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EFFECT OF WATER TABLE DEPTH ON RECHARGE DUE TO RAINFALL

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PREFACE

In many arid and semi-arid regions, surface water resources are limited and ground water is the major source for agricultural, industrial and domestic water supplies. Because of lowering of water tables and the consequently increased energy costs for pumping, it is recognized that ground water extraction should balance ground water recharge in areas with scarce fresh water supplies. This objective can be achieved either by restricting ground water use to the water volume which becomes available through the process of natural recharge or by recharging the aquifer artificially with surface water. Both options require knowledge of the ground water recharge process from the land surface to the regional water table through the unsaturated zone.

This report entitled "Effect of Water Table Depth on Recharge due to Rainfall" is a part of the research activities of 'Ground Water Assessment' division of the Institute. The purpose of this study is to determine the influence of the water table position on ground water recharge due to rainfall. The study has been carried out by Mr. C. P. Kumar, Scientist 'C' under the guidance of Dr. G. C. Mishra, Scientist 'F'.

(S. M. Seth)

Director

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ABSTRACT

Reliable estimates of recharge rates to an aquifer are often a pre-requisite to the development of efficient plans for management of a ground water resource. Ground water recharge is a complex function of meteorological conditions, soil, vegetation, physiographic characteristics, antecedent soil moisture regime and properties of the geologic material within the paths of flow. Soil layering in the unsaturated zone plays an important role in facilitating or restricting downward water movement to the water table. Depth to water table is also important in ground water recharge estimations.

When water is supplied to the soil surface, whether by precipitation or irrigation, some of the arriving water penetrates the surface and is absorbed into the soil, while some may fail to penetrate but instead accrue at the surface or flow over it. The water which does penetrate is itself later partitioned between that amount which returns to the atmosphere by evapotranspiration and that which seeps downward, with some of the latter reemerging as stream flow while the remainder recharges the ground water reservoir. The infiltrating recharge and water loss by evaporation are related to the depth of the ground water table.

The purpose of this study is to determine the effect of water table depth on recharge due to rainfall by studying one-dimensional vertical flow of water in the unsaturated zone. A model has been formulated for finite difference solution of the

non-linear Richards equation applicable to transient, one-dimensional water flow through the unsaturated porous medium. The ground water recharge has been estimated for various depths of the ground water table using appropriate initial and boundary conditions to study the influence of water table depth.

1.0 INTRODUCTION

The amount of water that may be extracted from an aquifer without causing depletion is primarily dependent upon the ground water recharge. Thus, a quantitative evaluation of spatial and temporal distribution of ground water recharge is a pre-requisite for operating ground water resources in an optimal manner.

In natural condition a static balance can not develop in the unsaturated zone, because there are always some water movements caused by evapotranspiration or infiltration. The former can be divided into two groups : (a) loss of water which evaporates directly because of climatic factors and (b) water loss by plant transpiration. The effect of these two phenomena is the same and continuous, only the amount varies. This continuous process can be broken at sometimes by infiltration. Part of the rainfall falling on the surface infiltrates into the pore space of the soil. The rate at which rainfall infiltrates into the ground depends on the amount of rainfall, surface evaporation and runoff. Consequently this process is controlled by climatic and hydrologic phenomena. Part of the water entering the soil layer will be stored in the capillary pore space contained in the unsaturated layer overlying the ground water table and another part of it will reach the gravitational ground water space. Thus the recharge of ground water depends upon the storage capacity of unsaturated soil and the loss of water from evaporation.

Rainfall is the principal means for replenishment of moisture in the soil water system and recharge to ground water. Moisture movement in the unsaturated zone is controlled by capillary pressure and hydraulic conductivity. The amount of moisture that will eventually reach the water table is defined as natural ground water recharge. The amount of this recharge depends upon the rate and duration of rainfall, the subsequent conditions at the upper boundary, the antecedent soil moisture conditions, the water table depth and the soil type.

When rain intensity exceeds soil infiltrability, in principle the infiltration process is similar to the case of shallow ponding. If rain intensity is less than the initial infiltrability value of the soil but greater than the final value, then at first the soil will absorb at less than its potential rate and the flow of water in the soil will occur under unsaturated conditions; however, if the rain is continued at the same intensity, and as the soil infiltrability decreases, the soil surface will eventually become saturated and henceforth the process will continue as in the case of ponding infiltration. Finally, if rain intensity is at all times lower than soil infiltrability (i.e., lower than the effective saturated hydraulic conductivity), the soil will continue to absorb the water as fast as it is applied without ever reaching saturation. After a long time, as the suction gradients become negligible, the wetted profile will attain a wetness for which the conductivity is equal to the water supply rate, and the lower this rate, the lower the degree of saturation of the infiltrating profile.

In areas where an aquifer is recharged by natural processes, a change in depth to water table will not ordinarily affect the recharge rate. However, exceptions occur if the water table is at such a shallow depth that storage is filled by ground water and there is variable space available for infiltrating water. Where water is discharged from the aquifer as upward flow to the land surface, changes in depth to the water table can markedly change the flow rate. This is because the length of travel is changed while the hydraulic potential remains relatively constant. The infiltrating recharge and water loss by evaporation are therefore related to the depth of the ground water table.

In the present study, the effect of water table depth on ground water recharge due to rainfall has been determined by studying one dimensional vertical flow of water in the unsaturated zone. The governing partial differential equation (Richards equation) has been numerically solved with appropriate initial and boundary conditions to estimate recharge due to rainfall for different depths of the ground water table.

2.0 REVIEW

The one-dimensional partial differential equation which describes the movement of moisture through unsaturated porous media subject to appropriate boundary and initial conditions has many field applications in the water environment. In hydrology, it describes the infiltration process that links the surface and sub-surface waters on land. In soil physics, it describes the capillary rise as well as drainage and evaporation of moisture in soils. In environmental pollution, it describes the longitudinal dispersion of pollutants in water courses. Therefore, the problem of seeking solutions to this equation has become a subject of concern for investigators from many different disciplines.

The unsaturated flow equation in its general form is highly non-linear. The parameters are often complex functions of the dependent variables. When the equation is used to describe the infiltration process, the problem is further complicated by the existence of two surface boundary conditions identified as the ponded infiltration condition and the rain infiltration condition. Under the latter condition, the problem formulation and the approach to the solution also depend upon the intensity of rainfall in relation to the surface saturated hydraulic conductivity.

There have been three modes of infiltration recognized due to rainfall : (1) nonponding infiltration, involving rain not intense enough to produce ponding, (2) preponding infiltration, due to rain that can produce ponding but that has not yet done so, and (3) rainpond infiltration, characterized by the presence of ponded water. Rainpond infiltration is usually preceded by preponding infiltration, the transition between the two being called incipient ponding. Thus, nonponding and preponding infiltration rates are dictated by rain intensity, and are therefore supply controlled (or flux controlled), whereas rainpond infiltration rate is determined by the pressure (or depth) of water above the soil surface as well as by the suction conditions and conductivity relations of the soil. Where the pressure at the surface is small, rainpond infiltration, like ponding infiltration in general, is profile controlled.

In the analysis of rainpond or ponding infiltration, the surface boundary condition generally assumed is that of a constant pressure at the surface, whereas in the analysis of nonponding and preponding infiltration, the water flux through the surface is considered to be equal either to the rainfall rate or to the soil's infiltrability, whichever is the lesser. In actual field conditions, rain intensity might increase and decrease alternately, at times exceeding the soil's saturated conductivity (and its infiltrability) and at other times dropping below it. However, since periods of decreasing rain intensity involve complicated hysteresis phenomena, the analysis of variable-intensity rainstorms is rather difficult.

The process of infiltration under rain is normally analysed based on the assumption of no hysteresis. The falling raindrops are taken to be so small and numerous that rain could be treated as a continuous body of 'thin' water reaching the soil surface at a specified rate. Soil air is regarded as a continuous phase, at atmospheric pressure. The soil is mostly assumed to be uniform and stable (i.e., no fabric changes such as swelling or surface crusting).

If a constant pressure head is maintained at the soil surface (as in rainpond infiltration), then the flux of water into this surface must be constantly decreasing with time. If a constant flux is maintained at the soil surface, then the pressure head at this surface must be constantly increasing with time. Infiltration of constant-intensity rain can result in ponding only if the relative rain intensity (i.e., the ratio of rain intensity to the saturated hydraulic conductivity of the soil) exceeds unity. During nonponding infiltration under a constant rain intensity q_r, the surface pressure head will tend to a limiting value h_{lim} such that $K(h_{lim}) = q_r$.

Under rainpond infiltration, the wetted profile consists of two parts: an upper, water-saturated part; and a lower, unsaturated part. The depth of the saturated zone continuously increases with time. Simultaneously, the steepness of the moisture gradient at the lower boundary of the saturated zone (i.e., at the wetting zone and the wetting front) is continuously decreasing. The higher the rain intensity is, the shallower is the saturated layer at incipient ponding and the steeper is the moisture gradient in the wetting zone.

A rainstorm of any considerable duration typically consists of spurts of high-intensity rain punctuated by periods of low-intensity rain. During such respite periods, surface soil moisture tends to decrease because of internal drainage, thus reestablishing a somewhat higher infiltrability. The next spurt of rainfall is therefore absorbed more readily at first, but soil infiltrability quickly falls back to, or even below, the value it had at the end of the last spurt of rain. A complete description would, of course, necessitate taking account of the hysteresis phenomenon in the alternately wetting-and-draining surface zone.

No analytical solution to the unsaturated flow equation in its general form is available at the present time. However, the linearized form of the equation is in mathematical form identical to the longitudinal dispersion equation with constant parameters. An analytical solution for the latter equation has been proposed by Ogata and Banks (1961), and can therefore be used for the linearized infiltration equation as well. A semi-analytical approach has also been proposed by Philip (1957). Both these solutions are for ponded infiltration condition only. Subsequently several researchers have proposed numerical solution procedures based upon the finite difference method for solving the ponded infiltration problem. For rain infiltration condition, Rubin and Steinhardt (1963, 1964) proposed a finite difference based numerical procedure for low rainfall intensities. Later, Rubin (1969) extended the method for analysing ponded rain infiltration. Similar finite difference based procedures have been proposed by Freeze (1969) and Whisler and Klute (1969). A finite element based procedure using complete discretization has been proposed by Bruch and Zyvoloski (1974) for vertical infiltration under ponded conditions. In most of these studies, the comparisons have been either with already published results or with data gathered from soil columns or horizontal field plots.

