

**A PRELIMINARY STUDY ON**  
**THE FATE OF AGROCHEMICALS IN THE VADOSE ZONE ENVIRONMENT**  
**AROUND LAKE NAIVASHA, KENYA**

**by**

**Anil Upendra de Silva  
(Sri Lanka)**

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*This thesis is dedicated to my late parents*

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## LIST OF MATHEMATICAL SYMBOLS

<u>Symbol</u>	<u>Units</u>	<u>Description</u>
$\gamma(\mathbf{h})$	$\text{cm}^2$	semivariance for penetration depth of pesticide of pairs at $\mathbf{h}$ distance apart
$z(\mathbf{x})$	cm	depth of penetration at location $\mathbf{x}$
$z(\mathbf{x}+\mathbf{h})$	cm	-do- at $(\mathbf{x}+\mathbf{h})$
$n$		number of pairs considered for semivarience between $\mathbf{x}$ and $\mathbf{x}+\mathbf{h}$
$w_{ij}$		weight function
$Z_k$		interpolated value
$Z_i$		$i^{\text{th}}$ variable used for the interpolation
$\lambda_i$		weight factor used for the $i^{\text{th}}$ variable
$ET_c$	$\text{mm}/\text{d}$	evapotranspiration
$ET_0$	$\text{mm}/\text{d}$	evapotranspiration of the reference crop
$K_c$		crop factor
$\theta$		volumetric moisture content
$A$	$\text{cm}^2$	cross sectional area of discrete soil compartment
$\Delta z$	cm	thickness of discrete soil compartment
$\rho_s$	$\text{g}/\text{cc}$	density of soil sample
$C_s$	$\text{g}/\text{g}$	sorbed concentration of pesticide
$C_w$	$\text{g}/\text{cc}$	dissolved concentration of pesticide
$C_g$	$\text{g}/\text{cc}$	gaseous concentration of pesticide
$J_D$	$\text{g}/\text{d}$	mass of transformation of pesticide by diffusion and dispersion in dissolved form
$J_V$	$\text{g}/\text{d}$	mass transformation of pesticide by advection in dissolved form
$J_{DW}$	$\text{g}/\text{d}$	mass of pesticide loss due to degradation in dissolved phase
$J_U$	$\text{g}/\text{d}$	mass of pesticide uptake by plants in dissolved phase
$J_{QR}$	$\text{g}/\text{d}$	mass of pesticide loss due to runoff
$J_{DS}$	$\text{g}/\text{d}$	mass of pesticide loss due to degradation in sorbed phase
$J_{ER}$	$\text{g}/\text{d}$	mass of pesticide loss due to erosion
$J_{GD}$	$\text{g}/\text{d}$	mass transformation of pesticide by dispersion and diffusion in vapour phase
$J_{DG}$	$\text{g}/\text{d}$	mass of pesticide loss due to degradation in vapour phase
$J_{FOF}$	$\text{g}/\text{d}$	mass of pesticide gain from washoff from plants to soil
$J_{TRN}$	$\text{g}/\text{d}$	mass of pesticide gain or loss due to parent/daughter transformation
$a$	$\text{cc}/\text{cc}$	volumetric air content
$D_g$	$\text{cm}^2/\text{d}$	molecular diffusivity of pesticide in air-filled pore space
$D_a$	$\text{cm}^2/\text{d}$	molecular diffusivity of pesticide in air
$D_w$	$\text{cm}^2/\text{d}$	diffusion-dispersion coefficient for dissolved phase
$R_s$	$1/\text{d}$	first order decay constant for solid/dissolved phase
$R_a$	$1/\text{d}$	first order decay constant for vapour phase
$f$	$1/\text{d}$	fraction of water used for transpiration in vadose zone
$A_w$	$\text{cm}^2$	watershed area

$K_d$	$\text{cm}^3/\text{g}$	partition coefficient between dissolved and solid phase
$K_H$	$\text{cm}^3/\text{cm}^3$	partition coefficient between liquid and vapour phase
V	$\text{cm}/\text{d}$	average flow velocity of water in the direction of measurement of soil depth
$SW^t$	$\text{cm}/\text{d}$	soil moisture in the soil compartment at time 't'
$SW_i$	$\text{cm}/\text{d}$	soil moisture in the $i^{\text{th}}$ soil compartment
INF	$\text{cm}/\text{d}$	infiltration of water into the soil compartment
$I_i$	$\text{cm}/\text{d}$	percolation of water to the $i^{\text{th}}$ soil compartment
$E_i$	$\text{cm}/\text{d}$	evaporation of water from the $i^{\text{th}}$ soil compartment
$U_i$	$\text{cm}/\text{d}$	transpiration of water from the $i^{\text{th}}$ soil compartment
Q	$\text{cm}/\text{d}$	runoff water from the soil compartment
P	$\text{cm}/\text{d}$	rainfall+irrigation
S	$\text{cm}/\text{d}$	watershed retention characteristic
$\theta(h)$		volumetric moisture content at suction head 'h'
$\alpha$	$1/\text{cm}$	inverse of air entry value of Van Genuchten's MRC model
$\theta_s$		saturated volumetric moisture content in soil
$\theta_r$		residual volumetric moisture content in soil
N		power constant in Van Genuchten's MRC model
m		power constant in Van Genuchten's MRC model, $m=1-1/N$
$K(se)$	$\text{cm}/\text{d}$	unsaturated hydraulic conductivity in the HCC model
se		$[\theta(h)-\theta_r]/[\theta_s-\theta_r]$
p		connectivity parameter used in HCC model
$q_w$	$\text{m}^3/\text{d}/\text{m}^2$	water flux in vadose zone
$\lambda$	$\text{m}$	solute dispersivity in vadose zone
$D_e$	$\text{m}^2/\text{d}$	effective diffusion constant between water and solute in soil media
$D_{if}$	$\text{m}^2/\text{d}$	chemical diffusion between water and solute in soil media
T	$^{\circ}\text{C}$	temperature in soil compartment
$T_a$	$^{\circ}\text{C}$	average daily soil surface temperature
$\gamma$	$^{\circ}\text{C}$	Max.-Min. temperature in a day
pF		suction pressure of 'F' in $\log_{10}(F)$
$m_1, m_2, m_3$		regression coefficient related to percentages content of carbon, clay and sand in soil
c		constant value of regression equation
$K_s$	$\text{cm}/\text{d}$	saturated hydraulic conductivity
So	ppm	solubility of pesticide in water
M	$\text{kg}/\text{ha}$	applied dose of pesticide
H	$1/\text{d}$	half-life of the pesticide
D	cm	simulated depth of penetration of the pesticide
Y	cm	calculated depth of penetration of the pesticide by regression coefficients
$k_1, k_2, k_3, k_0$		regression coefficients related to solubility, dose, half-life and the constant of residue
FOS		factor of safety against pesticide leaching
$\sigma_k^2$	$\text{cm}^2$	maximum variance in optimal sampling design

$\phi$	$\text{cm}^2$	lagrange parameter associated with the minimum variance in optimal sampling design
$\gamma(x_i, x_0)$	$\text{cm}^2$	semivariance between location $x_i$ & $x_0$

## **Abstract**

Potential danger due to leaching of agrochemicals can be analysed by simulation of chemical transport in unsaturated zone (vadose zone). For simulation of pesticides, PRZM2 model was used. Simulation of nitrogen fertiliser was done by using WAVE model. The soil parameters required to run the simulation, can be derived from the soil texture with basic field tests of soil such as saturated hydraulic conductivity, density and moisture retention characteristic. Statistical techniques based on texture analysis, and organic matter were used to estimate the parameters when no field test results were available. The texture of the soil varied from clay to loam and sandy loam. The results of the simulation showed that most of the leaching chemicals were retained in the first 100 cm of the soil depth. Potential risk of pesticide leaching was found to be low due to low annual rainfall and higher depth of vadose zone.

Irrigation supply has no significant effect on pesticide leaching when the rainfall is not excessively high. Among the properties of chemical, solubility, half-life and application dose were analysed on different soil texture to the effect of leaching.

# **Chapter 1**

## **1      *Introduction***

In this chapter under the introduction following topics will be discussed.

- a)General overview
- b)Study objectives
- c)Local importance in relevance to the study
- d)Research methodology
- e)Tools used for the analysis
- f)Limitations of the method

### **1.1    General**

Agrochemicals are one of a key inputs in commercial agriculture. Two type of chemicals were studied in this study, fertiliser and non-fertiliser(i.e, pesticide and other chemicals). Major constituents of a normal fertiliser are nitrogen, phosphorus, and potassium. These elements are normally known as nutrients because they are essential for growth of micro-organism. Non-fertilisers are used for controlling of pests, insects, weeds or used as growth hormones. Agrochemicals have long been applied by farmers for their cultivation even in early periods of agriculture, but with ever increasing demand for the food farmers are compelled to use more and more chemicals in view of increasing the agricultural production per hectare. With the increase in quantity and wide variety of types of the chemicals in use, their effects on the natural balance cannot be ignored. The impact on the environment due to use of agrochemicals has many facets, such as pollution of surface water, deposition and accumulation in human and animal tissues, soil and ground water pollution. Pollution of the vadose zone (unsaturated zone) is an immediate threat to contamination of underlying groundwater. Excessive soil pollution will also lead to high uptake of the chemicals by plants and vegetables and subsequent intake by animals and human.

To measure pollution by monitoring all possible chemicals using chemical analysis is not only prohibitively expensive, but also unproductive. Analysis for even target set chemicals is relatively expensive hence withdrawn from this study. A simpler and cost-effective method of a screening is, simulation of the pollutant transport in the soil and vadose media by modelling with varying input at different scenarios. A model could be physical (e.g. lysimeter) or mathematical. The environment in the physical model, is tried out to be represented as close as possible to the real situation at a given scale. In a mathematical model, this physical environment is replaced by governing laws of the natural phenomenon using mathematical tools. The basic tool in the analysis of this study are, two mathematical models namely WAVE and PRZM2, described in the Chapter 3. It should be noted that the soil media is highly complex, as it is non-homogeneous, non-isotropic and further complicated by its hysteresis behaviour. So obviously, the simulation of solute transport is a highly complex task and no formula(s) can replace the exact behaviour of a soil. Only an approximate situation, under certain conditions, can be represented by mathematical formulas. There are various types of models available for environmental risk assessment, ranging from simpler to sophisticated with varying degree of effectiveness, in applying to the existing problem. A model is considered to be simpler when the analysis is based on a macro level. In case more details are considered, then the model becomes sophisticated. Therefore one can say sophisticated models are more closer to the reality. However, there is always a trade off between simpler and sophisticated model, as sophisticated models need more parameters which are often difficult to measure or even to estimate.

## **1.2 Study Objectives**

The objective of the study is to analyse the factors which affect the extent of pollution in the vadose zone due to use of agricultural chemicals. The factors under study are:

- Physical and chemical properties of the agrochemical, i.e, solubility, degradation, sorptivity,
- Rainfall and Irrigation water supply: frequency, quantity, intensity,
- Soil type and properties: hydraulic parameters, texture, organic matter, etc.
- Depth of vadose zone and the groundwater table

- Type of vegetation: crop type and rotation

### **1.2.1 Specific objectives**

In addition to the above main objectives, there are two sub objectives,

- a)To identify how pollution varies spatially and identify relatively vulnerable zones in the study area;
- b)To identify pollution leaching areas, ground water contamination risk;

### **1.3 Local importance in relevance to the study**

Peripheral area around Lake Naivasha in Kenya in east Africa has been selected for this study. The lake is the second largest natural freshwater in Kenya . The peripheral of the lake has long been subject to commercial agriculture, mainly flowers and vegetables for the export market. As the agriculture is export oriented, the farmers do not depend entirely on natural rainfall and natural soil fertility. They use irrigation water, mineral and organic fertilisers to maximise yields and thereby the profit. Though some small scale farmers use organic fertilisers at lesser extent, inorganic fertiliser and pesticides are used in large quantities.

### **1.4 Research Methodology**

In order to achieve the main objective and the specific objectives, collection, analysis and presentation of the data were done at three stages viz. I)Pre-field work II)Field work III)Post field work.

#### **1.4.1 Pre field work**

In this phase the main tasks were:

- Collection and reviewing literature relevant to the study in the available data such as maps, aerial photographs, analysis of stream flow and rainfall data, details on landuse and irrigation pattern, etc.

## Chapter 1

- Studying the models to be used. Review of model parameters to be measured from various sources in the field work area.

### **1.4.2 Field Work**

In this phase the following was done

- Demarcation of areas to be studied in detail within the available time period and resources;
- With the aid of pre-field work study, collection of soil samples (both disturbed and undisturbed) in view of analysis for texture, density, moisture characteristic, etc.
- Measurement of saturated hydraulic conductivity. All visited sites were farms.
- Surveying to gather information on the inputs such as pesticides, irrigation, fertiliser, and also related information such as cultivation practices, frequency of application in each inputs, yields, etc.

### **1.4.3 Post field work**

Analysis of the field data and preparation for the final thesis report.

## **1.5 Tools used for the analysis**

In addition to the two models, statistical techniques and Geographic Information System(GIS) were used to analyse the field data and to perform spatial interpolation.

Penetration of chemicals and possible leaching was calculated by using the two models(described in Ch3). These models need quite a number of parameters, such as soil properties and chemical properties. Some of the properties are available in reference literature such as solubility and decay of chemical and other parameters are site specific and need to be determined in specific site locations. Most of site specific parameters are soil properties. Due to constraint in time and resources it is not possible to collect samples at every place and it not economical too and further it is necessary to get soil properties in much deeper layers. Collection of the samples in deeper layers is not practicable in a short

field test. To overcome this problem a selected number of samples were collected and tested for the properties. These properties were then related with the soil texture.

### **1.5.1 Soil texture analysis**

Normally soil can in first instance be identified by its texture. The concept of texture is directly associated with the concept of particle size composition. The texture is determined by the distribution of soil particles. In soil science there are three major texture class based on the particle size as follows:

<u>Type</u>	<u>Range of particle size</u>
Clay	<2 $\mu$
Silt	2-50 $\mu$
Sand	50-2000 $\mu$

In a soil sample there could be particles of size more than 2000 $\mu$  in small fraction but majority falls into above three classes hence in close approximation, the whole sample can be differentiated into above three classes in percentage(the percentages is measured by sieve analysis) making total percentage to be 100 i.e., Clay%+Silt%+Sand%=100. When the total percentage is equal to 100 then the particular sample could be fit into a triangle known as soil texture triangle(see Appendix D). Once the distribution of the soil sample in texture classes is determined with the physical properties, a statistical regression analysis was used to relate soil properties and the physical properties.

### **1.5.2 Regression analysis**

Regression analysis is one of a very useful technique to predict unmeasured parameters of which only limited number of measured ones are available. The central idea of regression is that of dependence of one variable's depending on one or more others in some sense. Examples of such dependence are common in soil science. For instance, saturated hydraulic conductivity could depend on amount of organic carbon, clay etc. Regression alone, however can not show whether there is a direct causal relationship between

## Chapter1

variables. Furthermore it does not matter from the point of view regression analysis which variable is thought of as cause and which as effect.

The idea of regression, however, are not restricted to situations in which there is obvious cause and effect. For example, the amount of carbon, clay in the soil do not determine the saturated hydraulic conductivity although they are likely to be related. Hence the relationship obtained by the regression analysis is highly localised in nature and its prediction can not applied universally.

Suppose a parameter, Y is likely to be related with variables  $X_1, X_2, X_3, \dots$ . Then Y could be expressed in terms of  $X_1, X_2, X_3, \dots$  or Y as a function of X

In order to find the relationship between Y and X there should be measured values of Y with corresponding values of X. Y could be related with X by several unknowns each X has one(if the relationship is linear) or more unknowns which need to be found to establish a relationship between Y and X. The relationship should guarantee that the error between the measured and the predicted is at the minimum. The number of unknowns should be less than the number of the measured set of data, more the difference higher the degree of freedom(degree of freedom = No of measured data - No of unknowns) but at the cost of the error between the measured and the predicted values or lesser  $R^2$ . Regression coefficients at higher degree of freedom increases the applicability of the prediction. Therefore quality of the prediction increase with number of available measured data since of more degree of freedom. So it is always better to relate Y with minimum number of independent variables(X). The parameters measured in the study area are related with %clay, %sand and %carbon(%silt is excluded since %clay+%sand+%silt=100).

### **1.5.3 Spatial interpolation**

When a certain data is not available where it is needed and if the data is spatially related then kind of estimation can be made to fill the known data from the surrounding known data. This is the basic assumption made in spatial interpolation. One such data is depth to ground water table.

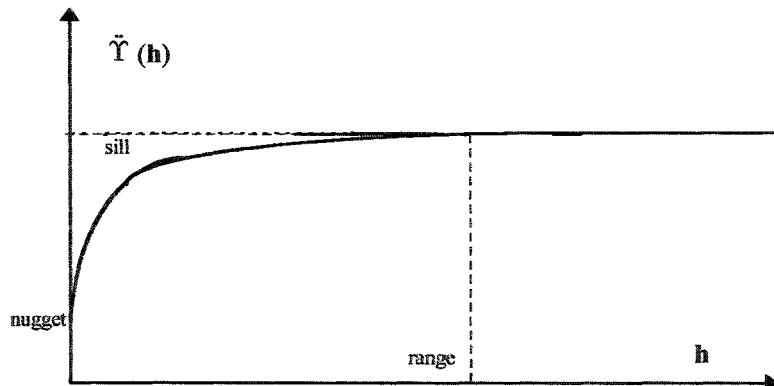
Depth to ground water is taken as the thickness of the vadose zone. When the depth is not shallow no field observation can be made and the depth has to be derived from the

previous observations in the vicinity. This technique has been adopted to find the depth of vadose zone where it is not measured directly. Analysis of semivarogram is the basic tool available for estimating or predicting the data. Semivariogram(or simply variogram) is the graph of semi-variance( $\frac{1}{2}$ Variance) against the distance. The semi-variance,  $\gamma(\mathbf{h})$  is given by the summation of variance between pair of points as follows

where,  $z(x)$  &  $z(x+h)$  are observation values at distance  $x$  and  $(x+h)$  [ $h$  apart] and  $n$  is the number of such pairs. Variogram is the graph of  $\gamma(h)$  Vs  $h$ , a variogram could be directional when  $h$  is measured in along a certain direction, or omnidirectional when no such direction is specified. Directional variograms are used when the effect of anisotropy is considered. Tolerance for the distance and the direction has to be applied in order to accommodate higher number of pairs.

The basic concept of the theory is that to predict or estimate certain geo-data by interpolation at a given location, spatial dependence should be observed. If the distribution of the data has no relation with the location then the variance of the data between two locations(between pairs) has complete random distribution with the distance of them. This situation is known as ‘pure nugget effect or sill=nugget’(described below) in such cases there is no point in using geostatistical interpolation methods as there is no spatial continuity of the random variation and the aerial average of the variable is simply the arithmetic average. When the distribution is not completely random and the data is related to its locality then variance at closer point should be lower and larger at higher distances. This effect is reflected in the variogram and the variogram is a property of the data set.. A model can be made for the variogram of the data set in order make the spatial interpolation. The model is an equation which gives  $\gamma(\mathbf{h})$  value for given  $\mathbf{h}$ . Normally according to the shape of the curve the models are named as linear, spherical, exponential, gaussian, etc. A veriogram is characterised by its sill, range and nugget where nugget is the semivariance at  $\mathbf{h}=0$ , the range is the distance where highest semivariance(sill) is reached. The curve of the variogram is considered to go on plateau at the sill when the  $\mathbf{h}$  is more

than the range; i.e., it is considered that the data at out of the range is no more dependence of the locality.



**Figure1.1: Typical variogram**

In order to make spatial interpolation, first a point map of the data has to be made, then semivariogram has to be checked whether spatial interpolation is meaningful. All spatial interpolations were done using ILWIS software(GIS) developed in the ITC, Enschede. In ILWIS the equation adopted to calculate semivariance( $c$ ) known as Geary's  $c$  (Odland, J. 1988),

### Geary's c

$$C = \frac{n-1}{2\sum w_{ij}} \frac{\sum \sum w_{ij} (x_i - x_j)}{\sum (x_i - \bar{x})^2} \dots \quad 1.2$$

where  $n$ =No of pairs( $i$  &  $j$ ),  $x_i = z(x)$ ,  $x_j = z(x+h)$ ,  $\bar{x}$  =mean

$w_{ij}$ -weight function

The difference between equation 1.1 and 1.2 is the introduction of a weight function and division by the variance [ $= (x_i - \bar{x})^2 / (n-1)$ ] of the whole sample set. The semivariance in equation 1.2 has an expected value of 1. It means that when calculated value of  $c=1$  within the limits of statistical significance then  $x_i$  in the region are independent of the values of  $x_j$  at neighbouring locations.

One possible interpolation technique of data by interpolation is known as kriging in geostatistics. The estimated value( $z_k$ ) in a point surrounded by observation points is obtained by the equation,

where  $\lambda_i$ =weighing factor on the neighbouring observation points, provided that,

1.  $\sum \lambda_i = 1$  for the estimation to be unbiased
  2. The variance between the estimated and observed data should be minimised.

## **1.6 Limitations of the method**

The methods used did not represent an actual measurement of chemical transports, but only an simulation based on available input data. So quality of the output depends on the inputs. The mapping is based on interpolation from point data hence the representation (i.e., variogram) of the point data critically affects to the final results. Some data/parameters were extrapolated from the soil texture even though this was the only option available within the limits of the study. This allows for some deviation from the reality. Moreover, with hand auguring no way of getting undisturbed deep soil parameters (below 1.5m). Hence the last layer of the auger hole had to be assumed representative up to the groundwater level.

## **Chapter 2**

### **2      *Description of the study area***

In this chapter under the description of the study area following topics have been covered.

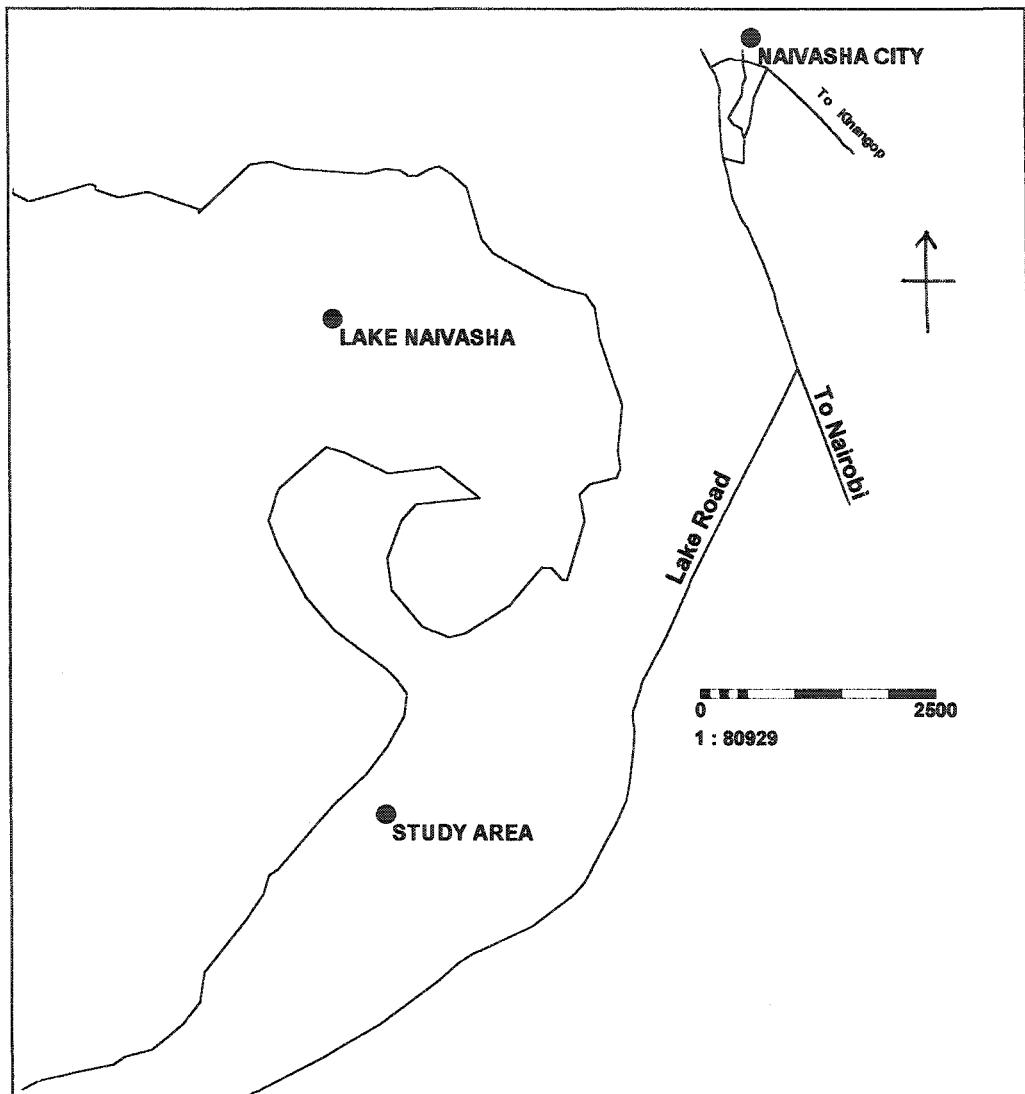
- a)General overview
- b)Location of study are
- c)Geology and soil type
- d)Climate
- e)Agriculture crops
- f)Water use and irrigation practices
- g)Type of chemical use for agriculture

#### **2.1    General overview**

The lake Naivasha is fed by several rivers from the North. The main inlet is Malewa river. The lake is situated in the rift valley. The catchment of the lake is formed by the Nayandarua mountains which rises up to 3960m in the east and, Mau Escarpment which rises up to 3000m. The lake has a shallow water depth in average of about 4m. The lake Naivasha is one of a major water resource in Kenya and it has been a tourist attractive area too. The government of Kenya is very concerned about the pollution of the lake as it contributes considerably to the countries economy.

#### **2.2    Location of the study area**

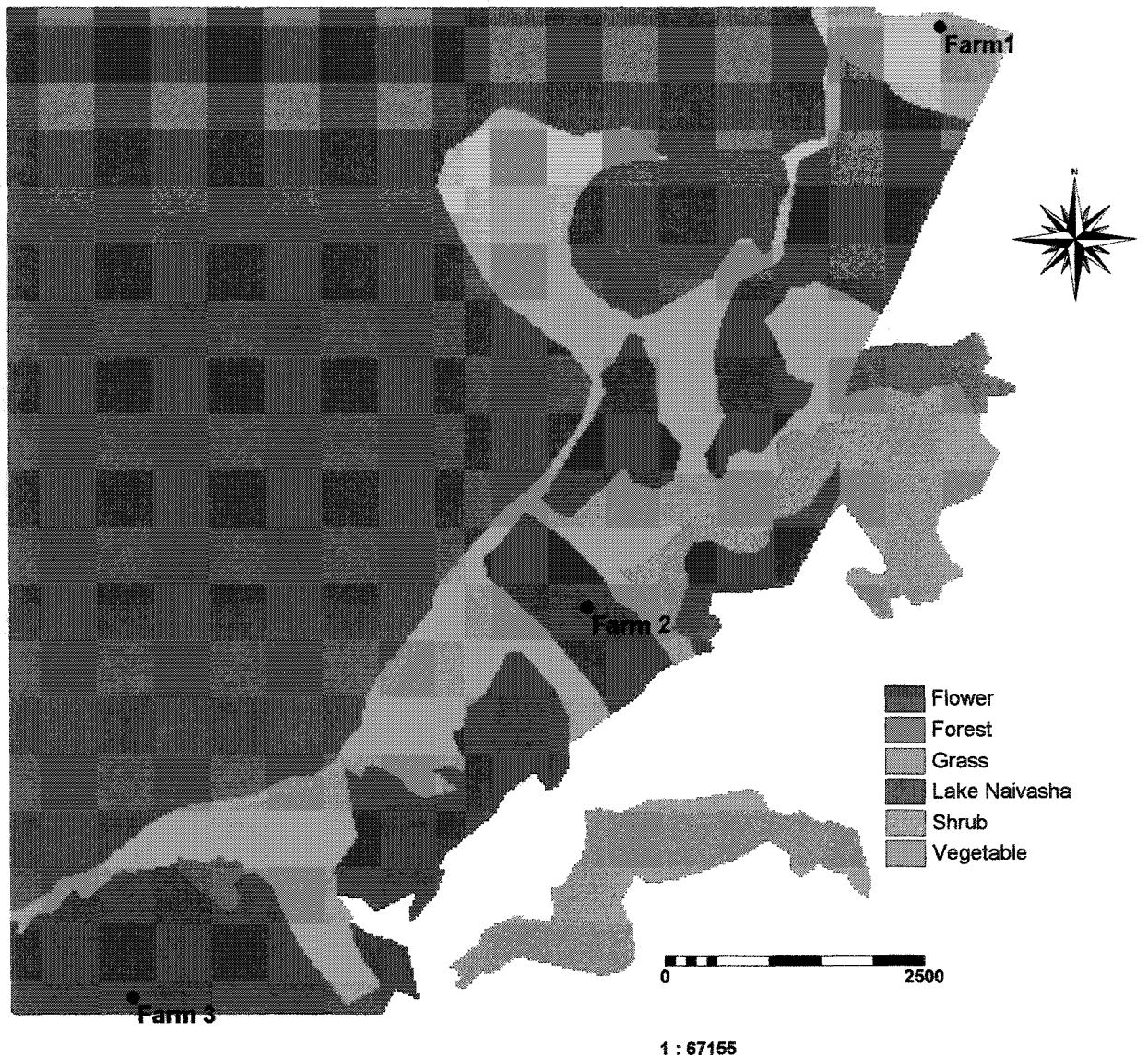
The study area is located along the lake road from the junction of the Naivasha-Nairobi road(linking road between Naivasha town close to the study area and the capital of Kenya, Nairobi) towards the South up to about 10km. The area stretching between the lake road and the eastern shores of the lake of about 1-1.5km in width covers an area of about 2043ha (see the location map of the study area below).



**Figure2.1:The Location map of the study area**

The area lies approximately within latitudes  $0^{\circ}475'$  and  $0^{\circ}48.3'S$  and longitudes  $36^{\circ}23.7'$  and  $36^{\circ}24.7'E$ . The altitude of the lake is 1900m above sea level.

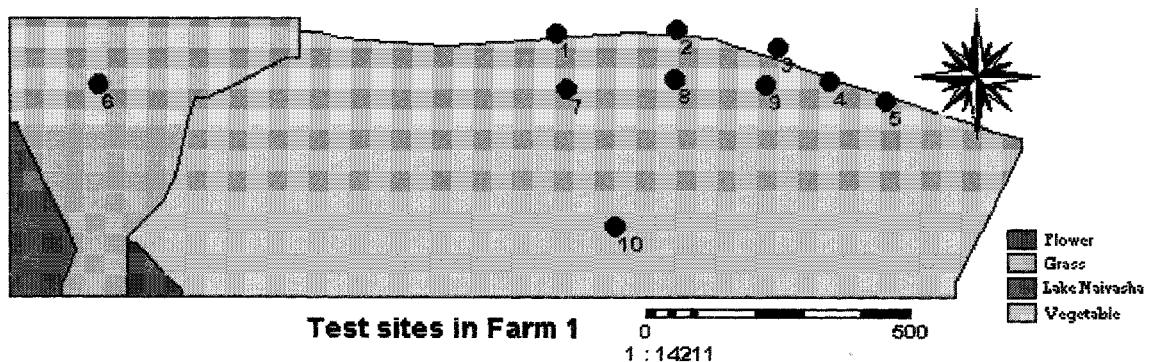
Three farms were visited during the field work. The farms were numbered as farm1, farm2 & farm3 from the North to the South(see the location map of the farms below). Cultivation of the farm1 was completely vegetables and both vegetables and flowers were in the other two.



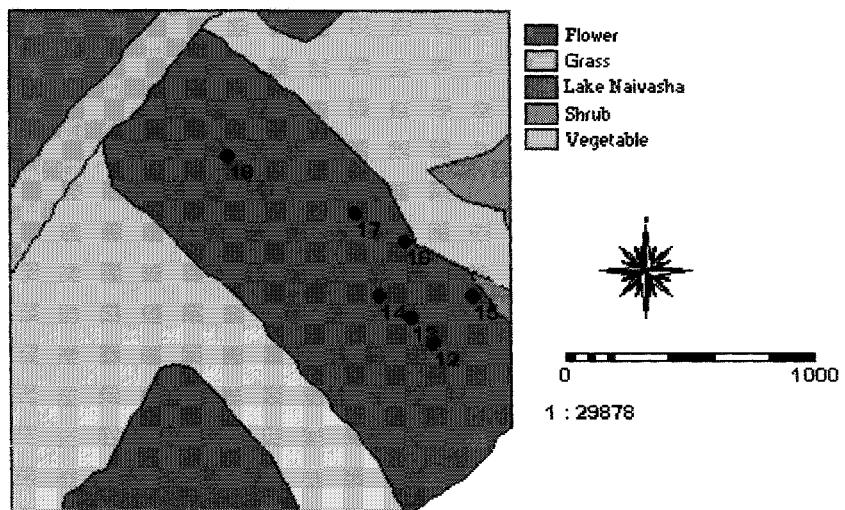
## Location map of the farms

(For test sites in the farms see the maps of Farm1, 2 & 3)

Figure2.2:The location map of the farms

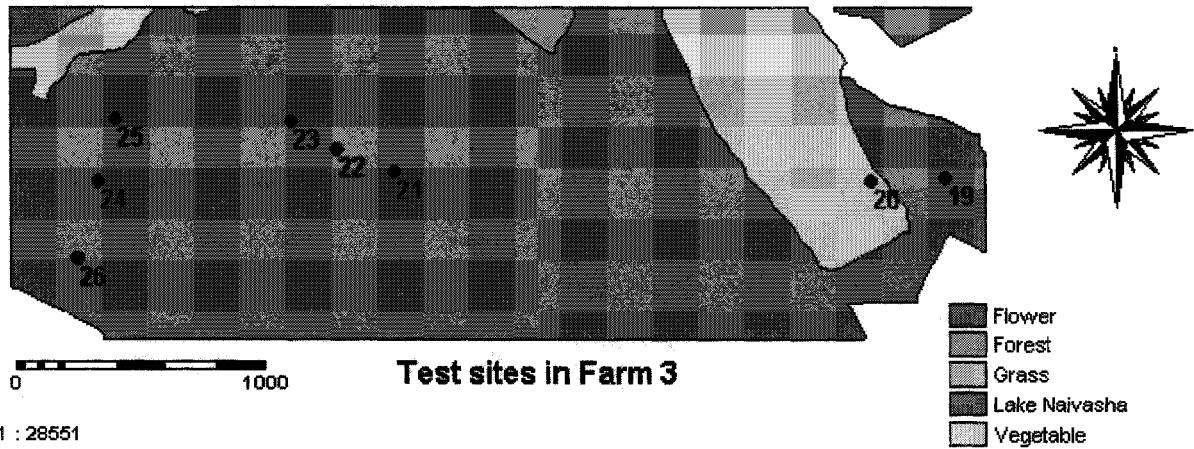


**Figure2.3:**Test sites in the farm 1



**Test sites in Farm 2**

**Figure2.4:**Test sites in the farm 2



**Figure2.5:Test sites in the farm 3**

### 2.3 Geology and soil type

The study area consist of two types of quaternary deposits, of mainly lacustrine and/or volcanic origin. (Thompson and Dodson, 1963). The older deposit vary in composition but largely comprise of fine white ashes with intercalations of puaceous gravel deposited in lacastrine conditions during the various phases of the Gambian lake. In the area these lacustrine deposits are calcareous.

The younger deposits are recent silts and clay adjacent to the present lake shores and which are still being deposited during high lake water level periods. The deposits, in addition to clay and silts also contain a large proportion of volcanic materials in the form of ashes. It lies under one physiographic unit - the sedimentary plain. Recent fluctuation of the lake level has resulted in numerous cycles of deposition and erosion of recent materials, which appear to be mainly coarse loamy, with occasional fine gravel. Near the lake the topography is flat and is part of the recent lacustrine plain. Slopes vary between 0-2%, in parts 2-5%. Away from the lake the land rises gradually and slopes of 2-5% are common.( Siderius W; 1980)

## 2.4 Climate

The table below gives the average monthly rainfall, temperatures, humidity, wind speed, radiation,  $ET_0$ -Penmon-Monteith according to the meteorological station at Naivasha.

**Table2.1:Climatic Data**

Month	Min-Tem (oC)	Max-Tem (oC)	Humidity (%)	W- Speed (Km/day)	Sunshine (Hrs)	Radiation (MJ/m <sup>2</sup> /d)	ET <sub>0</sub> -PenMon (mm/day)
January	8.0	27.6	62	104	5.3	17.1	3.8
February	8.1	28.2	61	104	5.9	18.5	4.1
March	9.7	27.2	65	104	5.3	17.8	3.9
April	11.5	25.0	75	104	4.7	16.3	3.4
May	11.2	23.7	80	121	4.9	15.8	3.1
June	9.8	23.0	79	121	4.8	15.0	3.0
July	9.2	22.5	77	121	4.2	14.4	2.9
August	9.3	22.8	76	130	4.7	15.9	3.2
September	8.7	24.5	74	130	5.4	17.7	3.6
October	9.0	25.5	72	130	5.5	17.9	3.8
November	9.2	24.6	77	104	4.4	15.8	3.3
December	8.6	25.7	72	104	4.2	15.1	3.3
Year	9.4	25.0	73	115	4.9	16.4	3.5

Variation of yearly rainfall for the past 36 years with cumulative probability of exceeding is shown in the page . Probability of exceeding(Pr) of yearly rainfall in each year is given by

$$Pr = \text{rank}/(1+\text{total no of years considered})$$

where r=rank of the rainfall as per descending order

An average dry year of rainfall(Pr at 90% ) yields about 473mm(1993).

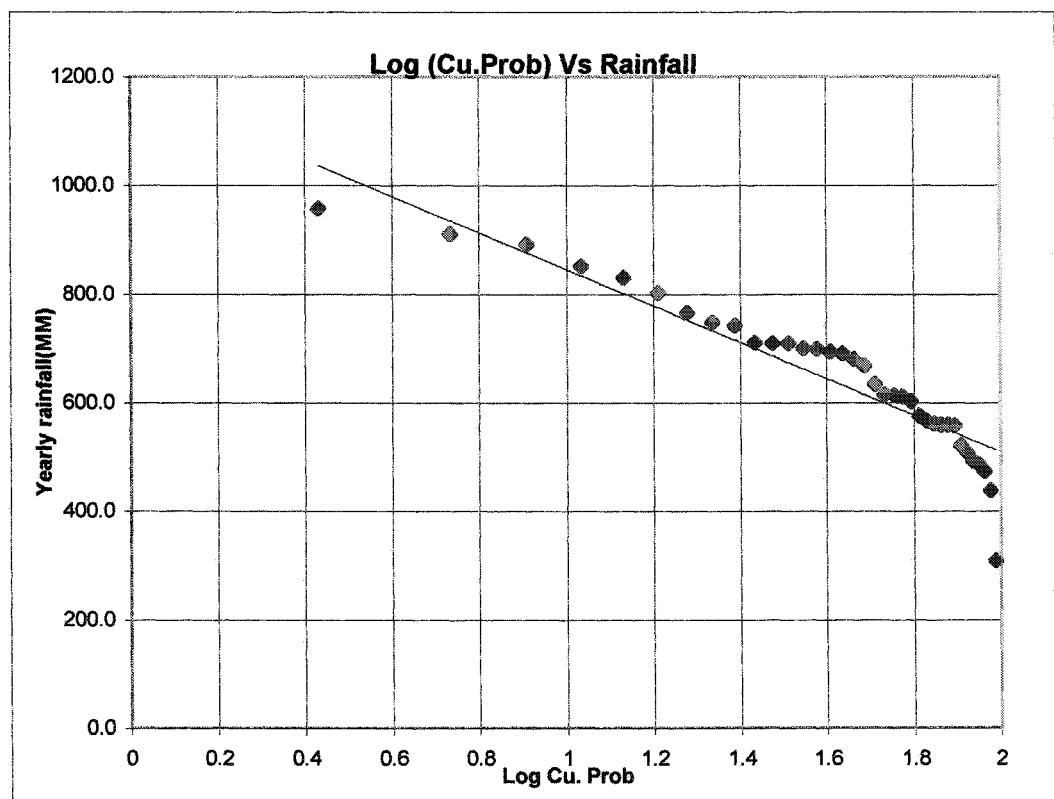
An average wet year of rainfall(Pr at 10% ) yields about 852mm(1989).

In normal year of rainfall(Pr at 50% ) yields about 634mm(1983).

## Chapter2

**Table 2.2:Rainfall figures**

Year	Rainfall (mm)	Daily max	Rank	% Cu. Pr	Log Cu.Pr
1961	957.0	50.0	1	2.7027	0.43
1978	909.4	38.7	2	5.4054	0.73
1990	891.1	37.1	3	8.1081	0.91
1989	851.5	40.7	4	10.811	1.03
1977	830.0	51.3	5	13.514	1.13
1963	802.1	51.1	6	16.216	1.21
1968	765.3	44.7	7	18.919	1.28
1966	748.0	47.0	8	21.622	1.33
1982	741.9	55.3	9	24.324	1.39
1964	710.1	40.1	10	27.027	1.43
1981	708.9	33.8	11	29.73	1.47
1974	708.7	39.5	12	32.432	1.51
1992	699.5	44.9	13	35.135	1.55
1967	699.0	34.3	14	37.838	1.58
1971	693.5	70.7	15	40.541	1.61
1958	689.9	40.6	16	43.243	1.64
1994	679.3	39.6	17	45.946	1.66
1960	668.4	50.8	18	48.649	1.69
1983	634.2	43.6	19	51.351	1.71
1987	613.8	62.5	20	54.054	1.73
1979	612.9	38.7	21	56.757	1.75
1986	610.0	61.7	22	59.459	1.77
1970	601.8	46.9	23	62.162	1.79
1973	575.2	41.9	24	64.865	1.81
1975	565.6	52.0	25	67.568	1.83
1972	561.6	55.8	26	70.27	1.85
1988	558.5	50.8	27	72.973	1.86
1985	558.4	40.8	28	75.676	1.88
1980	557.9	42.3	29	78.378	1.89
1965	520.9	32.0	30	81.081	1.91
1969	507.5	45.5	31	83.784	1.92
1991	492.3	36.3	32	86.486	1.94
1976	485.9	28.9	33	89.189	1.95
1993	473.1	42.2	34	91.892	1.96
1984	437.5	47.4	35	94.595	1.98
1959	309.3	21.6	36	97.297	1.99



**Figure 2.6:Plot of log cumulative probability Vs annual rainfall in Naivasha area**

Average rainfall =	650.8	A wet year	-1989
A mean year			-1983
A dry year			-1993

## 2.5 Agriculture crops

For the calculation of water balance consumptive use of the water by the plants need to be known. This is known as evapotranspiration. The plant density in the field is also necessary. The evapotranspiration( $ET_c$ ) is evaluated by

where  $ET_0$  = evapotranspiration of the reference crop(grass), in mm/d or cm/d

$K_c$  the factor which depends on type of crop and its stage of growth

Normally  $ET_0$  is taken as a fraction of the Pan evaporation value. In Naivasha area 2/3 is recommended for the multiplication factor to get crop water requirement (i.e  $ET_c = 2/3 * Pan\ Ev$ ).  $K_c$  value in the simulation has been taken as 1, since in the field growth stages of the plants are at different levels hence an average value had to be used further the plants can be assumed to be at no stress condition therefor evapotranspiration is closer to the potential value.

Rooting depth is another very important factor to be considered. The rooting depth increases during the entire growing period. As in the literature available, rooting depth is increasing with the time required for maturing as in the table below.

**Table 2.3: Rooting depth and maturing period for a normal plant**

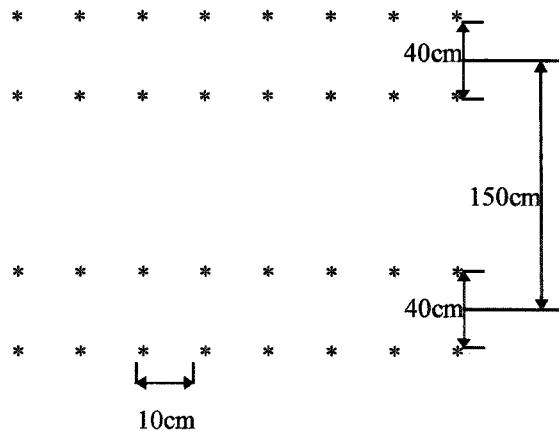
Maturing period	Rooting depth
2 month	60 to 100cm
3 to 4 month	100 to 150cm
6 month	180 to 305cm or more

Rooting depth of the plants in the study area was estimated according to the above guide and the information provided by the farmers.

The necessary details collected in the field for flowers and vegetables are as follows.

### 2.5.1 Flowers

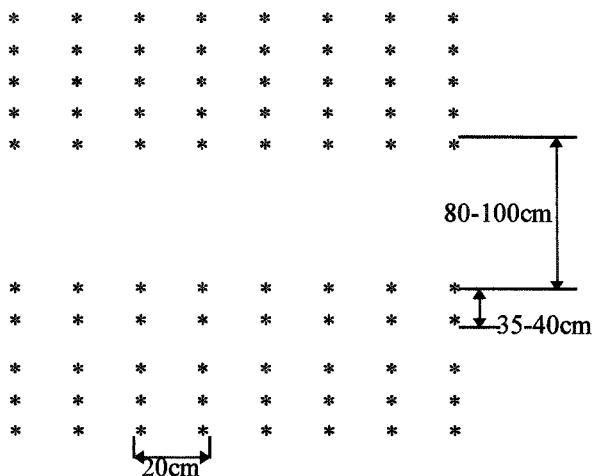
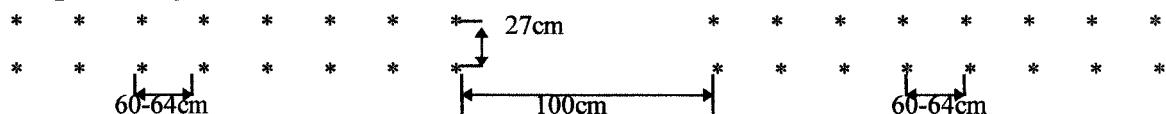
Main species of commercial flower is roses. In average about 60% of the lands is under green houses. The plants are grown in set of rows as shown in the diagram below. The harvesting period is about 40-45days. Rooting depth can be taken as 60cm.



**Figure 2.7:Distribution of the flowers in the field (not to scale)**

### 2.5.2 Vegetables

Two main type of vegetables have been considered in study i.e. beans and cabbages. Unlike flowers, vegetables are not grown in green houses. The distribution of the plants are given in the diagram. Farmers grow beans and cabbages in rotation in four times a year. (two times cabbage and two times beans). Rooting depth can be taken as 100cm for both beans cabbages.

***Crop:Beans******Crop:Cabbage***

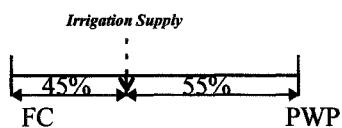
**Figure2.8:Distribution of the vegetables in the field (not to scale)**

## 2.6 Water use and irrigation practices

The lake is main source of water for the commercial crops. Non commercial crops grown by small scale farmers depends only on rainfall. They are maize growers. Since lake level is below the farm level gravity irrigation is non-existing. Sprinkler and drip irrigation are the two methods used by the all farmers. Inside the green house only the drip method is possible whereas in open surface both drip and sprinkler are in practice. Sprinkler is over-head and non-portable type. Most of the irrigation water percolates into the subsurface. Little evidence of any runoff was observed due to the low land slope(< 2%). Also farmers were conscious on the cost of the pumping, so over-irrigation is avoided. Irrigation water is supplied to create no “water” stress condition for plants so it is reasonable assumed that at the surface soil is closer its Field Capacity(FC) level. There is no continuous application of irrigation and the supply of irrigation depends on the requirements of the plant decided by the farmers. Therefore it is not possible to fix an exact quantity of irrigation supply, however based on average time of application and the output of water pumps, the maximum rate is around

14.4mm/day. Normally farmers do not continue pumping for irrigation more than 6hrs in a stretch.

As the soil moisture goes down plant has to exert more suction pressure to extract water. This is no longer possible once soil moisture content lowered to the Permanent Wilting Point(PWP). Depending on soil type, the PWP, suction pressure can be vary from 7 to 40 atmosphere. The difference of moisture contents between the FC and PWP is known as Available Moisture(AM) for the plants. Only fraction of the AM can be extracted by plants easily and known as Readily Available Moisture(RAM) normally express as a percentage of AM. Farmers trigger the irrigation when the moisture content is about to fall below RAM. For the study area this level is assumed at 45% of the AM.



**Figure2.9:Irrigation supply point**

## 2.7 Type of chemicals in use

List of pesticide and other chemicals used in the area is given below. The list is prepared according to the information obtained from the farms. The physical properties required by the model are also annexed to the list.

