



## SOIL INVESTIGATION OF WATER SCHEME SUPPLY (CASE STUDY: OTUOKPOTI IN OGBIA LGA, BAYELSA STATE)

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### ABSTRACT

*This geotechnical soil investigation focusses on developing a community- based portable water supply system for Otuokpoti communities in Bayelsa State, Niger Delta region. The research found silty clay soil to 2.8m depth, high plasticity (38.6%), and moisture content (36,67%), with a recommended raft foundation and allowable bearing capacity of 80KN/M2. Chemical analysis showed near-neutral pH and low sulfate content, indicating no significant concrete aggressiveness concerns.*

**KEYWORDS:** Soil Investigation, Water Scheme Supply

### INTRODUCTION

The water scheme comprises, in a nutshell, the soil study, design and supervision of the necessary construction works in the stations for the purpose of providing potable water in Otuokpoti communities in the Niger Delta area of Bayelsa State. It is now common knowledge that the people of this region feel a strong sense of neglect arising from perceived, relative deposition in the allocation of developmental resources against the enormity of resources generated from the region for the welfare of all Nigerians. It is against this background that this research is initiated for the technical appraisal of the benefiting rural settlements for the purpose of the establishment of community-based potable water supply system to meet the needs of the people in the Niger Delta region.

Water is a special kind of natural resources. It is probably the only “mineral” resource replenished and to a extent it determines the pace of development in a community. In fact, the history of civilization follows a watercourse.

Otuokpoti, a settlement with six neighbourhood units, is perhaps the biggest town in Ogbia Local Government Area. The town is accessible from Yenagoa city through Ikole Creek onto which it fronts. Ikole Creek is a tributary of the Nun River. Infrastructural development in the town is very impressive. Access roads apart, there are three parallel roads namely School Road, Okilo Road and Dike Road which edges the water front.



It is a natural phenomenon that the kind of forest in a particular region is in part a consequence of

Erosion, from this research, had been a menace to Otuokpoti but this has been checked by sand-filling the water-front from 150 metres off the foreshore. State Government environmental officials went a step further by constructing a canal behind the town to which is drained excess water from the community into the mainstream of the creek with the help of a water-pumping machine which is now defective. Community leaders complained of maintenance of canal but agreed that water-logging in parts of the town has greatly reduced even when the rains are pouring.

It is a common geographical feature in riverine settlements that the land is generally flat regardless of the height of the land above sea level. The land in Otuokpoti assumes this feature. But the water table moves up and down in accord with the seasonal changes – rainy and dry seasons.

It is a natural phenomenon that the kind of forest in a particular region is in part a consequence of the soil, climate and water supply in the region.

And the reverse is also the case, that is, the kind of soil is also in part a consequence of the type of forest. Otuokpoti enjoys the favourable circumstances of a rain forest and therefore rainforest habitants flourish.

## **PROBLEM STATEMENT/JUSTIFICATION**

The majority of communities in Niger Delta region experience serious lack of social infrastructural services necessary for the most basic health standards of living. This research identifies water supply for domestic consumption, as one of such critical and basic needs for continued survival of the people in the region with respect to the communities in Otuokpoti that must be urgently tackled. More so, the world over, the lack of clean drinkable water is linked to a variety of sanitary and health problems as is also prevalent among communities in the region.

Consequently, this research seeks immediate solution to this problem of lack of or shortage of potable water supply in the communities within its jurisdiction. Such solutions to the problem must also be technically functional within the scope of the communities: have acceptable budgetary limits and sustainability against the backdrop of a history of failed schemes of similar nature in the region.

### **Objective(s) of Study**

#### **Aim**

The principal aim of this study is to acquire relevant soil technical and scientific data: engineering design and cost estimation needed for the establishment of portable water schemes in the four Otuokpoti communities of Ogbia Local Government Area in Bayelsa State.



## Objectives of the Study

- i. To investigate water supply situation and needs for domestic uses in the proposed communities in Otuokpoti.
- ii. To determine/recommend the establishment of water supply scheme, including required supply capacity, technique etc. given the community size, population and future expansion and needs.
- iii. To acquire technical soil information needed for the design and costing of serviceable water supply schemes in the proposed or recommended communities.

## Literature Review

Water is a chemical with composition as atoms of hydrogen (H<sub>2</sub>) and oxygen (O<sub>2</sub>) combined to form molecules of water (H<sub>2</sub>O). It is colourless, odourless, tasteless and clear in its form. Water for domestic consumption is the focus of this study and contains a variety of useful minerals and salts. These substances confer on water its pleasant taste apart from their need and usefulness in the human body. However, they must be in controlled quantity. The presence of excess of these substances constitutes pollutant harmful to human and biological matter. Industrial pollutant cause hardness in water for domestic washing.

## Qualities of Water

Water must be fit for human consumption i.e. potable but it should also be palatable i.e. aesthetically attractive. It should be suitable for uses other than drinking e.g. sufficiently soft, for washing. Water quality is measured by carrying out analysis of several different properties under the broad headings of physical, chemical and biological characteristics.

The parameters required in determining the physical characteristics of water are:

- i. The temperature; this is important because of its effect and other properties e.g. speeding

The parameters required in determining the physical characteristics of water are:

up of chemical reaction, reduction of solubility of gases, accentuation of dissolution of some solids, application of odour etc.

- ii. Taste and odour: these subjective properties are difficult for standardized measurement often due to dissolved impurities.