3.0 PROBLEM DEFINITION

The objective of the present study is to determine the effect of water table depth on ground water recharge due to a rainfall event of specified duration with rain intensity approximately equal to soil infiltrability (i.e., constant pressure head maintained at the soil surface). A numerical model (finite difference scheme) is used for solving the nonlinear partial differential equation (Richards equation) describing one-dimensional water flow through the unsaturated porous medium. It uses a one-dimensional (vertical) formulation of soil moisture movement in the following modes :

(a) into the soil through infiltration during rainstorm ;

(b) out of the soil through evaporation of exfiltrated water after rainstorm ;

(c) downward percolation to the water table ; and

(d) upward capillary rise from the water table.

The amount of ground water recharge due to rainfall has been estimated for various depths of the ground water table to study the influence of water table depth.

4.0 METHODOLOGY

Most of the processes involving soil water flow in the field, and in the rooting zone of most plant habitats, occur while the soil is in an unsaturated condition. Unsaturated flow processes are in general complicated and difficult to describe quantitatively, since they often entail changes in the state and content of soil water during flow. Such changes involve complex relations among the variable water content, suction, and conductivity, which may be affected by hysteresis. The formulation and solution of unsaturated flow problems very often require the use of indirect methods of analysis, based on approximations or numerical techniques.

4.1 General Equation of Unsaturated Flow

Downward infiltration into an initially unsaturated soil generally occurs under the combined influence of suction and gravity gradients. As the water penetrates deeper and the wetted part of the profile lengthens, the average suction gradient decreases, since the overall difference in pressure head (between the saturated soil surface and the unwetted soil inside the profile) divides itself along an ever-increasing distance. This trend continues until eventually the suction gradient in the upper part of the profile becomes negligible, leaving the constant gravitational gradient in effect as the only remaining force moving water downward. Since the gravitational head gradient has the value of unity (the gravitational head decreasing at the rate of 1 cm with each centimeter of vertical depth below the surface), it follows that the flux tends to approach the hydraulic conductivity as a limiting value. In a uniform soil (without crust) under prolonged ponding, the water content of the wetted zone approaches saturation. However, in practice, because of air entrapment, the soil-water content may not attain total saturation but some maximal value lower than saturation which has been called 'satiation'. Total saturation is assured only when a soil sample is wetted under vacuum.

Darcy's equation for vertical flow is

$$q = -K \frac{\partial H}{\partial z} = -K \frac{\partial}{\partial z} (h - z) \qquad ...(4.1)$$

where q is the flux, H the total hydraulic head, h the soil water pressure head, z the vertical distance from the soil surface downward (i.e., the depth), and K the hydraulic conductivity. At the soil surface, q = i, the infiltration rate. In an unsaturated soil, h is negative. Combining this formulation of Darcy's equation (4.1) with the continuity equation $\partial\theta/\partial t = -\partial q/\partial z$ gives the general flow equation

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial z} (K \frac{\partial H}{\partial z}) = \frac{\partial}{\partial z} (K \frac{\partial h}{\partial z}) - \frac{\partial K}{\partial z} \qquad ...(4.2)$$

If soil moisture content θ and pressure head h are uniquely related, then the left-hand side of equation (4.2) can be written

$$\frac{\partial\theta}{\partial t} = \frac{d\theta}{dh} \cdot \frac{\partial h}{\partial t}$$

which transforms equation (4.2) into

$$C \frac{\partial h}{\partial t} = \frac{\partial}{\partial z} (K \frac{\partial h}{\partial z}) - \frac{\partial K}{\partial z} \qquad ...(4.3)$$

where C (= $d\theta/dh$) is defined as the specific (or differential) water capacity (i.e., the change in water content in a unit volume of soil per unit change in matric potential).

Alternatively, we can transform the right-hand side of equation (4.2) once again using the chain rule to render

$$\frac{\partial h}{\partial z} = \frac{dh}{d\theta} \cdot \frac{\partial \theta}{\partial z} = \frac{1}{C} \cdot \frac{\partial \theta}{\partial z}$$

We thus obtain

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left(\frac{K}{C} \cdot \frac{\partial \theta}{\partial z}\right) - \frac{\partial K}{\partial z}$$

or

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left(D \frac{\partial \theta}{\partial z}\right) - \frac{\partial K}{\partial z} \qquad \ldots(4.4)$$

where D is the soil water diffusivity. Equations (4.2), (4.3) and (4.4) can all be considered as forms of the Richards equation.

Note that the above three equations contain two terms on their right-hand sides, the first term expressing the contribution of the suction (or wetness) gradient and the second term expressing the contribution of gravity. Whether the one or the other term predominates depends on the initial and boundary conditions and on the stage of the process considered. For instance, when infiltration takes place into an initially dry soil, the suction gradients at first can be much greater than the gravitational gradient and the initial infiltration rate into a horizontal column tends to approximate the infiltration rate into a vertical. On the other hand, when infiltration takes place into an initially wet soil, the suction gradients are small from the start and become negligible much sooner. The effects of ponding depth and initial wetness can be significant during early stages of infiltration, but decrease in time and eventually tend to vanish in a very deeply wetted profile.

4.2 Initial and Boundary Conditions

There are three different initial and boundary conditions that can be applied to equations (4.3) and (4.4) when describing infiltration. They are briefly defined in the following equations:

Condition 1

$$\theta(z,0) = \theta_i \quad \text{for } z \geq 0, \quad t = 0 \qquad \ldots(4.5\text{ a})$$

$$\theta(0,t) = \theta_0 \quad \text{for } z = 0, \quad t \geq 0 \qquad \ldots(4.5\text{ b})$$

where θ_i and θ_0 are the initial and surface moisture contents, respectively (usually $\theta_0 > \theta_i$). They may be constants or functions of z or t. The most common condition in infiltration is when there is a thin layer of water available at the surface. Then, the surface moisture content is the saturated value θ_s and is called the ponded infiltration condition. Then :

$$\theta(0,t) = \theta_s \quad \text{for } z = o, \quad t \geq 0 \qquad \ldots(4.5\text{ c})$$

Condition 2

$$\theta(z,0) = \theta_i \quad \text{for } z \geq 0, \quad t = 0 \qquad \ldots(4.6\text{ a})$$

$$\text{Flux} = -K\left(\frac{\partial h}{\partial z} - 1\right) = q_r \quad \text{for } z = 0, \quad t > 0 \qquad \ldots(4.6\text{ b})$$

where q_r is the rainfall intensity. The condition (4.6 b) can also be written as :

$$\frac{\partial \theta}{\partial z} = - \frac{q_r - K}{D} \qquad \text{...(4.6 c)}$$

This condition corresponds to rain infiltration and is applicable from the beginning of rainfall to the time of occurrence of incipient ponding. For low rainfall intensities $[q_r < K(\theta_s)]$ rain infiltration can continue without giving rise to ponding. As time passes, the surface moisture content approaches a limiting value θ_1.

Condition 3

$$h(z,0) = h_i \qquad \text{for } z \geq 0, \quad t = 0 \qquad \text{...(4.7 a)}$$

$$h(0,t) = h_f \geq 0 \qquad \text{for } z = 0, \quad t \geq t_p \qquad \text{...(4.7 b)}$$

$$\text{Flux} = -K\left(\frac{\partial h}{\partial z} - 1\right) = q_r \qquad \text{for } z = 0, \quad 0 \leq t \leq t_p \qquad \text{...(4.7 c)}$$

where,

h_i = initial soil water pressure ;

h_f = surface soil water pressure during ponding (hydrostatic) ; and

t_p = time of incipient ponding.

This condition corresponds to rain infiltration in which the rain intensity is greater than the surface saturated hydraulic conductivity. The physical meaning being that the rainfall intensity is exceeding the infiltration capacity of the soil, and therefore ponding of water at the surface is taking place. In equation (4.7 b), h_f can be taken as zero without loss of generality.

For the present study, the initial and boundary conditions have been defined as follows.

I. Initial condition :

$\theta(z,0) = \theta_i$ for $z \geq 0$, $t = 0$ ...(4.5 a)

(Equilibrium moisture profile with surface moisture content = 0.10)

II. Upper boundary conditions :

(a) during rain infiltration -

$\theta(0,t) = (\theta_s - 0.001)$ for $z = 0$, $t \geq 0$ ...(4.5 c)

(b) during nonrainy period -

If the relative humidity (f) and the temperature of the air (T) as a function of time are known, and if it may be assumed that the pressure head at the soil surface is at equilibrium with the atmosphere, then h(o,t) can be derived from the thermodynamic relation (Edlefson and Anderson, 1943) :

$$h(0,t) = \frac{RT(t)}{Mg} \ln [f(t)] \qquad \text{...(4.8)}$$

where R is the universal gas constant (8.314×10^7 erg/mole/K), T is the absolute temperature (K), g is acceleration due to gravity (980.665 cm/s^2), M is the molecular weight of water (18 gm/mole), f is the relative humidity of the air (fraction) and h is in bars. Knowing $h(0,t)$, $\theta(0,t)$ can be derived from the soil water retention curve.

III. Lower boundary condition :

The phreatic surface acts as lower boundary of the system in case of ground water recharge due to rainfall. The lower boundary condition has therefore been set as

$$\theta(z=L,\ t) = \theta_s - 0.001 \qquad \text{...(4.9)}$$

where L is the depth of the ground water table and the subscript s denotes saturated condition.

4.3 Soil Moisture Characteristics

For the present study, functional relations, as reported by Haverkamp et al. (1977), for characterizing the hydraulic properties of a soil, were used. They compared six models, employing different ways of discretization of the non-linear infiltration equation in terms of execution time, accuracy, and programming considerations. The models were tested by comparing water content profiles calculated at given times by each of the model with results obtained from an infiltration experiment carried out in the laboratory. All models yielded excellent agreement with water content profiles measured at various times.