**Table2.4: Pesticide and other agrochemical data inventory in study area**

Chemical Name	Mode of action	Dose ( $\text{ha}^{-1}\text{month}^{-1}$ )*	Solubility in water (ppm)	Half-Life(d) in soil	Crops applied
Abamectin	Insecticide	0.027 lit	0	2	Flowers
Acrinathrin	Insecticide	0.023 lit	0.09	52	Flowers
Alachlor	Herbicide	2 lit	242	18	Vegetables
Amitraz	Insecticide	0.67 lit	1	0.5	Flowers
Azocyclotin	Acaricide	0.013 lit	0.9	7	Flowers
Bacillus Thuringiensis	Insecticide	0.033 lit	0	2	Flowers
Benomyl	Fungicide	0.13 lit	2	270	Flowers
Bitertanol	Fungicide	1 lit	5	2	Flowers
Chlorothalonil	Fungicide	0.013 lit	0	60	Flowers
Chlorpyrifos	Insecticide	0.5 lit	2	90	Vegetables
Clofentezine	Acaricide	0.033 lit	0.9	55	Flowers
Cyproconazole	Insecticide	0.1 lit	140	90	Flowers
Deltamethrin	Insecticide	0.067 lit	0.02	11	Flowers
Dichlofuanid	Fungicide	0.08 lit	1.3	3	Flowers
Dicofol	Acaricide	0.267 lit	0.8	5	V & F
Dienochlor	Acaricide	0.033 lit	0	2	Flowers
Endosulfan	Insecticide	1.33 lit	0.32	3	Flowers
Ethion	Acaricide	0.1 lit	0	2	Vegetables
Etridiazole	Fungicide	0.013 lit	50	3	Flowers
Fenarimol	Fungicide	0.267 lit	13.7	3	Flowers
Flufenoxuron	Insecticide	0.5	0	3	Vegetables
Gibberellic Acid	Fungicide	0.007 lit	5	600	Flowers
Iprodione	Fungicide	0.53 kg	13	90	Flowers
Lambda-Cyhalothrin	Insecticide	0.5 lit	0.01	56	Vegetables
Linnuron	Herbicide	0.007 lit	81	105	Vegetables
Mancozeb	Fungicide	1.33 lit	200	11	V& F
Metaldehyde	Molluscide	1.33 lit	230	13	Flowers
Methomyl	Insecticide	0.63 lit	57.9	4	V& F
Methyl Bromide	Soil Sterilants	6.67 kg	13.4	1	Flowers
Myclobutanil	Fungicide	0.067 lit	142	3	Flowers
Oxycarboxin	Fungicide	0.0267 lit	1000	3	Flowers
Pirimiphos-Methyl	Insecticide	0.01 lit	5	29	Vegetables
Sodium Fluoroalacetate	Rodenticide	1.6 kg	400	1	Flowers
Sulfur	Fungicide	3 kg	0	1	V& F
Thiophanatemethyl	Fungicide	0.133 lit	26.6	1.5	Vegetables
Tolclofos-Methyl	Fungicide	0.033 lit	0.35	1.5	Flowers
Triadimefon	Fungicide	0.05 kg	260	120	Flowers
Triadimenol	Fungicide	0.133 lit	95	120	Vegetables
Triforine	Fungicide	0.133 lit	6	21	Flowers
Vinclozolin	Fungicide	0.033 kg	3.4	650	Flowers



**Plate 2.1:A typical vegetable garden in the study area**



**Plate 2.2:A typical flower garden in the study area**



**Plate 2.3:Supply of irrigation by sprinklers**



**Plate 2.4:Flower (roses) grown inside a greenhouse**

## **Chapter 3**

### **3 Materials and methods**

In this chapter under the materials and methods, type of materials used to gather the information, the two models used for the analysis and the methods of field survey and soil investigation are described.

#### **3.1 Materials used**

- a)Aerial photos taken in 1984 of the study area in 1:50,000 scale
- b)Satellite imageries in 7 Bands of TM taken in 1994/95
- c)Topo sheet of the study area in 1:50,000 scale
- d)GPS(Global Positioning System)
- e)Hand Auger
- f)Hydraulic conductivity measurement equipment(inverse augerhole method)

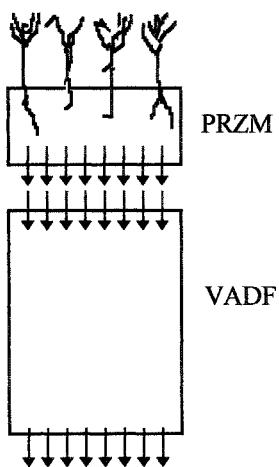
#### **3.2 Model description**

Two models namely PRZM2 and WAVE have been used to simulate vertical transport of Pesticide and Nitrogen respectively. PRZM2(March 1993) was developed by the United State Environmental Protection Agency, an organisation faced with issues concerning the registration and restriction of pesticides used for agricultural purposes. WAVE(December 1994) has been developed by the Institute for Land and Water Management of the Katholieke Universiteit Leuven(Belgium).

##### **3.2.1 PRZM2 model**

A computer software of a mathematical model written in FORTRAN language. The mathematical model is based on the transport of solutes in vadose zone. The vadose zone is discretized in distance and time and solved for concentration, water heads, and water

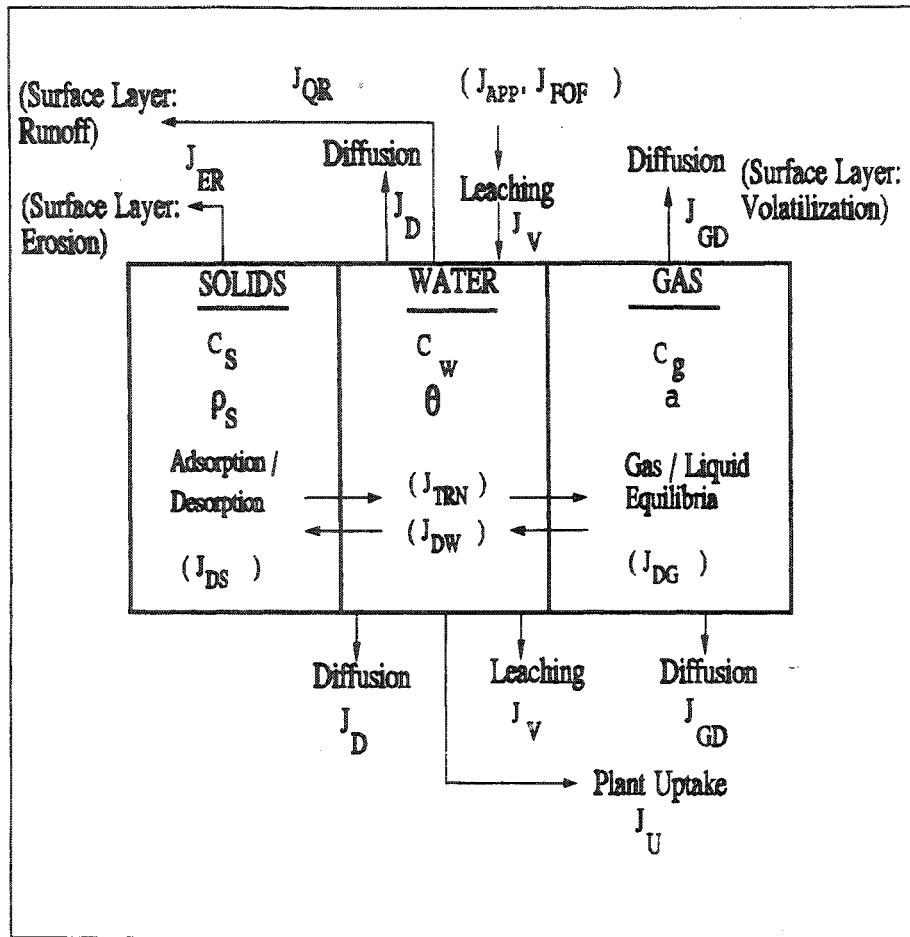
contents in each discretized compartment. The model essentially is one dimensional and outputs have to be dependent on numerical convergence. Basically the model divides the unsaturated zone into two zones simulated by two sub models viz.; PRZM and VADF. The PRZM simulates transport of pesticide in the upper layers where as for simulation of flow of water and transport of pollutants in more deeper layers, the VADF could be used. Each model can run independently or together. VADF has been a later development to the original version(PRZM1). PRZM alone can be used to represent the entire vadose zone.



**Figure 3.1: Link between PRZM and VADF**

The PRZM simulates

1. Transport of solutes in the zone
2. Volatilization
3. Water movements
4. Soil erosion
5. Irrigation



**Figure 3.2: Schematic representation of a single chemical in a soil layer**

According to the above diagram the mass balance equation can be written as follows.

### Change of solute concentration in dissolved(solution phase)

$$\frac{A\Delta z \partial(C_w \theta)}{\partial t} = J_D - J_V - J_{DW} - J_U - J_{QR} + J_{APP} + J_{FOF} \pm J_{TRN} \dots \quad 3.1,$$

### Change of chemical concentration to and from solid phase

$$\frac{A\Delta z \partial(C_s \rho_s)}{\partial t} = -J_{DS} - J_{ER} \dots \quad 3.2 \quad \text{and}$$

#### Change of chemical concentration in gaseous(vapour phase)

## Chapter 3

$$\frac{A\Delta z \partial(C_g a)}{\partial t} = -J_{GD} - J_{DG} \quad \dots \dots \dots \quad 3.3$$

Where

A=cross sectional area of soil column( $\text{cm}^2$ )

$\Delta z$ =depth dimension of compartment(cm)

$C_w$  = dissolved concentration of the pesticide(g/cm<sup>3</sup>)

$$C_s = - \text{do} - \text{sorbed(g/g)}$$

$$C_g = - \text{do} - \text{gaseous(g/cm}^3\text{)}$$

The above equations are also applicable for subsurface compartments without  $J_{OR}$ ,  $J_{FOF}$ ,  $J_{ER}$

The basic assumptions in relation with the environment to solve the above equations are discussed below.

The mass transformation given J-terms are determined using laws in physics related to soil-water environment. Fick's law in diffusion is used for  $J_D(g/d)$  i.e.

where  $D_w$ =diffusion coefficient( $\text{cm}^2/\text{d}$ )

Similarly for vapour phase diffusion,  $J_{GD}(g/d)$

$$J_{GD} = A\Delta z D_g \frac{\partial^2 (C_g - a)}{\partial z^2} \dots \quad 3.5$$

where  $D_g$ =molecular diffusivity of the pesticide( $\text{cm}^2/\text{d}$ )= $D_a(a^{1/3}/n^2)$

where  $a$ =air-filled porosity( $\text{cm}^3/\text{cm}^3$ ),  $n$ =total porosity( $\text{cm}^3/\text{cm}^3$ ),

$D_a$ =molecular diffusivity( $\text{cm}^2/\text{d}$ ), of the chemical in air considered to be constant

The advective term for the dissolved phase,  $J_v$  is given by

$$J_v = A\Delta z V \frac{\partial (C_w \theta)}{\partial z} \quad ..... 3.6.$$

where V=velocity of water movement(cm/d)

## Chapter 3

Degradation of pesticide in soil is assumed to be followed first order kinetics and further assumed in calculation of  $J_{DW}$ ,  $J_{DG}$ ,  $J_{DS}$  that same rate of constants for solid and dissolved phase.

### Degradation in water

#### Degradation in soil

## Degradation in air

where  $R_s$ =lumped, first order decay constant( $d^{-1}$ ) for solid and dissolved phases

$R_g$ =lumped, first order decay constant( $d^{-1}$ ) for vapour phases

$C_s$ =solid phase concentration of pesticide(g/g)

Plant uptake of pesticide,  $J_U$ (g/d) is assumed to be related to the transpiration rate as follows

where  $f$ =fraction of total water in the zone used for transpiration( $d^{-1}$ )

$\theta$ =moisture content( $\text{cm}^3/\text{cm}^3$ )

$\epsilon$ =uptake efficiency factor

Loss of pesticide due to runoff,  $J_{OR}$ (g/d) is obtained by

where  $A_w$ =watershed area( $\text{cm}^2$ ),  $Q$ =runoff volume( $\text{cm}^3/\text{d}$ )

Loss of pesticide due to erosion ( $J_{ER}$ ) was not considered in this study.

The pesticide can be applied to the soil directly onto the soil or on canopy. The portion of the applied pesticide deposited on the soil is termed as  $J_{APP}$  where as  $J_{FOF}$  is the pesticide applied

to the canopy and later transported to the soil surface. It is assumed that pesticide is directly applied to the soil, hence  $J_{FOF} = 0$ .

The sorbed phase concentration ( $C_s$ ) to dissolved phase concentration ( $C_w$ ) is related by

where  $K_d$ =partition coefficient between the dissolved and solid phase( $\text{cm}^3/\text{g}$ ). Similarly vapour phase

concentration ( $C_g$ ) is obtained by

where  $K_H$ =Henry's constant, i.e., partition coefficient between the liquid phase and vapour phase( $\text{cm}^3/\text{cm}^3$ )

Parent-daughter relation is ignored since only behaviour of independent pesticide is considered in the simulation. Hence  $J_{TRN}=0$

The final mass balance equation would be, according to the above equations

$$\frac{\partial [C_w(\theta + K_d \rho_s + aK_H)]}{\partial t} = D_w \frac{\partial^2 (C_w \theta)}{\partial z^2} + D_g \frac{\partial^2 (aC_w K_H)}{\partial z^2} - \frac{V \partial C_w \theta}{\partial z}$$

$$-C_w \left[ K_s \theta + K_s K_d \rho_s + f \theta \varepsilon + a K_g K_H + \frac{Q}{A_w \Delta z} \right] \quad ..... 3.14$$

and this is the equation normally known as advective-dispersion equation of movements of pollutants in the soil environment. This equation is solved numerically by adopting finite difference technique. To obtain a solution, relation between  $\theta$  and  $V$  has to be established by studying water movement.

## *Water movement*

Water movement in the zone is assumed to be governed by Darcy' law and mass continuity. Then,

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$$\frac{\partial \theta}{\partial t} = -\frac{\partial V}{\partial z} \quad \dots \dots \dots \quad 3.15$$

where,  $\theta$ =volumetric moisture content and  $V$  =Average velocity of water in the soil to the direction of 'z'

In discrete form for a unit area( $1 \text{ cm}^2$ ),

$$(\theta^{r+1} - \theta^t) / \nabla t = -(V_i - V_{i-1}) / \nabla z$$

where suffix ‘r’ & ‘i’ are referring to a discrete step of time and distance

$$\text{or } \theta^{r+1} \nabla z = \theta^t \nabla z - (V_i - V_{i-1}) \nabla t$$

$\theta \nabla z$  = soil moisture in the compartment (SW)

The model differentiates the entire soil layer into 3 zones i.e.; the surface, root zone and below root zone.

In the surface zone,

$$SW_i^{t+1} = SW_i^t + INF - I_i - E_i - U_i \quad \dots \quad 3.17$$

Similarly, in the root zone,

$$SW_i^{t+1} = SW_i^t + I_{i-1} - I_i - U_i \quad 3.18$$

and in the below root zone.

$$SW_i^{t+1} = SW_i^t + I_{i-1} - I_i \quad 3.19$$

where,  $J$  = percolation out from the compartment (cm/d)

E = evaporation(cm/d)

$U = \text{transpiration(cm/d)}$

INF = infiltration into the compartment = rainfall+irrigation supply(P) - runoff(Q) - evaporation(E) and

where, S=watershed retention characteristic used in calculation of run-off by curve number method.

From the above equations it appears that the final term in the water balance to be defined is the percolation, I. There are two options allowed in the model to represent the soil percolation properties namely, 1)free drainage 2)restricted drainage. Under the free drainage condition excess water(soil moisture in excess of field capacity level) in the entire soil profile is drained out within one time step(a day). Water balance accounting in this manner is most accurate for sandy soil in which water movement is relatively unimpeded and is least accurate for clay soils. The second option is applicable for less permeable soils in which the moisture content is allowed to rise up to a maximum soil moisture storage which is higher than the level at field capacity. The drainage rate is also modified to allow drainage to field capacity over a period in excess of one day and the rate is assumed to be a first order function of the water content above the level of field capacity.

The model considers the field capacity and wilting point to be at 0.33bar and 15bar suction pressure respectively.

### **3.2.2 WAVE model**

The model is a mathematical tool which simulates transfer and transformation of matter and energy in the environment of soil and crops in vadose zone. The main features of the model could be summarised as follows.

**Table 3.1:Main features of the WAVE model**

<b>Feature</b>	<b>Description</b>
Process-based	The laws of physics, chemistry and biology are considered in developing the model. For a given set of inputs gives a definite set of outputs.
Deterministic	For a given set of inputs gives a definite set of output.
Numerical	Finite difference technique is employed to solve equations governing the processes.
Holistic	Integrates the different sub processes (by means of sub models) ruling the complex whole process.
One-dimensional	Assumes the processes occur in the sub soil in the vertical direction only. (components in other directions are negligible)

The whole model consists five sub models i.e.:

1. Water and transport model (WAT)
2. Solute transport model (SOL)
3. Nitrogen fate model (NIT)
4. Heat transport model (HEAT)
5. Crop growth model (CROP)

Each of the above model has different functions to produce the outputs according to the requirements given in the input files. These models are inter connected except CROP which is optional and has separate input file. The user can select specific models in accordance with his requirements. The required models to be simulated has to be indicated in the input file, GENDATA.IN. The selection of models input files according to the requirements should be as follows.

**Table 3.2:Sub models and input file requirements**

<b>Requirement</b>	<b>Model to be selected</b>	<b>Input files</b>
1.1 Modelling water with no vegetation	WAT	GENDATA, WATDATA, CLIMDATA
1.2 Modelling water with vegetation without crop growth model	WAT	_do_
1.3 Modelling water with vegetation with crop growth model	WAT, CROP	as in 1.1+CROPDATA
2.1 Modelling heat with no crop growth model	WAT, HEAT	as in 1.1 + TEMPDATA.IN
2.2 Modelling heat with crop growth model	WAT, HEAT, CROP	as above+CROPDATA
3.1 Modelling solutes with no nitrogen and with no crop growth model	WAT, HEAT, SOL	as in 2.1+ SOLDATA.IN
3.2 Modelling nitrogen and with no crop growth model	WAT, HEAT, SOL, NIT	as in 3.1+ SOLDATA.IN +NITDATA.IN
3.3 Modelling solutes with nitrogen and with crop growth model	WAT, HEAT, SOL, NIT, CROP	as in 3.2 +CROPDATA.IN

The fate of the agrochemical is the main concern of the study, hence crop growth could be forgone and will not be discussed further. WAVE model is used to find the fate of

fertiliser(nitrogen) and it comes under 3.2 of the above table. Sub models in 3.2 is discussed in detail below.

**WAT:** This model simulates moisture balance in the vadose zone. The total zone is divided into layers according to the type of soil and in each soil layer is assumed to be homogeneous, isotropic, isothermal and rigid (incompressible) porous media. Flow of the moisture (water) is governed by Darcy's law and the mass conservation and the relation of time( $t$ ), depth( $z$ ), moisture content( $\theta$ ) with pressure head( $h$ ) in cm is given by

Where,  $K(\theta)$ =Hydraulic conductivity(cm/d) at the moisture content,  $\theta$

units of other parameters are same as in PRZM2

The soil moisture characteristics(MRC) and hydraulic conductivity(HCC) are used to calculate the pressure heads and thereby moisture content in each soil compartment. Soil compartment is discretised( $\Delta z$ ) form of the soil layer.

MRC of a soil is hysteresis function or the wetting and drying properties are not reversible. If the behaviour is assumed to be non-hysteretic as a simplification, then by Van Genuchten's MRC model can be applied as follows.

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left(1 + (\alpha|h|)^N\right)^m} \quad \dots \dots \dots \quad 3.22$$

Where,  $\theta_s$  =volumetric saturated soil moisture content( $\text{cm}^3/\text{cm}^3$ )

$\theta_r$  =volumetric residual soil moisture content( $\text{cm}^3/\text{cm}^3$ )

$\theta(h)$ = Volumetric soil moisture content at the pressure head 'h'

$\alpha$ =inverse of the air entry value( $\text{cm}^{-1}$ )

N & m are shape factors in MRC curve

The above values are input parameters (if non hysteresis condition is assumed) for each soil layer with the condition,  $m=1-1/N$

Similarly for HCC five model equations are available. For clarification of input parameters the equation to be used is given below.

$K(se)$ , Hydraulic conductivity at the pressure head 'h' is given by the Van Genuchten(1980) model, as follows.

$$K(se) = K_{sat}(se)^p (1 - (1 - se^{1/m})^m)^2 \dots \quad \dots \quad 3.23$$

Where,  $K_{sat}$ =Hydraulic conductivity(cm/d) at the saturation

$$se = (\theta - \theta_r) / (\theta_s - \theta_r)$$

m is same as in MRC model

$p$  is pore connectivity parameter that can be taken as 0.5

The model parameters  $\alpha$ ,  $N$ ,  $m$ ,  $\theta_r$  &  $\theta_s$  by curve fitting methods using non-linear optimisation techniques.

The curves need to be obtained by testing the field samples.

Vegetation properties needed by the model are

1. Starting date and the date of maximising plant senescence depth of water uptake
  2. Leaf Area Index(LAI)
  3. Root depth
  4. The potential soil water uptake rate - as a function of the depth below the surface
  5. Water sink terms

**Boundary conditions:** The soil profile drains freely at the bottom is taken as the boundary condition.

**SOL:** In this model it is assumed that transport of solute happens in three ways, by chemical diffusion, convection and dispersion. Here the solute means all inorganic matter. Organic matters are simulated in NIT model. Transport, solution and adsorption processes of three solutes viz. 1)Urea 2)Ammonium 3) Nitrate are simulated by the sub-model. It is further

assumed that the materials exist in a mobile and immobile phase. The description of the processes is given by the equations,

$$\frac{\partial(\theta_m C_m)}{\partial t} + \frac{\partial(\rho k_d C_m)}{\partial t} = \frac{\partial}{\partial x} \left( \theta_m D_m \frac{\partial C_m}{\partial x} \right) - \frac{\partial(q_w C_m)}{\partial x} \quad \dots \quad 3.24$$

Where,  $C_m$ =dissolved concentration of the solute(mg/m<sup>3</sup>)

$\theta_m$ =moisture content( $m^3/m^3$ )

$k_d$ =The sorption constant( $\text{cm}^3/\text{g}$ ), of the solute, same as described in the PRZM2 model.

$q_w$  is water flux( $\text{m}^3/\text{d}/\text{m}^2$ ) in the direction of 'z'

$$D_m = D_e \cdot \theta_m + \lambda V_m$$

where,  $\lambda$  is soil solute dispersivity(m) and

$V_m$ =Average macroscopic pore water velocity(m/d)

$D_e$  is effective diffusion constant( $m^2/d$ ), in water,

$D_e$  is related to the chemical diffusion,  $D_f(m^2/d)$ , by the equation of Kemper and Van

Schaik(1966), De= Dif.a.Exp(bθ<sub>m</sub>)/ θ<sub>m</sub>

where a & b are empirical constants

The equation 3.24 is the same as a classical advective-dispersion equation but without decay terms because of the conservative solutes, Urea, Ammonia and Nitrate are considered to be transformed into simpler form of chemicals the transformation together with the decay and volatilisation and plant uptake processes are dealt under the simulation of nitrogen in NIT model.

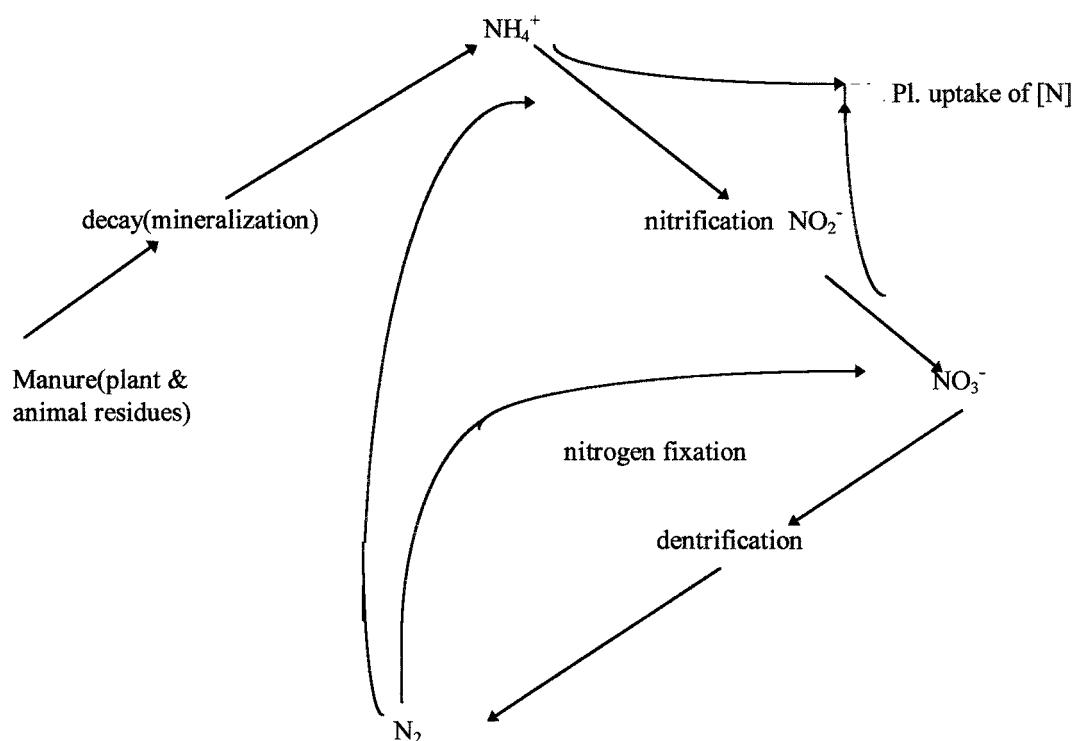
Boundary condition: Daily dry and wet atmospheric deposition amount of the solutes in the top and zero concentration gradient in the bottom

**NIT:** This model simulates the cycle of Nitrogen in the system. The processes related with fate of  $[N]$  and entertained by the model are

### Chapter 3

- Mineralization
- Denitrification
- Volatilisation
- Nitrification
- Hydrolysis of urea

The above processes are sub-processes of the whole nitrogen cycle. Organic nitrogen can be added to soil by direct application of manure(plant and animal residues) and by natural processes in which conversion of molecular  $N_2$  to combined forms occurs through the bacteria known as biological **nitrogen fixation**. Organic forms of nitrogen in turn are converted to ammonia known as **mineralization**. The conversion of the ammonia into nitrate by oxidation is known as **nitrification**. The accumulated nitrate has to be returned back to the atmosphere to complete the nitrogen cycle and this is done by the bacteria and the process is known as **denitrification**.



**Figure 3.3:Diagram of natural nitrogen cycle in soil**

### Chapter 3

The constants associated with these processes are:

volatilisation constant ( $C_v$ )

nitrification constant ( $C_n$ )

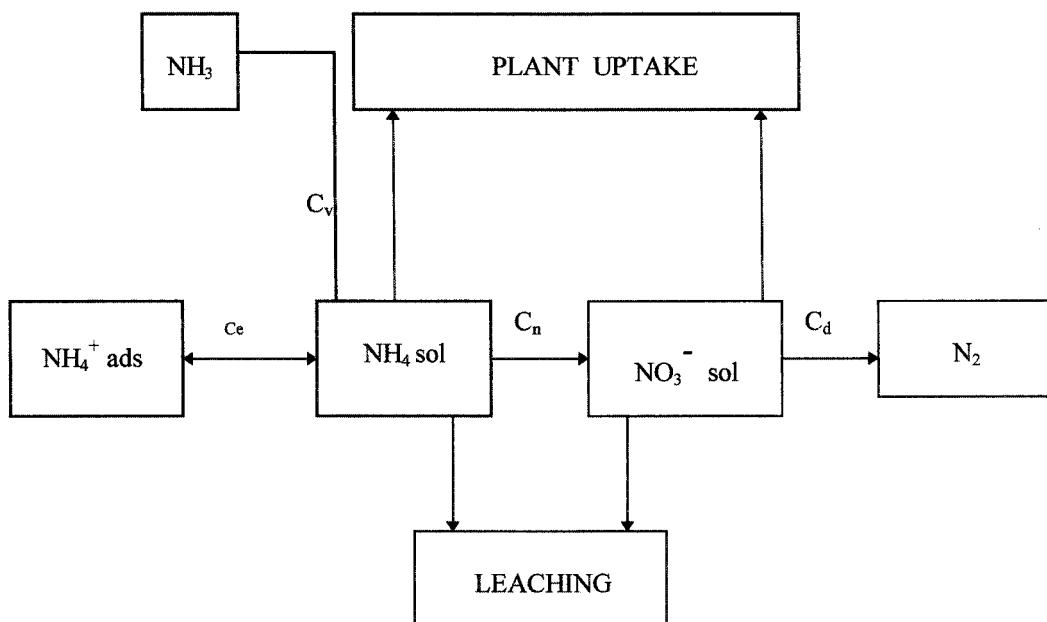
ureum hydrolyse constant ( $C_e$ )

dentrification constant ( $C_d$ )

The mineralization of organic carbon occurs in accumulation of organic matter at **Humus pool** by application of manure from the **manure pool**, and through bio\_mass, the **litter pool**. The transformation of [C] into organic matter is known as ‘decay’. A part of the turned\_over(decayed) [C] will decomposed into  $\text{CO}_2$  and other simpler forms, the balance of non\_decomposed humus is related with ‘synthesis efficiency constant ( $f_e$ ) and only a portion of this, goes to the humus pool, and the portion goes to the pool is related with ‘humification constant’ ( $f_h$ ). The ratio of C/N(known as  $r_0$ ) and the temperature of the media critically affect the rate of the process.

So the inputs for the model related to the process are  $r_0$ ,  $f_e$ ,  $f_h$ ,

The processes could be represented in a flow chart as follows.



**Figure 3.4:Schematic flow chart of the nitrogen cycle**

The produced [N] in the above processes is consumed by the plants at varying rates at different growing stages and the amount of consumption depends various factors and out of which the input for the model are:

- consumption period referred by *the period/total growing season* known as 'G'
  - peak value known as RNMAXP
  - root density at soil surface known as W0\_RDNS
  - reduction factor of the root density against depth known as ALFA\_RDENS is assumed to be related with root density at depth x, as follows.

RDENS= W0\_RDNS.exp(-ALFA\_RDENS.x).....3.25

The initial values of [C] and [N] in each of the pools(humus, litter & manure) are necessary inputs. As for the boundary condition, distribution of [N] in the plants should be given in fractions in above the ground level, living root and the balance remaining in the harvest.

**HEAT**: This model simulates temperature in soil compartments. The simulation results are utilised by the other models for example to simulate the organic carbon mineralization process in NIT model the temperature values are necessary input values. All the required inputs values to run the model are supplied by the climatic data input file.

Boundary condition: By default, the lower boundary condition is taken as 7°C. The upper BC is obtained by the equation,

$$T = T_a + \gamma \sin(2\pi t/p) \dots \quad 3.26$$

Where,  $T_a$ =average daily soil surface temperature( $^{\circ}\text{C}$ )

$\gamma = (\text{Max} - \text{min}) / \text{temperature}$

t & p=1 day

All the above values are available in the climatic data input file.

### **3.3 Field tests and Soil investigations**

For texture analysis of the soils disturbed samples were collected up to about 1.5m depth. The samples were tested for particle size distribution to determine the percentage of silt, sand, clay and also carbon content. The sample sites were chosen in best representative of the vicinity to achieve maximum information at minimum sampling. The aerial photos in 1:50,000 scale were used to select the site locations. All of the sites were from the farms. Few sites were selected at natural vegetation too for comparison. Hand auger was the instrument used to collect sample. All the disturbed samples were tested at the laboratory of Kenya Soil Survey. Deep auguring had to be avoided due to constrain in time and the equipment's.

Undisturbed samples were collected in core cylinders having standard diameter and height of 5cm.

Undisturbed samples were collected for measurement of density, moisture content, and also to obtain moisture retention characteristic). Soil moisture characteristic gives the variation of moisture content with suction pressure measured in pF scale.

pF is given by,

where ‘F’ is the amount by which the hydrostatic pressure of water in the soil pore space is less than the atmospheric pressure(suction pressure) in centimetres of water.

Determination of soil moisture characteristic can not be done in ordinary laboratory as the test needs special equipment and trained personnel hence half of the undisturbed samples were sent to Poland for the soil moisture characteristic determination. Density of the sample is measured as,

weight of the sample/volume of the sample = (weight of the sample in grams)/( $\frac{4}{3}\pi r^3$ ) g/cm<sup>3</sup>  
and,

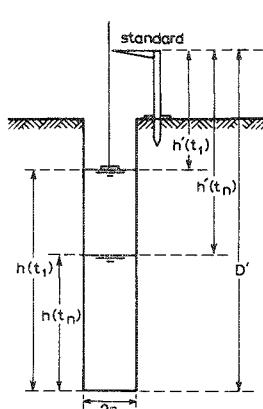
From the above two definitions, Dry Bulk density is defined as,

Dry Bulk Density =density/(1+moisture content)

Henceforth when it states "Bulk density" means Dry Bulk density.

Volumetric moisture content = Volume of water in the sample/Volume of the soil sample.

Saturated hydraulic conductivity( $K_s$ ) is a basic parameter necessary for analysis of movement of solutes. The method used for determination of  $K_s$  is known as Inverse Auger Hole method. The method is described in French literature as the Porchet method. This method can be adopted to determine the insitu  $K_s$  in unsaturated zone at shallow depths. Procedure of this method is to auger a hole up the depth where the  $K_s$  need to be measured. Then water is filled quickly up to the top of the hole(surface level) and the lowering depth of the water is measured against time using a stop watch and a floater connected to a measuring tape.



$h(t_1)$ =height of water at the start

$h(t_n) = h$  = height of water after time ' $t$ '

$h'(t_1)$ =reading at the start

$h'(t_n)$  = reading after time 't'

D' = maximum reading

$$\therefore h = D' - h'(t_n)$$

**Figure3.5:Arrangement of inverse auger hole apparatus**

### Method of calculation

Suppose at time  $t$ , the height of water in hole =  $h$

The area of infiltration =  $2\pi rh + \pi r^2$

where  $r$ =radius of the hole

According to Darcy's law

$$\text{Rate of flow} = -K_s \times (\text{hydraulic gradient})$$

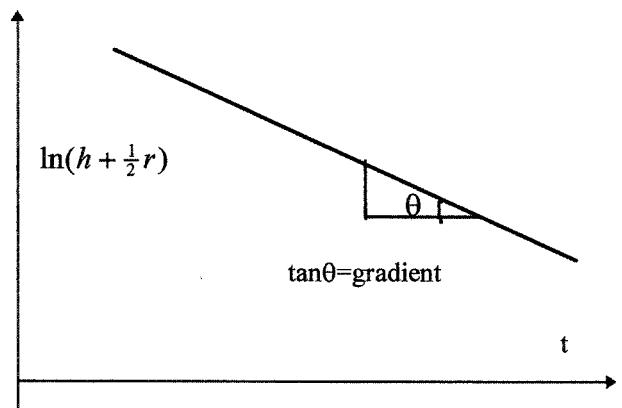
assuming hydraulic gradient=1, approximately

$$\text{Discharge} = \text{Area} \times \text{Rate of flow} = -(2\pi rh + \pi r^2) \cdot K_s \cdot 1$$

$$\text{Discharge} = d(\pi r^2 h) / dt$$

$\therefore \pi r^2 dh/dt = -K_a(2\pi rh + \pi r^2)$  by rearranging.

$$\int_{h_0}^h \frac{dh}{(h + \frac{1}{2}r)} = - \int_0^t \frac{2}{r} K_s dt$$



by integration,  $\ln(h + \frac{1}{2}r) \ln(h_0 + \frac{1}{2}r) = -(2 K_s / r)t$ .....3.29

where  $h_0$ =the height of water at  $t=0$

the graph of  $\ln(h + \frac{1}{2}r)$  Vs  $t$  would be a straight line and

the gradient=2 K<sub>s</sub> /r or K<sub>s</sub> =r/2.gradient

By plotting  $t$  Vs  $\ln(h + \frac{1}{2}r)$  a value for  $K_s$  can be obtained. This test was carried out at all visited sites.

The test results are shown in Appendix A.

## Chapter 4

### 4 Parameter estimation and data analysis

In this chapter the parameters which need to run the simulation models (PRZM2 & WAVE) were estimated. Field tested parameters were limited to six sites therefore those field tested parameters were correlated with their soil texture to estimate the parameters at other sites. With the estimated data the simulations were done and the results were analyzed.

#### 4.1 Field data

##### 4.1.1 Depth to groundwater

Previous bore hole records of groundwater depth were available and from this data set point map of the groundwater depth map was prepared. Location of bore holes and the depths to groundwater are shown in Fig. 4.1

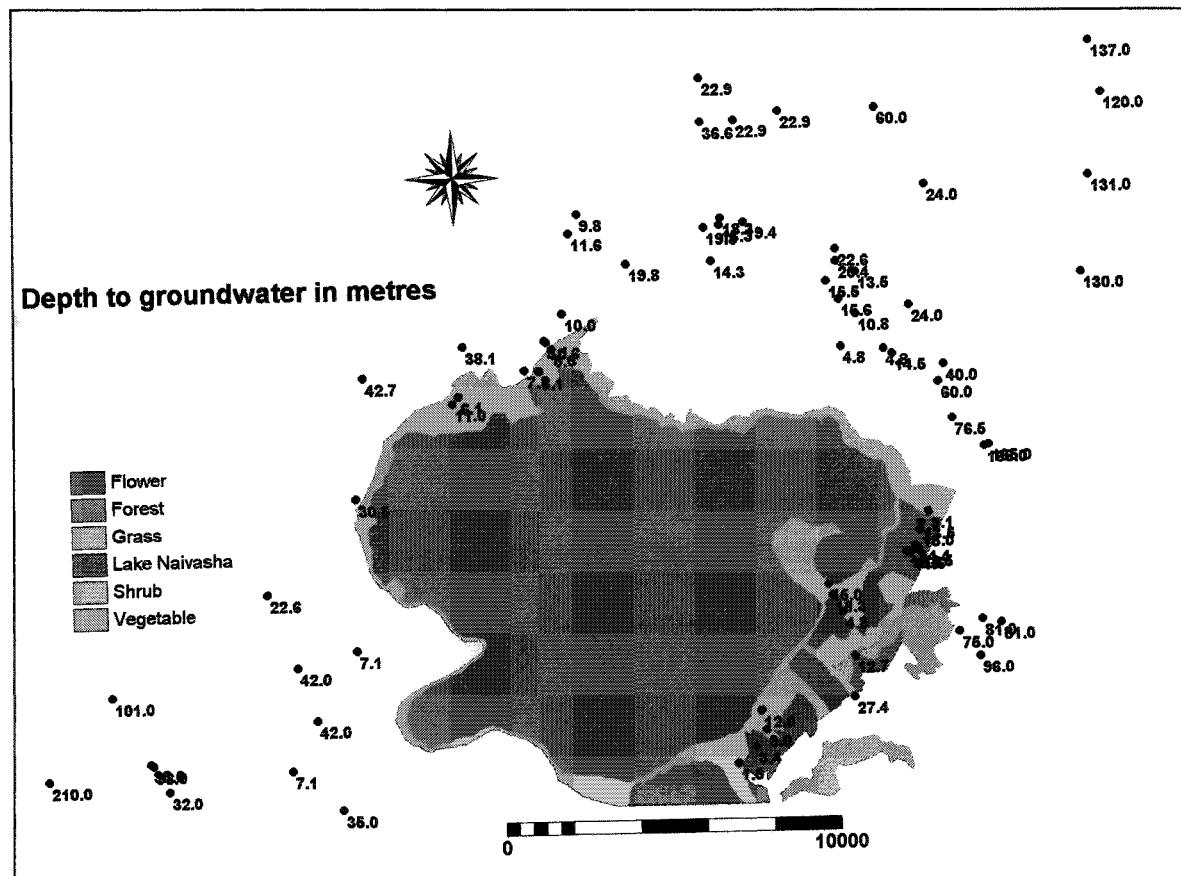
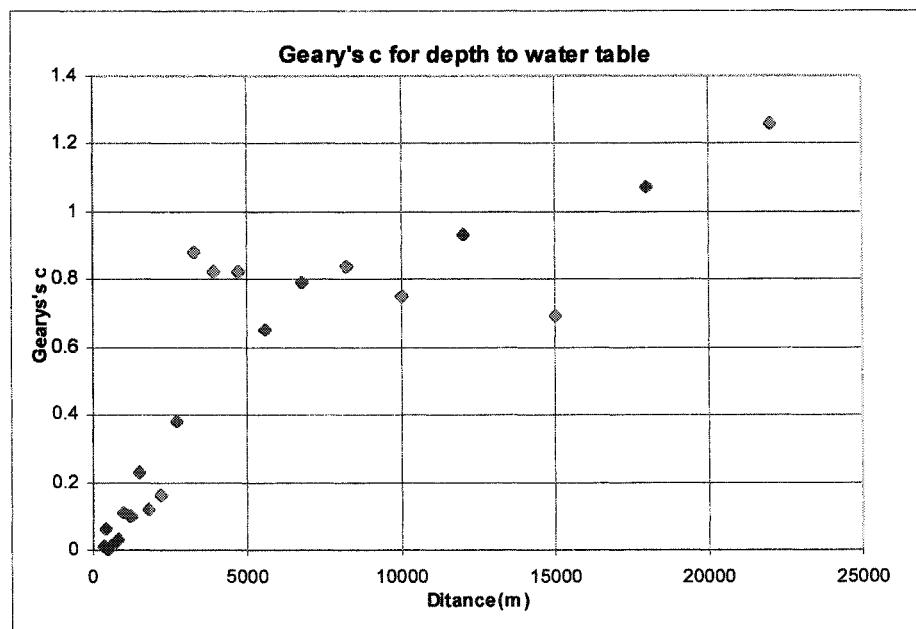


Figure 4.1: Distribution of groundwater bore hole and depth to groundwater

The above point map were used for interpolation by moving average in ILWIS in order to obtain the depth of the vadose zone. Before the interpolation Geary's c was checked and its variation is given below.

**Table 4.1:Geary's c  
for depth of groundwater table**

Distance (m)	No of pairs	Variance
330	5	0.01
390	4	0.06
470	3	0
680	12	0.02
820	9	0.03
1000	12	0.11
1200	17	0.1
1500	19	0.23
1800	19	0.12
2200	20	0.16
2700	40	0.38
3300	76	0.88
3900	78	0.82
4700	101	0.82
5600	120	0.65
6800	155	0.79
8200	183	0.84
10000	239	0.75
12000	302	0.93
15000	520	0.69
18000	337	1.07
22000	335	1.26



**Figure 4.2:Graph for the table 4.1**

From the graph, when the distance go beyond 18,000m the Geary's c closer to 1 i.e., the spatial independence is reached

## 4.2 Results of field investigation

### 4.2.1 Disturbed samples

The results obtained from the disturbed samples are as follows. Locations of the sites are shown in the page 13 and 14.

**Table 4.2:Test results of disturbed samples**

Site	Location		Soil layer thickness (cm)	Percentages					Texture Class
	X	Y		Sand	Silt	Clay	Org.C	Org.N	
1	214291	9917489	20	40	25	35	1.34	0.18	CL
			100	36	38	26	0.54	0.23	L
2	214517	9917495	23	20	42	38	1.64	0.16	C
			27	30	39	31	1.04	0.12	CL
3	214703	9917462	70	20	35	45	0.63	0.04	C
			30	26	40	34	1.88	0.19	CL
			20	35	38	27	0.75	0.17	CL
4	214802	9917397	50	36	38	26	0.57	0.04	L
			20	27	33	40	1.67	0.14	L
5	214909	9917360	30	23	41	36	0.99	0.02	CL
			20	25	30	45	1.64	0.42	C
6	213428	9917391	30	29	34	37	1.04	0.12	CL
			60	24	36	40	0.57	0.04	C
7	214311	9917382	20	28	21	51	3.49	0.65	C
			30	28	28	44	0.51	0.03	C
			70	44	11	45	0.45	0.04	SC/C
8	214514	9917399	19	46	22	32	0.00	0.34	SCL
			31	40	20	40	0.27	0.08	CL/C
			70	42	21	37	0.09	0.06	CL
9	214683	9917391	20	30	20	50	4.43	0.26	C
			30	35	30	35	0.87	0.07	CL
			70	40	35	25	0.63	0.05	L
10	211351	9911406	20	32	16	52	2.60	0.25	C
			30	28	28	44	1.28	0.10	CL/L
			70	52	28	20	0.57	0.06	SL/SCL
11	211270	9911507	20	54	28	18	2.44	0.05	L
			30	60	24	16	1.29	0.05	SL
			70	60	28	12	1.00	0.07	SL/L
12	211143	9911593	35	54	32	14	1.98	0.05	SL
			15	58	30	12	0.60	0.06	SL
			70	62	28	10	0.55	0.00	SL
13	211143	9911593	30	54	32	14	1.35	0.06	L
			20	54	32	14	0.49	0.07	L
			70	58	30	12	0.43	0.03	L
14	211513	9911587	20	46	42	12	2.04	0.04	L
			30	46	32	22	1.41	0.07	L
			60	52	34	14	0.66	0.05	L
15	211244	9911817	20	46	32	22	1.98	0.05	L
			30	54	32	14	1.64	0.04	SL
			70	60	28	12	0.55	0.07	SL
16	211042	9911922	20	56	28	16	1.23	0.02	SL
			30	50	28	22	1.12	0.06	L
			70	52	30	18	0.63	0.04	L
17	210541	9912155	20	66	18	16	1.46	0.07	SL
			30	68	22	10	0.63	0.05	SL
			60	60	28	12	0.51	0.04	SL

Site	Location		Soil layer thickness (cm)	Percentages					Texture Class
	X	Y		Sand	Silt	Clay	Org.C	Org.N	
19	209153	9908282	20	72	18	10	0.66	0.09	SL
			32	68	13	19	0.53	0.06	SL
			26	48	31	21	0.34	0.05	L
			32	42	35	23	0.53	0.03	L
20	208860	9908272	20	68	22	10	0.78	0.08	SL
			35	49	33	18	0.28	0.05	L
			25	44	36	20	0.09	0.03	CL
			30	48	34	18	0.16	0.02	SCL
21	206964	9908301	20	54	32	14	0.87	0.02	SL
			30	70	24	6	0.51	0.00	SL
			60	68	28	4	0.09	0.00	SL
22	206741	9908398	20	52	38	10	0.63	0.02	SLL
			30	58	38	4	0.21	0.00	SL
			70	76	20	4	0.21	0.01	LS
23	206561	9908508	20	40	46	14	0.69	0.01	L
			30	54	40	6	0.33	0.00	SL
			70	70	24	6	0.15	0.00	SL
24	205784	9908267	20	56	30	14	2.06	0.07	SL
			30	66	24	10	0.21	0.05	SL
			70	62	30	8	0.33	0.03	SL
25	205850	9908522	20	52	30	18	0.39	0.12	L
			30	54	32	14	0.39	0.03	SL
			70	66	28	6	0.09	0.04	SL
26	205702	9907957	20	74	16	10	0.87	0.02	SL
			30	76	14	10	1.22	0.02	SL
			70	68	26	6	0.21	0.00	SL

#### 4.2.2 Undisturbed samples

##### 4.2.2.1 MRC parameters of Van Genuchten's model

Undisturbed samples were collected to determine the parameters of Van Genuchten's moisture retention characteristic (MRC) model (see page 33), and other parameters. Undisturbed samples were collected from six sites( 2, 3, 7, 8, 18 & 26), two samples in each site. From this 12 samples, experimental MRC curves were obtained. The experimental MRC curves of the six sites are given in the appendix B. The experimental curves were fitted to the Van Genuchten's MRC model, using the curve fitting method. The model equation is,

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{(1 + \alpha h^N)^{1-\frac{1}{N}}}$$

The curve fitting procedure adopted here is as follows;

The differences between the actual and model values of  $\theta_s$ ,  $\theta_r$ ,  $\alpha$  and 'N' should be minimised. If the model fits with the experimental data, the curve between  $\theta(h)$  and  $1/(1+\alpha h^N)^{1-1/N}$  should give a straight line with  $\theta_r$  as intercept and  $\theta_s - \theta_r$  as gradient, where  $\theta(h)$  and  $h$  are values obtained experimentally. To achieve this,  $\alpha$  and  $n$  were fitted to yield maximum  $R^2$  of  $\theta(h)$  vs  $1/(1+\alpha h^N)^{1-1/N}$ . Computer spread sheet (excel) along with the built-in solver option was used to solve this. The curves of  $\theta(h)$  and  $1/(1+\alpha h^N)^{1-1/N}$  in the six sites are shown in the Appendix B. The average results of the paired samples in each site are tabulated in the Table 4.3 with their respective soil texture. The parameters directly obtained from the moisture characteristic curves are Field Capacity(FC) and Permanent Wilting Point(PWP).