- iii. Colour: Pure water has a pale blue tinted colour in large volume. Natural yellow colour is due to organic acids which are not harmful but similar to tannic acid from tea. Nevertheless, many consumes object to highly coloured water on aesthetic grounds and may be unacceptable for certain industrial uses



- iv. **Turbidity:** Presence of colloidal solids gives liquid a cloudy appearance, which is aesthetically unattractive and may be harmful. Turbidity in water is due to clay and silt particles, discharges of sewage or industrial waste or presence of large number of micro-organisms.
- v. **Solids:** These may be present in suspension and or in solution and can be categorized as organic or inorganic matters. Total dissolved Solids (TDS) are due to soluble materials whereas suspended solids are discrete particles, which can be measured by filtering a sample through filter paper. Settleable solids, are those settling out in a graduated cone and measured volumetrically. They can be determined from the difference between SS in the supernatant and the original (SS).
- vi. **Electrical conductivity:** It depends on the quantity of dissolved salts present and for dilute solutions, it is approximately proportional to the TDS content.

## CHEMICAL CHARACTERISTICS

They are more specific and more useful in assessment of the property of water sample. These include:

**PH (hydrogen potential)** it is useful determining the level of acidity or alkalinity of water sampled. It is measured on a scale, which indicates concentration of hydrogen ions present in the sample. On this scale 7 represents neutrality less than which is acidity and above which is alkalinity the scale ranges from 1 – 14. Many chemical and biological activities are often restricted to fairly narrow ranges 6 – 8. Highly acidic or alkaline waters are undesirable because of corrosion hazards and possible difficulties in treatment.

**i. Alkalinity:** It is due to the presence of  $\text{HCO}_3^-$  bicarbonate  $\text{CO}_3^{2-}$  carbonate or  $\text{OH}^-$  hydroxide. Most of natural alkalinity in waters is due to  $\text{HCO}_3^-$  produced by the action of groundwater on limestone /chalk  $\text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{Ca}(\text{HCO}_3)_2$ . Alkalinity is useful in waters and waste in that it provides buffering to react changes in PH.

**ii. Acidity:** Most natural water and domestic sewage are buffered by a  $\text{CO}_2\text{-HCO}_3^-$  system. Acid  $\text{H}_2\text{CO}_3$ .

**iii. Hardness:** This property of water is particularly important for domestic water uses. It prevents lather formation with soap and produces scale in hot water systems due mainly to metallic ions  $\text{Ca}^{2+}$  – although  $\text{Fe}^{2+}$  and  $\text{Sr}^{2+}$  are also responsible. They are usually associated with  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$  and  $\text{NO}_3^-$ . They originate no health hazard but economically disadvantageous resulting in wastage of soap and higher fuel cost.

**iv. Dissolved Oxygen (DO):** Very important element in  $\text{H}_2\text{O}$  quantity control. Presence is essential to maintain the higher forms of biological life and the effect of a waste storage on a river is largely determined by the oxygen demand balance in the system. Clean surface water is usually saturated with DO, which can be rapidly removed by organic matter. Oxygen saturated water has

a pleasant taste and the lack of it makes water taste insipid. Drinking water is thus often aerated if necessary to give it the required oxygen.

**v. Oxygen Demand:** Organic compounds are generally unstable and may be oxidized biologically or chemically to relatively meet the stable end products e.g. CO<sub>2</sub> NO<sub>3</sub>, H<sub>2</sub>O. Indication of organic content of waste can be given by the amount of oxygen regained for its stabilization.

**vi. Nitrogen:** It is an important chemical parameter of water quantity in biological systems. Biological treatment of waste can only be produced in the presence of sufficient nitrogen and nitrate Nitrogen. The relative concentration of different forms of Nitrogen gives a useful indication of the nature and strength of the water sample. Water with high organic Nitrogen indicates recent pollution and therefore may be unsafe, whereas high non-organic nitrogen shows that nitrification had occurred. This pollution could not have recurred.

**vii. Trace metal:** Water sample in Bayelsa State shows high content of ion Fe<sup>2</sup>. They are essential for growth of plants in minute quantities but toxic and poisonous in relatively high concentration.

## BIOLOGICAL CHARACTERISTICS

This water is a sensitive water quality parameter often under the subject of microbiology. The subject looks at the microorganism present in an environment. In this case water. Microorganisms often in water cause several water-borne diseases of man. Indicator organisms particularly coliforms are used to evaluate the sanitary quality of water for drinking and recreation.

It is therefore the task of the environmental water engineer to understand the role of microorganisms in a particular environment. To beneficially transform that environment, we need much chlorine to use when disinfecting potable water supplies or desiring purification process for water.

### The nature of water and water borne diseases due to pollution.

Water is a dominant feature in the Niger Delta State of Bayelsa. It is the same for the drainage holes through which water must pass. Without water there is no life and access to drinking water is a prime factor in human settlement.

The irony of the Niger Delta is that while water dominates the physical environment but decent drinking water is hard to find. The scarcity of drinking water has always determined the pattern of settlement.

The tidal area of the brackish and fresh water ecosystems are particularly susceptible and slow moving so that pollutants are inefficiently flushed over as incoming tides tend to push back upstream the column of water. Much of the water in the Niger Delta area is so polluted that illness and death from water borne diseases are part of life. However, useful statistics are diarrhea, dysentery cholera, others are typhoid, guinea worm and parts of the Delta environment are the causes of bilharzias and river blindness.

