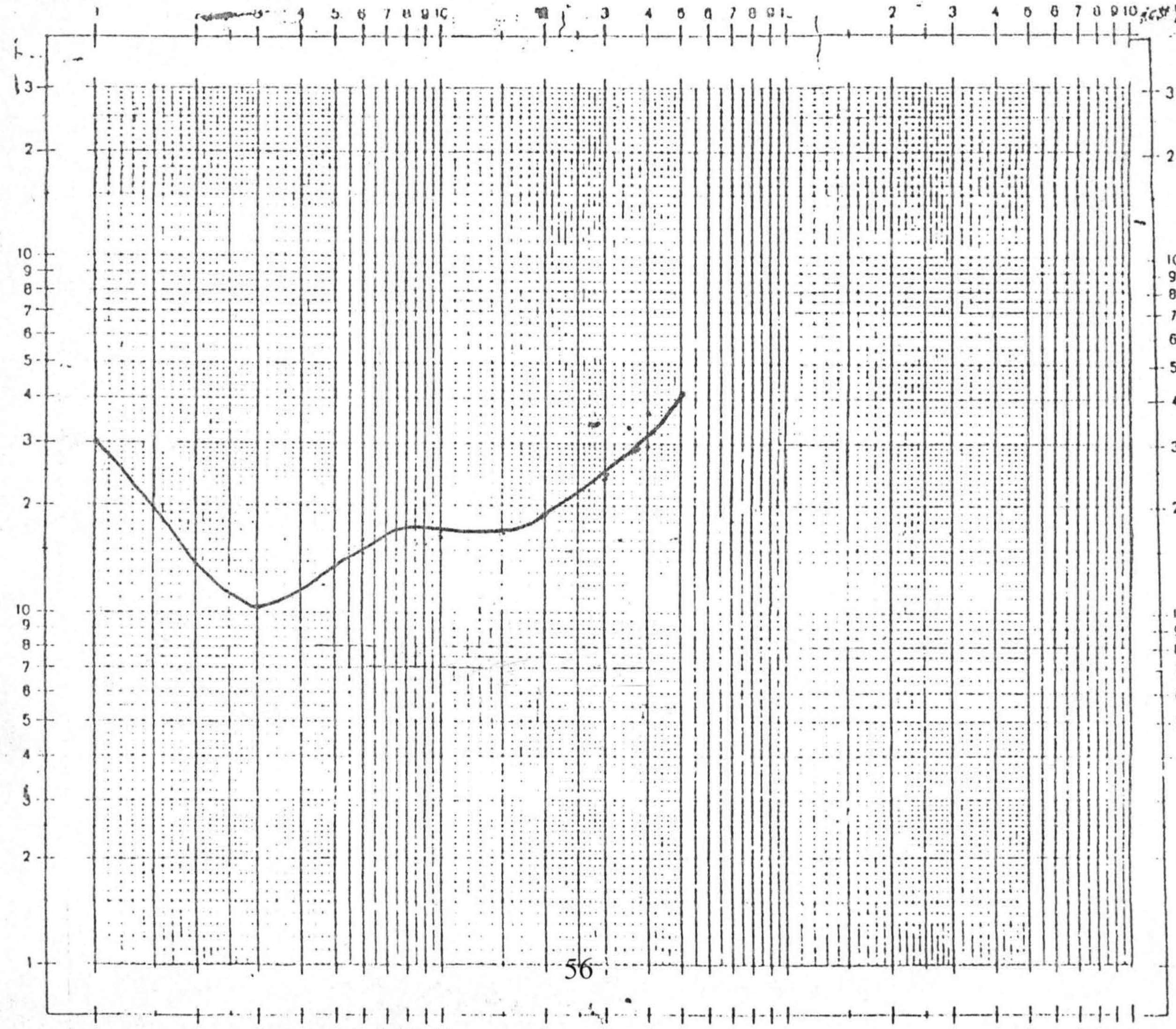
Surveyed By A. IDRIS Date 22/03/02 VES No. MIN/010/03/02

