# INVESTIGATION ON TRENDS OF PERCHED WATER TABLE FLUCTUATION IN INLAND VALLEY AREA OF FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA MAIN CAMPUS (PROJECT SITE)

BY

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## DEDICATION

This work is humbly dedicated to Almighty God, the most excellent, most merciful most magnificent of all and my late father Mr. Tirimisiu Eniade Bello. How can I forget when he was a father. May his soul rest in perfect peace (amen).

## CERTFICATION

This is to certify that this project work as carried out by Bello, Ismaila Olumide in the Department of Agricultural Engineering, Federal University of Technology, Minna.

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# ABSTRACT

An investigation on the trend of perched water table fluctuation was carried out in inland valleys area of F.U.T Minna permanent site farm (Giddan Paint). The field was laid out by taking an integral portion of the field along a valley formation of an area (20 x 100m$^2$). Three piezometric pipes were installed along the breath of the field at a distance of 30m apart to measure the ground water fluctuation below the ground surface. Ground water levels were measured at intervals of seven days. Some soil physical properties determined include; moisture content, hydraulic conductivity, infiltration rate and bulk density. From an investigation of the ground water levels fluctuation, about 67% of the wells in the project site had their water level above the depth of 120cm from the months of May to October, while the remaining 33% had their water level below the depth of 120cm in the months of May and June but later rose above 120cm from the months of July to October. One of the wells (Well A) was ponded from the months of May to October. So the water table in this well need to be lowered to a depth of about 120cm through drainage. This shows that except for well A the water table fluctuated within effective root depth of deep rooted crops.

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# 1.0 CHAPTER ONE: INTRODUCTION

## 1.1 THEORETICAL BACKGROUND

The occurrence of ground water necessitates a review of ground water existence. It may be subsurface distribution, the geologic zones, the structure in terms of water holding and water yielding capabilities.

Ground water flows towards points of discharge in river valleys and in some areas along the seacoast. The flow takes place in water bearing strata known as aquifers, which serve as the formation that contains saturated permeable materials to yield significant quantities of water of wells and spring (This implies an ability to store and transmit water). The velocity may be a few feet to several miles per year, depending upon the permeability of the aquifer and the hydraulic gradient of slope. A steep gradient or slope indicate relatively high pressure or head forcing the water through the aquifer. When the gradient is flat, the pressure forcing the water is small. When the velocity is extremely low, the water is likely to be highly mineralized, if there is no movement, the water is rarely fit for use. (Sybil, 1983)

The top or surface of the ground water in an unconfined stratum is the water table which marks the division between the ground water and the moisture zone in the soil. It may be within a few inches of the ground surface or hundreds of feet below. Normally, it follows the topography. (Sybil,1983).

When the deep percolation of ground water is impeded by a poorly permeable layer (aquitard), a saturated but relatively impermeable material (Aquiclude) and a relatively impermeable formation (aquifuge), and a so-called perched water table occur. The impermeable beds or poorly permeable layer use located well above the main water table that is on the height of capillary rise (Brandy and Wesseling, 1985). To be effective without seriously restricting growth, water should be near but below the depth from which the major portion of the plants needs are extracted. If ground water is too near the surface, the lands ability to economically produce most crops becomes almost nil. The optimum depth of water table is that depth which gives the maximum economic return. Preferred drainage practices could allow a water table at a depth, which will supply water by sub-irrigation for crops. But not so shallow that root aeration becomes a problem (Benz et al, 1985).

Therefore, for optimum water table, these will be different for different crops. Water quality, must be good to prevent salinity and other possible soil problems from affecting crop production when sub-irrigating.

The rate and distance of ground water movement are important criteria. Very detailed experiments will be required to determine ground water contribution to root zone under field conditions (Doorenbos and Pruitt, 1977; Hanks and Hills, 1980). Approaches to sub surface flow quantification usually entails sparse observational sampling of the system and rely upon interpolation or upon mathematical simulation techniques to extrapolate these observation to a more complete quantification of the entire system (Amerman and Nancy, 1982).

Measurement of water levels or piezometric heads are used in the analysis of ground water with respect to its occurrence, storage, movement, recharge and discharge; to be most valuable, they should be made as continuous records of water level fluctuation.

Evapotranspiration processes may result in dynamic water level responses seasonally. Confined aquifers respond readily to pressure effects due to natural phenomena such as barometric pressure, tidal movement near oceans and earth quakes. Man's activities also produce water level changes in aquifers, mainly by preparing, but locally also through after factors such as pressure and moving vehicles. Time lag features and pressure effects in aquifers are to be considered in analysis water level fluctuations. In such analysis, hydrographs, water level profiles and contours are used. The direction of flow can be obtained from the water table or piezometric surface (for confined aquifer) contour maps.

## 1.2 AIMS AND OBJECTIVES

(i) To identify pattern of fluctuation in inland valley of Gidan paint (F.U.T permanent site).

(ii) To identify period of recharge and discharge

(iii) To identify direction of ground water flow

## 1•3 PROJECT JUSTIFICATION

(i) To identify regime suitable for each type of crop production from the result of water fluctuation (specifically low or high water table conditions) in the project site so as to attain optimum water table for crop to be grown in the area

(ii) To investigate the availability and rate of contribution of ground water to net water requirement of each crop varieties to be grown in the project site.

(iii) To advise on irrigation periods and frequency; based on seasonal flux of water table.

# CHAPTER TWO: LITERATURE REVIEW

## 2.1.0 GEOLOGICAL FORMATIONS OF NIGER STATE

The Geology of Niger State is divided into two district geological zones, the basement complex and Nupe sandstone. Max lock group Nigeria Ltd. (1980) final report on Niger State regional planning. The dividing line runs approximately straight line to N.W – S.E. orientation from just south of Kontagora to just north of Lapai. (See appendix xi). The other significant, but much smaller, zone is the area of River Alluvium which is mainly found along the lower reaches of the Kaduna and Gbako rivers as they flow over the Nupe sandstones zone along the rivers Niger as it runs alongside the state southern boundary. Each geological formation exhibits different topographical, hydrological and soil features which are highly influential in determining existing settlement distribution.

### a. The Basement Complex Zone

The greater part of the area underlain by the basement is composed of banded gneisses and migmatrites. The meta-sediments comprise schist, phyllites, quartzite and marbles. The metamorphosed representatives of ancient sediments, such as clays, sandstones and limestones respectively. The terrain of the basement complex varies from small areas of plain through large areas of undulating land scope to severally scarped slopes and rock out crops. The basement mandate crop of the form. However, crops like cowpea, soya-beans and pigeon pea are planted to replenish the soil,

Complex terrain exhibits a fairly dense pattern of rivers. However, they are of only marginal value in that the majority are seasonal and some very short lived. Indeed, only those with a very large catchment area are perennial. The

Suleja, Paiko, Minna, Kuta, Kagara, Pandogari and Rijau area are conspicuous examples of these features (Max lock group Nigeria Ltd, 1980).

b. **<u>The Nupe Sandstone</u>**

The Nupe sandstone consist of weakly cemented fine to coarse-grained clays, siltstones and sandstones with locally inter bedded thin beds of carbonaceous shales. Lenses of conglomerate and pebbly sandstone also occur particularly near the contact with the underlying basement rocks.

Generally the terrain of the Nupe sandstone zone is much more hospitable than the Basement complex. Topography, therefore presents few constraints. The agricultural potential of the land is higher than that of the land is classified. The rivers network in the Nupe sandstone zone is closely related to the permeability of the geological formation, which varies from high in the north western cross to low in the Kutigi-Bida-Agaie areas. The more permeable, the less rivers it can carry rivers are less common on the Nupe sandstone zone than in the Basement complex but are usually perennial for most of their course. River density however varies enormously from almost none in Auna and Western Mashegu District to a density equivalent to that of the basement complex in Gbako and western Agaie LGA (Max Lock group Nigeria Ltd, 1980).

### 2.1.1 CLASSIFICATION OF WATER

Water in one or more of its three physical states solid, liquid, or gas is present greater or lesser quantities in or on virtually all the earth its atmosphere and all things living or dead. Water, important from the stand point of water resources development, falls into the categories of atmospheric water, surface waters, and sub surface water.

Atmospheric water and resultant precipitation occur in any of a number of forms and may change from one form to another during its descent. The forms of precipitation consisting of falling water droplets may be classified as drizzled or rain. Drizzle consists of quite uniform precipitation with drops less than 0.5m in diameter. Precipitation may also occur as frozen water particles including snow, sleet, and hail. Snow is composed of a grouping of small ice crystals known as snowflakes. Sleets forms when raindrops are falling through air having a temperature below freezing; a hail stone is an accumulation of precipitation, rain and snow make the greatest contribution to our water supply.

Atmospheric water and resultant precipitation are the source of replenishment of surface and subsurface waters. Surface and sub-surface water are the direct source of our developable water resources.

Sub surface and surface water: Water are being classified according to its flowing exposed or ponded upon the land known as surface water or subsurface water, occupying openings in the soil, over burden, or bed rock. That which is held in the soil within a few feet of the surface is termed as soil moisture, and is particularly concern of the botanist, soil scientist and Agricultural engineer. That which is held in the opening of the bedrock is usually referred to as a ground water (David, 1980).

## Ground Water

Sub surface water available for development is normally referred to as ground water. Ground water predominately results from precipitation that has reached the zone of saturation in the earth through infiltration and percolation. Ground water is developed for use through wells, springs or dugout ponds.

In many areas where ground water is an important source of water supply, it is being withdrawn much faster than it is being replenished from infiltration and percolation of precipitation. (Arthur, 1975).

### 2.1..2 VERTICAL DISTRIBUTION OF GROUND WATER

The subsurface occurrence of ground waters may be divided into zone of aeration and saturation. The zone of aeration consists of interstices occupied partially by water and partially by air. In the zone of saturation, all interstices are filled with water under hydrostatic pressure. On most of the land masses of the earth, a single zone of aeration over lies a single zone of saturation and extends upward to the ground surface. (Shown in Fig.2.1)

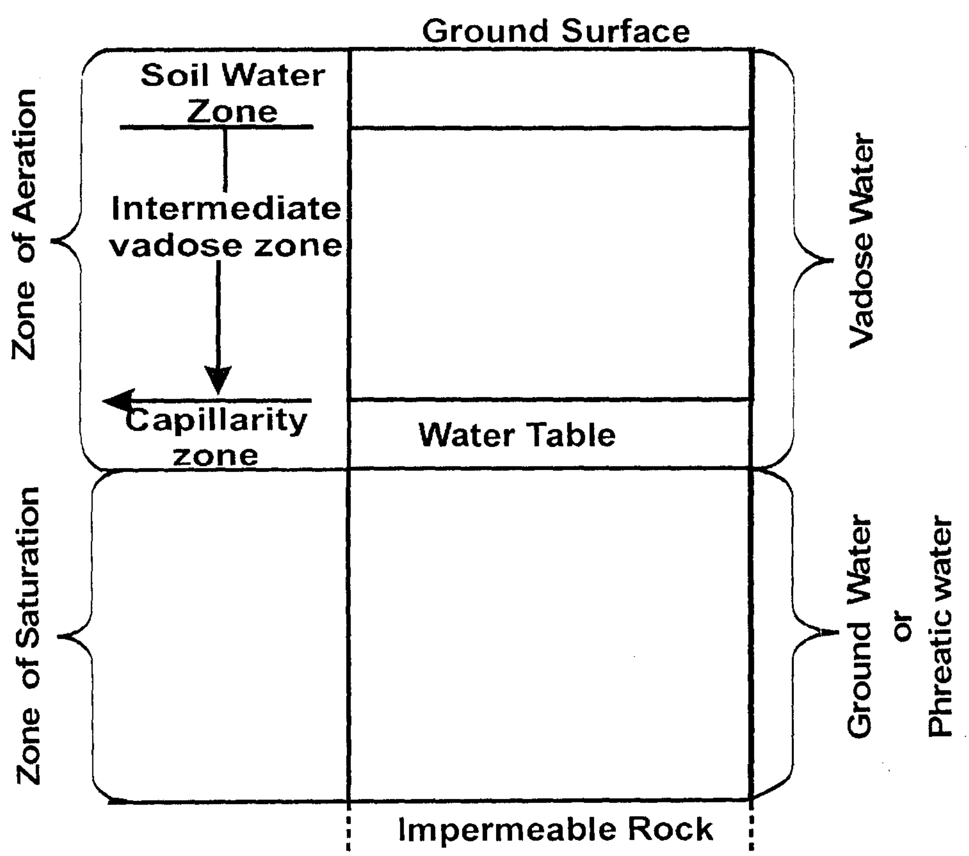



**Fig.2.1 Divisions of subsurface water**

Fig 2.1

In the zone of aeration, vadose water occurs. This general zone may be further sub divided into the soil water zone, the intermediate vadose zone, and the capillary zone.

The saturated zone extends from the upper surface of saturation down to underlying impermeable rock. In the absence overlying impermeable strata, the water table, or phreatic surface, forms the upper surface of the zone of saturation. This is defined as the surface of atmospheric pressure and appears as the level at which water stands in a well penetrating the aquifer. Actually, a saturation extends slightly above the water table due to capillary attraction; however, water is held here at less than atmospheric pressure. Water occurring in the zone of saturation is commonly referred to simply as ground water, but the term phreatic water is also employed (David, 1980).

### 2.1.3 THE OCCURRENCE OF GROUND WATER

Rainfall that infiltrate the soil and penetrate to the underlying strata is called ground water. The quantity of water that can be accommodated under the surface depends on the porosity of the sub-surface strata. The water bearing strata, called aquifer can consist of unconsolidated materials like sands, gravels and glacial drift or consolidated materials like sandstone and limestone. Limestone is relatively impervious but is soluble in water and so frequently has wide joint and solution passages that make the rock.

The water in the pores of an aquifer is subject to gravitational force and so tends to flow downward through the pores of the materials. The resistance to this underground flow varies widely and the permeability of the materials is a measure of this resistance. Aquifers with large pores such as coarse gravels are said to have a high permeability and those with very small pore such as clay, where the pores are microspic, have a low permeability.