## OCCURRENCE AND SOURCE OF WATER SUPPLY IN THE NIGER DELTA

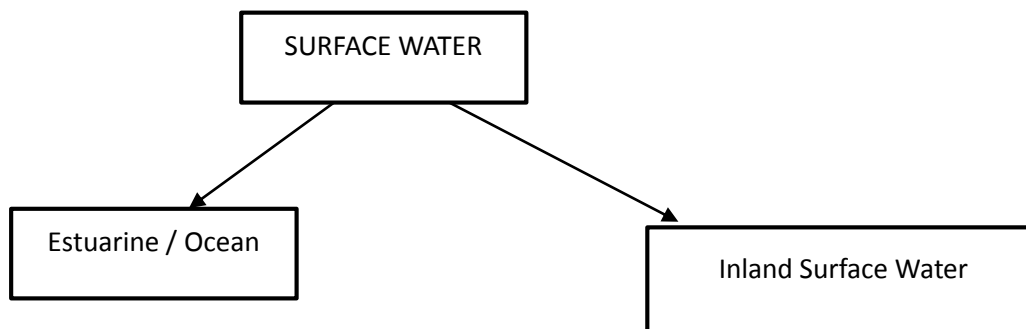
Water type is divided into:

1. Surface water
2. Underground water.

Surface water is further divided into estuarine water surface, oceans and inland surface water including rivers, creeks, lakes, dam, etc.

Origin of water and the hydrologic cycle:

The origin of water of the earth is itself still obscure. However, the system by which nature circulates water from ocean, through the atmosphere and returns it overland and underground back to the sea through devious paths is referred to as hydrologic cycle. The natural forces involved in the process include Radiation, Gravity, molecular attraction and capillarity. The energy for this process comes from the sun. The main feature of the cycle is shown below.



Water moves into the atmosphere from surface water bodies and from the ground surface by evaporation and transpiration. A part of this water falls back to the ocean while most of it is carried upwards into clouds. Maritime air masses move this cloud inland where condensation takes place. The vapour cools and falls back to the earth as precipitation. Some of the waters that fall as rain will evaporate into the atmosphere. Some will be intercepted by vegetation from where the intercepted water returns to the atmosphere by evaporation. Rainfall reaching the ground may collect to form surface run-off or it may infiltrate into the ground. The liquid water in the ground may be taken up by vegetation and hence transpired back to the atmosphere. The infiltration that continues downwards under gravity reaching the water table where the aquifer is fully saturated as ground water. Under these conditions, lateral flow can take place in the direction of the gradient on the water table. The flow is directed towards and is collected by the natural groundwater discharge points such as spring and seeps into rivers, seas and eventually, all the water reach the ocean and the process continues.



## WATER DISTRIBUTION IN NATURE

The surface of our planet earth has a total of 500,000,000Km<sup>2</sup> out of that water forms greater part of the surface i.e. 360,000,000Km<sup>2</sup>. Nature, obviously did not intend us to be short of water and yet such is tragic case in many parts of the world, because it is not always in the right location or of usable quality and quantity. Ground water forms a major source of global fresh water supply balance however, because surface water can be seen and observed, it is erroneously thought that surface water constitutes the world's major fresh water source. In fact, the truth is that less than 3% of fresh water on the earth occurs in lakes streams or rivers over which 97% occurs underground. The stage capacity of ground water reservoir combined with small flow rate provides large and extensively distributed source of ground supply. In the Niger Delta, both sources abound. However, surface water is usually heavily polluted and requires expensive treatment alternative source for community-based water supply schemes. Ground water extraction and utilization are core study areas in this research.

**OCCURRENCE OF GROUNDWATER** Ground water invariably occurs in geology formation, whilst the hydrologic condition may furnish water to the underground zone, it is the nature of the subsurface strata, which governs its distribution and movement. On the basis of water content of the earth, we have 3 spheres as follows:

**LITHOSPHERE:** The part that is composed dominantly of rocks is the soil. It is the solid environment which underlays the hydrosphere.

**HYDROSPHERE:** Consists of liquid and solid (ice) that covers the earth surface. It rests on the lithosphere.

**ATMOSPHERE:** The outer most part of the earth, it forms a gaseous envelop above the hydrosphere.

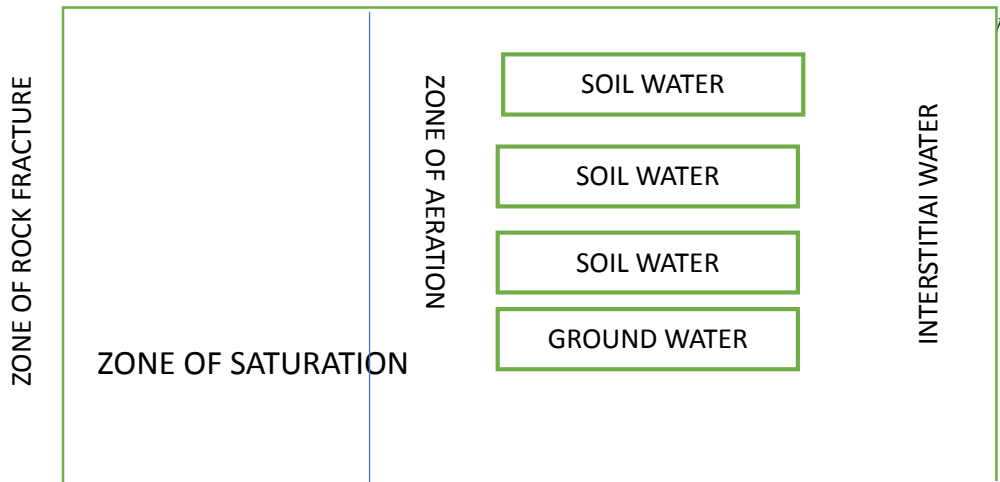
The cycle of activities of water extends through those three (3) parts of the earth system from an average depth of 1km in the lithosphere to height of 16km (10 miles) in the atmosphere. Water therefore can be described with respect to the sphere it occurs as:

**SURFACE WATER:** Referring to the hydrosphere usually in basins. A basin is the area from where all the falling rain is channeled towards a drainage system (catchments area). It is surface water body with all its tributaries e.g the Niger Delta basin.