The infiltration experiments were done in the laboratory using a plexiglass column, 93.5 cm long and 6 cm inside diameter uniformly packed with sand to a bulk density of 1.66 gm/cm^3. The column was equipped with tensiometers at depths of 7, 22, 37, 52, 67 and 82 cm below the soil surface. Each tensiometer had its own pressure transducer. The changes of water content at different depths were obtained by gamma ray attenuation using a source of Americium-241. A constant water pressure ($\theta = 0.10$) was maintained at the lower end of the column, a constant flux (13.69 cm/h) was imposed at the soil surface ($z = 0$) and initial condition as $\theta = 0.10$ throughout the depth. The hydraulic conductivity and water content relationship of the soil was obtained by analysis of the water content and water pressure profiles during transient flow. The soil water pressure and water content relationship was obtained at each tensiometer depth by correlating tensiometer readings and water content measurements during the experiments. The following analytical expressions, obtained by a least square fit through all data points were chosen for characterizing the soil :

$$K = K_s \frac{A}{A + |h|^{\beta_1}} ; \qquad \ldots(4.10)$$

$K_s = 34$ cm/h,
$A = 1.175 \times 10^6$,
$\beta_1 = 4.74$.

and

$$\theta = \frac{\alpha (\theta_s - \theta_r)}{\alpha + |h|^{\beta_2}} + \theta_r ; \qquad \ldots(4.11)$$

$\theta_s = 0.287$,
$\theta_r = 0.075$,
$\alpha = 1.611 \times 10^6$,
$\beta_2 = 3.96$.

where subscript s refers to saturation, i.e. the value of θ for which $h = 0$, and the subscript r to residual water content.

Figure 1 present the relationships between the soil water pressure h, the water content θ and the hydraulic conductivity K for the above soil used in this study.

4.4 Finite Difference Approximation

Equation (4.3) is a non-linear partial differential equation (PDE) because the parameters K(h) and C(h) depend on the actual solution of h(z,t). The non-linearity of the equation causes problems in its solution. Analytical solutions are known for special cases only. The majority of practical field problems can only be solved by numerical methods. In this respect one can use either explicit or implicit methods. Although an implicit approach is more complicated, it is preferable because of its better stability and convergence . Moreover, it permits relatively large time steps thus keeping computer costs low. For a given grid point at a given time, the values of the coefficients C(h) and K(h) can be expressed either from their values at the preceding time step (explicit linearization) or from a prediction at time $(t+1/2\ \Delta t)$ using a method described by Douglas and Jones, 1963 (implicit linearization).

Let us now solve equation (4.3) by a finite difference technique and appropriate initial and boundary conditions. We have

$$C \frac{\partial h}{\partial t} = \frac{\partial}{\partial z} \left[K \left(\frac{\partial h}{\partial z} - 1\right)\right]$$

or

$$C \frac{\partial h}{\partial t} = \frac{\partial K}{\partial z} \left(\frac{\partial h}{\partial z} - 1\right) + K \frac{\partial^2 h}{\partial z^2}$$

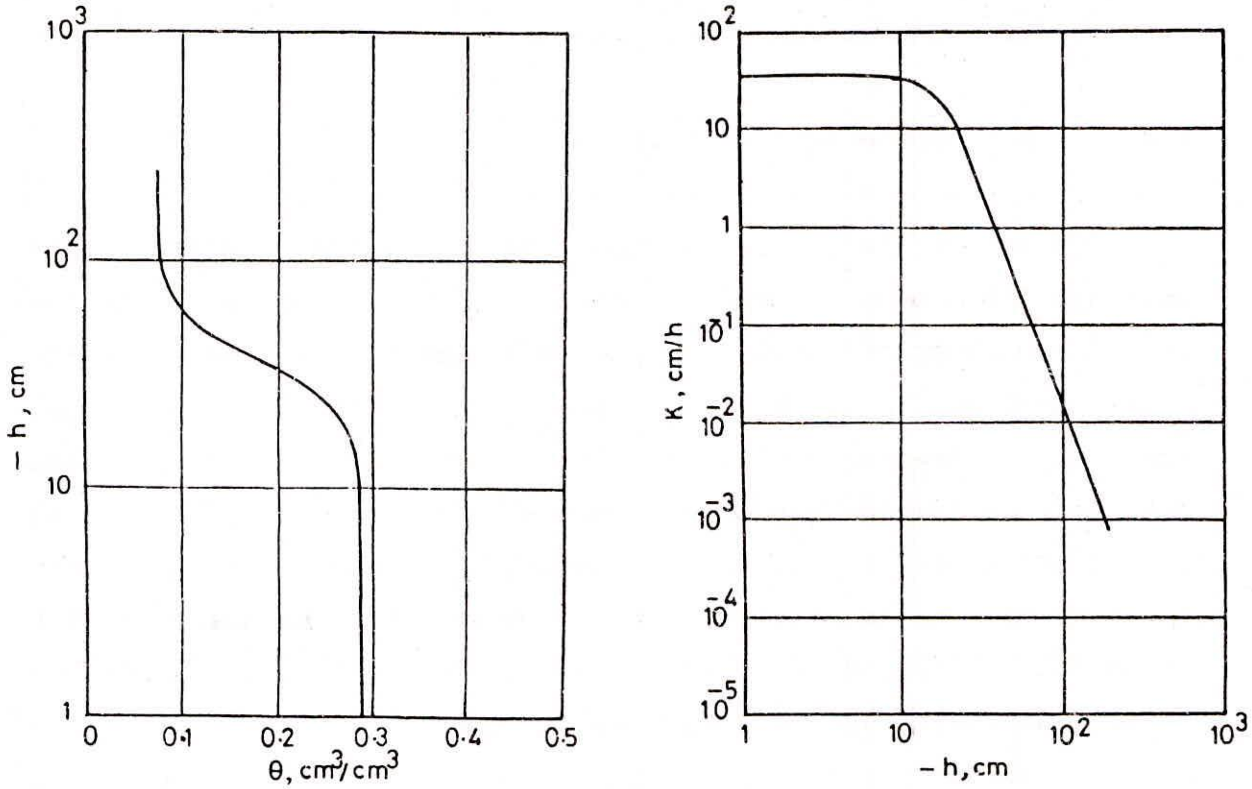

FIG.1. RELATIONSHIPS BETWEEN THE SOIL WATER PRESSURE h, THE WATER CONTENT θ AND THE HYDRAULIC CONDUCTIVITY K FOR THE SOIL USED IN THE STUDY

or $$\frac{C}{K}\frac{\partial h}{\partial t} = \frac{\partial^2 h}{\partial z^2} + \frac{1}{K}\frac{\partial K}{\partial z}\left(\frac{\partial h}{\partial z} - 1\right) \qquad \ldots (4.12)$$

Using implicit evaluation of the coefficients at time $(t+1/2\ \Delta t)$, that is values for K and C are obtained at time $(t+1/2\ \Delta t)$, then pressure distribution is evaluated at time $(t+\Delta t)$. The partial differential equation is approximated by a finite difference equation replacing ∂t and ∂z by Δt and Δz, respectively.

Prediction (estimation of C_i^j and K_i^j)

From equation (4.12), by taking time step as $\Delta t/2$, we have

$$\frac{2C_i^j}{K_i^j} \cdot \frac{h_i^{j+1/2} - h_i^j}{\Delta t} = \frac{h_{i+1}^{j+1/2} - 2h_i^{j+1/2} + h_{i-1}^{j+1/2}}{(\Delta z)^2}$$

$$+ \frac{1}{K_i^j} \cdot \frac{K_{i+1}^j - K_{i-1}^j}{2\Delta z}\left[\frac{h_{i+1}^j - h_{i-1}^j}{2\Delta z} - 1\right]$$

where i refers to depth and j refers to time. Rearranging the terms, we get

$$- \frac{\Delta t}{(\Delta z)^2} h_{i-1}^{j+1/2} + \left[\frac{2C_i^j}{K_i^j} + \frac{2\Delta t}{(\Delta z)^2}\right] h_i^{j+1/2} - \frac{\Delta t}{(\Delta z)^2} h_{i+1}^{j+1/2}$$

$$= \frac{2C_i^j}{K_i^j} h_i^j + \frac{1}{2} \frac{K_{i+1}^j - K_{i-1}^j}{K_i^j} \frac{\Delta t}{\Delta z}\left[\frac{h_{i+1}^j - h_{i-1}^j}{2\Delta z} - 1\right] \qquad \ldots (4.13)$$

Correction (estimation of h_i^j)

From equation (4.12), by taking time step as Δt, we have

$$\frac{C_i^{j+1/2}}{K_i^{j+1/2}} \cdot \frac{h_i^{j+1} - h_i^j}{\Delta t} = \frac{1}{2}\left[\frac{h_{i+1}^{j+1} - 2h_i^{j+1} + h_{i-1}^{j+1}}{(\Delta z)^2} + \frac{h_{i+1}^{j} - 2h_i^{j} + h_{i-1}^{j}}{(\Delta z)^2}\right]$$

$$+ \frac{1}{K_i^{j+1/2}} \cdot \frac{K_{i+1}^{j+1/2} - K_{i-1}^{j+1/2}}{2\Delta z}\left[\frac{h_{i+1}^{j+1/2} - h_{i-1}^{j+1/2}}{2\Delta z} - 1\right]$$

Rearranging the terms, we get

$$-\frac{1}{2}\frac{\Delta t}{(\Delta z)^2} h_{i-1}^{j+1} + \left[\frac{C_i^{j+1/2}}{K_i^{j+1/2}} + \frac{\Delta t}{(\Delta z)^2}\right] h_i^{j+1} - \frac{1}{2}\frac{\Delta t}{(\Delta z)^2} h_{i+1}^{j+1}$$

$$= \frac{C_i^{j+1/2}}{K_i^{j+1/2}} h_i^j + \frac{1}{2}\frac{\Delta t}{(\Delta z)^2}\left[h_{i+1}^j - 2\, h_i^j + h_{i-1}^j\right]$$

$$+ \frac{1}{2}\frac{K_{i+1}^{j+1/2} - K_{i-1}^{j+1/2}}{K_i^{j+1/2}} \frac{\Delta t}{\Delta z}\left[\frac{h_{i+1}^{j+1/2} - h_{i-1}^{j+1/2}}{2\Delta z} - 1\right] \qquad \ldots(4.14)$$

When equation (4.13) or (4.14) is applied at all nodes, the result is a system of simultaneous linear algebraic equations with a tridiagonal coefficient matrix with zero elements outside the diagonals and unknown values of h. In solving this system of equations, a so-called direct method was used by applying a tridiagonal algorithm of the kind discussed by Remson et al. (1971).

