RECHARGE AND DISCHARGE STUDIES IN LATERITE SOILS

By
KAVITHA M. N.
SANFRED JOSEPH LUIZ
SINI K.

PROJECT REPORT

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DECLARATION

We hereby declare that this project report entitled **"Recharge and Discharge Studies in laterite soils"** is a bonafide record of the project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Kavitha M.N.
Sanfred Joseph Luiz
Sini. K.

CERTIFICATE

Certified that this project report entitled **" Recharge and Discharge Studies in Laterite soils"** is a record of project work jointly done by **Kavitha M.N., Sanfred Joseph Luiz** and **Sini K.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, associate ship or fellowship to them.

Er. Sathian K.K.
Assistant Professor
Department of Land
and Water Resources and
Conservation Engineering

Place : Tavanur
Date :

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Kavitha M.N.
Sanfred Joseph Luiz
Sini K.

Dedicated

To

Our Loving Parents

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SYMBOLS AND ABBREVIATIONS

Anon.	- Anonymous
ASAE	- American Society of Agricultural Engineers
cm	- centimeter
et al.	- and others
etc	- etcetera
Fig.	- Figure
ha	- Hectare
hr	- hour
IDE	- Irrigation and Drainage Engineering
J.	- Journal
K.C.A.E.T.	- Kelappaji College of Agricultural Engineering and Technology
Kg	- Kilograms
LWRCE	- Land and Water Resources Conservation Engineering
m	- meter
m/day	- meter per day
min	- minute
ml	- millilitre
NE	- North East
PFDC	- Precision Farming Development Centre
ppm	- parts per million

SW	- South West
Trans	- Transaction
USWB	- United States Weather Bureau
Viz.	- namely
WT	- Water Table
Yr	- year
^{0}C	- Degree Celcius
/	- per
%	- percent.

Introduction

INTRODUCTION

The State of Kerala is blessed with abundance of annual rainfall of about 300 cm. The receipt of annual rainfall of the state is about 2.5 to 3.0 times the national average. Even world over there are very few places receiving an annual rainfall of about 300 cm. Hence, the state of Kerala has a very good standing in rainfall receipt. However, the state is experiencing water scarcity of different order. There are places with no drinking water in summer. Scarcity for irrigation is very common; even the minor irrigation schemes installed at the major riverbanks are disfunctional due to non-availability of water. Scarcity for industry appears in two ways; no water for their captive use and less water for safe disposal of effluents.

The above described water scenario of the state may be attributed to a few numbers of reasons. Long spell of non-rainy period is the foremost reason. The state has six months of rainy period from June to November and the other six months are without or any appreciable rainfall. This raises our eyebrows towards water conservation. Since the topography of the state is steep sloping from east to west except along the coastal belt, natural subsurface conservation of rainfall will take place provided the entire land surface is covered with forest, as was the case till some too hundred years back. The spread of habitation to forest areas has totally changed the land cover from the point of view of water conservation.

Hence, the need of the hour is water conservation. The moment one talk about conserving water, we cannot refrain from answering the question ‘by what way?’, that is whether insitu or exitu measures. After the independence of the nation, the state has gone in for many medium and large dams across various rivers. Most of the commissioned reservoirs barring the exception of hydroelectric projects threw open one question in our mind ‘were they really needed?’. Even the hydroelectric projects disturb our mind owing to their environmental adversities. But in the case of hydroelectric projects, we have no other way but to compromise for our cheap source of energy.

Medium reservoirs constructed across the rivers for meeting drinking and irrigation needs have proved to be a failure in many counts. Many of them could not achieve their set objectives due to poor planning and work execution. Even those meeting the partial objectives stood nowhere when viewed through their cost effectiveness. Environmental adverse effects are applicable to these reservoirs also.

As a result of all these, the decision makers and the public at large have realized that exitu conservation measures are no solution to water scarcity especially in a state like Kerala with steep and undulating terrain and with high density of human settlement. A realization that insitu water conservation is the only scientific and sustainable mode of conserving water has come to the mind. Hence, several programs to popularize the insitu water conservation methods have been initiated by the government and quasi government agencies. In the state of Kerala, insitu water conservation measures will have to be done in midland and high land areas and the areas covered by laterite soil.

Laterite and lateritic soil occupies a very large portion of the total geographical area of the state and has a major role in its economy. Hence any water management program of kerala will have to address the limitations and issues of water conservation in laterite.

Laterite is residual deposit seen in some areas of the tropics and is a product of intense weathering in a hot and humid climate. In Kerala, at Angadippuram, a ferruginous, vesicular, soft material occurring within the soil which hardens irreversibly on exposure and used as a building material was first recognized as laterite by Hamilton Buchanan (1807), soil survey staff of USDA introduced the term oxisols to cover laterite soil in general. Laterite may develop over a wide range of bed rocks and sediments and is characterized by textural diversities.

In the global scenario, laterite is widely distributed through out the tropics and subtropics of India, Africa, Australia, South East Asia and South America. Its arial coverage as a percentage of total geographical area is 9%. In India, it is well developed on the summits of Deccan hills, Karnataka, Kerala, Eastern Ghats, West Maharashtra and central parts of Orissa and Assam. Total area occupying laterite in the national level is 130066km^2

In the state of Kerala, presence of laterite is very significant. Almost entire midland, elevations ranging from 7.5-75m above mean sea level is covered by laterite and lateritic soils. The real extent of this midland is 41% of the total area of the state. The lateritic midland region is said to be the backbone of the economy of Kerala. The most important cash crops grown in this area are coconut, rubber, cashew etc. In the water front its role is highly significant. More than 75% of domestic water requirement of midland region is met from open wells constructed in shallow aquifers in laterite. Also a considerable portion of the irrigation requirement and water requirements of many small scale industries are met by water stored in this laterite.

