COMPUTERIZATION OF PUMPING TEST ANALYSIS. A CASE STUDY OF FEDERAL MINISTRY OF WATER RESOURCES AND RURAL DEVELOPMENT

BY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF
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TECHNOLOGY MINNA,
IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE
AWARD OF POSTGRADUATE DIPLOMA IN COMPUTER SCIENCE.

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DECLARATION

I hereby declare that this project of computerization of pumping test analysis is done by me and has not been submitted in any form for another degree or diploma at any other University or Institution.

Information derived from published or unpublished work of others has been acknowledge in the text.

CERTIFICATION

/e certify that this project on the computerization of pumping test analysis. A case History of 'ederal Ministry of Water Resources and Rural Development is an approved original work lone by Mr. Bodunrin Olatunji Alamu under our supervision we have examined and found it ıcceptable for the award of Post Graduate Diploma (PGD) certificate in computer science at Federal University of Technology Minna

.... 02-04-98 ....

Dr. S. Reju — Date

Supervisor

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DEDICATION.

This project is dedicated to my son Jeremiah Morolayo Bodunrin and my Late Wife Mrs Kehinde Morolayo Bodunrin.

ABSTRACT

Pumping test has been a major determinant of productivity of borehole either in confined or unconfined aquifer in all geological formations.

A critical look was given to manual analysis of this pumping test. Pumping test for confined aquifer and unconfined aquifer are computerize in this work.

Using qbasic program.

ACKNOWLEDGEMENT

I ascribed thanks giving, honour and glory to almighty God for making this Post graduate course a reality.

I am indebted to the Head of Department of Maths and Computer science for his contribution towards the success of this programme. I acknowledge with gratitude to my supervisor, Dr. Reju for sparing time to go through the scripts and his constructive criticism.

My profound gratitude goes to all academic staff of Maths and Computer department of Federal University of Technology Minna for their encouragement and importing of the knowledge to me. I am also indebted to my wife Mrs. Alaba Bodunrin who took care of the home and backing me up with prayer during my absence, Moreover her physical, moral and financial support and encouragement brought this project to a successful completion.

I also acknowledge with gratitude the encourage given to me by all my friends like Engr. Ayodeji, Engr. Salami Babangida to mention but a few. May God almighty undertake for them.

I acknowledge with gratitude the chance given to me by my Employer, Federal Ministry of Water Resources and Rural Development. to undertake this course.

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CHAPTER ONE

INTRODUCTION OF PUMPING TEST.

1.1 INTRODUCTION.

Groundwater under natural conditions flows from area of recharge, normally aquifer 's out crops area to points of discharge at springs, rivers or in the sea. The driving force of this groundwater flow is the hydraulic head i.e. the difference in level of the groundwater surface between the recharge and discharge areas.

The pumping test is a method by which the yield of borehole is determined, if the borehole is to be equipped with a permanent pump to operate at the highest efficiency it should be accurately tested for draw down and yield before the pump is purchased. Many times high pumping costs an unsatisfactory pump performance have been erroneously charged to the well. In those cases, an accurate test of the well in advance of the pump purchase would have more than paid for itself in the first cost of equipment and later in the operating costs.

There are many ways to test a well for capacity. If a well is important enough to be tested for capacity on completion it is essential that it be tested accurately by the use of approved measuring devices and standard methods. Knowing the capacity of a well and its drawdown the aquifer characteristics can be determined by monitoring the effects of the pumping test in surrounding wells known as observation wells.

1.2 BRIEF HISTORY OF FEDERAL MINISTRY OF WATER RESOURCES AND RURAL DEVELOPMENT

In order to harness Nigeria's water resources to combact the effects of drought, the Federal Government in 1973 created the Sokoto Rima and Chad Basin Development

Authorities. These authorities were charged with the responsibilities of not only full development of irrigation schemes but also water supply, flood control, pollution control.

In 1976, the Federal Ministry of Water Resources was first created in this country to formulate national water resources development policies and co - ordinate their development. The Ministry then had only one operational department called the Federal Department of water Resources with Sokoto Rima Basin Development Authority and Chad Basin Development as the only parastatals.

Later in 1976, the Federal Government through Decree No.25 set up eleven River Basin Development Authorities and the authorities were under the supervision of the Federal Ministry of Water Resources.

In 1977, the Federal Ministry of Water Resources was merged with Federal Ministry of Agriculture. The Federal Department of Water Resources remained intact under this new Ministry along with the 11 river Basins. In 1979 a Federal Ministry of Water Resources was created, it still had the Federal Department of Water Resources as the only operational Department the 11 River Basin Development and the National Water Resources Institute that was established in 1987 as the parastatals . The Federal Ministry of Water Resources was for the second time merged with the Federal Ministry of Agriculture in 1984. In the same year the River basin were reorganized into 18 River Basins and Rural Development. In another reorganization in 1987, the 18 River Basin were reverted to their former 11 River Basin Development structures as before in 1984.

In 1989, a Federal Ministry of Water Resources was created for the third time. This time the ministry had a tremendous boost and quickly expanded from one Department of Water

Resources. It inherited to eight new department namely Department of hydrology and hydrogeology; Department of Irrigation and Drainage, Department of Water Supply and Quality Control, Department of Dams and Reservoir Operations Department of Soil Erosion and Flood Control, The services departments i.e. Planning, Research and Statistics, Finance and Supplies, Personnel and Management Departments.

1.2.1 Functions of the Ministry

The functions of the Federal Ministry of Water Resources is as follows:

(i) to formulate and implement a Water Resources Master Plan for Irrigation development;

(ii) to develop and support irrigated agriculture and reduce the nations dependences on rain-fed agriculture

(iii) to promote and sustain national food security by minimising undesirable short falls in domestic food production and agro-based raw materials caused by the variation of weather;

(iv) to collect, store, analyses and disseminate hydrometeorological and hydrological data.

(v) to support, monitor and evaluate the programs and performances of the River Basin Development Authorities and National Water Resources Institute.

(vi) to explore and develop underground water Resources

(vii) to undertake hydrological and hydrogeological investigations.

(viii) to formulate and implement national irrigation policy that is consistent and complementary to the national agriculture policy.

(ix) to formulate and implement programs for drought, erosion, and flood control

(x) to liaise with all relevant national and international Agencies on all matters relating to water resources development.

(xi) to formulate and review from time to time the National Water legislation.

(xii) To co-ordinates the development and utilisation of water resources for irrigation and water supply.