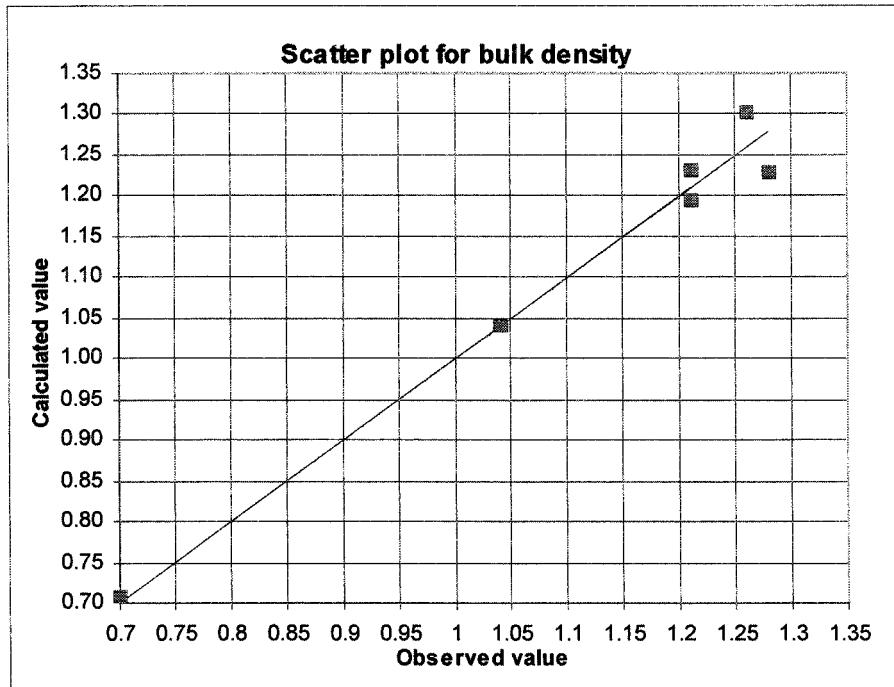
**Table 4.3:Summary of test results of undisturbed samples**

Site	Percentages				B.density (g/cm <sup>3</sup> )	FC(%) (pF=2.54)	PWP(%) (pF=4.2)	$\alpha(\text{cm}^{-1})$	N	$\theta_s$	$\theta_r$
	Sand	Silt	Clay	Carbon							
2	20	42	38	1.64	1.21	39.49	26.05	0.08343	1.10779	54.54	0.00
3	26	40	34	1.88	1.21	43.92	32.76	0.03686	1.08298	53.97	0.00
7	46	22	32	0.00	1.04	36.81	26.05	0.18698	1.09426	53.74	0.00
8	30	20	50	4.43	0.70	38.57	25.75	0.06946	1.22556	65.92	12.68
18	66	18	16	1.46	1.28	28.71	14.27	0.04537	1.19635	49.14	0.61
26	74	16	10	0.87	1.26	30.56	18.79	0.07221	1.20621	51.65	7.05

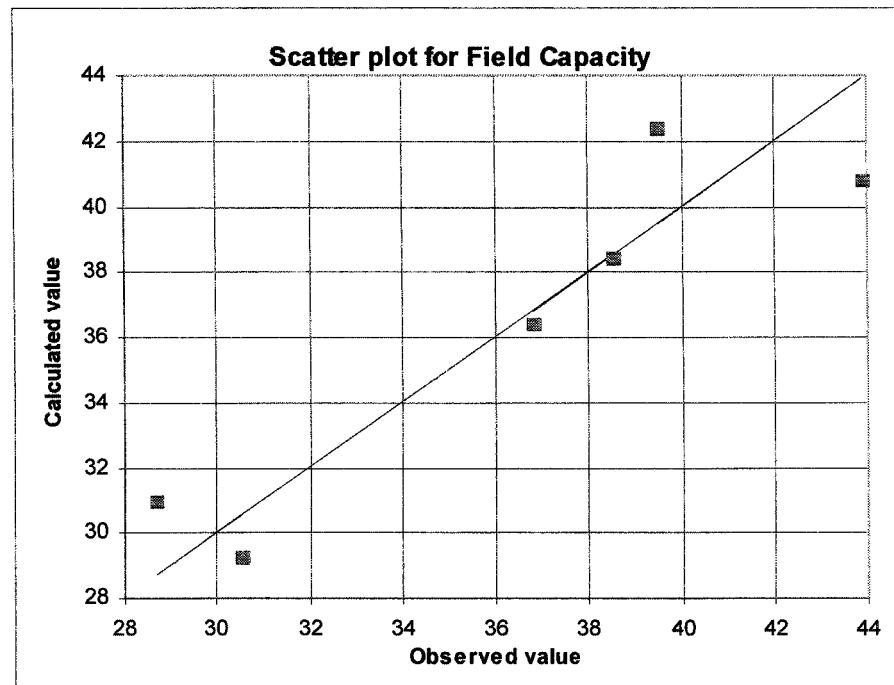
#### **4.2.2.2 Correlation between soil texture and the parameters**

It is possible to use multiple regression analysis to correlate the above parameters with their soil texture (Cl% and Sa%) and percentage organic carbon (C%). For the regression analysis C%, Cl% and Sa% were used as the independent variables. The relationship between calculated(predicted) value and the independent variables is:

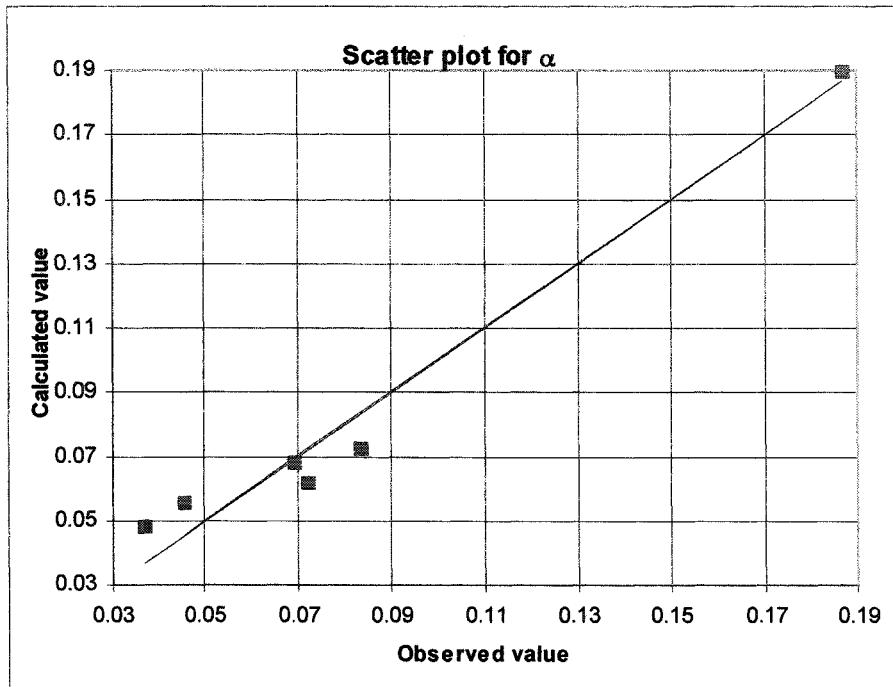
where  $m_1$ ,  $m_2$ ,  $m_3$  &  $c$  regression coefficients. The regression coefficients thus obtained for each parameter are tabulated in the Table 4.4. For comparison, the predicted values obtained from regression coefficients and measured(observed) values from the sample tests are plotted for each parameter as shown in Figures 4.3 to 4.9. These scatter plots compare the observed values for the parameters with the values based on texture information and carbon content.



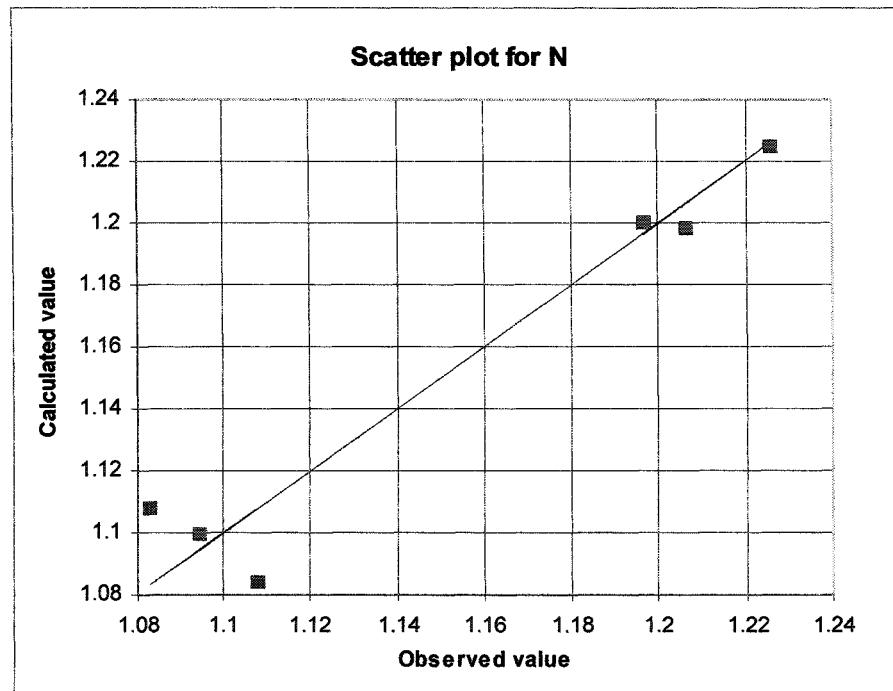
**Figure 4.3:Scatter plot for regression analysis of density**



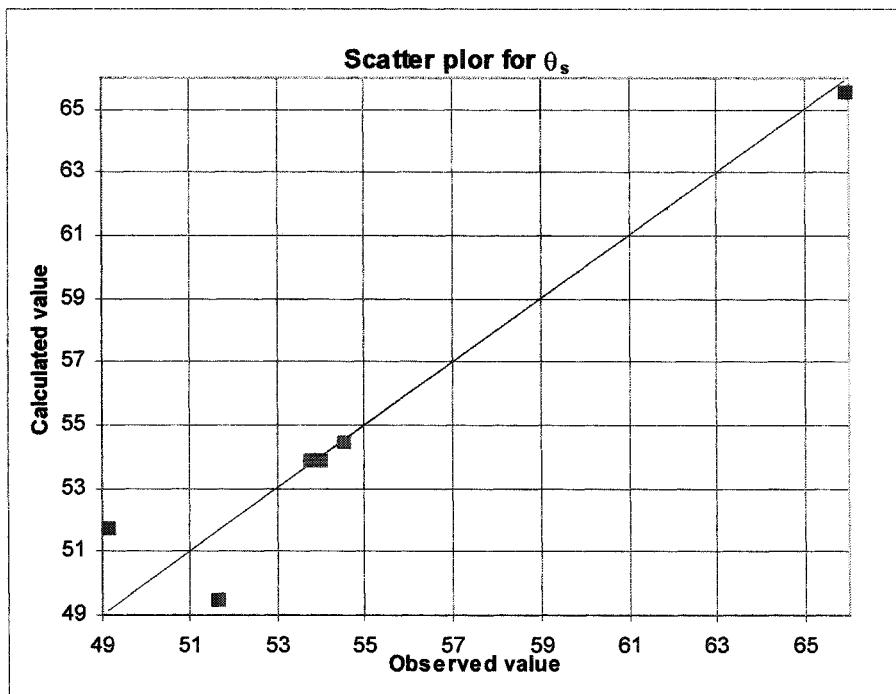
**Figure 4.4:Scatter plot for regression analysis of field capacity**



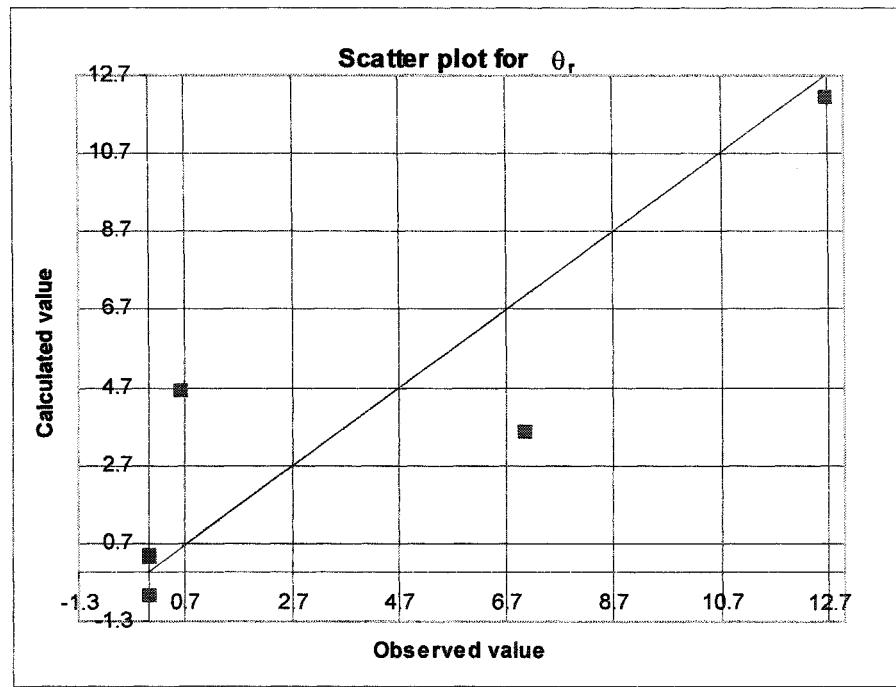
**Figure 4.5:**Scatter plot for regression analysis of  $\alpha$



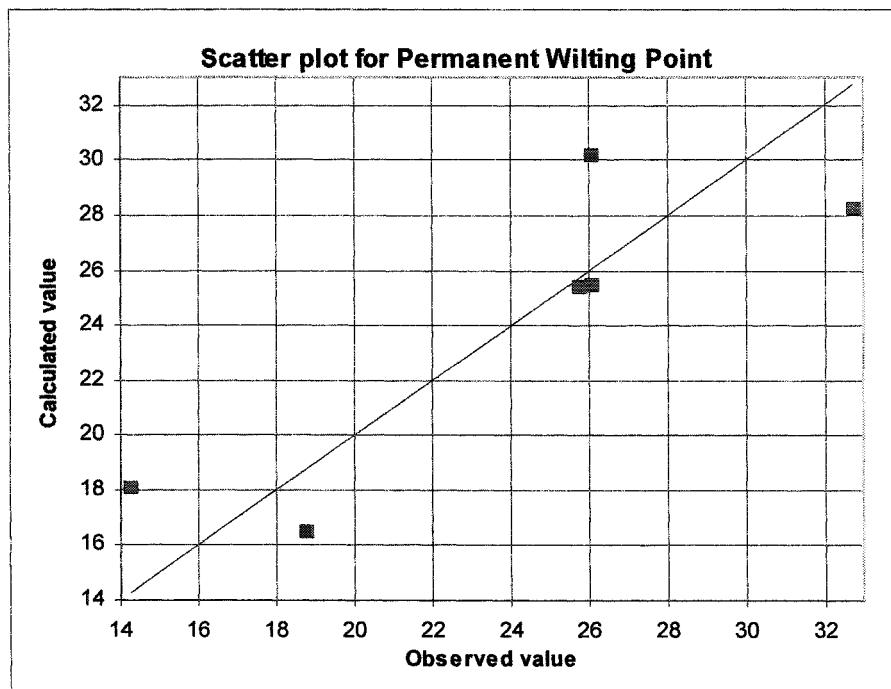
**Figure 4.6:**Scatter plot for regression analysis of N



**Figure 4.7:Scatter plot for regression analysis of  $\theta_s$**



**Figure 4.8:Scatter plot for regression analysis of  $\theta_r$**



**Figure 4.9:**Scatter plot for regression analysis of permanent wilting point

**Table 4.4:**Regression coefficients for deriving soil physical parameters from texture data in the study area

Parameter	$m_1$	$m_2$	$m_3$	c	$R^2$
BD	-0.00633	-0.02847	-0.0129	2.5451	0.979945
FC	-0.039394	-0.02362	-0.026044	49.09934	0.84768
$\alpha$	-0.04856	0.008148	0.003338	-0.22464	0.968079
N	0.036052	0.000789	0.003043	0.933875	0.937153
$\theta_s$	1.336711	0.473866	0.172718	30.77843	0.930976
$\theta_r$	2.464255	0.277567	0.256671	-20.3671	0.793809
PWP	-1.12279	0.06118	-0.2383	34.43891	0.724386

### 4.3 Saturated hydraulic conductivity ( $K_s$ )

The values of  $K_s$  were measured by inverse augerhole method at 13 different sites. Summary of the test results are tabulated below in the Table 4.5. In the table, the contents of carbon, clay and sand are representative of the core height of the test, i.e., the average value of the texture in first and second layers of the soil in each test site was taken as the representative soil texture for the  $K_s$ .

**Table 4.5:  $K_s$  values at test sites**

Farm No.	Site No.	K <sub>s</sub> (cm/d)	C%	Sa%	Cl%
1	2	15.6	1.34	25	41
1	3	41.8	1.32	31	31
1	7	12.8	0.13	43	36
1	8	34.7	2.65	33	43
2	12	136.8	1.87	57	17
2	14	48	0.92	54	14
2	18	221.3	1.05	64	13
3	21	118.0	0.69	62	10
3	22	140.0	0.42	55	7
3	23	111.3	0.51	47	10
3	24	135.2	1.14	61	12
3	25	118.3	0.39	53	16
3	26	185.0	1.05	75	10

There are several empirical relationships established between  $K_s$  and soil texture, density etc. For example, Vereecken et al. (1990),

$K_s = \exp(20.62 - 0.96\ln(Cl\%) - 0.66\ln(Sa\%) - 0.46\ln(C\%) - 8.43.d)$  cm/d  
where d=bulk density(g/cc)

Since only limited measurements(6) were made for bulk density,  $K_s$  was related with only Cl%, C% and Sa%. In general,  $K_s$  can be expressed as follows

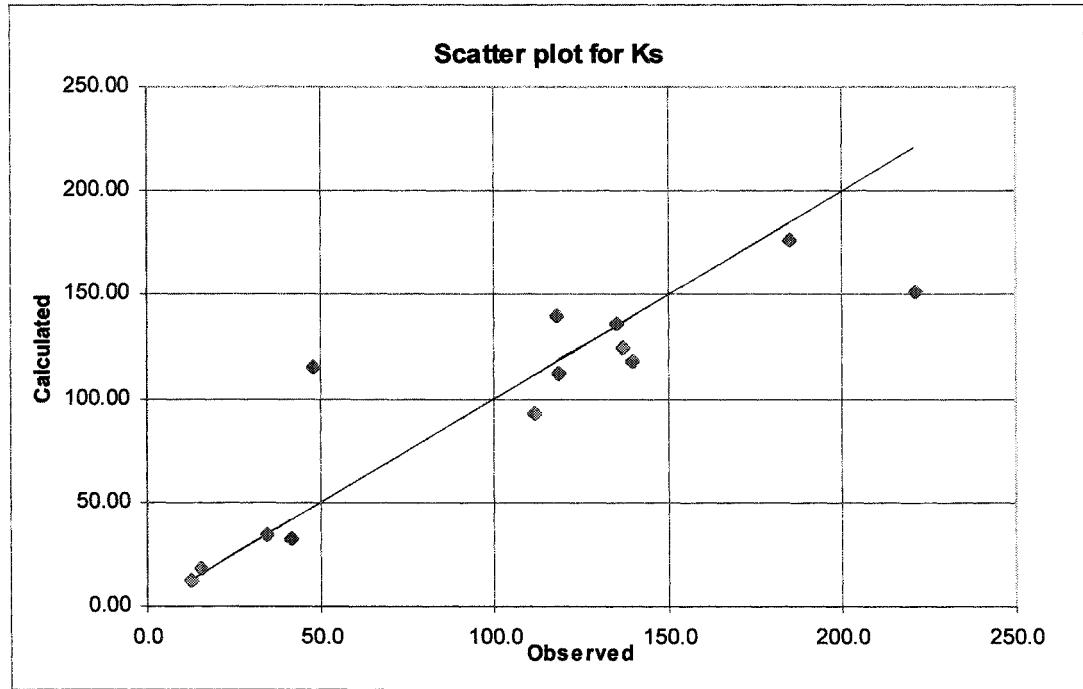
$$\ln(K_s) = C_0 + C_1(C\%)^a + C_2(C\%)^b + C_3(C\%)^c$$

Where  $C_0, C_1, C_2, C_3, a, b$ , &  $c$  are constants

The above constants were found by curve fitting method i.e., the constants were found at minimum error between the observed and predicted values. To achieve this, curve fitting method was adopted as described in the Van Genuchten's MRC model, at maximising the  $R^2$ . The maximum obtained,  $R^2=0.89$ . The final equation obtained is given below with the scatter plot.

$$\ln(K_s) = 6.681029 - 7.8731 \times 10^{-11} (C\%)^{-11.67} - 50.71453 (Sa\%)^{-0.811792} - 2.23364 \times 10^{-14} (Cl\%)^{8.022837} \dots \dots \dots 4.2$$

From the equation 4.2, we can observe that %C has a negligible effect on  $K_s$  compared to %Sa and %Cl.

Figure 4.10: Scatter plot for regression analysis of K<sub>s</sub>

#### 4.4 Estimation of the parameters

With the regression coefficients in the Table 4.4, the parameters were estimated for all sites using equation 4.1 & 4.2. The results are tabulated below.

Table 4.6: Estimated values of the parameters

Site	Soil layer thickness (cm)	Texture Class	FC(%)	PWP(%)	B. density (g/cm <sup>3</sup> )	N	a(cm <sup>-1</sup> )	θ <sub>s</sub> (%)	θ <sub>r</sub> (%)	K <sub>s</sub> (cm/day)
1	20	CL	37.33	25.54	1.02	1.13152	0.12901	56.06	2.92	63.1
	100	L	38.90	26.84	1.34	1.08341	0.08117	50.04	0.00	53.0
2	23	C	39.49	26.05	1.21	1.10779	0.08343	54.54	0.00	15.6
	27	CL	40.14	28.02	1.27	1.08712	0.07760	52.04	0.00	33.8
3	70	C	42.58	31.72	1.29	1.05297	0.17819	56.40	0.00	16.7
	30	CL	43.92	32.76	1.21	1.08298	0.03686	53.97	0.00	41.8
	20	CL	39.05	26.91	1.32	1.08872	0.07578	50.62	0.00	49.7
4	50	L	38.88	26.81	1.34	1.08449	0.07971	50.08	0.00	53.0
	20	L	40.46	28.58	1.19	1.10781	0.11032	56.63	1.78	22.2
	30	CL	41.87	30.05	1.22	1.06797	0.09740	53.13	0.00	15.0
5	20	C	40.88	29.39	1.09	1.10459	0.14584	58.61	2.58	13.8
	30	CL	40.26	28.62	1.11	1.08882	0.12315	54.71	0.00	29.0
	60	C	41.68	30.53	1.34	1.05903	0.15372	54.64	0.00	15.7
6	20	C	39.23	26.97	0.93	1.18516	0.11492	64.45	9.58	39.4
	30	C	40.57	29.89	1.04	1.07219	0.20258	57.15	0.29	20.4
	70	SC/C	36.40	26.20	1.10	1.11950	0.26706	60.30	4.53	53.3
7	19	SCL	36.81	26.05	0.90	1.09426	0.18698	53.74	0.00	12.8
	31	CL/C	37.63	27.05	0.95	1.09690	0.22170	57.00	1.67	56.8
	70	CL	37.25	26.59	1.04	1.09412	0.21268	55.69	0.90	76.6

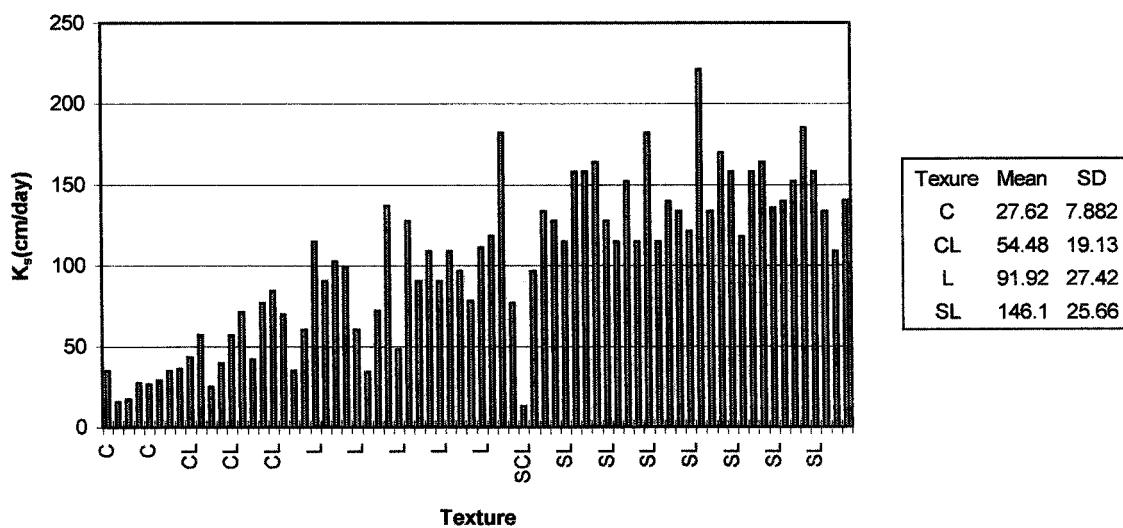
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Site	Soil layer thickness (cm)	Texture Class	FC(%)	PWP(%)	B. density (g/cm <sup>3</sup> )	N	a(cm <sup>-1</sup> )	θ <sub>s</sub> (%)	θ <sub>r</sub> (%)	K <sub>s</sub> (cm/day)
8	20	C	38.57	25.75	1.09	1.22556	0.06946	65.92	12.68	34.7
	30	CL	38.81	27.26	1.26	1.09937	0.13514	54.57	0.48	47.4
	70	L	37.84	25.73	1.31	1.09803	0.08201	50.38	0.00	66.4
9	20	C	38.51	27.08	0.94	1.16603	0.17963	64.42	8.69	11.0
	30	CL/L	40.26	29.02	1.02	1.09995	0.16519	58.18	2.19	20.4
	70	SL/SCL	34.86	22.63	1.30	1.12843	0.08424	50.00	0.00	107.5
12	20	L	33.65	19.93	1.32	1.20036	0.00100	51.90	4.50	136.8
	30	SL	32.59	19.67	1.31	1.17558	0.04340	50.45	2.65	134.2
	70	SL/L	32.80	19.75	1.42	1.16196	0.02489	48.16	0.83	134.2
13	35	SL	33.92	20.20	1.44	1.18062	0.00100	49.39	2.26	114.4
	15	SL	33.47	20.68	1.45	1.14146	0.03763	47.28	0.00	127.7
	70	SL	32.50	19.66	1.46	1.15024	0.03712	46.96	0.00	140.7
14	30	L	34.17	20.91	1.44	1.15790	0.00416	48.54	0.71	48.0
	20	L	34.51	21.88	1.45	1.12690	0.04591	47.39	0.00	114.4
	70	L	33.54	20.87	1.45	1.13533	0.04589	47.06	0.00	127.7
15	20	L	36.03	21.92	1.30	1.15686	0.00100	47.14	0.00	87.1
	30	L	36.04	23.24	1.32	1.14204	0.03972	51.03	1.02	87.0
	60	L	34.97	22.16	1.47	1.12694	0.03098	47.28	0.00	107.6
16	20	L	35.82	22.60	1.31	1.16259	0.01204	51.80	2.43	87.0
	30	SL	34.06	20.59	1.44	1.16836	0.00100	48.93	1.42	114.4
	70	SL	32.97	20.26	1.43	1.14574	0.04674	47.56	0.00	134.2
17	20	SL	33.65	20.69	1.36	1.16124	0.03296	49.68	1.48	121.0
	30	L	35.12	22.61	1.27	1.14376	0.06715	51.34	1.33	100.7
	70	L	34.88	22.44	1.36	1.12902	0.06503	49.13	0.00	107.6
18	20	SL	28.71	14.27	1.28	1.19635	0.04537	49.14	0.61	221.3
	30	SL	30.91	18.14	1.38	1.17139	0.05326	48.10	1.41	159.7
	60	SL	32.99	20.30	1.43	1.14430	0.04868	47.51	0.00	134.2
19	20	SL	29.85	17.15	1.33	1.18464	0.06516	48.84	2.52	171.8
	32	SL	30.73	18.80	1.12	1.17489	0.13145	52.24	3.67	159.6
	26	L	35.97	23.90	1.33	1.10876	0.09020	49.47	0.00	93.9
	32	L	37.41	25.24	1.34	1.09893	0.07724	49.64	0.00	73.3
20	20	SL	30.85	17.97	1.38	1.17679	0.04598	48.30	1.78	159.7
	35	L	35.80	23.55	1.40	1.10727	0.07201	48.15	0.00	97.3
	25	CL	37.13	25.08	1.41	1.08679	0.08084	47.98	0.00	84.1
	30	SCL	36.11	23.92	1.41	1.09990	0.07450	47.81	0.00	80.6
21	20	SL	34.36	21.45	1.44	1.14060	0.02746	47.90	0.00	118.0
	30	SL	30.53	17.55	1.47	1.16999	0.03318	46.39	0.52	165.8
	60	SL	31.26	18.38	1.55	1.14718	0.03060	44.54	0.00	157.8
22	20	SL/L	35.07	21.95	1.40	1.12270	0.00100	45.34	0.00	140.0
	30	SL	33.82	20.63	1.48	1.12108	0.00100	42.97	0.00	126.9
	70	LS	29.13	16.34	1.45	1.17585	0.05148	46.08	0.77	182.4
23	20	L	38.08	24.99	1.41	1.09151	0.00100	45.24	0.00	111.3
	30	SL	34.76	21.57	1.44	1.11481	0.00100	43.39	0.00	114.4
	70	SL	30.67	17.96	1.47	1.15701	0.05066	45.91	0.00	119.8
24	20	SL	33.37	19.64	1.41	1.18959	0.00100	49.84	2.97	135.2
	30	SL	31.59	19.09	1.41	1.15016	0.06698	47.20	0.00	152.5
	70	SL	32.63	19.78	1.52	1.14073	0.03150	45.72	0.00	140.7

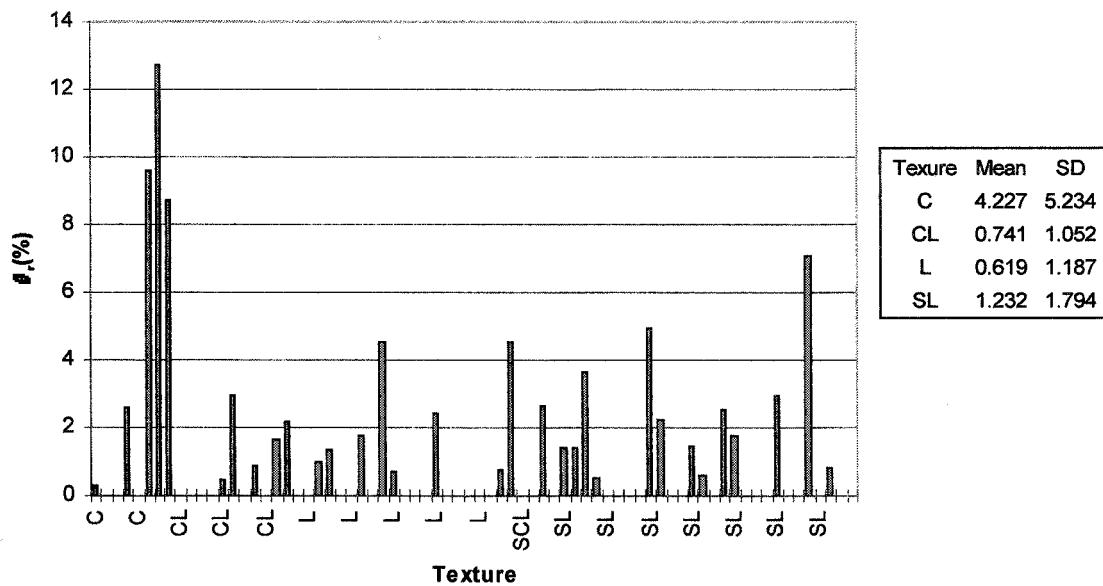
Site	Soil layer thickness (cm)	Texture Class	FC(%)	PWP(%)	B. density (g/cm <sup>3</sup> )	N	a(cm <sup>-1</sup> )	θ <sub>s</sub> (%)	θ <sub>r</sub> (%)	K <sub>s</sub> (cm/day)
25	20	L	34.98	22.71	1.36	1.12037	0.07668	48.81	0.00	118.3
	30	SL	34.55	21.99	1.45	1.12329	0.05077	47.26	0.00	114.4
	70	SL	31.73	18.98	1.52	1.14267	0.04022	45.14	0.00	151.7
26	20	SL	30.56	18.79	1.26	1.20621	0.07221	51.65	7.05	185.0
	30	SL	28.59	15.57	1.27	1.21700	0.05132	50.27	4.92	183.6
	70	SL	31.17	18.37	1.50	1.15309	0.04107	45.65	0.00	158.6

#### 4.5 Variation of the parameters with the soil texture class

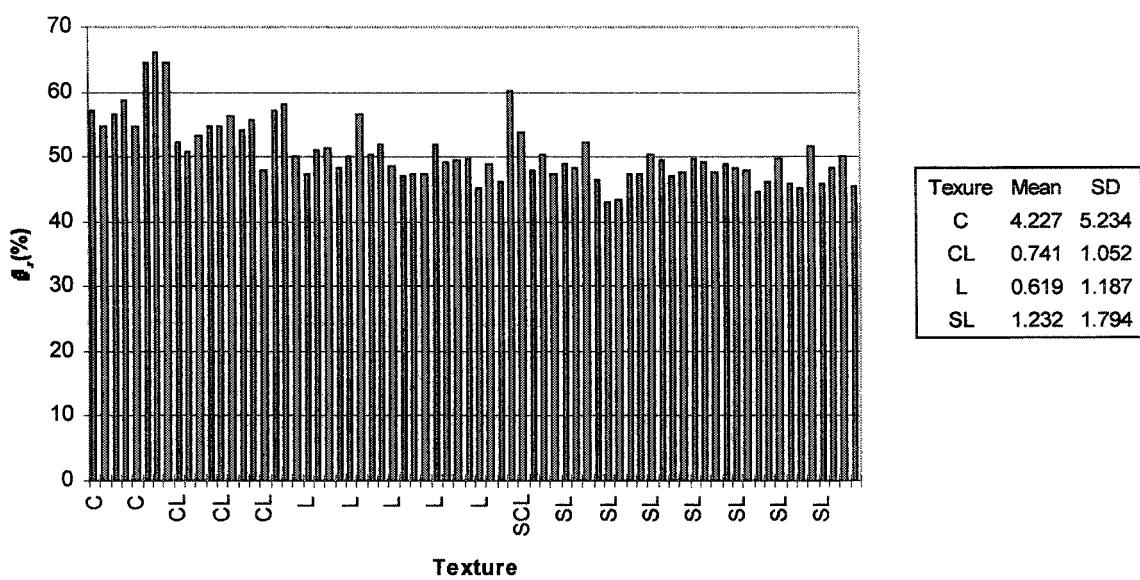
The estimated soil parameters in the table 4.6 were used to observe the variation of the parameter as a function of soil texture class. The variation in some parameters is clear, for example, K<sub>s</sub> shows higher values in sandy soil and low values at clayey soil. The variation charts are shown below (Fig. 4.11 to Fig 4.18).



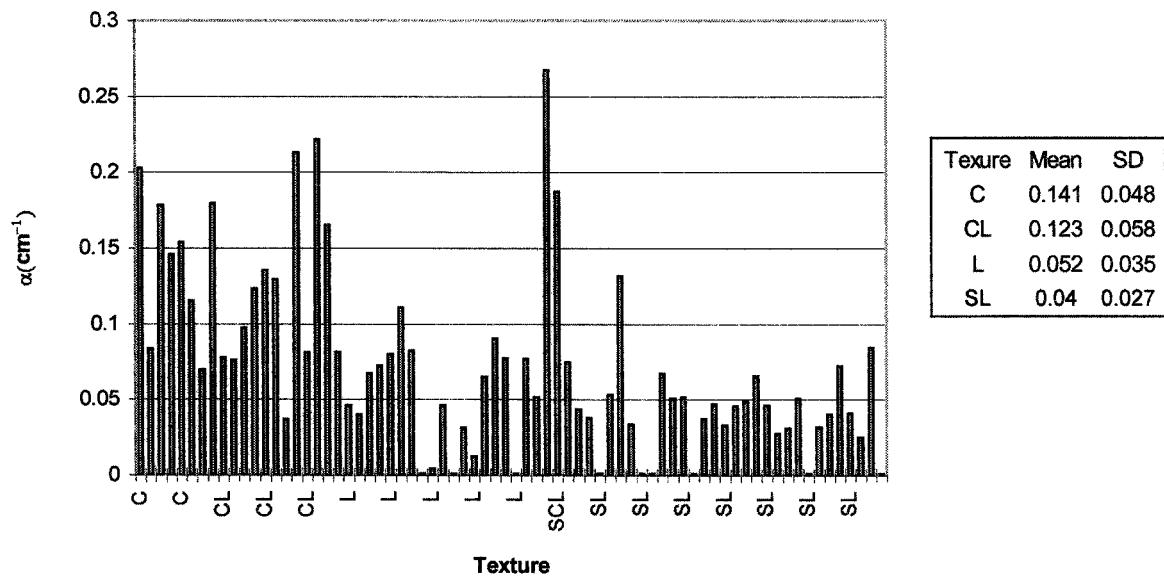
**Figure 4.11:Variation of K<sub>s</sub> with soil texture**



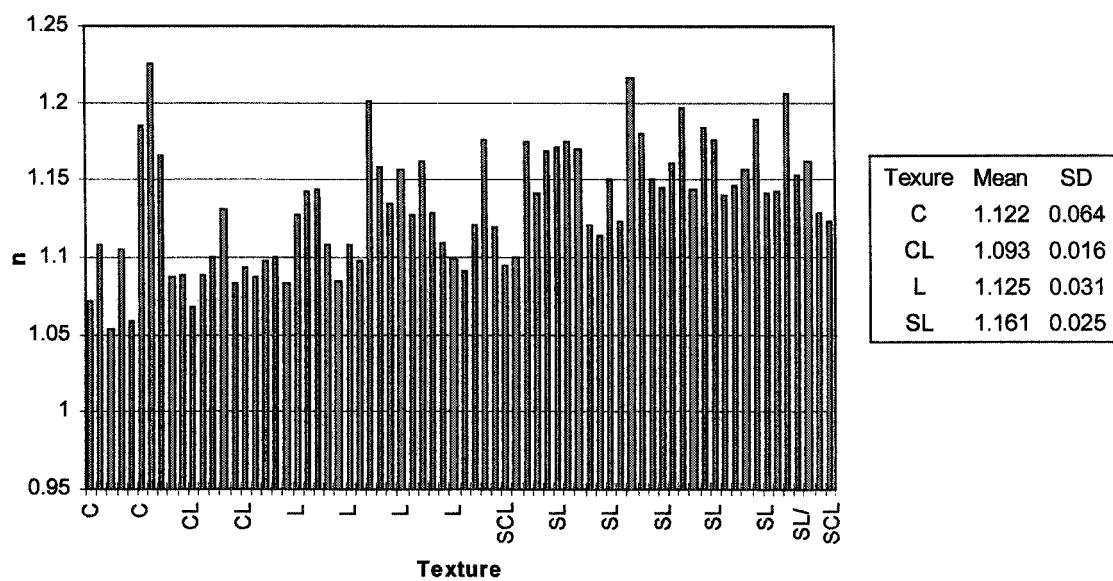
**Figure 4.12:Variation of  $\theta_r$  with soil texture**



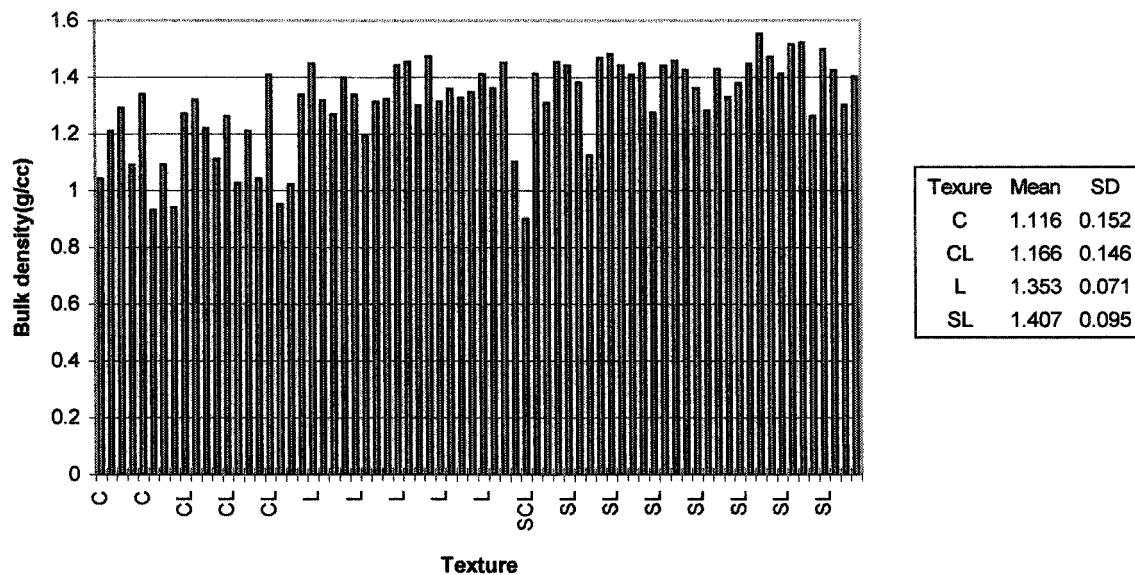
**Figure 4.13:Variation of  $\theta_s$  with soil texture**



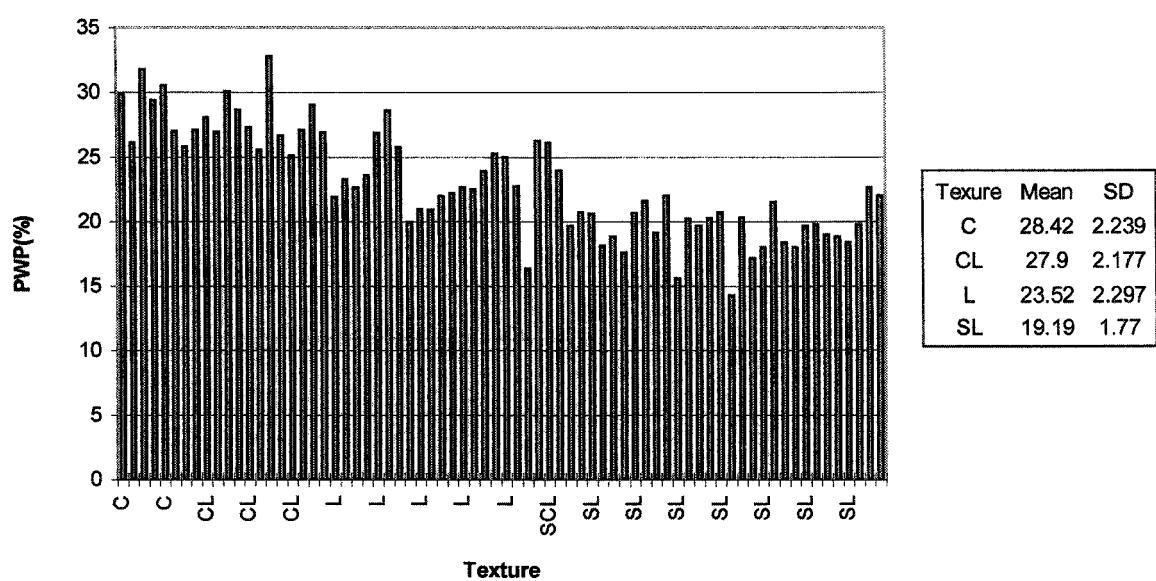
**Figure 4.14: Variation of  $\alpha$  with soil texture**



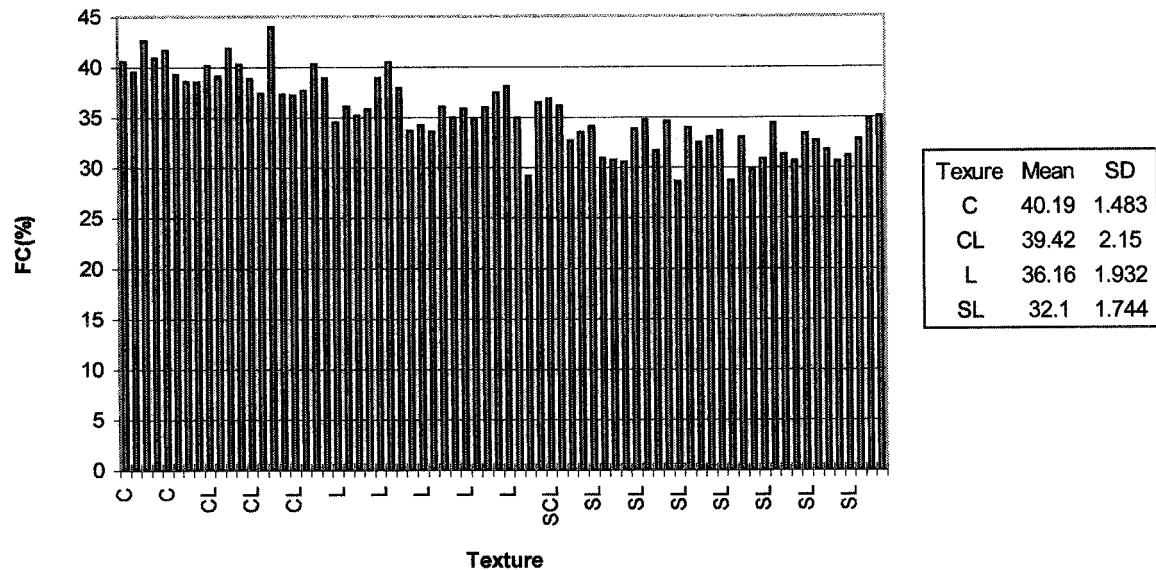
**Figure 4.15: Variation of N with soil texture**



**Figure 4.16:Variation of bulk density with soil texture**



**Figure 4.17:Variation of PWP with soil texture**



**Figure 4.18:Variation of FC with soil texture**

## **4.6 Analysis of leaching potential of agrochemicals by simulation**

### **4.6.1 Simulation of pesticide using PRZM-2 model**

A number of simulations of pesticide leaching were done, using Triadimenol (for vegetables) and Triadimefon (flowers) as test chemicals. The US.EPA Pesticide Root Zone model release 2 (Mullins et al, 1993), was used to this extent. Simulations were performed on three soil textures ranging from clay to clay loam, loam and sandy loam sites. Also a series of simulation runs were performed using variable chemical properties i.e., solubility, half-life and application dose. A set of input files used for the simulation in a sample site(site 15) is shown in the appendix E-I. Here, the penetration depth of the agrochemical was used as an output and evaluation criteria. The results of the simulation done on the site No.5, i.e., the depth of penetration (D) for varying solubility (So), half-life (H) and application dose (M) is given in the table 4.7.

**Table 4.7:Results of PRZM2 simulation (pesticide penetration depth) on the site No.5**

D(cm)	So(ppm)	H(d)	M(kg/ha)
116	242	18	0.33
47	2	90	0.083
11.5	0.01	56	0.083
149	81	105	0.0067
41	57.9	4	0.633
44	5	29	0.01
30	26.6	1.5	0.033
160	95	120	0.133

#### **4.6.1.1 Parameter sensitivity analysis**

From the list of chemicals in the table 2.4, the chemical that potentially might penetrate to the highest depth into the soil was selected for the analysis. For the selection of the chemical, a sensitivity analysis has been done (as shown below) on the three major textures of soil prevailing in the area viz. clay to clay loam (C\CL), loam (L), and sandy loam (SL). Chemical properties are characterised by its application dosage, solubility and half-life. The sensitivity analysis is based on the above three properties. Suppose depth of penetration(D), is a function of solubility(So), application dosage(M), and half-life(H), or

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$D=F(S,M,H)$  and  $\delta D=\delta F=\partial F/\partial S \cdot (\delta S) + \partial F/\partial M \cdot (\delta M) + \partial F/\partial H \cdot (\delta H)$ , if no change of other factors that effects  $D$ .

where  $\delta S_o$ ,  $\delta M$ ,  $\delta H$  are small changes to make  $\delta D$  in  $D$ . So the respective partial differential coefficients give sensitivity coefficients of  $S_o$ ,  $M$  and  $H$ . To compare the sensitivities of each parameters, Normalised Sensitivity Coefficient(NSC) is defined as,

$$NSC = \frac{\partial F}{\partial p} \cdot \left( \frac{p}{F} \right)$$

which gives the percentage change of the parameter ‘*p*’ to make 1% change of *F* or *D*(Cacuci et al., 1980; Sykes et al., 1985).

Since D is related to So, M and H, it is possible to correlate D with So, M and H as follows.

where  $k_0$ ,  $k_1$ ,  $k_2$ , and  $k_3$  are correlation coefficient corresponding to natural logarithmic of the variables.

by differentiating the equation 4.3,

$$k_1 = \partial D / \partial S_o \cdot (S/D), \quad k_2 = \partial D / \partial M \cdot (M/D), \quad k_3 = \partial D / \partial H \cdot (H/D)$$

Hence,  $k_1$ ,  $k_2$ ,  $k_3$  are NSDs which could be obtained from the regression coefficient of  $\ln(D)$  Vs  $\ln(So)$ ,  $\ln(M)$ , &  $\ln(H)$ . When relationship between D and So, M, & H does not follow strictly the equation 4.3 (at low  $R^2$ ) then  $k_1$ ,  $k_2$ ,  $k_3$  will give average values of NSCs. The simulation by using PRZM2 was done to obtain the values of D in site No.5 at varying Dose, half-life and solubility and the results are in the table 4.7. The site No.5 was selected as a representative site of clay to clay loam soil and the crop being vegetable.

Then these results can be used to find the  $k_1$ ,  $k_2$ ,  $k_3$  &  $k_0$  in the equation 4.3.

Natural logarithmic of the variables in the table 4.7 are given in the table 4.8.

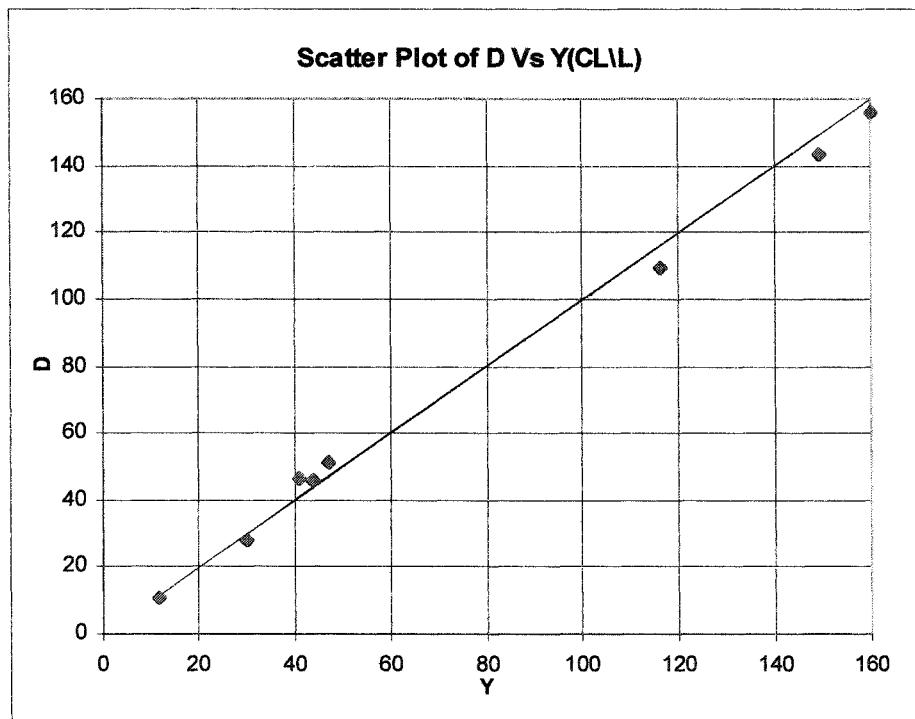
**Table 4.8:Natural logarithmic of the values in the table 4.7**

ln(M)	ln(So)	ln(H)	ln(D)
-1.10866	5.488938	2.890372	4.75359
-2.48891	0.693147	4.49981	3.850148
-2.48891	-4.60517	4.025352	2.442347
-5.00565	4.394449	4.65396	5.003946
-0.45728	4.058717	1.386294	3.713572
-4.60517	1.609438	3.367296	3.78419
-3.41125	3.280911	0.405465	3.401197
-2.01741	4.553877	4.787492	5.075174

From the regression analysis(at  $R^2=0.99$ ) the values obtained for  $k_1$ ,  $k_2$ ,  $k_3$  &  $k_0$  are:

$k_1=0.263895$ ,  $k_2=0$ ,  $k_3=0.317839$  &  $k_0=2.327$  for clay to clay loam soil

The scatter plot of simulated value, D Vs value obtained from the equation 4.3 i.e.,  
 $Y=\exp(0.246\ln(So)+0.318\ln(H)+2.33)$



**Figure 4.19:Scatter plot of sensitivity analysis in clay to clay loam soil**

Similarly, the site 15 can be taken as representative of loam soil and the crop being flowers.