Water conservation in laterite remains as a major issue in Kerala even today. Or in other words, the most important reasons of drought in the state are the lack of awareness of appropriate technologies in conserving water in laterite. Studies and observations have revealed that laterite has got a very high rate of infiltration. It is also observed that hydraulic conductivity and subsurface flows in laterite show great disparities. At the same time, discharge studies in laterite are very much limited in an international context. Even national level studies are not up to the expectations.

Under these circumferences, a recharge and discharge study in laterite has been envisaged with the following objectives.

1. To determine the direction of subsurface flow and its interactions with the surface slope.
2. To determine the rate and pattern of saturated flow in lateritic region.
3. To determine the velocity of groundwater flow in laterite

Review of Literature

REVIEW OF LITERATURE

Laterite was first recognized at Angadipuram in Kerala state, India by Francis (Hamilton) Buchanan (1762-1829). He suggested the name laterite, from Latin word 'later' for brick. Laterite is a ferruginous, vesicular soft material occurring within the soil and hardens irreversibly on exposure. It is used as building material. The word Laterite first appeared in scientific literature in the book "A journey from Madras through the countries of Mysore, Canara and Malabar" authored by Buchanan.

The world over, laterite and lateritic soils are of interest to Pedologists, Agronomists, Geologists, Geomorphologists, Mining Engineers, Agricultural Engineers, Civil Engineers and Ore traders. Its global distribution in the tropical and inter tropical regions and the problems it possess are the reasons for its widespread interest. Harrassowitz (1930) presented a morphological definition for laterite as one with a characteristic profile developing under tropical savannah and forming the fair horizons in ascending order from subsurface to surface: (a) fresh zone (b) a zone of primary alteration to kaovolinite (c) a laterite bed proper (d) a surface zone with ferruginous incrustation and concretions. Excellent literature on laterite and associated soil have been presented by Kellogg (1949), Robinson (1949), Prescott and Penleton (1952), Mohr and Van Baran (1954), Sivarajasingham et al (1962), Mcfarlane (1976) and Varghese (1981).

Laterite and associated soils are widely distributed in the tropics and sub tropics of Africa, Australia, India, South East Asia and America. It is shown in world soil resources map prepared by FAO. Laterite extends beyond sub humid tropical climate to desert region where they are an indication of more humid influences in the past.

Laterite consists mainly of superficial cuirasses of oxides of iron and alumina. The massive form of laterite may show either a vesicular or conglomeritic structure. The chief and visible feature of laterite is the accumulation, form, colour and consistency of iron hydroxide and oxides which impart yellow, pink, brown and red colours to the soil. The different colours of laterite are due to the oxides of iron and in various degrees of hydration and sometimes also due to manganese. The apparent density of laterite will be higher at the surface and decreases with increase in depth.

2.1. Properties of Laterite.

Richards (1941) applied the principles of hydraulics to the movement of water in an unsaturated soil. He defined the hydraulic gradient as the loss in hydraulic head per unit distance along an average flow line. If soil tensiometers are placed in soil at various depths, the direction of movement of soil moisture in an unsaturated soil can be determined by the hydraulic gradients between any two zones in the soil.

Davison et al (1969) measured the hydraulic conductivity and soil water content relation for different depths in fields for three soil profiles. The soil varied in physical properties from loamy sand to silty clay in surface soil texture. The soil water flux at various soil depths with and without evaporation at the soil was measured. The rate at which water drained from each of the profile was predicted using Darcy's equation

Hillel et al (1972) pointed out the importance of hydraulic properties of soil profile. They used instantaneous profile method for determining soil hydraulic properties based on simultaneously monitoring the changing wetness and matric suction profiles during internal drainage. The results were analyzed to obtain the function of conductivity vs. water content for each layer in the profile as well as for the profile as a composite whole.

Jabro (1992) conducted a study on the estimation of saturated hydraulic conductivity of soils from particle size distribution and bulk density data. In this study a multiple linear regression model was developed to predict the saturated hydraulic conductivity of soils. Additional field measured data were collected to test and validate the model using several statistical evaluation procedures.

Asare et al (1993) conducted a study on seasonal variability of hydraulic conductivity. They determined saturated hydraulic conductivity and matrix flux potential during fall (October-November) and spring (March-April) seasons. They found out that at a depth of 0.12m the field measured hydraulic conductivity was 40% higher in spring than in fall.

Gupta et al (1993) conducted a study on comparison of saturated hydraulic conductivity measured by various field methods. Field measurements were conducted to compare the saturated hydraulic conductivity using four different techniques, double ring infiltrometer (RI), rainfall simulator (RS), Guelph permeameter (GP) and Guelph infiltrometer (GI)

Ruprecht and Schofield (1993) conducted a study on the infiltration characteristics of a complex laterite soil profile. In this study large infiltration ponds were used, in conjunction with a ring infiltrometer and a well permeameter, to determine the infiltration characteristics. They determined that the conductivity of subsurface lateritic duric crust to have high saturated hydraulic conductivity (Ks) of 2.7 m/day

Noble and Tiwari (1999) reported quick down slope delivery of water through macro pores in the lateritic formation at Odakkali, Kerala

2.2. Studies on Recharge.

Balek (1989) conducted a study on the behaviour of ground water regime under given environmental conditions. An assessment was undertaken to analyze the ground water flow and its interaction with the Stream network, and hence forecasting the future use of water resources based on various exploitation alternatives.

