# SOIL MOISTURE RETENTION CHARACTERISTICS AT RD 838 OF I. G. N. P. STAGE - II

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**ABSTRACT**

Mathematical models of hydrologic and agricultural systems require knowledge of the relationships between soil moisture content (θ), soil water pressure (h) and unsaturated hydraulic conductivity (K). Hence, a sustained research effort towards the parameterisation of K(h) and h(θ) has resulted in the development of several laboratory, field and theoretical methods.This paper presents the soil moisture retention characteristics at RD 838 of Indira Gandhi Nahar Priyojana, Stage - II. A total of 15 soil samples were collected from 4 locations at different depths. Extensive laboratory measurements were made for each soil sample collected. Soil bulk density, particle density and porosity were measured for each soil sample. Saturated hydraulic conductivity was measured through Permeameter. Retention data was obtained through pressure plate apparatus. Parameters of water retention function of the van Genuchten model were determined through non-linear regression analysis.

## INTRODUCTION

The water movements in the unsaturated zone, together with the water holding capacity of this zone, are very important for the water demand of the vegetation, as well as for the recharge of the ground water storage. A fair description of the flow in the unsaturated zone is crucial for predictions of the movement of pollutants into ground water aquifers.

For analytical studies on soil moisture regime, critical review and accurate assessment of the different controlling factors is necessary. The controlling factors of soil moisture may be classified under two main groups viz. climatic factors and soil factors. Climatic factors include precipitation data containing rainfall intensity, storm duration, interstorm period, temperature of soil surface, relative humidity, radiation, evaporation, and evapotranspiration. The soil factors include soil matric potential and water content

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relationship, hydraulic conductivity and water content relationship of the soil, saturated hydraulic conductivity, and effective medium porosity. Besides these factors, the information about depth to water table is also required.

The general soil physical properties are those which govern the transport and storage of energy, momentum and mass. In many cases, soil water properties govern gas, solute and heat transport in the soil. Fundamental soil water properties include volumetric water content, soil water flux density, soil water potential and hydraulic conductivity while derived properties are the soil water diffusivity, sorptivity and macroscopic capillary length.

The relation between matric potential and volumetric water content in a soil is termed as the soil moisture characteristic curve because the curve is characteristic of each soil. The differences among soil moisture characteristic curves are attributed primarily to the differences in pore size distribution among soils. These curves are sensitive to the changes in bulk densities and disturbances of soil structures. In addition, the curves generally show hysteresis according to the wetting or drying of soils.

In the present study, field and laboratory investigations have been carried out to determine the soil moisture retention characteristics at RD 838 of Indira Gandhi Nahar Priyojana, Stage - II. A total of 15 soil samples were collected from 4 locations at different depths. Extensive laboratory measurements were made for each soil sample collected. Soil bulk density, particle density and porosity were measured for each soil sample. Saturated hydraulic conductivity was measured through Permeameter. Average values for each soil parameter were computed. Retention data was obtained through pressure plate apparatus. Parameters of water retention function of the van Genuchten model were determined through non-linear regression analysis.

**STUDY AREA**

The Indira Gandhi Nahar Pariyojana (IGNP) with a command area of 1.543 million hectare is the largest irrigation and drinking water project in the north western Rajasthan. The main canal gets water from the river Sutlej in Punjab through a feeder canal. The project was taken up in two stages, the first stage has already been completed and the second stage is under execution. The Stage II area of IGNP starts from Pugal and comprises main canal from 620 RD to 1458 RD.

The climate of the region is arid with an average rainfall of about 200-250 mm. The temperature ranges from freezing point in winter to above $50^{o}$ C in summer. The area covered by IGNP is comprised of sandy undulating plains with various types of low to medium sand dunes. The sand cover varies from few centimetres to 200 meters in thickness. The top aeolian soils have high permeability but the underlying sediments, comprising of sand silty clay and kankar, have low permeability.

Prior to the introduction of the canal irrigation, only rainfed agriculture was being practised. But the introduction of the canal irrigation has changed the agricultural practices. Ground water was also not generally available before the introduction of this canal system. Where present, it was deep and saline barring to a few sweet water locations along buried channels. After the introduction of the canal system, the ground water is reported to be rising. The main cause of water table rise in IGNP Stage-II command is the presence of hard pan at shallow depths. This pan restricts the downward movement of the ground water resulting in the formation of perched water table.

The study area selected for the present study (figure 1) falls in the Survey of India toposheet no. 44 D/12 and lies near RD 838 on the left bank of the main canal, at a distance of about 130 km from Bikaner. The study area is located near Bajju town (30 km) and has an area of about 105 hectares. Out of the total area, about 95% is the cropped area and rest is either barren or has standing water. The topography of the area is slightly undulating and generally sloping towards the canal.

The water is applied to the field through flood irrigation method. The water is distributed to the farmers on warabandi at the outlet. The main crops grown in the area are wheat, gram, groundnut, cotton and vegetables. As in most of the Western Rajasthan , top soils of the study area are well sorted dune sands. There is a less permeable layer (hydrological barrier) at a depth of 2 to 4 meters, consisting of fine sand mixed with little clay and kanker, which restricts the percolation of water to deeper zones.