**ATMOSPHERE WATER:** Refers to water normally in the gaseous state. The atmosphere in the presence of dust and pilling grain at any given temperature holds water in vapour or cloudy form. A saturation point is the maximum it can hold at the given temperature it will hold water in vapour or cloudy form. A saturation point is the maximum it can hold at the given temperature.

**SUB-SURFACE WATER:** Referring to water in the lithosphere being the main area for study we shall deal with it a little further.

**SUB-SURFACE WATER:**



**ZONE OF ROCK FLOWAGE** **INTERNAL WATER**  
 In this zone the interstices of the functional permeable rocks are occupied partly by air and is divided into:

1. Soil -water zone
2. Intermediate
3. The capillary zone.

**ZONE OF SATURATION**

Here all functional permeable rocks are with water under hydrostatic pressure. It extends from the upper surface of saturation down to the underlining impermeable bedrock. The water table forms the surface of the zone. Ground water, technically speaking refers to water in the saturation zone. In this zone water occurs in geology formation technically referred to as aquifers which serve both to store (storage function) and to transmit (conduct function) the ground water.

**GROUND WATER STORAGE:** Not all water contained in the interstices of the saturation zone can be removed by drainage or pumping from a well. This is because Molecular or surface tension forces would tend to hold a portion of the water in place. Generally speaking in the zone of saturation (dome of ground water) the proportion of total groundwater, which may be regarded as mobile, will depend entirely on the size distribution of the interstices in the water bearing material. It will be high for clean gravel or well-jointed sandstone or very low in clay in which most of the water is retained in very small interstices. The ease with which water is released to drainage forces is mainly expressed in term of either Retention or Specific Yield.

**SPECIFIC RETENTION:** Of rock or soil is a measure of water retaining capacity of the rock and; quantity expressed as a percentage of the volume of water relent saturation against the force of gravity to its own volume.



$$S_r = \frac{100W_r}{V} \text{ where } \frac{V}{W} = \begin{matrix} \text{gross volume of rock or soil} \\ \text{Volume occupied by retain water.} \end{matrix}$$

### SPECIFIC RETENTION:

It is a measure of the water yielding capacity of the rock and is quantifiably expressed as a percentage of the volume of water which after being saturated can be drained by gravity to its own volume.

$$S_y = \frac{100W_y}{V} \text{ where } \frac{V}{W} = \begin{matrix} \text{gross volume of rock or soil} \\ \text{Volume occupied by retain water.} \end{matrix}$$

### Specific Yield Capacity:

It is a measure capacity of the rock and is quantitatively expressed as a percentage of volume of water which after being saturated can be drained by gravity to its own volume.  $S_y = \frac{100W_y}{V}$

Where  $V =$  gross of the rock / soil  
 $W_y =$  roller occupied by water drained out.

### GROUND WATER DEVELOPMENT (ENGINEERING)

Ground water studies are normally carried out in units of basin. A ground water basin is a physiographic unit containing one large aquifer or several connected or inter-related aquifers. It may correspond directly to a river or surface basin at a time the two may not coincide. The ground water basin can be visualized as a large underground reservoir and water contained there in it is united. Therefore groundwater utilization in a basin can offer safe yield is the amount of water that can be withdrawn from it annually without producing undesirable results. It may be related to an amount less than recharged. It is also limited either by physical size of the reservoir or by rate of which water moves through the reservoir from the recharge area to the area of withdrawal. Any draft or withdrawal in excess of safe yield is an overdraft and come from storage within the aquifer. Storage deflation is referred to as ground water mining.

Undersirable effects in event of overdraft include:

1. Permanent damage resulting from undue depletion of water in the reservoir.
2. Destruction of water
3. Economics of pumping from basin
4. Water right of other individuals in or near basin.
5. Salt water Intrusion in coastal aquifers.
6. Land subsidence (lowering of and settlement of the ground surface).

## GROUND WATER INVENTORY

The balancing of all additions from all sources to ground water reservoir in an area against the discharges of every type from it is called GROUND WATER INVENTORY.

### Source of addition

1. Rainfall
2. Infiltration
3. Influent seepage from stream or springs
4. Irrigation water
5. Leakages from other aquifers
6. Artificial e.g Leakage from septic tank

### Source of Discharge

1. Effluent seepages
2. Spring flow
3. Discharge by surface flow
4. Evapo-transportation
5. Pumping.
6. Surface discharge

$DS = QR - QD$       when DS charging GWS  
QR recharging to GWB  
QD discharging from GWB

### Water wells

A well is a hydraulic structure usually vertical, which when properly constructed, permits the economic with-drawl of water from water bearing formation, horizontal well including collection wells and infiltration galleries. These are constructed where special groundwater conditions exist. Successful wells are designed and the constructor should:

1. use materials that will provide efficient well with long service life.
2. Use technology in drilling and well construction that takes maximum advantage of a hydro-geologic condition.
3. Apply principle of well hydraulics in a practical way in the analysis of well and aquifer performance.