1.2.2. STRUCTURE OF THE FEDERAL MINISTRY OF WATER RESOURCES AND RURAL DEVELOPMENT.

The Federal Ministry of Water Resources Operates through the following eight departments consisting of three service departments and five operational departments

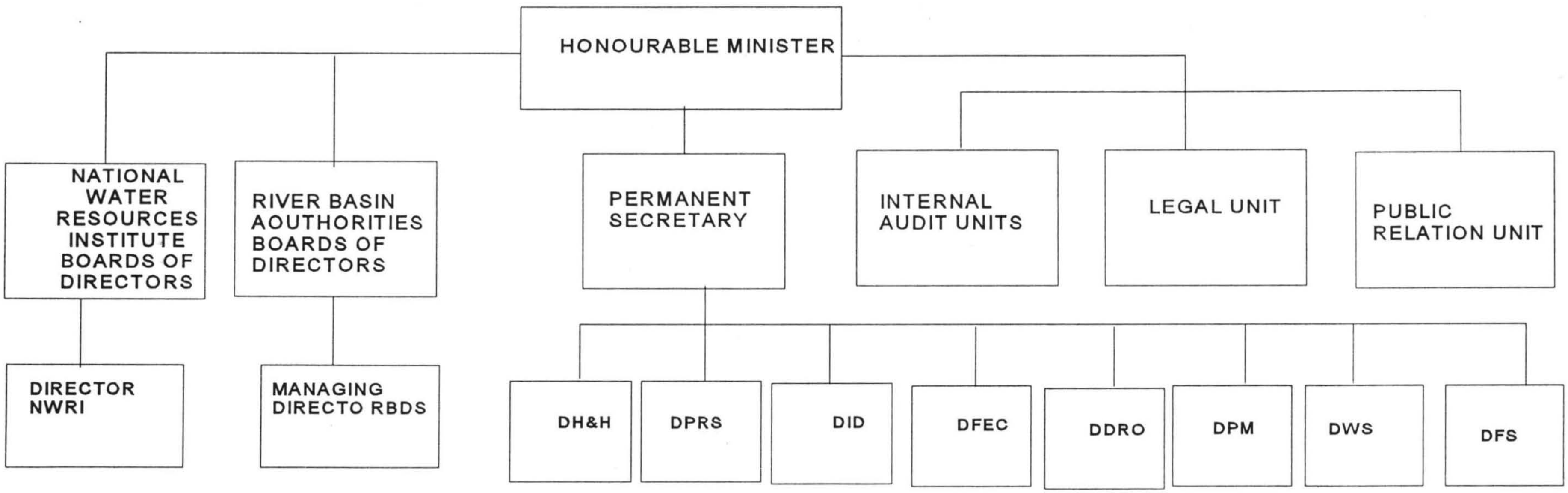
The three service departments are:

(i) Department of Planning, Research and Statistics
(ii) Department of Finance and Supplies
(iii) Department of Personnel Management

The Operational Departments are:

(i) Department of Hydrology and Hydrogeology
(ii) Department of Irrigation and Drainage
(iii) Department of Water Supply and Quality Control
(iv) Department of Dams and Reservoir Operations
(v) Department of Soil Erosion and Flood Control

ORGANOGRAM OF FEDERAL MINISTRY OF WATER RESOURCES



1.2.3 Department of Hydrogeology and Hydrology Activities.

The department is responsible for hydrometeorological and hydrogeological data which forms the backbones of water resources evaluation, planning development and management. The department was established in 1976.

1.2.3.1 Functions of the Department

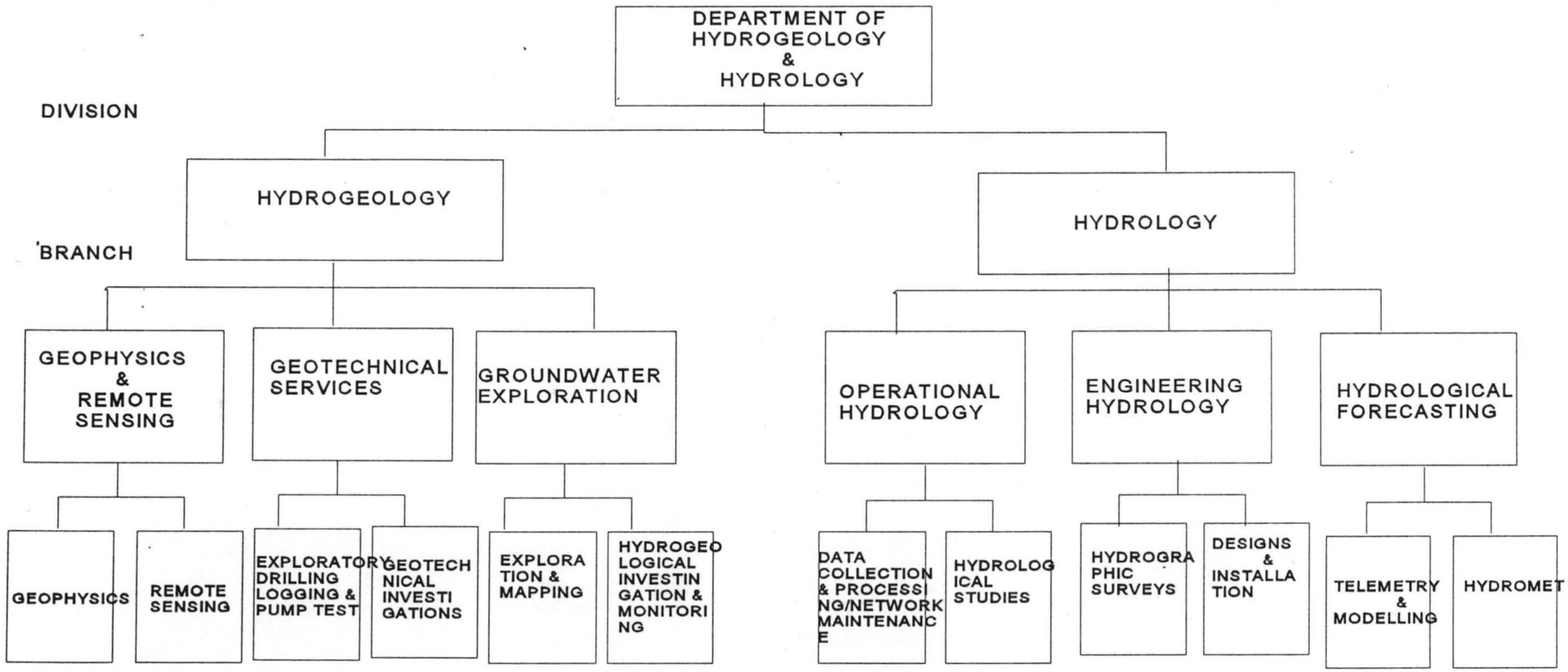
The main functions of the Department are:

(i) Establishment, Operation and maintenance of Hydrometeorological stations for basic data collection, analysis, storage and dissemination through periodic publications for real - time forecasting of hydrological phenomena

(ii) Groundwater exploration, evaluation, development and monitoring using exploration geophysical techniques, remote sensing, hydrogeological mapping and borehole drilling.

(iii) Policy formulation on hydrogeological and hydrological codes of practice.

DEPARTMENT OF HYDROGEOLOGY& HYDROLOGY MANAGEMENT SCHEDULES



1.3 TERMINOLOGY.

Terminology is not standard throughout the world and different names are commonly applied to identical constructions. In this project the following names are used.