## SOIL MOISTURE RETENTION CHARACTERISTICS

The graph giving the relation between soil moisture tension and soil moisture content is called moisture retention curve or soil moisture characteristic. If the tension is expressed as the logarithmic value of cm water, the graph is referred to as a pF-curve. Moisture retention curves are used:

(a) to determine an index of the available moisture in soil (the portion of water that can be readily absorbed by plant roots) and to classify soils accordingly, e.g. for irrigation purposes,

(b) to determine the drainable pore space (effective pore space, effective porosity, specific yield) for drainage design,

(c) to check changes in the structure of a soil, e.g. caused by tillage, mixing of soil layers etc.,

(d) to ascertain the relation between soil moisture tension and other physical properties of a soil (e.g. capillary conductivity, thermal conductivity, clay and organic matter content).

To construct the moisture retention curve of a soil sample, the moisture content of that sample must be measured. This is done by equilibrating the moist soil sample at a succession of known pF values and each time determining the amount of moisture that is retained. If the equilibrium moisture content (expressed preferably as volume percentage) is plotted against the corresponding tension (pF), the moisture retention curve (pF-curve) can be drawn. There is no single method of inducing the whole range of tensions from pF = $-\infty$ (total saturation) to pF = 7 (oven dry).

The ceramic plates equipment is suitable for determination of pF-curves in the pF range of 2.0-4.2 (0.1-15 bar of suction). Soil moisture is removed from the soil samples by raising air pressure in an extractor. A porous ceramic plate serves as a hydraulic link for water to move from the soil to the exterior of the extractor. The high-pressure air will not flow through the pores in the plate since the pores are filled with water. The smaller the pore size, the higher the pressure that can be exerted before air will pass through. During an experimental run, at any set pressure in the extractor, soil moisture will flow around each of the soil particles and out through the ceramic plate and outflow tube. Equilibrium is reached when water flow from the outflow tube ceases. At equilibrium, there is an exact relationship between the air pressure in the extractor and the soil suction (and hence the moisture content) in the samples. Accuracy of equilibrium values will be no more accurate than the regulation of air supply; therefore the pressure control panel has independent double regulators.

For each soil type, the characteristic pF-curve may be developed. These curves relate the soil suction to its moisture content. This relationship is important in studies of soil moisture movement and quantity and availability of soil moisture for plant growth. The moisture retention curves can be developed for different soil types with this type of equipment. These “moisture characteristic” curves for each soil are extremely important in soils research and development of practical, effective irrigation practices.

## ANALYSIS AND RESULTS

To model the retention and movement of water and chemicals in the unsaturated zone, it is necessary to know the relationships between soil water pressure (h), water content ($\theta$) and hydraulic conductivity (K). It is often convenient to represent these functions by means of relatively simple parametric expressions. The problem of characterizing the soil hydraulic properties then reduces to estimating parameters of the appropriate constitutive model.

The measurements of $\theta(h)$ from soil cores (obtained through pressure plate apparatus) can be fitted to the desired soil water retention model. Once the retention function is estimated, the hydraulic conductivity relation, K(h), can be evaluated if the saturated hydraulic conductivity, $K_s$, is known. For the van Genuchten (1980) model, the water retention function is given by

$$S_e = (\theta - \theta_r)/(\theta_s - \theta_r) = [\, 1 + (\alpha_v |h|\,)^n \,]^{-m} \qquad \text{for } h < 0$$

$$= 1 \qquad \text{for } h \geq 0 \qquad \ldots (1)$$

and the hydraulic conductivity function is described by

$$K = K_s\, S_e^{1/2} [\, 1 - (1 - S_e^{1/m}\,)^m \,]^2 \qquad \ldots (2)$$

where, $\alpha_v$ and n are van Genuchten model parameters, m = 1 – 1/n.

In the present study, parameters $\alpha_v$ and n of soil moisture retention function and hydraulic conductivity function were obtained through non-linear regression analysis. The saturated moisture content ($\theta_s$) was assumed to be equal to (0.93*soil porosity).

**Table 1 : Soil Parameters at RD 838 of Indira Gandhi Nahar Priyojana, Stage - II**

| S.No. | Soil Parameter | Value |
|---|---|---|
| 1 | Bulk Density | 1.439 g/cm$^3$ |
| 2 | Particle Density | 2.379 g/cm$^3$ |
| 3 | Porosity | 0.395 |
| 4 | Saturated Moisture Content | 0.367 |
| 5 | Saturated Hydraulic Conductivity | 9.110 cm/h |
| 6 | van Genuchten Parameter, $\alpha_v$ | 0.117 |
| 7 | van Genuchten Parameter, n | 1.483 |

Table 1 presents the averaged values of soil bulk density, particle density, porosity, saturated moisture content, saturated hydraulic conductivity, and van Genuchten model parameters $\alpha_v$ and n. The "proportion of variance explained" was found to be 83% for van Genuchten model parameters obtained through non-linear regression analysis. Equations (1) and (2) can therefore be applied for obtaining $h(\theta)$ and $K(\theta)$ relationships in IGNP, Stage II at RD838.

Knowledge of the physics of soil water movement is crucial to the solution of problems in watershed hydrology, for example, the prediction of runoff and infiltration following precipitation, the subsequent distribution of infiltrated water by drainage and evaporation, and estimation of the contribution of various parts of a watershed to the ground water storage. Convenient and reliable techniques for estimating the soil hydraulic properties are therefore required for prediction of soil water flow.

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