As the ground water percolates down, the aquifer becomes saturated. The surface of saturation is referred to as the ground water table or the phreatic surface. This surface may slope steeply and its stability is dependent on supply from above. It falls during dry spells and rise in rainy weather. The water in the aquifers is usually moving slowly towards the nearest free waters surface such as lake or river, or the sea. However, if there is an impermeable layer underling an aquifer and this layer out crops on the surface, then the ground waters will appear on the surface in a seepage zone or as a spring. It is equally possible for a ground water aquifer to become overlain by impermeable material and so be under pressure such an aquifer fed from a distance, is called a confined aquifer and surface to which the water would rise if it could is called the piezometric surface. Another name, used for well drilled into such confined aquifers, it artesian wells, and the words artesian is sometimes applied also to the aquifers. If piezometric surface is above ground levels at an artesian well, it is called a flowing well, and fracture or flow in the impermeable overlay will, in such condition results in an artesian spring. Sometimes a small area of impermeable material exists in a larger aquifer. This happens through geological faulting or for example through a lens of clay occurring in other wise sandy glacial drift. A small local water table, called a perched water table may result and this can often be a long way above the true phreatic surface (Cedestorm et al, 1975).

## The Water Table (Phreatic Level)

The water table marks the division between the ground water and the moisture zones in the soil. Its location is found by sinking a bore-hole into the ground water body. Water from the surrounding soil will flow into the hole and fill it to the water table level. For regular water table depth measurements, the borehole may be fitted with a perforated pipe in order to give the hole a degree of permanence.

When a deep percolation is impeded by a poorly permeable layer, a so called perched water table may develop (see Fig.2·2) its occurrence is temporary as the impeded water will continues to seep through a deeper layers or drain laterally. It may, however exist long enough to cause a serious problems of excess water in the soil. Perched waters tables may be detected by drilling a bore-holed into (but not through) the impeding layer (Michael, 1985)

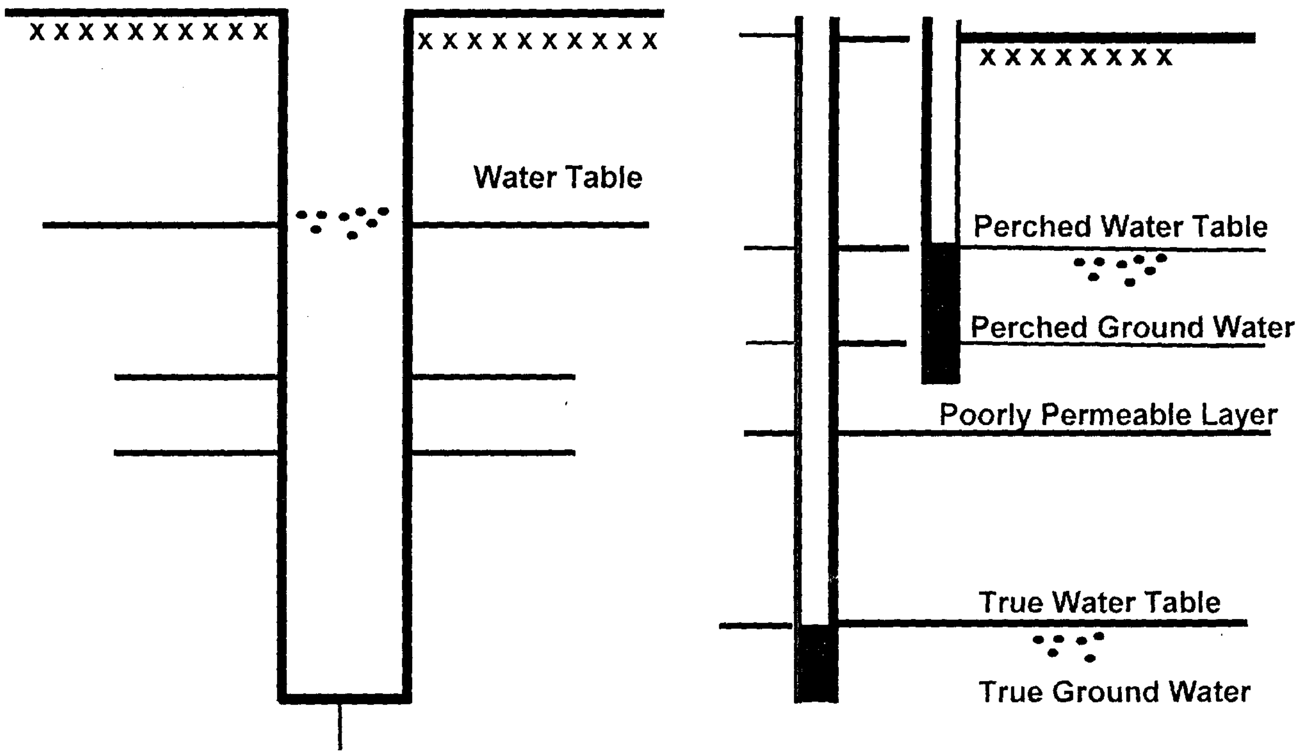



**Fig. 2·2Shows water Table observation well and perched water table**

Fig 2.2

## 2.1.4 GEOLOGIC FORMATIONS AS AQUIFERS

A geologic formation that will yield significant quantities of water defined as Aquifer. Many types of formations serves as aquifers. A key requirement is their ability to store water in the rock pores (Todd, 1962).

## 2.1.5 TYPES OF AQUIFERS

Most aquifers are of large extent and may be visualized as underground storage reservoirs. Waters enters a reservoirs from natural or artificial exchange, it flows out under the action of gravity or is extracted by wells. Ordinarily, the annual volume of water removed or replaced represents only a small fraction of the total storage capacity. Aquifers may be classed as unconfined, depending on the presence or absence of water table, while a leaky aquifers represents a combination of the two types.

### Unconfined Aquifers

An unconfined aquifers is one which a water table varies in undulating form and in slope, depending on areas of recharge and discharge, pumpage from wells, and permeability. Rises and falls in water table correspond to changes in the volume of water storage within an aquifer.

A special case of confined aquifers involves perched water bodies. This occur when ever a ground water body is separated from the main ground waters by a relatively impermeable stratum of small real extent and by the zone of aeration above the main body of ground water.

## Confined Aquifers

Confined aquifers, also known as artesian or pressure aquifers, occur where ground water is confined under pressure greater than atmospheric by overlying relatively impermeable strata. In a well penetrating such as an aquifers, the water level will rise above the bottom of the confining bed. Water enters a confined aquifer in an area where the confining bed rises to the surface, where the confining beds ends underground the aquifer become unconfined (Jacob, 1940).

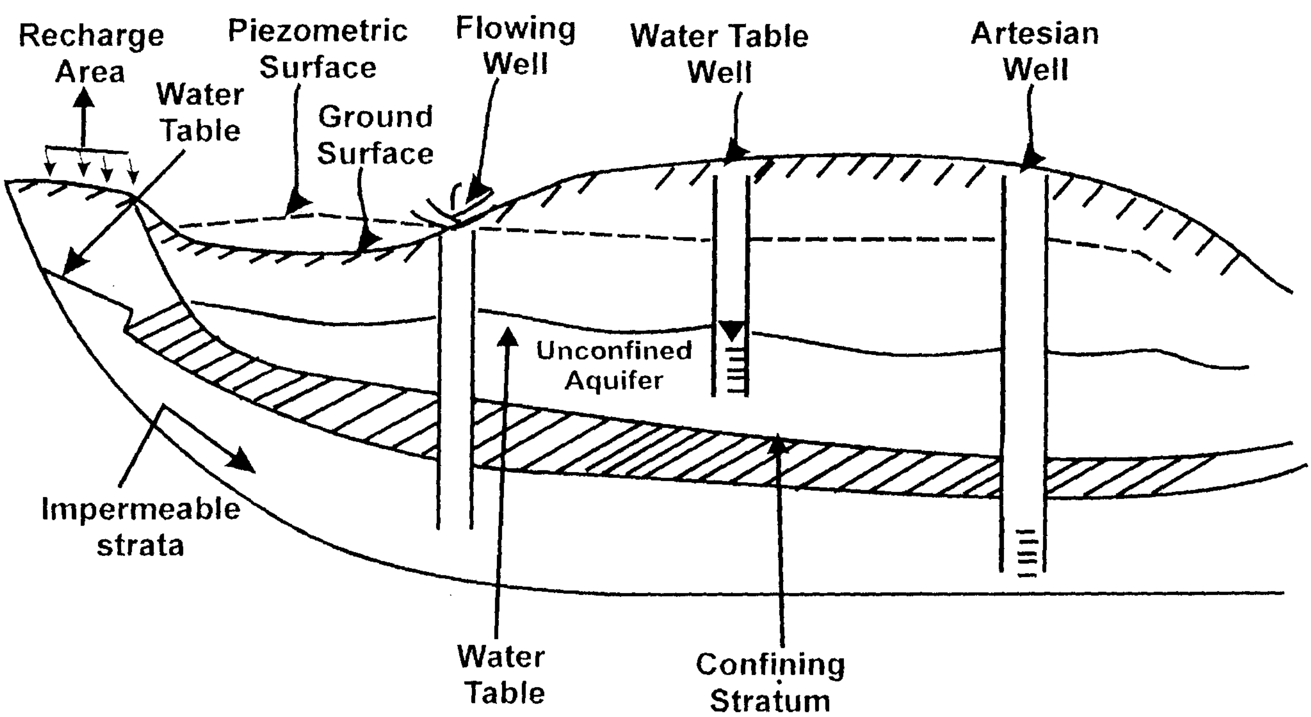



Fig 2.3: Schematic cross section illustrating Unconfined and confined aquifers.

A region supplying water to a confined aquifer is known as a recharge area, water may also enter by leakage through confining bed. Rises and falls of water in wells penetrating confined aquifers results primarily from changes in pressure rather than changes in storage volumes. Hence, confined aquifers displays only small changes in storage and serve primarily as conduits for conveying water from recharge area to locations of natural or artificial recharge.

The piezomertric surface, or potentiometric surface of confined aquifer is an imaginary surface coinciding with the hydrostatic pressure level of the water in the aquifer. The water level in a well is penetrating a confined aquifer defines the elevation of the piezometric surface at that point. It should be noted that a confined aquifer becomes an unconfined aquifer when the piezometric surface falls below the bottom of the upper confining bed. Also, quite commonly an unconfined aquifer exist above a confined one.

## Leaky Aquifers

Aquifers that are completely confined or Unconfined occurred less frequently than leaky, or semi confined aquifers. These are a common feature in alluvial valleys, plains, or former lake basins where a permeable stratum is overlain or underlain by semi pervious aquitard, or semi confining layer.

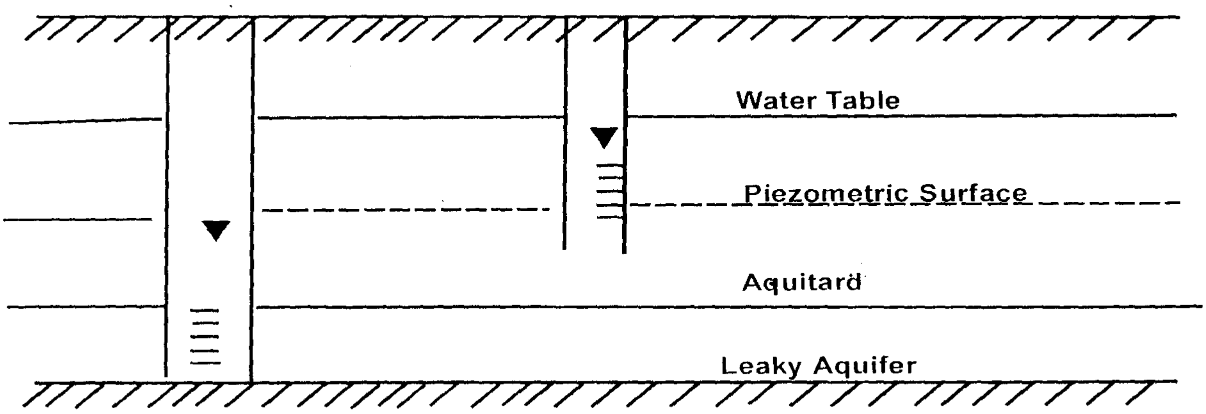



Fig:24: Sketch of a leaky, impermeable strata or semi confined aquifer.

Pumping from a well in leaky aquifer remove water into two ways: by horizontal flow within the aquifer and by vertical flow through the aquitard into the aquifer.

## Idealized Aquifers

For mathematical calculations of the storage and flow of ground water, aquifers are frequently assumed to be homogeneous and isotropic. A homogeneous aquifer possesses hydrology properties that are everywhere identical.

An isotopic aquifer is one with its properties independent of direction. Such idealized aquifers do not exist, however, good quantitative approximations can be obtained by these assumptions, particularly where average aquifer conditions are employed on a large scale. Anisotropic aquifer which possess directional characteristics. (Jacob et al,1973).

## 2.1.6 STORAGE COEFFICIENT

A storage coefficient (or storativity) is defined as the volume of water that an aquifer release from or takes into storage per unit surface area of aquifer unit change in the component of head normal to that surface. For a vertical column of unit area extending through a confined aquifer, the storage coefficients equals the volume of water released from the aquifer, when the piezometric surface declines a unit distance. The coefficient is a dimensionless quantity involving a volume of water per volume of aquifer. In most confined aquifers, values fall in the range $0.00005 < S < 0.005$, indicating that large pressure changes over extensive areas are required to produce substantial water yield.

### 2.1.7 GROUND WATER BASINS

A ground water basin may be defined as a hydro geologic unit containing one large aquifer or several connected and inter related aquifer. Such a basin may or may not coincide with physiographic unit.

The concept of groundwater basin becomes important because of the hydraulic continuity that exist for the contained ground water resource. In order to ensure contained availability of subsurface water, basin wide management of ground water become essential.

### 2.1.8 SPRINGS

A spring is a concentrated discharge of ground water appearing at the ground surface as a current of flowing water. To be distinguished from springs are seepage areas, which indicate a slower movements ground water to the ground surface. Water in seepage area my pond and evaporate or flow depending on the magnitude of the seepage, the climate, and the topography.