WATER WELL	-	A borehole drilled for the principal purpose of obtaining a water supply.
TEST WELL	-	A borehole drilled to test an aquifer by means of pumping Tests.
AN AQUIFER	-	This is a water bearing geological formation capable of yielding groundwater economically.
AN AQUICLUDE	-	This is geological formation with extremely low permeability.
A PIE ZOMETER	-	This is a small diameter tube specially constructed for the measurement of hydraulic head at specific depth within an aquifer system.
CONFINED AQUIFER-		This is an aquifer that is overlayed by impermeable formation.
UNCONFINED AQUIFER		This is an aquifer that is not overlay by impermeable formation.
HYDRAULIC CONDUCTIVITY	-	This is the rate at which water is transmitted through a unit cross sectional area of aquifer under unit hydraulic gradient.
TRANSMISSIVITY	-	This is the rate at which water can pass through the thickness of saturated aquifer of unit width under a unit hydraulic gradient.
PUMPING TEST	-	This is the pumping of a well under controlled conditions so that the response of the abstraction well and the growth of the cone of depression can be measured.

1.4 OBJECTIVE OF THE PROJECT.

This project focuses attention on the manual calculation being done during the pumping test analysis for confined and unconfined aquifers characteristics and the well capacity with the aim of computerizing this pumping test method. The qbasic software program is employed in achieving this goal. At the end of the project, the programm will be tested. It is assumed that this computerization will reduce the work load and time wasted in manual method of analysis of pumping test data. A case study of both confined and unconfined aquifer are considered so that it can be applied in any geological formation.

1.5 WELL AND BOREHOLE DESIGN

The design of a water well depends on the type of aquifer system being exploited and the discharge rate required. The discharge rate must be decided before a water well can be designed, because it will dictate the size of pump required which in turn will govern the internal diameter of the pump chamber casing. The cardinal rule of well design is that the internal diameter of the pump chamber must be large enough to accommodate the pump. Aquifer have been divided into three broad classes for the purpose of water -well designs.

(a) crystalline aquifers

(b) consolidated aquifers

(c) unconsolidated aquifers.

Crystalline aquifers are typified by the igneous and metamorphic rocks which underline large area. They have no primary porosity or permeability and have no well -defined base. Water -bearing voids in them are usually the form of rocks usually do not needs support.

Consolidated aquifers are sedimentary formation that have sufficient strength to stand in an open borehole without support. They retain some of their initial -or primary -porosity and permeability, and normally have clearly defined tops and bases. Many regional sand stone and sand stone formations are good examples of consolidated aquifers.

Unconsolidated aquifers are sediments which cannot stand in an open borehole, so that any well in such a formation will require support by casing and screens. These aquifer include alluvium and Mesozoic sand stones.

1.5.1 **Wells in Crystalline:-** Groundwater occurs in crystalline aquifers in the secondary porosity caused by weathering and fissuring, since both weathering and fussuring decrease with depth there will be a depth beyond which the cost of drilling out weighs the chance of significantly increasing the yield of a borehole. This depth is the optimum total depth of a water well and will vary from places to places depending on the geological and geomorphological history of the site. The yield of water wells in crystalline aquifers is low; A pump with 150 mm outside diameter will cope with the available discharge from almost all water wells in crystalline rocks, and so a 200mm internal diameter pump chamber should be adequate in their construction. In most situations only the upper few meters need casing and grouting to seal off surface water, and the rest of the well can be left open. Care has to be taken when completing a water well in crystalline rocks, so as not to case- off the more prolific shallow water bearing zones just because they are unstable.

1.5.2 **Wells in Consolidated Aquifers:-** A water well designed to exploit an aquifer of limited thickness will be drilled to penetrate the whole aquifer. In an area where there has been drilling in the past experience will indicate the potential discharge rate of well, but in virgin territory, test wells will be needed to provided this information.

In shallow aquifers, water wells are usually drilled in two stages. A borehole is drilled at a diameter about 50mm greater than the pump chamber outside diameter to about 2 meters into the target aquifer, and then the pump chamber is set and grounted. Drilling then continues to total depth for an open hole completion. Water wells in deep aquifers may be drilled in several stages. The design of a water well in a very thick, consolidated aquifer is similar to that in a crystalline aquifer, because there is no well - defined base to the aquifer. Also the ground water flow in almost all consolidated aquifers is largely through fissures or zones of enhanced permeability.

So criteria for optimizing well design, based on a uniform aquifer cannot be applied. The depth of borehole needed for a specific discharge will depend on the distribution and size of water bearing fissures.

1.5.3 **Wells in Unconsolidated Aquifers:-** The most common unconsolidated aquifers are alluvial deposits along river flood plains, and these range from thin gravel beds along small rivers, to multi-aquifer systems several hundred metres thick. The design of water wells in unconsolidated aquifers has much in common with that of wells in consolidated strata, except that the former invariably require screening to prevent formation collapse. A water well design varies with the number of aquifers to be exploited and the depth of those aquifer but each design will incorporate the following features, total depth, drilled diameter, casing selection screen selection and gravel pack. In the case of a single aquifer of limited thickness, it is generally recognized that a screen covering at least 70% of the aquifer thickness will perform almost as effectively as if the whole aquifer was screened. This allows for casing to be set into the top of the aquifer. The total screening of a thick aquifer may not be feasible but a spacing of short lengths of screen, separated by lengths of blind casing, enables a thick section of aquifer to be exploited without undue partial penetration effects.

1.6 WELL AND BOREHOLE CONSTRUCTION.

Drilling techniques vary, most of them can be classified as either percussion or rotary techniques. Percussion techniques depths, while rotary methods predominate in the construction of deep boreholes or wells.

1.6.1 **Percussion Techniques:-** The drilling of a borehole is started by installing a short, larger diameter conductor or start pipe in the ground, either by digging or by drilling a pit 1 - 2 m deep. This conductor pipe is to prevent the surface material beneath the rig from collapsing into the hole and to guide the tool in the initial drilling. The tool string is assembled and lowered into the conductor pipe, and then drilling begins. The driller can vary the number of stokes per minute and the length of each stroke by adjusting the engine speed and the crank connection on the spudding arm. The tool string is held in such a position that the drill bit will strike the bottom of the hole sharply, and the cable is feel out at such a rate that this position is maintained. The actual procedure of drilling will depend on the formation to be drilled. It may be hard rock formation as in sedimentary rock.

Hard rock drilling: The drilling proceeds from the bottom of the conductor pipe to the base of the weathered zone. A length of permanent casing. This casing must be set accurately vertical in order to ensure verticality of the whole borehole. The borehole is then continued openhole to its total depth. The action of the heavy chisel is to fracture and pound the rock into send size fragments. The slight rotation of the bit imported by the lay of the cable ensures that the hole is drilled with a circular section. The bottom of the hole becomes filled with rock debris which has to be removed periodically to allow drilling to progress freely in a dry borehole, a few litres of water are poured into the borehole to allow the debris to be mixed into slurry and removed by bailer.

The bailer is usually held on a separate cable to the tool string, so that the tool string can be withdrawn from the hole and the bailer lowered with minimum interruption of the operations.