Smith *et al.* (1992) conducted a study on the water table fluctuations in sandy soils using ground penetrating radar. The study site was located near Tifton, US. Twenty eight shallow monitoring wells were located adjacent to the transects. Sections of galvanized iron pipes were buried at three depths as depth standards. The GPR was used to map the position of water table nine times during ten day intervals.

Langshot (1992) observed that recharge represent a major portion of rainfall and recommends further model studies to reveal the complex groundwater recharge in this region based on the studies conducted on a $600m^2$ field site in Kerala.

Lanzholts (1994) conducted a water balance modeling study in lateritic terrain. The field study undertaken in the state of Kerala mainly focused on three main aspects namely, the rapid water table response, and Hortonian surface runoff generation and soil suction variability.

Lall (1995) developed a yield model for screening surface and ground water development. The model may be used to perform a preliminary screening of alternatives for water supply development and identify storage capacities at reservoir sites, as well as aquifers pumping at candidate locations

Pesti *et al.* (1996) conducted a study on combining geophysical and well data for identifying best well locations. The best well location is selected based on a compromise solution for two conflicting objectives (1) Maximum well yield (2) Maximum well head protection, i.e., maximum total travel time related to fixed set back distance, expected value and 75% reliability maps are developed for yield and total travel time.

Ranfrez and Finnerty (1996) conducted a study on the precipitation and water table effects on agricultural production and economics. Capillary rise was modeled as a function of soil moisture content and depth to water table. The capillary rise model was used to define the sensitivity of soil moisture depletion, actual evapotranspiration and agricultural benefits to change in water table depths.

Rajan (1997) in his notes prepared for implementing ground water estimation methodology gives two methods for the calculation of rainfall recharge and they are rainfall infiltration factor method and water table fluctuation method.

Jain and Sondhi (1998) conducted an experiment to estimate the ground water potential of Bist Doab Tract in Punjab through seasonal ground water recharge and water balance studies. The results showed that the average total ground water recharge in the area in Kharif and Rabi seasons were 28.02% and 24.28% of the total water inputs namely rainfall, irrigation from tube wells and canal network during the corresponding seasons.

Gaur (2001) conducted a study on ground water recharge estimate of a small watershed. The total annual recharge was calculated as the sum of total monsoon rainfall recharge, non monsoon recharge from surface sources of irrigation and potential recharges. The net utilizable recharge is taken as 85 % of gross recharge

2.3. Ground Water Movement and Discharge Studies.

Fedler *et al.* (1989) conducted study of tracer movement in shallow alluvial aquifers. The field study performed made use of bromide tracers. This was used to observe movements in confined shallow aquifer. The data collected were used to estimate the apparent hydraulic heterogeneity at the test site. Anisotropy of transmissivity had a major effect on the speed and spreading of the tracer plume.

Tabrizi *et al.* (1990) conducted a study on the use of identification techniques to develop a water table prediction model. Data recorded near Aurora in the North Carolina coastal plains over a two year period were used to develop and test a model. Rainfall and water table elevations were recorded continuously in this site and the observed water table elevations were compared to predicted day end values. The model was developed using measured results from one year and tested against observed data for a second year.

Jackson (1995) conducted partitioning tracer test for detection, estimation and remediation performance assessment of subsurface non aqueous phase liquids. The study show how partitioning inter well tracer test can be used to estimate the amount of tetrachloroethylene contaminant before the remedial action and as remediation proceeds.

Boyd (1999) conducted a study on the characterization of ground water flow in municipal well fields using tracers. He collected water samples and analyzed for selected isotopes and chlorofluorocarbons to characterize ground water flow systems near the municipal well fields.

Chen *et al.* (1999) conducted a study on two well methods to evaluate transverse dispersivity for tracer test in a radially convergent flow field. A two dimensional mathematical model was derived and applied to illustrate how transverse dispersion influence tracer transport in convergent radial tracer test. The proposed method allows one to evaluate the transverse dispersivity from field tracer test as long as the observed breakthrough curves at the pumping well and the observing well are known

2.4. Specific Yield Studies

Boonstra (1994) developed a computer programme named SATEM, Selected Aquifer Test Evaluation Methods, for the determination of aquifer parameters in consolidated aquifers.

Ambili and Biju (2002) conducted a study on the evaluation of aquifer parameters from pumping test data in KCAET, Tavanur. Aquifer parameters of laterite, clay and alluvial formation were determined. The specific yield of lateritic formation was found to be 0.00134. The hydraulic conductivity of laterite was estimated to be 3.7 $X10^{-5}$ m/s.

Bineesh *et al.* (2004) conducted a study on the estimation of ground water recharge in KCAET campus Tavanur Malapuram. They estimated the specific yield of lateritic formation to be between 0.07 to 0.13 for different sites within the campus.