Most spring fluctuate in their rate of discharge. Fluctuations are in response to variations in rate of recharge with periods ranging from minutes to years depending on geologic and hydrologic conditions. (Fennia,1928).

### 2.1.9 GROUND WATER MOVEMENT

Ground water in its natural state is invariably moving. This movement is governed by establishing hydraulic principles. The flow through aquifers, most of which are natural porous media, can be expressed by what is known as Darcy's law hydraulic conductivity which is a measure of the permeability of the media, is an important constant in the flow equation. Determination of hydraulic conductivity can be made by several laboratory or field techniques applications of Darcy's law enable ground water flow rates and direction to be evaluated. (Cooper and Rorabaugh, 1963).

## 2.2.0 HYDRAULIC CONDUCTIVITY

The hydraulic conductivity K, as applied to an aquifer, is defined as the rate of flow of water in litres per day through a horizontal cross sectional area of one square metre of the aquifer under a hydraulic gradient of one meter per metre at the prevailing temperature of water.

The rate of flow of ground water in response to a given hydraulic gradient is dependent upon the hydraulic conductivity of the aquifer (Mazumder, 1983).

## 2.2.1 PERMEABILITY

Permeability is defined as the readiness with which a soil transmits fluid. Generally, water moves slowly downward through a highly dispersed soil because the micro pores are clogged by the swelling of dispersed clay.

Soil permeability also depends on soil texture structure and depth of the water table (David, Eagle and Finney 1986).

## 2.2.2 INFILTRATION

The term infiltration refers specifically to the entry of water into the soil surface. Infiltration rate has the dimensions of volume per unit of time per unity of area. These units reduce to depth per unit time. Infiltration is the sole source of soil moisture to sustain the growth of vegetation and of the ground water supply of wells, springs, and streams.

The movement of water into the soil by infiltration may be limited by any restriction to the flow of water through the soil profile. Although such restriction often occurs at the soil surface, it may occur at some point in the lower ranges of the profile. The most important items influencing the rate of infiltration have to do with the physical characteristics of the soil and the cover on the soil surface, but such factors as soil moisture, temperature, and rainfall intensity are also involved (Michael, 1985).

### 2.2.3 PERCOLATION

The term percolation refers to the downward movement of water through saturated or nearly saturated soil in response to the force of gravity. Percolation occurs when water is under pressure or when the tension is smaller than ½ atmosphere.

### 2.2.4 SEEPAGE

Seepage is the infiltration (vertically) downward and lateral movements of water into soil or substrata from a source of supply such as a reservoir or irrigation carnal. Such water may reappear at the surface as wet spot or seeps or may percolate to join the ground water or may join the sub surface flow to springs or streams. Seepage rate depends on the wetted perimeters of the reservoir or the canal and the capacity of the soil to conduct water both vertically and laterally. (Vaugum, 1986).

## 2.2.4 RUN-OFF

Run-off is that portion of the precipitation that makes its way toward stream channel, lakes, or oceans as surface or sub surface flow. The term "run-off" usually means surface flow.

Before run-off can occur, precipitation must satisfy the demands of evaporation, interception, infiltration, surface storage, surface detention, and channel detention. (Orso and Glen, 1980).

## 2.2.6 IRRIGATION

Irrigation is the artificial application of water to soil for the purpose of crop production. Irrigation water is supplied to supplement the water available from rainfall and the contribution to soil moisture from ground water. In many areas of the world the amount and timing of rainfall are not adequate to meet the moisture requirement of crops and irrigation is essential to raise crops necessary to meet the needs of food and fibre.

Irrigation wells: A water well is an hydraulic hole in the earth down to a supply of water excavated for the purpose of bringing ground water to the surface. Irrigation wells differ from those used to supply water for domestic purpose because of the large volumes of water that have to be pumped from them for irrigation even small forms.

Flow of ground water into wells is influenced by the physical characteristic of the water bearing formations (Michael, 1985).

### 2.2.7 LAND DRAINAGE

The main objectives of Agricultural land drainage is to remove excess water in order to improve the profitability of farming the land. There are periods on most land when excess water occurs. However, there are periods on most land when excess water occurs. However, these need not be too harmful provided the quantities are small, the periods of occurrence are of short duration. Or the excess occur during a non-critical season (e.g outside to the main farming season). Most land also has some natural drainage which assist in the removal of a certain amount of the excess waters. It is only when large quantities, occurs for prolonged durations at critical periods, that its removal by artificial means may be feasible.

Excess water may occurs on the land surface (surface ponding often combined with waterlogging of the top soil) or deeper down in the soil profile (water logging of the root zone due to impeded percolation or due to high water tables). (Vaughn Orson and Glen, 1980).

### 2.2.8 THE EFFECTS OF WATER LOGGING

In water logged soils, the air content of the soil is low because most pores are filled with water. Moreover, the exchange between the remaining air in the soil and the air in the atmosphere above ($O_2$ moving into the soil, $CO_2$ moving out) is very restricted by these conditions. In consequence, respiration is restricted by the oxygen deficiency while at the same time the carbon dioxide accumulates to toxic levels, directly impairing the root growth and the roots ability to absorb nutrients.

## 2.2.8 SOIL MOISTURE

Soil moisture refers to the zone of soil water in the in saturated soil above the water table the pores are partly occupied by water and partly by air. The amount of soil moisture varies greatly with depth and in time.

Soil moisture generally reduces or limits the infiltration rate. The reduction is due in large part to the fact that moisture causes some of the colloids in the soil to swell, and thereby reduce both the pore space and the rate of water movement.

The soil moisture content in the upper soil layer (down to 0.5 – 1.0m) is particularly variable, mainly due to variations in daily weather conditions (especially rainfall variations). Deeper down, variation occur over a long term, in parallel with seasonal weather variations (Donahue, 1982).

## 2.3.0 CROP WATER REQUIREMENT

The estimation of the water requirements (WR) of crops is one of the basic needs for crop planning on the farm and for the planning of any irrigation project.

Water requirement may be defined as the quantity of water, regardless of its source, required by a crop or diversified pattern of crops in a given period of time for its normal growth under field conditions at a place. Water requirement includes the losses due to evaporation (ET) or consumptive use (cu) plus the losses during the application of irrigation water (unavoidable losses) and the quantity of water required for special operations such as land preparation, transpirating, leaching, etc. it may thus be formulated as follows:

WR = ET OR Cw + application losses + special needs.

Water requirement is, therefore, a "demand" and the "supply" would consist of contribution from any of the sources of water, the major sources being the irrigation water (IR), effective rainfall (ER) and soil profile contribution(s) including that from shallow water tables. Numerically, therefore water requirement is given as:

$$WR = IR + ER + S$$

The field irrigation requirement of a crop, therefore, refers to the water requirement of crops, exclusive of effective rainfall and contribution from soil profile, and it may be given as

$$IR = WR - (ER + S)$$

Cu = Consumptive use

WR = Water Requirement

IR = Irrigation Water

ER = Effective Rainfall

S = Soil Profile Contribution

### 2.3.1 PRECIPITATION

precipitation includes all water that falls from atmosphere to the earth's surface. Precipitation occurs in a variety of forms, ligerial precipitation (rainfall) and frozen precipitation. (Dirisu, 1997).

### 2.3.2 EVAPOTRANSPIRATION

Evaporation: of the water that is precipitated on the earth, a large amount is returned to the atmosphere as vapour, through to the combine action of evaporation, transpiration and sublimation. These are in essence three variations of single process due to the energy of the solar engine that keeps the hydrological cycle running (veihmeyer and Brooks, 1954).

Evaporation or vaporization is the process by which molecules of water at the surface of water or moist acquires enough energy through sun radiation to escape the liquid and to pass into the gaseous state.

Transpiration is the process by which plant loose water to the atmosphere.

### 2.3.3 RECHARGE

Critical shortages of underground water due to limited natural recharge, small storage capacity, and over use here stimulated efforts to recharge ground water reservoirs with surface waters. Flood flows would otherwise have been lost are diverted and applied to the land, thus providing water to seep into underground reservoir.

Full conservation and use of available water supplies requires an integrated use of surface and sub surface water and storage facilities. Water percolates into the ground water reservoir to be stored until needed for irrigation.

### 2.3.4 GROUND WATER HYDROLOGY

The occurrence of ground water necessitates a review of where and how ground water exists. Sub surface distribution, in both vertical and area extents, needs to be considered. The geologic zones important to ground water must be identified as well as their structure in term of water holding and water yielding capacities.

Almost all ground water can be thought of as a past of the hydrological cycle, including surface and atmosphere (meteoric) waters. Relatively minor amounts of ground water may enter this cycle from other origins.

Water that has been out of contact with the atmosphere for at least in appreciable part of a geologic period is termed connate water. Essentially, it consist of fossil interstitial water that has migrated from its original burial location. This water may have been derived from oceanic or fresh water sources and typically, is highly mineralized. Magmatic water derived from magma, where the separation is deep, the term plutonic water is applied, while volcanic water designates water from relatively shallow depth (perhaps 3 to 5km). New water of magmatic or cosmic origin that has not previously been a part of the hydrosphere is referred to as juvenile water. And finally, metamorphic water is or has been associated with rock during their metamorphism.

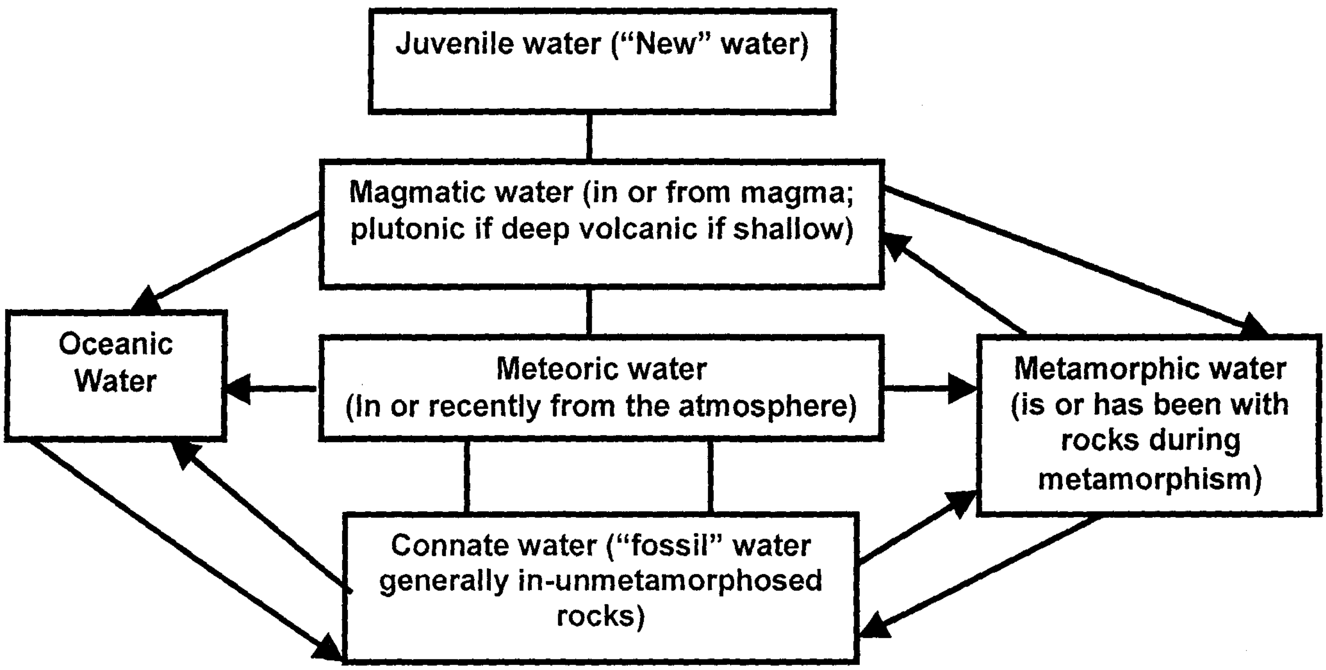



**Fig25:The diagram illustrate the inter relations of those genetic type of ground water.**

**(Courtesy: The geological Society of America, 1975)**

## 2.3.5 SOIL WATER BALANCE STUDY

Once the extent of an aquifer has been established and its boundaries identified, it should be possible to quantify the volume of water that are passing through the ground water system. The amount of recharge can be assessed using information about rainfall and evaporation. Discharges from the aquifer can be estimated from spring flow measurement, stream gauges and amount of water pumped from local well. This stage of investigation constitutes a summary of all previous work and is the point at which it becomes possible to start to answer those questions, which caused you to initiate the investigation in the first place. This may include the availability, of ground water resources and the suitability of the resources abstraction, or the treat of pollution from the proposed waste disposal operations.

Ground water recharge to an aquifer cannot be measured, directly but only, inferred from other measurements. As ground water is part of the hydrological cycle, measurements of other components of the cycle can be used to estimate the value of the resources, using a technique called a water balance. In this type of calculation, it is assumed that all the water leaving an area, plus or minus any change in storage. This can be written more fully as in the equation given below (Barrsington, 1993)

**Inflows**

The addition: (of rainfall, recharge from surface water, sea water intrusion, inflow from other aquifers, leakage, artificial recharge) equal to (abstraction, spring flow, base flow in rivers, discharge to the sea, flows to other aquifer, evapotranspiration plus or minus (change in aquifer storage).

## Types of Flow

**A. Inflows**

(1) Rainfall: This is usually the most significant recharge component and consist of that proportion of rainfall, which percolates into an aquifer. Some rainfall is lost an evapotranspiration or run-off. Estimates are based on rainfall and evapotranspiration data and the consideration of the geology and ground water levels.

(2) Recharge from surface water: when streams, rivers, lakes or ponds have a permeable bottom or sides, water can percolate into an aquifer when the ground water levels are lower. This recharge is estimated using Darcy's law by consideration of the geology and the difference between surface water and the ground water levels.

3. Sea – water intrusion: When the water levels in coastal aquifers are lowered by pumping, the potential exists for sea water intrusion Apply Darcy's law to calculate inflows from information on ground water levels and aquifer hydraulic conductivity.