ALT ________ Latitude ________ Longitude ________ Azimuth ________

$K = (AB/2)^2 - (MN/2)^2 \; 3.1415/MN$

$\rho a = KR \quad R = V/I$

Electrode Spacing (m) AB/2	MN/2	Geometric Factor (k)	Resistivity (ρ) Ω	Apparent Resistivity (ρa) Ω-m	Interpretation: Layer res. Ω-m	Interpretation: Geoelectric Layer	Well Design
1	0.50	2.36	127.1	300			
2	"	11.8	11.41	135	300		6" blind casing
3	"	27.5	3.793	104			
5	"	77.8	1.696	132			
6	"	112	1.429	160			
6	1.00	55	2.669	148			
8	"	99	1.749	173			
10	"	156	1.038	162			
10	2.50	58.9	2.872	169			5" open hole
15	"	137	1.223	168	150		
20	"	247	0.761	188			
30	"	562	0.423	238			
40	"	1001	0.291	291			
40	7.50	323	1.133	366			
50	"	512	0.812	416			
60	"	742					
70	"	1014			400		
80	"	1329					
80	15	647					
90	"	825					
100	"	1024					
110	"	1244					
120	"	1488					
130	"	1746					



VERTICAL ELECTRICAL SOUNDING DATA ENTRY FORM

Locality: KONTAGORA LGA: KONTAGORA State: NIGER

Surveyed By: A - IDRIS Date: 26/06/02 VES No. KNT/021/06/02

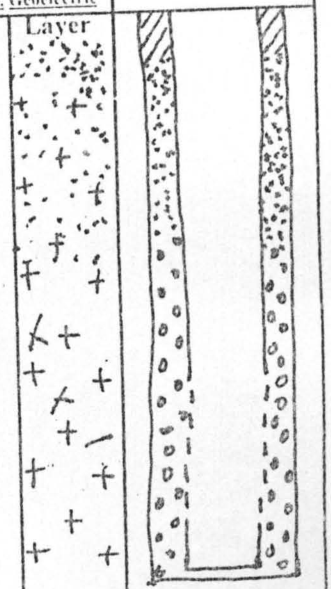
ALT____ Latitude____ Longitude____ Azimuth____