Agitation of the bailer to the bottom of the borehole ensures that the drilling debris is held in suspension and is forced into bailer through the back valve. The slurry is removed from the hole and the operation repeated until the hole is clean. The moment the water has been struck there is no need to add water to the debris in the bailer or for drilling.

1.6.2 **Drilling in soft formation:-** The tool string used for drilling in soft formation is simpler than for hard formations. The most common tool is a steel tube or shell . The cutting shoe differ in design in order to cope with different lithologies. With sand, the shoe may have a serrated or smooth edge to chop the formation, but a clock valve will be set inside the shell, just behind the shoe, to retain the sand as it is cut. Clay tends to be more coherent than sand, and with stiff clay, a sharp edged cutting shoe with thin chisel blades set across its aperture may be used. The chisels cut the clay into pieces as it enters the shell and help to retain the clay in the shell. Drilling begins with a large diameter shell, to drill a hole deep enough to set the first length of temporary casing. This casing will have a sharp - edged drive shoe screwed on the bottom, to help the driving of the caseing into the soft formation. Drilling progress by removing the formation from inside and ahead of the casing for one or two meters, and driving the casing to the bottom of the hole. Extra casing length are added as the top of previous casing is driven down to the surface on reaching the total depth the design of the permanent casing and screen is finalized. The screen must be located in aquifer accurately.

(a) **Rotary Drilling:-** Rotary method of drilling make use of hydrostatic pressure of circulating drilling fluid to support the borehole walls. This use of drilling fluids enables boreholes to be drilled to much greater depths than can be achieved by percussion method Rotary technique can be divided into two main types namely direct circulation and reverse circulation.

(i) **Direct circulation** :- The body of the rig comprises a floor on which is mounted a diesel engine power unit, a mud pump for circulating the fluid, a winch for raising or lowering the drill string and a mast from which the drill string is suspended. The drill string is made up of lengths of heavy - duty steel tubing or drill pipe, with the drill bit assembly attached to the bottom, Drilling begins with the installation of a length of conductor pipe to prevent erosion of the surface by the mud flow. The water swived is then hoisted up the mast and the drill bit assembly screwed on to the kelly. The bit is lowered into the hole, the kelly damped into the rotary table, and mud circulation and rotation of the drill stem are begin. The kelly can pass vertically through the rotary table quite freely and drilling progresses under the weight of the drill string. When the swived reaches the rotary table, the drill string is held suspended continued until all the cuttings have been removed from the hole then stopped, the drill pipe suspended by friction slips in the rotary table and the kelly is unscrewed . A new length of drill pipe is fastened to the kelly and drill string, the slips removed, and circulation and rotation restored to start drilling again. The momentum of drilling needs to stop only when the final depth is reached.

(ii) **Reverse Circulation:-** The reverse circulation system was developed for drilling large diameter boreholes in loose formations. The rig used is similar to a direct circulation rig; but the drilling fluid is circulated in the opposite direction and many rig component are larger than on a direct circulation rig. The rate of rotation is much slower than with direct circulation, but the weight of the drill string leads to rapid drilling. The drilling fluid is usually water which is pulled up the drill pipe by a centrifugal pump commonly aided by airlift. The kelly and drill pipe lengths are short to avoid the need for high suction heads in the system. The water passes through the swived, is discharged into a large settling pit, and then flows by gravity down the annulus around the drill string to the bit. The flow of water up the drill string is at high velocity and is capable of lifting pieces of drilling debris of a size close to the water way diameter. Reverse circulation is based on the ability of the borehole walls to be supported by the hydro static pressure exerted by the water column and the positive flow of water from the borehole to the formation.

CHAPTER TWO

2.1 ON WELL TESTING.

Testing a well is necessary to evaluate the well hydraulics of the pumping well and aquifer characteristics of the exploited aquifer.

Under natural condition, ground water flows through aquifers, from areas of high hydraulic head to areas of low hydraulic head where the water discharges to the surface. The natural flow is disturbed when a water well is pumped, and a pumping test is designed to cause such a disturbance under controlled condition, so that its effects can be analysed to obtain values of well performance, well efficiency or the aquifer characteristics. There are two types of well testing namely stepdrawdown and constant discharge test.

The disturbance to ground water flow is observed by measuring the changes in the water levels in an array of observation boreholes specially drilled around the pumping well.

The site measurements involved are those of time through the tests, and the discharge rate of the pumped well. the pumping lowers the water level in the well, and the resultant head difference between the aquifer and the well induces flow into the well. The flow into a well from an ideal aquifer is radial, and the effect of pumping spread outwards radially as a cone of depression in the piezometric surface. The need to observe the growth of this cone, and its possible interference with surface features such as streams, dictates the distribution of boreholes at each site.

The analysis of constant discharge tests are dependent on the comparison of the observed behaviour of the groundwater levels with the theoretical behaviour in a perfect aquifer, as defined by the Theis equation. The traditional method of comparison is by graphical superposition of data curves over type curves or by analysis of the data curves. This project is to replace this by computer analysis.

2.2 PRINCIPLE OF WELL TESTING.

When a well is pumped, water is removed from the aquifer surrounding the well and the water stable or piezometric surface depending upon the type of aquifer is lowered. The drawdown at a given point is the distance the water level is lowered. A drawdown curve shows the variation of drawdown with distance from the well (see fig 2.2.1)

In three dimensions the drawdown curve describes a conic shape known as cone of depression. Also, the outer limit of the cone of depression defines the area of influence of the well.

2.2.1 Derivation of Radial Flow Equation for Confined and Unconfined Aquifer.

Figure 2.2.1. **Drawdown in Confined Aquifer.**

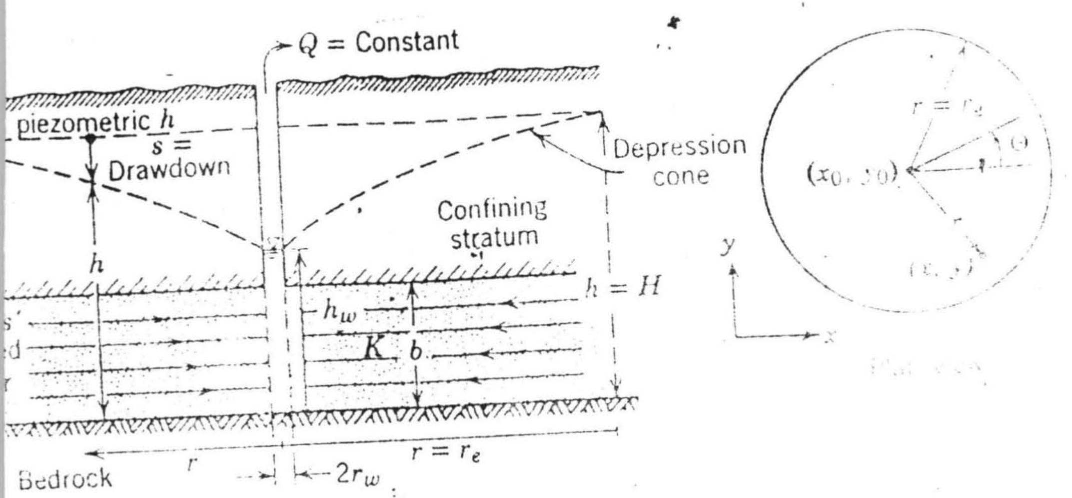


Figure 2.2.1. **Drawdown in Confined Aquifer.**

The radial flow equation relates the well discharge to drawdown for a well completely penetrating a confined aquifer. Consider fig. 2.1.