4. Flow from the aquifers: All aquifer which are adjacent to the study area should be examined as the potential sources of recharge. Geological information, ground water levels and chemical evidence will help to decide if flow is taking place across boundaries. Estimate inflow using Darcy's law.

5. Leakage: This is an artificial type of inflow caused by leakage from water – supply reservoirs, water pipes and sewers, resulting from damage or deterioration. Leakage is estimated by measuring inflows and outflows of the water – supply or sewers system.

(6) Artificial recharge: In some aquifers, actual recharge is artificially supplemented by water being recharge through special lagoons or boreholes. This component of recharge can be easily quantified from direct readings. Sewage disposals may sometimes also be another source of recharge water.

## B. Outflows

(1) Abstractions: Use metered records whenever possible otherwise estimate from the pump capacity and hours run or from the water requirement of crop.

(2) Spring flows: Ground water discharge from springs can be assessed by measuring each of separately or from stream flow measurements, which will include the flow from a number of springs.

(3) Base flow: The ground water component of surface water flow can be estimated from stream flow records.

(4) Discharge to the sea: Ground water may discharge directly into the sea. Sometime this forms a spring – line between high and low watermarks which may be identified from the observation, temperature or conductivity measurements. Apply Darcy's law to estimate quantities involved.

(5) Flow to other aquifer: use ground water level information and flow net analysis to estimate quantities. Discharge to other aquifer may occur along boundaries, and these should be estimated in the similar manner. Used

geological information, ground water level records and chemical information to decide if such flow can occur.

(6) Evapotranspiration: In areas where the water table lies close to the ground surface, ground water may be removed by plants taking water up through their leaves. Generally, however, evapotranspiration removes water from the soil, there by creating a deficit which is made good by the following precipitation. This process reduces the quantity, of rainwater for recharge. Evaporation also takes place from bare soil, with water flowing upwards under capillary forms to replace losses.

# 3.0 CHAPTER THREE: MATERIALS AND METHODS

The focus of this chapter is on the methodology by which this project was carried out, ranging from field experiment to the laboratory experiments carried out, as well as materials used

## 3.1 EXPERIMENTAL LAYOUT

The site was located at the inland valley of the permanent site of the Federal University of Technology Minna. The field was on an area covering one side of the valley formation and is about 100m in breadth.

Only an integral portion of the field was considered for the purpose of this work. This was due to some limitations and scope of this work. The integral portion considered covered an area of 2000m$^2$ (20 x 1000). The area was divided into two parts according to the parts of the slope i.e upper part of the slope and lower part of the slope. (See Fig. 3.3)

Ranging poles, pegs and tape were used to locate three points A, B and C at different portion along the slope of the land presumably that the water table depth would decrease down the slope. The three points were located where the wells would be drilled. They were located in such a way that they were on line and at the middle of the area considered. The points were at a distance of 30 metre apart. Point A was at the upper part of slope and point C at the lower part very close to the valley. Point B was in-between point A and C.

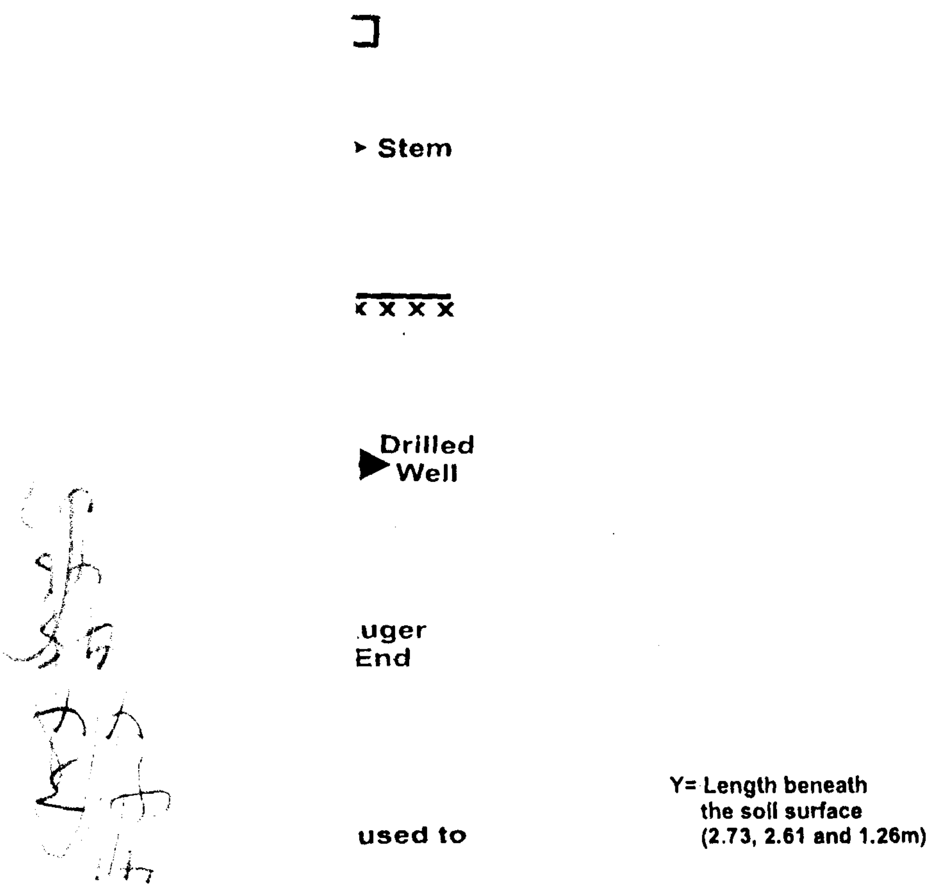
## 3.2 MODE OF INSTALLATIONS OF PIEZOMETRIC PIPES

A cutlass was used to clear the location points, a hand driven anger of length 4.2m and screed dimension 5.5 x $10^{-2}$ m was used to drill a well at each point A, B and C were drilled to depth of 2.73m, 2.61m and 1.26m respectively.

Piezometric pipes of diameter 0.04 m and length range of 1.9 m to 2.9 m were installed at points A, B and C respectively. The pipes were radially perforated across bottom length to allow sufficient and effective inflow of ground water into the pipes to assume its original form and level. At the neck of the pipes

between the well and the pipe was sealed

ıter into the well by surface run-off and



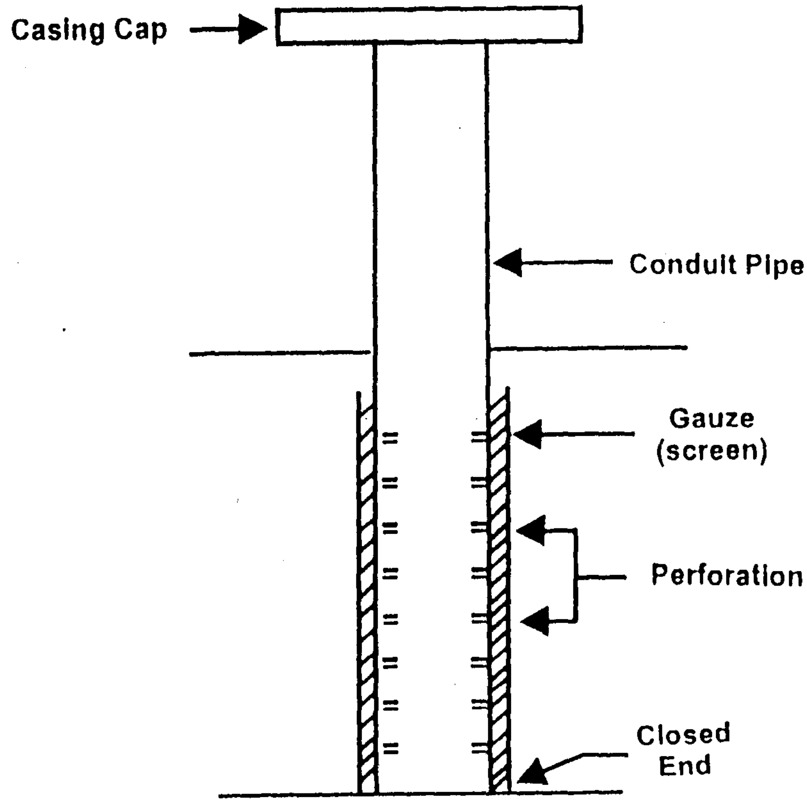



Fig. 3.2: Cross section of constructed piezometric pipe.

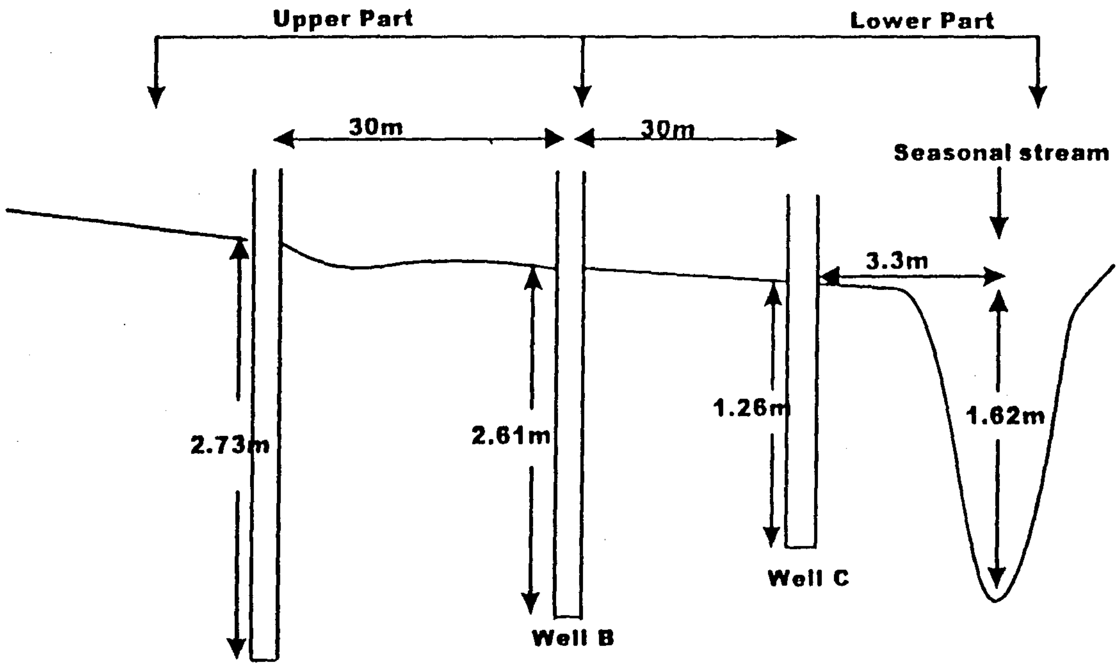



**Fig. 3.3:** **A cross section of installed piezometric pipes at project site**

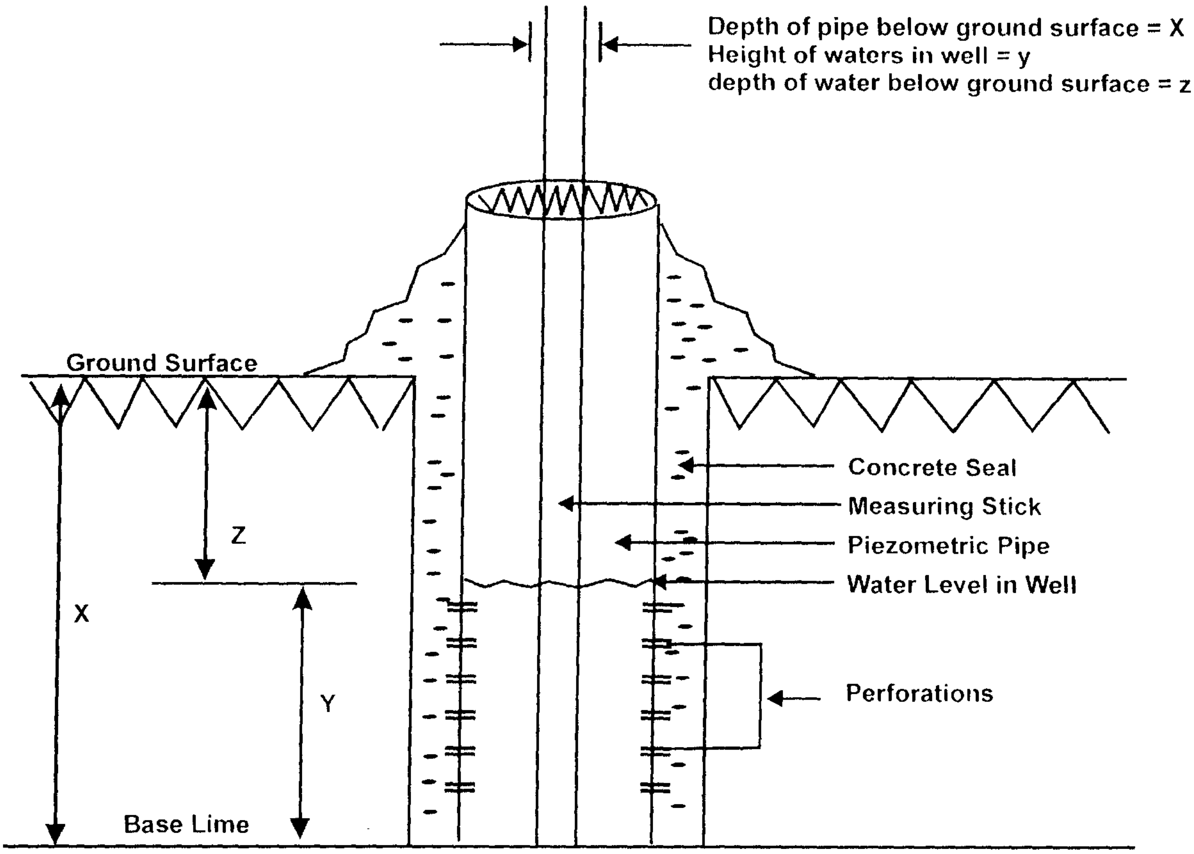



**Fig. 3.4: Cross section of pipe in well**

## 3.3 DETERMINATION OF MOISTURE CONTENT, BULK DENSITY AND POROSITY

A core ring of 6cm in diameter and 6 cm in height was placed on the soil (0 – 20) cm and pressed into the soil by tapping it gently with a mallet until the core was completely filled with soil. It was then removed gently by placing a cutlass under the core sampler. This was necessary so as to prevent the soil in the core from falling off. After removing, the core sampler from the soil, the soil was gently transferred into a moisture can and covered immediately so as to avoid moisture loss or gain by evaporation or condensation. The moisture can was then placed in a cool place. The same procedure was then repeated for (20 - 40)cm, (40 -

60)cm, (60 – 80)cm, and (80 - 100) cm soil depth at the upper and lower part of the slope.