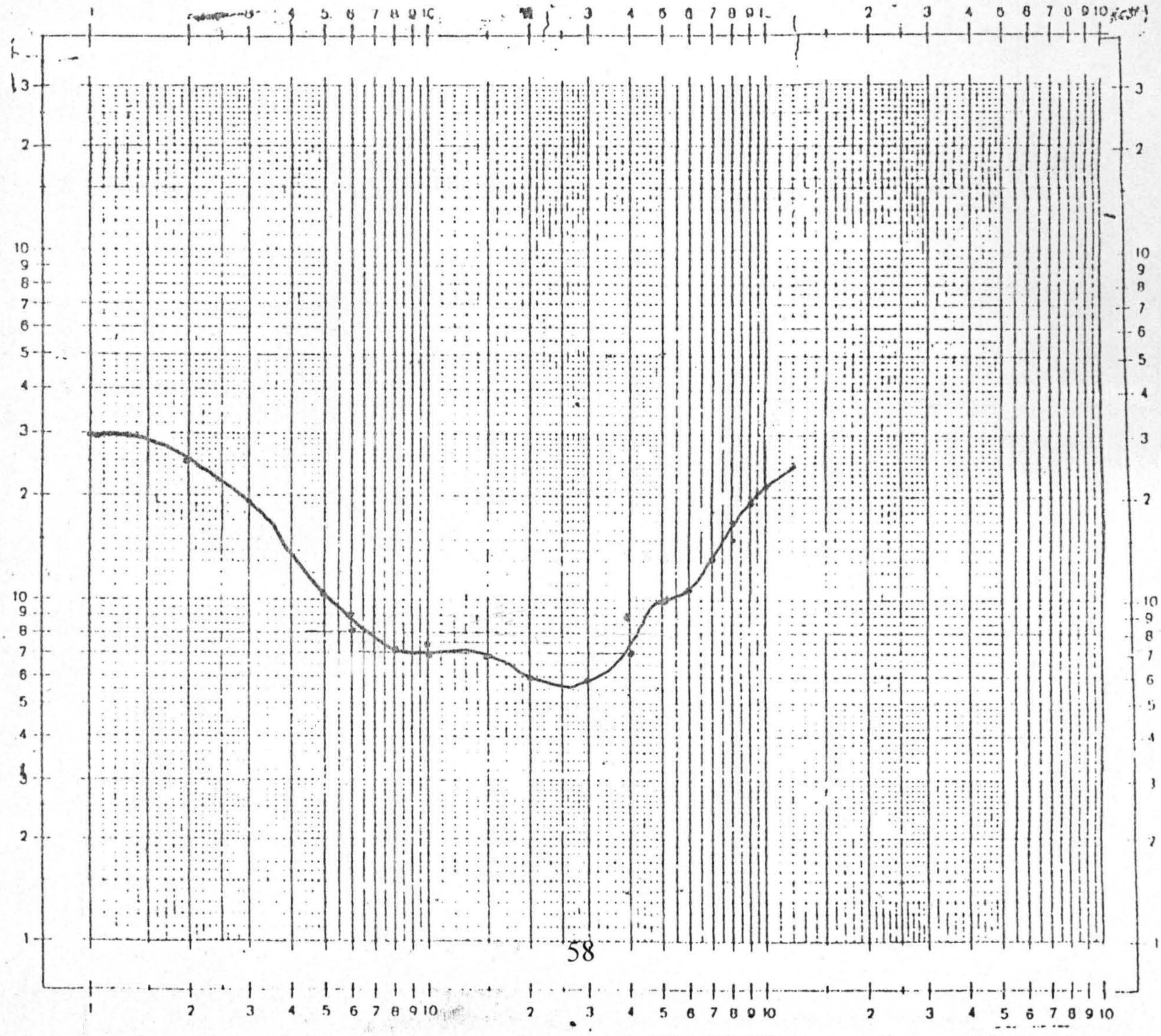
$K = (AB/2)^2 - (MN/2)^2\ 3.1415/MN$

$\rho a = KR \quad R = V/I$

Electrode Spacing (m) AB/2	MN/2	Geometric Factor (k)	Resistivity (ρ) Ω	Apparent Resistivity (ρa) Ω-m
1	0.50	2.36	126.7	299
2	"	11.8	21.01	248
3	"	27.5	7.200	198
5	"	77.8	1.414	110
6	"	112	0.812	91
6	1.00	55	1.454	80
8	"	99	0.727	72
10	"	156	0.442	69
10	2.50	58.9	1.273	75
15	"	137	0.496	68
20	"	247	0.238	59
30	"	562	0.123	59
40	"	1001	0.0699	70
40	7.50	323	0.279	90
50	"	512	0.195	100
60	"	742	0.151	112
70	"	1014	0.128	130
80	"	1329	0.107	142
80	15	647	0.248	161
90	"	825	0.218	180
100	"	1024	0.205	210
110	"	1244		
120	"	1488		
130	"	1746		

Interpretation (Layer res. Ω-m / Geoelectric Layer) | Well Design





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UNICEF A

UNICEF ASSISTED RURAL WATER SUPPLY
AND SANITATION (RUWATSAN)

WATER SUPPLY UNIT

BOREHOLE LOG

L.G.