A bore hole is a hole or shaft excavated with the aim of bringing ground water to the surface for obtaining information on the geological characteristic of an area, it may also serve for sub-surface exploration, observations, artificial recharge, sewage and industrial waste disposal.

The method of particular well construction in the area depends on:

1. Groundwater condition in the area
2. Purpose of water supply
3. Quantity of water supply
4. Depth of ground water table
5. Geologic condition
6. Economic consideration.

Wells can be generally grouped with two (2) shallow and deep wells. Shallow wells are dug, cored, bored and felted. DEEP WELLS are usually drilled by cable tool (percussion) or rotary methods followed up by development for optimum yield before pumping installation and pumping itself.

## WELL STING:

Before wells are sunk into any locality it is a technical requirement to take geological survey: Aerial photographs, geological techniques and geomorphic surveys and geophysical survey. Meteorological data record of wells in the hydrological vicinity, surface flows and hydrological information about the area. Such wells are very carefully logged, tested and conclusions obtained used while drilling the production well.

## SHALLOW WELL ARE:

Usually of depths less than 20m deep and are constructed by digging boring, coring, and felting.

**1. DUG WELLS:** Range from 3.5m deep. This range is arbitrary because there are deep dug wells up to 30m. They are dug using shovel and pick, loose material are handled using suitable pulleys and hicks loose material are handled using suitable pulleys and hicks or ropes for safety and to prevent caring hiring of wood and sheet piling is placed in holes to brace the walls. Often the wall is permanently lined with brick concrete but must be permeable for water entry into the well. These wells are the oldest form used to date in rural communities. Yields are 1 -2 litres/see and can yield 10 litre /see when well dug.

**2. BORED WELLS:** Are constructed by hand operated or power driven earth augers. There are different types of augers but all have cutting blades at the bottom, which bore into the ground with rotary motion. When the blade is full of loose earth, the auger is removed and emptied. They work best in formation that do not cure. Casing may be lower in sand and gravel levels as boring continues in the casing.

**3. DRIVEN WELLS:** They are restricted to unconsolidated formations. They are usually very small in diameter and operated by driving connected pipes down by impact. Water enters the well cutting up and out of the well. Diameters are small also.

**4. SETTED WELLS:** Are constructed by cutting action of a downward directed high velocity stream of water aided by a special chisel-like point or bit. The water washes the earth away while the casing, which is lowered into the driving hole, conducts the water and cutting up and out of the well.

Diameters are small also.



**DEEP WELLS:** Usually constructed by drilling, using any or a combination of the following methods:

1. Percussion/Cable tools method
2. Rotary method

Every drilling operation consists of three basic assignments.

1. Lessening of materials
2. Taking the loose materials out of hole
3. Installation of casing/screen to prevent carno-in

## **PERCUSSION /CABLE TOOL METHOD**

This is used for drilling through consolidated rock materials, loosening of earth materials by regular lifting and dropping of a string of tools. The bit at the lowest part determines the diameter of the well. and is relatively sharp chisel edged. Moved up and down, it loosens the formation. For the impacts to be effective, some weight is needed hence a drill stem of steel provides this additional weight. A dull jar above the stems consists of two loops linked with allowance for space serves to loosen material that may block the borehole. Under construction above the jar is the SWIVEL. Cutting from one-way valve at its bottom prevents cutting from return, which enters the pipe and close-up. The cutting is made into slurry by introducing water or drilling mud, which is napped by the bailer action and hauled up and out.

**THE ROTARY METHOD:** The lowest part again is the bit, which breaks and cuts rock materials. Movement here is by rotary action as against up and down notion. The bit here consists of rollers 2 or 3 in number having teeth which attacks the formation as the bit rotates. Drill collars hallow at center adds weight and pressure for effective cutting. The wall of the collar is about 6m long a piece. Above the collar comes the drill pipe which when rotated transfers motion to a Kelly, having the swivel that hangs all the string of tool except the rotary table that is part of the drilling machine.

Drilling mud is pumped into the string of tools and comes out through the bit at some pressure. Cutting in, the muds are deposited in the setting pit while clean mud move to the mud pit where it can be reintroduced or pumped back into the swivel

## **FUNCTION OF DRILLING MUD**

1. Lifting the cutting from the bottom of the hole and carrying them to a settling pit.
2. Support and stabilizing the borehole wall to prevent caving. This occurs because the drilling fluid exerts pressure against the wall of the borehole. As long as hydrostatic pressure of the fluid exceeds the earth pressure i.e. formation pressure and the confining pressure in the aquifer, the hole will remain open.
3. Seal the borehole wall to reduce fluid loss into the formation (mud cake).
4. Cool and clean bit.
5. Allow cuttings to drop out in settling pit.
6. Lubricate the bit, bearings, pump mud and drill pipes.

## WELL DEVELOPMENT

Wells are to be developed after completion, the main aim being to remove finer materials from the aquifer. Hence rearrange formation sands to allow water enter the well from the aquifer with minimum resistance. It also increases porosity and permeability of the natural formation adjacent to the well. It also stabilizes the sand and builds up an envelop of coarse sand – free yield. Other benefits include:

- Increase the specific yield of the well
- Prevents sanding or bridging
- Helps to obtain maximum economic well life, well is developed by
- Pumping
- Use of plunger (surging)
- Injection of compressed air (air lifting)
- Back washing (back flushing)
- Addition of stool CO<sub>2</sub>
- Detonation of explosives
- Combinations of more than 1 of the allowed methods.