Materials and Methods

MATERIALS AND METHODS

3.1. Study Area.

The study area is located at Tavanur in Malappuram district, Kerala. It is situated at 10^0 53' 30'' North latitude and 76^0 East longitude and lie adjoining to the Bharathapuzha River. The region has a humid tropical climate and falls within the monsoon zone. It is exposed to a 'hot weather period' from March to May, a SW monsoon period from June to September and a NE monsoon period from October to December. The SW monsoon is the dominant rainy season in this region. The region under consideration is of laterite underlain by weathered rock and fresh rock, mostly Gneiss's and Charnockites. The soil profile consists of massive laterite up to a maximum depth of 15 meter. The study was conducted in three adjoining locations.

3.1.1. Location 1: K.C.A.E.T. Campus

This location lies wholly in KCAET campus, is covered with bushes and trees. This area comprises of six observation wells and ten open wells.

3.1.2. Location 2: Near to the Northern Boundary of KCAET

The location is situated at the southern part adjoining the first location. It is a probable influencing area of recharge activities carried out in K.C.A.E.T campus. The study area includes five open wells.

3.1.3. Location 3: K.M.G.P.B. High school

The study was also conducted in the surrounding areas of the school compound. The eighteen open wells from which the observations were taken are distributed on either side of the school on a sloping terrain.

3.2. Topographic map of Study area

Topographic map of location 1 was prepared by theodolitic survey. The primary objective of the survey was to determine the reduced levels of wells under study and to prepare the contour map of the study area.

3.3. Climatic parameters

Various climatological data relevant to the study were collected from Agro met Observatory located inside the campus. The data include

Daily rainfall: The rainfall was recorded using non self-recording type rain gauge.

Evaporation: The Evaporation was recorded using USWB Class A pan evaporimeter.

3.4. Observation of Water Table Depth

Water table depths in the study areas were monitored on weekly basis. A specially fabricated electronic sounding system was used to monitor the water table depths of observation wells.

The electronic sounding system consists of a buzzer attached in series to resistors and a battery (Fig. 3.1.). The electronic circuit for an automatic sounding system is described here. When two contacts shown at A and B get closed, the circuit completes its path through D_1, B, A, R_1, T, R_2 to the buzzer. When there is no contact between the points A and B, the circuit will not complete its path making the buzzer inactive. As the points A and B get closed, current flows through the base of the Transistor making its Base-Emitter junction forward biased causing the transistor to conduct. As it conducts, the buzzer will produce the alarm.

3.5. The Estimation of Ground Water Recharge.

The ground water recharge estimation can be done by various methods of which, rainfall infiltration factor method and ground water level fluctuation method are considered for the present study.

3.5.1. The Ground Water Level Fluctuation method.

The ground water estimation committee of the Government of India (1984) recommended that the ground water recharge might be estimated based on the ground water level fluctuation method. In this method use is made of data on seasonal variations of ground water level, rainfall and applied irrigation. This method is generally not applicable to confined aquifers. It covers recharge only at the soil surface.

When the recharge is seasonal the ground water level may fluctuate in a sine curve pattern with varying amplitudes. By plotting the annual rise corresponding to annual rainfall P, an average relationship is derived which gives a limiting value of rainfall (threshold value) below, which there is no recharge. This amount of rainfall is completely lost in ET and surface runoff. The recharge in any particular year is the difference between the observed annual rainfall and the total losses. The rise and fall of water table over an area is a measure of change in ground water storage or recharge and computed as

$$\mathbf{R = \Delta h . S_y . A}$$

Where,

R = Ground water recharge, ha-m

Δh = Change in water level due to recharge, m

S_y = Specific yield of the formation in the zone of fluctuation, dimensionless

A = Surface area of the aquifer, ha

3.5.2. Rainfall Infiltration Factor method

The rainfall infiltration factor method can be employed during both monsoon season and non-monsoon season. The basic assumptions include:

1. The rainfall recharge in a given unit during a given season is considered to be a linear function of only the quantum of rainfall during that season. Hence the distribution of rainfall is therefore ignored.
2. The rainfall recharge during the non-monsoon season is considered to be nil if the normal non-monsoon season rainfall is less than or equal to 10% of the normal annual rainfall.
3. The rainfall infiltration factor depends on the type of terrain.

3.5.3. Determination of Rainfall Infiltration factor.

The infiltration factor is determined by the formulae given below:

$$\mathbf{R=P.A.R_F}$$

Where,

R = Ground water recharge, ha-m

P = Rainfall, m

A = Area, ha

$\mathbf{R_F}$ = Rainfall infiltration factor

3.6. Actual recharge

Water level hydrographs can be decomposed to obtain fluctuation in response to rainfall and other inputs of water to the aquifer. The water level rise in an aquifer represents the net response to a process of simultaneous drainage or discharge from and recharge to the aquifer. In order to find the actual recharge, the water level recession has to be extended till the period of maximum rise of water. If the recharge is discontinuous with large time gaps, the water level will decline between two recharge periods. The total recharge will be the sum of individual rises. A detailed description is given in Fig 3.2., where the actual recharge W between the time interval $t_1$and t_2 will be

$$W = S\,(H_{R1} + H_{R2} + H_{D1} + H_{D2})$$

The subscripts R refers to the actual rise and D to the additional rise that would have been recorded had there been no simultaneous drainage from the aquifer.

3.7. Rejected recharge for shallow water table

When the water table is shallow, the actual recharge may be less than the potential recharge if the water table were deeper. The additional quantity of water that would have recharged the aquifer, had there been enough storage space in the aquifer, is termed rejected recharge. The rejected recharge is given by the equation,

$$W_R = S H_{1A}\,(H_{2B}/H_{1B} - 1)$$

Where,

W_R = rejected recharge

S = specific yield

H_{1A}= water level rise in a well located within the area of rejected recharge at time t_1, when the water level ceased rising.