As in site 5, the simulated depth of penetration (D) at varying M, So, H for site 15 are tabulated in the table 4.9 and natural logarithmic of the same in the table 4.10.

**Table 4.9 Results of PRZM2 simulation on the site No. 15**

D(cm)	So(ppm)	H(d)	M(kg/ha)
44	3.4	650	0.033
31	6	21	0.133
149	260	120	0.05
10	0.35	1.5	0.833
71.8	1000	3	0.0267
37	142	3	0.0667
72	13	90	0.267
32	2	270	0.133
15	0.09	52	0.023
49	5	600	0.0067
31	57.9	4	0.663

**Table4.10: Natural logarithmic of the values in the table 4.9**

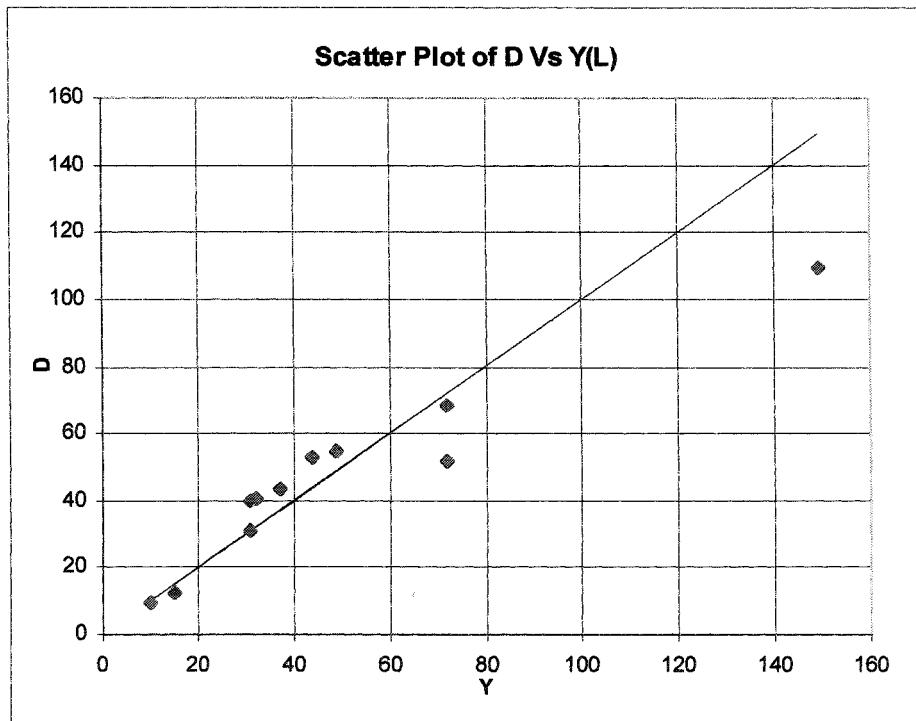
ln(M)	ln(So)	ln(H)	ln(D)
-3.41125	1.223775	6.476972	3.78419
-2.01741	1.791759	3.044522	3.433987
-2.99573	5.560682	4.787492	5.003946
-0.18272	-1.04982	0.405465	2.302585
-3.62309	6.907755	1.098612	4.273884
-2.70755	4.955827	1.098612	3.610918
-1.32051	2.564949	4.49981	4.276666
-2.01741	0.693147	5.598422	3.465736
-3.77226	-2.40795	3.951244	2.70805
-5.00565	1.609438	6.39693	3.89182
-0.41098	4.058717	1.386294	3.433987

From the regression analysis(at  $R^2=0.92$ ) the vales obtained for  $k_1$ ,  $k_2$ ,  $k_3$  &  $k_0$  are:

$k_1=0.246173$ ,  $k_2=0.029688$ ,  $k_3=0.211523$  &  $k_0=2.40254$  for loam soil

The scatter plot of simulated value, D Vs Y is given below.

Where,  $Y=\exp(0.246\ln(\text{So})+0.029688\ln(\text{M})+0.211523\ln(\text{H})+2.40254)$  and D=Simulated depth of penetration

**Figure 4.20:Scatter plot of sensitivity analysis in loam soil**

Similarly in site 26 of sandy loam soil and the crop being flowers, the variables used for sensitivity analysis are given in the table 4.11 and the natural logarithmic of the same in the table 4.12 .

**Table 4.11 Results of PRZM2 simulation on the site No. 26**

D(cm)	So(ppm)	H(d)	M(kg/ha)
72	3.4	650	0.033
29	6	21	0.133
215	260	120	0.05
9	0.35	1.5	0.833
89	1000	3	0.0267
45	142	3	0.0667
94	13	90	0.267
60	2	270	0.133
14	0.09	52	0.023
80	5	600	0.0067
33	57.9	4	0.663

**Table 4.12 : Natural logarithmic of the values in the table 4.11**

ln(M)	ln(So)	ln(H)	ln(D)
-3.41125	1.223775	6.476972	4.276666
-2.01741	1.791759	3.044522	3.367296
-2.99573	5.560682	4.787492	5.370638
-0.19031	-1.04982	0.405465	2.197225
-3.62309	6.907755	1.098612	4.488636
-2.70755	4.955827	1.098612	3.806662
-1.32051	2.564949	4.49981	4.543295
-2.01741	0.693147	5.598422	4.094345
-3.77226	-2.40795	3.951244	2.639057
-5.00565	1.609438	6.39693	4.382027
-0.41098	4.058717	1.386294	3.496508

From the regression analysis(at  $R^2=0.962$ ) the vales obtained for  $k_1$ ,  $k_2$ ,  $k_3$  &  $k_0$  are:

$k_1=0.2877$ ,  $k_2=0.0444$ ,  $k_3=0.31199$  &  $k_0=2.21766$  for sandy loam soil

The scatter plot of simulated value, D Vs Y is given below.

Where,  $Y=\exp(0.2877\ln(So)+0.0444\ln(M)+0.31199\ln(H)+2.212766)$  and  $D=\text{Simulated depth of penetration}$ .

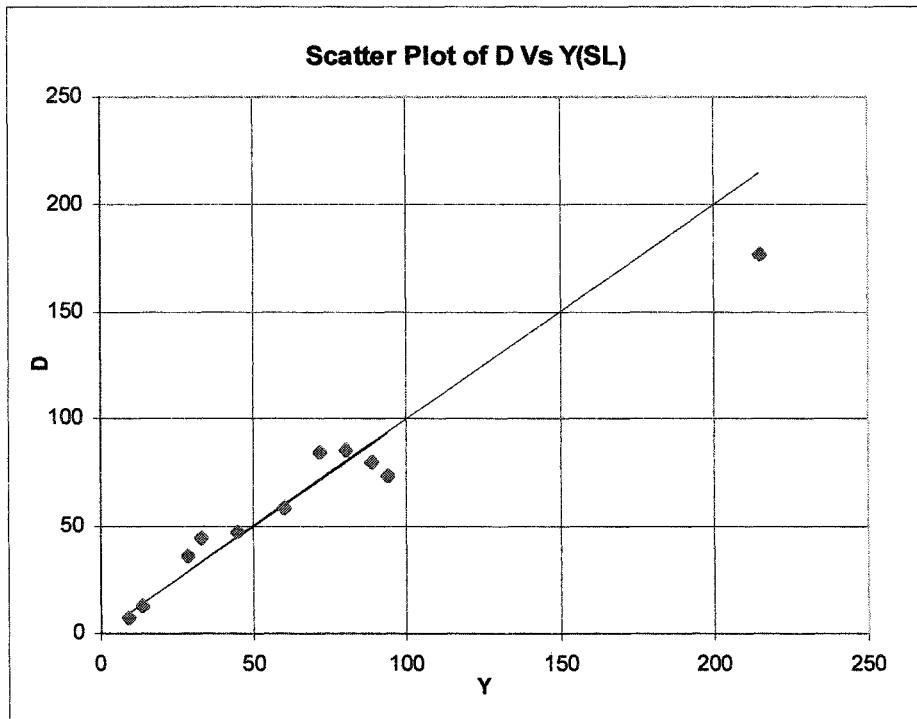


Figure 4.21: Scatter plot of sensitivity analysis in sandy loam soil

From the above sensitivity analysis it appears that change of application dosage has a negligible effect on the penetration and slightly more sensitive to half-life than solubility do. The highest penetration would give the TRIADIMENOL pesticide in vegetable gardens, since it has highest value of  $k_1 \cdot \ln(S_0) + k_2 \cdot \ln(M) + k_3 \cdot \ln(H)$  ( $=0.264\ln 95 + 0.318\ln 120 = 2.725$ ) among all the chemicals for vegetables. Therefore TRIADIMENOL was chosen for the analysis of the penetration in vegetables. The few changes in soil type from site to site within the whole area of vegetable cropping were not up to change the selection of a chemical. The same analysis were done for sandy loam soil (site 26) and loam soil (site 15). According to the sensitivity results, TRIADIMEFON was selected for the analysis of penetration in flower garden as in the case of TRIADIMENOL. It should be noted that in order to study the effect of rainfall, dry & wet spells of rainfall were tried out in addition to the normal intensity of rainfall with the irrigation supply in the analysis but were found to be of little effect to the penetration depth. This could be expected since rainfall and irrigation balances each other, i.e., when the rainfall is high, less irrigation and vice versa and the total input of water (irrigation +rainfall) is more or less same and around 1200mm/year. This aspect can be seen from the result of the simulation of rainfall and irrigation chart at a typical site (site 8) given in the appendix C, for a typical dry, wet and normal year of rainfall.

#### **4.6.1.2 Multi-year leaching risk**

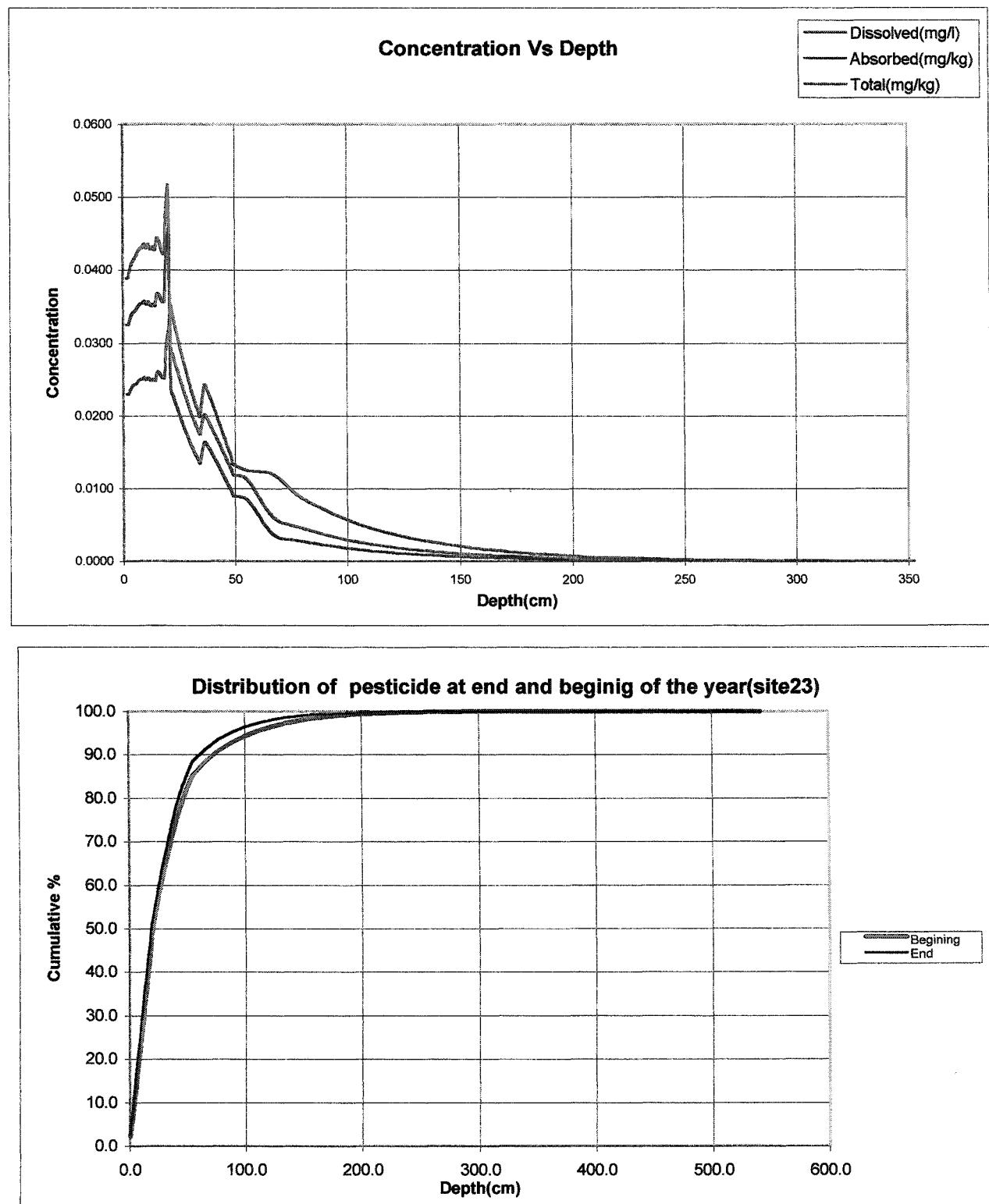
Since the application of the chemicals is a repetitive process the total concentration of the chemicals in the soil could be assumed to be in equilibrium state. In order to study this aspect, in a sample site (site 23), the simulation was done for two consecutive years with zero concentration at the beginning and carried on with the residuals for the second year. The details of the distribution of the chemical, TRIADIMEFON in the site 23 (variation of the penetration with depth) is shown in Fig 4.22. The cumulative variation along the depth is also shown. The summary of the results after simulation of two consecutive years is given in the Table 4.13 the total remained in the core in both years is more less same, 0.25kg/ha.

**Table 4.13:Summary of the pesticide balance in site 23**

	TRIAL-1(1st year)		TRIAL-2(2nd year)	
	Amount (kg/ha)	% of applied dose	Amount (kg/ha)	% of applied dose
Total of decay chemical in soil	0.361	60.13	0.5583	93.05
Total runoff chemical	0.0143	2.4	0.0143	2.4
Leached to GW	0.0	0.0	0.0	0.0
Total soil in volatilization	0.00043	0.07	0.0005252	0.087
Added to the zone	0.2242	37.37	0.0269	4.48
Total applied	0.6	100	0.6	100
Leached below (60cm) root zone	0.05426	9	0.08653	14.4

From the trial-2 above it appears that main disposal mechanism of fate of the chemical is decay. The remaining amount in the soil is more or less constant after 2 years of application. The results presented in the Fig.4.22, is for the second trial. Penetration depth of the chemical within the vadose zone is taken as at the distance which contains more than 99.99% of the total chemical cumulatively and accordingly, 347cm can be taken as the maximum depth of penetration at site 23.

Site: 23  
Chemical: Triadimefon (Fungicide)

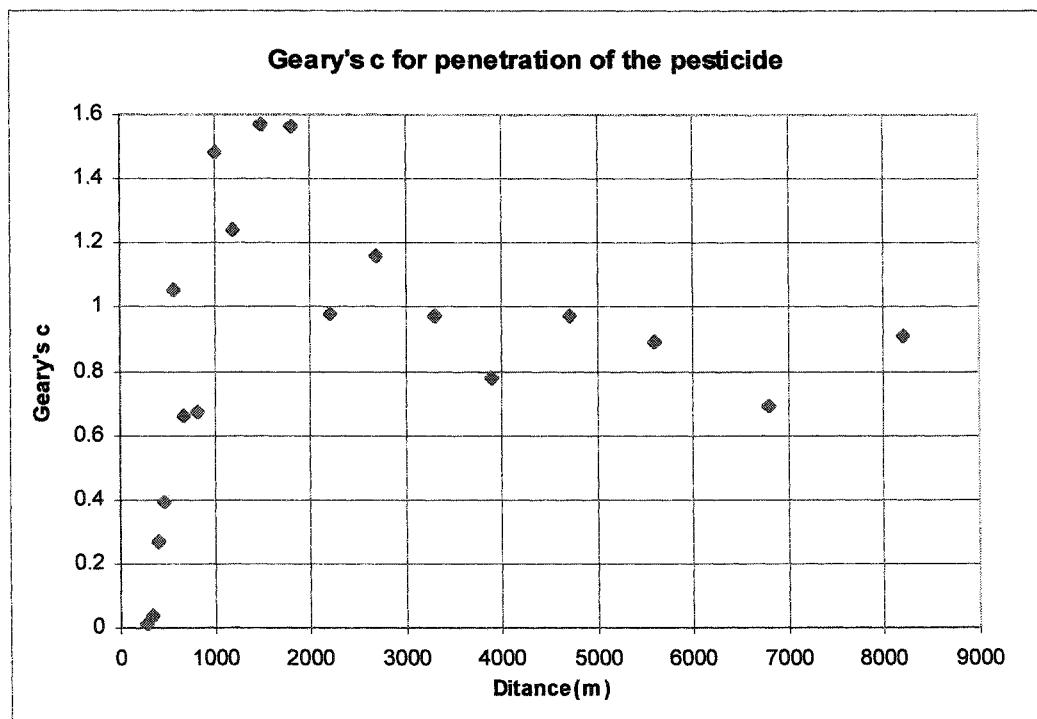


**Figure 4.22:Simulation results of the pesticide at site 23**

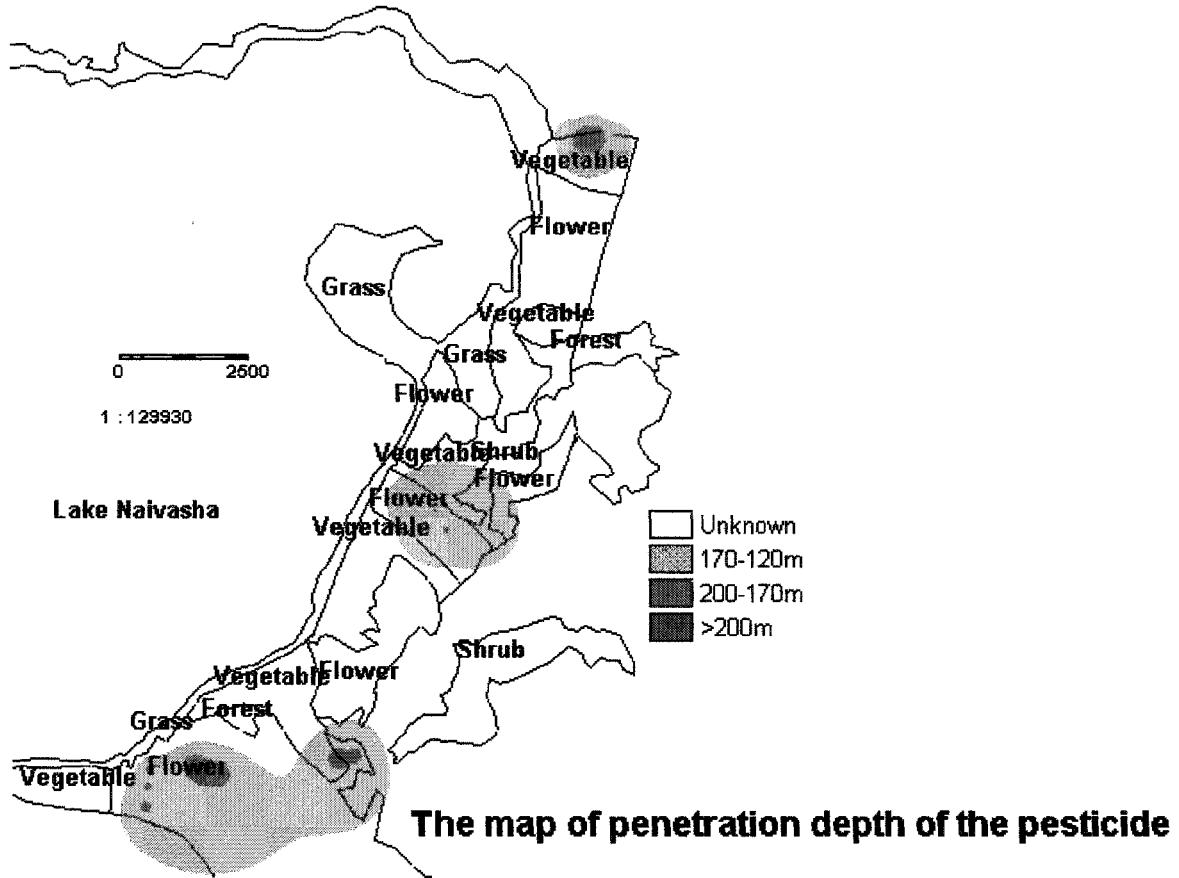
#### 4.6.2 Mapping pesticide leaching potential

With the above results of the penetration depth of pesticide a point interpolation has been done to prepare a raster map. Moving average in ILWIS was used for the interpolation. The map shows the relative level of leaching potential of the selected chemical in the area. The map is not a complete representation for the area as lot of unknown areas are remained due to lack of required sample test sites (see Fig 4.24).

The variation of Geary's c for the penetration of the pesticide is as follows.

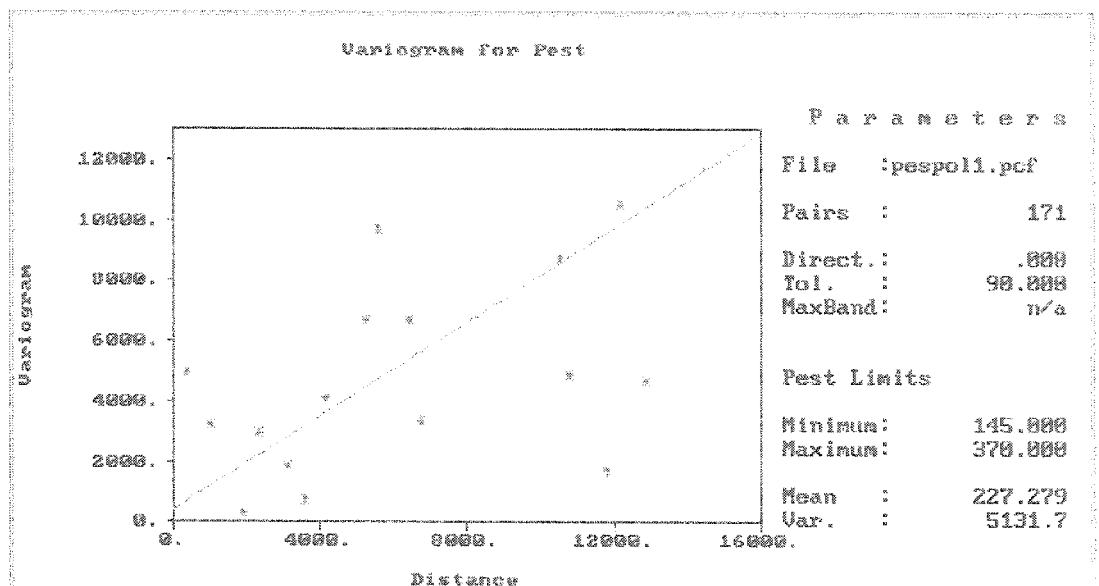


**Figure4.23:Geary's c for penetration of pesticide**



**Figur4.24:Distribution map of potential pesticide penetration**

To prepare the above map kriging could have been adopted instead of moving average as a mean of interpolation however the kriging variation at the simulated sites are larger in comparison (see the table 4.14) to the values obtained by the moving average. In kriging anisotropy is ignored as directional variation can not be checked due to non-availability of sample sites in different directions. The kriging variogram model is taken as linear, with nugget= $410\text{cm}^2$  and slope= $0.75\text{cm}^2/\text{m}$  as shown below.



**Figure4.25:Variogram model for leaching of the pesticide**

**Table: 4.14:Penetration estimated by moving average and kriging**

Site	Simulated penetration(cm)	Estimated by moving av.	Estimated by kriging
4	145	146.4	207.8
5	160	154.7	193.4
7	340	297.0	267.1
8	370	358.1	224.3
9	149	153.5	168.9
12	149	149.0	174.3
13	149	170.0	244.6
14	204	192.8	164.9
16	171	165.8	176.6
17	182	172.0	180.0
18	190	182.1	181.6
19	224	221.1	276.9
20	273	271.3	307.8
21	305	267.4	287.9
22	281	249.0	241.4
23	347	304.4	267.1
24	194	194.0	251.8
25	240	214.6	243.9
26	237	221.5	226.7

#### **4.6.2.1 Factor of safety against leaching**

A tentative factor of safety (FOS) against the leaching risk of pesticide is proposed in order to measure amount of risk associated with the application of the chemical. The proposed FOS=Total depth of the vadose zone/Maximum depth of leaching

The FOS in the site 23 =  $1840/347 = 5.3$

For safe against contamination of ground water, FOS>1. FOS in each site is tabulated below using a typical chemical and the depth to the groundwater table is interpolated from the point map in Fig 4.1 .

**Table 4.15:Factor of safety against penetration**

Site	Penetration(cm)	Chemical	FOS
4	145	Triadimenol	28.1
5	160	Triadimenol	26.2
7	340	Triadimenol	10.5
8	370	Triadimenol	10.1
9	149	Triadimenol	26.6
12	149	Triadimefon	17.0
13	149	Triadimefon	16.8
14	204	Triadimefon	12.2
16	171	Triadimefon	14.6
17	182	Triadimefon	13.5
18	190	Triadimefon	12.5
19	224	Triadimefon	8.7
20	273	Triadimenol	7.2
21	305	Triadimefon	5.8
22	281	Triadimefon	6.4
23	347	Triadimefon	5.3
24	194	Triadimefon	10.1
25	240	Triadimefon	8.1
26	237	Triadimefon	8.3

#### 4.6.3 Simulation of fate of fertiliser using WAVE model

For the fertilisers, application dose was varying from place to place proper records were unavailable due to reluctance shown by the farmers to disclose the details. But most of them admitted that they were using urea 100 kg/ha/month in peak during certain months of the cultivation. The dose of calcium nitrate was approximately 100 kg/ha/year which is equivalent to 75.6 kg/ha/year in nitrate as weight ratio of  $\text{Ca}(\text{NO}_3)_2$ [164] and  $(\text{NO}_3)_2$ [124] is 0.7561

The above dose of inorganic fertilisers was assumed to be used by the flower growers. The farmers said that they did not apply organic fertilisers.

For the vegetable growers, the application of inorganic fertilisers was 100 kg/ha/month of ureum with the manure of animal waste 15,000kg/ha/year as said by the farmers. Nitrogen content of the manure was taken as 1-2% (Jacob and von Uexkull, 1963).

The simulation was done for one year. Some exaggerated fertiliser dose were used in the simulation to check leaching risk. To find the initial level of the chemicals in the soil, number of iterations were done until the change of concentration results after two consecutive simulations are negligible. The results after one year simulation showed that the leaching of chemicals to the groundwater was 2mg/m<sup>2</sup>/year and no leaching of nitrate or ammonium has been found.

Summary of the material balance of the three chemical i.e.; ureum, nitrate and ammonium in a typical site(site12) is given below.

**Table 4.16: Summary of inorganic fertiliser material balance in the site 12**

All figures are in Kg/ha

Fertiliser	Initial	Applied	transformed #	Retained	Leached out	Final total
Ureum	330.60	1200	-1193.31	6.68	0.01	337.28
$[\text{NO}_3^-]$	376.72	75.6	-32.77	42.83	0	419.55
$[\text{NH}_4^+]$	18.76	0	+7.33	7.33	0	26.09

\*(+ve) indicates net influx from the other two

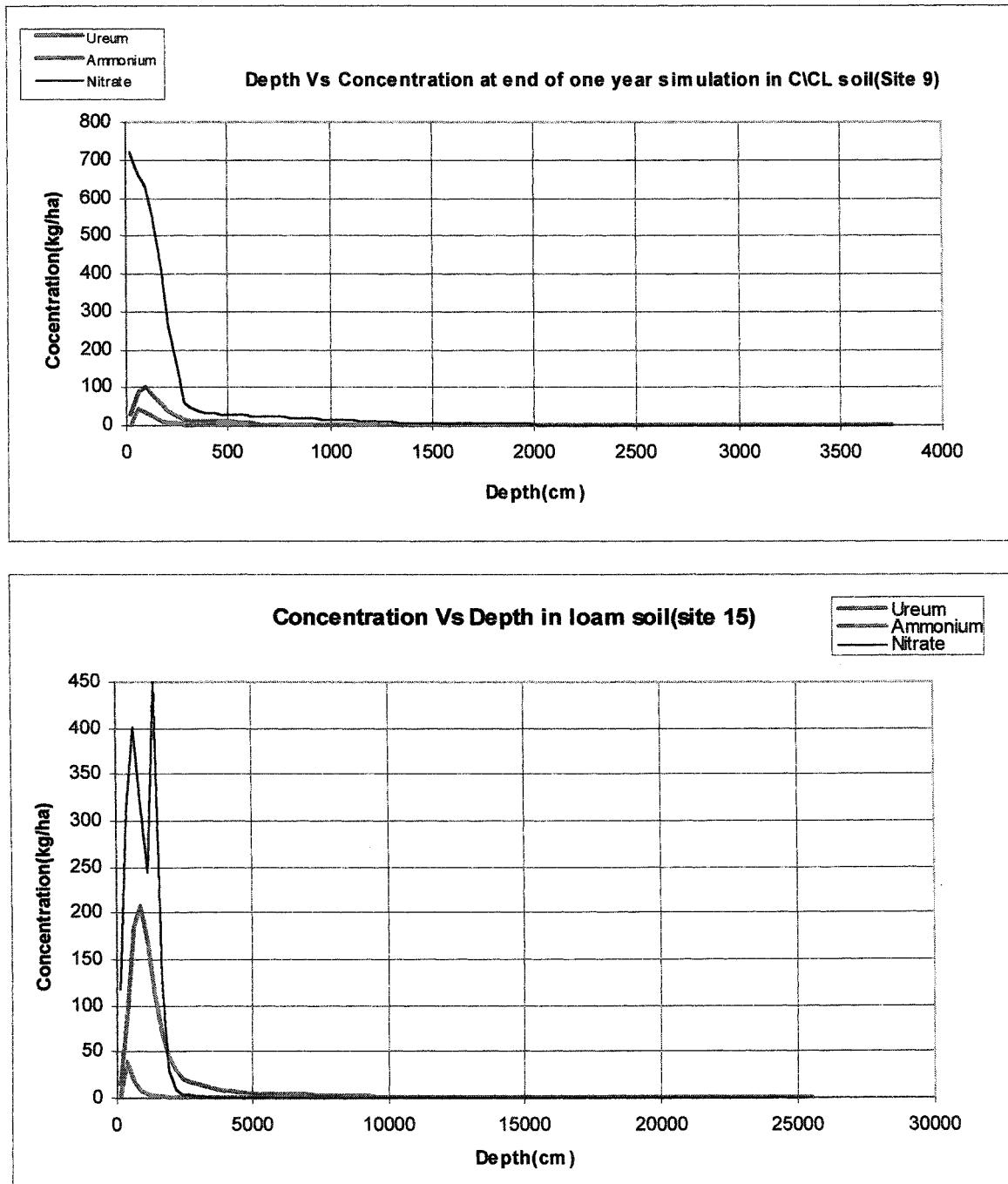
(-ve) indicates net break down into the other two

# loss by chemical transformation and plant uptake

## Chapter 4

Details of the variation of mass with time and depth for two typical sites in vegetable garden (site 9) and flower garden (site15) are shown below.

A set of input files used for the simulation in a sample site (site 15) is given in Appendix E-II.



**Figure 4.26:Simulation results of fertiliser at two typical sites in vegetable (site 9) and flower (site 15) gardens**

# **Chapter 5**

## **5      Summary and Conclusion**

Summary of findings and concluding remarks are given in this chapter.

A summary of the findings are as follows:

### **5.1 Soil pesticide leaching simulations**

- based on a series of soil leaching simulations of agrochemicals using the Pesticide Root Zone Model (PRZM2 v1.02), in combination with a parameter sensitivity analysis of the more important chemical characteristics influencing leaching, this first assessment indicates a relatively low risk of immediate groundwater contamination by pesticide or nitrogen fertilisers. Most pesticides were retained in the first 100 cm of soil depth.

As reasons explaining these observations, we can mention:

- the general textures of the soils composing the near lake lacustrine sediments and lake deposits, are generally medium (loam) to heavy (silty clay), with only moderate hydraulic conductivities.
- the depth to groundwater table, is on average above 10 m adding to a lower vulnerability of the area;
- natural rainfall in the near lake area (in high contrast to the neighbouring mountain area) is relatively low (600 mm in average), and almost no natural (see rainfall induced) downward drainage water fluxes could be simulated in these soil types; when irrigation is applied, it is practiced (sprinkler on legumes or drip irrigation for flower cultures) at very regular intervals but in relatively small quantities, also yielding low downward water fluxes;
- although a huge range of agrochemicals is used in the area (see table 2.4), developments in the phyto pharmaceutical industries (producing agrochemicals) are in a direction for less dangerous chemicals, with quicker bio-decay, low solubility, etc.; this makes that for many pesticides, the “through soil and vadose zone” pathway may not be predominant one; pesticides residues on plant materials as well as pesticide wash-off and topsoil extraction

by runoff and transport may be critical pathway to be researched; since the models used for the analysis are one dimensional (vertical) pollution in lateral direction is ignored on the assumption that major part of solutes transport in vertical direction. Hence there is no way of assessing pollution of the lake due to use of agrochemical through seepages. The PRZM simulations indicated that about 2-2.5% per hectare of the applied pesticide was released into the surface runoff. To our opinion, this value seems however quite low, and more investigation on the parameters for runoff generation should be done.

- the possibility or occurrence of lateral (horizontal direction) water and chemical fluxes should also be verified.

## **5.2 Soil texture and the parameters**

The parameters of soil and its texture were correlated in order to:

- derive soil parameters of the moisture retention and hydraulic conductivity characteristic curves (MRC and HCC), used in the modelling from texture data and carbon content of soils.
  - to analyse effect of chemical properties of the pesticides (solubility, half-life, application dose) on leaching or penetration depth of the chemicals;

The parameter sensitivity analysis shows that application dose has very low weight on leaching and solubility and degradation(half-life) are more important factors to be considered. Variation of the sensitivity from one soil type to another is relatively low. Normalised Sensitivity Factors(NFS) can be used for comparison of potential penetration depth of the pesticides as illustrated below.

Let us take loam to clay loam soil of which  $K_1 = 0.264$ ,  $K_3 = 0.318$  (see page 61)

Let us consider the potential penetration of two pesticide A & B,  $D_a$  &  $D_b$  and whose solubility and half-life are  $S_{0a}$ ,  $H_a$  and  $S_{0b}$ ,  $H_b$  respectively. Then, according to the equation 4.3,

$$\ln(D_a) = 0.264 \ln(S_{0a}) + 0.318 \ln(H_a) + k_0 \quad \text{and,}$$

$$\ln(D_b) = 0.264 \ln(S_{ob}) + 0.318 \ln(H_b) + k_0$$

$$\text{Hence, } \ln(D_a/D_b) = 0.264\ln(So_a/So_b) + 0.318\ln(H_a/H_b)$$

$$\text{or } D_a/D_b = (S_{0a}/S_{0b})^{0.264} (H_a/H_b)^{0.318} \dots \quad 5.1$$

Therefor the ratio,  $D_a/D_b$ , can be obtained

### **5.3 Fertiliser fate and leaching potential**

Some simulation for nitrogen behaviour in the soil and leaching risk were done using the WAVE model v.2.01. Due to similar reasons as mentioned above with the pesticide, the simulations indicated, in first instance, a limited leaching (e.g. nitrate) below the root zone. The simulation results showed that there is high concentration of nitrate in soil in the vegetable garden and low in the flower gardens. This has been in par with the high organic nitrogen in the soil of vegetable gardens (see table 4.2). This could be expected as vegetable farmers use organic manure. According to the well samples tested in the vicinity of the area the nitrate concentration was 1-2 ppm.

#### **5.4 Suggestion for improved sampling scheme for future investigations**

Due to lack of sampling test sites the map of pesticide leaching shown in the page 68, is not a complete one. A better sampling scheme could have avoided this. The variogram developed in the page 69, can use for this purpose. In kriging, the point interpolation is done according to the equation 1.3 (page 9). The estimation is done at minimum variance between the observed and the measured values according to the equations below.

and minimum variance,  $\sigma_k$  is given by,

$$\sigma_k^2 = \sum_i^n \lambda_i \gamma(x_i, x_o) + \varphi \quad \dots \quad 5.3$$

where  $x_0$  is the point where estimation is done

$x_i$  &  $x_j$  are surrounding pair of points used for the interpolation of which total is 'n'

$\lambda_i$  weight factor in the equation

φ Lagrange parameter associated with the minimisation of the variance

The equation can be written in matrix form as follows.

$$\begin{pmatrix} \gamma(x_1, x_1) & \gamma(x_2, x_1) & \dots & \gamma(x_n, x_1) & 1 \\ \gamma(x_1, x_2) & \gamma(x_2, x_2) & \dots & \gamma(x_n, x_2) & 1 \\ \vdots & \vdots & & \vdots & \\ \gamma(x_1, x_n) & \gamma(x_2, x_n) & \dots & \gamma(x_n, x_n) & 1 \\ 1 & 1 & & 1 & 0 \end{pmatrix} \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_n \\ \varphi \end{pmatrix} = \begin{pmatrix} \gamma(x_1, x_0) \\ \gamma(x_2, x_0) \\ \vdots \\ \gamma(x_n, x_0) \\ 1 \end{pmatrix}$$

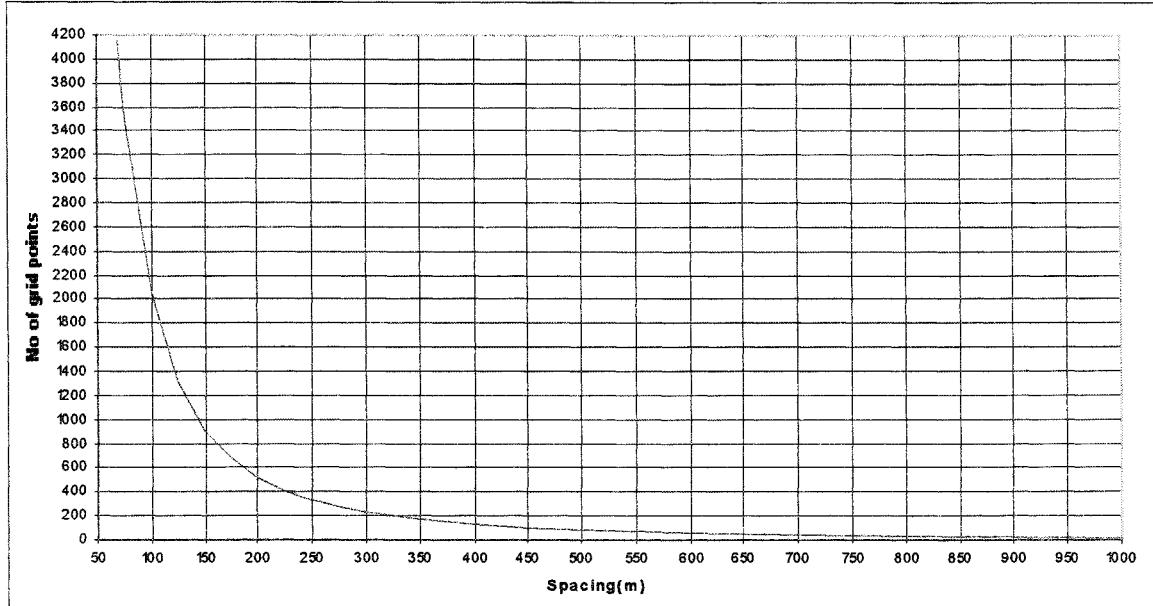
Once the variogram is known all  $\gamma$  values related to the given distances can be determined. And from the matrix equation all  $\lambda$  values and thereby the estimation at  $x_0$  can be made. From the above it is revealed that the estimation variances depend on the variogram and through it on the configuration of observation points in relation to the point to be estimated and distances among them. They do not depend on the observed values themselves. Hence it is possible to develop sampling schemes at a desired precision for further investigations. From the above equations it is evident that  $\sigma_k^2$  depends on the position of  $x_0$  and it is found that there is a position for  $x_0$  to yield maximum  $\sigma_k^2$  depending on the configuration of the sampling points. This position should be centre of the sampling point because it is the point with the highest uncertainty. And also the maximum average distance to the sampling occurs is at the centre. This maximum  $\sigma_k^2$  would be lowest when regular equilateral triangular grid sampling scheme is used.(Mcbrtney, Webster, Burgess., 1981) Hence regular equilateral triangular grid scheme is the best sampling scheme to be adopted. Provided that each point is accessible and that the space is (in principle) unbounded. Also the variogram should be valid throughout the region. Lower the grid spacing better the precision. With the variogram in the page 69, using the software, OPTIM (Winkels, Stein et al, 1997) developed for optimal sampling design, a relationship between number of sample points and the sampling spacing has been developed and is given in the table 5.1 below. Even though the triangular grid spacing is better square grid spacing is considered for easy calculation and configuration. The relation between the grid spacing and the number of sampling points were obtained by rasterizing the polygon map of the study area at different pixel sizes to be same as the grid spacing and counting the number of pixels in vegetable and flower gardens that should be equal to the number of grids at the corresponding pixel size or sample spacing.

**Table 5.1:Precision and grid spacing of the sampling scheme**

Precision(cm) of penetration of the pesticide	Grid spacing required(m) at 12-neighbour	Grid spacing required(m) at 16-neighbour
30	937.0	938.5
28	674.5	675.0
25	332.0	332.2
23	144.2	147.5

Heights precision which can be achieved is 21cm.

The last two columns in the table 5.1 are to show the variation of grid spacing when 12-neighbours and 16-neighbours are considered for kriging. However the variation is negligible. In 12- neighbours first and second round of neighbours are taken for the charging whereas in 16- neighbour additionally third round is also taken. In order to convert the sampling space into number of sampling points the following graph can be used.



**Figure 5.1:Relation between sampling spacing and number of grids**

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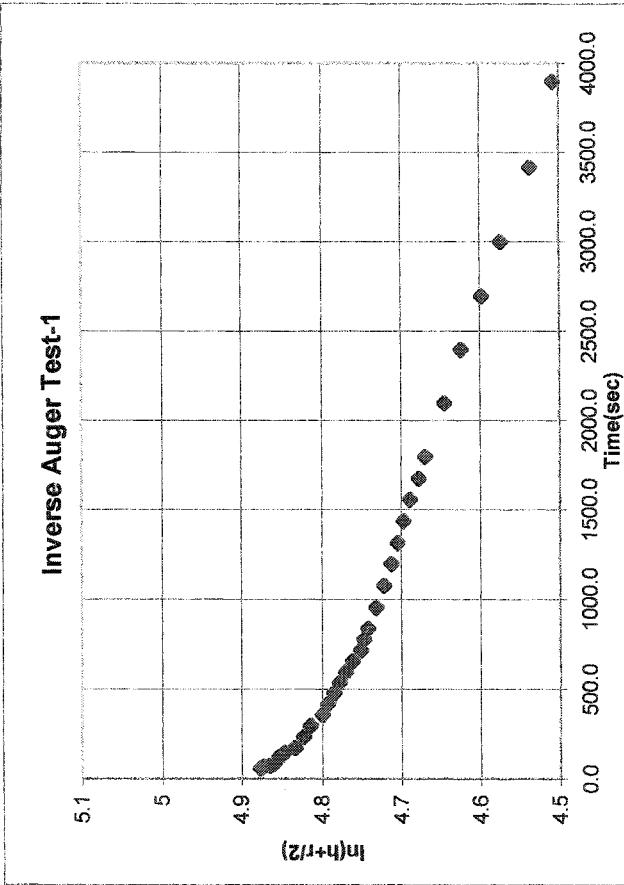
## **APPENDIX - A**

Test results of saturated hydraulic conductivity

Appendix-A

Max. reading = 189.5 cm  
 $r = 4.5$  m  
 Site No. 2  
 Depth of the hole(cm) 147.5  
 Tested on: 14/10/97

Time(sec)	Level(cm)	$ r $ (cm)	$\ln(h+r/2)$
0.0	42.0	147.5	5.0369837237
15.0	57.5	132.0	4.8997037533
30.0	58.6	130.9	4.8914763112
60.0	60.4	129.1	4.877865516
70.0	61.0	128.5	4.873287103
80.0	62.0	127.5	4.866609522
90.0	62.6	126.9	4.86097452
130.0	63.5	126.0	4.853981484
140.0	64.0	125.5	4.850075229
150.0	64.3	125.2	4.8477241131
180.0	66.0	123.5	4.834295809
240.0	67.4	122.1	4.82310017
300.0	68.4	121.1	4.815025843
360.0	70.2	119.3	4.800325701
420.0	71.0	118.5	4.793722233
480.0	72.0	117.5	4.785406236
540.0	72.8	116.7	4.778703237
600.0	73.7	115.8	4.771108264
660.0	74.8	114.7	4.761748483
720.0	76.0	113.5	4.751422638
780.0	76.5	113.0	4.747103632
840.0	77.0	112.5	4.742755849
960.0	78.2	111.3	4.732243269
1080.0	79.3	110.2	4.722508678
1200.0	80.4	109.1	4.712618394
1320.0	81.3	108.2	4.70456393
1440.0	82.1	107.4	4.697293475
1560.0	83.0	106.5	4.68905167
1680.0	84.2	105.3	4.67795836
1800.0	85.1	104.4	4.66552445
2100.0	87.6	101.9	4.645832168
2400.0	89.8	99.7	4.624482497
2700.0	92.4	97.1	4.598648999
3000.0	94.8	94.7	4.57419532
3420.0	98.3	91.2	4.537426534
3900.0	101	88.5	4.508108473



$$\text{slope of the curve} = -8.0402E-05 \text{ sec}^{-1}$$

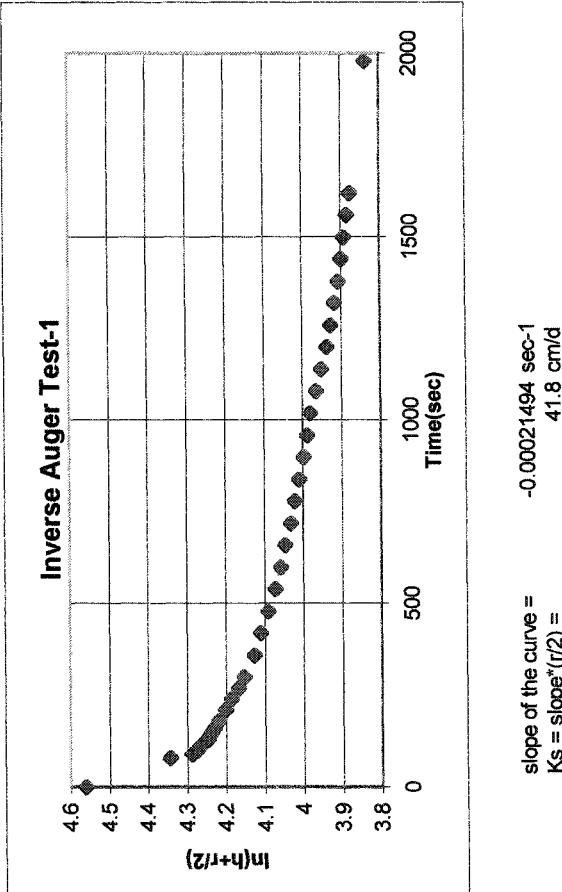
$$K_s = \text{slope}^*(r/2) = 15.6 \text{ cm/d}$$

Appendix-A

Max. reading = 129 cm  
 $r = 4.5$  m

Site No. 3  
 Tested on: 17/10/97

Time(sec)	Level(cm)	$h(cm)$	$In(h+r/2)$
0	36.5	93.5	4.5811740628
80	54.2	74.8	4.3444546862
90	58.4	70.6	4.288402533
100	59.4	69.6	4.274580613
110	59.8	69.2	4.268997904
120	60.5	68.5	4.259152537
130	61.4	67.6	4.246350086
140	61.6	67.4	4.2434827
150	62.0	67.0	4.237723745
160	62.4	66.6	4.231930225
180	63.3	65.7	4.218772141
210	64.5	64.5	4.200954287
240	65.4	63.6	4.187379428
270	66.6	62.4	4.168888105
300	67.6	61.4	4.153398325
360	69.2	59.8	4.127940512
420	70.3	58.7	4.110053656
480	71.5	57.5	4.090169191
540	72.5	56.5	4.073291153
600	73.4	55.6	4.057853454
660	74.1	54.9	4.04567939
720	74.9	54.1	4.03158224
780	75.5	53.5	4.02087741
840	76.1	52.9	4.010086746
900	76.7	52.3	3.999117712
960	77.3	51.7	3.988057692
1020	77.6	51.4	3.982481469
1080	78.5	50.5	3.985563772
1140	79.2	49.8	3.982204795
1200	80.0	49.0	3.986715618
1260	80.5	48.5	3.926911618
1320	81.0	48.0	3.917010547
1380	81.5	47.5	3.907010464
1440	81.9	47.1	3.888892776
1500	82.2	46.8	3.892840186
1560	82.6	46.4	3.884681809
1620	83.0	46.0	3.876395828
1980	84.9	44.1	3.886221292