## PUMPING TESTS

After well development comes test pumping which may be controlled to determine

- The performance characteristics of the well
- The hydraulic parameters of the aquifers: T.S.K etc.

For well performance least yield and draw down are recorded so that the specific capacity can be calculated. The second purpose of pumping test is to provide basic data from which principal factors of well completion.

## WELL COMPLETION

After a deep well has been drilled, it must be completed to enable the ground water move with minimum resistance in and out of the well. Procedures that comprises borehole completion are:

- Installation of casings, screens and centralization.
- **Gravel parking**

**INSTALLATION OF CASING SCREENS:** Water may flow into uncased well in formations that are competent. However, in unconsolidated formations a casing may be necessary. At the aquifer section of the well allow water entrance with least resistance. Screens are available in various sizes, designs and materials.

**GRAVEL PARKING:** Geologic conditions that favour the use of gravel packing to improve well efficiency are:

1. Fine uniform sand
2. Thick artesian aquifer
3. Loosely cemented sand stone aquifer



4. Extensively laminated formations such as wells contain gravel screen or such wells contain gravel screen or envelope surrounding the screen.

## Methodology

### Materials and Methods:

#### Materials

- i. The equipment used for the testing and analysis were;
  - a. Set of sieves and sieve shaker.
  - b. Thermostat Electric Oven.
  - c. Electronic Weighing Balance
  - d. Set of bowls
  - e. Cassangrande apparatus
  - f. Proctor Compaction Mould and 2.5kg Rammer.
  - g. CBR mould and Machine
  - h. UCS machine and cylinder
  - i. Record book and other stationary
  - j. Laptop computer and data analysis software
  - k. Laptop computer and data analysis software
  - L. Hand Augers

To undertake this, the following lines of approach were taken and others yet to be undertaken will have proposed methodology presented.

1. We had developed a systematic data, based on as much information as required for smooth gathering of field and technical information, review with field work.
2. We undertook initial study trips to similar schemes to broaden our appreciation of the nature of scheme that may be required in the first instance.
3. We undertook field trips to all proposed communities where we had consultation and oral briefs from local stake/holders in the proposed scheme.
4. Within the communities, we made locational visits to inspect existing on-going or proposed schemes to acquire pictorial data and have on the spot assessment of site situation and detailed measurements taken.
5. Other necessary data from review of appropriate literature were also taken to fill information requirements.

The above items were requirements for preliminary stage works only.



**Results**

From the samples collected from the borings, brownish silty clay was recorded from ground level to a depth of 1.8metres, from 1.8metres to 2.8metres, brown grayish silty. This is underlain with gravel sand to a depth of 5metres which is the depth of boring.

**CHEMICAL EFFECTS:**

The chemical tests conducted on soil samples gave the results:

**Table 1**

Chemical Test Results

<b>BOREHOLE</b>	<b>TESTS</b>				
S/N	DEPTH (M)	PH	ORGANIC IMPURITIES	SULPHATE (SO4)	CHLORIDE (CL)
1.	0.5	6.8	9.8	1.2	40
2.	1.0	6.8	10.7	1.1	54
3.	1.5	6.9	11.6	1.4	48

The near - neutral PH values and the low Sulphate content indicates no serious measure of potential aggressiveness of the concrete.

**A summary of some laboratory test results are as follows:**

Summary of soil test results	maximum	minimum	Av.	
1. Liquid limit (LL) (%)	82.0	40.8	61.4	
2. Plastic limit (PL) (%)	31.2	14.6	22.9	
3. Plasticity index (PI) (%)		50.8	26.3	38.6
4. Moisture content (MC) (%)	40.2	33.2	36.67	
5. Percentage passing sieve 200(%)	99.0	14.7	56.9	
6. Specific Gravity		2.67	2.11	2.39
7. Angle of Internal friction (%) (0)6				6
8. Cohesion (KN/M2) (cu)		32		32
9. General classification				Silty Sand

**Groundwater Conditions:** The is at 0.6metres as at the time of boring.

**SETTLEMENT**

A foundation settlement has been evaluated base on net foundation width of 1.0m founded at a depth of 2.0m below ground level. Based on explored depth, a clay thickness of 2m below foundation level has been assumed with a coefficient of volumetric compressibility of above 0.25m<sup>2</sup>/MN, A total settlement of 25-50mm was obtained.



**BEARING CAPACITY**

Bearing capacity analysis based on the relationship proposed by Terzaghi for a foundation extending to depth of 2.0m, an undrained cohesion of 32kpa, angle of internal friction of 6° and unit weight of 1.802KN/M<sup>3</sup> has been explored in computing the ultimate bearing capacity of 80KN/M<sup>2</sup> with a factor of safety of 3.

**CONCLUSION AND REMARKS**

The predominant soil type at the proposed project site is identified as Silty clay within the limits of investigation. An allowable bearing capacity of 80KN/M<sup>2</sup> is recommended. A raft foundation is suggested.