It is assumed that the flow is two - dimensional to a well centered on a circular Island and penetrating a homogeneous and isotropic aquifer. Because the flow is every where horizontal and with dupuit assumptions. Using plane polar coordinates with the well as the origin, the well discharge Q at any distance R equals

$$Q=A\,V=2\pi r\,b\,k\frac{dh}{dr} \quad \ldots 2.1$$

Steady radial flow to the well. Rearranging an Integrating for the boundary condition at the well edge of the well, $h = h_w$ and $r = r_w$ and at the edge of the Island $h = h_o$ and $r = r_o$ yields

$$h_o-h_w=\frac{Q}{2\pi k\,b}\ln\frac{r_o}{r_w} \quad \ldots 2.2$$

$$Q = 2\pi k\, b \frac{h_o - h_w}{\ln r_o / r_w} \quad \ldots 2.3$$

$$K = \frac{Q}{2\pi k\, b (h_o - h_w)} \ln \frac{r_o}{r_w} \quad \ldots 2.4$$

Where K = hydraulic coefficient of the aquifer.

h_o -h_w = drawdown in the two wells.

Q = Rate of pumping

b = Thickness of aquifer

kb = Transmissivity

r = radius of the well

Equation 2.4 is known as Theims equation for confined aquifer.

In order to apply the equation, pumping must continue at a uniform rate for a sufficient time to approach a steady - state condition, i.e. one in which the drawdown changes negligibly with time. The observation wells should be located close enough to the pumping well appreciable and can be readily measured. The derivation assumes that the aquifer is homogeneous and Isotropic and is of infinite areal extent, that the well penetrates the entire aquifer, and that the flow is laminar.

2.2 DERIVATION OF RADIAL FLOW EQUATION FOR UNCONFINED AQUIFER

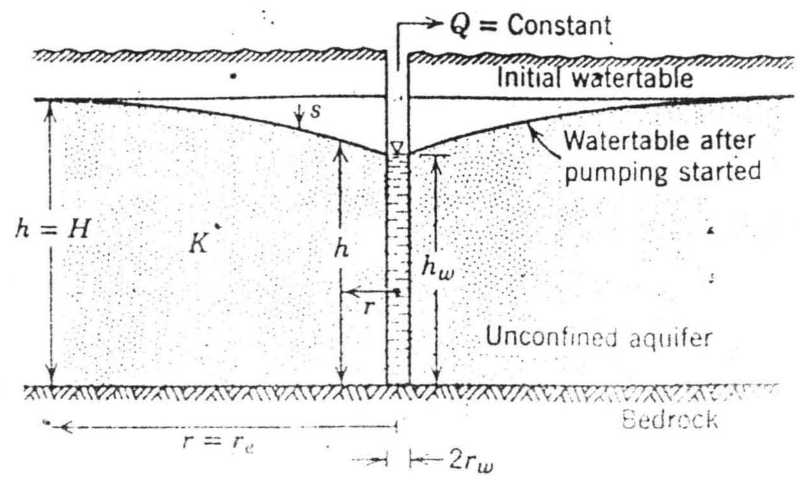


Fig.2.2.2 **Drawdown in Unconfined Aquifer**

$$Q = 2\pi r h k \frac{dh}{dr} \quad .....2.5$$

The boundary condition h=H for r = re

$$K = \frac{Q}{\pi(h_1^2 - h_2^2)} \ln\frac{r_e}{r} \quad ...2.7$$

$$K = \frac{Q}{\pi(h_1^2 - h_2^2)} \ln\frac{r_1}{r_2} \quad ...2.8$$

Where K = hydraulic coefficient of the aquifer

where $h^2{}_1 - h^2{}_2$ = drawdown in the two wells.

Equation 2.8 is known as Theims equation for unconfined aquifer

2.3 STEP DRAWDOWN TEST

The primary aim of a step draw down test is to evaluate the well performance rather than the aquifer performance. The drawdown in the pumped well is measured while the discharged rate in each step is kept constant through the step and changes in rate between steps is make as quickly as possible.

A step drawdown test measures the variation of specific capacity with discharge rate. data, which can be analysed to differentiate the proportion of the dawdown, which is aquifer oss and that wich is well loss. The test data can also give the value of the aquifer ransmissivity an indication of the storativity. The data on the specific capacity of the well are of great practical value, because they gave a basis on which to choose the pump size and pump etting for the well in long term production. An analysis of a test involves the plotting of the pecific drawdown i.e. the reciprocal of specific capacity and the discharge rate for each step. n order for the relationship between specific capacity and discharge rate deduced from such nalysis to be valid, a minimum of four steps are required, and five or six steps is optimal. The scharge rates through a test should start at the smallest and increase with successive steps. he length of the steps are most commonly btewwn 60 and 120 minutes.

2.4 CONSTANT - DISCHARGE TEST.

The aim of a constant discharge test is to obtain data which can be interpreted by comparison with the behaviour of type aquifers predicted by Theim. The purpose of the test is to assess the well performance, to obtain values of the aquifer transmissivity and storativity, and to obtain some indication of the aquifer geometry in order to predict long term aquifer and well performance. The test programme inlude the following.

(i) Pre - test observation

(ii) Pumping test.

(iii) Recovery test.

The pretest observations cover all those factors to be measured during the test, and should be made for a sufficient lenght of time in order to establish trend or base level at each observation point. In a borehole where the water level is stable, measurements every few hours over a day, may be sufficient to establish the situation where the well to be tested is used for a water supply and cannot be switched off for more than a few hours for example in a factory, hen after it is switched off proir to the test, the water - level recovery must be measured continuously.

An important part of pre-test observation is short equipment test after the pump and all ieasuring equipment have been installed. The test pump is switched on to ensure the pump nd discharged measuring devices are working. The water level in the well is measured during ie few minutes pumping to ensure that the discharge rate for the test does not exceed the ipacity of the well. The discharge rate and duration of the pumping test itself are decided efore the test begins. The water level in a pumping well is very susceptible to pumping rate changes in ground water levels caused by discharge

The assumptions for Theims equation are as follows.

(a) The aquifer has a seemingly infinite areal extent.

(b) The aquifer is a homogeneous, Isotopic, and of uniform thickness over the area influence by the test.

(c) Prior to pumping, the piezonmetric surface is horizontal over the area that will be influenced by the test.

(d) The aquifer is pumped at a constant discharge rate.

(e) The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow.

(f) The water removed from storage is discharged instantaneously with decline of head.

(g) The diameter of hte well is small.

2.5 PHYSICAL PROPERTIES

In the equations describing the flow to a pumped well, various physical properties and ıerameters of aquifers and aquitards appear. These are dicussed below.