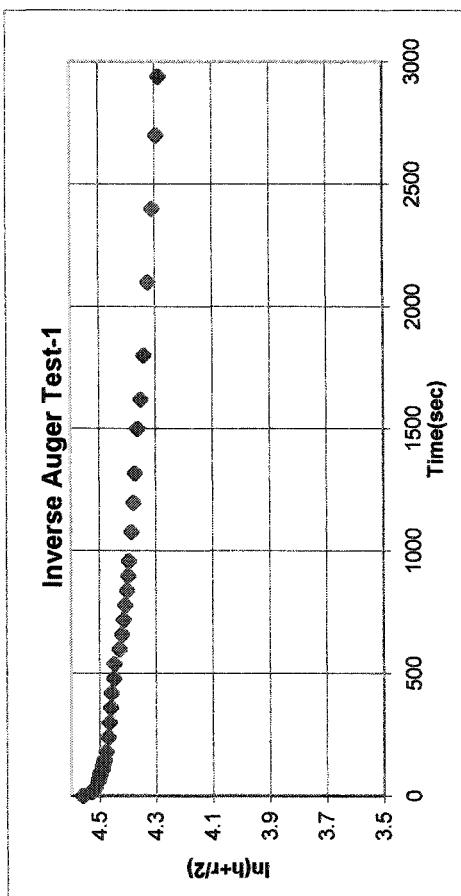
Appendix-A

Max. reading = 126.5 cm  
 r = 4.5 m

Site No. 7 Depth of the hole(cm) 93.5

Tested on: 17/10/97

Co-ordinates	
X	Y
214311	9917382



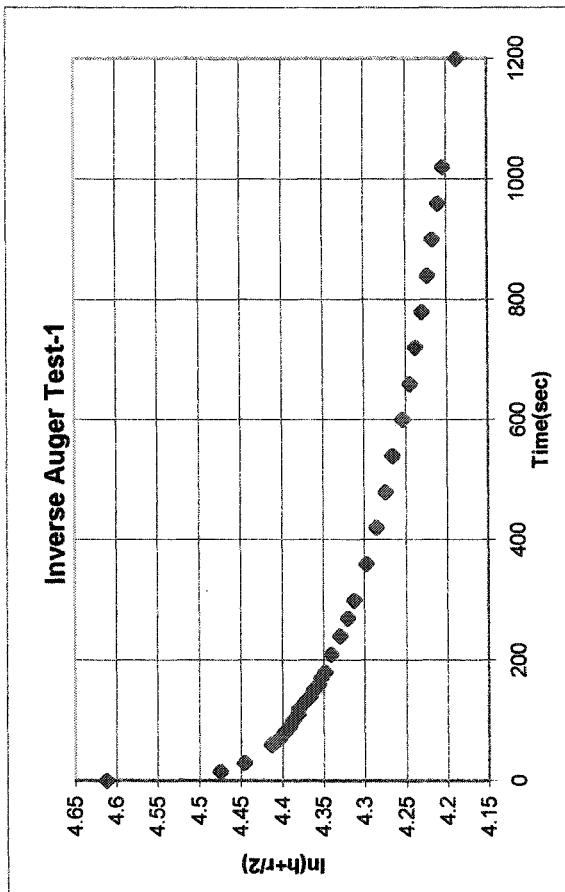
slope of the curve =  
 $K_s = \text{slope}^*(r/2) =$

-6.4062E-05 sec<sup>-1</sup>  
 12.8 cm/d

Appendix-A

Max. reading = 131.5 cm  
 $r = 4.5$  m  
 Site No. 8  
 Depth of the hole(cm) 98.5  
 Tested on: 17/10/97

Time(sec)	Level(cm)	$h(cm)$	$\ln(h+r/2)$
0	33.0	98.5	4.6126422
15	46.0	85.5	4.47449186
30	48.5	83.0	4.44558812
60	51.2	80.3	4.41340417
70	52.0	79.5	4.40366581
80	52.5	79.0	4.39753082
90	53.0	78.5	4.39135796
100	53.3	78.2	4.38763587
110	53.8	77.7	4.38140144
120	53.9	77.6	4.38014987
130	54.4	77.1	4.37386845
140	55.0	76.5	4.36627828
150	55.3	76.2	4.36246148
160	55.8	75.7	4.3560676
170	56.0	75.5	4.35349855
180	56.4	75.1	4.34834058
210	57.0	74.5	4.34055339
240	57.8	73.7	4.33607523
270	58.5	73.0	4.3208359
300	59.1	72.4	4.31281052
360	60.2	71.3	4.29796545
420	61.1	70.4	4.28865339
480	61.9	69.6	4.27458061
540	62.5	69.0	4.26619482
600	63.4	68.1	4.25348278
660	64.0	67.5	4.24491742
720	64.5	67.0	4.23772315
780	65.0	66.5	4.23047674
840	65.5	66.0	4.22317743
900	65.9	65.6	4.21729939
960	66.4	65.1	4.209929
1020	66.8	64.7	4.20394607
1200	67.9	63.6	4.18737943



$$\text{slope of the curve} = -0.00018 \text{ sec}^{-1}$$

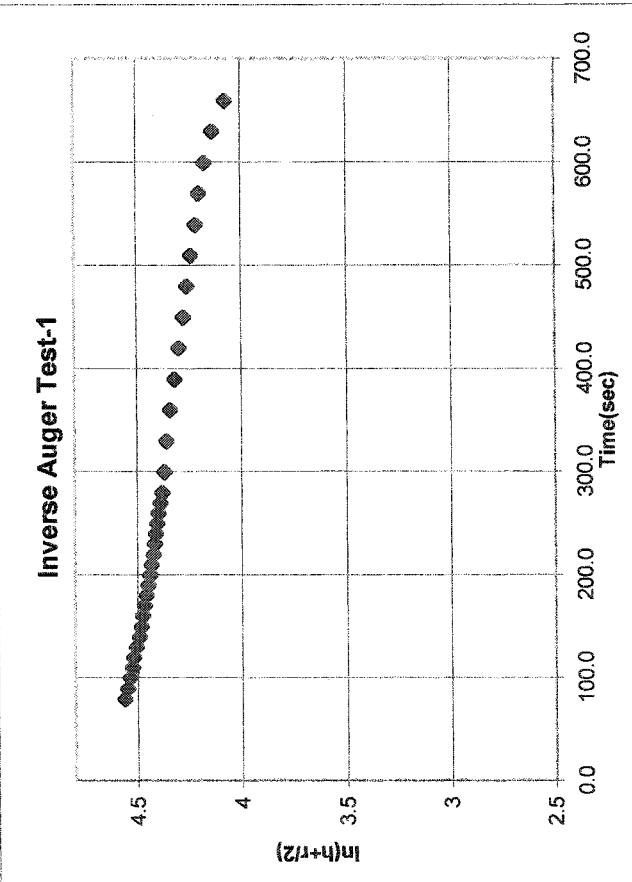
$$K_s = \text{slope}^*(r/2) = 34.7 \text{ cm/d}$$

Appendix-A

Max. reading = 136.8 cm  
 $r = 4.5$  m

Site No. 12  
 Tested on: 20/10/97

Time(sec)	Level(cm)	$ r(h-r/2) $
0.0	22.0	114.8
60.0	40.0	96.8
70.0	41.5	95.3
80.0	43.0	93.8
90.0	44.0	92.8
100.0	45.2	91.6
110.0	46.3	90.5
120.0	47.0	89.8
130.0	48.0	88.8
140.0	49.5	87.3
150.0	50.4	86.4
160.0	51.0	85.8
170.0	51.8	85.0
180.0	52.5	84.3
190.0	53.3	83.5
200.0	54.0	82.8
210.0	54.6	82.2
220.0	55.3	81.5
230.0	55.9	80.9
240.0	56.5	80.3
250.0	57.0	79.8
260.0	57.5	79.3
270.0	58.2	78.6
280.0	58.8	78.0
300.0	59.8	77.0
330.0	60.5	76.3
360.0	62.0	74.8
390.0	63.8	73.0
420.0	65.2	71.6
450.0	66.8	70.0
480.0	68.2	68.6
510.0	69.4	67.4
540.0	71.2	65.6
570.0	72.3	64.5
600.0	74.1	62.7
630.0	76.5	60.3
660.0	80.1	56.7

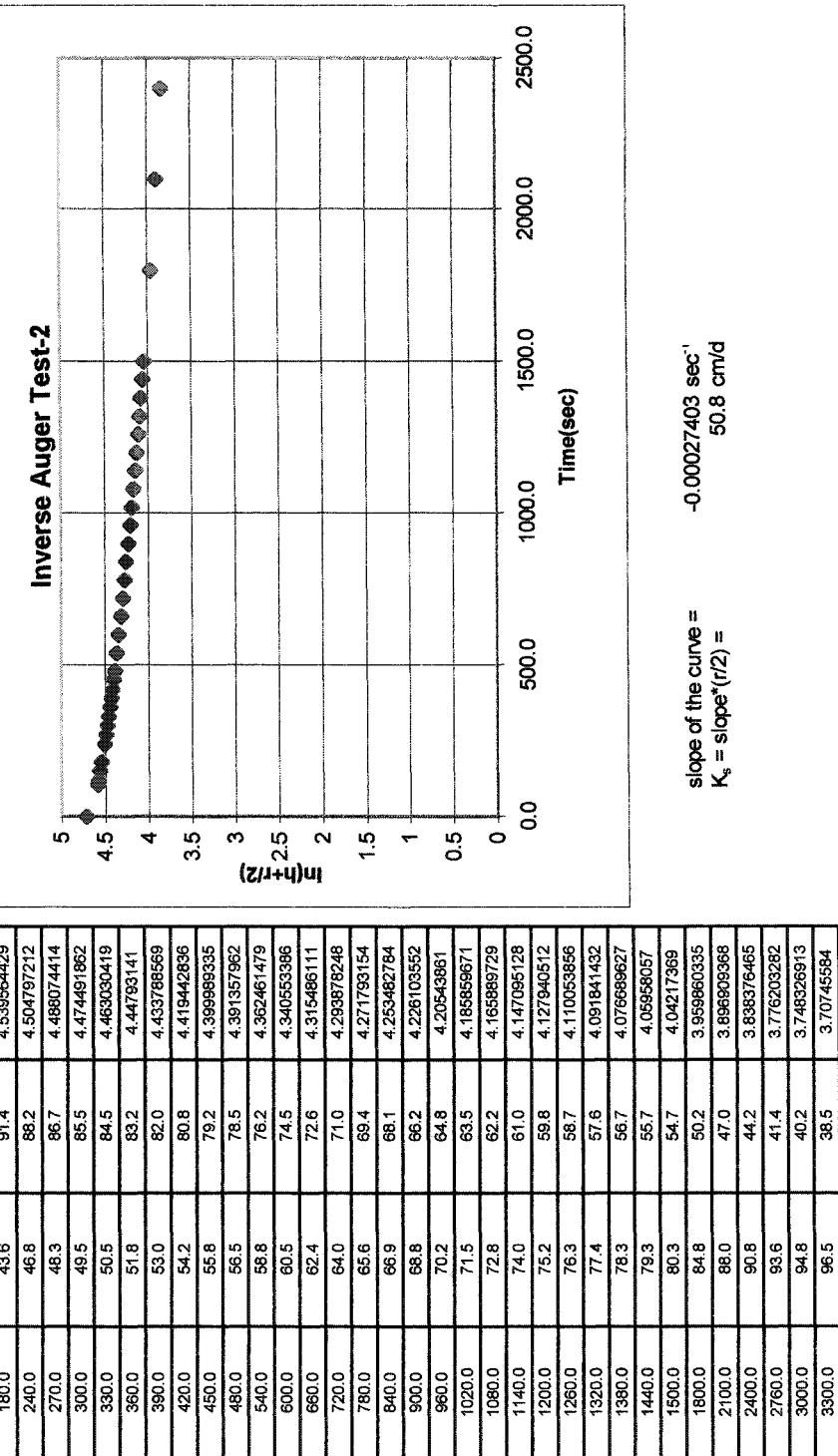


$$\text{slope of the curve} = -0.0007013 \text{ sec}^{-1}$$

$$K_s = \text{slope} (r/2) = 136.8 \text{ cm/d}$$

Appendix-A

Max. reading = 135 cm  
 r = 4.5 m

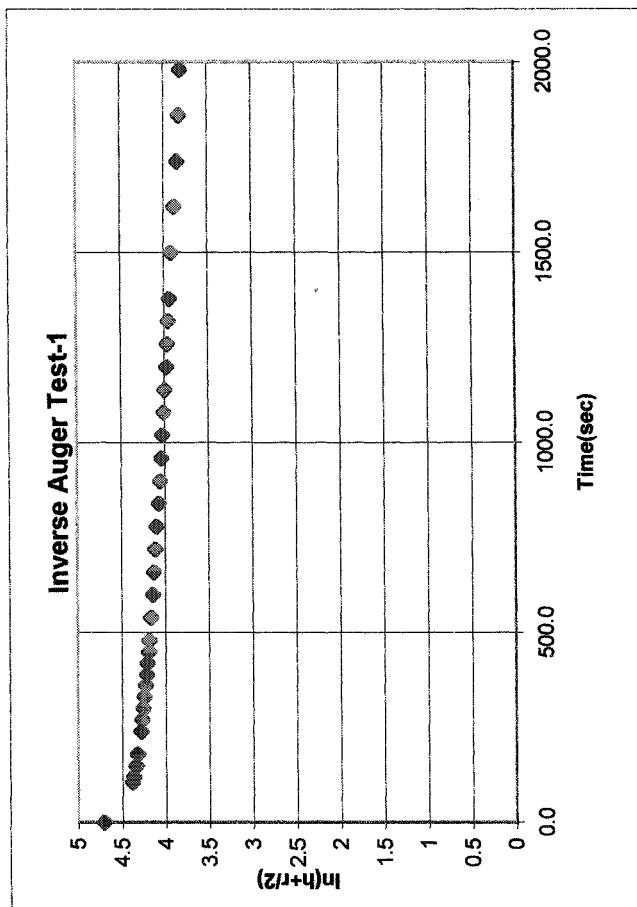


Appendix-A

Max. reading = 133.2 cm  
 $r = 4.5 \text{ m}$

Site No. 14 Depth of the hole(cm) 109.2  
 Tested on: 20/10/97

Time(sec)	Level(cm)	$h(cm)$	$\ln(h+r/2)$
0.0	24.0	109.2	4.71557606
105.0	55.0	78.2	4.387655813
120.0	56.0	77.2	4.375127883
150.0	58.2	75.0	4.347046916
180.0	59.2	74.0	4.334017415
240.0	62.5	70.7	4.289774275
270.0	63.5	69.7	4.275971438
300.0	64.5	68.7	4.261975404
330.0	65.5	67.7	4.247780701
360.0	66.4	66.8	4.23483088
390.0	67.3	65.9	4.221711158
420.0	68.1	65.1	4.209902903
450.0	68.9	64.3	4.197953545
480.0	69.5	63.7	4.188896879
540.0	70.9	62.3	4.167440117
600.0	72.2	61.0	4.147095128
660.0	73.2	60.0	4.131158525
720.0	74.2	59.0	4.114963849
780.0	75.1	58.1	4.100160948
840.0	76.5	56.7	4.076689527
900.0	77.4	55.8	4.061304708
960.0	78.3	54.9	4.04657939
1020.0	79.2	54.0	4.029806041
1080.0	80.1	53.1	4.013676659
1140.0	81.0	52.2	3.997292849
1200.0	81.9	51.3	3.980615797
1260.0	82.6	50.6	3.967457712
1320.0	83.3	49.9	3.954124181
1380.0	84.0	49.2	3.940610462
1440.0	85.2	48.0	3.917010547
1500.0	87.0	46.2	3.880552358
1560.0	88.5	44.7	3.849083206
1620.0	89.6	43.6	3.825375199
1680.0	90.5	42.7	3.805550761
1740.0	91.6	41.6	3.780774719
1800.0	95.9	37.3	3.677565634
1860.0	99.8	33.4	3.573749147
1920.0	103.9	28.3	3.451573589



$$\text{slope of the curve} = -0.00021535 \text{ sec}^{-1}$$

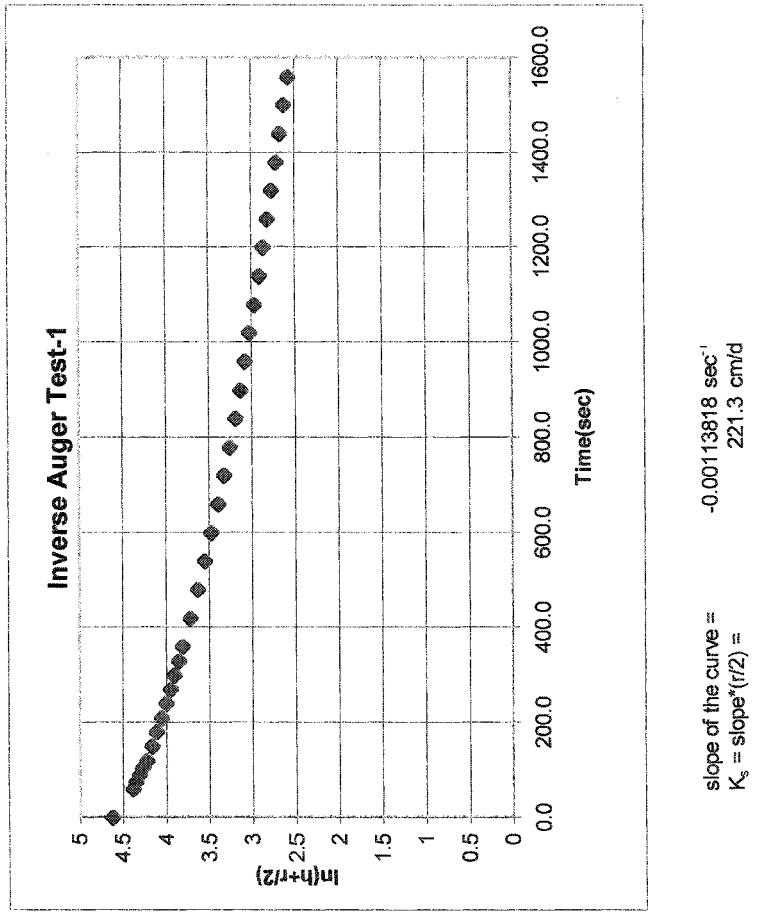
$$K_s = \text{slope}''(r/2) = 43.5 \text{ cm/d}$$

Appendix-A

Max. reading = 137 cm  
 $r = 4.5$  m

Site No. 18  
 Tested on: 18/10/97

Time(sec)	Level(cm)	$ h  (h+r/2)$
0.0	37.0	100.0
60.0	58.6	78.4
75.0	61.5	75.5
90.0	64.6	72.4
105.0	67.0	70.0
120.0	70.8	68.2
150.0	74.5	62.5
180.0	78.0	59.0
210.0	81.5	55.5
240.0	84.3	52.7
270.0	87.0	50.0
300.0	89.6	47.4
330.0	92.0	45.0
360.0	94.0	43.0
420.0	98.0	39.0
480.0	101.5	35.5
540.0	104.4	32.6
600.0	107.0	30.0
660.0	109.4	27.6
720.0	111.3	25.7
780.0	113.1	23.9
840.0	114.9	22.1
900.0	116.3	20.7
960.0	117.4	19.6
1020.0	118.5	18.5
1080.0	119.7	17.3
1140.0	120.9	16.1
1200.0	121.6	15.4
1260.0	122.5	14.5
1320.0	123.4	13.6
1380.0	124.2	12.8
1440.0	124.9	12.1
1500.0	125.5	11.5
1560.0	126.2	10.8

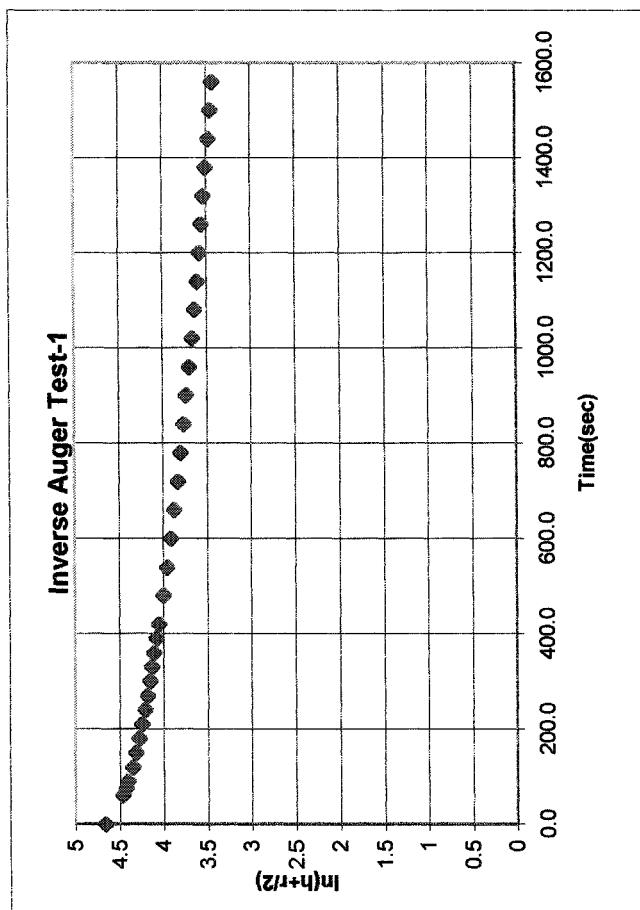


Appendix-A

Max. reading = 141.5 cm  
 $r = 4.5 \text{ m}$

Site No. 21 Depth of the hole(cm) 103.5  
 Tested on: 22/10/97

Time(sec)	Level(cm)	$ r (cm)$	$\ln( r +r/2)$
0.0	38.0	103.5	4.661077818
60.0	56.8	84.7	4.465333241
75.0	59.5	82.0	4.433788559
90.0	61.8	79.7	4.408108305
120.0	66.0	75.5	4.353498551
150.0	69.1	72.4	4.312810524
180.0	71.5	70.0	4.280132327
210.0	74.0	67.5	4.244917421
240.0	76.2	65.3	4.212868084
270.0	78.0	63.5	4.1838585671
300.0	80.0	61.5	4.1549868184
330.0	81.7	59.8	4.127940512
360.0	83.0	58.5	4.106767092
390.0	84.5	57.0	4.081765718
420.0	86.2	55.3	4.052654135
480.0	89.0	52.5	4.002777369
540.0	91.4	50.1	3.957951937
600.0	93.6	47.9	3.915018514
660.0	95.5	46.0	3.876396828
720.0	97.7	43.8	3.829727753
780.0	98.9	42.6	3.803323598
840.0	100.6	40.9	3.764682448
900.0	101.8	39.7	3.736478433
960.0	103.3	38.2	3.700086644
1020.0	104.6	36.9	3.667400422
1080.0	105.8	35.7	3.636268504
1140.0	106.9	34.6	3.606855619
1200.0	107.9	33.6	3.579342567
1260.0	108.8	32.7	3.553916469
1320.0	109.6	31.9	3.530762586
1380.0	110.5	31.0	3.504054767
1440.0	111.4	30.1	3.478614021
1500.0	112.1	29.4	3.454738149
1560.0	112.9	28.6	3.42913675
1740.0	115.0	26.5	3.356537787
1920.0	116.8	24.7	3.289858297
2100.0	118.1	23.4	3.244543572



$$\text{slope of the curve} = -0.00056351 \text{ sec}^{-1}$$

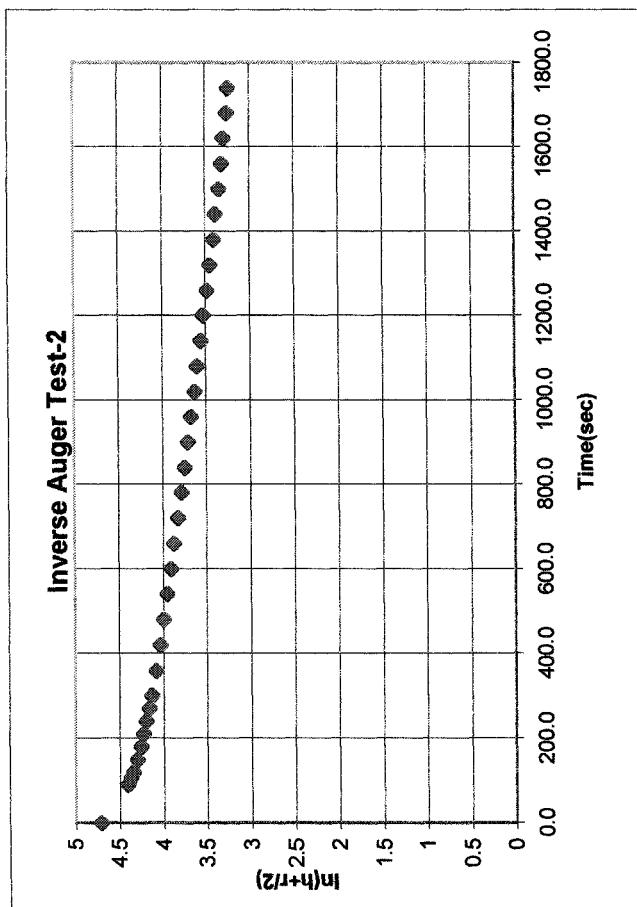
$$K_s = \text{slope}^*(r/2) = 109.5 \text{ cm/d}$$

Appendix-A

Max. reading = 135 cm  
 $r = 4.5 \text{ m}$

Site No. 21  
 Tested on: 23/10/97

Time(sec)	Level(cm)	$h(\text{cm})$	$h(r/2)$
0.0	26.0	109.0	4.711779821
90.0	54.8	80.2	4.412192049
105.0	57.5	77.5	4.376886742
120.0	59.6	75.4	4.35221155
150.0	63.3	71.7	4.303889188
180.0	66.2	68.8	4.263863656
210.0	68.5	66.5	4.230476737
240.0	70.5	64.5	4.200954297
270.0	72.6	62.4	4.168888105
300.0	74.8	60.2	4.134366237
360.0	77.8	57.2	4.085135623
420.0	80.5	54.5	4.038655656
480.0	82.7	52.3	3.989117712
540.0	84.9	50.1	3.957951937
600.0	87.2	47.8	3.913022506
660.0	89.1	45.9	3.874321138
720.0	91.2	43.8	3.82977763
780.0	93.2	41.8	3.785325852
840.0	94.6	40.4	3.753027274
900.0	96.2	38.8	3.714790636
960.0	97.7	37.3	3.677565694
1020.0	99.4	35.6	3.63363098
1080.0	100.6	34.4	3.601413428
1140.0	102.0	33.0	3.562465529
1200.0	103.2	31.8	3.52783003
1260.0	104.5	30.5	3.488692962
1320.0	105.7	29.3	3.451573589
1380.0	107.0	28.0	3.409496184
1440.0	107.8	27.2	3.35263391
1500.0	109.1	25.9	3.33754735
1560.0	109.9	25.1	3.308716529
1620.0	110.5	24.5	3.286534473
1680.0	111.3	23.7	3.25617161
1740.0	111.7	23.3	3.240637317
1800.0	112.3	22.7	3.216873822
1920.0	113.6	21.4	3.183363115
2100.0	115.6	19.4	3.075005454

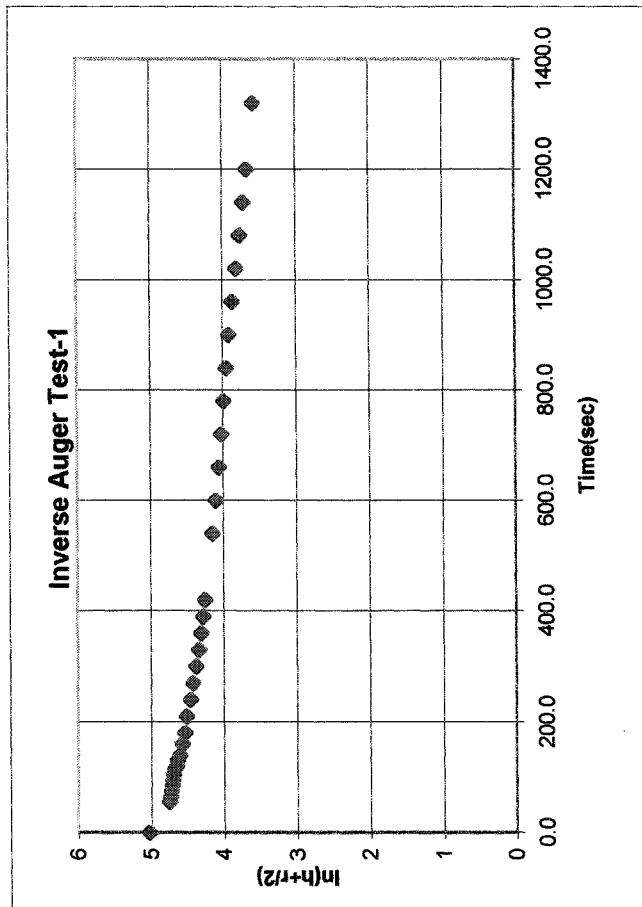


$$\begin{aligned} \text{slope of the curve} &= -0.00063449 \text{ sec}^{-1} \\ K_s &= \text{slope} \cdot (r/2) = 125 \text{ cm/d} \end{aligned}$$

Appendix-A

Max. reading = 181.4 cm  
 $r = 4.5 \text{ m}$   
 Site No. 22  
 Tested on: 12/10/97  
 Depth of the hole(cm) 151.4

Time(sec)	Level(cm)	$h(cm)$	$\ln(h+rt/2)$
0.0	30.0	151.4	5.034677289
55.0	68.0	113.4	4.750568389
65.0	70.0	111.4	4.73312355
75.0	71.0	110.4	4.724285667
85.0	72.0	109.4	4.715368978
95.0	73.0	108.4	4.706372086
105.0	74.0	107.4	4.697293475
115.0	76.0	105.4	4.678885224
120.0	79.0	102.4	4.650621449
130.0	80.0	101.4	4.641019839
140.0	83.0	98.4	4.611649152
150.0	87.0	94.4	4.571086206
160.0	90.0	91.4	4.539864429
210.0	93.0	88.4	4.507005937
240.0	97.0	84.4	4.461877016
270.0	100.5	80.9	4.420646206
300.0	104.0	77.4	4.377842036
330.0	106.5	74.9	4.345751579
360.0	109.2	72.2	4.310127759
390.0	111.4	70.0	4.280132327
420.0	113.2	68.2	4.254603238
540.0	120.0	61.4	4.1533989325
600.0	122.8	58.6	4.108411819
660.0	125.4	56.0	4.064744092
720.0	127.8	53.6	4.022689526
780.0	129.7	51.7	3.988057692
840.0	131.6	49.8	3.952204795
900.0	133.4	48.0	3.917010547
960.0	135.6	45.8	3.872242135
1020.0	138.4	43.0	3.81220267
1080.0	140.6	40.8	3.762362231
1140.0	142.5	38.9	3.717223927
1200.0	144.5	36.9	3.66740422
1320.0	147.9	33.5	3.5765650269
1440.0	150.6	30.8	3.498021556
1560.0	153.5	27.9	3.406184923
1680.0	154.0	27.4	3.389462125



$$\begin{aligned} \text{slope of the curve} &= -0.00084148 \text{ sec}^{-1} \\ K_s &= \text{slope} \cdot (r/2) = 163.6 \text{ cm/d} \end{aligned}$$

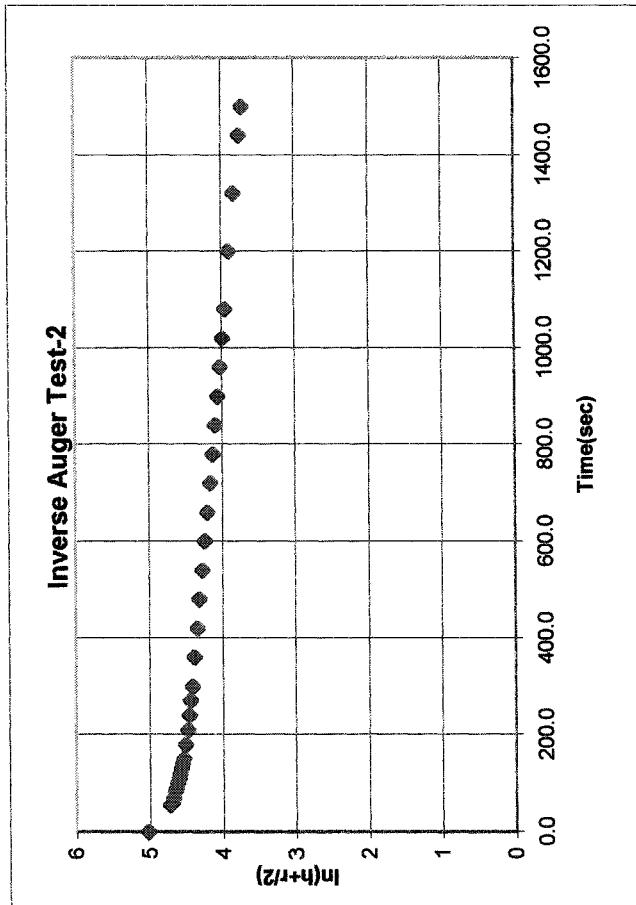
Appendix-A

Max. reading = 181.8 cm  
 $r = 4.5 \text{ m}$

Site No. 22  
 Tested on: 12/10/97

Depth of the hole(cm) 149.8

Time(sec)	Level(cm)	$h(cm)$	$\ln(h+r/2)$
0.0	32.0	149.8	5.0242094114
56.0	71.0	110.8	4.727830199
60.0	74.0	107.8	4.700334808
70.0	76.0	105.8	4.682594083
85.0	79.0	102.8	4.654436427
90.0	80.0	101.8	4.644871553
100.0	82.0	99.8	4.625462289
110.0	84.0	97.8	4.605570061
120.0	85.0	96.8	4.595624773
130.0	87.0	94.8	4.57522631
140.0	88.5	93.3	4.559949871
150.0	90.0	91.8	4.543826556
160.0	93.0	88.8	4.511408806
210.0	95.5	86.3	4.483567384
240.0	97.0	84.8	4.466482656
270.0	99.0	82.8	4.443239319
300.0	101.0	80.8	4.419442538
360.0	103.0	78.8	4.395066248
420.0	106.4	75.4	4.35221156
480.0	109.0	72.8	4.318154558
540.0	111.8	70.0	4.280132327
600.0	114.5	67.3	4.242045918
660.0	117.0	64.8	4.20543861
720.0	119.8	62.0	4.162781724
780.0	121.8	60.0	4.131158535
840.0	123.9	57.9	4.096341442
900.0	126.0	55.8	4.061304708
960.0	128.0	53.8	4.028244115
1020.0	130.0	51.8	3.989009544
1080.0	131.8	50.0	3.9560398691
1200.0	134.7	47.1	3.888937776
1220.0	137.9	43.9	3.8313956961
1440.0	141.3	40.5	3.755369795
1500.0	143.0	38.8	3.714790836
1560.0	143.8	38.0	3.69511004
1680.0	144.6	37.2	3.675034047

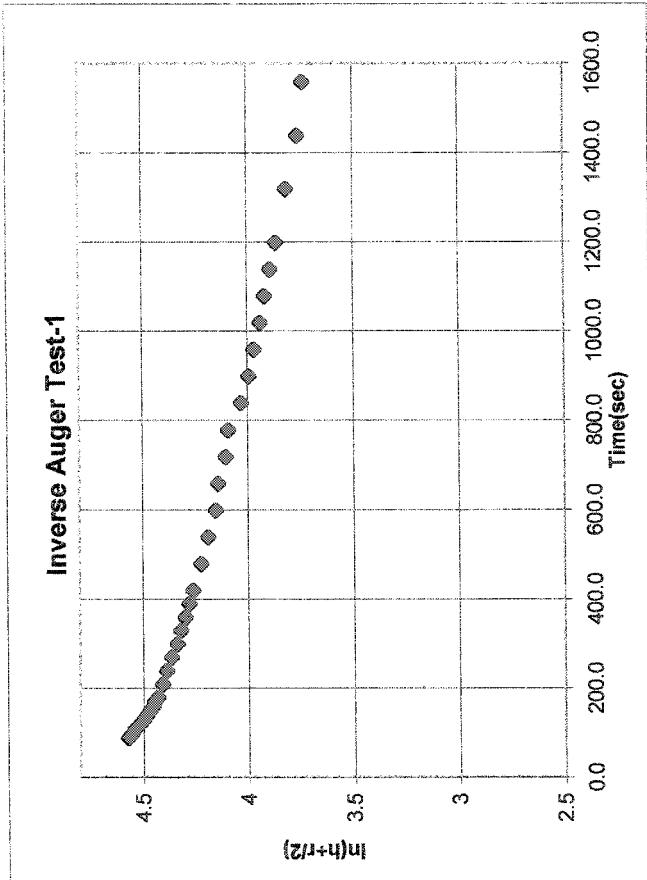


$$\begin{aligned} \text{slope of the curve} &= -0.00063001 \text{ sec}^{-1} \\ K_s &= \text{slope}^{\frac{1}{2}}(r/2) = 120.1 \text{ cm/d} \end{aligned}$$

Appendix-A

Max. reading = 188.7 cm  
 r = 4.5 m  
 Site No. 23  
 Depth of the hole(cm) 156.7  
 Tested on: 13/10/97

(times)	Level(cm)	h(cm)	h(r+r/2)
0.0	32.0	156.7	5.068598687
70.0	83.5	100.2	4.629374875
80.0	90.5	98.2	4.609860091
90.0	93.8	94.9	4.576256176
100.0	95.5	93.2	4.55860255
110.0	97.0	91.7	4.542762726
120.0	98.8	89.9	4.523417684
130.0	100.5	88.2	4.504797212
140.0	102.0	86.7	4.488074414
150.0	103.2	85.5	4.474491862
160.0	104.6	84.1	4.468408305
170.0	105.2	83.5	4.461426106
180.0	106.5	82.2	4.436159843
210.0	108.6	80.1	4.410378457
240.0	110.0	78.7	4.39883168
270.0	112.0	76.7	4.368814741
300.0	114.0	74.7	4.34315386
330.0	115.5	73.2	4.323470185
360.0	117.2	71.5	4.300680935
390.0	118.5	70.2	4.282896989
420.0	119.8	69.9	4.2641790325
450.0	122.5	68.2	4.226103552
540.0	124.7	64.0	4.193435465
600.0	127.2	61.5	4.154969184
660.0	128.0	60.7	4.14234076
720.0	130.3	58.4	4.105119635
780.0	131.0	57.7	4.083510981
840.0	134.5	54.2	4.033365291
900.0	136.6	52.1	3.985444614
960.0	137.9	50.8	3.971234865
1020.0	139.4	49.3	3.94255221
1080.0	140.6	48.1	3.918986819
1140.0	141.9	46.8	3.882840186
1200.0	143.2	45.5	3.855979057
1320.0	145.5	43.2	3.836612821
1440.0	147.9	40.8	3.762362231
1560.0	149	39.7	3.738478433



$$\text{slope of the curve} = -0.00058872 \text{ sec}^{-1}$$

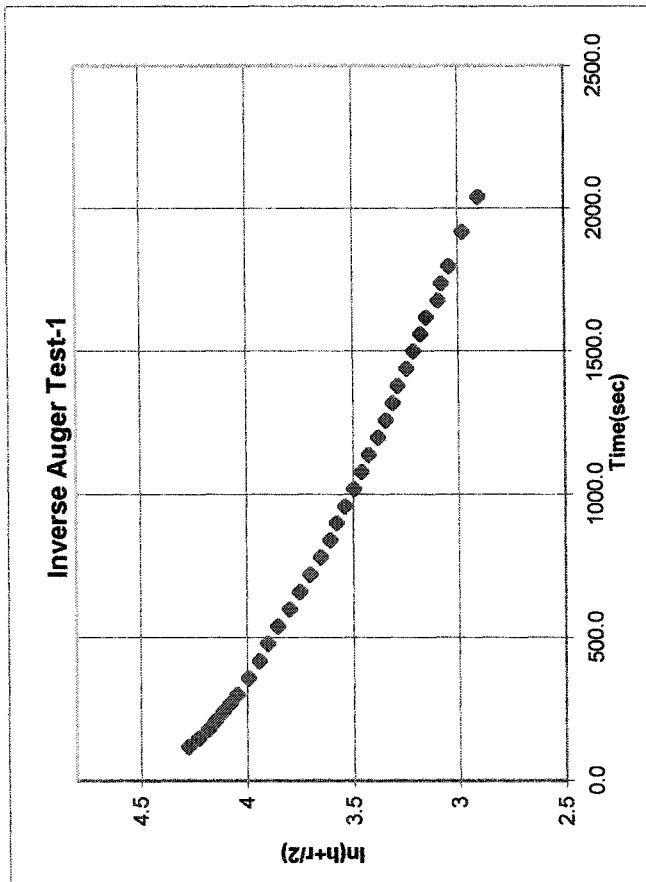
$$K_s = \text{slope}^*(r/2) = 111.3 \text{ cm/d}$$

Appendix-A

Max. reading = 141.4 cm  
 $r = 4.5$  m

Site No. 24 Depth of the hole(cm) 115.6  
 Tested on: 22/10/97

Time(sec)	Level(cm)	h(cm)	In( $\pi r/2$ )
0.0	25.8	115.6	4.789412829
90.0	67.0	74.4	4.339249605
105.0	69.2	72.2	4.310127759
120.0	71.5	69.9	4.278747385
150.0	75.0	66.4	4.229021132
180.0	77.9	63.5	4.186859871
210.0	80.1	61.3	4.151826998
240.0	82.3	59.1	4.116895171
270.0	84.4	57.0	4.081755778
300.0	86.3	55.1	4.049172844
360.0	89.4	52.0	3.9838502982
420.0	92.1	49.3	3.94255221
480.0	94.1	47.3	3.902982261
540.0	96.4	45.0	3.885452654
600.0	98.9	42.5	3.801091445
660.0	101.1	40.3	3.750679865
720.0	103.1	38.3	3.702535781
780.0	105.0	36.4	3.654546775
840.0	106.7	34.7	3.609865647
900.0	107.8	33.6	3.579343367
960.0	109.2	32.2	3.539508997
1020.0	110.6	30.8	3.486021966
1080.0	111.8	29.6	3.461037382
1140.0	112.9	28.5	3.42588994
1200.0	114.2	27.2	3.382639391
1260.0	115.3	26.1	3.34462703
1320.0	116.2	25.2	3.312386168
1380.0	116.9	24.5	3.286534473
1440.0	118.0	23.4	3.244543572
1500.0	118.8	22.6	3.212857753
1560.0	119.6	21.8	3.180134987
1620.0	120.3	21.1	3.150596884
1680.0	121.6	19.8	3.083312802
1740.0	121.9	19.5	3.079613758
1800.0	122.7	18.7	3.042138646
1820.0	124	17.4	2.978077338
2040.0	125.4	16	2.90416508



slope of the curve = -0.00071377 sec<sup>-1</sup>  
 $K_s = \text{slope}^*(\pi r/2) = 135.2 \text{ cm/d}$

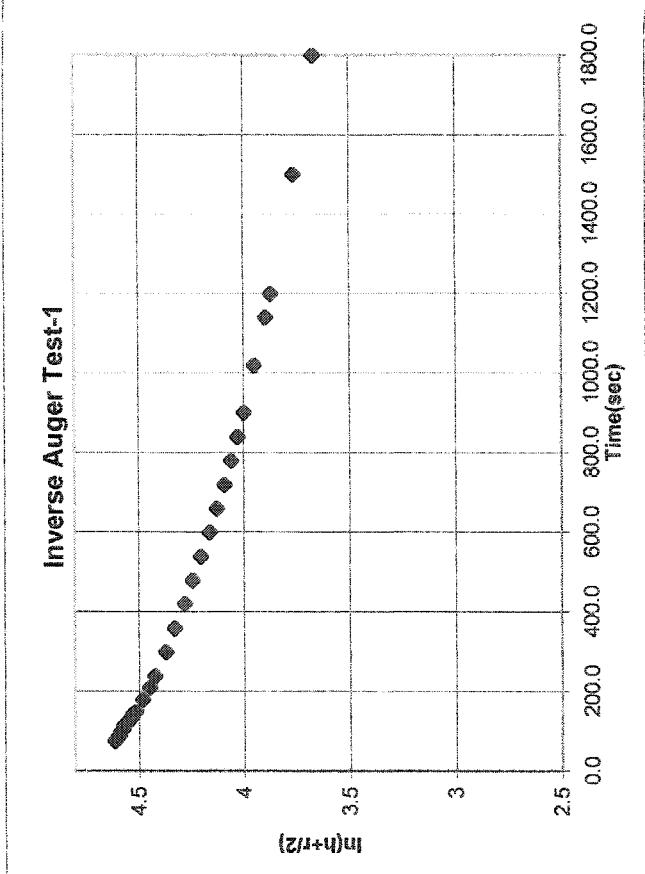
Appendix-A

Max. reading = 149 cm  
 r = 4.5 m

Site No. 25 Depth of the hole(cm) 120

Tested on: 22/10/97

Time(sec)	Level(cm)	H(cm)	In(h+1/2)
0.0	29.0	120.0	4.805038128
65.0	49.5	98.5	4.622518224
70.0	50.0	98.0	4.617592706
75.0	50.2	98.8	4.615615444
80.0	51.0	98.0	4.607667056
85.0	51.5	97.5	4.602667056
90.0	52.3	96.7	4.594614672
100.0	53.0	96.0	4.587515251
105.0	53.8	95.2	4.579339426
110.0	54.2	94.8	4.57522031
115.0	54.6	94.4	4.571398206
120.0	55.0	93.5	4.561740676
125.0	56.5	92.5	4.551241844
130.0	57.0	92.0	4.545950526
135.0	58.0	91.0	4.535284059
140.0	58.3	90.7	4.532061714
145.0	58.5	90.5	4.529807701
150.0	59.6	89.4	4.517976874
180.0	62.7	86.3	4.443567364
210.0	65.5	83.5	4.451436266
240.0	67.5	81.4	4.428641427
300.0	71.8	77.2	4.375127883
360.0	75.2	73.8	4.331394019
420.0	78.7	70.3	4.284275879
480.0	81.5	67.5	4.244917421
540.0	84.1	64.9	4.205928823
600.0	87.0	62.0	4.162781724
660.0	89.0	60.0	4.131158556
720.0	91.2	57.8	4.085177549
780.0	93.2	55.8	4.031304708
840.0	95.0	54.0	4.029806341
900.0	96.6	52.4	4.000949215
1020.0	99.3	49.7	3.950281718
1140.0	102.0	47.0	3.886809368
1200.0	103.2	45.8	3.872242135
1500.0	108.2	40.8	3.762362231
1800.0	112.1	36.9	3.667490422



slope of the curve =  
 Ks = slope\*(r/2) =

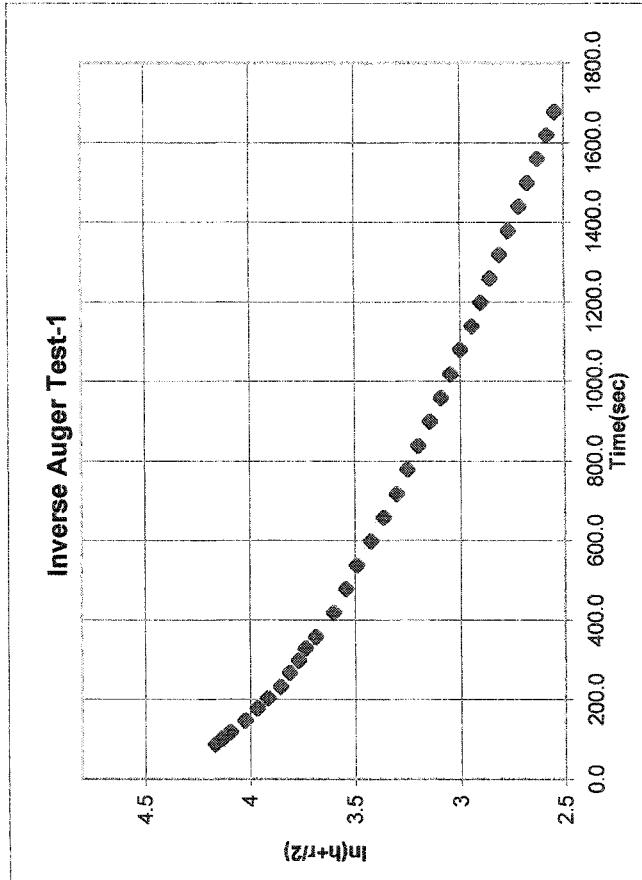
-0.00061542 sec-1  
 118.3 cm/d

Appendix-A

Max. reading = 139 cm  
 r = 4.5 m

Site No. 26  
 Tested on: 22/10/97

Time(sec)	Level(cm)	$ h (cm)$	$ h (h+r/2)$
0.0	21.0	118.0	4.789572809
60.0	70.2	68.8	4.263383885
75.0	73.6	65.4	4.214347385
90.0	76.5	62.5	4.170533701
105.0	78.8	60.2	4.154365237
120.0	81.0	58.0	4.085652572
150.0	86.1	53.9	4.028026681
180.0	88.3	50.7	3.9693481072
205.0	90.8	48.2	3.920982747
235.0	93.8	45.2	3.8595676525
270.0	95.8	43.2	3.8166612821
300.0	97.7	41.3	3.773989703
330.0	99.2	39.8	3.736859386
360.0	101.1	37.9	3.69262244
420.0	104.5	34.5	3.604138226
480.0	106.5	32.5	3.548179572
540.0	108.3	30.7	3.484981281
600.0	110.4	28.6	3.42913675
660.0	112.3	26.7	3.365570204
720.0	114.0	25.0	3.3050533521
780.0	115.4	23.6	3.252310601
840.0	116.7	22.3	3.200711854
900.0	118.0	21.0	3.146305132
960.0	119.2	19.8	3.093312052
1020.0	120.2	18.8	3.046980056
1080.0	121.1	17.9	3.003254288
1140.0	122.2	16.8	2.947087102
1200.0	123.0	16.0	2.90416508
1260.0	123.8	15.2	2.859339849
1320.0	124.6	14.4	2.812410216
1380.0	125.3	13.7	2.75946829
1440.0	126.1	12.9	2.718000532
1500.0	126.7	12.3	2.677550984
1560.0	127.4	11.6	2.628285233
1620.0	128.0	11.0	2.563987552
1680.0	128.5	10.5	2.545531272



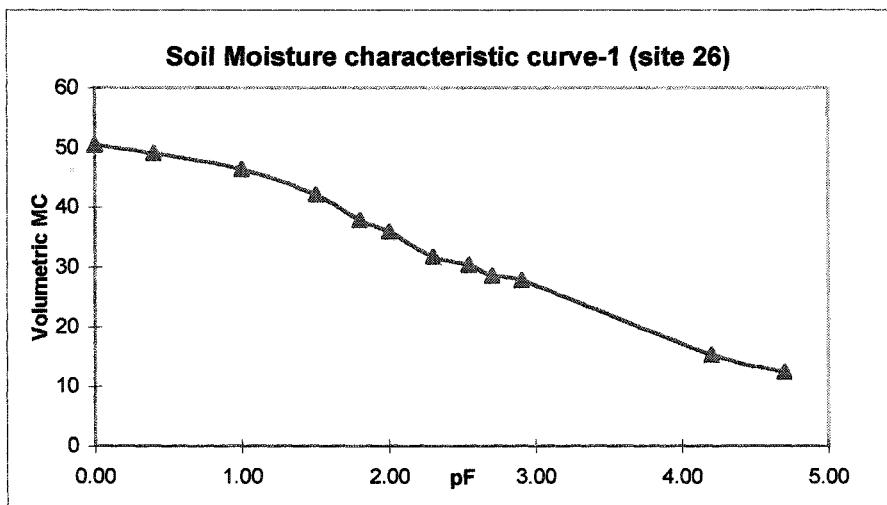
$$\begin{aligned} \text{slope of the curve} &= -0.00095151 \text{ sec}^{-1} \\ K_s &= \text{slope}^*(r/2) = 185 \text{ cm/d} \end{aligned}$$