4.5 Effect of Water Table Depth

After obtaining the pressure (and soil moisture) distribution at each time step, the ground water recharge due to rainfall was estimated for the given depth of ground water table. The flux was calculated as the product of the unsaturated hydraulic conductivity and the hydraulic gradient. According to Darcy's law, for one dimensional vertical flow, the volumetric flux q ($cm^3/cm^2/h$) can be written as

$$q = -K \frac{\partial}{\partial z} (h - z) \qquad (cm/h) \qquad \ldots(4.1)$$

or

$$q = -K \left(\frac{\partial h}{\partial z} - 1\right) \qquad (cm/h)$$

The ground water recharge (RR) was estimated by applying the above equation for two vertically adjacent nodal points (at and above the water table) for each time step.

$$RR = -K^j_{i+1/2} \left(\frac{h^j_{i+1} - h^j_i}{\Delta z} - 1\right) \qquad \ldots(4.15)$$

where,

$$K^j_{i+1/2} = \sqrt{(K^j_i \, K^j_{i+1})}$$

Geometric mean of K was taken following suggestions of Haverkamp and Vauclin (1979). The net ground water recharge at the specified duration was estimated by cumulating the RR values obtained at each time step. The recharge was estimated for different water table depths in a similar manner.

The computer code, for discretization scheme used in the model and estimation of ground water recharge due to rainfall as per the procedure described above, has been written in FORTRAN and presented in Appendix-I.

5.0 RESULTS

The numerical model described in section 4.4 was tested by comparing water content profiles calculated at given times with results obtained from quasi-analytical solution of Philip subject to condition of a constant pressure at the soil surface ($\theta = 0.267$ cm^3/cm^3). The infiltration profiles at various times for infiltration in the sand (under consideration) obtained by quasi-analytical solution of Philip were reported by Haverkamp et al. (1977). The model yielded good agreement with water content profiles at various times (Kumar and Mishra, 1991).

The present study was carried out for bare-surface (i.e. no vegetation) and therefore transpiration by plants was not taken into account. The sub-surface profile was divided into uniform layers of thickness 4 cm each (depth interval, Δz) down to the water table position which was varied from 40 cm to 200 cm below the soil surface. Keeping in view the stability of the numerical scheme, the time step (Δt) was taken as 3 seconds during the entire study period. One rainfall event of 1 hour duration (t = 0 to 1 hour) was considered for the study. Uniform evaporative conditions (temperature = $25^{o}C$, relative humidity = 0.75) were assumed during the study period. The value of potential evaporation was obtained through Meyer's equation (for T = 25^{0} C, relative humidity = 0.75, and wind speed = 10 miles/hour) as 5.99 mm/day. Therefore, the maximum limit of evaporation from soil surface was imposed as the equivalent 0.025 cm/hour.

The upper boundary condition during the rain infiltration was defined as

$$\theta(0,t) = 0.286 \quad \text{for } z = 0, \quad t \geq 0$$

implying that a constant pressure head corresponding to θ = 0.286 (h = - 9.56 cm) was maintained at the soil surface during the rain infiltration. The lower boundary condition was defined as

$$\theta(z=L,\ t) = 0.286$$

The following assumptions were made in carrying out the study :

i) The water table was considered as static at the lower boundary of unsaturated zone.

ii) The soil cover was assumed to be homogeneous and isotropic.

iii) Soil air was regarded as a continuous phase, essentially at atmospheric pressure.

iv) The falling raindrops were assumed to be so small and numerous that rain may be treated as a continuous body of water reaching the soil surface at a certain rate.

v) K(h) and θ were assumed to be single-valued, non-decreasing functions of h.

vi) Thermal and osmotic gradients were assumed to be negligible.

It is evident that if the ground water table lies in the vicinity of the surface, evaporation will become preponderant. Thus the loss of water from the ground water space is increased with the decrease in the depth of the ground water table. Taking into account the evaporation losses from shallow water table, the net ground water recharge due to rainfall was estimated at the end of 36 hours for different water table depths (varying from 40 cm to 200 cm). The input data to the model and output are given in Appendix-II and Appendix-III respectively.

Table 1 presents the net ground water recharge values for different water table depths at the end of 36 hours. Figure 2 also illustrates the effect of water table depth. It can be observed that the net ground water recharge remains nearly constant for depths of ground water table greater than 80 cm. However, net ground water recharge reduces from 32.32 cm to 30.24 cm when water table depth is reduced from 80 cm to 60 cm. Further reduction of water table depth from 60 cm to 40 cm leads to an abrupt decrease in net ground water recharge from 30.24 cm to 17.80 cm. It can therefore be concluded that for the given soil type and boundary conditions, the water table depth shallower than 80 cm will result in decreased net ground water recharge due to rainfall.

It should be emphasized that the above results have not been subjected to empirical testing in the laboratory and in the field. Furthermore, the usefulness of the numerical model presented here is subject to several limitations as indicated below.

Table 1 : Net Ground Water Recharge for different Water Table Depths

S.No.	Water Table Depth (cm)	Net Ground Water Recharge (cm)
1	40	17.801960
2	44	22.702520
3	48	25.822610
4	52	27.913450
5	56	29.305690
6	60	30.242470
7	64	30.924960
8	68	31.460570
9	72	31.818490
10	76	32.130520
11	80	32.316100
12	100	32.921240
13	120	33.257160
14	140	33.492280
15	160	33.683810
16	180	33.830310
17	200	33.931660

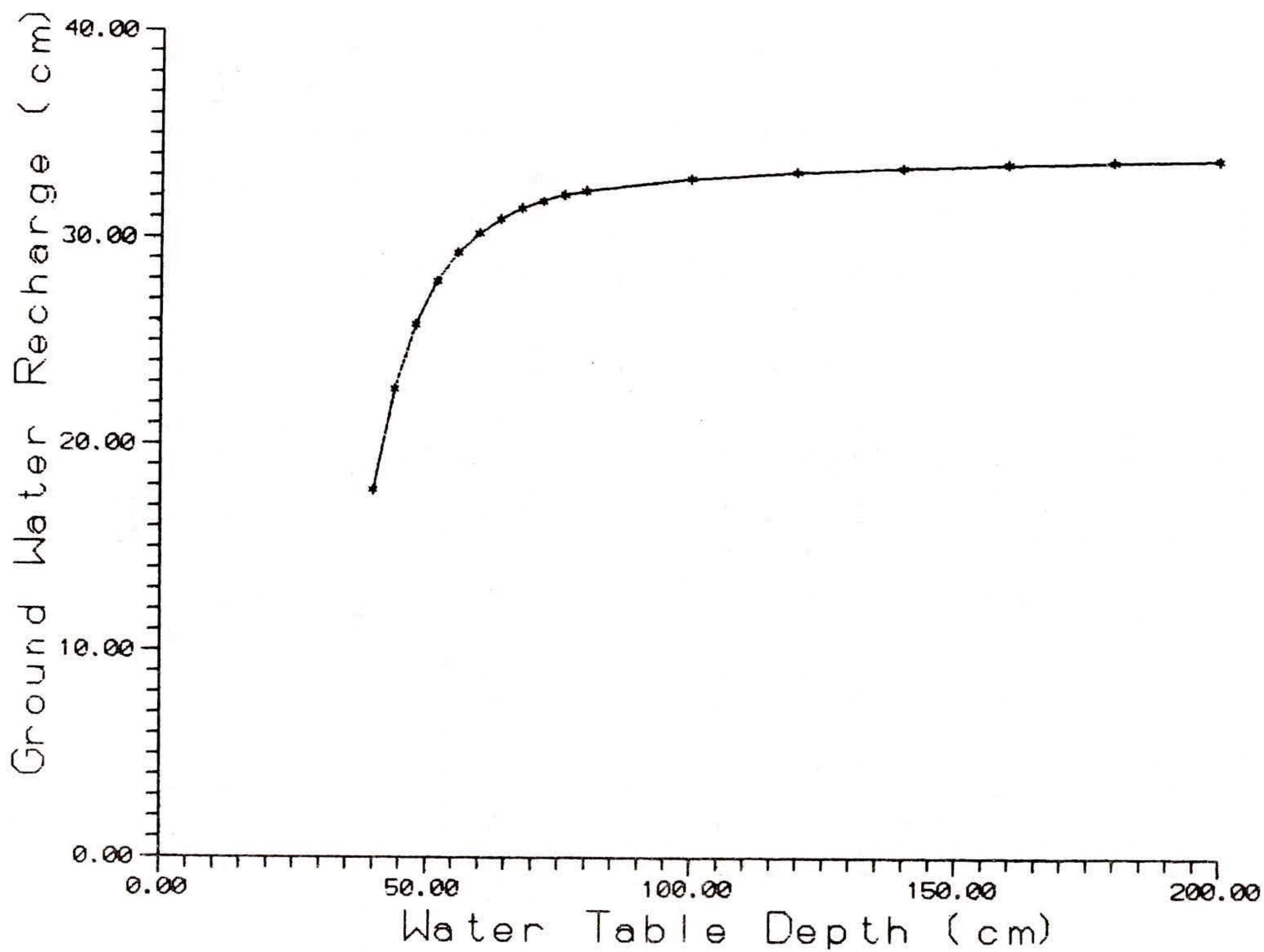

Figure 2 : Variation of Recharge with Depth of the Ground Water Table

(a) A static water table has been considered at the base. This water table condition is not realistic from the point of view of continuity of flow between the saturated and unsaturated domains for various reasons. The existence of a static water table (pressure head equal to zero at a fixed location) does not take into account the fact that the water table will fluctuate in position, and that it will do so in response to the distribution of flow in both the unsaturated and saturated zones. A stronger objection can be raised in reference to flux calculations that show the flux across the water table to vary rapidly with time and in response only to the unsaturated flow conditions. In actual fact, the regional ground water flow pattern to which the water table is the upper boundary is only capable of accepting a given amount of recharge and thus offers a constraint on the possible flux of water across the water table. A basal boundary condition in which the pressure head equals zero at a fixed location is actually a statement of the gravity drainage problem, and the results should be interpreted in that light.