The cans were all covered with polythene after filling them with soil. All the samples were taken gently in a container and conveyed to the laboratory where an electronic machine was used to weigh the cans and the soil. The moisture cans were clearly labelled to distinguish the sample's depth and location. They were then placed in an oven at a temperature of $105^0$c for 24 hours after which the oven was switched off and open for the cans to cool a little before it was then re – weighted. The initial weight, final weight and weight of can sampler were taken. The moisture content, bulk – density, and porosity were then calculated. Table (4.2) .

## 3.4 HYDRAULIC CONDUCTIVITY (UNSATURATED)

A plot of land of (5 x 5)$m^2$ was marked out at the upper and lower part of the slope. Ridges were constructed around the marked plot. The plot were then saturated (flooded) with water for two days to allow the water to sink to a depth of 1m. The plots were then mulched and covered with polythene sheets to prevent evaporation.

Soil samples were collected hourly at depths (0 – 20) cm, (20 – 40)cm, (60 – 80)cm and (80 - 100)cm for six hours. On the first day and there after, daily for the next six days. The soil samples were collected in tins and covered with polythene sheet to prevent gain or less of moisture. The tins and their contents were conveyed to laboratory, where they were weighted and oven dried for 24 hours, after which they were reweighed.

The volumetric moisture content for each depth was determined and the hydraulic conductivity was calculated as in Table 4.4

### 3.5 DETERMINATION OF INFILTRATION RATE

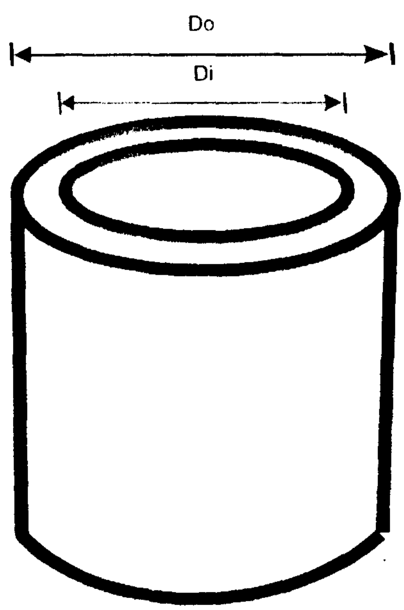
The infiltration rate was determined by using the double cylinder infiltrometer. The double cylinder infiltrometer consisted of an inner cylinder of height 25cm and diameter 30cm, and an outer cylinder of height 25cm and diameter 60cm.

The inner cylinder was inserted into the soil by placing a plank across the ring and tapped gently until the cylinder has gone into the soil to a depth of 10cm. The inner cylinder has a ruler attached to the inner side, which allows for the reading of the water level as infiltration progresses.

After installing the inner cylinder, the outer cylinder was installed in the same manner to a depth of 10 cm. During the installation of the outer cylinder, care was taken to centralized the radial distance between the two cylinders (concentric) by monitoring it after each tap. A small quantity of grass was placed in the inner and outer cylinder to avoid puddling when pouring water in the cylinder. Water was measured with four litre capacity can and the water was set at zero reading.

After the infiltrometer was put in place, water was poured into the inner cylinder and simultaneously the watch was started. The inner cylinder was ponded up to a level of 11 cm reading on the ruler. This implies that 11cm on the ruler is the reference point which is approximately the average depth of the water level expected in border or basin irrigation. When the inner cylinder has been filled up to the same reference point to maintain a constant average infiltration rate head. The water level in the inner cylinder was monitored as in the outer cylinder. Readings was taken at an interval of 10, and 20 minutes as the water level is lowered in the cylinder at a slow rate due to infiltration rate of clay soil. Water percolation, was very high at the initial point of experiments.

After every references time expired, a reading is taken and then cylinders were filled back to the to the reference water level taking into cognizance the inner cylinder.



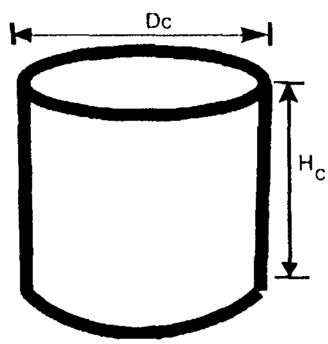




FIG. 3.6 Cross section of installed core sampler
H = Height of Core Sampler (7.5cm)
D c = Diameter of core sampler (7.5cm)

FIG. 3.5 Isometric view of infiltrometer
Di = Diameter of inner cylinder = (30cm)
Do = Diameter of outer cylinder = (60cm)

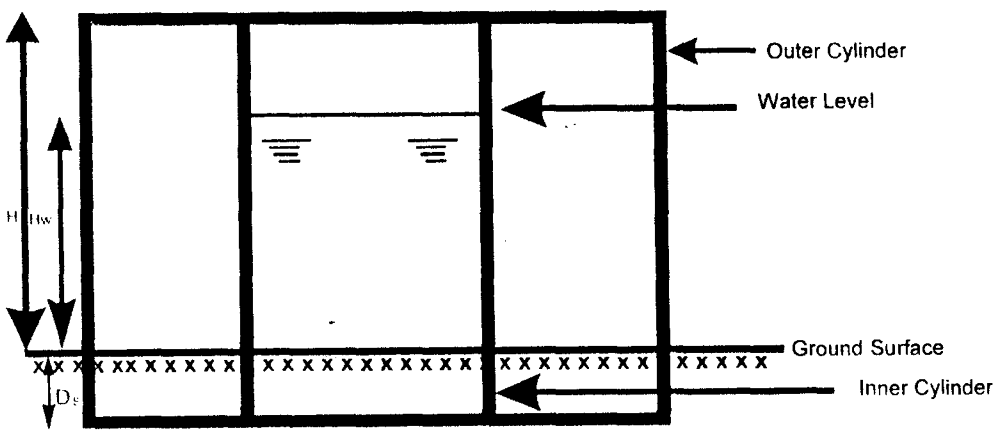



FIG 3.7: cross section of installed infiltrometer
H = Height of cylinder (25cm)
Hw = Height of water ponded (11cm)
Ds - Depth of cylinder in the soil (4cm)

## 3.6 DETERMINATION OF MECHANICAL COMPOSITION OF SOIL (SIEVE ANALYSIS)

The sieves were initially weighed and recorded. The sieves were of different diameters mesh and they were arranged in such a way that the sieve with smallest diameters came first and progressed to the sieve with largest mesh diameter. Below the smallest mesh diameter was a pan that collected the samples that passes through the sieves.

One kilogram sample was poured into the largest mesh diameter sieve and covered. The whole content was placed on a sieve shaker and shaken or pulsated for five minutes, after which sample retained on each sieve was weighted. Thus, the proportion of clay soil, and clay in the soil sample were determined as in table 4.1.

## 3.7 TOPOGRAPHICAL REPORT

The method of survey used was the grid method. When the topographic profile was plotted from the contour map, it revealed a gentle slope. The upper part reveal a slope of 0.12 while the lower part reveal a slope of 0.07. (See Appendix ix).

# 4.0 CHAPTER FOUR: RESULTS AND DISCUSSIONS

It is important to state that limitations encountered in the course of the project like inavailability of an electronic probe or echo sounder to measure water table depth below the ground surface. Also when performing the experiment on infiltration rate using the infiltrometer test, the time of refilling both the inner and outer cylinder after every reading varies with about 2-3 seconds. This will in no doubt affect the accuracy of the result.

## 4.1 PHYSICAL PROPERTIES OF THE SOIL

From the result of mechanical composition analysis table 1 at a depth of (0-20cm), both the upper and lower part of the slope had sand fraction of 33 – 35%, silt fraction of 40 – 42% and clay fraction 24 – 25%. When measured on the textural triangle, it was discovered that the sample fitted into loam class. At a depth of (20 – 40cm), both the upper and lower part of the slope had sand fraction of 25 – 34%, silt fraction of 30 – 40% and clay fraction 34 –36%. When measured on the textural triangle, it fits into clay loam class. For the remaining depth of (40 – 100cm), the fractions were in the following ranges; sand 2 – 20%, silt 15 –35%, clay 50 –81%.

Table4·2 contains the parameters obtained for soil moisture content analysis carried out on the field and in the laboratory. Moisture content was observed to be higher at the upper part of the slope. This could be as a result of the ponding that usually take place in the area as a result of depression storage of precipitation. The low moisture content recorded at the lower part of the slope could be as a result of the seasonal stream channel situated at the bottom of the

**TABLE 41: MECHANICAL COMPOSITION OF THE SOIL AT INLAND VALLEY OF FUT MAIN CAMPUS (PROJECT STIE)**

**UPPER PART OF THE SLOPE** | **LOWER PART OF THE SLOPE**

| Soil profile (cm) | Soil particle (fraction) | Mass retain (g) | % Composition | Soil type | Soil profile (cm) | Soil particle fraction | Mass Retain (g) | % Composition | Soil type |
|---|---|---|---|---|---|---|---|---|---|
| | Sand | 350.00 | 35.00 | | | Sand | 330.00 | 33.00 | |
| 0.20 | Silt | 404.30 | 40.30 | Loam | 0-20 | Silt | 415.20 | 41.52 | Loam |
| | Clay | 245.6 | 24.56 | | | Clay | 251.00 | 25.10 | |
| | Sand | 335.2 | 33.52 | | | Sand | 253.20 | 40.31 | |
| 20-40 | Silt | 300.00 | 30.00 | Clay-Loam | 20-40 | Silt | 403.10 | 34.10 | Clay. |
| | Clay | 362.00 | 36.20 | | | Clay | 341.00 | 20.20 | |
| | Sand | 181.00 | 18.10 | | | Sand | 202.00 | 20.20 | |
| 4-0-60 | Silt | 293.00 | 29.30 | Clay | 40-60 | Silt | 293.00 | 29.30 | Clay |
| | Clay | 522.10 | 52.20 | | | Clay | 503.00 | 50.30 | |
| | Sand | 102.00 | 10.20 | | | Sand | 82.00 | 8.20 | |
| 60-80 | Silt | 300.00 | 30.00 | Clay | 60-80 | Silt | 326.10 | 32.61 | Clay |
| | Clay | 595.00 | 59.50 | | | Clay | 585.20 | 58.52 | |
| | Sand | 45.00 | 4.50 | | | Sand | 28.50 | 28.50 | |
| 80-100 | Silt | 150.00 | 15.00 | Clay | | Silt | 178.20 | 17.82 | |
| | Clay | 803.00 | 80.30 | | 80-100 | Clay | 788.00 | 78.80 | Clay |

**A = TOTAL MASS = 1000g = 1kg**

## TABLE 42 SOME SOIL PHYSICAL PROPERTIES (MOISTURE CONTENTS, BULK DENSITY, POROSITY, AVAILABLE AT THE PROJECT SITE)

| | I | II | III | IV | V | VI | VII | VIII | IX |
|---|---|---|---|---|---|---|---|---|---|
| Sections | Depth (cm) | Weight of wet soil (g) | Weight of dry soil (g) | Moisture content (%) $\frac{(II-III)}{III} \times 100$ | Wet Bulk Density (g/cm$^3$) | Dry Bulk Density (g/cm$^3$) | Porosity (%) $1 - \frac{v}{vi} \times 100$ | Available moisture holding capacity (cm/m IV x V) | Available moisture holding capacity in root zone (cm/m.) |
| | 0- 20 | 360.90 | 299.50 | 20.50 | 1.76 | 2.12 | 16.98 | 36.08 | |
| Upper | 20-40 | 334.00 | 280.10 | 19.20 | 1.65 | 1.96 | 15.82 | 31.68 | |
| part of | 40 -60 | 351.30 | 295.20 | 19.00 | 1.74 | 2.07 | 15.94 | 33.06 | |
| The slope | 60 – 80 | 352.00 | 288.50 | 22.00 | 1.70 | 2.07 | 17.87 | 37.40 | |
| | 80 -100 | 371.00 | 298.50 | 24.50 | 1.75 | 2.18 | 19.73 | 42.88 | 181.10 |
| | 0-20 | 365.14 | 307.10 | 18.90 | 1.81 | 2.15 | 15.81 | 34.21 | |
| Lower | 20-40 | 352.66 | 297.60 | 18.50 | 1.75 | 2.08 | 15.87 | 32.38 | |
| part of the | 40 - 60 | 353,13 | 299.01 | 18.10 | 1.76 | 2.08 | 15.39 | 31.86 | |
| slope | 60-80 | 345.52 | 285.51 | 21.02 | 1.68 | 2.03 | 17.24 | 35.31 | |
| | 80 - 100 | 367.63 | 297.80 | 23.45 | 1.75 | 2.16 | 18.98 | 41.04 | 174.80 |