NAME OF VILLAGE	IBADAN WAY – NEW BUSSA	BOREHOLE No	NBS/JI/08/02
TOTAL DEPTH	50 M	DATE STARTED 26/08/2002	COMPLETED 30/08/02
DRILLED BY	BABA BOLOGI	LOGGED BY	ISAH SADI
STATIC WATER LEVEL	12 M	DRILLING METHOD	AIR
DYNAMIC WATER LEVEL	42 M	TYPE & SIZE OF CASINGS/SCREENS	4" x 3m pvc
PUMPING RATE	l/min	YIELD	Good

Drilling and Casing Program: Bit Size	Casing and Screen Size	Depth (m)	Water Level	Log	Description of Lithology
9 7/8" drag + Roller (0–30 m)		0–10		· · ·	Top soil. Highly weathered basement.
		10–20		+ +	Dry basement rock – granitic.
		20–30		+ +	Blackish biotite granite – water content very low.
6" Button (30–55 m)		35–45		+ +	fractured granite at 43m, water content appreciable.
		45–50		+	fresh basement.

Electrical Logging: Spontaneous Potential (mv)	Depth (m)	Resistivity (Ωm)

UNICEF ASSISTED RURAL WATER SUPPLY
AND SANITATION (RUWATSAN)

WATER SUPPLY UNIT

BOREHOLE LOG

L.G.

NAME OF VILLAGE	SULEJA	BOREHOLE No	SUL/JII/006/05
TOTAL DEPTH	40 M	DATE STARTED	12th/05/02 COMPLETED 15th/05
DRILLED BY	MUHAMMAD YASODE	LOGGED BY	A. SADIQ IDRIS
STATIC WATER LEVEL	14 M	DRILLING METHOD	AIR
DYNAMIC WATER LEVEL	32 M	TYPE & SIZE OF CASINGS/SCREENS	5"x3m UPVC
PUMPING RATE	8/2 l/min	YIELD	GOOD

Drilling and Casing Program: Bit Size	Drilling and Casing Program: Casing and Screen Size	Depth (m)	Lithology Data: Water Level	Lithology Data: Log	Lithology Data: Description of Lithology	Electrical Logging: Spontaneous Potential (mv)	Electrical Logging: Depth (m)	Electrical Logging: Resistivity (Ωm)
9 7/8"	5" UPVC Casings	0–15			Brownish top soil; Highly to fairly weathered bedrock; 15m Basement			
6 1/2"	open hole	15–40	1.2 l/s (at ~31 m)	+	Granitic basement, fracture encountered at 31m, 36m. Borehole stopped at 40m.			
	3" upvc screen	40			40m			
		45						

UNICEF A

UNICEF ASSISTED RURAL WATER SUPPLY
AND SANITATION (RUWATSAN)

WATER SUPPLY UNIT

BOREHOLE LOG

L.G.

NAME OF VILLAGE LAPAI	BOREHOLE No LAP / PAT 201/05/05
TOTAL DEPTH 46 M	DATE STARTED 18/05/02 COMPLETED 19/05/02
DRILLED BY BABA NDALU	LOGGED BY UMAR DOGO
STATIC WATER LEVEL 9 M	DRILLING METHOD MUD
DYNAMIC WATER LEVEL 30 M	TYPE & SIZE OF CASINGS/SCREENS 5" uPVC
PUMPING RATE l/min	YIELD GOOD

Drilling and Casing Program: Bit Size	Drilling and Casing Program: Casing and Screen Size	Depth m	Lithology Data: Water Level	Lithology Data: Log	Lithology Data: Description of Lithology	Electrical Logging: Spontaneous Potential (mv)	Electrical Logging: Depth (m)	Electrical Logging: Resistivity (Ωm)
9" Roller		0–4			Reddish brown top soil			
		4–12			Clayey sand			
		12–20			yellowish brown clay fm.			
		20–23			Greyish sandy clay fm			
		23–43			medium to fine grained greyish sandstone formation. water content noticeably high.			
		43–46			Clayey sand 46m			

Depth scale: 10, 15, 20, 25, 30, 35, 40, 45, 50

UNICEF ASSISTED RURAL WATER SUPPLY
AND SANITATION (RUWATSAN)

WATER SUPPLY UNIT

BOREHOLE LOG

L.G.