## **APPENDIX - B**

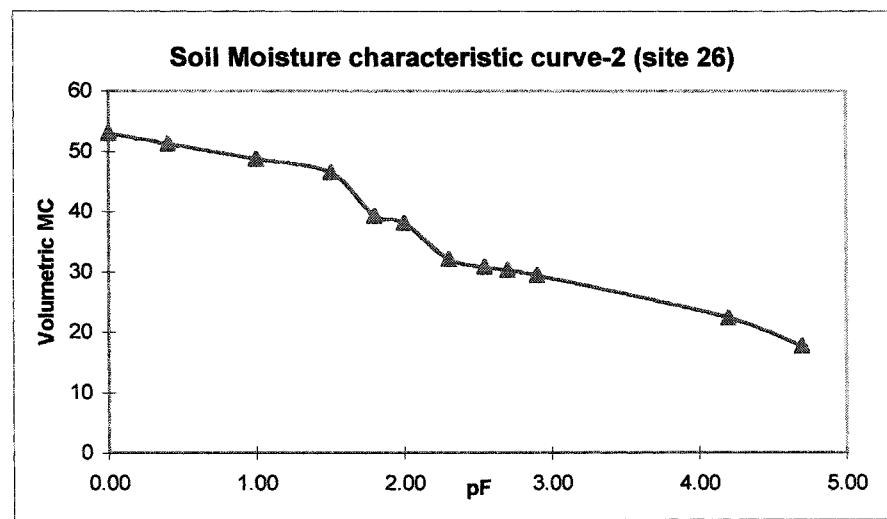
Moisture retention characteristic curves

Appendix-B

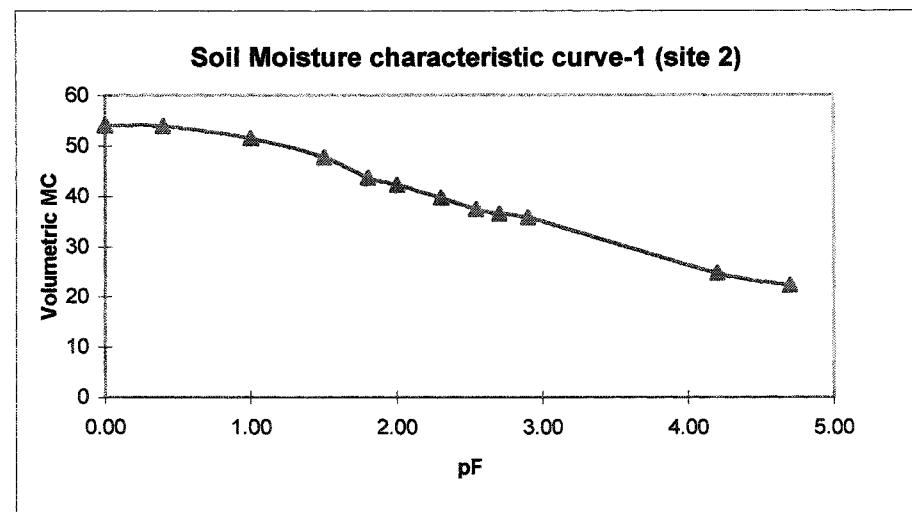
pF	Volumetric MC
0.00	50.37
0.40	49.03
1.00	46.33
1.50	42.08
1.80	37.81
2.00	35.86
2.30	31.68
2.54	30.27
2.70	28.52
2.90	27.77
4.20	15.22
4.70	12.34



pF	Volumetric MC
0.00	52.93
0.40	51.24
1.00	48.64
1.50	46.48
1.80	39.29
2.00	38.08
2.30	32.04
2.54	30.84
2.70	30.31
2.90	29.45
4.20	22.36
4.70	17.65

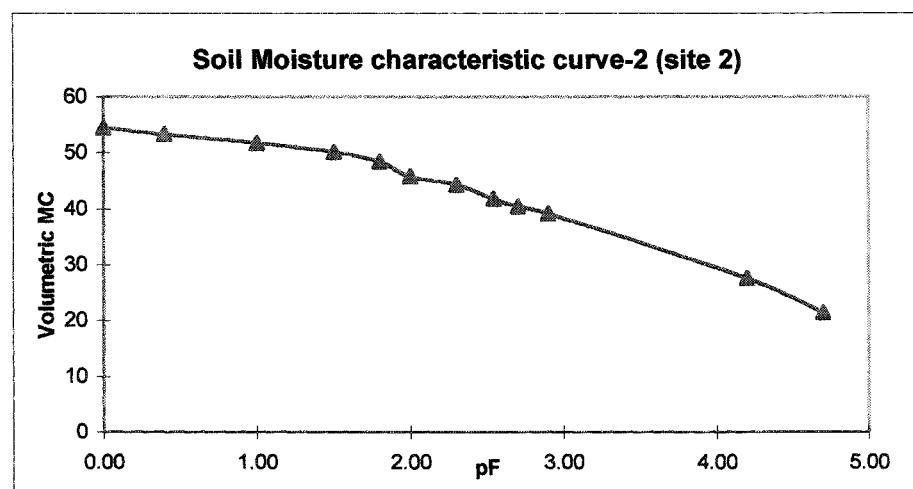


pF	Volumetric MC
0.00	53.94
0.40	53.75
1.00	51.42
1.50	47.59
1.80	43.45
2.00	42.14
2.30	39.59
2.54	37.28
2.70	36.45
2.90	35.68
4.20	24.64
4.70	22.23

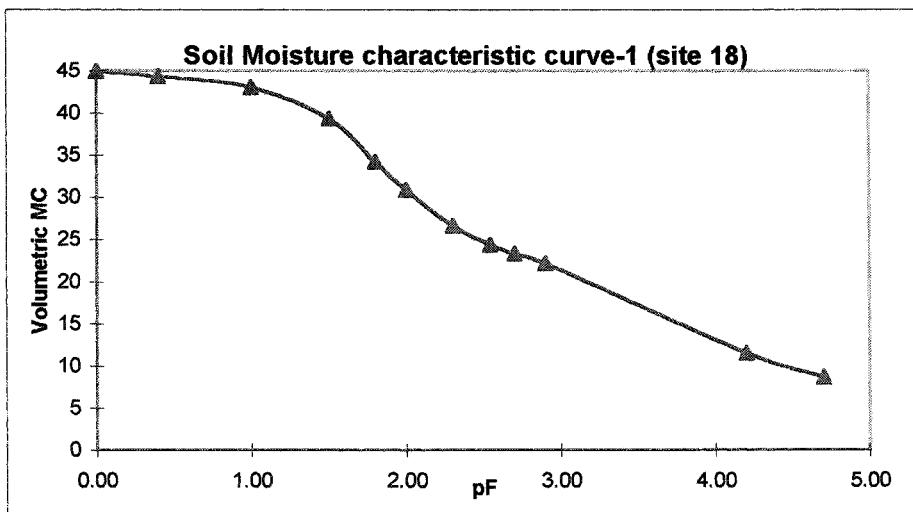


Appendix-B

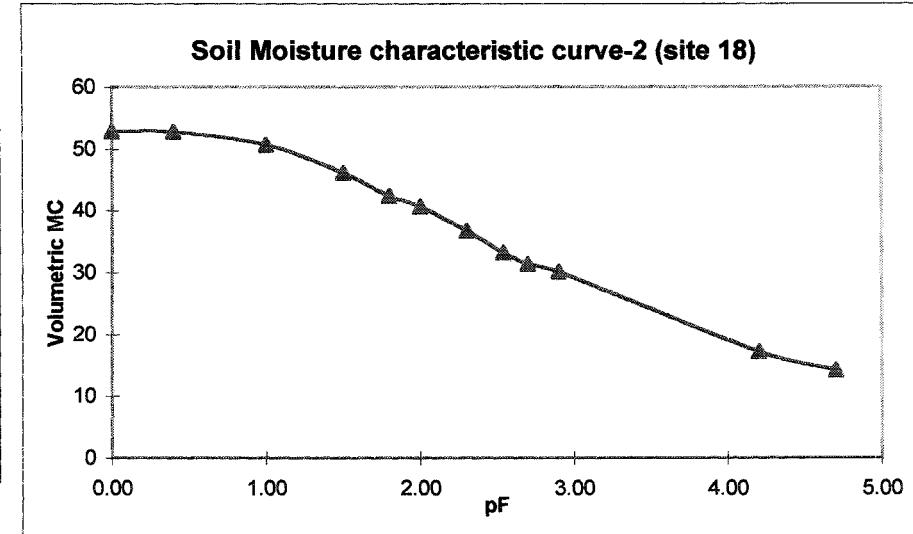
pF	Volumetric MC
0.00	54.44
0.40	53.19
1.00	51.67
1.50	50.06
1.80	48.31
2.00	45.65
2.30	44.19
2.54	41.69
2.70	40.28
2.90	39.06
4.20	27.46
4.70	21.31



pF	Volumetric MC
0.00	44.96
0.40	44.34
1.00	43.04
1.50	39.35
1.80	34.15
2.00	30.86
2.30	26.6
2.54	24.32
2.70	23.33
2.90	22.14
4.20	11.52
4.70	8.63

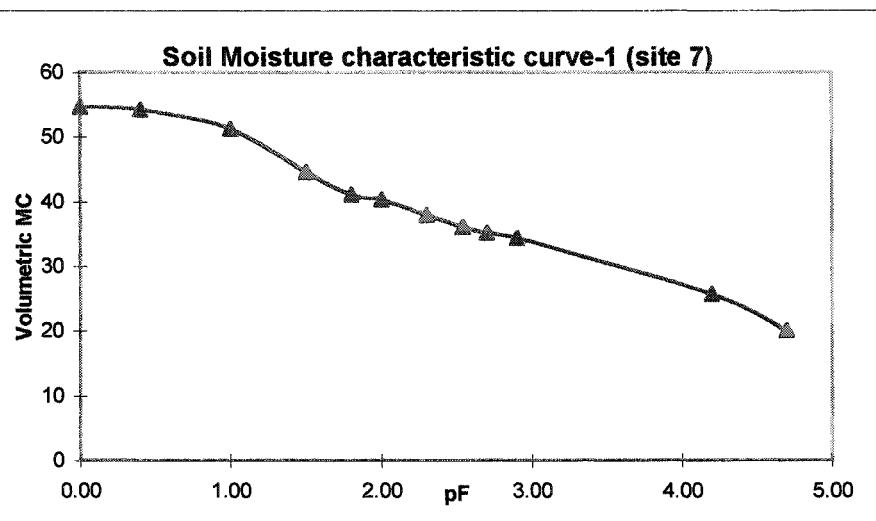


pF	Volumetric MC
0.00	52.76
0.40	52.61
1.00	50.56
1.50	46.07
1.80	42.26
2.00	40.52
2.30	36.58
2.54	33.1
2.70	31.24
2.90	29.99
4.20	17.02
4.70	14.03

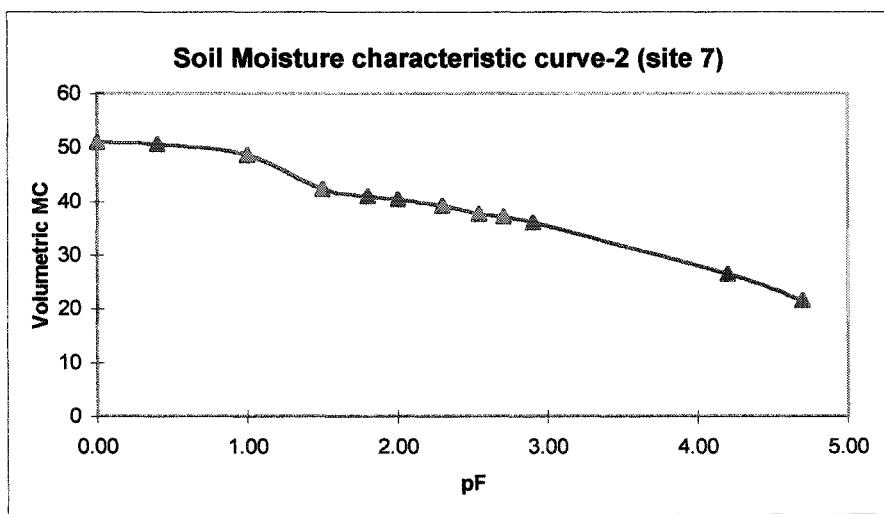


## Appendix-B

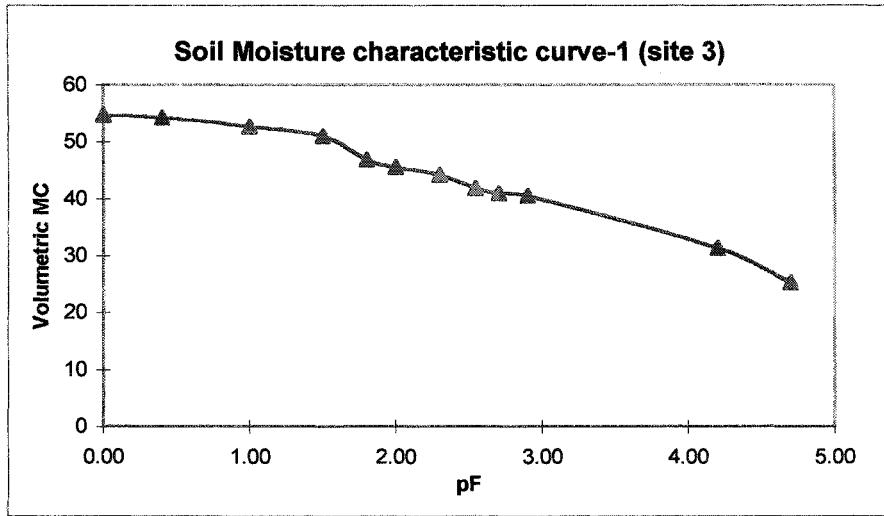
pF	Volumetric MC
0.00	54.56
0.40	54.13
1.00	51.18
1.50	44.49
1.80	41.06
2.00	40.31
2.30	37.87
2.54	35.99
2.70	35.13
2.90	34.31
4.20	25.64
4.70	20.08



pF	Volumetric MC
0.00	50.84
0.40	50.49
1.00	48.46
1.50	42.25
1.80	40.92
2.00	40.34
2.30	39.17
2.54	37.63
2.70	37.07
2.90	36.09
4.20	26.45
4.70	21.56

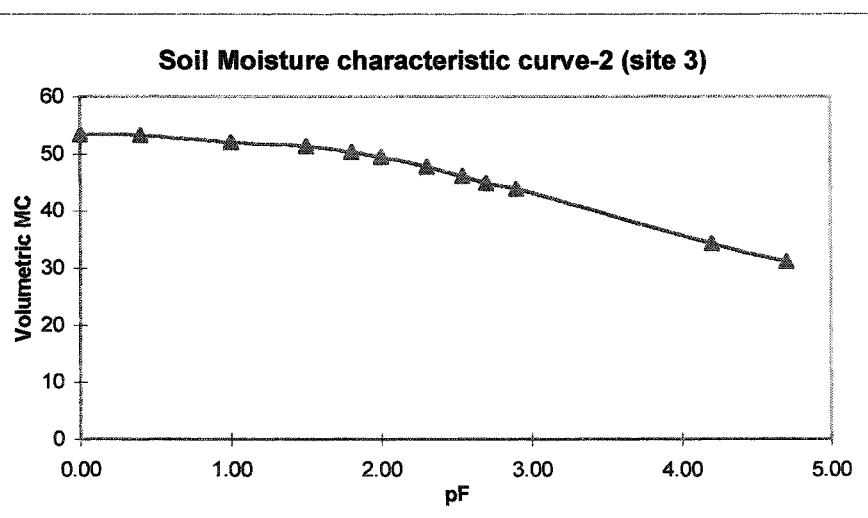


pF	Volumetric MC
0.00	54.58
0.40	54.21
1.00	52.58
1.50	50.95
1.80	46.8
2.00	45.46
2.30	44.12
2.54	41.8
2.70	40.9
2.90	40.4
4.20	31.23
4.70	25.14

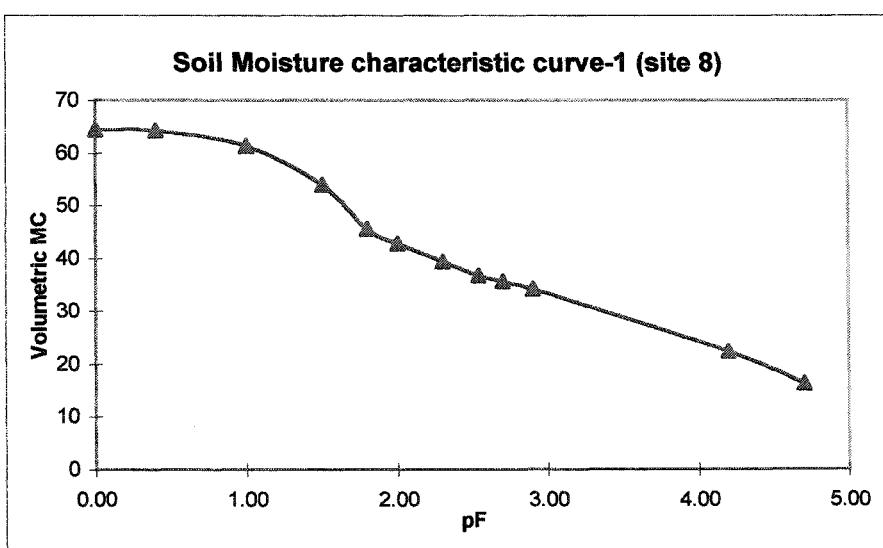


Appendix B

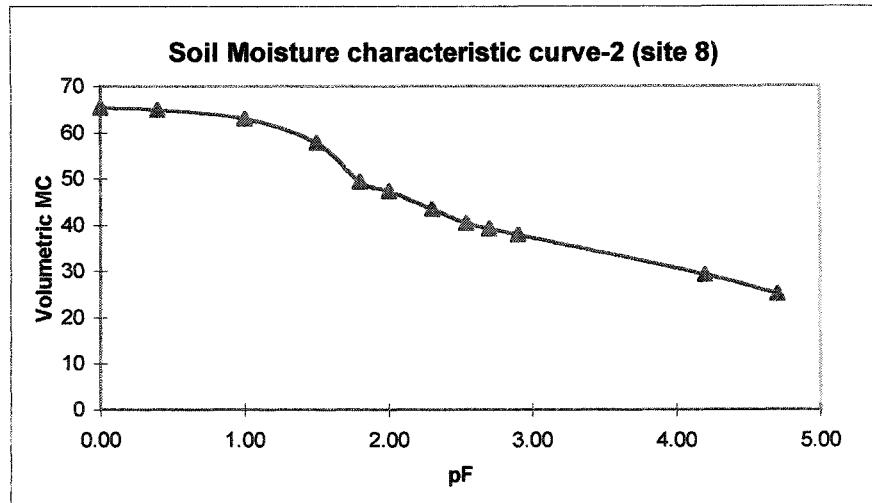
pF	Volumetric MC
0.00	53.26
0.40	53.24
1.00	51.98
1.50	51.29
1.80	50.26
2.00	49.37
2.30	47.75
2.54	46.03
2.70	44.88
2.90	43.86
4.20	34.29
4.70	31.14



pF	Volumetric MC
0.00	64.31
0.40	64.2
1.00	61.27
1.50	53.91
1.80	45.56
2.00	42.71
2.30	39.42
2.54	36.73
2.70	35.6
2.90	34.18
4.20	22.23
4.70	16.17

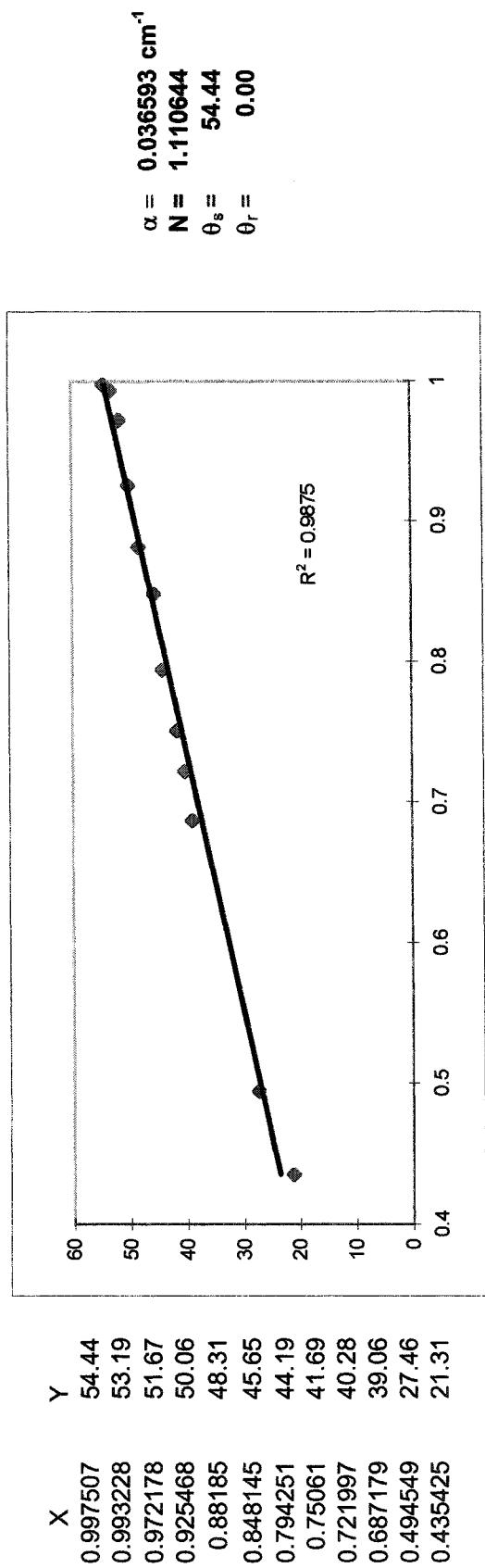
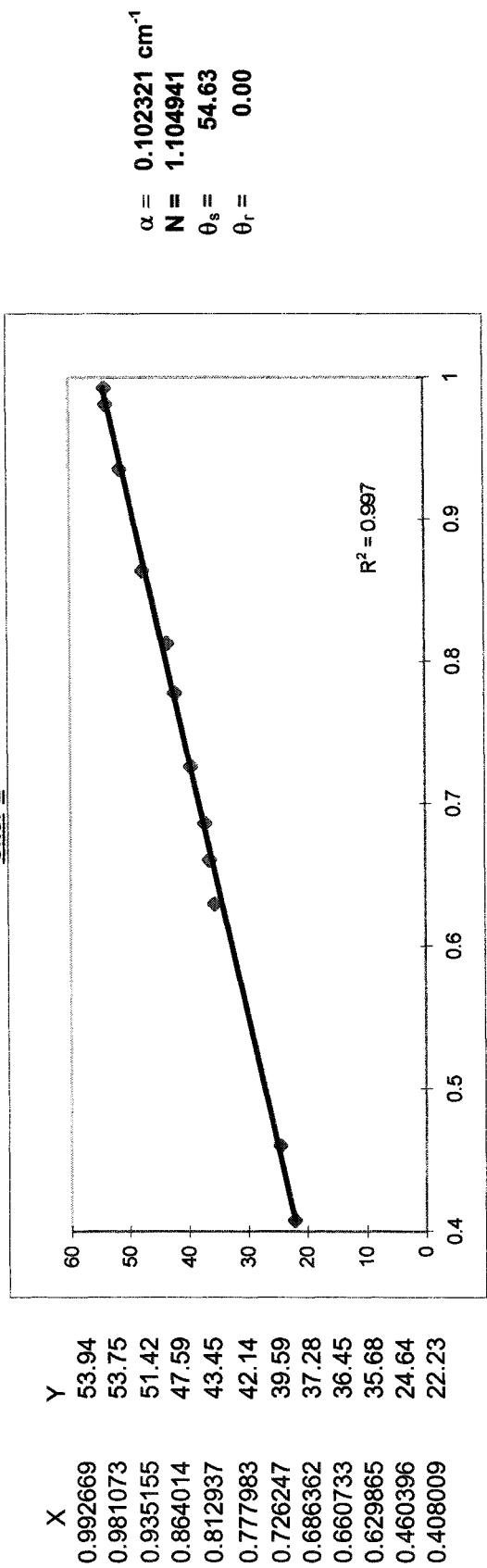


pF	Volumetric MC
0.00	65.25
0.40	64.85
1.00	63.01
1.50	57.7
1.80	49.28
2.00	47.33
2.30	43.45
2.54	40.44
2.70	39.14
2.90	37.85
4.20	29.26
4.70	25.14



Appendix-B

Site: 2

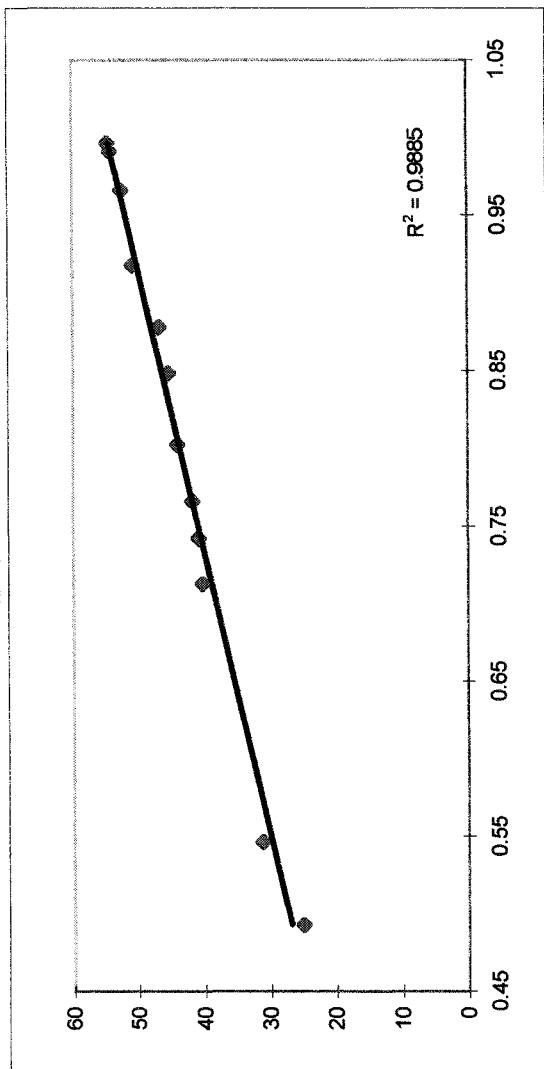


$$X = 1 + (\alpha h)^N \cdot Y^{(1/(N-1)}$$

$$Y = \theta$$

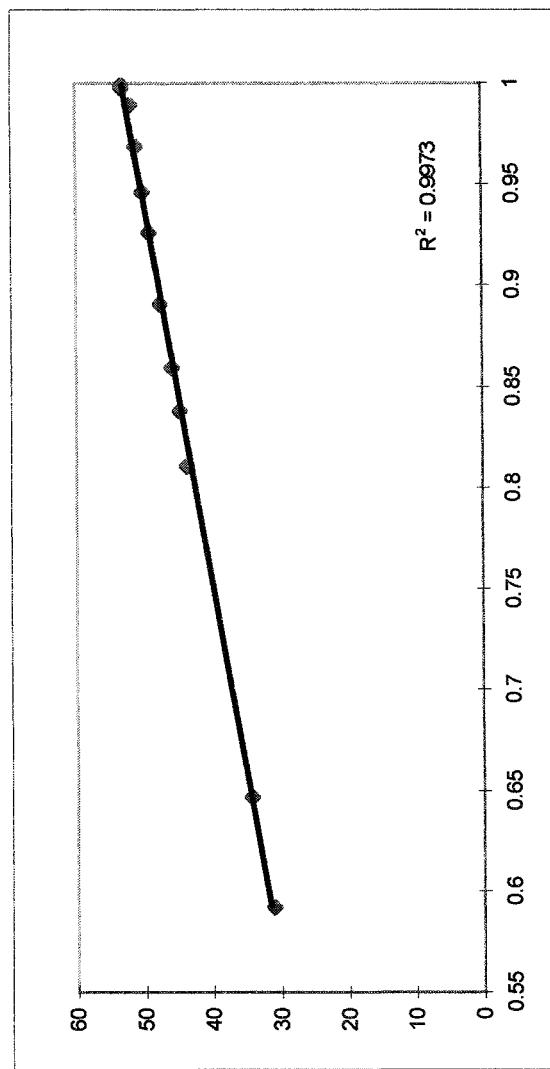
Appendix-B

Site: 3



X	Y
0.999039	53.26
0.99744	53.24
0.989352	51.98
0.968813	51.29
0.946046	50.26
0.926117	49.37
0.890786	47.75
0.859467	46.03
0.837894	44.88
0.810728	43.86
0.646785	34.29
0.592182	31.14

6



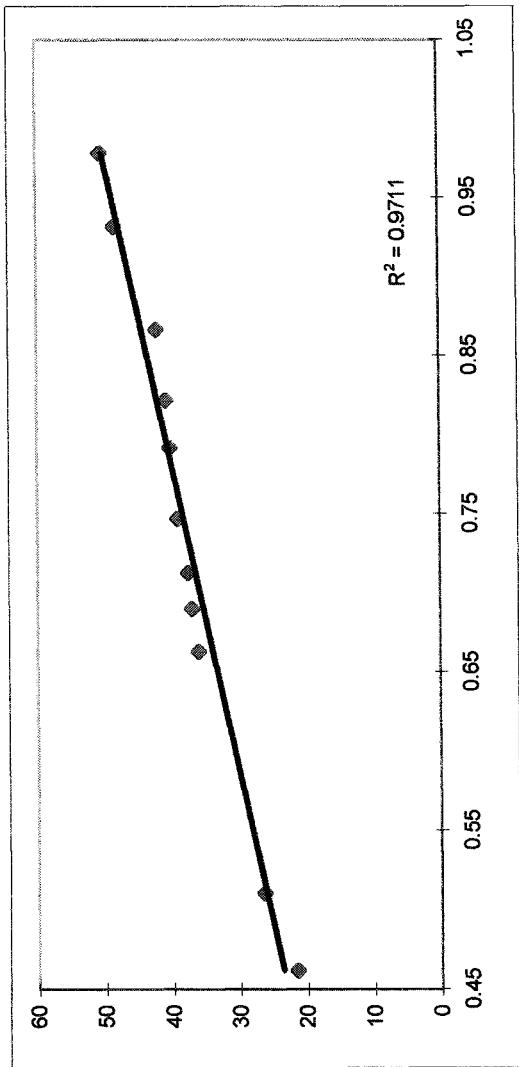
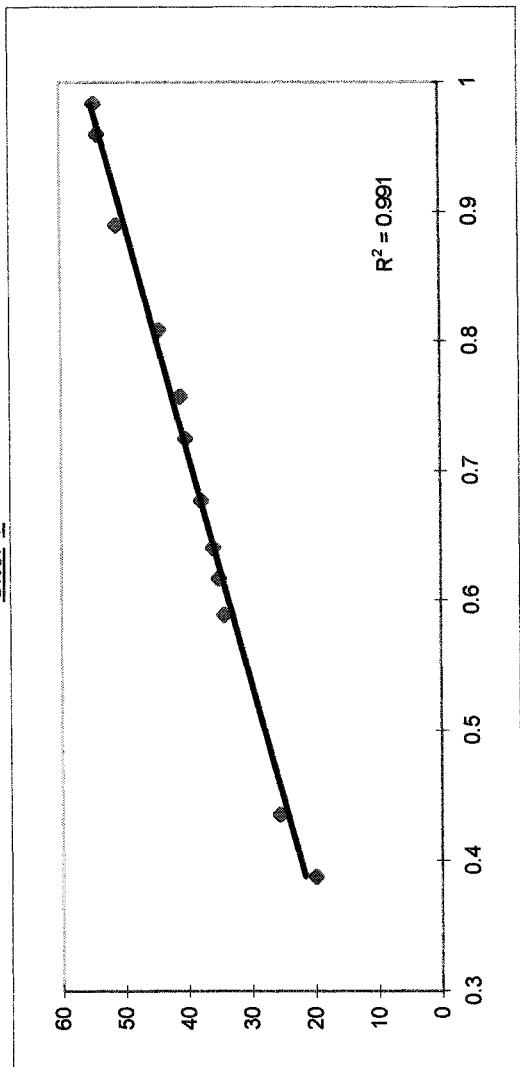
X	Y
0.999039	53.26
0.99744	53.24
0.989352	51.98
0.968813	51.29
0.946046	50.26
0.926117	49.37
0.890786	47.75
0.859467	46.03
0.837894	44.88
0.810728	43.86
0.646785	34.29
0.592182	31.14

$$X = 1 + (\alpha h)^N \cdot Y^{(1/(N-1))}$$

$$Y = \theta$$

Appendix-B

Site: 7

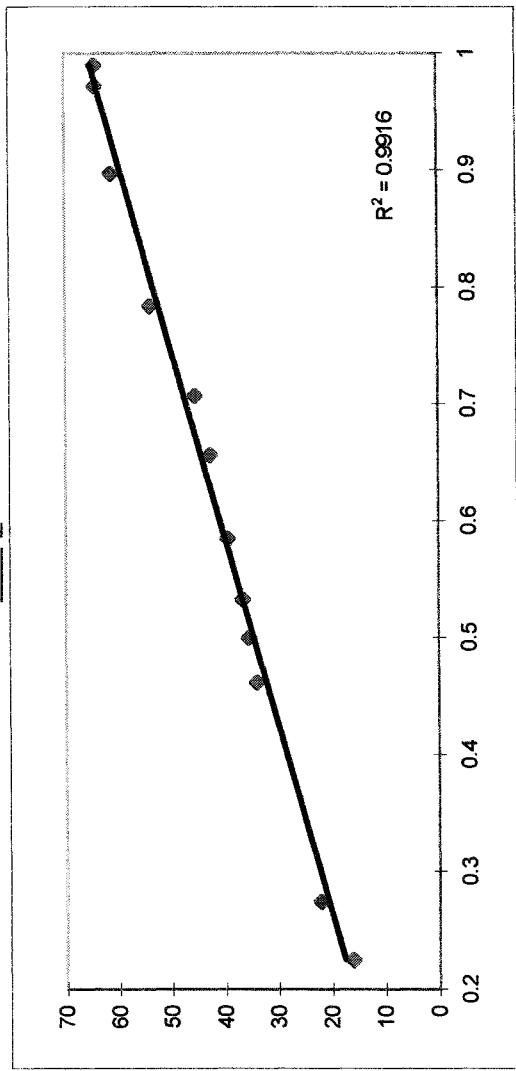


$$X = 1 + (\alpha h)^N \gamma^{(1/N-1)}$$

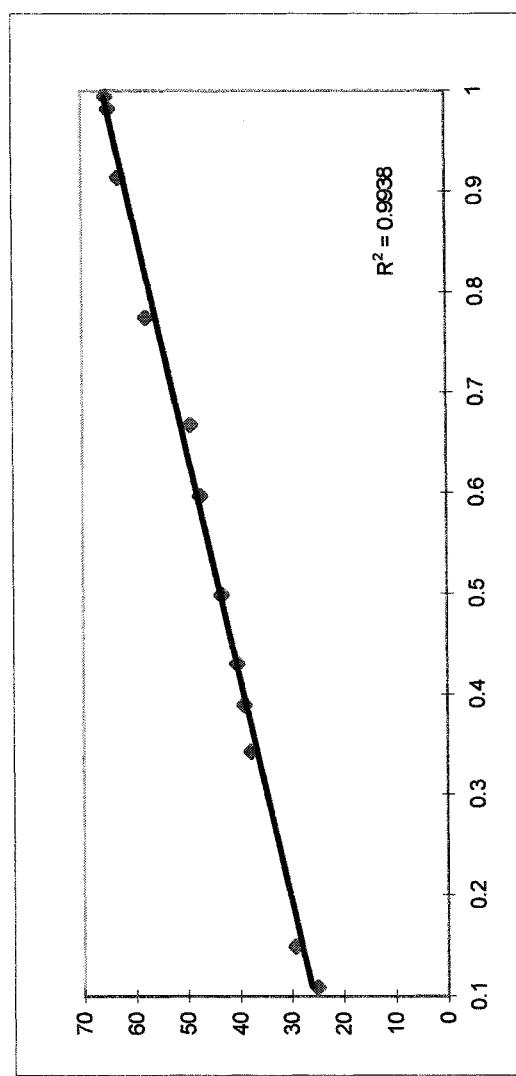
$$Y = 0$$

Appendix-B

Site: 8



X	Y
0.994196	65.25
0.981828	64.85
0.913779	63.01
0.774683	57.7
0.6667909	49.28
0.597045	47.33
0.498957	43.45
0.429973	40.44
0.388847	39.14
0.342636	37.85
0.149562	29.26
0.10867	25.14



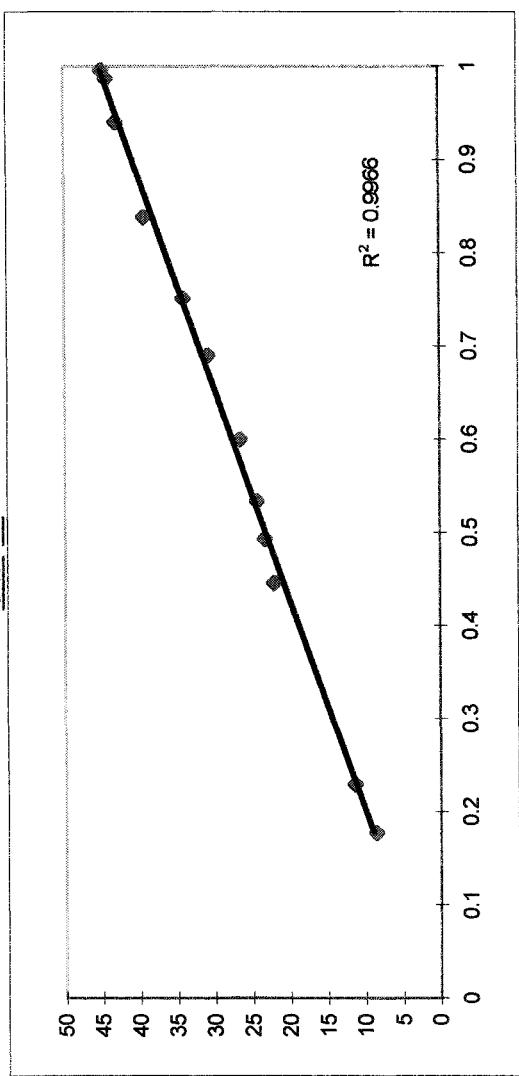
X	Y
0.994196	65.25
0.981828	64.85
0.913779	63.01
0.774683	57.7
0.6667909	49.28
0.597045	47.33
0.498957	43.45
0.429973	40.44
0.388847	39.14
0.342636	37.85
0.149562	29.26
0.10867	25.14

$$X = 1 + (\alpha h)^N \cdot [1/(N-1)]$$

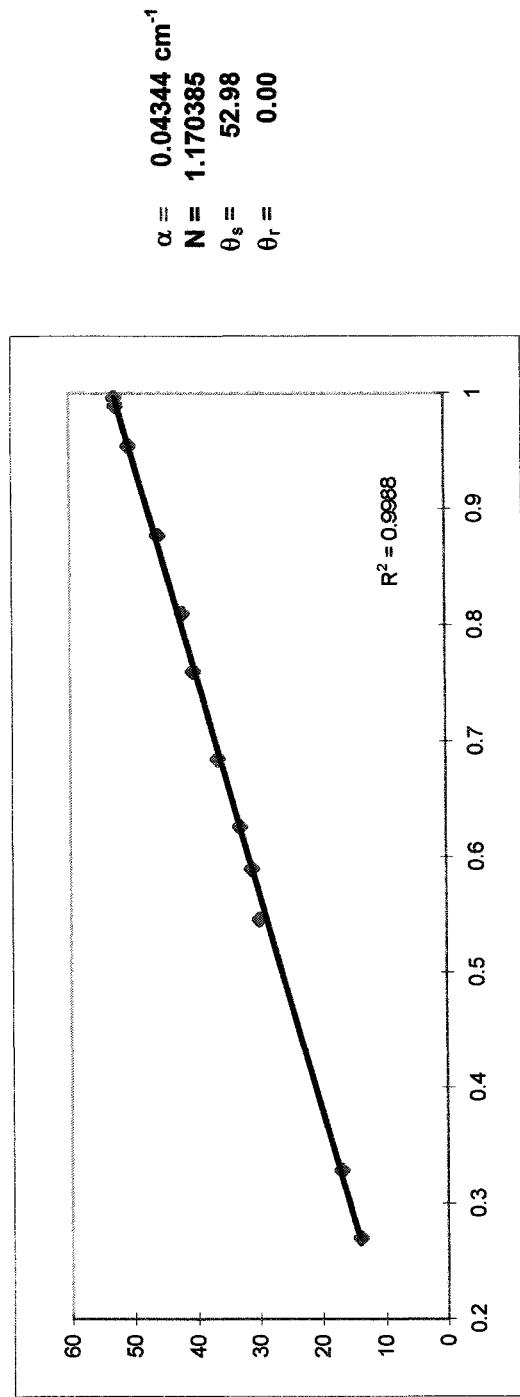
$$Y = \theta$$

Appendix-B

Site: 18



X	Y
0.995696	44.96
0.987104	44.34
0.940591	43.04
0.83841	39.35
0.751657	34.15
0.690194	30.86
0.600304	26.6
0.533823	24.32
0.49288	23.33
0.445633	22.14
0.229553	11.52
0.177724	8.63



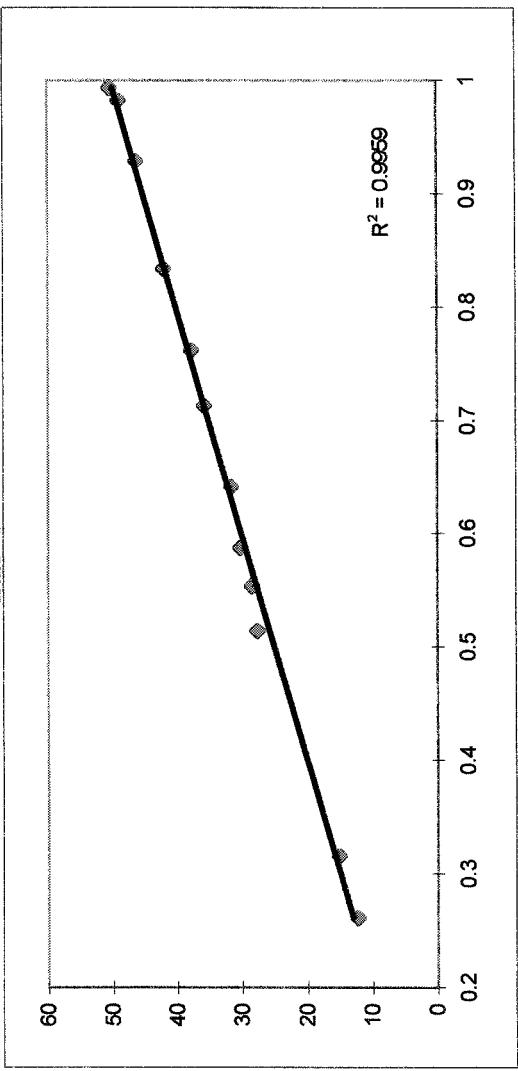
X	Y
0.996347	52.76
0.989552	52.61
0.954509	50.56
0.877695	46.07
0.809936	42.26
0.760133	40.52
0.684448	36.58
0.626203	33.10
0.589316	31.24
0.545723	29.99
0.328425	17.02
0.2669939	14.03

$$X = 1 + (\alpha h)^N \cdot Y^{(1/N-1)}$$

$$Y = \theta$$

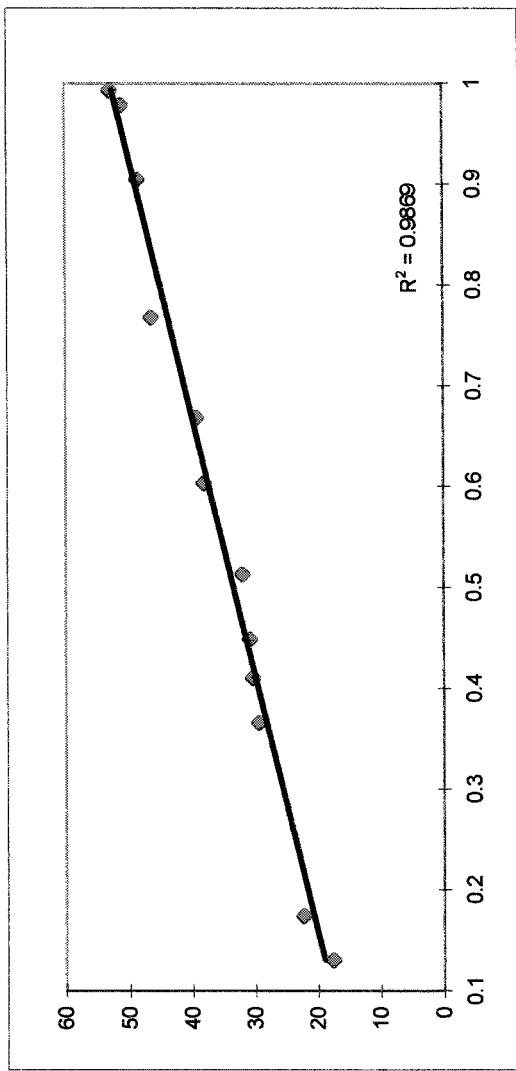
Appendix-B

Site: 26



X	Y
0.992808	52.93
0.978273	51.24
0.904537	48.64
0.768139	46.48
0.668668	39.29
0.603382	38.08
0.512809	32.04
0.448459	30.84
0.409691	30.31
0.365669	29.45
0.173753	22.36
0.130449	17.65

10



$$X = 1 + (\alpha h)^N \cdot t^{(1/N-1)}$$

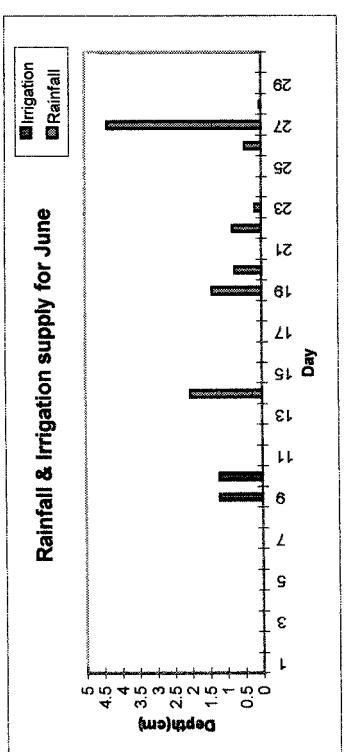
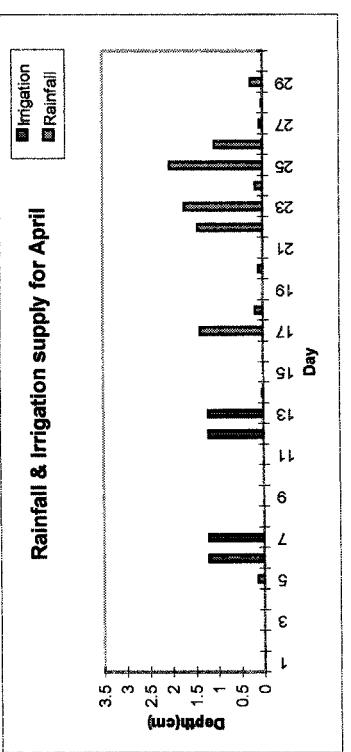
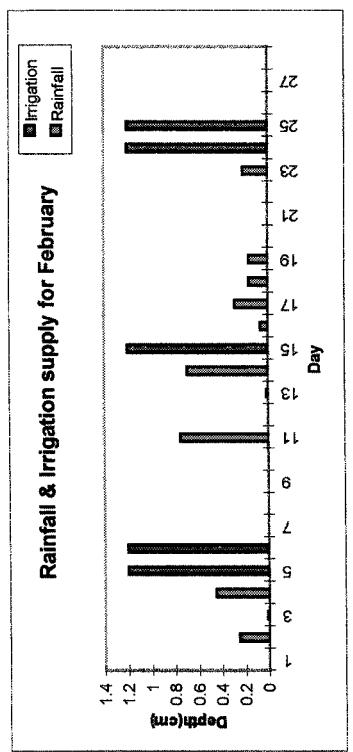
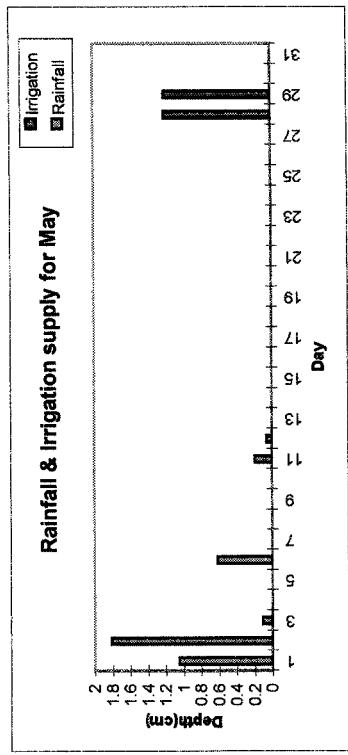
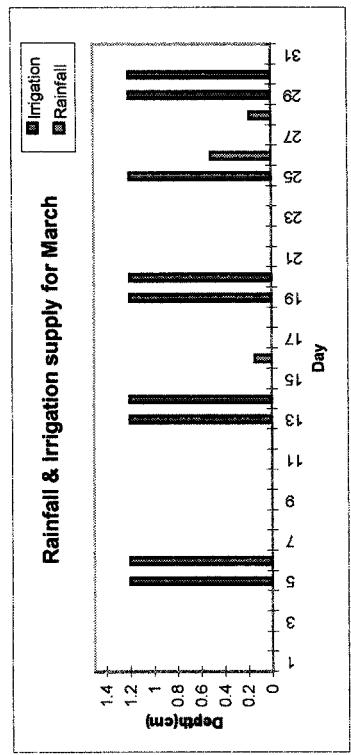
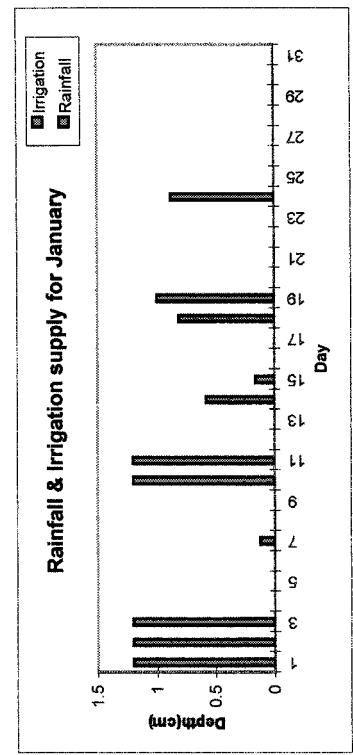
$$Y = \theta$$