**N.B. VOLUME OFCORE SAMPLER = 170.00cm$^3$**

## TABLE 43: CLINDER INFILTROMETER TEST AT F.U.T PERMANENT SITE (PROJECT SITE)

UPPER PART OF THE SLOPE | LOWER PART OF THE SLOPE

| TIME (Min) | Water Level (cm) | Readings (cm) | Difference Depth (cm) | Accumulated Infiltration (cm) | Average Infiltration Rate (cm/hrs) | | Readings (cm) | Difference Depth (cm) | Accumulated Infiltration (cm) | Average Infiltration Rate (cm/hrs) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 11.00 | 11.00 | - | - | - | | 11.00 | - | - | - |
| 10.00 | 11.00 | 9.80 | 1.20 | 1.20 | 7.20 | | 9.65 | 1.35 | 1.35 | 8.10 |
| 20.00 | 11.00 | 9.80 | 1.20 | 2.40 | 7.20 | | 9.67 | 1.33 | 2.68 | 7.98 |
| 40.00 | 11.00 | 10.10 | 0.90 | 3.30 | 2.70 | | 9.81 | 1.19 | 3.87 | 3.57 |
| 60.00 | 11.00 | 10.00 | 1.00 | 4.30 | 3.00 | | 9.80 | 1.20 | 5.07 | 3.60 |
| 80.00 | 11.00 | 10.20 | 0.80 | 5.10 | 2.40 | | 9.85 | 1.15 | 6.22 | 3.45 |
| 100.00 | 11.00 | 10.20 | 0.80 | 5.90 | 2.40 | | 9.84 | 1.16 | 7.38 | 3.48 |
| 120.00 | 11.00 | 10.21 | 0.79 | 6.69 | 2.37 | | 9.95 | 1.05 | 8.43 | 3.15 |
| 140.00 | 11.00 | 10.20 | 0.80 | 7.49 | 2.40 | | 9.95 | 1.05 | 9.48 | 3.15 |
| 160.00 | 11.00 | 10.20 | 0.80 | 8.29 | 2.40 | | 9.97 | 1.03 | 10.51 | 3.09 |
| 180.00 | 11.00 | 10.40 | 0.60 | 8.89 | 1.80 | | 9.96 | 1.04 | 11.55 | 3.12 |

**Date 8/10/2001**

**TABLE 4.4 HYDRUALIC CONDUCTIVITY (UNSATURATED) OF SOIL WITHIN EXPERIMENTAL PLOTS AT FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA PERMANENT SITE FARM (PROJECT SITE)**

Upper Part of the slope | Lower part of the slope

| $\bar{\theta}$ | $L\bar{\theta}$ (cm) | t (h) | $L\Delta\bar{\theta}$ (cm) | $\Delta t$ (h) | $K(\bar{\theta})$ (cm/h) | | $\bar{\theta}$ | $L\bar{\theta}$ (cm) | t (h) | $L\Delta\bar{\theta}$ (cm) | $\Delta t$ (h) | $K(\bar{\theta})$ (cm/h) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.2193 | 21.93 | 0 | | | | | 0.2104 | 21.04 | 0 | | | |
| 0.2001 | 20.01 | 1 | -1.92 | 1 | 1.92 | | 0.1979 | 19.79 | 1 | -1.25 | 1 | 1.25 |
| 0.1885 | 18.85 | 4 | -1.16 | 3 | 0.39 | | 0.1870 | 18.70 | 4 | -1.09 | 3 | 0.36 |
| 0.1695 | 16.95 | 18 | -1.9 | 14 | 0.14 | | 0.1690 | 16.90 | 18 | -1.8 | 14 | 0.13 |
| 0.1534 | 15.34 | 42 | -1.61 | 24 | 0.07 | | 0.1532 | 15.32 | 42 | -1.58 | 24 | 0.06 |
| 0.1506 | 15.06 | 66 | -0.28 | 24 | 0.01 | | 0.1505 | 15.05 | 66 | -0.27 | 24 | 0.01 |

$\bar{\theta}$ = Average water content

L = Thickness of the profile = 100cm

t = Time (h)

$K(\bar{\theta})$ = Hydraulic conductivity = $-\dfrac{L\Delta\bar{\theta}}{\Delta t}$ (cm/h)

## TABLE 45: WEEKLY WATER TABLE MEASUREMENT BELOW GROUND SURFACE (CM) AT THE INLAND VALLEY OF F.U.T MINNA MAIN CAMPUS (PROJECT SITE).

| MONTHS | | MARCH | | | | | APRIL | | | | MAY | | | | JUNE | | | | | JULY | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WELLS | DATES | 6th | 10th | 17th | 24th | 31st | 7th | 14th | 21st | 28th | 5th | 12th | 19th | 26th | 2nd | 9th | 16th | 23rd | 30th | 7th | 14th | 21st | 28th |
| A | | | 140 | 140 | 142 | 151 | 157 | 162 | 139 | 122 | 120 | -25 | -17 | 21 | 9 | -23 | -25 | -26 | -25 | -20 | -26 | -26 | -26 |
| B | | | 255 | 256 | 257 | 260 | - | - | 255 | 242 | 240 | 176 | 243 | 246 | 248 | 256 | 225 | 150 | 101 | 102 | 98 | 95 | 92 |
| C | | | | | | | - | - | 125 | 123 | 121 | 118 | 82 | 89 | 120 | 118 | 117 | 119 | 121 | 84 | 84 | 74 | 74 |

| MONTHS | | AUGUST | | | | SEPTEMBER | | | | | OCTOBER | | | | NOVEMBER | | | | DECEMBER | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WELLS | DATES | 4th | 11th | 18th | 25th | 1st | 8th | 15th | 22nd | 29th | 6th | 13th | 20th | 27th | 3rd | 10th | 19th | 24th | 1st | 8th | 15th | 22nd |
| A | | -24 | -26 | -22 | -26 | -26 | -20 | -22 | -24 | -14 | 3 | -26 | -26 | -19 | 12 | 63 | 83 | 94 | | | | |
| B | | 52 | 71 | 60 | 54 | 40 | 57 | 51 | 62 | 67 | 66 | 151 | 71 | 111 | 200 | 200 | - | - | | | | |
| C | | 71 | 80 | 76 | 65 | 55 | 78 | 68 | 65 | 85 | 88 | 92 | 94 | 96 | - | - | - | | | | | |

**NOTE: Negative sign (-ve) indicates that water table level is above ground surface**

TABLE 46: MEAN MONTHLY WATER DEPTHS BELOW GROUND SURFACE (CM)
AT THE INLAND VALLEY OF F.U.T MINNA (PROJECT SITE)

| WELLS | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEPTEMBER | OCTOBER | NOVEMBER |
|---|---|---|---|---|---|---|---|---|---|
| A | 143.3 | 145 | 24.8 | -18 | -24.5 | -25 | -21.2 | -17 | 63 |
| B | 257 | 248.5 | 226.3 | 202 | 96.8 | 59.3 | 55.4 | 99.8 | 200 |
| C | | 124 | 102.5 | 119 | 79 | 73 | 70.2 | 92.5 | - |

NOTE: Negative sign (-ve) indicates that water table levels is above ground surface.

**TABLE 47: MEAN MONTHLY WATER DEPTH RELATIVE TO WATER DEPTH IN WELL A.**

| WELLS | MARCH | APRIL | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. |
|---|---|---|---|---|---|---|---|---|---|
| A | 143.3 | 145 | 24.8 | -18 | -24.5 | -25 | -21.2 | -17 | 63 |
| B | 267 | 258.5 | 236.3 | 212 | 106.8 | 69-3 | 65.4 | 109.8 | 210 |
| C | - | 154 | 132.5 | 149 | 109 | 103 | 100.2 | 122.5 | - |

**NOTE: Negative sign indicates that water levels is above the ground surface.**

## 4.3 TREND OF WATER TABLE FLUCTUATION

From the graph (Fig. 3.3) the three wells shows three different types of fluctuation. From middle of March to middle of May, well A fluctuated within the depth of (0.2 to 1.51m). At the end of May, the well was ponded up to the month of October. This could be attributed to the depression around the well which usually store precipitation. The well can thus be said to be submerged well. Well B fluctuated within the depth of (0.5 to 2.6m). Well C fluctuated within the depth of (0.7 to 1.3m). Both well B and C hitted their peak in the month August and September as precipitation was high in those months, though not maximum. There was the possibility that the seasonal stream could have charged well C and B during that period (August - September) because the stream was fitted up that time. The fact that there was interference between the seasonal stream and well C and B was evidence in the reading taken on 2nd of June. Before that day there was heavy rainstorm on the 30th of May, but on getting to the site on the 2nd of June, the rainstorm effect was only seen in well A as it was the only well that showed a rise in water level. The level of water in well B and C fell below expectation. It seened that there was seepage of water into the stream from well B and C at that point in time.

The graph of water level depth relative to water level in well A is shown in Fig. 4.5 the pattern of fluctuation is similar to that in Fig. 4.4 this is as a result of little difference in altitude of the points where the wells are positioned.

The direction of ground water flow can be seen in Fig. 4.5 which shows that water flows from well A to well B and from well B to well C.

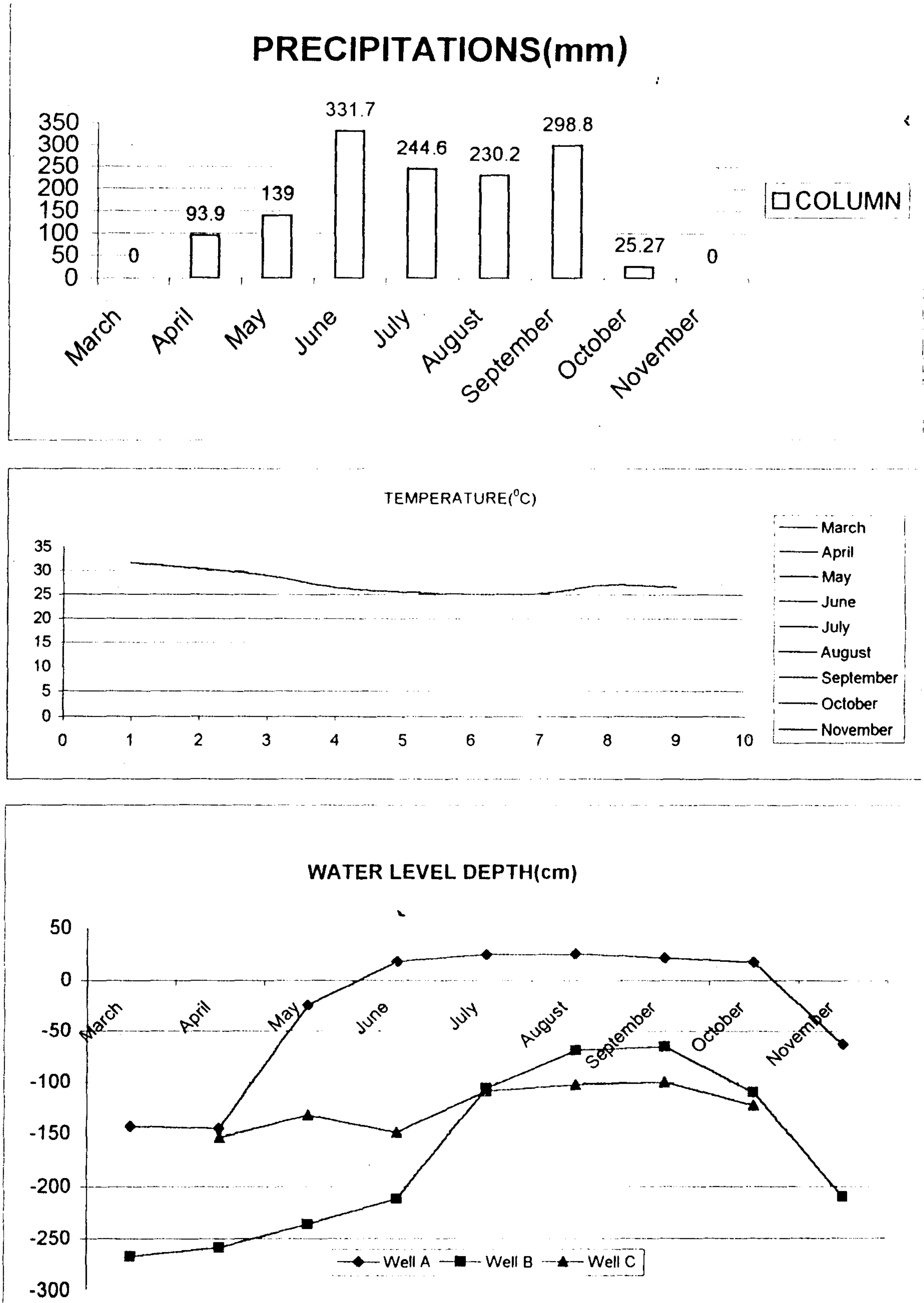
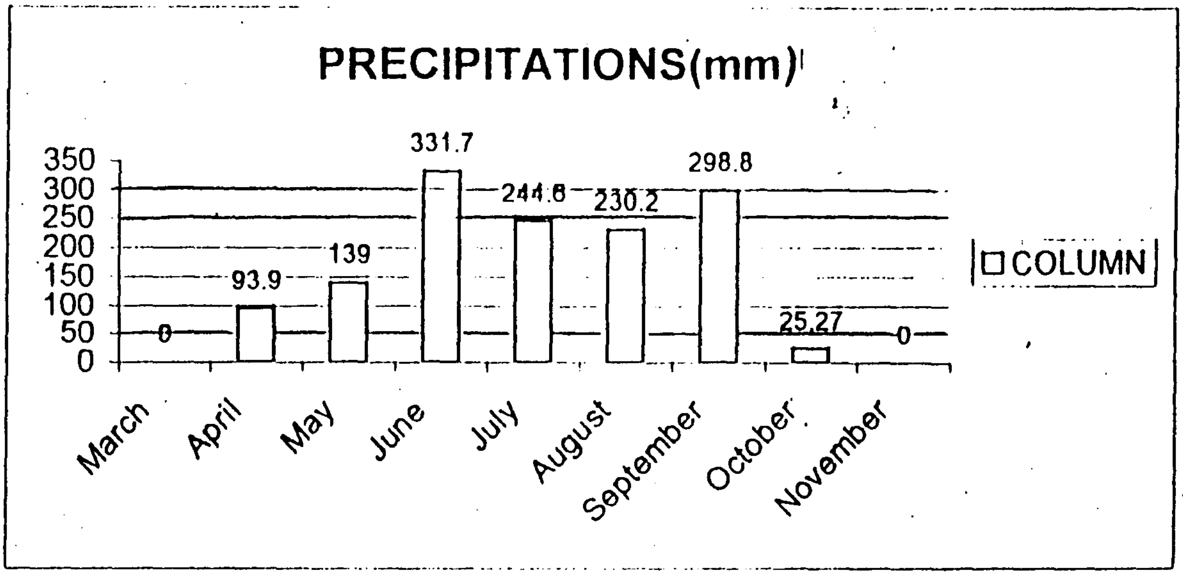
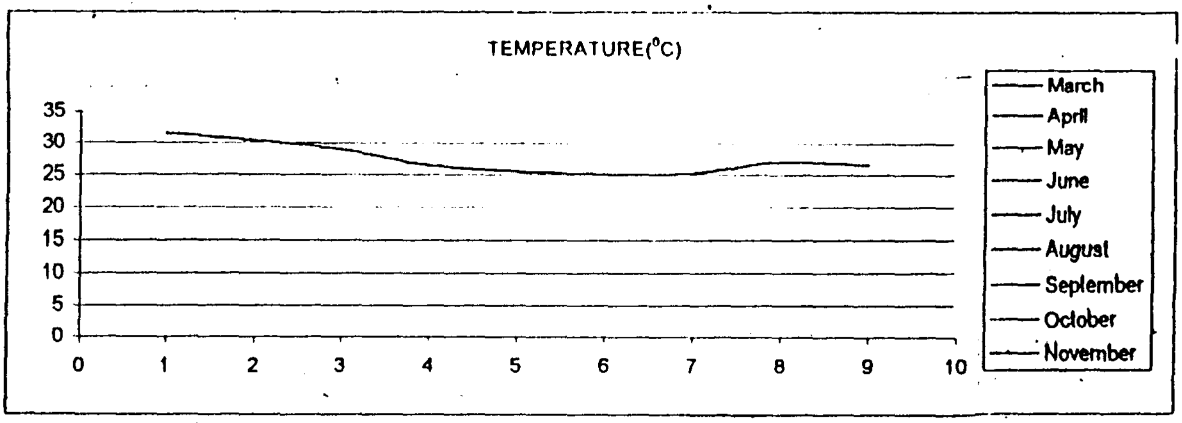