H_{1B}= water level rise in a well outside the area of rejected recharge at time t_1.

H_{2B}= maximum water level rise in the well outside the area of rejected recharge at time t_2

Rejected recharge is a feature common to ground water discharge areas. Because of this, the recharge values for the topographic lows are comparatively lower than those for topographic higher. The Fig.3.3. gives a detailed representation of the graphical procedure developed to estimate the rejected recharge.

3.8. Ground Water Discharge by Tracer Technology.

A Tracer is a matter or energy carried by ground water which will give information concerning the direction of movement and/or velocity of water and potential contaminants which might be transported by water. It helps us in determining hydraulic conductivity, porosity, dispersivity, and other parameters.

A tracer can be entirely natural, such as heat carried by hot spring waters; it can be accidentally introduced such as fuel oil from a ruptured storage tank; or it can be introduced intentionally, such as dyes placed in water flowing within lime stone caverns. A tracer should have a number of properties in order to be generally useful. The most important criterion is that the potential chemical and physical behaviour of the tracer in groundwater must be understood. The objective is to use a tracer which travels with the same velocity and direction as the water and does not interact with solid materials. A tracer should be nontoxic and it should be relatively inexpensive to use. For most practical problems, it should be easily detectable with widely available and simple technologies. Finally, the tracer itself should not modify the hydraulic conductivity or any other properties of the medium being studied

3.8.1. Types of Tracers

The chemical tracers usually applied are sodium chloride, in the form of common salt, sodium dichromate, lithium chloride, sodium nitrate, manganese sulphate and potassium iodide. The cheapest and most convenient tracer used in many countries is common salt (NaCl), preferably fine grained table salt which dissolves in water quickly. Many fluorescent and radioactive tracers are also available, but its cost and complexities compel to use chemical salts for tracer studies. For this study NaCl was used.

The salt was initiated into the well $1Wo_4$. The concentration changes of the tracer were monitored in both the injection and collection wells, i.e. $1Wo_4$ and $1Wo_5$.

3.8.2. Dosage of the Tracer

The volume of the water in $1Wo_4$ was found out to be 6473.6 liters and 16 kg of NaCl was added to it to get a concentration of 2.47 gm/liter (2470ppm).

3.8.3. Sampling of the water from the wells

Samples before the application of the tracer (NaCl) were taken from both the wells. Daily samples were collected from the $1Wo_4$ and $1Wo_5$ for 20 days. The samples were taken everyday at 5.30 pm to have a uniform time interval between samplings.

3.8.4. Determination of the concentration of tracers

The samples were examined for tracer concentration by Flame Photometry. Initial calibration was done with known concentrations of NaCl solutions to standardize the instrument. Then the sample collected before application of NaCl was used as blank solution (Reference solution). The concentration values were obtained from the instrument.

3.8.5. Borehole Dilution Method

This technique was used to measure the magnitude and direction of horizontal tracer velocity and vertical flow. Also hydraulic conductivity values can be obtained by applying Darcy's law. Procedure is to introduce a known quantity of tracer instantaneously into the borehole, mix it well and then measure the concentration decrease with time.

Velocity, $$V = \frac{r \ln (c_0/c)}{4tn}$$

Where,

- r = borehole radius
- t = time of observation
- n = effective porosity
- c_0 = Input concentration of the tracer.
- c = concentration of tracer at time 't'

Results and Discussion

RESULTS AND DISCUSSION

The present study highlights the recharge and discharge of ground water resources in laterite soils viz., the ground water behaviour, water table depths and their fluctuation, natural ground water discharge and recharge and velocity of ground water flow.

4.1. Contour map of the study areas.

A topographic survey of a study area (site 1) at K.C.A.E.T. was conducted using theodolite. Base map of the area and its contour map was prepared using the Surfer software (Fig.4.1. and Fig.4.2.). Reduced level readings were taken by theodolite surveying (Appendix 2). The layout map of the site 2 and site 3 were also plotted. (Fig.4.3.1. & Fig.4.3.2.).

4.2. Profile of the Area along the Slope

The profile of the site 1 and site 2 were plotted using the reduced ground levels versus the longitudinal distance. Four wells were selected from 1st and three from the 2nd site which were coming approximately along a straight line. Water table positions of these wells were also shown along the ground profile (Fig. 4.4.). Altitude and land slope have got marked impact on depth to water table.

4.3. Climatic parameters

The various climatic parameters including, rainfall, evaporation, maximum temperature and minimum temperature were noted during the study period (Aug '04 to Feb '04). The cumulative rainfall for the study period was 764.1 mm. The cumulative evaporation during the study period was 1146.22 mm. (The value is not inclusive of the month of November). The maximum daily rainfall recorded was 110 mm. Maximum and minimum temperatures were found to be 37 ^oC and 25.5 ^oC respectively. Detailed views of the climatic parameters during the period of study are given in appendix 1.

4.4. Temporal Variations of Water Table Depth.

The Ground Water levels of all the three study areas were recorded with the help of sounding tape. The weekly monitored water table positions as indicated by observation wells (Table 4.1., Table 4.2. & Table 4.3.). The maximum fluctuation recorded in the wells were, 4.41m, 4m, and 5.57m in site 1 ($1Wo_{10}$), site 2 ($2Wo_4$) and site 3 ($3Wo_{17}$ and $3Wo_{18}$) respectively.