## **APPENDIX - C**

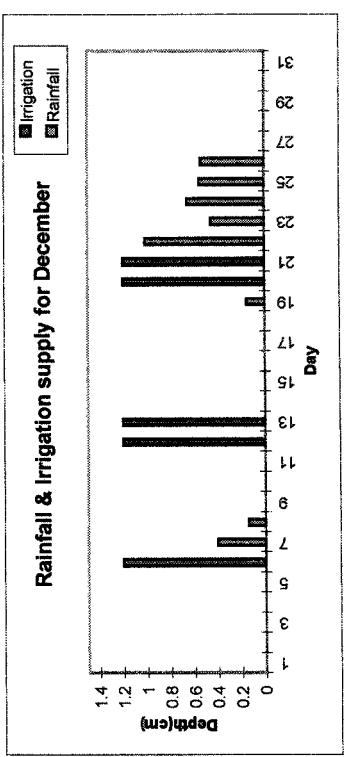
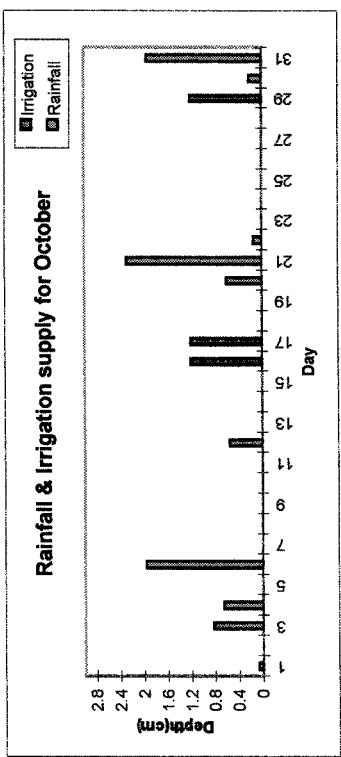
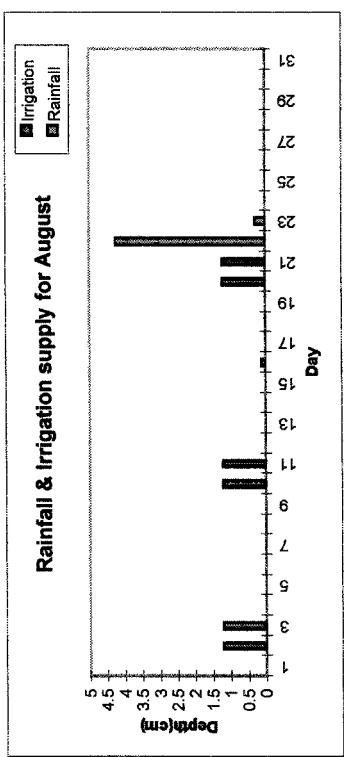
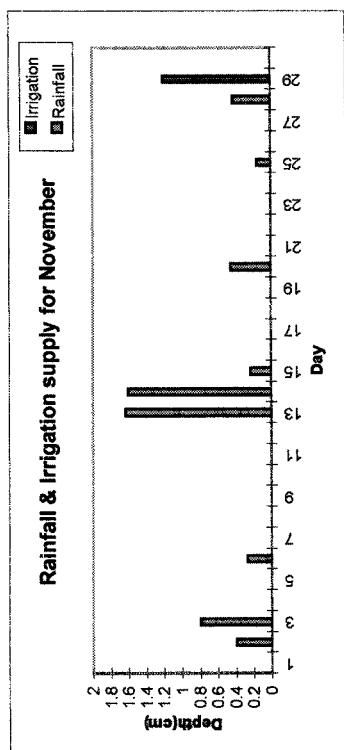
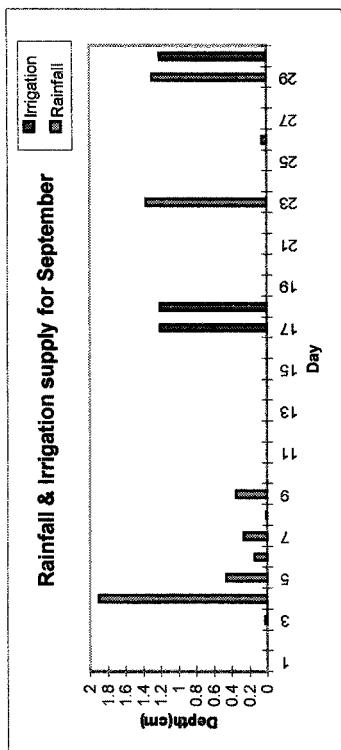
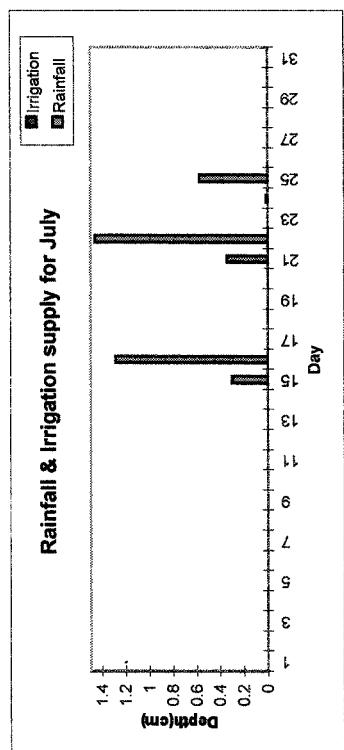
Distribution of irrigation and rainfall at site No.8

Site No: 8

**Irrigation supply pattern in a normal year of rainfall (January to June)**



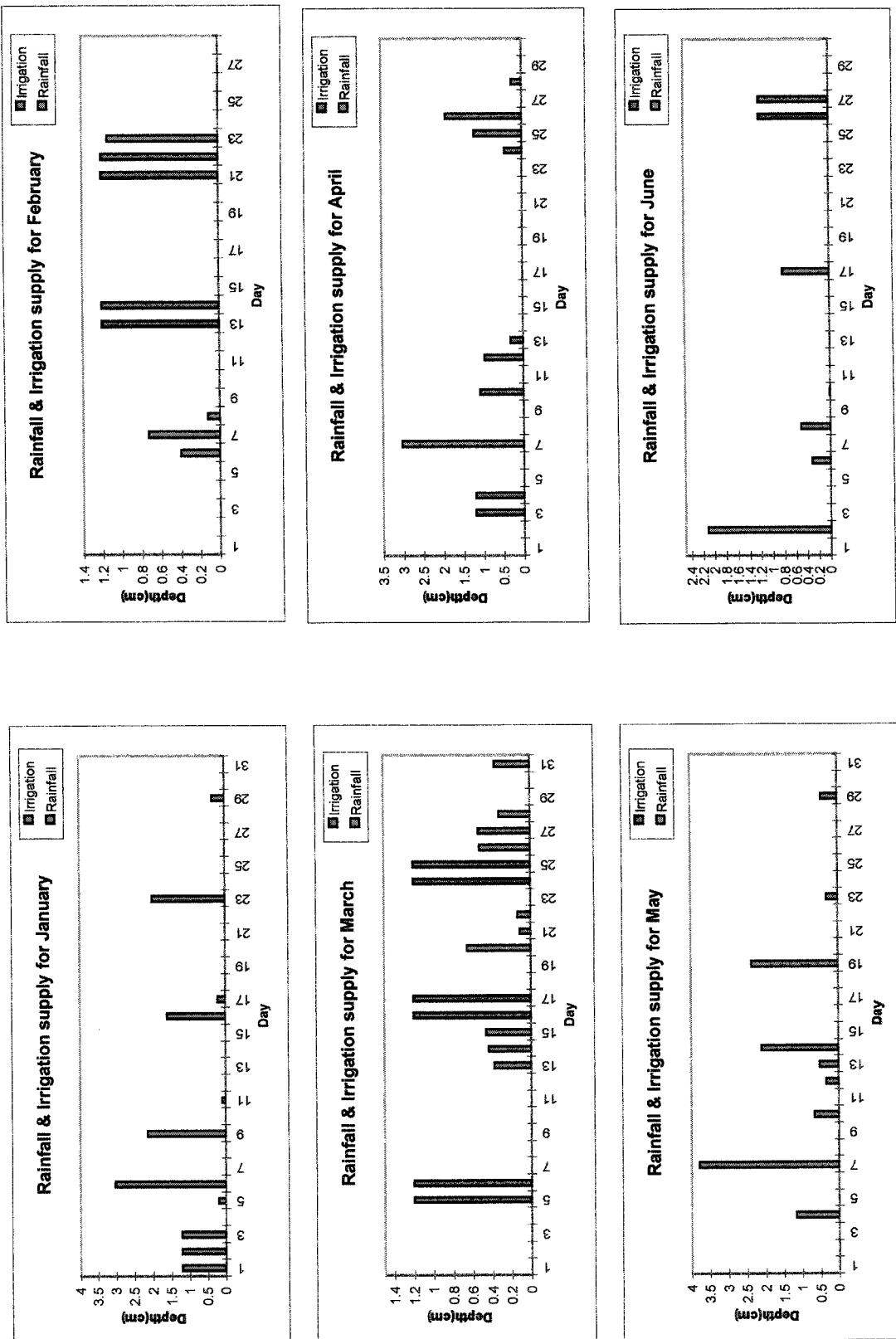
### Irrigation supply pattern in a normal year of rainfall (July to December)



Site No: 8

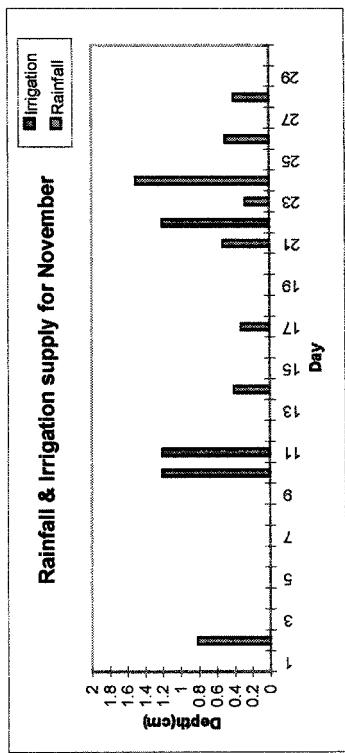
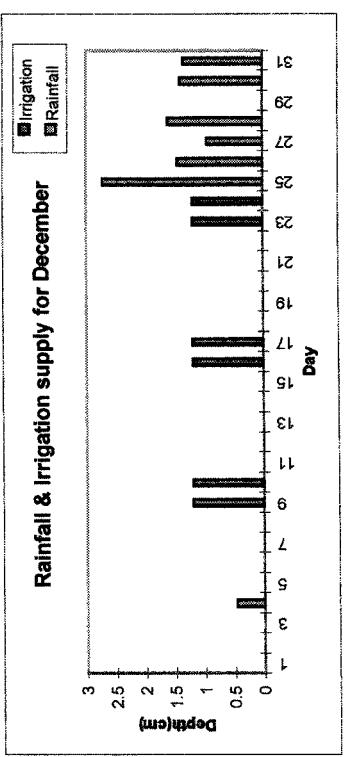
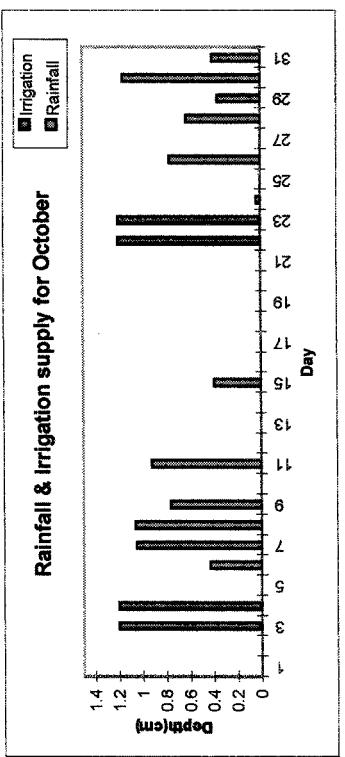
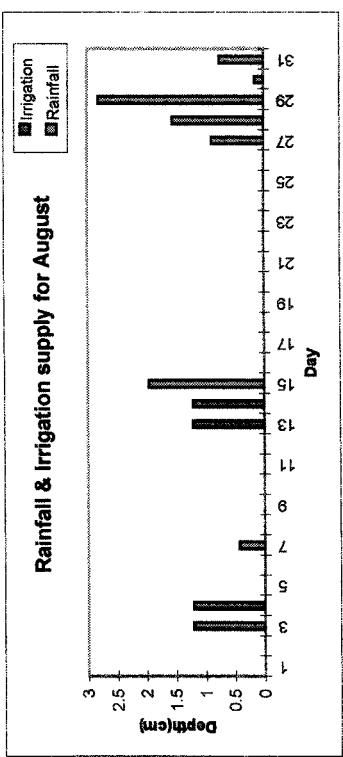
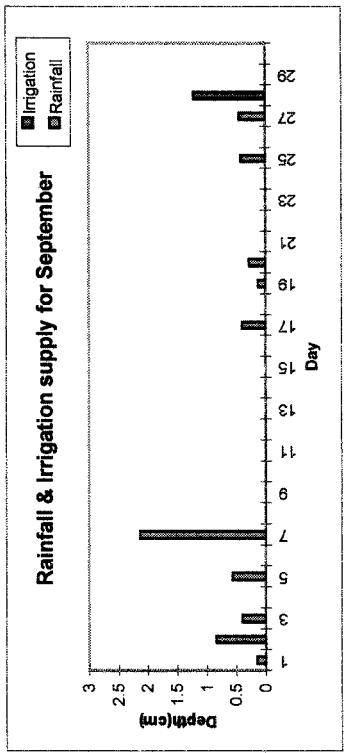
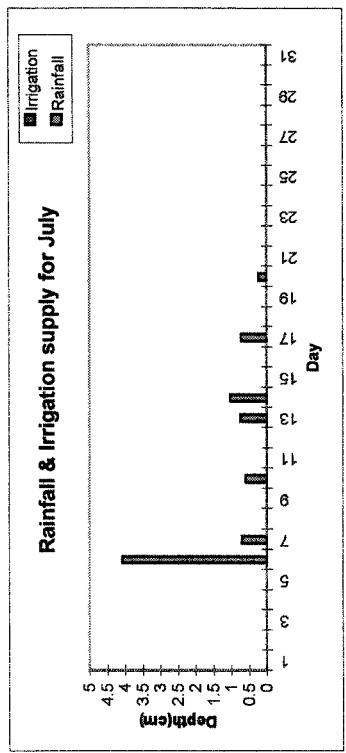
### Irrigation supply pattern in a wet year of rainfall (January to June)

#### Appendix C



Site No: 8

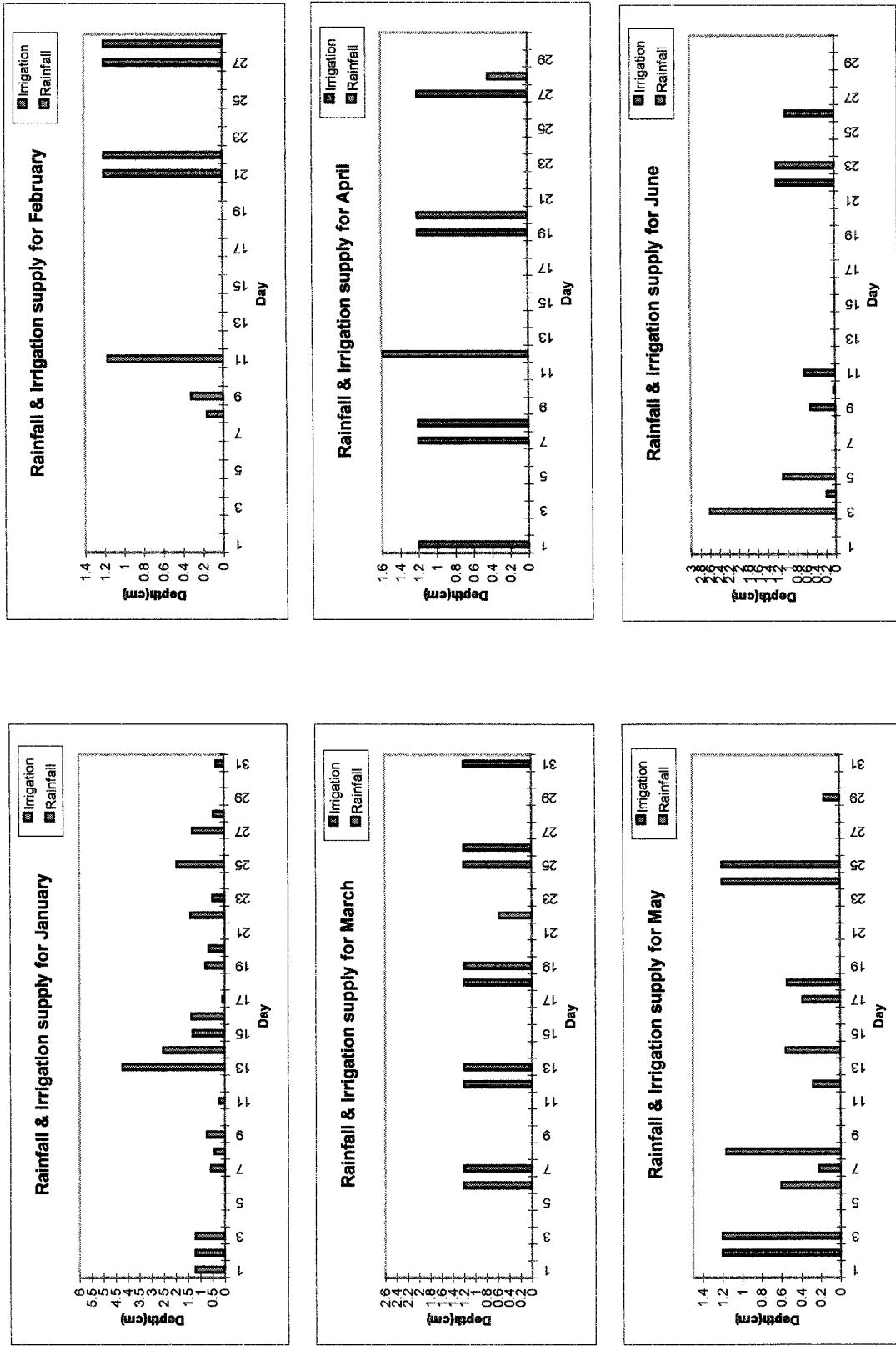
### Irrigation supply pattern in a wet year of rainfall (July to December)



Site No: 8

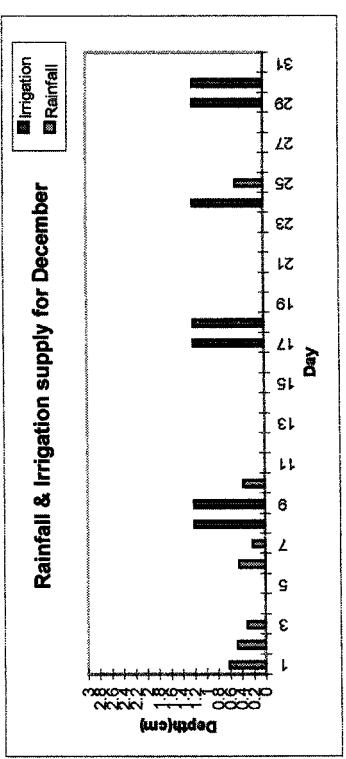
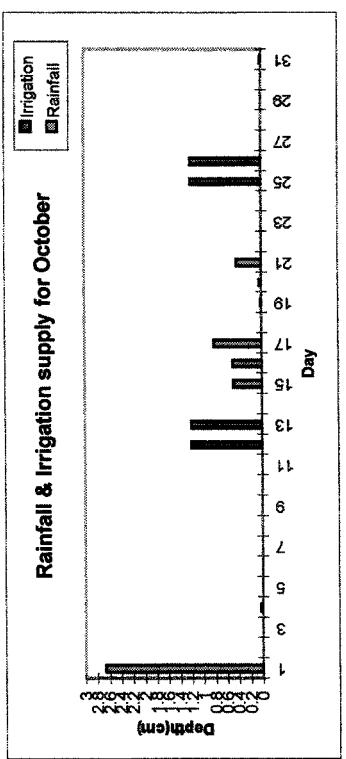
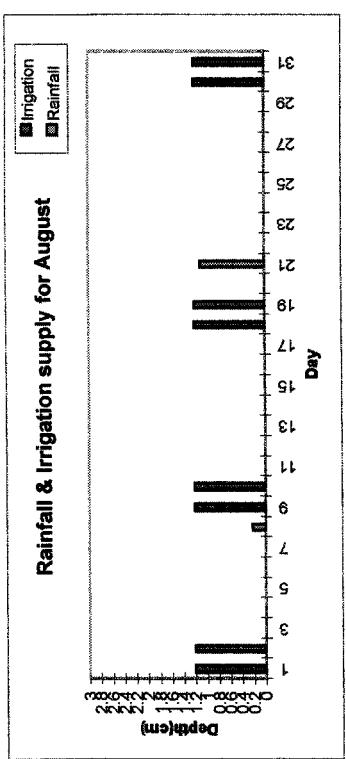
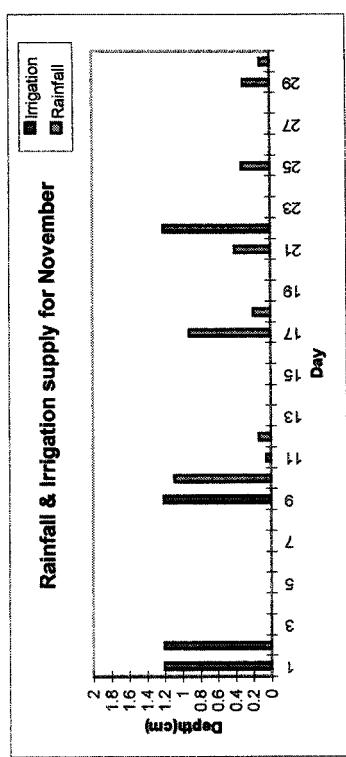
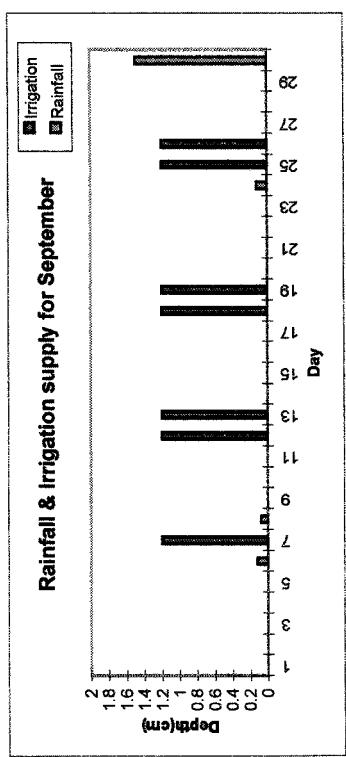
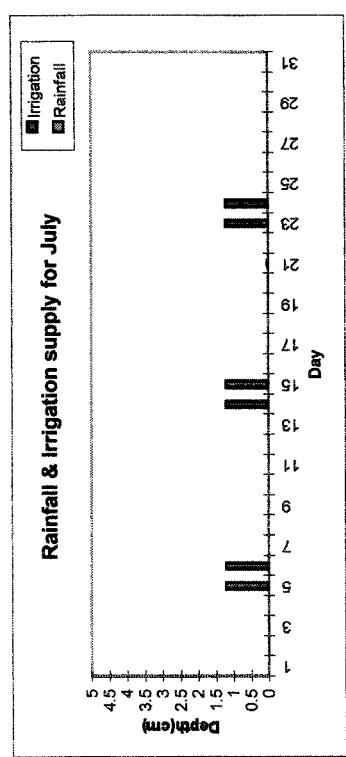
Irrigation supply pattern in an dry year of rainfall (January to June)

Appendix C



Site No.: 8

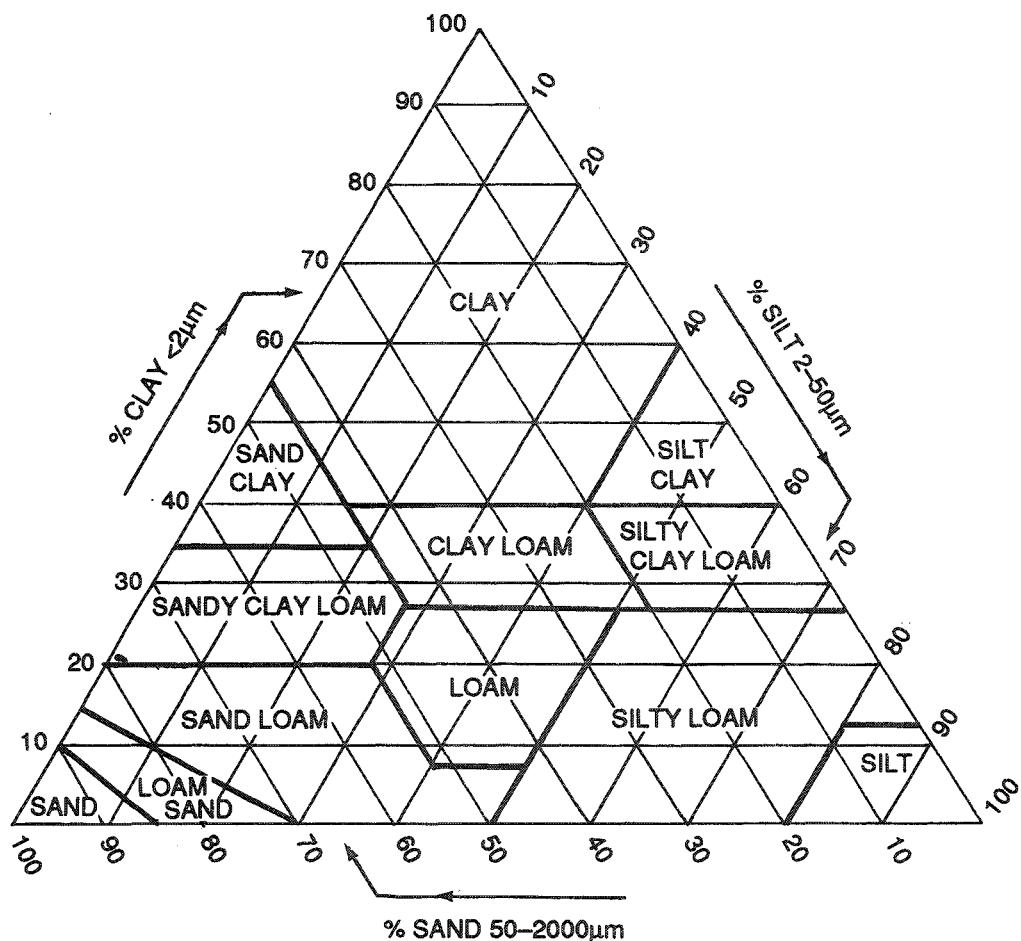
## Irrigation supply pattern in a dry year of rainfall (July to December)



## **APPENDIX - D**

Soil texture triangle

Appendix D



US Dept. of Agriculture textural classes

Abbreviations

S-sand, SL-sandy loam, LS-loamy sand, SIL-silty loam, SI-silt, C-clay, SIC-silty clay, SC-sandy clay, SICL-silty clay loam, CL-clay loam, SCL-sandy clay loam, L-loam

## **APPENDIX - E-I**

A sample input files for the simulation in PRZM2 model (site 15)

## Appendix E-I

### **File:PRZM2.RUN**

```
*****
*** PRZM2 version 1.02 | Date: Thursday, 11 February 1993. Time: 13:10:35. ***
*** _____
*** File PRZM2.RUN, run time supervisor file for PRZM2 model, required ***
*** for all model runs. This file, as distributed by CEAM, is configured ***
*** for the data sets PRZM3.INP and VADF3.INP. Modify this file, as ***
*** as shown below within comment lines, to execute PRZM2 model with ***
*** other test input data sets distributed with PRZM2 model system. ***
*** Lines beginning with *** (i.e., three asterisks) are comment lines. ***
*****
```

\*\*\*  
\*\*\* option records  
PRZM               ON  
VADOFT             Off  
\*\*\* To execute the PRZM2 model with MONTE CARLO simulation,  
\*\*\* 1) turn the MONTE CARLO option switch to ON. The MONTE  
\*\*\* CARLO input file that will be read from option MCIN  
\*\*\* is MC.INP.  
\*\*\* 2) Set the PRZM2 INPUT file option to read the files  
\*\*\* PRZM3.INP and VADF3.INP.  
MONTE CARLO       OFF  
TRANSPORT SIMULATION   ON  
\*\*\* zone records  
PRZM ZONES        1  
VADOFT ZONES      1  
ENDRUN  
\*\*\* input file records  
PATH               c:\PRZM2\INPUT\  
MCIN               MC.INP  
METEOROLOGY       1 METn.INP  
\*\*\* Change the next two lines to reflect the file names of the PRZM2  
\*\*\* and/or VADOFT input files (e.g., PRZM.INP, PRZM1.INP, PRZM2.INP,  
\*\*\* PRZM3.INP or VADF.INP, VADF1.INP, VADF2.INP, VADF3.INP).  
PRZM INPUT        1 tr1.INP  
VADOFT INPUT      1 VADF1.INP  
\*\*\* ouptut file records  
PATH               c:\PRZM2\OUTPUT\TEST\  
TIME SERIES       1 TIMES.OUT  
PRZM OUTPUT       1 PRZM.OUT  
VADOFT OUTPUT     1 VADF.OUT  
MCOUT              MC.OUT  
MCOUT2             MC2.OUT  
\*\*\* scratch file records  
PRZM RESTART      1 RESTART.PRZ  
VADOFT FLOW RST   1 VFLOW.RST  
VADOFT TRANS RST  1 VTRANS.RST  
VADOFT TAPE10     1 VADF.TAP  
ENDFILES  
\*\*\* global records  
START DATE        010187  
END DATE          311287  
\*\*\* For input files PRZM.INP and PRZM1.INP the number of chemicals  
\*\*\* must be set to a value of one; for PRZM2.INP and PRZM3.INP the  
\*\*\* number of chemicals must be set to a value of 3.  
NUMBER OF CHEMICALS  1  
\*\*\* For input files PRZM.INP and PRZM1.INP comment out the next

## Appendix E-I

\*\*\* two lines; for PRZM2.INP and PRZM3.INP uncomment the next  
\*\*\* two lines (i.e., PARENT OF 2... and PARENT OF 3...).

PARENT OF 2

PARENT OF 3

ENDDATA

\*\*\* display records

ECHO 7

TRACE OFF

Appendix E-I

**File:MET.INP**

\*\*\*\*\*

1 187	0.000	0.381	17.600	120.400	408.700
1 287	0.000	0.381	17.600	120.400	408.700
1 387	0.000	0.381	17.600	120.400	408.700
1 487	0.000	0.381	17.600	120.400	408.700
1 587	0.000	0.381	17.600	120.400	408.700
1 687	0.000	0.381	17.600	120.400	408.700
1 787	0.120	0.381	17.600	120.400	408.700
1 887	0.000	0.381	17.600	120.400	408.700
1 987	0.000	0.381	17.600	120.400	408.700
11087	0.000	0.381	17.600	120.400	408.700
11187	0.000	0.381	17.600	120.400	408.700
11287	0.000	0.381	17.600	120.400	408.700
11387	0.000	0.381	17.600	120.400	408.700
11487	0.580	0.381	17.600	120.400	408.700
11587	0.160	0.381	17.600	120.400	408.700
11687	0.000	0.381	17.600	120.400	408.700
11787	0.000	0.381	17.600	120.400	408.700
11887	0.810	0.381	17.600	120.400	408.700
11987	1.000	0.381	17.600	120.400	408.700
12087	0.000	0.381	17.600	120.400	408.700
12187	0.000	0.381	17.600	120.400	408.700
12287	0.000	0.381	17.600	120.400	408.700
12387	0.000	0.381	17.600	120.400	408.700
12487	0.880	0.381	17.600	120.400	408.700
12587	0.000	0.381	17.600	120.400	408.700
12687	0.000	0.381	17.600	120.400	408.700
12787	0.000	0.381	17.600	120.400	408.700
12887	0.000	0.381	17.600	120.400	408.700
12987	0.000	0.381	17.600	120.400	408.700
13087	0.000	0.381	17.600	120.400	408.700
13187	0.000	0.381	17.600	120.400	408.700
2 187	0.000	0.636	17.700	120.400	442.160
2 287	0.250	0.636	17.700	120.400	442.160
2 387	0.010	0.636	17.700	120.400	442.160
2 487	0.450	0.636	17.700	120.400	442.160
2 587	0.000	0.636	17.700	120.400	442.160
2 687	0.000	0.636	17.700	120.400	442.160
2 787	0.000	0.636	17.700	120.400	442.160
2 887	0.000	0.636	17.700	120.400	442.160
2 987	0.000	0.636	17.700	120.400	442.160
21087	0.000	0.636	17.700	120.400	442.160
21187	0.750	0.636	17.700	120.400	442.160
21287	0.000	0.636	17.700	120.400	442.160
21387	0.010	0.636	17.700	120.400	442.160
21487	0.690	0.636	17.700	120.400	442.160
21587	0.000	0.636	17.700	120.400	442.160
21687	0.060	0.636	17.700	120.400	442.160
21787	0.280	0.636	17.700	120.400	442.160
21887	0.160	0.636	17.700	120.400	442.160
21987	0.160	0.636	17.700	120.400	442.160
22087	0.000	0.636	17.700	120.400	442.160
22187	0.000	0.636	17.700	120.400	442.160
22287	0.000	0.636	17.700	120.400	442.160

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22387	0.210	0.636	17.700	120.400	442.160
22487	0.000	0.636	17.700	120.400	442.160
22587	0.000	0.636	17.700	120.400	442.160
22687	0.000	0.636	17.700	120.400	442.160
22787	0.000	0.636	17.700	120.400	442.160
22887	0.000	0.636	17.700	120.400	442.160
3 187	0.000	0.613	18.300	120.400	425.430
3 287	0.000	0.613	18.300	120.400	425.430
3 387	0.000	0.613	18.300	120.400	425.430
3 487	0.000	0.613	18.300	120.400	425.430
3 587	0.000	0.613	18.300	120.400	425.430
3 687	0.000	0.613	18.300	120.400	425.430
3 787	0.000	0.613	18.300	120.400	425.430
3 887	0.000	0.613	18.300	120.400	425.430
3 987	0.000	0.613	18.300	120.400	425.430
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31787	0.000	0.613	18.300	120.400	425.430
31887	0.000	0.613	18.300	120.400	425.430
31987	0.000	0.613	18.300	120.400	425.430
32087	0.000	0.613	18.300	120.400	425.430
32187	0.000	0.613	18.300	120.400	425.430
32287	0.000	0.613	18.300	120.400	425.430
32387	0.000	0.613	18.300	120.400	425.430
32487	0.000	0.613	18.300	120.400	425.430
32587	0.000	0.613	18.300	120.400	425.430
32687	0.510	0.613	18.300	120.400	425.430
32787	0.000	0.613	18.300	120.400	425.430
32887	0.180	0.613	18.300	120.400	425.430
32987	0.000	0.613	18.300	120.400	425.430
33087	0.000	0.613	18.300	120.400	425.430
33187	0.000	0.613	18.300	120.400	425.430
4 187	0.000	0.497	18.000	120.400	389.580
4 287	0.000	0.497	18.000	120.400	389.580
4 387	0.000	0.497	18.000	120.400	389.580
4 487	0.000	0.497	18.000	120.400	389.580
4 587	0.130	0.497	18.000	120.400	389.580
4 687	0.000	0.497	18.000	120.400	389.580
4 787	0.000	0.497	18.000	120.400	389.580
4 887	0.000	0.497	18.000	120.400	389.580
4 987	0.000	0.497	18.000	120.400	389.580
41087	0.000	0.497	18.000	120.400	389.580
41187	0.000	0.497	18.000	120.400	389.580
41287	0.000	0.497	18.000	120.400	389.580
41387	0.000	0.497	18.000	120.400	389.580
41487	0.010	0.497	18.000	120.400	389.580
41587	0.000	0.497	18.000	120.400	389.580
41687	0.000	0.497	18.000	120.400	389.580
41787	1.370	0.497	18.000	120.400	389.580
41887	0.150	0.497	18.000	120.400	389.580
41987	0.000	0.497	18.000	120.400	389.580
42087	0.080	0.497	18.000	120.400	389.580
42187	0.000	0.497	18.000	120.400	389.580

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42287	1.410	0.497	18.000	120.400	389.580
42387	1.710	0.497	18.000	120.400	389.580
42487	0.160	0.497	18.000	120.400	389.580
42587	2.030	0.497	18.000	120.400	389.580
42687	1.050	0.497	18.000	120.400	389.580
42787	0.060	0.497	18.000	120.400	389.580
42887	0.010	0.497	18.000	120.400	389.580
42987	0.260	0.497	18.000	120.400	389.580
43087	0.000	0.497	18.000	120.400	389.580
5 187	1.050	0.426	17.100	140.000	377.630
5 287	1.810	0.426	17.100	140.000	377.630
5 387	0.100	0.426	17.100	140.000	377.630
5 487	0.000	0.426	17.100	140.000	377.630
5 587	0.000	0.426	17.100	140.000	377.630
5 687	0.610	0.426	17.100	140.000	377.630
5 787	0.000	0.426	17.100	140.000	377.630
5 887	0.000	0.426	17.100	140.000	377.630
5 987	0.000	0.426	17.100	140.000	377.630
51087	0.000	0.426	17.100	140.000	377.630
51187	0.190	0.426	17.100	140.000	377.630
51287	0.060	0.426	17.100	140.000	377.630
51387	0.000	0.426	17.100	140.000	377.630
51487	0.000	0.426	17.100	140.000	377.630
51587	0.000	0.426	17.100	140.000	377.630
51687	0.000	0.426	17.100	140.000	377.630
51787	0.000	0.426	17.100	140.000	377.630
51887	0.000	0.426	17.100	140.000	377.630
51987	0.000	0.426	17.100	140.000	377.630
52087	0.000	0.426	17.100	140.000	377.630
52187	0.000	0.426	17.100	140.000	377.630
52287	0.000	0.426	17.100	140.000	377.630
52387	0.000	0.426	17.100	140.000	377.630
52487	0.000	0.426	17.100	140.000	377.630
52587	0.000	0.426	17.100	140.000	377.630
52687	0.000	0.426	17.100	140.000	377.630
52787	0.000	0.426	17.100	140.000	377.630
52887	0.000	0.426	17.100	140.000	377.630
52987	0.000	0.426	17.100	140.000	377.630
53087	0.000	0.426	17.100	140.000	377.630
53187	0.000	0.426	17.100	140.000	377.630
6 187	0.000	0.400	16.000	140.000	358.510
6 287	0.000	0.400	16.000	140.000	358.510
6 387	0.000	0.400	16.000	140.000	358.510
6 487	0.000	0.400	16.000	140.000	358.510
6 587	0.000	0.400	16.000	140.000	358.510
6 687	0.000	0.400	16.000	140.000	358.510
6 787	0.000	0.400	16.000	140.000	358.510
6 887	0.000	0.400	16.000	140.000	358.510
6 987	0.000	0.400	16.000	140.000	358.510
61087	0.000	0.400	16.000	140.000	358.510
61187	0.000	0.400	16.000	140.000	358.510
61287	0.000	0.400	16.000	140.000	358.510
61387	0.000	0.400	16.000	140.000	358.510
61487	2.020	0.400	16.000	140.000	358.510
61587	0.000	0.400	16.000	140.000	358.510
61687	0.000	0.400	16.000	140.000	358.510
61787	0.000	0.400	16.000	140.000	358.510
61887	0.000	0.400	16.000	140.000	358.510

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61987	1.380	0.400	16.000	140.000	358.510
62087	0.740	0.400	16.000	140.000	358.510
62187	0.000	0.400	16.000	140.000	358.510
62287	0.810	0.400	16.000	140.000	358.510
62387	0.170	0.400	16.000	140.000	358.510
62487	0.000	0.400	16.000	140.000	358.510
62587	0.000	0.400	16.000	140.000	358.510
62687	0.460	0.400	16.000	140.000	358.510
62787	4.360	0.400	16.000	140.000	358.510
62887	0.030	0.400	16.000	140.000	358.510
62987	0.000	0.400	16.000	140.000	358.510
63087	0.000	0.400	16.000	140.000	358.510
7 187	0.000	0.403	15.500	140.000	344.170
7 287	0.000	0.403	15.500	140.000	344.170
7 387	0.000	0.403	15.500	140.000	344.170
7 487	0.000	0.403	15.500	140.000	344.170
7 587	0.000	0.403	15.500	140.000	344.170
7 687	0.000	0.403	15.500	140.000	344.170
7 787	0.000	0.403	15.500	140.000	344.170
7 887	0.000	0.403	15.500	140.000	344.170
7 987	0.000	0.403	15.500	140.000	344.170
71087	0.000	0.403	15.500	140.000	344.170
71187	0.000	0.403	15.500	140.000	344.170
71287	0.000	0.403	15.500	140.000	344.170
71387	0.000	0.403	15.500	140.000	344.170
71487	0.000	0.403	15.500	140.000	344.170
71587	0.300	0.403	15.500	140.000	344.170
71687	1.280	0.403	15.500	140.000	344.170
71787	0.000	0.403	15.500	140.000	344.170
71887	0.000	0.403	15.500	140.000	344.170
71987	0.000	0.403	15.500	140.000	344.170
72087	0.000	0.403	15.500	140.000	344.170
72187	0.340	0.403	15.500	140.000	344.170
72287	1.460	0.403	15.500	140.000	344.170
72387	0.000	0.403	15.500	140.000	344.170
72487	0.010	0.403	15.500	140.000	344.170
72587	0.570	0.403	15.500	140.000	344.170
72687	0.000	0.403	15.500	140.000	344.170
72787	0.000	0.403	15.500	140.000	344.170
72887	0.000	0.403	15.500	140.000	344.170
72987	0.000	0.403	15.500	140.000	344.170
73087	0.000	0.403	15.500	140.000	344.170
73187	0.000	0.403	15.500	140.000	344.170
8 187	0.000	0.458	15.800	150.500	380.020
8 287	0.000	0.458	15.800	150.500	380.020
8 387	0.000	0.458	15.800	150.500	380.020
8 487	0.000	0.458	15.800	150.500	380.020
8 587	0.000	0.458	15.800	150.500	380.020
8 687	0.000	0.458	15.800	150.500	380.020
8 787	0.000	0.458	15.800	150.500	380.020
8 887	0.000	0.458	15.800	150.500	380.020
8 987	0.000	0.458	15.800	150.500	380.020
81087	0.000	0.458	15.800	150.500	380.020
81187	0.000	0.458	15.800	150.500	380.020
81287	0.000	0.458	15.800	150.500	380.020
81387	0.000	0.458	15.800	150.500	380.020
81487	0.000	0.458	15.800	150.500	380.020
81587	0.000	0.458	15.800	150.500	380.020

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81687	0.110	0.458	15.800	150.500	380.020
81787	0.000	0.458	15.800	150.500	380.020
81887	0.000	0.458	15.800	150.500	380.020
81987	0.000	0.458	15.800	150.500	380.020
82087	0.000	0.458	15.800	150.500	380.020
82187	0.000	0.458	15.800	150.500	380.020
82287	4.230	0.458	15.800	150.500	380.020
82387	0.280	0.458	15.800	150.500	380.020
82487	0.000	0.458	15.800	150.500	380.020
82587	0.000	0.458	15.800	150.500	380.020
82687	0.000	0.458	15.800	150.500	380.020
82787	0.000	0.458	15.800	150.500	380.020
82887	0.000	0.458	15.800	150.500	380.020
82987	0.000	0.458	15.800	150.500	380.020
83087	0.000	0.458	15.800	150.500	380.020
83187	0.000	0.458	15.800	150.500	380.020
9 187	0.000	0.527	16.200	150.500	423.040
9 287	0.000	0.527	16.200	150.500	423.040
9 387	0.020	0.527	16.200	150.500	423.040
9 487	1.900	0.527	16.200	150.500	423.040
9 587	0.460	0.527	16.200	150.500	423.040
9 687	0.140	0.527	16.200	150.500	423.040
9 787	0.260	0.527	16.200	150.500	423.040
9 887	0.010	0.527	16.200	150.500	423.040
9 987	0.350	0.527	16.200	150.500	423.040
91087	0.000	0.527	16.200	150.500	423.040
91187	0.000	0.527	16.200	150.500	423.040
91287	0.000	0.527	16.200	150.500	423.040
91387	0.000	0.527	16.200	150.500	423.040
91487	0.000	0.527	16.200	150.500	423.040
91587	0.000	0.527	16.200	150.500	423.040
91687	0.000	0.527	16.200	150.500	423.040
91787	0.000	0.527	16.200	150.500	423.040
91887	0.000	0.527	16.200	150.500	423.040
91987	0.000	0.527	16.200	150.500	423.040
92087	0.000	0.527	16.200	150.500	423.040
92187	0.000	0.527	16.200	150.500	423.040
92287	0.000	0.527	16.200	150.500	423.040
92387	1.360	0.527	16.200	150.500	423.040
92487	0.000	0.527	16.200	150.500	423.040
92587	0.000	0.527	16.200	150.500	423.040
92687	0.050	0.527	16.200	150.500	423.040
92787	0.000	0.527	16.200	150.500	423.040
92887	0.000	0.527	16.200	150.500	423.040
92987	1.290	0.527	16.200	150.500	423.040
93087	0.000	0.527	16.200	150.500	423.040
10 187	0.070	0.590	17.200	150.500	427.820
10 287	0.000	0.590	17.200	150.500	427.820
10 387	0.830	0.590	17.200	150.500	427.820
10 487	0.650	0.590	17.200	150.500	427.820
10 587	0.000	0.590	17.200	150.500	427.820
10 687	1.960	0.590	17.200	150.500	427.820
10 787	0.000	0.590	17.200	150.500	427.820
10 887	0.000	0.590	17.200	150.500	427.820
10 987	0.000	0.590	17.200	150.500	427.820
101087	0.000	0.590	17.200	150.500	427.820
101187	0.000	0.590	17.200	150.500	427.820
101287	0.540	0.590	17.200	150.500	427.820

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101387	0.000	0.590	17.200	150.500	427.820
101487	0.000	0.590	17.200	150.500	427.820
101587	0.000	0.590	17.200	150.500	427.820
101687	0.000	0.590	17.200	150.500	427.820
101787	0.000	0.590	17.200	150.500	427.820
101887	0.000	0.590	17.200	150.500	427.820
101987	0.000	0.590	17.200	150.500	427.820
102087	0.590	0.590	17.200	150.500	427.820
102187	2.280	0.590	17.200	150.500	427.820
102287	0.130	0.590	17.200	150.500	427.820
102387	0.000	0.590	17.200	150.500	427.820
102487	0.000	0.590	17.200	150.500	427.820
102587	0.000	0.590	17.200	150.500	427.820
102687	0.000	0.590	17.200	150.500	427.820
102787	0.000	0.590	17.200	150.500	427.820
102887	0.000	0.590	17.200	150.500	427.820
102987	0.000	0.590	17.200	150.500	427.820
103087	0.210	0.590	17.200	150.500	427.820
103187	1.940	0.590	17.200	150.500	427.820
11 187	0.000	0.447	16.800	120.400	377.630
11 287	0.390	0.447	16.800	120.400	377.630
11 387	0.790	0.447	16.800	120.400	377.630
11 487	0.000	0.447	16.800	120.400	377.630
11 587	0.000	0.447	16.800	120.400	377.630
11 687	0.270	0.447	16.800	120.400	377.630
11 787	0.000	0.447	16.800	120.400	377.630
11 887	0.000	0.447	16.800	120.400	377.630
11 987	0.000	0.447	16.800	120.400	377.630
111087	0.000	0.447	16.800	120.400	377.630
111187	0.000	0.447	16.800	120.400	377.630
111287	0.000	0.447	16.800	120.400	377.630
111387	1.630	0.447	16.800	120.400	377.630
111487	1.600	0.447	16.800	120.400	377.630
111587	0.230	0.447	16.800	120.400	377.630
111687	0.000	0.447	16.800	120.400	377.630
111787	0.000	0.447	16.800	120.400	377.630
111887	0.000	0.447	16.800	120.400	377.630
111987	0.000	0.447	16.800	120.400	377.630
112087	0.450	0.447	16.800	120.400	377.630
112187	0.000	0.447	16.800	120.400	377.630
112287	0.000	0.447	16.800	120.400	377.630
112387	0.000	0.447	16.800	120.400	377.630
112487	0.000	0.447	16.800	120.400	377.630
112587	0.150	0.447	16.800	120.400	377.630
112687	0.000	0.447	16.800	120.400	377.630
112787	0.000	0.447	16.800	120.400	377.630
112887	0.420	0.447	16.800	120.400	377.630
112987	0.000	0.447	16.800	120.400	377.630
113087	0.000	0.447	16.800	120.400	377.630
12 187	0.000	0.510	17.000	120.400	360.900
12 287	0.000	0.510	17.000	120.400	360.900
12 387	0.000	0.510	17.000	120.400	360.900
12 487	0.000	0.510	17.000	120.400	360.900
12 587	0.000	0.510	17.000	120.400	360.900
12 687	0.000	0.510	17.000	120.400	360.900
12 787	0.400	0.510	17.000	120.400	360.900
12 887	0.140	0.510	17.000	120.400	360.900
12 987	0.000	0.510	17.000	120.400	360.900

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121087	0.000	0.510	17.000	120.400	360.900
121187	0.000	0.510	17.000	120.400	360.900
121287	0.000	0.510	17.000	120.400	360.900
121387	0.000	0.510	17.000	120.400	360.900
121487	0.000	0.510	17.000	120.400	360.900
121587	0.000	0.510	17.000	120.400	360.900
121687	0.000	0.510	17.000	120.400	360.900
121787	0.000	0.510	17.000	120.400	360.900
121887	0.000	0.510	17.000	120.400	360.900
121987	0.150	0.510	17.000	120.400	360.900
122087	0.000	0.510	17.000	120.400	360.900
122187	0.000	0.510	17.000	120.400	360.900
122287	1.010	0.510	17.000	120.400	360.900
122387	0.450	0.510	17.000	120.400	360.900
122487	0.650	0.510	17.000	120.400	360.900
122587	0.550	0.510	17.000	120.400	360.900
122687	0.540	0.510	17.000	120.400	360.900
122787	0.000	0.510	17.000	120.400	360.900
122887	0.000	0.510	17.000	120.400	360.900
122987	0.000	0.510	17.000	120.400	360.900
123087	0.000	0.510	17.000	120.400	360.900
123187	0.000	0.510	17.000	120.400	360.900