**Fig. 4.3: Water Level, Temperature and Precipitation Versus month at Federal University of Technology, Minna Permanent Site Farm Gidanpaint**



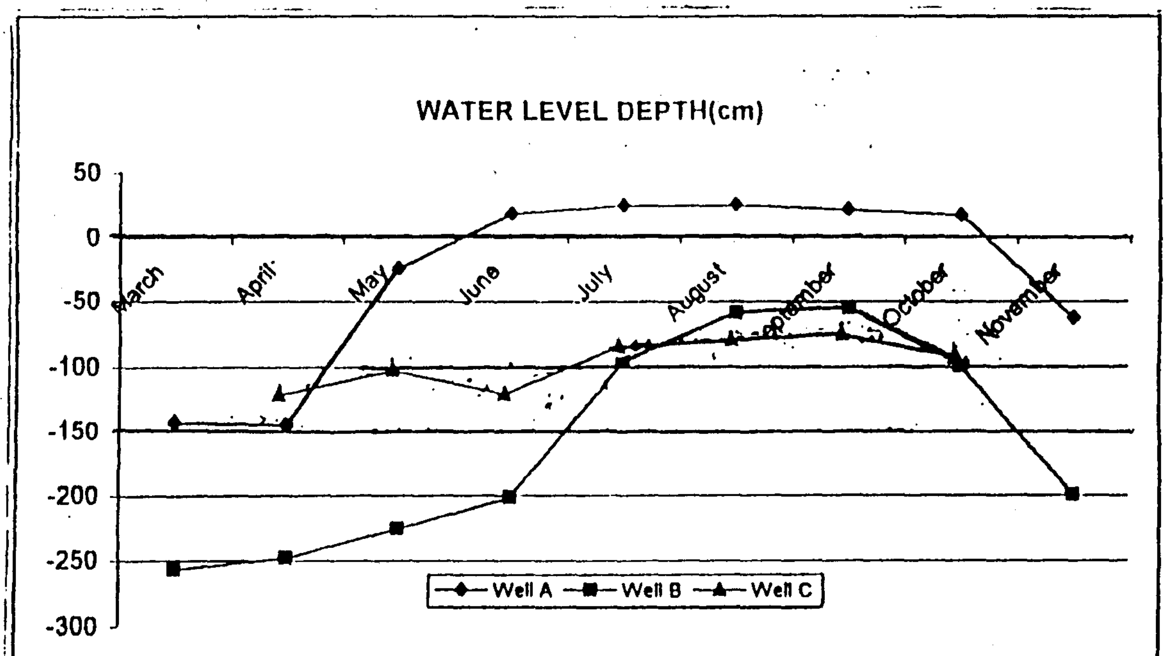




**Fig. 4.4: Water Level, Temperature and Precipitation Versus month of Federal University of Technology, Minna Permanent Site Farm Gidanpaint**

# 5.0 CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

## 5.1 CONCLUSION

This study has indicated that, from the records of water level fluctuation obtained form the project site, about 67% of the wells had their water level above the depth of 120cm from the months of May to October, while the remaining 33% of the study area had their water level below the depth of 120cm in the months of May and June but later rose above 120cm from the months of July to October. One of the wells (well A) was ponded from the month of May to October. This may be due to depression storage of precipitation in the surrounding area of the well. So the water table in this well need to be lowered to a depth of about 120cm through drainage.

Therefore, crops like Maize, Sorghum, Soybean, Tomato, and pearl millet are needed to be planted at the project site because they are the suitable crops for the area.

## 5.2 RECOMMENDATION

Thorough research work should be conducted continuously for at least three consecutive years by another students to give details of possible irrigation and drainage requirements / layout of the particular field.

With availability of adequate facilities, it will be possible to investigate the trend of perched water table fluctuation and come out with optimum water depths for field crops over a period of time. A suitable gentle slope around well A should be introduced to avoid a depression storage of precipitation in the area.

Crops like Maize, sorghums, peart millet, soybean, sugarbeet and tomato are deep rooted crops are recommend to be planted at the project site because they are the suitable crops for such particular area.

Furthermore, effective monitoring of the soil related properties as well as the factors that cause water table fluctuations will generate more accurate data.

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## APPENDIX 1: MONTHLY RELATIVE HUMIDITY (%) (1991 - 2001)

| YEAR | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG | SEP. | OCT | NOV. | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | 27.00 | 51. 00 | 49. 00 | 69.00 | 81.00 | 95.00 | 88.00 | 90.00 | 81.00 | 77.00 | 46.00 | 34.00 |
| 1992 | 28.00 | 25. 00 | 55. 00 | 68.00 | 76.00 | 82.00 | 87.00 | 88.00 | 83.00 | 77.00 | 49.00 | 38.00 |
| 1993 | 33.00 | 40. 00 | 53.00 | 63.00 | 72.00 | 80.00 | 86.00 | 86.00 | 81.00 | 71.00 | XX | 44.00 |
| 1994 | 40. 00 | 25. 00 | 55.00 | 63.00 | 74.00 | 80.00 | 84.00 | 87.00 | 85.00 | 76.00 | 45.00 | 30.00 |
| 1995 | 34. 00 | 27.00 | 48.00 | 62.00 | 72.00 | 77.00 | 81.00 | 86.00 | 80.00 | 73.00 | 39.00 | 34.00 |
| 1996 | 33. 00 | 42. 00 | 57.00 | 63.00 | 73.00 | 81.00 | 87.00 | 85.00 | 84.00 | 74.00 | 32.00 | 31.00 |
| 1997 | 31. 00 | 18. 00 | 46.00 | 64.00 | 70.00 | 82.00 | 85.00 | 85.00 | 82.00 | 78.00 | 45.00 | 28.00 |
| 1998 | 32.00 | 32. 00 | 25.00 | 61.00 | 76.00 | 80.00 | 86.00 | 87.00 | 83.00 | 77.00 | 47.00 | 36.00 |
| 1999 | 31. 00 | 36. 00 | 58.00 | 57.00 | 70.00 | 78.00 | 84.00 | 81.00 | 82.00 | 79.00 | 50.00 | 33.00 |
| 2000 | 40. 00 | 25. 00 | 34.00 | 63.00 | 69.00 | - | 85.00 | 87.00 | 84.00 | 74.00 | 45.00 | 33.00 |
| 2001 | 31.10 | 30.10 | 44.90 | 57.00 | 61.00 | 70.00 | 76.00 | 79.00 | 73.00 | 52.00 | 43.70 | 35.60 |
| TOTAL | 359.70 | 351.12 | 524.92 | 689.7 | 794.20 | 805.20 | 929.00 | 949.30 | 897.60 | 803.00 | 442.20 | 376.20 |
| MEAN | 32.7.00 | 31.92 | 47.72 | 62.70 | 72.20 | 73.20 | 86.30 | 85.50 | 81.60 | 73.00 | 40.20 | 34.20 |

SOURCE: DEPT OF METEOROLOGICAL SERVICES
FED. MIN. OF AVIATION,
MINNA AIRPORT, NIGER STATE.

## APPENDIX II: TOTAL MONTHLY TEMPERATURE ($^0C$) (1991 - 2001)

| YEAR | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG | SEP. | OCT | NOV. | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | 28.50 | 31.00 | 31.65 | 30.00 | 27.40 | 27.10 | 25.90 | 25.60 | 26.00 | 26.65 | 27.45 | 26.85 |
| 1992 | 26.55 | 29.35 | 31.15 | 29.55 | 28.25 | 26.30 | 25.65 | 25.30 | 25.55 | 27.15 | 27.30 | 27.40 |
| 1993 | 26.65 | 27.60 | 30.40 | 31.50 | 29.40 | 26.85 | 25.70 | 25.55 | 25.50 | 27.25 | xxx | 27.65 |
| 1994 | 27.25 | 29.90 | 32.20 | 30.50 | 28.45 | 26.65 | 26.05 | 25.25 | 25.80 | 26.20 | 26.70 | 26.45 |
| 1995 | 26.75 | 29.40 | 31.95 | 31.30 | 28.40 | 27.10 | 26.10 | 25.40 | 26.10 | 26.95 | 27.15 | 26.75 |
| 1996 | 27.75 | 30.25 | 31.60 | 31.30 | 28.05 | 26.00 | 25.25 | 24.70 | 25.45 | 25.95 | 26.25 | 26.70 |
| 1997 | 28.20 | 28.35 | 30.85 | 29.80 | 27.50 | 26.60 | 25.85 | 26.30 | 26.20 | 26.85 | 27.20 | 26.90 |
| 1998 | 27.35 | 31.15 | 32.25 | 32.35 | 28.95 | 27.10 | 26.10 | 25.35 | 25.95 | 26.95 | 27.80 | 27.65 |
| 1999 | 28.05 | 29.90 | 32.05 | 31.65 | 28.95 | 27.05 | 25.70 | .25.35 | 25.70 | 26.95 | 27.65 | 27.25 |
| 2000 | 28.70 | 28.60 | 31.70 | 31.75 | 30.50 | 26.25 | 25.60 | 25.20 | 25.95 | 26.95 | 27.10 | 26.65 |
| 2001 | 27.65 | 29.95 | 31.55 | 30.35 | 28.95 | 26.40 | 25.55 | 25.00 | 25.20 | 27.05 | 26.55 | 27.50 |
| TOTAL | 303.38 | 325.49 | 347.38 | 339.90 | 314.82 | 293.37 | 283.8 | 278.96 | 283.36 | 293.7 | 271.15 | 297.77 |
| MEAN | 27.58 | 29.59 | 31.58 | 30.90 | 28.62 | 26.67 | 25.80 | 25.36 | 25.76 | 26.70 | 24.65 | 27.07 |

SOURCE: DEPT OF METEOROLOGICAL SERVICES
FED. MIN. OF AVIATION,
MINNA AIRPORT, NIGER STATE.

## APPENDIX III: TOTAL MONTHLY RAINFALL (MM) (1991 - 2001)

| YEAR | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG | SEP. | OCT | NOV. | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | 0.0 | TR | TR | 14.50 | 336.00 | 180.10 | 192.90 | 218.50 | 190.80 | 33.90 | 0.00 | 0.0 |
| 1992 | 0.00 | 0.00 | 0.00 | 1.30 | 158.20 | 176.80 | 162.90 | 196.40 | 231.50 | 230.30 | 46.60 | 379.5 |
| 1993 | 0.00 | 0.00 | 0.00 | 0.00 | 174.40 | 170.50 | 189.70 | 271.10 | 178.30 | 63.30 | xx | 0.00 |
| 1994 | 0.00 | 0.00 | 7.30 | 72.50 | 114.40 | 239.00 | 142.50 | 367.20 | 261.30 | 208.10 | 0.00 | 0.00 |
| 1995 | 0.00 | 0.00 | 0.00 | 100.50 | 123.20 | 144.50 | 153.70 | 409.00 | 189.10 | 135.70 | 236.00 | 0.00 |
| 1996 | 0.00 | 0.00 | 0.00 | 48.60 | 164.70 | 225.00 | 259.70 | 257.00 | 191.10 | 127.90 | 0.00 | 0.00 |
| 1997 | 0.00 | 0.00 | 3.60 | 80.60 | 238.40 | 233.00 | 172.40 | 192.90 | 273.30 | 115.00 | 6.10 | 0.00 |
| 1998 | 0.00 | 0.00 | TR | 92.20 | 121.20 | 221.00 | 155.50 | 243.00 | 261.90 | 212.60 | 0.00 | 0.00 |
| 1999 | 0.00 | 7.90 | 0.00 | 35.70 | 102.80 | 164.20 | 243.90 | 254.70 | 237.10 | 212.20 | 0.00 | 0.00 |
| 2000 | 0.00 | 0.00 | | 3.60 | 135.90 | 161.00 | 208.80 | 308.50 | 303.00 | 153.40 | 0.00 | 0.00 |
| 2001 | 0.00 | 0.00 | 0.00 | 93.90 | 139.00 | 331.70 | 244.60 | 230.20 | 298.80 | 25.70 | 0.00 | 0.00 |
| TOTAL | 0.00 | 7.90 | 10.89 | 543.40 | 1808.40 | 2247.30 | 2126.30 | 2939.20 | 2615.80 | 1518.00 | 288.20 | 379.50 |
| MEAN | 0.00 | 0.72 | 0.99 | 49.40 | 164.40 | 204.30 | 193.30 | 267.20 | 237.80 | 138.00 | 26.20 | 34.50 |