(b) The theory of rainfall infiltration presented here is not applicable when the assumption about soil air with approximately constant atmospheric pressure is not fulfilled.

(c) The theory under consideration can not be used whenever the effects of hysteresis in soil moisture properties are significant. Such effects may be created by the discreteness of raindrops. They might also be associated with decreases in rain intensity during flux-controlled rainfall uptake or with diminution in surface pressure heads during rainpond infiltration.

(d) The theory in question is also inapplicable to a soil in which infiltration-induced fabric transformations change the parametric moisture properties. If merely known time-dependencies of K(h) and h(θ) were involved, perhaps it would not be too difficult to extend the current numerical methods so as to take such a dependence into account, at least approximately. However, usually information on such a dependence is unavailable. Furthermore, fabric transformations under consideration usually decrease K(h). Such a decrease creates difficulties that can not be overcome, because it generates hysteresis effects.

(e) Difficulties in utilizing the theory in question are created also by the commonly met heterogeneity of soil cover. It is thought that an application of the methods developed in connection with flood water infiltration to the rainfall uptake case would not be difficult. Much more formidable is the areal treatment of infiltration into a soil with properties varying in the horizontal directions. In such a case one section of the area influences the infiltration into another by affecting the runoff.

(f) Finally, certain practical limitations on the utilization of the rainfall infiltration theory are due to the inadequacy of field methods for determining the pertinent soil moisture parametric functions. However, in certain cases of interest, the existing laboratory techniques may provide the required information.

In spite of the limitations outlined above, it is thought that under many conditions, the method presented here is applicable to estimate the ground water recharge due to rainfall by incorporating the appropriate modifications in the initial and boundary conditions and to determine the influence of water table position.

6.0 CONCLUSIONS

Ground water recharge is that amount of water which reaches the water table by downward percolation through the overlying zone of aeration. It is this quantity which may in the long term be available for abstraction and which is therefore of prime importance in the assessment of any ground water resource. The natural phenomenon of rainfall recharge is very complex to study and analyse and any work on the estimation of recharge of aquifers by rainfall needs a clear understanding of the physical processes of the soil, vegetation and atmosphere systems. It depends upon the intensity and duration of rainfall, evaporative demand, soil moisture deficiency, soil moisture characteristics, depth of unsaturated zone etc. Given all these parameters, it is possible to estimate the ground water recharge due to rainfall.

A numerical model study has been carried out to examine the effect of water table depth on recharge due to rainfall. An implicit finite-differencing technique is used for a mathematical model of one-dimensional, vertical, unsteady, unsaturated flow above a water table. The solution is applicable to homogeneous, isotropic soils in which the functional relationships between hydraulic conductivity, moisture content, and soil moisture tension do not show hysteresis properties. The model has been applied for upper boundary condition of rain infiltration (equal to soil infiltrability) for a specified period. The ground water recharge due to rainfall has been estimated for different depths of ground water table to determine the influence of its position. It has been shown that for the given soil type and boundary conditions, the water table depth shallower than a certain limit leads to decreased net ground water recharge due to rainfall at the specified duration.

The model presented can furnish information useful in quantification of the rate of ground water recharge, for soils with known moisture parameters and rains of a given intensity pattern, by suitably modifying the initial and boundary conditions. However, the method is not utilizable when the soil exhibits significant air compression, parameter hysteresis, fabric transformations, or areal heterogeneity.

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```
C         EFFECT OF WATER TABLE DEPTH ON RECHARGE DUE TO RAINFALL
C
C         IMPLICIT SCHEME WITH IMPLICIT LINEARIZATION (PREDICTION - CORRECTION)
C         (MODEL 4 OF HAVERKAMP ET AL., 1977)
C
          DIMENSION SUB(100),SUP(100),DIAG(100),B(100)
          DIMENSION H(100,2),CCC(100,2)
          DIMENSION THETA(100,2),HYDCON(100,2)
          DIMENSION HP(100,2),THETAP(100,2)
          DIMENSION RR(2),RJOIN(2)
          OPEN(UNIT=1,FILE='EDEPTH.DAT',STATUS='OLD')
          OPEN(UNIT=2,FILE='EDEPTH.OUT',STATUS='NEW')
C
C         J REFERS TO TIME
C         I REFERS TO DEPTH
C         Z      = DEPTH (CM), ORIENTED POSITIVELY DOWNWARD
C         R      = UNIVERSAL GAS CONSTANT (ERGS/MOLE/K)
C         T      = ABSOLUTE TEMPERATURE (K)
C                  (READ IN CENTIGRADE AND CONVERTED IN K)
C         WM     = MOLECULAR WEIGHT OF WATER (GM/MOLE)
C         G      = ACCELERATION DUE TO GRAVITY (CM/SEC/SEC)
C         RH     = RELATIVE HUMIDITY OF THE AIR (FRACTION)
C         THETA  = VOLUMETRIC MOISTURE CONTENT (CUBIC CM / CUBIC CM)
C         H      = SOIL WATER PRESSURE (RELATIVE TO THE ATMOSPHERE)
C                  EXPRESSED IN CM OF WATER
C         THETAR = RESIDUAL MOISTURE CONTENT
C         THETAS = MOISTURE CONTENT AT SATURATION
C         THETAU = MOISTURE CONTENT AT THE SURFACE NODE DURING RAINFALL
C                  (PART OF UPPER BOUNDARY CONDITION)
C         BETA1, CONA  = PARAMETERS IN THE HYDRAULIC CONDUCTIVITY
C                        AND SOIL WATER PRESSURE RELATIONSHIP
C         BETA2, ALPHA = PARAMETERS IN THE MOISTURE CONTENT AND
C                        SOIL WATER PRESSURE RELATIONSHIP
C         HYDCON = HYDRAULIC CONDUCTIVITY OF THE SOIL (CM/HOUR)
C         AKS    = HYDRAULIC CONDUCTIVITY AT SATURATION (CM/HOUR)
C         DELT   = TIME STEP (HOURS)
C         DELZ   = DEPTH INTERVAL (CM)
C         NTIME  = NUMBER OF TIME STEPS
C         NNODE  = NUMBER OF NODES
C         CCC    = SPECIFIC WATER CAPACITY (/CM) DEFINED AS d(theta)/dh
C
C         STORM PERIOD = 0-LT1
C
          READ(1,11)THETAR,THETAS,THETAU
11        FORMAT(3F12.3)
          READ(1,12)BETA1,BETA2
12        FORMAT(2F12.3)
          READ(1,13)CONA,ALPHA
13        FORMAT(2F12.3)
          READ(1,14)AKS
14        FORMAT(F12.3)
```

```
      READ(1,15)DELT,DELZ
15    FORMAT(F12.8,F12.3)
      READ(1,16)NTIME,NNODE
16    FORMAT(I7,5X,I5)
      READ(1,61)LT1
61    FORMAT(I12)
      READ(1,62)T
62    FORMAT(F5.2)
      READ(1,63)RH
63    FORMAT(F5.2)
C
C     READING OF INITIAL CONDITIONS
C
      READ(1,17)(THETA(I,1),I=1,NNODE)
17    FORMAT(5F12.6)
C
      WRITE(2,18)
18    FORMAT('EFFECT OF WATER TABLE DEPTH ON RECHARGE DUE TO RAINFALL')
      WRITE(2,19)
19    FORMAT(/2X,'IMPLICIT SCHEME WITH IMPLICIT LINEARIZATION')
      WRITE(2,20)
20    FORMAT(2X,'(PREDICTION - CORRECTION)')
      DEPTH = (NNODE-1)*DELZ
      WRITE(2,64)
64    FORMAT(/2X,'WATER TABLE DEPTH')
      WRITE(2,65)DEPTH
65    FORMAT(2X,F7.3)
      WRITE(2,71)
71    FORMAT(/2X,'TEMPERATURE IN CENTIGRADE')
      WRITE(2,72)T
72    FORMAT(F7.2)
      WRITE(2,73)
73    FORMAT(2X,'RELATIVE HUMIDITY OF THE AIR')
      WRITE(2,74)RH
74    FORMAT(F7.3)
      WRITE(2,21)
21    FORMAT(/2X,'THETAR',9X,'THETAS',9X,'THETAU')
      WRITE(2,31)THETAR,THETAS,THETAU
31    FORMAT(2X,F5.3,10X,F5.3,10X,F5.3)
      WRITE(2,22)
22    FORMAT(2X,'BETA1',10X,'BETA2')
      WRITE(2,32)BETA1,BETA2
32    FORMAT(2X,F5.3,10X,F5.3)
      WRITE(2,23)
23    FORMAT(2X,'CONA',11X,'ALPHA')
      WRITE(2,33)CONA,ALPHA
33    FORMAT(2X,F11.3,4X,F11.3)
      WRITE(2,24)
24    FORMAT(2X,'AKS')
      WRITE(2,34)AKS
34    FORMAT(2X,F6.3)
      WRITE(2,25)
25    FORMAT(2X,'DELT',11X,'DELZ')
      WRITE(2,35)DELT,DELZ
35    FORMAT(2X,F10.8,5X,F6.3)
      WRITE(2,26)
26    FORMAT(2X,'NTIME',10X,'NNODE')
```