Appendix E-I

**File:PRZM.INP**

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1 CHEMICAL, 1 HORIZON, TEMP CORRECTION, BACKGROUND LEVELS  
HYDROLOGY PARAMETERS

0.67 0.0 0 15.000 1 2  
0  
1  
1 0.09 60 60.000 2 86 78 82 0.0 0.0 0.0 65.0  
18  
101286 010187 230187 1  
230187 130287 080387 1  
080387 290387 210487 1  
210487 120587 040687 1  
040687 250687 180787 1  
180787 080887 010987 1  
010987 220987 151087 1  
151087 051187 281187 1  
281187 191287 110188 1  
010187 220187 140287 1  
140287 070387 300387 1  
300387 200487 130587 1  
130587 030687 260687 1  
260687 170787 090887 1  
090887 300887 220987 1  
220987 131087 051187 1  
051187 261187 191287 1  
191287 090188 010288 1

PESTICIDE TRANSPORT AND TRANSFORMATION AND APPLICATION PARAMETERS

12 1 0

TRIADIMEFON

010187 0 2.8 .0500  
010287 0 2.8 .0500  
010387 0 2.8 .0500  
010487 0 2.8 .0500  
010587 0 2.8 .0500  
010687 0 2.8 .0500  
010787 0 2.8 .0500  
010887 0 2.8 .0500  
010987 0 2.8 .0500  
011087 0 2.8 .0500  
011187 0 2.8 .0500  
011287 0 2.8 .0500

1 0

SOILS PARAMETERS

550.0 0.0 0 0 1 1 1 1 0 0 0  
4.3E03 1.0E-7 5.5E-3  
3 0.25 0.55 0.05  
2 260.00  
4  
1 20.0 1.30 0.299 1.63 30.0  
.005775 .005775 .0  
1.0 .3603 .2192 2.04 0.00  
2 30.0 1.32 0.299 1.95 30.0  
.005775 .005775 .0  
1.0 .3604 .2324 1.41 0.00  
3 275.0 1.47 0.252 1.88 30.0  
.005775 .005775 .0

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11.0 .3497 .2216 0.66 0.00  
4 225.0 1.47 .2400 1.55 30.0  
.005775 .005775 .0  
15.0 .3497 .2216 0.66 0.00  
1 1

WATR MNTH 1 PEST MNTH 1 CONC MNTH 1  
7 YEAR  
VFLX1 TCUM  
RZFX1 TSER  
RFLX1 TCUM  
AFLX1 TCUM 65  
PRCP TSER  
SWTR TSER 15  
TPST TCUM 1

## **APPENDIX - E-II**

A sample input files for the simulation in WAVE model (site 15)

## Appendix E-II

```
C ****
C GENDATA.IN
C *****

C SIMULATION TYPE
C TTTTTTTTTTTTTT
- ARE THERE PLANTS? (Y/N) .....: Y
- IF THERE ARE PLANTS, WILL SUCROS BE USED? (Y/N) .....: n
- IS TEMPERATURE MODELED? (Y/N) .....: n
- ARE SOLUTES MODELED? (Y/N) .....: n
- IS NITROGEN MODELED? (Y/N) .....: y

C SOIL PROFILE DEVELOPMENT
C TTTTTTTTTTTTTTTTTTTT
- COMPARTMENT SIZE (MM) .....: 256.00
- NUMBER OF SOIL LAYERS .....: 4

C- NUMBER OF COMPARTMENTS FOR EACH SOIL LAYER
C LR_NO_OF_COMPARTMENTS
C -- -----
1 1
2 2
3 55
4 42
ET

C IF MODELING SOLUTES (NITROGEN) OR HEAT TRANSPORT SPECIFY BULK DENSITY
C LR_BULK_DENSITY
C KG L-1
C -- -----
1 1.30
2 1.32
3 1.47
4 1.47
ET

C SIMULATION TIME VARIABLES
C TTTTTTTTTTTTTTTTTTTT
- START OF CALCULATIONS (Y M D) .....: 1987 01 01
- END OF CALCULATIONS (Y M D) .....: 1987 12 31
C NEXT TWO DATES ARE ONLY INPUT IF THERE ARE PLANTS
C IN CASE THE CROP GROWTH IS MODELED THE FIRST DATE IS THE EMERGENCE DATE
- PLANTING OR EMERGENCE DATE (M D) .....: 01 01
- HARVEST DATE (M D) .....: 12 31

C PARAMETERS CONCERNING THE NUMERICAL SOLUTION
C TTTTTTTTTTTTTTTTTTTTTTTTTTTT
- THE MAXIMUM TIME STEP (DAY) (> 0.001 DAY) .....: 0.261
- THE MINIMUM TIME STEP (DAY) (< 1 DAY) .....: 0.01
- THE MAX. ALLOWED MOISTURE CONTENT CHANGE (CM3 CM-3)(0.002<<0.05): 0.01
- THE MAXIMUM ALLOWED BALANCE ERROR(0.00001<<1.) (CM3 CM-3DAY-1): 0.01
```

## Appendix E-II

C PARAMETERS CONCERNING PRINTING  
C TTTTTTTTTTTTTTTTTTTTTTT  
C - STOP THE PROGRAM WHEN THERE ARE RANGE ERRORS IN THE INPUT? (Y/N): Y  
C - IS THE TIME INCREMENT BETWEEN THE PRINTING OF THE SUMMARYTABLES  
C LISTING THE DIFFERENT STATE VARIABLES CONSTANT? (Y/N) .....: Y  
C IF "YES"  
C GIVE THE TIME INCREMENT (DAY) (INTEGER).....:30  
C IF "NO"  
C 1) GIVE THE NUMBER OF DATES THERE IS A SUMMARY TABLE.....:  
C 2) GIVE THE DATES AT WHICH THE SUMMARY TABLE MUST BEPRINTED  
C M D  
C --  
C - SPECIFY ISD, THE BOTTOM COMPARTMENT OF THE TOP LAYER FOR WHICH THERE IS  
C OUTPUT IN THE SUMMARY FILES .....: 12

C - COMPARTMENT RANGES FOR THE TIME SERIES FILES  
C 1) NUMBER OF COMPARTMENT RANGES FOR THE TIME SERIES FILES .....:22  
C 2) GIVE THE UPPER AND LOWER COMPARMENT FOR EACH RANGE  
C UPPER LOWER  
C -----  
1 2  
3 4  
5 6  
7 8  
9 10  
11 12  
13 14  
15 16  
17 18  
19 20  
21 22  
23 24  
25 26  
27 28  
29 34  
35 40  
41 46  
47 55  
56 64  
65 73  
74 84  
85 100

ET

## Appendix E-II

C\*\*\*\*\*

C WATDATA

C\*\*\*\*\*

C HYDRAULIC PROPERTIES

C TTTTTTTTTTTTTTTTT

- INPUT FROM EXTERNAL FILE WATPAR.WP? (Y/N).....: N
- MULTIPOROSITY (Y/N?) .....: N

C IF YOU ARE USING MULTIPOROSITY MODELS FOR THE HYDRAULIC PROPERTIES,  
C SKIP THIS SECTION AND GOTO THE MULTIPOROSITY SECTION

C SINGLE POROSITY

C -----

- MOISTURE RETENTION CHAR (MODEL NR) (INTEGER) .....: 1

C MODELS AVAILABLE

C MOISTURE RETENTION CHARACTERISTIC MODEL NUMBER

C NO HYSTERESIS:

C VAN GENUCHTEN SE = 1/(1+(ALPHA\*H)\*\*N1)\*\*M 1  
C WITH SE = (WC-WCR)/(WCS-WCR)

C HYSTERESIS:

C MUalem UNIVERSAL MODEL BASED ON MUalem MODEL II 2  
C MUalem MODEL II 3

- HYDRAULIC CONDUCTIVITY MODEL (MODEL NR) (INTEGER) .....: 5

C MODELS AVAILABLE

C HYDRAULIC CONDUCTIVITY MODEL NUMBER

C GARDNER(POWER) K = KSAT/(1+(BH)\*\*N2) 1

C GARDNER (EXPON) K = KSAT\*E\*\*((ALPHA2\*H)) 2

C GILHAM K = A\*WC\*\*N2 3

C BROOKS&CORREY K = KSAT\*SE\*\*((2+3\*LAMBDA)/LAMBDA) 4

C MUalem K = KSAT\*SE\*\*L\*((1-SE\*\*((1/M))\*\*M)\*\*2 5

C MOISTURE RETENTION PARAMETERS FOR EACH SOIL LAYER

C -----

C LR WCR WCS ALPHA N M (MODEL 1)

C LR WCR WCS ALPHAW N M (MODEL 2)

C LR WCR WCS ALPHAD ND MD ALPHAW NW MW (MODEL 3)

1 0.0000 .4714 .00100 1.15686 .13559

2 0.0102 .5103 .03972 1.14204 .12437

3 0.0000 .4728 .03098 1.12694 .11264

4 0.0000 .4728 .03098 1.12696 .11264

ET

C IN CASE OF A HYSTERESIS MODEL GIVE THE MAXIMUM RELATIVE CHANGE

C IN PRESSURE HEAD (-) ELSE SKIP .....

C HYDRAULIC CONDUCTIVITY PARAMETERS FOR EACH SOIL LAYER

C -----

C LR KSAT B N (GARDNER POWER FUNCTION)

C LR KSAT ALPHA (GARDNER EXPONENTIAL FUNCTION)

C LR KSAT N (GILHAM)

C LR KSAT LAMBDA (BROOKS AND CORREY)

C LR KSAT L (MUalem)

C (CM/DAY)

1 90.20 0.5

2 90.20 0.5

3 108.70 0.5

## Appendix E-II

4 108.70 0.5  
ET

### C MULTIPOROSITY MODELS

C -----

C - IF MULTI POROSITY MODEL IS ASSUMED, MOISTURE RETENTION IS DESCRIBED  
C WITH A SUM OF DIFFERENT VON GENUCHEN EQUATIONS (DURNER, 1994) AND  
C THE HYDRAULIC CONDUCTIVITY WITH MUalem's GENERAL MODEL (MUalem, 1976).

C - SPECIFY FOR EACH LAYER

C NR\_POR = NUMBER OF POROSITY CLASSES (-)

C WCR = RESIDUAL MOISTURE CONTENT (M3/M3)

C WCS = SATURATED MOISTURE CONTENT (M3/M3)

C L = TORTUOSITY FACTOR OF THE MUalem MODEL

C KSAT = SATURATED CONDUCTIVITY (CM/DAY)

C SPECIFY FOR EACH POROSITY CLASS

C W(NR\_POR) = WEIGHT FACTOR FOR EACH PARTIAL MRC

C ALFA(NR\_POR)= INVERSE AIR ENTRY VALUE FOR EACH PARTIAL MRC

C N(NR\_POR) = N FOR EACH PARTIAL MRC

C M(NR\_POR) = M FOR EACH PARTIAL MRC

C IN THE FOLLOWING ORDER

C NR\_POR WCR WCS L KSAT

C W(1) ALFA(1) N(1) M(1)

C .....

C W(I) ALFA(I) N(I) M(I)

### C WATER UPPER BOUNDARY CONDITIONS

C TTTTTTTTTTTTTTTTTTTTTTTTTTT

- INPUT FROM EXTERNAL FILE WATUBC.WU? (Y/N) .....: N

- GIVE THE MINIMUM ALLOWED PRESSURE HEAD AT THE SURFACE (CM): -1.E+07

- MAXIMUM PONDING DEPTH (MM).....: 0.E0

### C PLANT WATER UPTAKE ASPECTS

C TTTTTTTTTTTTTTTTTTTTTTT

- INPUT FROM EXTERNAL FILE WATCROPWC? (Y/N) .....: N

### C KC-FACTORS

C -----

C - IF THE CROP GROWTH MODEL IS USED

C DO YOU WANT TO USE USE DVS UNITS FOR CROP STAGES? (Y/N):

C ELSE

C DON'T ANSWER THE PREVIOUS QUESTION (ONLY DATES ARE POSSIBLE)

C - NUMBER OF DATES OR DVS.....: 5

C NOTE IN CASE OF BARE SOIL, PUT THE KC EQUAL TO 1

C DATES (M D) OR DVS KC

C -- -- --

01 01 1.0

03 30 1.0

06 30 1.0

09 30 1.0

12 31 1.0

ET

## Appendix E-II

C -IF THERE ARE NO PLANTS SKIP THIS SECTION  
C AND GO TO THE BOTTOM BOUNDARY SECTION

C INACTIVATION OF THE ROOTS NEAR THE SURFACE DUE TO SENESCENCE  
C -----

- DATE WHEN ROOTS START TO BECOME INACTIVE (M D) .....: 12 31
- DATE WHEN ROOTS REACH THEIR MAX INACTIVITY (M D) .....: 12 31
- DEPTH ABOVE WHICH THERE IS NO WATER UPTAKE (MM) .....: -0.0

C LEAF AREA INDEX AND ROOTING DEPTH

C -----

C - IF THE CROP GROWTH IS MODELED SKIP THIS SECTION  
C AND GOTO 'THE WATER SINK TERM VARIABLES'

C - SPECIFY A TIME SERIES OF LAI VALUES (ONE VALUE = CONSTANT)  
C M D LAI (M2/M2)

C -----  
1 01 0.25  
3 31 0.25  
8 30 0.25  
12 31 0.25

ET

C - SPECIFY A TIME SERIES OF EFFECTIVE ROOTING DEPTH (ONE VALUE = CONSTANT)  
C M D DRZ (MM)

C -----  
1 1 -600.00  
3 1 -600.00  
12 31 -600.00

ET

C WATER SINK TERM VARIABLES

C -----

C - IS THE RELATION BETWEEN THE REDUCTION FACTOR OF THE  
C ROOT WATER UPTAKE (ALPHA) AND THE PRESSURE HEAD LINEAR? (Y/N).: Y  
C - SPECIFY THE VALUE OF THE PRESSURE HEAD BELOW WHICH THE ROOTS  
C START TO EXTRACT WATER FROM THE SOIL (CM) .....: -10.  
C - SPECIFY THE VALUE OF THE PRESSURE HEAD BELOW WHICH THE ROOTS  
C START TO EXTRACT WATER OPTIMALLY FROM THE SOIL (CM) .....: -46.

C - SPECIFY THE VALUE OF THE PRESSURE HEAD BELOW WHICH THE ROOTS CAN NO  
C LONGER EXTRACT WATER OPTIMALLY

C AT A HIGH EVAPORATIVE DEMAND (CM).: -500.  
C AT A LOW EVAPORATIVE DEMAND (CM).: -500.

C - THE VALUE OF THE PRESSURE HEAD AT WHICH THE WATER

C UPTAKE BY THE ROOTS CEASES (WILTING POINT) (CM) .....: -16000.

C - IS THE FUNCTION BETWEEN THE POTENTIAL ROOT WATER UPTAKE

C AND DEPTH LINEAR ? (Y/N) .....: N

C - IF "YES" SPECIFY THE PARAMETERS OF THE EQUATION

C SMAX=ARER+BRER\*ABS(DEPTH IN MM)

C 1 ARER (INTERCEPT) (DAY-1) .....

C 2 BRER (SLOPE) (DAY-1 MM-1) .....

C - IF "NO" INPUT MAXIMAL ROOT WATER UPTAKE FOR EACH COMPARTMENT

C COMP SMAX

C (DAY-1)

C -----

1 0.029  
2 0.018  
3 0.013

## Appendix E-II

4	0.008
5	0.004
6	0.002
7	0.001
8	0.0008
9	0.0006
10	0.0004
11	0.0002
12	0.0001
13	0.00
14	0.00
15	0.00
16	0.00
17	0.00
18	0.00
19	0.00
20	0.00
21	0.00
22	0.00
23	0.00
24	0.00
25	0.00
26	0.00
27	0.00
28	0.00
29	0.00
30	0.00
31	0.00
32	0.00
33	0.00
34	0.00
35	0.00
36	0.00
37	0.00
38	0.00
39	0.00
40	0.00
41	0.00
42	0.00
43	0.00
44	0.00
45	0.00
46	0.00
47	0.00
48	0.00
49	0.00
50	0.00
51	0.00
52	0.00
53	0.00
54	0.00
55	0.00
56	0.00
57	0.00
58	0.00
59	0.00
60	0.00

ET

## Appendix E-II

C WATER BOTTOM BOUNDARY CONDITION  
C TTTTTTTTTTTTTTTTTTTTTTTTT

C - INPUT FROM EXTERNAL FILE WATBBC.WB? (Y/N).....: N  
C - IS THE GROUNDWATER LEVEL INPUT (MM)? (Y/N) .....: N  
C M D GWL  
C (MM)  
C -- -----  
C - IS THE FLUX FROM THE SATURATED ZONE INPUT? (Y/N).....: N  
C IF THE FLUX FROM THE SATURATED ZONE IS INPUT THEN SPECIFY  
C - THE INITIAL GROUNDWATER LEVEL (MM)(REAL).....:  
C - THE FLUX  
C M D FLUXSAT  
C (MM DAY-1)  
C -- -----  
C - IS THE FLUX FROM THE SATURATED ZONE CALCULATED? (Y/N).....: N  
C IF THE FLUX FROM THE SATURATED ZONE IS CALCULATED AS  
C A FUNCTION OF THE GROUNDWATER LEVEL,THEN SPECIFY  
C - THE INITIAL GROUNDWATER LEVEL (MM).....:  
C - THE PARAMETERS OF THE EQUATION  
C FLUX=AREL\*EXP(BREL\*ABS(GROUNDWATER LEVEL))  
C - AREL (MM DAY-1).....:  
C - BREL (MM-1).....:  
C - IS THE PRESS. HEAD OF THE BOTTOM COMPARTMENT INPUT? (Y/N).....: N  
C M D PH  
C (CM)  
C -- -----  
C - IS THE FLUX AT THE BOTTOM OF UNSATURATED ZONE ZERO? (Y/N).....: N  
C - IS THE PROFILE DRAINING FREELY? (Y/N).....: Y  
C - IS THERE A LYSIMETER BOTTOM BOUNDARY CONDITION? (Y/N).....: N

C WATER INITIAL VALUES  
C TTTTTTTTTTTTTTTTT

C - INPUT FROM EXTERNAL FILE WATINIT.WI? (Y/N).....: N  
C - SHOULD THE PRESSURE HEAD (CM) AT EACH NODAL POINT BE CALCULATED  
C IN EQUILIBRIUM WITH THE INITIAL GROUNDWATER TABLE ? (Y/N).....: N  
C - IF "YES" THEN SKIP THIS SECTION  
C AND GOTO SECTION 'WATER PRINTING CONTROL'  
C ELSE  
C CONTINUE  
C - IS THE PRESSURE HEAD AT EACH NODAL POINT INPUT? (Y/N) ..... : N  
C - IF "NO"  
C GIVE THE INITIAL MOISTURE CONTENT (CM3 CM-3) FOR EACH COMPARTMENT  
C ELSE  
C GIVE THE INITIAL PRESSURE HEAD (CM) FOR EACH COMPARTMENT  
C COMP PH OR MC  
C (CM OR CM3 CM-3)  
C -- -----  
1 0.363  
100 0.472  
ET

C WATER PRINTING CONTROL  
C TTTTTTTTTTTTTTTTT

## Appendix E-II

- DETAILED ITERATION HISTORY (WAT\_HISTOR.OUT)? (Y/N) .....: N
- SUMMARY FILE (WAT\_SUM.OUT)? (Y/N) .....: y
- CUMULATIVE TERMS OF THE WATER BALANCE (WAT\_CUM.OUT)? (Y/N) .....: n
- EVAPOTRANSP. AND GROUND WATER TABLE LEVEL (WAT\_ET.OUT)? (Y/N).....: n

### C TIME SERIES

- PRESSURE HEAD (PH.OUT)? (Y/N) .....: n
- WATER CONTENT (WC.OUT)? (Y/N) .....: n
- CUM. ROOT EXTRACT (CRTEX.OUT)? (Y/N) .....:n

## Appendix E-II

C \*\*\*\*\*

C CLIMDATA

C \*\*\*\*\*

C SPECIFY THE CLIMATOLOGICAL DATA

C IF NITROGEN IS MODELLED THEN SPECIFY MIN AND MAX TEMPERATURES

C IF SUCROS IS USED THEN SPECIFY MIN, MAX TEMPERATURES AND GLOBAL RADIATION

C ELSE SKIP LAST THREE COLUMNS

C YR M DAY ET0 PREC IRRIG INTC MINTEM MAXTEMP GLOBAL RAD  
C (MM) (MM) (MM) (C) (C) (J/CM2/DAY)

C -----

1987 1 1 3.80 0.0 .0 .0 7.9 27.4 1710.0

1987 1 2 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 3 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 4 3.80 2.4 .0 .0 7.9 27.4 1710.0

1987 1 5 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 6 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 7 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 8 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 9 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 10 3.80 .0 12 .0 7.9 27.4 1710.0

1987 1 11 3.80 .0 12 .0 7.9 27.4 1710.0

1987 1 12 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 13 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 14 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 15 3.80 2.7 .0 .0 7.9 27.4 1710.0

1987 1 16 3.80 2.6 .0 .0 7.9 27.4 1710.0

1987 1 17 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 18 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 19 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 20 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 21 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 22 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 23 3.80 .0 12 .0 7.9 27.4 1710.0

1987 1 24 3.80 .0 12 .0 7.9 27.4 1710.0

1987 1 25 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 26 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 27 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 28 3.80 .5 .0 .0 7.9 27.4 1710.0

1987 1 29 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 30 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 1 31 3.80 .0 .0 .0 7.9 27.4 1710.0

1987 2 1 4.10 .0 .0 .0 8.1 28.0 1850.0

1987 2 2 4.10 .0 12 .0 8.1 28.0 1850.0

1987 2 3 4.10 .0 12 .0 8.1 28.0 1850.0

1987 2 4 4.10 .0 .0 .0 8.1 28.0 1850.0

1987 2 5 4.10 .0 .0 .0 8.1 28.0 1850.0

1987 2 6 4.10 .0 .0 .0 8.1 28.0 1850.0

1987 2 7 4.10 .0 .0 .0 8.1 28.0 1850.0

1987 2 8 4.10 .0 12 .0 8.1 28.0 1850.0

1987 2 9 4.10 .6 .0 .0 8.1 28.0 1850.0

1987 2 10 4.10 .0 .0 .0 8.1 28.0 1850.0

1987 2 11 4.10 8.1 .0 .0 8.1 28.0 1850.0

1987 2 12 4.10 .0 12 .0 8.1 28.0 1850.0

1987 2 13 4.10 .0 .0 .0 8.1 28.0 1850.0

1987 2 14 4.10 .0 .0 .0 8.1 28.0 1850.0

1987 2 15 4.10 .0 .0 .0 8.1 28.0 1850.0

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1987	2	16	4.10	.0	.0	.0	8.1	28.0	1850.0
1987	2	17	4.10	.0	12	.0	8.1	28.0	1850.0
1987	2	18	4.10	.0	12	.0	8.1	28.0	1850.0
1987	2	19	4.10	.4	.0	.0	8.1	28.0	1850.0
1987	2	20	4.10	.1	.0	.0	8.1	28.0	1850.0
1987	2	21	4.10	10.1	.0	.0	8.1	28.0	1850.0
1987	2	22	4.10	.0	.0	.0	8.1	28.0	1850.0
1987	2	23	4.10	.0	.0	.0	8.1	28.0	1850.0
1987	2	24	4.10	.0	.0	.0	8.1	28.0	1850.0
1987	2	25	4.10	.0	.0	.0	8.1	28.0	1850.0
1987	2	26	4.10	.0	12	.0	8.1	28.0	1850.0
1987	2	27	4.10	.0	12	.0	8.1	28.0	1850.0
1987	2	28	4.10	.0	.0	.0	8.1	28.0	1850.0
1987	3	1	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	2	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	3	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	4	3.90	.0	12	.0	9.6	27.2	1780.0
1987	3	5	3.90	.0	12	.0	9.6	27.2	1780.0
1987	3	6	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	7	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	8	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	9	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	10	3.90	10.0	.0	.0	9.6	27.2	1780.0
1987	3	11	3.90	2.1	.0	.0	9.6	27.2	1780.0
1987	3	12	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	13	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	14	3.90	.0	12	.0	9.6	27.2	1780.0
1987	3	15	3.90	5.6	.0	.0	9.6	27.2	1780.0
1987	3	16	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	17	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	18	3.90	2.4	.0	.0	9.6	27.2	1780.0
1987	3	19	3.90	24.5	.0	.0	9.6	27.2	1780.0
1987	3	20	3.90	.0	12	.0	9.6	27.2	1780.0
1987	3	21	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	22	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	23	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	24	3.90	1.2	.0	.0	9.6	27.2	1780.0
1987	3	25	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	26	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	27	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	28	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	3	29	3.90	.0	12	.0	9.6	27.2	1780.0
1987	3	30	3.90	.0	12	.0	9.6	27.2	1780.0
1987	3	31	3.90	.0	.0	.0	9.6	27.2	1780.0
1987	4	1	3.40	.0	.0	.0	11.3	25.0	1630.0
1987	4	2	3.40	.0	.0	.0	11.3	25.0	1630.0
1987	4	3	3.40	.0	.0	.0	11.3	25.0	1630.0
1987	4	4	3.40	.0	.0	.0	11.3	25.0	1630.0
1987	4	5	3.40	9.1	.0	.0	11.3	25.0	1630.0
1987	4	6	3.40	14.9	.0	.0	11.3	25.0	1630.0
1987	4	7	3.40	12.2	.0	.0	11.3	25.0	1630.0
1987	4	8	3.40	1.5	.0	.0	11.3	25.0	1630.0
1987	4	9	3.40	.0	.0	.0	11.3	25.0	1630.0
1987	4	10	3.40	.0	.0	.0	11.3	25.0	1630.0
1987	4	11	3.40	.0	.0	.0	11.3	25.0	1630.0
1987	4	12	3.40	8.1	.0	.0	11.3	25.0	1630.0
1987	4	13	3.40	.0	.0	.0	11.3	25.0	1630.0
1987	4	14	3.40	.0	.0	.0	11.3	25.0	1630.0

## Appendix E-II

1987 4 15	3.40	.0	.0	.0	11.3	25.0	1630.0
1987 4 16	3.40	.0	.0	.0	11.3	25.0	1630.0
1987 4 17	3.40	.0	.0	.0	11.3	25.0	1630.0
1987 4 18	3.40	11.2	.0	.0	11.3	25.0	1630.0
1987 4 19	3.40	.0	12	.0	11.3	25.0	1630.0
1987 4 20	3.40	.0	.0	.0	11.3	25.0	1630.0
1987 4 21	3.40	1.8	.0	.0	11.3	25.0	1630.0
1987 4 22	3.40	3.1	.0	.0	11.3	25.0	1630.0
1987 4 23	3.40	.0	.0	.0	11.3	25.0	1630.0
1987 4 24	3.40	.0	.0	.0	11.3	25.0	1630.0
1987 4 25	3.40	.0	.0	.0	11.3	25.0	1630.0
1987 4 26	3.40	.7	.0	.0	11.3	25.0	1630.0
1987 4 27	3.40	2.7	.0	.0	11.3	25.0	1630.0
1987 4 28	3.40	.0	.0	.0	11.3	25.0	1630.0
1987 4 29	3.40	2.5	.0	.0	11.3	25.0	1630.0
1987 4 30	3.40	.0	12	.0	11.3	25.0	1630.0
1987 5 1	3.10	.0	12	.0	11.2	23.7	1580.0
1987 5 2	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 3	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 4	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 5	3.10	1.6	.0	.0	11.2	23.7	1580.0
1987 5 6	3.10	3.4	.0	.0	11.2	23.7	1580.0
1987 5 7	3.10	1.4	.0	.0	11.2	23.7	1580.0
1987 5 8	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 9	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 10	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 11	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 12	3.10	39.5	.0	.0	11.2	23.7	1580.0
1987 5 13	3.10	.0	12	.0	11.2	23.7	1580.0
1987 5 14	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 15	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 16	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 17	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 18	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 19	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 20	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 21	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 22	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 23	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 24	3.10	36.5	.0	.0	11.2	23.7	1580.0
1987 5 25	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 26	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 27	3.10	6.9	.0	.0	11.2	23.7	1580.0
1987 5 28	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 29	3.10	.0	.0	.0	11.2	23.7	1580.0
1987 5 30	3.10	17.8	.0	.0	11.2	23.7	1580.0
1987 5 31	3.10	13.2	.0	.0	11.2	23.7	1580.0
1987 6 1	3.00	49.9	.0	.0	9.8	23.0	1500.0
1987 6 2	3.00	13.4	.0	.0	9.8	23.0	1500.0
1987 6 3	3.00	0.3	.0	.0	9.8	23.0	1500.0
1987 6 4	3.00	2.3	.0	.0	9.8	23.0	1500.0
1987 6 5	3.00	3.8	.0	.0	9.8	23.0	1500.0
1987 6 6	3.00	12.5	.0	.0	9.8	23.0	1500.0
1987 6 7	3.00	42.5	.0	.0	9.8	23.0	1500.0
1987 6 8	3.00	1.0	.0	.0	9.8	23.0	1500.0
1987 6 9	3.00	.0	.0	.0	9.8	23.0	1500.0
1987 6 10	3.00	.0	.0	.0	9.8	23.0	1500.0
1987 6 11	3.00	.0	.0	.0	9.8	23.0	1500.0

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1987	6	12	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	13	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	14	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	15	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	16	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	17	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	18	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	19	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	20	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	21	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	22	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	23	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	24	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	25	3.00	2.8	.0	.0	9.8	23.0	1500.0
1987	6	26	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	27	3.00	16.9	.0	.0	9.8	23.0	1500.0
1987	6	28	3.00	.0	.0	.0	9.8	23.0	1500.0
1987	6	29	3.00	4.4	.0	.0	9.8	23.0	1500.0
1987	6	30	3.00	2.7	.0	.0	9.8	23.0	1500.0
1987	7	1	2.9	21.5	.0	.0	9.2	22.5	1440.0
1987	7	2	2.9	2.8	.0	.0	9.2	22.5	1440.0
1987	7	3	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	4	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	5	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	6	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	7	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	8	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	9	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	10	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	11	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	12	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	13	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	14	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	15	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	16	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	17	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	18	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	19	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	20	2.9	2.5	.0	.0	9.2	22.5	1440.0
1987	7	21	2.9	25.4	.0	.0	9.2	22.5	1440.0
1987	7	22	2.9	2.4	.0	.0	9.2	22.5	1440.0
1987	7	23	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	24	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	25	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	26	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	27	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	28	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	29	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	30	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	7	31	2.9	0.0	.0	.0	9.2	22.5	1440.0
1987	8	1	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	2	3.2	0.0	12	.0	9.3	22.8	1590.0
1987	8	3	3.2	0.0	12	.0	9.3	22.8	1590.0
1987	8	4	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	5	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	6	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	7	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	8	3.2	0.0	.0	.0	9.3	22.8	1590.0

## Appendix E-II

1987	8	9	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	10	3.2	0.0	12	.0	9.3	22.8	1590.0
1987	8	11	3.2	0.0	12	.0	9.3	22.8	1590.0
1987	8	12	3.2	2.6	.0	.0	9.3	22.8	1590.0
1987	8	13	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	14	3.2	0.9	.0	.0	9.3	22.8	1590.0
1987	8	15	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	16	3.2	12.4	.0	.0	9.3	22.8	1590.0
1987	8	17	3.2	19.0	.0	.0	9.3	22.8	1590.0
1987	8	18	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	19	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	20	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	21	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	22	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	23	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	24	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	25	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	26	3.2	2.7	.0	.0	9.3	22.8	1590.0
1987	8	27	3.2	4.4	.0	.0	9.3	22.8	1590.0
1987	8	28	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	29	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	30	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	8	31	3.2	0.0	.0	.0	9.3	22.8	1590.0
1987	9	1	3.6	0.0	12	.0	8.7	24.5	1770.0
1987	9	2	3.6	0.0	12	.0	8.7	24.5	1770.0
1987	9	3	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	4	3.6	1.9	.0	.0	8.7	24.5	1770.0
1987	9	5	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	6	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	7	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	8	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	9	3.6	0.0	12	.0	8.7	24.5	1770.0
1987	9	10	3.6	0.0	12	.0	8.7	24.5	1770.0
1987	9	11	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	12	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	13	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	14	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	15	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	16	3.6	0.0	12	.0	8.7	24.5	1770.0
1987	9	17	3.6	0.0	12	.0	8.7	24.5	1770.0
1987	9	18	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	19	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	20	3.6	4.9	.0	.0	8.7	24.5	1770.0
1987	9	21	3.6	4.0	.0	.0	8.7	24.5	1770.0
1987	9	22	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	23	3.6	0.7	.0	.0	8.7	24.5	1770.0
1987	9	24	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	25	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	26	3.6	0.0	12	.0	8.7	24.5	1770.0
1987	9	27	3.6	0.0	12	.0	8.7	24.5	1770.0
1987	9	28	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	29	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	9	30	3.6	0.0	.0	.0	8.7	24.5	1770.0
1987	10	1	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987	10	2	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987	10	3	3.8	0.0	12	.0	9.0	25.5	1790.0
1987	10	4	3.8	0.0	12	.0	9.0	25.5	1790.0
1987	10	5	3.8	0.0	.0	.0	9.0	25.5	1790.0

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1987 10 6	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 7	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 8	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 9	3.8	0.0	12	.0	9.0	25.5	1790.0
1987 10 10	3.8	0.0	12	.0	9.0	25.5	1790.0
1987 10 11	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 12	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 13	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 14	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 15	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 16	3.8	0.0	12	.0	9.0	25.5	1790.0
1987 10 17	3.8	0.0	12	.0	9.0	25.5	1790.0
1987 10 18	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 19	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 20	3.8	1.2	.0	.0	9.0	25.5	1790.0
1987 10 21	3.8	3.4	.0	.0	9.0	25.5	1790.0
1987 10 22	3.8	.9	.0	.0	9.0	25.5	1790.0
1987 10 23	3.8	0.0	12	.0	9.0	25.5	1790.0
1987 10 24	3.8	0.0	12	.0	9.0	25.5	1790.0
1987 10 25	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 26	3.8	6.5	.0	.0	9.0	25.5	1790.0
1987 10 27	3.8	6.4	.0	.0	9.0	25.5	1790.0
1987 10 28	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 29	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 30	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 10 31	3.8	0.0	.0	.0	9.0	25.5	1790.0
1987 11 1	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 2	3.30	0.0	12	.0	9.2	24.6	1580.0
1987 11 3	3.30	0.0	12	.0	9.2	24.6	1580.0
1987 11 4	3.30	6.8	.0	.0	9.2	24.6	1580.0
1987 11 5	3.30	0.1	.0	.0	9.2	24.6	1580.0
1987 11 6	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 7	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 8	3.30	3.4	.0	.0	9.2	24.6	1580.0
1987 11 9	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 10	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 11	3.30	3.3	.0	.0	9.2	24.6	1580.0
1987 11 12	3.30	12.2	.0	.0	9.2	24.6	1580.0
1987 11 13	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 14	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 15	3.30	25.5	.0	.0	9.2	24.6	1580.0
1987 11 16	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 17	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 18	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 19	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 20	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 21	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 22	3.30	3.4	.0	.0	9.2	24.6	1580.0
1987 11 23	3.30	2.2	.0	.0	9.2	24.6	1580.0
1987 11 24	3.30	.9	.0	.0	9.2	24.6	1580.0
1987 11 25	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 26	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 27	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 28	3.30	0.0	.0	.0	9.2	24.6	1580.0
1987 11 29	3.30	0.0	12	.0	9.2	24.6	1580.0
1987 11 30	3.30	0.0	12	.0	9.2	24.6	1580.0
1987 12 1	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 2	3.30	0.0	.0	.0	8.6	25.7	1510.0

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1987 12 3	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 4	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 5	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 6	3.30	5.1	.0	.0	8.6	25.7	1510.0
1987 12 7	3.30	0.0	12	.0	8.6	25.7	1510.0
1987 12 8	3.30	0.0	12	.0	8.6	25.7	1510.0
1987 12 9	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 10	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 11	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 12	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 13	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 14	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 15	3.30	0.0	12	.0	8.6	25.7	1510.0
1987 12 16	3.30	0.0	12	.0	8.6	25.7	1510.0
1987 12 17	3.30	2.2	.0	.0	8.6	25.7	1510.0
1987 12 18	3.30	4.1	.0	.0	8.6	25.7	1510.0
1987 12 19	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 20	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 21	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 22	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 23	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 24	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 25	3.30	0.0	12	.0	8.6	25.7	1510.0
1987 12 26	3.30	0.0	12	.0	8.6	25.7	1510.0
1987 12 27	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 28	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 29	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 30	3.30	0.0	.0	.0	8.6	25.7	1510.0
1987 12 31	3.30	0.0	.0	.0	8.6	25.7	1510.0

ET

## Appendix E-II

C\*\*\*\*\*  
C SOLDATA.IN  
C\*\*\*\*\*

C GENERAL INFORMATION  
C TTTTTTTTTTTTTTTTT

NUMBER OF SOLUTES.....: 3  
USE THE MOBILE/IMMOBILE CONCEPT? (Y/N).....: N

C SOLUTE TRANSPORT PARAMETERS  
C TTTTTTTTTTTTTTTTTTT

C INPUT FROM EXTERNAL FILE SOLPAR.SP? (Y/N).....: N

C SPECIFY THE SOIL SPECIFIC TRANSPORT PARAMETERS

C \_\_\_\_\_

C FOR EACH SOIL LAYER

C -----

C IF NOT MOBILE/IMMOBILE CONCEPT, SKIP THE LAST 3 PARAMETERS

C NUMBER PARAMETER

C 1 HYDRODYNAMIC DISPERSIVITY (MM)

C 2 MOBILE/TOTAL MOISTURE CONTENT (-)

C 3 MASS TRANSFER COEFFICIENT (DAY -1)

C 4 ADSORBED FRACTION IN THE MOBILE ZONE (-)

C LR 1 2 3 4

C --- --- --- ---

1 170

2 170

3 170

4 170

ET

C SPECIFY THE SPECIES SPECIFIC TRANSPORT PARAMETERS

C -----

C FOR EACH SOLUTE SPECIES, FOR EACH SOIL LAYER

C NUMBER PARAMETER

C 1 DISTRIBUTION COEFFICIENT (L KG-1)

C 2 CHEM DIFFUSION IN PURE WATER (MM2 DAY-1)

C 3 A COEFFICIENT

C 4 B COEFFICIENT

C SOLUTE 1

C LR 1 2 3 4

C --- --- --- ---

1 0.9 0.01 0.01 10.

2 0.9 0.01 0.01 10.

3 0.9 0.01 0.01 10.

4 0.9 0.01 0.01 10.

ET

C SOLUTE 2

C LR 1 2 3 4

C --- --- --- ---

1 0.9 0.01 0.01 10.

## Appendix E-II

2 0.9 0.01 0.01 10.  
3 0.9 0.01 0.01 10.  
4 0.9 0.01 0.01 10.

ET

C SOLUTE 3  
C CLR 1 2 3 4  
C -- -----  
1 0.90 0.01 0.01 10.  
2 0.90 0.01 0.01 10.  
3 0.90 0.01 0.01 10.  
4 0.90 0.01 0.01 10.

ET

C SOLUTE UPPER BOUNDARY CONDITIONS  
C TTTTTTTTTTTTTTTTTTTTTTTTT

C INPUT FROM EXTERNAL FILE SOLUBC.SU? (Y/N) .....: N

C - DRY AND WET DEPOSITION  
C IS THERE DRY AND WET DEPOSITION (Y/N) .....: N  
C RAINCOSAL = AVERAGE LOAD OF SPECIES I IN PRECIPITATION (MG L-1)  
C DDEPSAL = AVERAGE DAILY DRY DEPOSITION OF SPECIES I (MG M-2)  
C SPECIES RAINCOSAL DDEPSAL  
C -----

C - INORGANIC FERTILIZATION  
C NUMBER OF APPLICATIONS OF INORGANIC FERTILISER.....: 8  
C DOSE(I) = APPLIED DOSE OF SPECIES I ON SPECIFIED DAY (MG/M\*\*2)  
C NOTICE THAT - THERE ARE THREE SOLUTE SPECIES  
C - THE APPLICATIONS ARE NUMBERED 1, 2, .. , NUMBER  
C OF APPLICATIONS  
C APPL M D DOSE(SOL1) DOSE(SOL2)...DOSE(NR OF SPEC)  
C -----  
1 01 02 15000 0 945  
2 02 15 15000 0 945  
3 04 01 15000 0 945  
4 05 15 15000 0 945  
5 07 01 15000 0 945  
6 08 15 15000 0 945  
7 10 01 15000 0 945  
8 11 15 15000 0 945

ET

C - IRRIGATION  
C DOSE(I) = APPLIED DOSE OF SPECIES I ON SPECIFIED DAY (MG/M\*\*2)  
C NUMBER OF IRRIGATIONS.....: 0  
C APPL M D DOSE(SOL1) DOSE(SOL2)...DOSE(NR OF SPEC)  
C -----

C - PLOWING  
C SPECIFY NUMBER DATE OF PLOWING AND PLOWING DEPTH (MM)  
C NUMBER OF TIMES PLOWED.....: 8  
C NR M D DEPTH  
C -----  
1 01 02 250

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2 02 15 250  
3 04 01 250  
4 05 15 250  
5 07 01 250  
6 08 15 250  
7 10 01 250  
8 11 15 250

ET

C SOLUTE SINK TERM  
C TTTTTTTTTTTTTTT

C INPUT FROM EXTERNAL FILE SOLSINK.SS? (Y/N) .....: N

C SPECIFY THE POTENTIAL FIRST ORDER DECAY RATE FOR EACH SOLUTE SPECIES (DAY-  
1)

C THESE RATES ARE NORMALLY 0 FOR NITROGEN SPECIES

C COMP RATES(1..NR\_OF\_SOL)

C --- - - - -

1 0.0 0.0 0.0

ET

C SOLUTE INITIAL VALUES  
C TTTTTTTTTTTTTTTTT

C INPUT FROM EXTERNAL FILE SOLINIT.SI? (Y/N) .....: N

C SPECIFY THE INITIAL VALUES FOR THE SOLUTE MASS IN EACH COMPARTMENT

C FOR THE DIFFERENT SOLUTE SPECIES (MG M-2)

C COMP CONC SOLUTES(1..NR\_OF\_SOL)

C --- - - - -

1 962 100.1 3620.6  
2 4053 507.0 7309  
3 5796 320.8 9905  
4 5643 197.5 7348  
5 4169 113 3772  
6 2646 64.2 15707  
7 1631 39.6 630.7  
8 1025 26.5 275.4  
9 682 20.1 144.3  
10 500 17.7 91.3  
11 405 17.4 63.0  
12 352 17.7 43.6  
14 283 16.2 18.0  
18 126 8.1 4.3  
39 12.5 0.6 0.4  
95 0.8 0 0

ET

C SOLUTE PRINTING CONTROL  
C TTTTTTTTTTTTTTTTT

C OUTPUT FOR WHICH SOLUTES? (1.. NR OF SOL)

C SPEC (Y/N)

(SOLUTE 1 = UREUM IN CASE OF NITROGEN) : 1 y

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(SOLUTE 2 = AMMON. IN CASE OF NITROGEN) : 2 y  
(SOLUTE 3 = NITRATE IN CASE OF NITROGEN) : 3 Y  
ET

C WHAT KIND OF OUTPUT

C

THE SUMMARY TABLE BE PRINTED(SOL\_SUM.OUT)? : Y

THE CUMULATIVE TERMS OF THE SOLUTE BALANCE (SOL\_CUM.OUT)?: n

C TIME SERIES

C

THE SOLUTE CONCENTR (CONC.OUT)? : Y

THE SINK TERM (SINK.OUT)? : Y

## Appendix E-II

C\*\*\*\*\*  
C NITDATA  
C\*\*\*\*\*

C NITROGEN UPPER BOUNDARY CONDITION  
C TTTTTTTTTTTTTTTTTTTTTTTTTTT

INPUT FROM EXTERNAL FILE NITUBC.NU?(Y/N): N

C -DISTRIBUTION OF NITROGEN IN THE PLANT AT HARVEST

C FAG = ABOVE GROUND FRACTION (-)

C FLR = LIVING ROOTFRACTION (-)

C FHP = HARVEST FRACTION (-)

FAG.....: 0.04

FLR.....: 0.86

FHP.....: 0.1

C -ORGANIC FERTILIZATION

C CARBORG = ORGANIC CARBON IN FERTILIZER (MG M-2)

C NITORG = ORGANIC NITROGEN IN FERTILIZER (MG M-2)

NUMBER OF APPLICATIONS OF ORGANIC FERTILIZER.....: 2

C APPLNR MONTH DAY CARBORG NITORG

C -----

1 01 01 0 0

2 06 15 0 0

ET

C NITROGEN TRANSFORMATION PARAMETERS  
C TTTTTTTTTTTTTTTTTTTTTTTTTTTTT

INPUT FROM EXTERNAL FILE NITSINK.NS? (Y/N) .....: N

C MINERALIZATION

C RO = C/N RATIO OF THE BIOMASS

C FE = SYNTHESIS EFFICIENCY CONSTANT

C FH = HUMIFICATION COEFFICIENT

RO .....: 10.0

FE .....: 0.3

FH .....: 0.4

C PLANT UPTAKE PARAMETERS

C - IF THERE ARE NO PLANTS SKIP THIS PART

C AND GO TO SECTION 'POTENTIAL UPTAKE RATES'

C - SPECIFY

C RORAD = AVERAGE ROOT RADIUS (MM)

C RDO = AVERAGE DISTANCE BETWEEN SOIL SOLUTION AND ROOT SURFACE (MM)

C RORAD .....: 0.2224

C RDO .....: 0.1

C - IF CROP GROWTH IS MODELED SKIP THIS PART

C G = FRACTION OF GROWING SEASON OF POTENTIAL UPTAKE (-)

C RNMAXP = MAXIMUM NITROGEN UPTAKE (MG M-2)

C W0\_RDENS = ROOT DENSITY AT SOIL SURFACE (CM L-1)

C ALFA = REDUCTION FACTOR OF ROOT DENSITY VS DEPTH (MM-1)

C G .....: 3

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C RNMAXP .....:4E4  
C W0\_RDENS .....:1500  
C ALFA\_RDENS.....:0077

C POTENTIAL TRANSFORMATION RATE CONSTANTS  
C TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT

INPUT FROM EXTERNAL FILE NITDEC.ND? .....: N

C RKNITRI = NITRIFICATION CONSTANT (DAY-1)  
C RKDENIT = DENITRIFICATION CONSTANT (DAY-1)  
C RKHYD = UREUM HYDROLYSE CONSTANT (DAY-1)  
C RKVOL = VOLATILIZATION CONSTANT (DAY-1)  
C RKLIT = DECAY FROM LITTER POOL (DAY-1)  
C RKMAN = DECAY FROM MANURE POOL (DAY-1)  
C RKHUM = DECAY FROM HUMUS POOL (DAY-1)  
C COMP RKNITRI RKDENIT RKHYD RKVOL RKLIT RKMAN RKHUM  
C -----  
1 3.22 0.4 .39 0.01 0.0 0.0 0.0000  
2 0.06 0.35 .04 0.0 0.0 0.0 0.0000  
3 .01 0.0 .00 0.0 0.0 0.0 0.0000  
14 0.0 0.0 .00 0.0 0.0 0.0 0.0000  
25 0.0 0.00 .00 0.0 0.0 0.0 0.0000  
50 0. 0.0 0. 0.0 0.0 0.0 0.0000  
80 0. 0.0 0. 0.0 0.0 0.0 0.0000

ET

C ORGANIC POOL INITIAL VALUES  
C TTTTTTTTTTTTTTTTTTTTTTTTT

INPUT FROM EXTERNAL FILE NITINIT.NI? (Y/N) .....: N

C CCMANO = INITIAL CARBON IN MANURE POOL (MG M-2)  
C CNMANO = INITIAL NITROGEN IN MANURE POOL (MG M-2)  
C CCLITO = INITIAL CARBON IN LITTER POOL (MG M-2)  
C CNLITO = INITIAL NITROGEN IN LITTER POOL (MG M-2)  
C CCHUMO = INITIAL CARBON IN HUMUS POOL (MG M-2)  
C CNHUMO = INITIAL NITROGEN IN HUMUS POOL (MG M-2)

C COMP CCMANO CNMANO CCLITO CNLITO CCHUMO CNHUMO  
C -----  
3 20200 2020 20200. 2020. 924200. 92410.  
4 1500. 150.0 1500. 150.0 296400. 29620.  
5 1000. 100.0 1000. 100.0 197600. 19780.  
11 1000. 100.0 1000. 100.0 197600. 19780.  
22 50. 50.0 50. 10.00 9600. 960.

ET

C NITROGEN PRINTER CONTROL  
C TTTTTTTTTTTTTTTTTTTTT

C OVERVIEW TABLES?

- OVERVIEW OF MAIN ORGANIC STATE VARIABLES (NIT\_SUM.OUT) : y
- CUMULATIVE TERMS OF THE ORGANIC POOL (NIT\_CUM.OUT) : n

## Appendix E-II

### C MASS IN THE DIFFERENT ORGANIC MATTER POOLS?

- ORGANIC LITER N CONCENTRATION (ORGNLIT.OUT) : N
- ORGANIC MANURE N CONCENTRATION (ORGNMAN.OUT) : N
- ORGANIC HUMUS N CONCENTRATION (ORGNHUM.OUT) : y
- ORGANIC LITTER C CONCENTRATION (ORGCLIT.OUT) : N
- ORGANIC MANURE C CONCENTRATION (ORGCMAN.OUT) : N
- ORGANIC HUMUS C CONCENTRATION (ORGCHUM.OUT) : y

### C CUMULATIVE NITROGEN BALANCE TERMS?

- NH4 UPTAKE (NH4UPT.OUT) : N
- NO3 UPTAKE (NO3UPT.OUT) : n
- DENITRIFICATION (DENITRIF.OUT) : N
- NITRIFICATION (NITRIFIC.OUT) : N
- HYDROLYSIS (HYDROLYS.OUT) : N
- VOLATILISATION (VOLATIL.OUT) : N
- NH4 MINERALISATION (NH4MIN.OUT) : N
- NO3 MINERALISATION (NO3MIN.OUT) : n