A rise in water table indicates the groundwater recharge and a fall in water table level indicate discharge of water from the aquifer. The fluctuation of water table level recorded were plotted against time for wells $1W_{O1}$, $1Wo_2$, $1Wo_7$, $1W_{10}$ in site 1 (Fig.4.5.1), for site 2, three wells viz. $2Wo_1$, $2Wo_3$, $2Wo_4$, were chosen (Fig.4.5.2.) and for site 3 $3Wo_{10}$, $3Wo_{11}$, and $3Wo_{12}$ were selected (Fig.4.5.3.).

4.5. Water Table Contour Maps

The Water Table Contour Maps were plotted using surfer software utilizing the depth to water table from ground level. Separate contour maps were obtained for monsoon rainfall data and post monsoon rainfall data (Fig.4.6.1.and Fig. 4.6.2.). The study had to depend on existing open wells and shallow bore wells. Wells were not evenly distributed in the study area. This shortcoming was reflected in the Water Table Contour Map.

4.6. Seasonal Ground Water Recharge and Discharge.

Time series water table depth data are presented in the Table 4.1. to Table 4.3. Seasonal recharge and discharge can easily be obtained by analyzing the time series data of the water table depth, in the K.C.A.E.T. campus. The well in the highest altitude of the lateritic terrain gave maximum water table depth with a maximum variation of 2.65m. The highest water table was recorded in the fourth week of August 2004. From the month of December onwards, the water table depth was steadily going down at the rate of about 5 cm per week.

In the middle altitude highest water table level was recorded at the third week of September. Maximum level difference was obtained as 2.80 m. Water table depletion rate during December to February were about 10 cm per week. Water table was at very shallow level in the lower altitude range. The recorded variation in water table was 1.67m. There was a pond of about 15*15 plan area in the lower region of the lateritic terrain. Interestingly, water table variations between the minimum and the maximum levels were very low (0.75m) in the case of the pond. One probable reason for this could be the higher quantum of interception of the interflow of the pond.

The wells located in the paddy fields near the river side showed maximum water level variation between the highest and the lowest values (4.41 m). The well became dry by the second week of January. Had the well been deeper the water table depletion that would have obtained would have been still higher. The rate of depletion was 0.25m per week or higher. The reason for this high discharge could be higher permeability of the aquifer of that well and also the proximity of river Bharathapuzha with deep bottom level.

Water table levels were also recorded by two shallow bore wells located in this steep sloping area of the lateritic terrain between the highest and middle altitude region. The rate of depletion of water table levels was about 5 cm per week. This area was covered with undisturbed forest. That could be the reason for the lower rate of depletion despite higher land slope.

Water table position at the 2nd study area is explained by Table 4.2. This area is assumed to be influenced by the ground water recharge works done in K.C.A.E.T campus. At same time intervals, water table increase is remarkably high between 24-09-04 and 01-10-04 an increase of 2.1m is shown in $2W_{O1}$. Corresponding values is 2.24m in $2W_{O4}$. All other wells in the area also show very high increase of water table. Water table rise for the same period in the site 1 is just 10 cm. Hence, it is to be inferred that ground water recharge done in K.C.A.E.T. campus is giving great positive result to the wells in site 2.

Water Table Fluctuations of the Site 3 is given in Table 4.3. Highest water table depth is seen in the wells located in the upper position of the lateritic terrain. Water level variations up to 3.59m are experienced in highest altitude areas of the terrain. Water table depletion is seen at the rate of about 15 cm per week. In the lower most terrain of the laterite, water table variation is seen to the extend of 3.29m. Rate of lowering of water table is 22 cm per week.

4.7. Actual Recharge

Actual recharge was calculated using the procedure explained in section 3.6. The actual recharge value computed for the highest altitude of site 1 is 0.2626 m. The study period being from August '04 to February' 05, does not include considerable magnitude of rainfall and its resulting recharge not applicable for a whole year. The recharge value for the uppermost well is only 0.2626m which will account for 11.1% of the corresponding rainfall. Other well in the site has still higher recharge potential. The maximum recharge value for K.C.A.E.T site is for the alluvial tract, where $1W_{O10}$ exits. The actual recharge computed for site 2 is considerably higher than that for similar areas of site 1. This indicates the positive impact of Recharge increases in the K.C.A.E.T. campus. The actual recharge and the infiltration factor were determined (Table 4.4.) The actual recharge as % of the rainfall is determined for SW monsoon and NE monsoon periods (Table 4.5. and Table 4.6.).

4.8. Rejected Recharge.

It is attempted to estimate the rejected recharge of the area represented by wells W_{O7} and W_{O10}. The recharge of that area has been compared with that of an area where water table is deeper.

4.9. Ground Water Flow Velocity.

A combination of single well-borehole dilution and two well technique with NaCl as a tracer was carried out to determine the ground water flow velocity. NaCl was introduced into the injection well and its diffusion was monitored on daily basis. Similarly concentration increases in the collecting well was also monitored. Test was continued for 20days from the date of injection. (24-01-05)

The diffusion of NaCl in the injection well is given in the Table 4.7. The concentration ranges from 2280ppm on the date of ignition to 1310 ppm on the 20^{th} day. However, there was no concentration increases in the collection wells. Hence the test had to be confined to single well-borehole dilution. Diffusion curve of the injection well is shown in Fig.4.7.