**OTUOKPOTI**

**TABLE 2 SOIL TYPES AND SUMMARY OF GRADING AND PLASTICITY TESTS RESULTS**

BH	Depth (m)	Description	Sieve analysis - % finer (mm)			MC (%)	Plasticity		
			10	40	200		LL	PL	PI
1.	1.7	Silty Clay	100	100	98.0	39.2	82.0	82.0	50.8
2.	0.5	Silty Clay	100	100	99.0	35.7	60.6	23.6	36.9
2	1.7	Silty Clay	100	99.2	97.3	38.2	81.0	31.15	49.9
1.	2.4	Silty Clay	100	77.01	55.34	40.2	40.8	14.55	26.3
1.	2.8	Sand	98.33	60.00	14.66	34.2	_____	_____	_____
1.	3.2	Sand	85.33	43.99	25.99	33.2	_____	_____	_____

**TABLE 3**

**SOIL CLASSIFICATION (ATTERBERG LIMITS)**

**OTUOKPOTI**

Borehole No	Depth of Sample (M)	Liquid Limits (%)	Plastic Limits (%)	Plasticity Index	Unified system classification (USC)
1	0. 1.5	65.2	26.15	26.15	SC
2	0.5	60.5	23.55	36.95	SC
2	1.7	81.0	31.15	49.85	CH

**TABLE 4****STRENGTH TEST (UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST)**

Borehole No	Depth of Sample (M)	Natural Moisture Content (%)	Bulk unit Weight (KN/M <sup>2</sup> )	Undrained Cohesion (KNm <sup>2</sup> )	Angle of Internal Friction (θ)	Description
1	0 – 1.0	39.2	1.802	32	6	Silty Clay
2	1.5 – 2.0	39.3	1.836			

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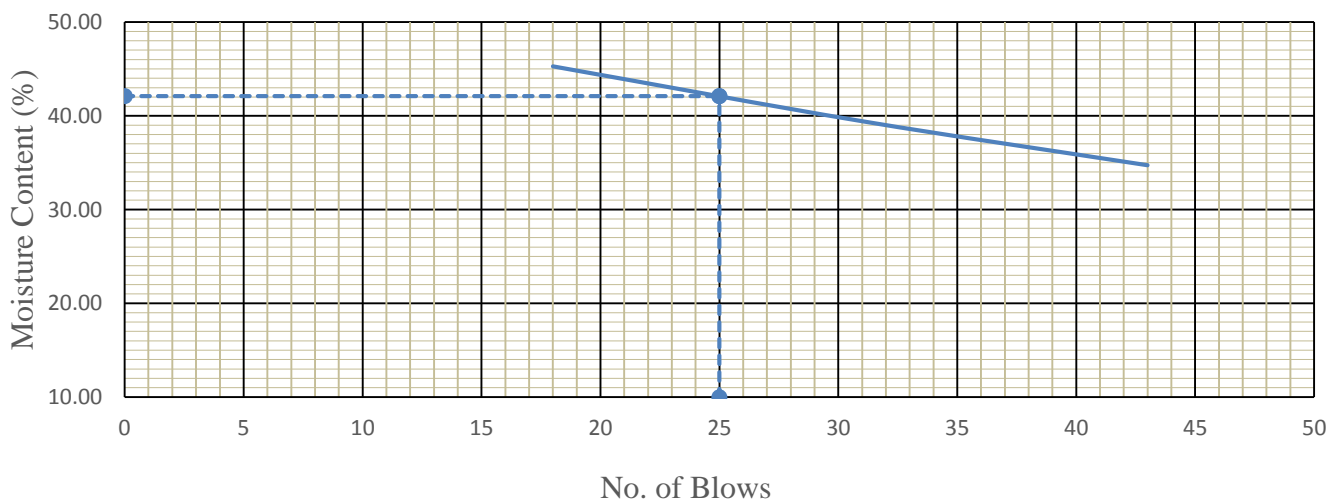
## APPENDICES

### Appendix I

#### LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No: OTUOKPOTI BH2 (2.4m)	Liquid Limit	42.1	Plastic Limit	14.54	
Date:	Plastic Index	27.56	Linear Shrinkage		
Job:	Description of Soil				
Machine No:	Operator:				
Proportion of Sample retained on No 36 B.S Sieve				Percent	
Type of Test	Liquid Limit			Plastic Limit	
No. of Blows (Liquid Limit Test)	43	31	18		
Container No.	L	f15	P	D	
				11	
Wt of wet soil and container (g)	36.30	38.00	37.30	19.90	19.90
Wt of dry soil and container (g)	33.00	33.90	33.00	19.00	19.10
Wt of container (g)	23.50	23.50	23.50	13.20	13.20
Wt of moisture Wm (g)	3.30	4.10	4.30	0.90	0.80
Wt of dry soil Wd (g)	9.50	10.40	9.50	5.80	5.90
Moisture Content (%)	34.74	39.42	45.26	15.52	13.56
Average Moisture Content (%)				14.54	

Liquid Limit Graph





## Appendix II

### LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No:

OTUOKPOTI BH1  
(1.5m)

Liquid Limit                      Plastic Limit  
71.19                                  26.15

Date:

Plastic Index                      Linear Shrinkage  
45.04

Job:

Description of Soil

Machine No:

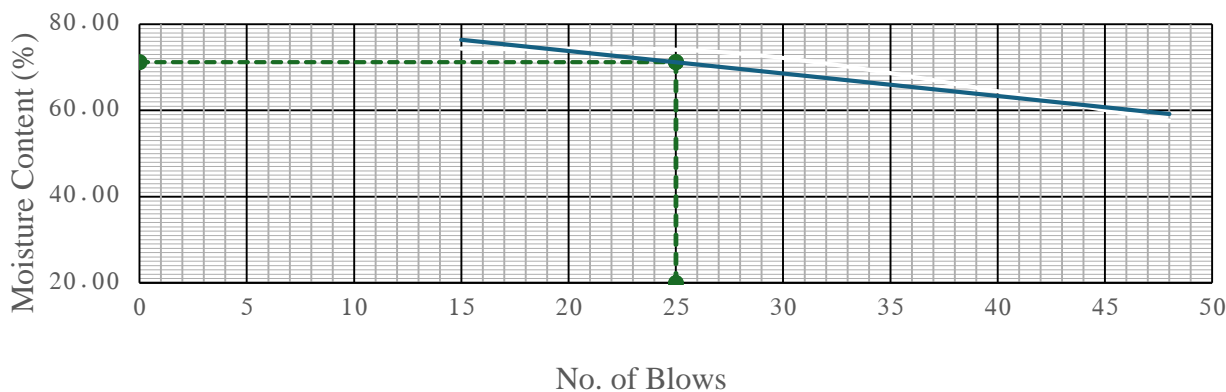
Operator:

Proportion of Sample retained on No 36 B.S Sieve

Percent

Type of Test	Liquid Limit			Plastic Limit	
No. of Blows (Liquid Limit Test)	48	29	15		
Container No.	W	44	U6	T2	V
Wt of wet soil and container (g)	36.90	38.70	37.10	19.40	20.00
Wt of dry soil and container (g)	32.00	32.30	31.30	18.20	18.50
Wt of container (g)	23.50	23.50	23.50	13.20	13.20
Wt of moisture Wm (g)	4.90	6.40	5.80	1.20	1.50
Wt of dry soil Wd (g)	8.50	8.80	7.80	5.00	5.30
Moisture Content (%)	57.65	72.73	74.36	24.00	28.30
Average Moisture Content (%)				26.15	

Liquid Limit Graph



73.19

0 71.19  
25 71.19

25 20  
25 71.19

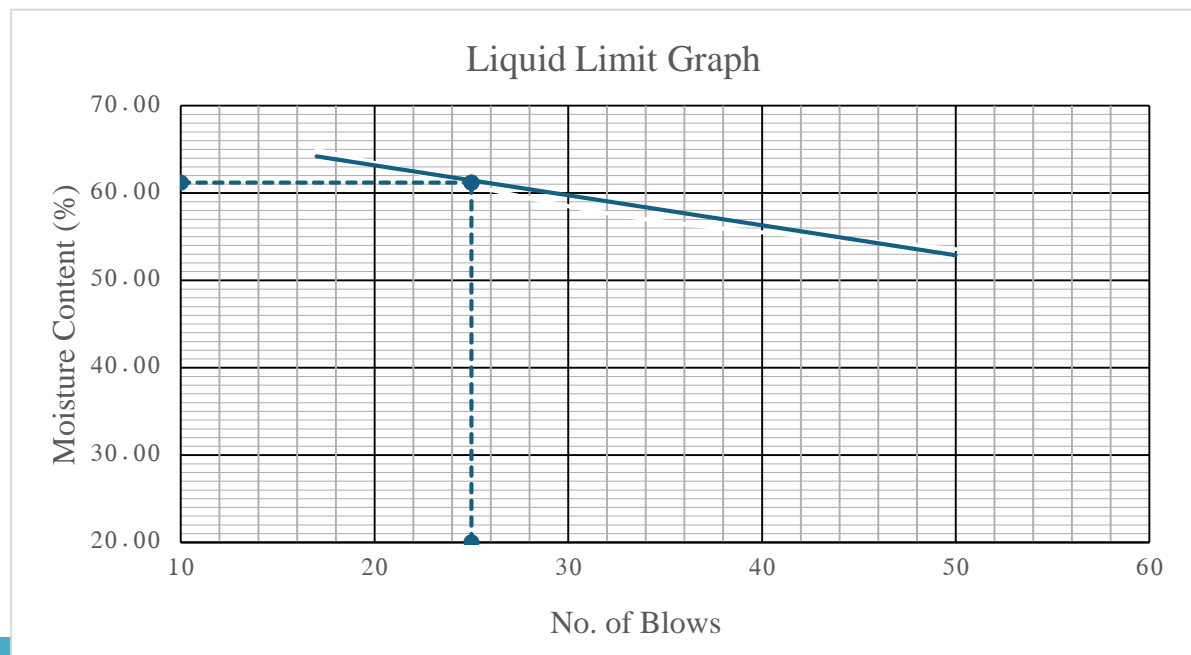


### Appendix III

#### LIQUID AND PLASTIC LIMITS, LINEAR SHRINKAGE

Sample No: OTUOKPOTI Top (0.5m)      Liquid Limit      Plastic Limit      23.54  
 Date:      Plastic Index      37.66      Linear Shrinkage  
 Job:      Description of Soil  
 Machine No:      Operator:  
 Proportion of Sample retained on No. 36 B.S Sieve      Percent

Type of Test	Liquid Limit		Plastic Limit		I	E
No. of Blows (Liquid Limit Test)	50	33	17			
Container No.	NI	8E	L3			
Wt of wet soil and container (g)	36.40	35.30	36.20	19.10	18.90	
Wt of dry soil and container (g)	31.90	31.00	31.20	18.10	17.70	
Wt of container (g)	23.50	23.50	23.50	13.20	13.20	
Wt of moisture W <sub>m</sub> (g)	4.50	4.30	5.00	1.00	1.20	
Wt of dry soil W <sub>d</sub> (g)	8.40	7.50	7.70	4.90	4.50	
Moisture Content (%)	53.57	57.33	64.94	20.41	26.67	
Average Moisture Content (%)				23.54		





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