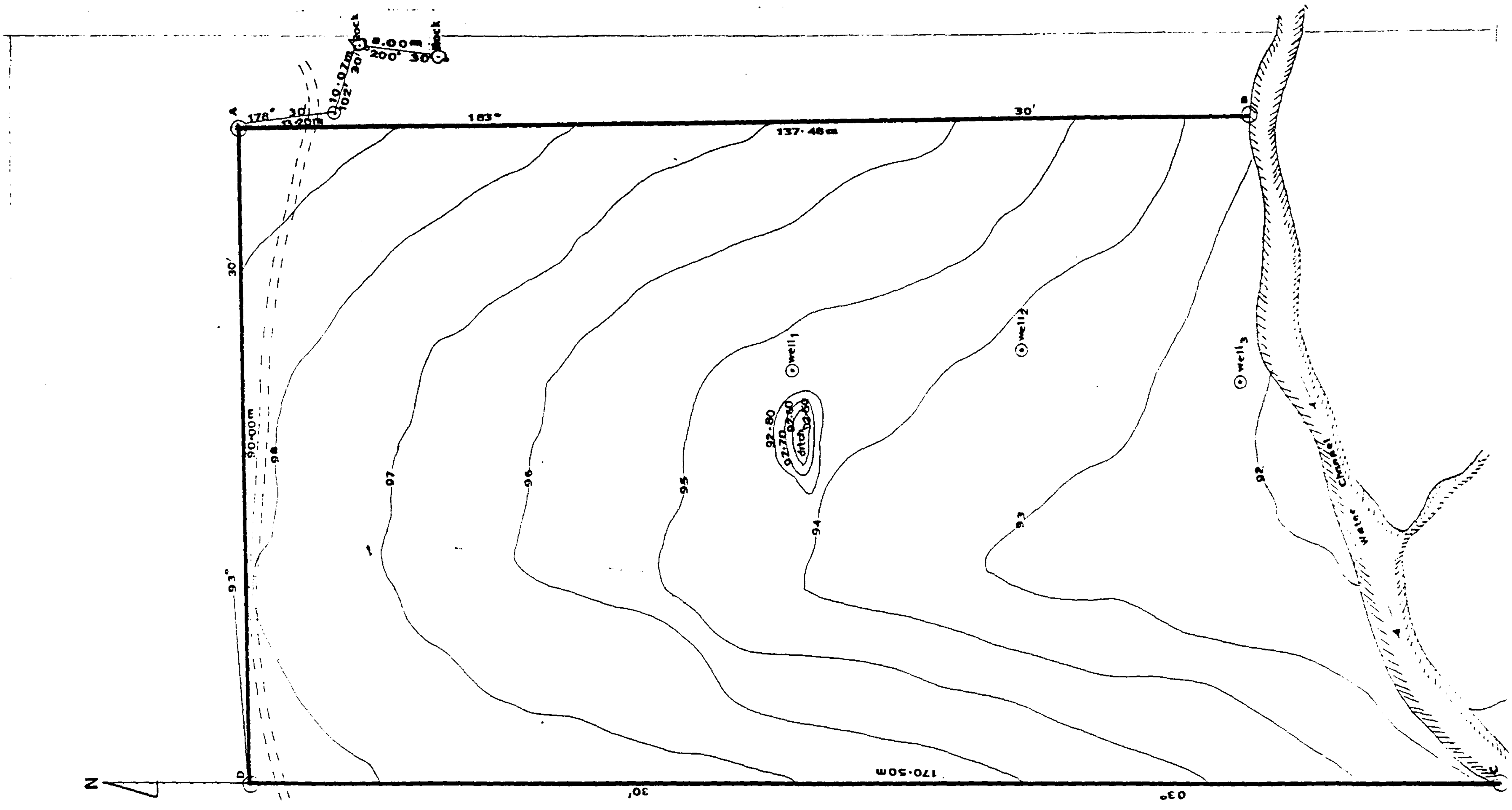
**SOURCE: DEPT OF METEOROLOGICAL SERVICES**
**FED. MIN. OF AVIATION,**
**MINNA AIRPORT, NIGER STATE.**

## APPENDIX IV: CLIMATOLOGICAL REPORT FOR MINNA (2001)

| MONTH | RAINFALL (MM) | MAX TEMP. ($^0C$) | MIN. TEMP. ($^0C$) | RELATIVE HUMIDITY (%) | MEAN MONTHLY TEMP. ($^0C$) |
|---|---|---|---|---|---|
| JAN | 0.00 | 34.90 | 20.40 | 31.10 | 27.65 |
| FEB | 0.00 | 37.10 | 22.80 | 30.10 | 29.95 |
| MAR | 0.00 | 37.90 | 25.20 | 44.90 | 31.55 |
| APR | 93.90 | 36.30 | 24.40 | 57.00 | 30.35 |
| MAY | 139.00 | 33.70 | 24.20 | 61.00 | 28.95 |
| JUNE | 331.70 | 30.90 | 21.90 | 70.00 | 26.40 |
| JULY | 244.60 | 29.20 | 21.90 | 76.00 | 25.55 |
| AUG | 230.20 | 28.30 | 21.70 | 79.00 | 25.00 |
| SEPT | 298.80 | 29.50 | 20.90 | 73.00 | 25.20 |
| OCT | 25.27 | 33.00 | 21.10 | 52.00 | 27.05 |
| NOV | 0.00 | 33.20 | 19.10 | 43.70 | 26.55 |
| DEC. | 0.00 | 34.90 | 20.10 | 35.60 | 27.50 |

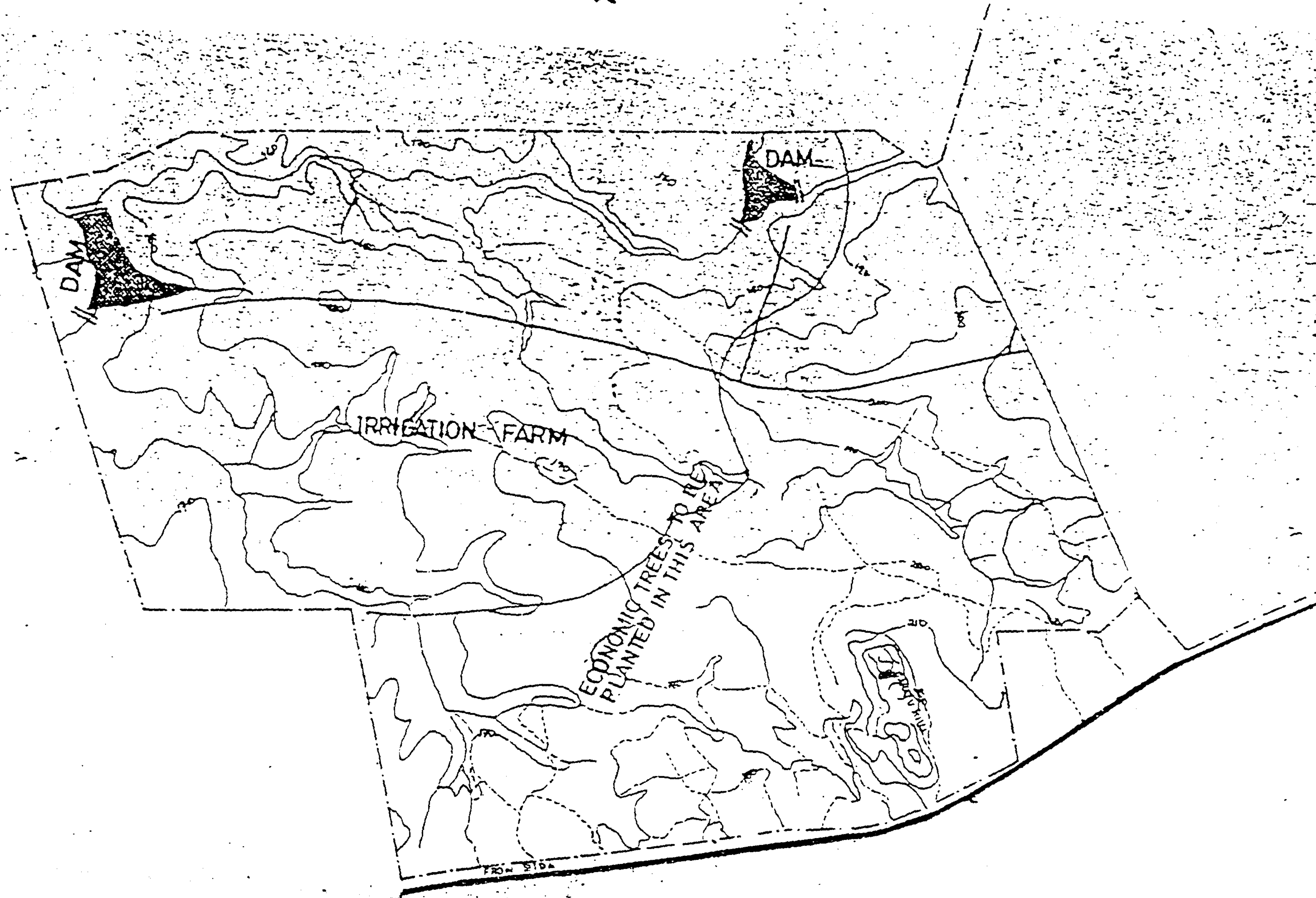
SOURCE: DEPT OF METEOROLOGICAL SERVICES
FED. MIN. OF AVIATION,
MINNA AIRPORT, NIGER STATE.

# APPENDIX IX




TOPOGRAPHICAL MAP AT F.U.T MINNA MAIN CAMPUS (PROJECT SITE) SCALE 1:500

# APPENDIX X




SCALE 1:250

# APPENDIX XI


KEBBI STATE
BENIN REP.
KADUNA STATE
KWARA STATE
KOGI STATE
F.C.T ABUJA
RIJAU
AGWARA
KONTAGORA
MASKO
KAGARA
NEW BUSSA
KUTA
WUSHISHI
MINNA
MOKWA
LEMU
PAIKO
KUTIGI
BIDA
AGAIE
LAPAI
GAWU
SULEJA
Warari
Chifu
Rigolo
Ukata
Alawa
Mashegu
Duba
Kutiwenji
Lapai
Kuba
Bangi
Wamba
Tegina
Kafin Koro
Kwakuti
Shiroro
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Baro
Nupeko
Doko
Kudu
Kabe
Agwara
Auna
Pallegi
Bosso
Kaa
Egba

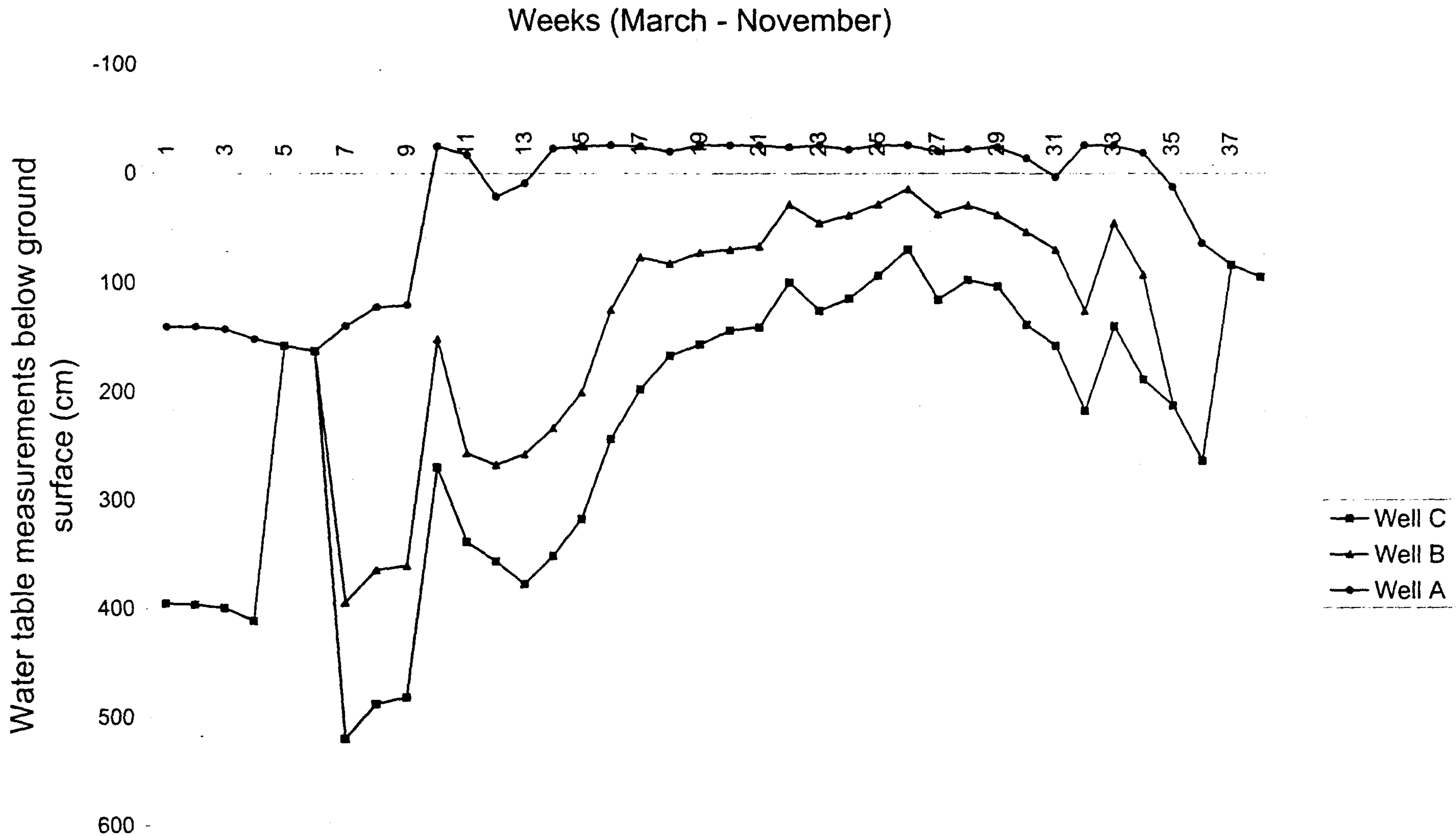


Fig. 4.5: Graph of direction of ground water flow (cm)