The velocity of flow computed by the equation, in the section 3.8.5., was found to vary from $1.28*10^{-5}$ to $4.5*10^{-4}$ m/day (Table 4.8.).Since the test was conducted during summer, when the hydraulic gradient is small, the obtained velocity must be rounded as appreciable.

Table 4.1.1. Water Table Level Readings from Open Wells in m. (Site 1)

Date	$1Wo_1$	$1Wo_2$	$1Wo_3$	$1Wo_4$	$1Wo_5$	$1Wp_6$	$1Wo_7$	$1Wo_8$	$1Wp_9$	$1Wo_{10}$
06/08/04	15.60	5.20	2.78	2.50	2.30	2.02	2.05	1.90	0.85	1.25
13/08/04	15.50	5.00	2.60	2.30	2.10	1.90	1.98	1.85	0.80	1.20
20/08/04	14.22	4.88	2.55	1.95	1.94	1.76	1.95	1.90	0.65	1.25
26/08/04	13.45	4.80	2.90	2.30	2.10	1.80	1.50	2.10	0.95	2.01
03/09/04	15.60	4.98	2.80	2.65	2.30	2.00	2.16	2.21	1.10	2.60
10/09/04	14.95	5.18	2.80	2.78	2.20	2.00	2.22	2.80	1.01	3.08
17/09/04	15.50	4.86	2.56	2.28	1.50	2.00	1.86	1.90	0.96	3.48
24/09/04	14.85	4.90	2.80	2.80	2.50	2.00	2.18	2.25	1.00	3.36
01/10/04	15.09	4.82	2.70	1.78	2.28	1.98	1.91	1.63	0.80	2.48
08/10/04	14.79	5.80	2.71	2.30	2.02	2.00	2.16	1.81	0.76	1.28
15/10/04	14.94	5.02	2.67	2.57	2.03	1.90	2.14	2.00	0.67	1.70
29/10/04	14.95	5.04	2.80	2.75	2.30	2.00	1.95	2.10	0.73	1.80
03/12/04	15.15	5.10	2.80	3.10	2.90	2.00	2.42	2.50	1.10	2.50
10/12/04	15.00	5.02	2.90	2.95	2.55	1.90	2.45	2.25	1.20	4.40
17/12/04	15.50	5.20	2.90	3.65	3.60	1.95	2.65	2.90	1.30	4.75
24/12/04	15.58	4.80	2.94	3.51	3.30	1.98	2.65	3.08	1.35	4.93
31/12/04	15.65	5.34	2.85	3.65	3.35	1.98	2.70	3.22	1.35	5.61
07/01/05	15.75	5.42	2.93	3.76	3.58	1.99	2.82	3.30	1.35	5.61
14/01/05	15.83	5.50	3.00	3.86	3.80	2.00	2.93	3.40	1.36	-
21/01/05	15.87	5.53	3.05	3.88	3.85	2.00	2.94	3.60	1.37	-
28/01/05	15.90	5.55	3.10	3.95	3.90	2.01	2.95	2.87	1.37	-
04/02/05	16.00	5.55	3.15	4.15	4.06	2.01	2.88	3.14	1.38	-
11/02/05	16.05	5.10	3.23	4.23	4.18	2.05	2.95	3.20	1.39	-
18/02/05	16.10	4.65	3.30	4.30	4.30	2.10	3.02	3.25	1.40	-

Table 4.1.2. Water Table Readings from Bore Wells in m. (Site 1)

Date	$1Wb_{11}$	$1Wb_{12}$
10/12/04	5.40	6.35
17/12/04	5.40	6.35
24/12/04	5.50	6.42
31/12/04	5.53	6.45
07/01/05	5.56	6.49
14/01/05	5.61	6.52
21/01/05	5.68	6.56
28/01/05	5.75	6.60
04/02/05	5.75	6.61
11/02/05	5.80	6.61
18/02/05	5.85	6.61

Location 4.2. Water Table Depth Readings of Open wells in m. (Site 2)

Date	$2Wo_1$	$2Wo_2$	$2Wo_3$	$2Wo_4$	$2Wo_5$
03/09/04	10.55	9.65	8.58	8.80	10.50
10/09/04	10.50	9.64	8.70	8.80	10.50
17/09/04	9.94	9.33	8.17	8.50	10.52
24/09/04	10.50	9.70	8.51	8.84	10.60
01/10/04	8.40	8.13	6.35	6.60	9.63
08/10/04	10.50	9.65	8.35	8.36	9.57
15/10/04	10.46	9.60	8.42	8.62	10.22
29/10/04	10.52	9.60	8.71	8.82	10.50
03/12/04	10.50	9.62	8.82	9.25	10.37
10/12/04	10.52	9.60	8.78	9.49	10.45
17/12/04	10.48	9.60	8.95	9.85	10.45
24/12/04	10.54	9.59	8.92	9.93	10.84
31/12/04	10.52	9.63	8.90	10.10	11.22
07/01/05	10.55	9.65	8.98	10.15	11.90
14/01/05	10.58	9.67	9.05	10.20	11.75
21/01/05	10.59	9.68	9.07	10.35	11.70
28/01/05	10.61	9.70	9.08	10.50	11.60
04/02/05	10.74	9.77	9.26	10.60	11.50
11/02/05	10.71	9.73	9.21	10.55	11.40
18/02/05	10.70	9.70	9.15	10.50	11.30

Table 4.3. Water Table Level Readings from Open Wells in m. (Site3)