Iydraulic conductivity (K) :- The hydraulic conductivity is the constant of proportionality in ıorcy's law it is defined as the volume of water that will move through a porous medium in ıit time under a unit hydraulic gradient through a unit are measured at right angles to the rection of flow, Hydraulic conductivity has units of lenght per time.

Specific yield (s):- The specific yield is the volume of water that an unconfined aquifer leases from storage per unit surfaces area of aquifer per unit decline of the water table. The specific yield is also called effective porousity or unconfined storativity. Leakage factor (L):- This is a measure for the spatial distribution of the leakage through an aquitard into a leaky aquifer it is defined as

$$L=\sqrt{K\ D}..C 2.9$$

Transmissivity :- This is the product of the average hydraulic conductivity and the saturated thickness of the aquifer. It is the rate of flow under a unit hydraulic gradient through cross - section of unit width over the whole saturated thickness of the aquifer.

T = KD 2.10

The measurements to be taken .

The measurements to be taken during a pumping test are of two kinds. namely. Measurement of the water levels in the well and the piezometers, measurement of the discharge rate of the well.

2.5.1 **Water - Level Measurement.**

The water levels in the well and the piezometers must be measured many times during a test. Because water levels are droping fast during the first one or two hours of the test, the readings in the period should be made at brief intervals. As pumping continues, the intervals can be gradually lengthened.

2.5.2 **Discharge - Rate Measuremenents.**

During the pumping test, the discharge rate must properly controlled. The discharge rate should be kept constant throughtout the test. The discharge rate can be kept constant by a valve in the discharge pipe.

2.5.3 **Duration of Pumping Test.**

The period of pumping depends on the type of aquifer and the degree of accuracy desired in establishing its hydraulic characteristic. Better and more reliable data are obtained if pumping continous until steady state has been attained.

PUMPING - TEST FORM.

Piezometer ....Depth..........................Distance................

Pumping Test by ....Well Location...

Time Start...........................Time stop...

Initial Water Level.................................

Final Water Level..................................

Reference Level...................................

Remark:..

TIME	WATER LEVEL	DRAW DOWN	TIME	WATER LEVEL	DRAW DOWN

2.5.6 **Procedure for Determine the Transmissivity of a Confined Aquifer**

Plot the observed drawdown in each piezometer against the corresponding time on a sheet of semi- log paper, the drawdown on the vertical axis on a linear scale and the time on the horizontal axis on a logarithm scale. Construct the time - draw down curve for each piezometer this is the curve that fits best through the points.

It will be seen that for the late time data the curves of the different piezomenters run parallel.

For each piezometer the value of the steady - state drawdown is read.

The values of the steady - state drawdown and for two piezometers is substituted in the theims equation together with the corresponding values of r and the known value of Q, the value for KD can then be calculated.

2.6 WATER LEVEL MEASURING DEVICES

The most accurate recordings of water - level changes are made with fully - automatic microcaomputer - controlled system. This uses pressure transducers or acoustic transducers for continuous water - level recordings which are stored on magentic tape.

A good alternative is the conventional automatic recorder which also produces a continuous record of water - level can be taken by hand. The most common devices are electrical sounder, the wetted - tape and a floating steel tape standard with pointer. For piezometers far from the well, conventional automatic recorders are the most suitable devices because only slow water-level changes can be interpreted from their graphs. However for piezomenters at intermediate distances, either floating or hand operated water level indicators can be used.

2.6.1 **Discharge Measuring Devices**

To measure the discharge rate, a commercial water meter of appropriate capacity can be used The meter should be connected to the discharge pipe in a way that ensures accurate readings being made at the bottom of a U - bend, if the water is being discharged through a smallditch a flume can be used to measure the discharge. Other methods of measuring the discharge are container, orifice weir, Orifice bucket and Jet - stream method.

2.6.2 **Container Method**

A very Simple and accurate method is to measure the time it takes to fill a container of known capacity. This method can only be used if the discharge rate is low.

2.6.3 **Orifice Weir Method**

The circular orifice weir is commonly used to measure the discharge from a pump. The orifice is a perfectly round hole in the centre of a circular steel plate which is fastened to the outer end of a level discharge pipe. A piezometer tube is fitted in a hole made in discharge pipe about 61cm from the orifice plate. The water level in the piezometer represents the pressure in the discharge pipe when water is pumped through the orifice. The discharge is reading from a standard table which show the flow rate for various combinations of orifice and pipe diameter.

2.6. 4 **Orifice Bucket**

The orifice bucket consists of a small cylindrical tank with circular opening s in the bottom. The water from the pump flows into the tank and discharge through openings. The tank fills with water to a level where the pressure head causes the out flow through the openings to equal the inflow from the pump. If the tank overflows, one or more orifices are opened. If the water in the tank does not rise sufficiently, one or more orifices are closed with plugs. A piezometr tube is connected to the outer wall of the tank near the bottom, and a vertical scale is fastened behind the tube to allow accurate readings of the water level in the tank. A calibration curve is required, showing the rate of discharge through a single orifice of a given size for various value of the presure head. The discharge rate taken from this curve multiplied by the numbers of orifices through which the water is being discharge, gives the total rate of discharge for any given water level readings.

2.6.5 **Jet - Stream Method.**

This method is by measuring the dimensions of a stream flowing either vertically or horizontally from an open pipe, one can roughly estimate the discharge if the water is discharge through a vertical pipe, estimates of the discharge can be made from the diameter of the pipe and the height to which the water rises above the top of the pipe. If the water is discharge through a horizontal pipe, flowing full and with a free fall from the discharge opening, estimates of the dischage can be made from the horizontal and vertical distance from the end of the pipe to a point in the flowing stream of water . The table formed by Driscoll (1986) shows the discharge rates for different pipe diameters and for various horizontal and vertical distances of the stream of water.

2.6.6 **Duration of the Pumping Test.**

The period of pumping test depends on the type of aquifer and the degree of accuracy desired in establishing its hydraulic characteristics. Better and more reliable data are obtained if pumping continues until steady or pseudo - steady flow has been attained.

At the begining of the test, the cone of depression developes rapidly because the pumped water is initially derived from the aquifer storage immediatelly around the well. As pumping continues, the cone expands and depens more slowly because, with each additional metre of horizontal expansion, a larger volume of stored water becomes available. The cone of depression will continue to expand untill the recharge of hte aquifer equals the pumping rate.

In some tests, steady - state or equilibium conditions occur a few hours after the start of pumping, in others, they occur within a few days or weeks. Under average condtions, a steady state is reached in leaky aquifers after 15 to 20 hours of pumping, in a confined aquifer, it is good to pump for twenty four hours.

CHAPTER THREE

SYSTEM ANALYSIS

3.1 EXISTING METHOD OF PUMPING TEST ANALYSIS.

The existing method of pumping test analysis involved collection of data from the boreholes processing this data in the X - Y graph. i.e. plotting time versus Draw down. From the graph the transmissivity will be calculated. The method is cubersum and time consuming. While reading from the graph, there may be error of judgement.