```
      WRITE(2,36)NTIME,NNODE
36    FORMAT(I7,10X,I5)
      WRITE(2,75)
75    FORMAT(2X,'STORM PERIOD')
      WRITE(2,76)LT1
76    FORMAT(I6)
      WRITE(2,27)
27    FORMAT(/2X,'SOIL MOISTURE AT DIFFERENT NODES')
      WRITE(2,28)
28    FORMAT(/2X,'INITIAL CONDITIONS'/)
      WRITE(2,38)(THETA(I,1),I=1,NNODE)
38    FORMAT(5F12.6)
C
      DO 100 I=1,NNODE
      H(I,1)=-(ALPHA*(THETAS-THETA(I,1))/(THETA(I,1)
     1       -THETAR))**(1./BETA2)
100   CONTINUE
C
C     GENERATION OF LOWER BOUNDARY CONDITION
C
      THETA(NNODE,2)=THETA(NNODE,1)
      THETAP(NNODE,1)=THETA(NNODE,1)
      THETAP(NNODE,2)=THETA(NNODE,1)
      H(NNODE,2)=H(NNODE,1)
      HP(NNODE,1)=H(NNODE,1)
      HP(NNODE,2)=H(NNODE,1)
C
      RAIN=0.0
      EVAP=0.0
      RR(1)=0.0
      RJOIN(1)=0.0
      R=8.314E+7
      WM=18.0
      G=980.665
      E1=BETA1/BETA2
      E2=(THETAS-THETAR)
      E3=ALPHA**E1
      E4=CONA*AKS
      E5=1./BETA2*ALPHA**(1./BETA2)
C
      DO 400 J=2,NTIME
C
C     GENERATION OF UPPER BOUNDARY CONDITION
C
      IF(J.LE.LT1)GO TO 300
      TMP=T+273.15
      HU=R*TMP*ALOG(RH)/(WM*G)
      HU=HU/1019.80
      H(1,1)=HU
      H(1,2)=HU
      HP(1,1)=HU
      HP(1,2)=HU
      THETA(1,1)=ALPHA*(THETAS-THETAR)/(ALPHA+
     1           ABS(H(1,1))**BETA2)+THETAR
      THETA(1,2)=THETA(1,1)
      THETAP(1,1)=THETA(1,1)
      THETAP(1,2)=THETA(1,1)
```

```
      GO TO 200
300   THETA(1,1)=THETAU
      THETA(1,2)=THETAU
      THETAP(1,1)=THETAU
      THETAP(1,2)=THETAU
      H(1,1)=-(ALPHA*(THETAS-THETA(1,1))/(THETA(1,1)
     1        -THETAR))**(1./BETA2)
      H(1,2)=H(1,1)
      HP(1,1)=H(1,1)
      HP(1,2)=H(1,1)
200   CONTINUE
C
      DO 500 I=1,NNODE
      HYDCON(I,1) = E4/(CONA+(ABS(H(I,1)))**BETA1)
      CCC(I,1)=1./(E5*E2)*(THETAS-THETA(I,1) )**(-1./BETA2+1.)*
     1          (THETA(I,1)-THETAR ) **(1./BETA2+1.)
500   CONTINUE
C
      DO 600 I=2,NNODE-1
      DIAG(I-1)=2.*CCC(I,1)/HYDCON(I,1)+2.*DELT/DELZ**2
      SUB(I-1)=-DELT/DELZ**2
      SUP(I-1)=-DELT/DELZ**2
      B(I-1)=2.*CCC(I,1)/HYDCON(I,1)*H(I,1)+DELT/DELZ*.5
     1       *(HYDCON(I+1,1)-HYDCON(I-1,1))/HYDCON(I,1)*((H(I+1,1)-
     2       H(I-1,1))/(2.*DELZ)-1.)
600   CONTINUE
C
      B(1)=B(1)-SUB(1)*H(1,2)
      B(NNODE-2)=B(NNODE-2)-SUP(NNODE-2)*H(NNODE,2)
      DO 700 I=1,NNODE-3
700   SUB(I)=SUB(I+1)
      M=NNODE-2
      CALL TRID(M,SUP,SUB,DIAG,B)
      DO 800 I=1,NNODE-2
800   HP(I+1,2)=B(I)
      DO 900 I=2,NNODE-1
      THETAP(I,2)=ALPHA*(THETAS-THETAR)/(ALPHA+ABS(HP(I,2))**
     1            BETA2)+THETAR
900   CONTINUE
C
      DO 1000 I=1,NNODE
      HYDCON(I,1) = E4/(CONA+(ABS(HP(I,2)))**BETA1)
      CCC(I,1)=1./(E5*E2)*(THETAS-THETAP(I,2) )**(-1./BETA2+1.)*
     1          (THETAP(I,2)-THETAR ) **(1./BETA2+1.)
1000  CONTINUE
C
      DO 1100 I=2,NNODE-1
      DIAG(I-1)=CCC(I,1)/HYDCON(I,1)+DELT/DELZ**2
      SUB(I-1)=-DELT/DELZ**2*.5
      SUP(I-1)=-DELT/DELZ**2*.5
      B(I-1)=CCC(I,1)/HYDCON(I,1)*H(I,1)+DELT/DELZ*.5
     1       *(HYDCON(I+1,1)-HYDCON(I-1,1))/HYDCON(I,1)*((HP(I+1,2)-
     2       HP(I-1,2))/(2.*DELZ)-1.)+DELT/DELZ**2*.5*(H(I+1,1)-2.*
     3       H(I,1)+H(I-1,1))
1100  CONTINUE
C
```

```
      B(1)=B(1)-SUB(1)*H(1,2)
      B(NNODE-2)=B(NNODE-2)-SUP(NNODE-2)*H(NNODE,2)
      DO 1200 I=1,NNODE-3
1200  SUB(I)=SUB(I+1)
      M=NNODE-2
      CALL TRID(M,SUP,SUB,DIAG,B)
      DO 1300 I=1,NNODE-2
1300  H(I+1,2)=B(I)
      DO 1400 I=2,NNODE-1
      THETA(I,2)=ALPHA*(THETAS-THETAR)/(ALPHA+ABS(H(I,2))**BETA2)+
     1           THETAR
1400  CONTINUE
C
      DO 1500 I = 1, NNODE
      HYDCON(I,2) = E4/(CONA+(ABS(H(I,2)))**BETA1)
1500  CONTINUE
C
      RJOIN(2)=-((HYDCON(NNODE-1,2)*HYDCON(NNODE,2))**0.5)*
     1          (((H(NNODE,2)-H(NNODE-1,2))/DELZ)-1.0)*DELT
      RR(2)=RR(1)+RJOIN(2)
      IF(RJOIN(1).GT.0.0.AND.RJOIN(2).LE.0.0)JRECH=J
      RINPUT=-((HYDCON(1,2)*HYDCON(2,2))**0.5)*
     1        (((H(2,2)-H(1,2))/DELZ)-1.0)*DELT
      IF(RINPUT.LE.0.0)GO TO 97
      IF(RINPUT.GT.0.0)GO TO 98
97    EFACT=RINPUT+0.025*DELT
      IF(EFACT.GT.0.0)EVAP=EVAP+ABS(RINPUT)
      IF(EFACT.LE.0.0)EVAP=EVAP+0.025*DELT
      GO TO 99
98    RAIN=RAIN+RINPUT
99    CONTINUE
C
      IF (J.EQ.2)     GO TO 111
      IF (J.EQ.1201)  GO TO 111
      IF (J.EQ.2401)  GO TO 111
      IF (J.EQ.3601)  GO TO 111
      IF (J.EQ.4801)  GO TO 111
      IF (J.EQ.6001)  GO TO 111
      IF (J.EQ.7201)  GO TO 111
      IF (J.EQ.8401)  GO TO 111
      IF (J.EQ.9601)  GO TO 111
      IF (J.EQ.10801) GO TO 111
      IF (J.EQ.12001) GO TO 111
      IF (J.EQ.13201) GO TO 111
      IF (J.EQ.14401) GO TO 111
      IF (J.EQ.15601) GO TO 111
      IF (J.EQ.16801) GO TO 111
      IF (J.EQ.18001) GO TO 111
      IF (J.EQ.19201) GO TO 111
      IF (J.EQ.20401) GO TO 111
      IF (J.EQ.21601) GO TO 111
      IF (J.EQ.22801) GO TO 111
      IF (J.EQ.24001) GO TO 111
      IF (J.EQ.25201) GO TO 111
      IF (J.EQ.26401) GO TO 111
      IF (J.EQ.27601) GO TO 111
      IF (J.EQ.28801) GO TO 111
```

```
      IF (J.EQ.30001) GO TO 111
      IF (J.EQ.31201) GO TO 111
      IF (J.EQ.32401) GO TO 111
      IF (J.EQ.33601) GO TO 111
      IF (J.EQ.34801) GO TO 111
      IF (J.EQ.36001) GO TO 111
      IF (J.EQ.37201) GO TO 111
      IF (J.EQ.38401) GO TO 111
      IF (J.EQ.39601) GO TO 111
      IF (J.EQ.40801) GO TO 111
      IF (J.EQ.42001) GO TO 111
      IF (J.EQ.43201) GO TO 111
      IF (J.EQ.JRECH) GO TO 111
      GO TO 222
111   CONTINUE
      ITIME=J-1
      HOUR=ITIME*DELT
      WRITE(2,81)ITIME,HOUR
81    FORMAT(/2X,'TIME STEP  =',I7,6X,'DURATION  = ',F10.4,1X,'HOURS'/)
      WRITE(2,82)(THETA(I,2),I=1,NNODE)
82    FORMAT(5F12.6)
      WRITE(2,83)RAIN
83    FORMAT(/2X,'CUMULATIVE INFILTRATION            = ',F12.6,2X,'CM')
      WRITE(2,84)EVAP
84    FORMAT(2X,'CUMULATIVE EVAPORATION              = ',F12.6,2X,'CM')
      WRITE(2,85)RR(2)
85    FORMAT(2X,'CUMULATIVE RECHARGE                 = ',F12.6,2X,'CM')
222   CONTINUE
C
      DO 333 I = 2, NNODE-1
      THETA(I,1)=THETA(I,2)
      H(I,1)=H(I,2)
333   CONTINUE
      RR(1)=RR(2)
      RJOIN(1)=RJOIN(2)
C
400   CONTINUE
      STOP
      END
C
      SUBROUTINE TRID(M,SUP,SUB,DIAG,B)
      DIMENSION SUP(100),SUB(100),DIAG(100),B(100)
      N=M
      NN=N-1
      SUP(1)=SUP(1)/DIAG(1)
      B(1)=B(1)/DIAG(1)
      DO 51 I=2,N
      II=I-1
      DIAG(I)=DIAG(I)-SUP(II)*SUB(II)
      IF (I.EQ.N) GO TO 51
      SUP(I)=SUP(I)/DIAG(I)
51    B(I)=(B(I)-SUB(II)*B(II))/DIAG(I)
      DO 52 K=1,NN
      I=N-K
52    B(I)=B(I)-SUP(I)*B(I+1)
      RETURN
      END
```

EDEPTH.DAT