NAME OF VILLAGE	ODUOYE QTRS MINNA	BOREHOLE No	MIN/HALCO1/MBP/07/03
TOTAL DEPTH	36 M	DATE STARTED	26/07/2002 COMPLETED 27/07
DRILLED BY	SANI BAKO	LOGGED BY	CONSTANTINE S.
STATIC WATER LEVEL	4 M	DRILLING METHOD	AIR
DYNAMIC WATER LEVEL	24 M	TYPE & SIZE OF CASINGS/SCREENS	6" uPVC
PUMPING RATE	1.6 l/min	YIELD	V. Good

Drilling and Casing Program: Bit Size	Drilling and Casing Program: Casing and Screen Size	Depth (m)	Lithology Data: Water Level	Lithology Data: Log	Lithology Data: Description of Lithology	Electrical Logging: Spontaneous Potential (mv)	Electrical Logging: Depth (m)	Electrical Logging: Resistivity (Ωm)
9 7/8 Roller	6" upvc	0			Top soil			
					weathered bedrock			
		5		6m				
		10			Granitic bedrock			
6" Button	open hole	15–20			Highly fractured at 26m, 30m and 34m.			
		25			fresh basement 36m. Drilling Stopped			
		30						
		35		36m				
		40						

UNICEF ASSISTED RURAL WATER SUPPLY
AND SANITATION (RUWATSAN)

WATER SUPPLY UNIT

BOREHOLE LOG

L.G.

NAME OF VILLAGE	JAIFI - PAIKO	BOREHOLE No	PAK/RII/07/02
TOTAL DEPTH	36 M	DATE STARTED 18/07/2002	COMPLETED 20/07/02
DRILLED BY	BABA BOLOGI	LOGGED BY	ISAH DADI
STATIC WATER LEVEL	9 M	DRILLING METHOD	AIR
DYNAMIC WATER LEVEL	32 M	TYPE & SIZE OF CASINGS/SCREENS	4" x 3m PVC
PUMPING RATE	l/min	YIELD	GOOD

Drilling and Casing Program: Bit Size	Drilling and Casing Program: Casing and Screen Size	Depth (m)	Lithology Data: Water Level	Lithology Data: Log	Lithology Data: Description of Lithology	Electrical Logging: Spontaneous Potential (mv)	Electrical Logging: Depth (m)	Electrical Logging: Resistivity (Ωm)
8½" Roller		0–1			Top soil			
		5			Highly weathered rock.			
		7–10			fairly to moderately weathered rock			
6" Button		15			fairly weathered rock.			
		20–25			Granitic basement fairly loose. Collapse rate high. water content high.			
		33–35			fresh crystalline bedrock.			

UNICEF A

UNICEF ASSISTED RURAL WATER SUPPLY
AND SANITATION (RUWATSAN)

WATER SUPPLY UNIT

BOREHOLE LOG

L.G.

NAME OF VILLAGE U/LIMAN KONTAGORA	BOREHOLE No KNT/JII/009/07/0[illegible]
TOTAL DEPTH 40 M	DATE STARTED 06/07/02 COMPLETED 08/07/[illegible]
DRILLED BY NBAGI YAGODE	LOGGED BY A. SADIQ IDRIS
STATIC WATER LEVEL 36 M	DRILLING METHOD AIR
DYNAMIC WATER LEVEL 14 M	TYPE & SIZE OF CASINGS/SCREENS 6" x 3m PV[illegible]
PUMPING RATE l/min	YIELD fairly good

Drilling and Casing Program: Bit Size	Drilling and Casing Program: Casing and Screen Size	Depth m	Lithology Data: Water Level	Lithology Data: Log	Lithology Data: Description of Lithology	Electrical Logging: Spontaneous Potential (mv)	Electrical Logging: Depth (m)	Electrical Logging: Resistivity (Ωm)
9⅞" Roller		0			brownish top soil			
		5			Highly weathered clayey soil. Collapse rate very high.			
		10						
		15						
6" Button		20						
		25			Highly weathered to fairly weathered basement.			
		30		+ +				
		33		+	Granitic basement			
		35		+				
		40						
		45						

6