3.2 PROPOSED METHOD OF PUMPING TEST ANALYSIS

This involves collection of data from boreholes pump tested either confined or unconfined aquifer. These data are fed into computer using a qbasic program in DOS environment and within a short period the results are out in tabular form on the screen. This results can be printed for record purposes.

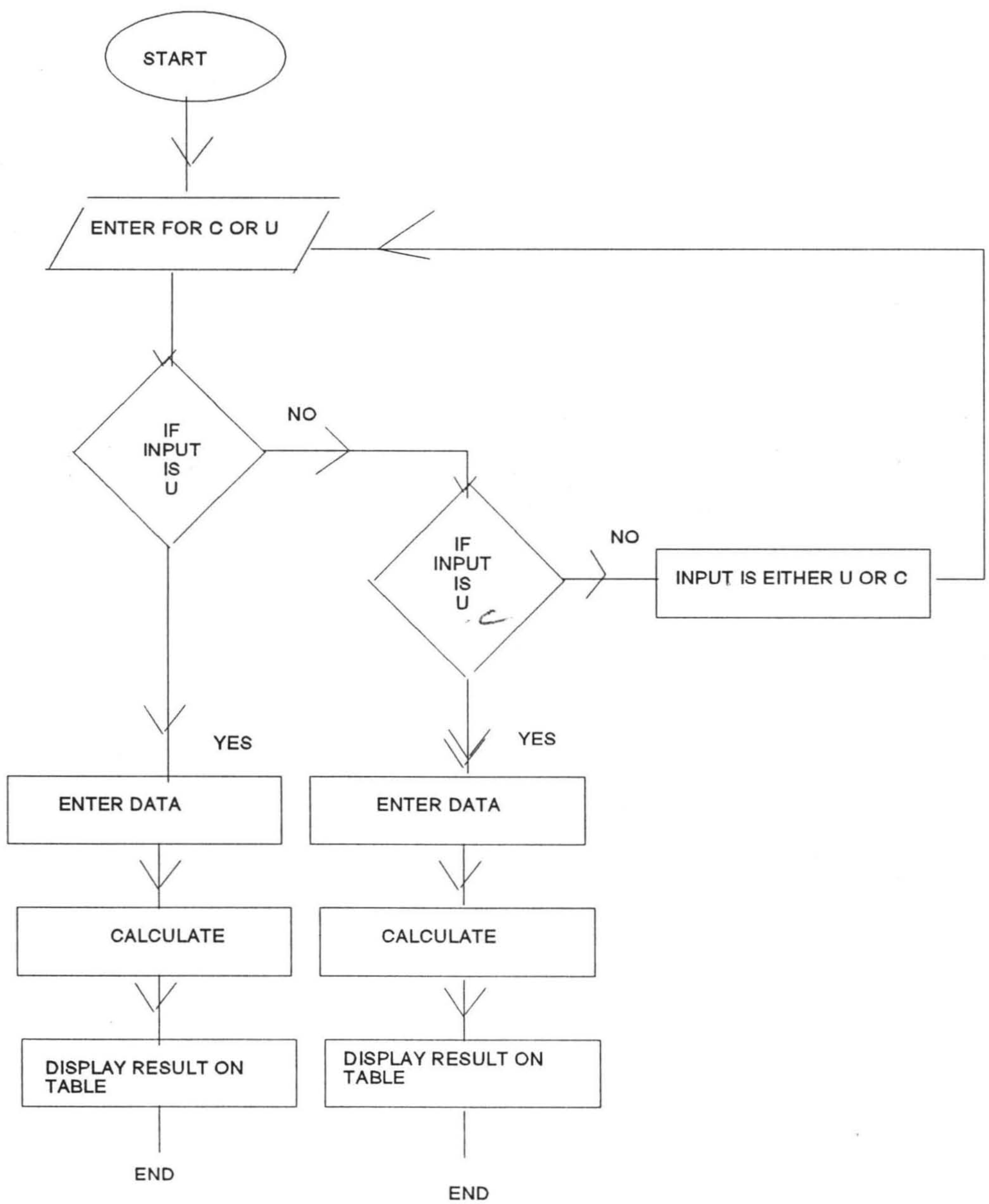
3.3 BENIFIT OF THE PROPOSE METHOD

This new method eleminate data redundancy. It incorporates changes easily and quickly. It improves accuracy and consistency. It provides data security from unauthorised use. The propose system will also have facilities of adding new data. The proposed system is designed so that a casual and a novice user, who has little prior knowledge of what is expected of them will be able to handle it.

CHAPTER FOUR

DESIGN FEATURES AND PROGRAM SUITES.

4.1 PROGRAM FLOWCHART FOR PUMPING TEST ANALYSIS



4.2 DATA ENTRY

This simple Program is very easy to run. When the computer is at C prompt, you change directory to DOS on getting to DOS, environment you go to qbasic. At qbasic you will see a Menu: File, Edit, Window, option.

Press Alt and enter keys at the same time. The file will be activated under the file there is sub menu which is as follows.

New

Open

Save

Print

Quit

Press O for open. Insight the Diskette then type BOD at A prompt. Press F5 to run the program and follow the Instructions as they appear on the screen.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION.

5.1 CONCLUSION

With the mathematical precision adopted in the program design and testing of automation of pumping test analysis under the supervision of Dr. Reju I concluded that the program is capable of determining the aquifer characteristic such as transmissivity, coefficient of pemeability or hydraulic conductivity and leakage factor. It has been tested for both confined aquifer and unconfined aquifers. It has eliminated the time consuming in manual procedure in pumping test analysis.

5.2 RECOMMENDATION

The system was observed to perform otimally irrgardless of the data and P.C. such as I.B.M. KINGTECH (and all I.B.M. compatibles).

It works within the limit of Theims assumption of calculating coefficient of permeability. This proposed method of pumping test analysis is recommended for use in any geological formation, either sedimentary or basement complexes.

APPENDICES.

(i) Output of pumping test analysis for confined aquifer.

(ii) Output of pumping test analysis for unconfined aquifer.