```
0.075          0.287          0.286
4.740          3.960
1175000.000 1611000.000
34.000
0.00083333  4.000
43201          36
1201
25.00
00.75
0.100000    0.100000    0.100000    0.100000    0.100000
0.100000    0.100000    0.100000    0.100000    0.100000
0.100000    0.100000    0.100000    0.100000    0.100000
0.100000    0.100000    0.100000    0.100000    0.100000
0.100000    0.100000    0.100000    0.106202    0.114577
0.125431    0.139324    0.156679    0.177478    0.200872
0.224933    0.246971    0.264515    0.276398    0.283064
0.286000
```

EFFECT OF WATER TABLE DEPTH ON RECHARGE DUE TO RAINFALL

IMPLICIT SCHEME WITH IMPLICIT LINEARIZATION
(PREDICTION - CORRECTION)

WATER TABLE DEPTH
140.000

TEMPERATURE IN CENTIGRADE
25.00
RELATIVE HUMIDITY OF THE AIR
.750

THETAR	THETAS	THETAU
.075	.287	.286
BETA1	BETA2	
4.740	3.960	
CONA	ALPHA	
1175000.000	1611000.000	
AKS		
34.000		
DELT	DELZ	
.00083333	4.000	
NTIME	NNODE	
43201	36	
STORM PERIOD		
1201		

SOIL MOISTURE AT DIFFERENT NODES

INITIAL CONDITIONS

.100000	.100000	.100000	.100000	.100000
.100000	.100000	.100000	.100000	.100000
.100000	.100000	.100000	.100000	.100000
.100000	.100000	.100000	.100000	.100000
.100000	.100000	.100000	.106202	.114577
.125431	.139324	.156679	.177478	.200872
.224933	.246971	.264515	.276398	.283064
.286000				

TIME STEP = 1 DURATION = .0008 HOURS

.286000	.120462	.100068	.100000	.100000
.100000	.100000	.100000	.100000	.100000
.100000	.100000	.100000	.100000	.100000
.100000	.100000	.100000	.100000	.100000
.100000	.100000	.100024	.106203	.114577
.125431	.139324	.156679	.177478	.200872
.224933	.246971	.264515	.276398	.283065
.286000				

CUMULATIVE INFILTRATION = .030399 CM
CUMULATIVE EVAPORATION = .000000. CM
CUMULATIVE RECHARGE = .000000 CM

```
TIME STEP  =   1200     DURATION  =    1.0000 HOURS

   .286000      .286000      .286000      .286000      .286000
   .286000      .286000      .286000      .286000      .286000
   .286000      .286000      .286000      .286000      .286000
   .286000      .286000      .286000      .286000      .286000
   .286000      .286000      .286000      .286000      .286000
   .286000      .286000      .286000      .286000      .286000
   .286000      .286000      .286000      .286000      .286000
   .286000

CUMULATIVE INFILTRATION          =    35.190450  CM
CUMULATIVE EVAPORATION           =      .000000  CM
CUMULATIVE RECHARGE              =    14.336430  CM

TIME STEP  =   2400     DURATION  =    2.0000 HOURS

   .075018      .084789      .101234      .117274      .131492
   .143689      .154059      .162889      .170456      .176995
   .182695      .187707      .192149      .196115      .199682
   .202910      .205848      .208537      .211013      .213307
   .215448      .217467      .219404      .221311      .223271
   .225416      .227966      .231271      .235839      .242252
   .250820      .260946      .270879      .278701      .283603
   .286000

CUMULATIVE INFILTRATION          =    35.190450  CM
CUMULATIVE EVAPORATION           =      .025000  CM
CUMULATIVE RECHARGE              =    24.571050  CM

TIME STEP  =   3600     DURATION  =    3.0000 HOURS

   .075018      .079686      .087832      .096751      .105747
   .114444      .122637      .130230      .137204      .143577
   .149392      .154698      .159547      .163989      .168068
   .171826      .175300      .178525      .181534      .184359
   .187037      .189614      .192153      .194750      .197556
   .200813      .204898      .210367      .217923      .228181
   .241077      .255212      .268101      .277654      .283350
   .286000

CUMULATIVE INFILTRATION          =    35.190450  CM
CUMULATIVE EVAPORATION           =      .049999  CM
CUMULATIVE RECHARGE              =    27.327350  CM

TIME STEP  =   4800     DURATION  =    4.0000 HOURS

   .075018      .077902      .082927      .088644      .094719
   .100936      .107132      .113183      .119010      .124561
   .129814      .134759      .139403      .143758      .147839
   .151668      .155265      .158655      .161864      .164925
   .167879      .170786      .173734      .176860      .180377
   .184617      .190073      .197414      .207391      .220464
   .236151      .252537      .266887      .277217      .283249
   .286000

CUMULATIVE INFILTRATION          =    35.190450  CM
CUMULATIVE EVAPORATION           =      .074997  CM
CUMULATIVE RECHARGE              =    28.920420  CM
```

TIME STEP = 6000 DURATION = 5.0000 HOURS

.075018	.077022	.080475	.084469	.088824
.093422	.098159	.102945	.107707	.112386
.116939	.121338	.125566	.129614	.133480
.137169	.140692	.144063	.147304	.150450
.153546	.156667	.159924	.163490	.167634
.172758	.179432	.188382	.200324	.215525
.233152	.250979	.266202	.276976	.283194
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .099536 CM
CUMULATIVE RECHARGE = 29.984540 CM

TIME STEP = 7200 DURATION = 6.0000 HOURS

.075018	.076509	.079043	.081998	.085264
.088776	.092471	.096291	.100180	.104089
.107977	.111813	.115572	.119237	.122798
.126251	.129600	.132855	.136037	.139181
.142341	.145605	.149106	.153052	.157754
.163668	.171415	.181736	.195277	.212115
.231150	.249968	.265767	.276825	.283160
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .119976 CM
CUMULATIVE RECHARGE = 30.745530 CM

TIME STEP = 8400 DURATION = 7.0000 HOURS

.075018	.076179	.078124	.080399	.082935
.085692	.088634	.091723	.094920	.098190
.101498	.104817	.108123	.111397	.114628
.117808	.120938	.124030	.127103	.130197
.133375	.136737	.140438	.144714	.149913
.156528	.165211	.176691	.191535	.209650
.229737	.249268	.265469	.276722	.283137
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .136790 CM
CUMULATIVE RECHARGE = 31.311970 CM

TIME STEP = 9600 DURATION = 8.0000 HOURS

.075018	.075953	.077494	.079300	.081322
.083537	.085923	.088456	.091109	.093858
.096678	.099546	.102442	.105350	.108258
.111162	.114062	.116971	.119913	.122933
.126102	.129534	.133403	.137968	.143606
.150839	.160329	.172786	.188692	.207813
.228703	.248763	.265257	.276649	.283120
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .150984 CM
CUMULATIVE RECHARGE = 31.744820 CM

TIME STEP = 10800 DURATION = 9.0000 HOURS

.075018	.075789	.077042	.078510	.080158
.081971	.083937	.086041	.088266	.090594
.093009	.095492	.098028	.100607	.103218
.105860	.108537	.111263	.114069	.117004
.120151	.123635	.127646	.132465	.138491
.146262	.156445	.169721	.186494	.206415
.227925	.248387	.265099	.276596	.283108
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .163194 CM
CUMULATIVE RECHARGE = 32.081740 CM

TIME STEP = 12000 DURATION = 10.0000 HOURS

.075018	.075666	.076705	.077921	.079288
.080797	.082440	.084210	.086094	.088082
.090161	.092320	.094549	.096838	.099184
.101587	.104055	.106609	.109283	.112134
.115253	.118777	.122912	.127954	.134318
.142557	.153331	.167290	.184772	.205332
.227330	.248101	.264981	.276555	.283099
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .173855 CM
CUMULATIVE RECHARGE = 32.347640 CM

TIME STEP = 13200 DURATION = 11.0000 HOURS

.075018	.075572	.076447	.077470	.078621
.079894	.081286	.082790	.084402	.086113
.087916	.089803	.091769	.093808	.095921
.098112	.100394	.102791	.105343	.108114
.111205	.114763	.119006	.124243	.130903
.139543	.150818	.165346	.183409	.204483
.226867	.247880	.264889	.276524	.283093
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .183272 CM
CUMULATIVE RECHARGE = 32.559710 CM

TIME STEP = 14400 DURATION = 12.0000 HOURS

.075018	.075497	.076245	.077117	.078099
.079186	.080377	.081670	.083061	.084546
.086120	.087780	.089524	.091350	.093261
.095267	.097384	.099641	.102084	.104785
.107849	.111437	.115775	.121183	.128099
.137082	.148780	.163783	.182321	.203810
.226502	.247707	.264818	.276500	.283087
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .191671 CM
CUMULATIVE RECHARGE = 32.730220 CM

TIME STEP = 15600 DURATION = 12.9999 HOURS

.075018	.075437	.076083	.076836	.077682
.078621	.079651	.080773	.081984	.083283
.084668	.086138	.087694	.089339	.091078
.092923	.094897	.097032	.099380	.102019
.105062	.108676	.113097	.118654	.125790
.135067	.147122	.162519	.181447	.203273
.226213	.247571	.264761	.276481	.283083
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .199223 CM
CUMULATIVE RECHARGE = 32.868180 CM

TIME STEP = 16800 DURATION = 13.9999 HOURS

.075018	.075389	.075952	.076608	.077345
.078163	.079063	.080044	.081108	.082253
.083481	.084793	.086191	.087682	.089273
.090982	.092833	.094864	.097131	.099717
.102742	.106380	.110874	.116560	.123885
.133412	.145766	.161492	.180741	.202842
.225981	.247461	.264716	.276466	.283080
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .206062 CM
CUMULATIVE RECHARGE = 32.980500 CM

TIME STEP = 18000 DURATION = 14.9999 HOURS

.075018	.075348	.075845	.076421	.077069
.077789	.078581	.079447	.080388	.081406
.082503	.083682	.084948	.086308	.087775
.089368	.091114	.093055	.095253	.097795
.100807	.104468	.109027	.114825	.122314
.132051	.144656	.160654	.180167	.202493
.225794	.247373	.264680	.276454	.283077
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .212294 CM
CUMULATIVE RECHARGE = 33.072320 CM

TIME STEP = 19200 DURATION = 15.9999 HOURS

.075018	.075315	.075756	.076267	.076841
.077479	.078182	.078952	.079792	.080704
.081691	.082759	.083913	.085163	.086525
.088019	.089677	.091544	.093684	.096190
.099192	.102874	.107490	.113385	.121012
.130928	.143744	.159967	.179699	.202208
.225642	.247302	.264651	.276444	.283075
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .218005 CM
CUMULATIVE RECHARGE = 33.147660 CM

TIME STEP = 20400 DURATION = 16.9999 HOURS

.075018	.075286	.075681	.076137	.076650
.077220	.077849	.078540	.079295	.080118
.081013	.081987	.083047	.084206	.085479
.086890	.088474	.090278	.092370	.094847
.097842	.101543	.106208	.112187	.119932
.129999	.142991	.159403	.179316	.201976
.225519	.247244	.264627	.276436	.283073
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .223265 CM
CUMULATIVE RECHARGE = 33.209720 CM

TIME STEP = 21600 DURATION = 17.9999 HOURS

.075018	.075262	.075618	.076029	.076490
.077003	.077570	.078194	.078878	.079626
.080444	.081339	.082320	.083401	.084599
.085941	.087463	.089215	.091267	.093720
.096711	.100431	.105140	.111189	.119034
.129229	.142370	.158940	.179001	.201786
.225417	.247197	.264608	.276429	.283071
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .228133 CM
CUMULATIVE RECHARGE = 33.260830 CM

TIME STEP = 22800 DURATION = 18.9999 HOURS

.075018	.075242	.075565	.075937	.076355
.076820	.077334	.077902	.078526	.079212
.079965	.080793	.081708	.082723	.083859
.085143	.086612	.088320	.090341	.092775
.095763	.099498	.104246	.110358	.118289
.128591	.141856	.158556	.178742	.201630
.225335	.247158	.264592	.276424	.283070
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .232660 CM
CUMULATIVE RECHARGE = 33.303290 CM

TIME STEP = 24000 DURATION = 19.9999 HOURS

.075018	.075224	.075519	.075859	.076240
.076664	.077135	.077655	.078228	.078861
.079559	.080332	.081191	.082151	.083234
.084469	.085895	.087568	.089562	.091981
.094968	.098719	.103499	.109663	.117666
.128059	.141428	.158237	.178527	.201501
.225266	.247126	.264579	.276419	.283069
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .236888 CM
CUMULATIVE RECHARGE = 33.338070 CM

TIME STEP = 25200 DURATION = 20.9999 HOURS

.075018	.075209	.075480	.075792	.076142
.076532	.076965	.077444	.077975	.078563
.079215	.079941	.080752	.081667	.082706
.083900	.085290	.086933	.088905	.091312
.094299	.098063	.102873	.109083	.117148
.127617	.141073	.157974	.178349	.201394
.225209	.247100	.264568	.276416	.283069
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .240853 CM
CUMULATIVE RECHARGE = 33.367150 CM

TIME STEP = 26400 DURATION = 21.9999 HOURS

.075018	.075196	.075447	.075735	.076058
.076419	.076820	.077265	.077760	.078310
.078923	.079609	.080380	.081256	.082258
.083418	.084778	.086396	.088350	.090748
.093736	.097512	.102347	.108595	.116712
.127246	.140776	.157754	.178200	.201304
.225162	.247078	.264559	.276413	.283068
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .244588 CM
CUMULATIVE RECHARGE = 33.391180 CM

TIME STEP = 27600 DURATION = 22.9999 HOURS

.075018	.075185	.075418	.075686	.075986
.076322	.076696	.077112	.077576	.078094
.078674	.079326	.080064	.080907	.081878
.083009	.084345	.085943	.087882	.090273
.093262	.097049	.101905	.108185	.116347
.126935	.140527	.157568	.178076	.201230
.225123	.247059	.264551	.276410	.283067
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .248121 CM
CUMULATIVE RECHARGE = 33.410940 CM

TIME STEP = 28800 DURATION = 23.9999 HOURS

.075018	.075176	.075393	.075644	.075925
.076239	.076590	.076982	.077419	.077910
.078461	.079085	.079795	.080610	.081555
.082663	.083978	.085559	.087487	.089873
.092863	.096660	.101534	.107843	.116043
.126677	.140321	.157416	.177974	.201169
.225090	.247044	.264545	.276408	.283067
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .251477 CM
CUMULATIVE RECHARGE = 33.427590 CM

TIME STEP = 30000 DURATION = 24.9999 HOURS

.075018	.075167	.075372	.075607	.075872
.076168	.076499	.076870	.077285	.077752
.078280	.078880	.079566	.080358	.081281
.082369	.083666	.085234	.087152	.089533
.092525	.096331	.101222	.107555	.115786
.126459	.140146	.157287	.177887	.201117
.225063	.247031	.264540	.276406	.283066
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .254676 CM
CUMULATIVE RECHARGE = 33.441320 CM

TIME STEP = 31200 DURATION = 25.9999 HOURS

.075018	.075160	.075354	.075576	.075827
.076107	.076421	.076774	.077170	.077617
.078125	.078704	.079371	.080143	.081048
.082119	.083402	.084958	.086869	.089246
.092240	.096053	.100958	.107312	.115570
.126275	.140000	.157180	.177814	.201074
.225040	.247021	.264536	.276405	.283066
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .257737 CM
CUMULATIVE RECHARGE = 33.452240 CM

TIME STEP = 32400 DURATION = 26.9999 HOURS

.075018	.075154	.075338	.075549	.075787
.076055	.076354	.076691	.077072	.077502
.077993	.078555	.079204	.079960	.080849
.081906	.083177	.084723	.086628	.089002
.091998	.095818	.100734	.107105	.115386
.126120	.139877	.157089	.177755	.201038
.225021	.247012	.264532	.276404	.283066
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .260679 CM
CUMULATIVE RECHARGE = 33.461390 CM

TIME STEP = 33600 DURATION = 27.9999 HOURS

.075018	.075148	.075324	.075526	.075754
.076009	.076297	.076621	.076987	.077404
.077880	.078427	.079062	.079804	.080680
.081725	.082986	.084524	.086424	.088796
.091792	.095618	.100544	.106930	.115231
.125988	.139771	.157011	.177702	.201007
.225005	.247004	.264529	.276403	.283066
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .263516 CM
CUMULATIVE RECHARGE = 33.470430 CM

TIME STEP = 34800 DURATION = 28.9999 HOURS

.075018	.075143	.075313	.075506	.075725
.075971	.076248	.076560	.076915	.077319
.077783	.078318	.078940	.079671	.080536
.081571	.082824	.084355	.086250	.088621
.091618	.095449	.100384	.106782	.115099
.125878	.139683	.156945	.177658	.200980
.224991	.246998	.264526	.276402	.283065
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .266263 CM
CUMULATIVE RECHARGE = 33.475010 CM

TIME STEP = 36000 DURATION = 29.9999 HOURS

.075018	.075139	.075302	.075489	.075700
.075937	.076205	.076508	.076853	.077247
.077700	.078224	.078836	.079557	.080413
.081440	.082685	.084211	.086103	.088472
.091471	.095306	.100249	.106659	.114991
.125786	.139611	.156893	.177623	.200959
.224980	.246993	.264524	.276401	.283065
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .268930 CM
CUMULATIVE RECHARGE = 33.479580 CM

TIME STEP = 37200 DURATION = 30.9999 HOURS

.075018	.075136	.075294	.075474	.075679
.075909	.076169	.076464	.076800	.077185
.077629	.078144	.078747	.079460	.080308
.081328	.082567	.084089	.085978	.088346
.091346	.095185	.100135	.106554	.114898
.125709	.139550	.156848	.177594	.200942
.224971	.246988	.264523	.276401	.283065
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .271525 CM
CUMULATIVE RECHARGE = 33.484160 CM

TIME STEP = 38400 DURATION = 31.9999 HOURS

.075018	.075133	.075286	.075462	.075660
.075884	.076137	.076425	.076754	.077132
.077568	.078076	.078672	.079377	.080218
.081232	.082467	.083985	.085871	.088238
.091240	.095082	.100037	.106464	.114819
.125642	.139497	.156810	.177568	.200927
.224963	.246985	.264521	.276400	.283065
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .274060 CM
CUMULATIVE RECHARGE = 33.488740 CM

TIME STEP = 39600 DURATION = 32.9999 HOURS

.075018	.075130	.075280	.075451	.075644
.075863	.076111	.076393	.076715	.077086
.077516	.078017	.078607	.079306	.080142
.081151	.082381	.083896	.085780	.088146
.091149	.094994	.099954	.106388	.114751
.125585	.139451	.156776	.177546	.200914
.224956	.246982	.264520	.276400	.283065
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .276544 CM
CUMULATIVE RECHARGE = 33.492280 CM

TIME STEP = 40800 DURATION = 33.9999 HOURS

.075018	.075128	.075274	.075441	.075631
.075845	.076088	.076364	.076682	.077047
.077472	.077967	.078552	.079245	.080076
.081081	.082308	.083820	.085703	.088069
.091073	.094920	.099885	.106325	.114697
.125539	.139415	.156750	.177529	.200904
.224951	.246979	.264519	.276399	.283065
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .278983 CM
CUMULATIVE RECHARGE = 33.492280 CM

TIME STEP = 42000 DURATION = 34.9999 HOURS

.075018	.075126	.075269	.075433	.075619
.075829	.076068	.076340	.076653	.077014
.077433	.077925	.078504	.079194	.080021
.081022	.082246	.083756	.085637	.088003
.091009	.094858	.099826	.106271	.114649
.125498	.139383	.156726	.177513	.200894
.224946	.246977	.264518	.276399	.283065
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .281382 CM
CUMULATIVE RECHARGE = 33.492280 CM

TIME STEP = 43200 DURATION = 35.9999 HOURS

.075018	.075124	.075265	.075427	.075609
.075816	.076051	.076320	.076628	.076985
.077401	.077888	.078464	.079149	.079973
.080972	.082193	.083701	.085581	.087947
.090953	.094804	.099775	.106224	.114608
.125464	.139356	.156706	.177499	.200886
.224942	.246975	.264517	.276399	.283065
.286000				

CUMULATIVE INFILTRATION = 35.190450 CM
CUMULATIVE EVAPORATION = .283745 CM
CUMULATIVE RECHARGE = 33.492280 CM

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