LIST OF FIGURES

```
 PRINT "WELCOME TO UNCONFINED AQUIFER SECTION PLEASE FOLLOW
INSTRUCTION CAREFULLY"
 PRINT
"______________________________________________________________________
____"
PRINT
INPUT "ENTER FOR DISCHARGED Q"; Q
INPUT "ENTER FOR INITIAL HEAD (M)"; Ho
INPUT "ENTER FOR HEAD OF WATER (M)"; Hw
INPUT "ENTER FOR DISTANCE OF FIRST OBSERVATION WELL"; R1
INPUT "ENTER FOR DISTANCE OF SECOND OBSERVATION WELL"; R2
C = 4.56
PI = 3.142
a = (R1 / R2)
Z = LOG(a)
T = (Q * Z)
T1 = (T * (-1))
D = ((Ho ^ 2) - (Hw ^ 2))
E = (PI * D)
K = (T1 / E)
CLS
100 LOCATE , 27: PRINT "THIS IS THE UNCONFINED AQUIFER TABLE"
LINE (180, 8)-(500, 8)
LINE (0, 25)-(510, 25) 'UP
LINE (0, 170)-(510, 170)  'DW
LINE (0, 10)-(0, 170)
LINE (85, 10)-(85, 170): LOCATE 2.55, 2: PRINT "Q (M/s)": LOCATE
5, 2: PRINT USING "###.###"; Q
LINE (170, 10)-(170, 170): LOCATE 2.55, 15: PRINT "HO (M)":
LOCATE 5, 15: PRINT USING "##.###"; Ho
LINE (250, 10)-(250, 170): LOCATE 2.55, 24: PRINT "HW (M)":
LOCATE 5, 24: PRINT USING "##.###"; Hw
LINE (340, 10)-(340, 170): LOCATE 2.55, 34: PRINT "R1 (M)":
LOCATE 5, 34: PRINT USING "##.###"; R1
LINE (425, 10)-(425, 170):  LOCATE 2.55, 45: PRINT "R2 (M)":
LOCATE 5, 45: PRINT USING "##.###"; R2
LINE (510, 10)-(510, 170): LOCATE 2.55, 58: PRINT "K M/s": LOCATE
5, 57: PRINT USING "##.###"; K

SUB DISCHARGE
INPUT "HOW MANY DISCHARED DATA YOU WANT TO ENTER"; D
FOR DA = 1 TO D
INPUT "ENTER FOR FIRST DISCHARGE"; D1
INPUT "ENTER FOR SECOND DISCHARGE"; D2
INPUT "ENTER FOR THIRD DISCHARGE"; D3
INPUT "ENTER FOR FOURTH DISCHARGE"; D4
INPUT "ENTER FOR FIFTH  DISCHARGE"; D5
INPUT "ENTER FOR SIXTH  DISCHARGE"; D6
INPUT "ENTER FOR SEVENTH DISCHARGE"; D7
INPUT "ENTER FOR EIGTH DISCHARGE"; D8
INPUT "ENTER FOR NINETH DISCHARGE"; D9
INPUT "ENTER FOR TENTH DISCHARGE"; D10
NEXT DA
END SUB
```

```
SCREEN 2: CLS : GOTO 100
PI = 3.142
1 INPUT "ENTER C FOR CONFINED OR U FOR UNCONFINED AQUIFER"; a$
IF a$ = "c" OR a$ = "C" THEN GOSUB 10 ELSE 5
5  IF a$ = "U" OR a$ = "u" THEN GOSUB 20 ELSE 6
6 PRINT "YOU HAVE TO ENTER FOR EITHER U OR C": FOR K = 1 TO
10000: NEXT K: CLS
GOTO 1
10 PRINT : CLS
 PRINT "WELCOME TO  CONFINED AQUIFER SECTION PLEASE FOLLOW
INSTRUCTION CAREFULLY"
 PRINT
"________________________________________________________________
_____"
PRINT
INPUT "ENTER FOR RATE OF PUMPING(DISCHARGED)  Q"; Q
INPUT "ENTER FOR  THICKNESS OF AQUIFER B (M)"; B
INPUT "ENTER FOR DRAW DOWN IN OBSEVATION WELL Ho (M)"; Ho
INPUT "ENTER FOR DRAW DOWN IN PRODUCTION WELL Hw (M)"; Hw
INPUT "ENTER FOR RADIUS OF  OBSERVATION WELL R1"; R1
INPUT "ENTER FOR RADIUS OF PRODUCTION WELL R2"; R2
INPUT "ENTER FOR CONSTANT C"; C
a = (R1 / R2)
Z = LOG(a)
T = (Q * Z)
T1 = (T * (-1))
D = (Ho - Hw)
E = (2 * PI * D * B)
K = (T1 / E)
V = SQR(K * B)
L = (C * V)
CLS
40 LOCATE , 27: PRINT "THIS IS THE CONFINED AQUIFER TABLE"
LINE (180, 8)-(500, 8)
LINE (0, 25)-(600, 25) 'UP
LINE (0, 170)-(600, 170)  'DW
LINE (65, 10)-(65, 170)
LINE (0, 10)-(0, 170)
LINE (130, 10)-(130, 170): LOCATE 2.55, 2: PRINT "Q(M/s)": LOCATE
5, 2: PRINT USING "###.###"; Q
LINE (195, 10)-(195, 170): LOCATE 2.55, 11: PRINT "B (M)": LOCATE
5, 11: PRINT USING "##.###"; B
LINE (260, 10)-(260, 170): LOCATE 2.55, 19: PRINT "HO (M)":
LOCATE 5, 19: PRINT USING "##.###"; Ho
LINE (325, 10)-(325, 170): LOCATE 2.55, 27: PRINT "HW (M)":
LOCATE 5, 27: PRINT USING "##.###"; Hw
LINE (390, 10)-(390, 170): LOCATE 2.55, 35: PRINT "R1 (M)":
LOCATE 5, 35: PRINT USING "##.###"; R1
LINE (455, 10)-(455, 170):  LOCATE 2.55, 43: PRINT "R2 (M)":
LOCATE 5, 43: PRINT USING "##.###"; R2
LINE (520, 10)-(520, 170): LOCATE 2.55, 51: PRINT "L  (M)":
LOCATE 5, 51: PRINT USING "##.###"; L
LINE (585, 10)-(585, 170): LOCATE 2.55, 60: PRINT "T M²/s":
LOCATE 5, 58: PRINT USING "##.###"; K * B
LOCATE 2.55, 70: PRINT "K M/s": LOCATE 5, 67: PRINT USING
"##.###"; K
FOR y = 1 TO 10000: NEXT y
END
20 PRINT : CLS
```

THE CONFINED AQUIFER TABLE

Q(M/s)	D(M)	HO(M)	HW(M)	R1(M)	R2(M)	L(M)	T M^2/s	K(M/s)
200	15	30	20	10	20	1.485	2.206	0.147
200	15	25	10	10	12			
150	15	25	10	10	12			
100	15	25	10	10	12			
80	15	25	10	10	12			
150	15	40	35	15	10			
100	15	40	35	15	10			
300	20	20	15	10	6			
250	20	20	15	10	6			
200	20	20	15	10	6			
150	20	20	15	10	6			
100	20	20	15	10	6			
80	20	20	15	10	6			
60	20	20	15	10	6			
400	25	40	30	15	20			
350	25	40	30	15	20			
300	25	40	30	15	20			
250	25	40	30	15	20			
200	25	40	30	15	20			
150	25	40	30	15	20			

THE UNCONFINED AQUIFER TABLE

Q(M/s)	HO(M)	HW(M)	R1(M)	R2(M)	K(M/s)
200	30	20	15	20	
200	15	10	5	6	
200	30	25	10	12	
150	40	30	10	12	
150	40	35	15	10	
100	20	15	10	6	
100	20	18	10	6	
300	20	15	10	6	
300	35	30	10	12	
250	15	10	5	6	
250	30	25	10	12	
180	40	30	10	12	
80	10	6	4	8	
70	10	6	4	8	
60	10	6	4	8	
50	10	6	4	5	
400	50	40	20	35	
350	50	40	20	35	
300	50	40	20	35	
250	50	40	20	35	
200	50	40	20	35	