Date	$3Wo_1$	$3Wo_2$	$3Wo_3$	$3Wo_4$	$3Wo_5$	$3Wo_6$	$3Wo_7$	$3Wo_8$	$3Wo_9$
20/07/04	9.85	9.15	8.4	9.00	3.54	3.10	0.40	9.91	10.90
27/07/04	9.80	9.10	8.17	8.90	3.40	2.87	0.29	9.93	10.84
03/08/04	9.80	9.05	8.27	8.83	3.49	2.90	0.35	9.88	10.82
10/08/04	8.75	8.13	7.79	8.43	2.96	2.54	0.13	8.40	10.02
31/08/04	10.02	9.40	8.55	9.15	3.74	3.25	0.65	9.90	10.87
07/09/04	10.38	9.72	8.82	9.47	4.10	3.84	0.91	9.91	11.07
14/09/04	10.53	9.80	8.95	9.55	3.84	3.93	1.05	10.45	11.20
21/09/04	10.33	9.65	8.71	9.31	3.94	3.54	0.73	10.41	11.20
26/10/04	10.10	9.43	8.48	9.15	3.64	3.92	0.55	10.15	10.96
30/11/04	10.83	10.15	9.25	9.95	4.48	3.96	1.29	10.87	11.54
07/12/04	11.00	10.30	9.47	10.08	4.65	4.08	1.51	10.95	11.70
14/12/04	11.20	10.48	9.65	10.25	4.84	4.28	1.65	11.05.	11.82
21/12/04	11.26	10.66	9.77	10.43	5.03	4.48	1.81	11.17	11.90
28/12/04	11.46	10.75	9.99	10.61	4.89	4.88	1.99	11.26	12.24
04/01/05	11.60	10.91	10.21	10.79	5.36	4.93	2.22	11.36	12.26
11/01/05	11.80	11.09	10.40	10.97	5.56	5.02	2.50	11.58	12.28
18/01/05	11.93	11.20	10.55	11.22	5.81	5.24	2.73	11.72	12.37
25/01/05	12.07	11.32	10.70	11.46	6.06	5.46	2.96	11.87	12.46
01/02/05	12.21	11.43	10.84	11.71	6.32	5.69	3.19	12.02	12.55
08/02/05	12.34	11.55	10.99	11.95	6.58	5.93	3.42	12.17	12.66

Table 4.3. Continued…

Date	3Wo1	3Wo11	3Wo12	3Wo13	3Wo14	3Wo15	3Wo16	3Wo17	3Wo18
20/07/04	9.57	7.40	3.00	3.15	1.90	2.45	2.32	2.85	1.40
27/07/04	9.48	7.20	2.82	2.95	1.67	2.30	2.17	2.59	1.30
03/08/04	9.32	7.25	2.83	3.05	1.80	2.30	2.22	2.65	1.70
10/08/04	7.76	5.23	1.63	2.43	0.76	2.01	2.05	2.40	1.03
31/08/04	10.05	7.60	3.24	3.30	2.05	2.59	2.46	2.92	1.82
07/09/04	10.5	7.85	3.64	3.65	2.30	2.88	2.77	3.22	1.85
14/09/04	10.85	7.90	3.71	3.80	2.70	2.98	1.88	3.40	2.30
21/09/04	10.63	7.80	3.48	3.73	2.38	2.86	2.62	3.12	1.84
26/10/04	9.94	7.55	3.25	3.20	2.15	2.68	2.42	2.90	1.81
30/11/04	11.81	8.27	4.46	4.40	3.27	3.67	3.33	3.75	3.10
07/12/04	12.07	8.28	4.71	4.55	3.40	3.78	3.61	3.97	3.30
14/12/04	12.30	8.50	4.95	4.80	3.68	4.02	3.86	4.20	3.53
21/12/04	12.62	8.72	5.14	5.02	3.91	4.23	4.10	4.45	3.76
28/12/04	12.37	9.06	5.45	5.50	4.30	4.30	4.76	5.04	4.00
04/01/05	12.65	9.12	5.6	5.80	4.51	4.51	5.73	5.65	4.30
11/01/05	13.11	9.28	5.79	6.00	4.72	-	6.19	5.87	4.50
18/01/05	13.34	9.34	5.84	6.02	4.75	-	6.30	6.39	5.02
25/01/05	13.57	9.40	5.89	6.04	4.78	-	6.41	6.91	5.57
01/02/05	13.81	9.33	5.94	6.07	4.82	-	6.53	7.44	6.10
08/02/05	14.05	9.53	5.99	6.09	4.87	-	6.66	7.97	6.60

Table 4.4. Actual Recharge of different Wells during the Study Period

Wells	Actual Recharge (m)	Rainfall infiltration factor
$1Wo_1$	0.2626	11.1
$1Wo_2$	0.288	12.38
$1Wo_7$	0.29	12.46
$1Wo_{10}$	0.35	15.1
$2Wo_1$	0.346	14.6
$3Wo_1$	0.28	12.1
$3Wo_9$	0.25	10.79

Table 4.5. Recharge as % of Rainfall for different Wells during SW Monsoon Period

Well	Specific yield	SW monsoon rainfall, cm	Actual WT rise, m	Recharge m	Recharge as % of rainfall	Topography
$1Wo_1$	0.101	11.76	1.85	0.187	15.9	Regional High
$1Wo_2$	0.101	11.76	1.9	0.192	15.6	Middle
$1Wo_7$	0.101	11.76	2.12	0.214	18.2	Middle
$1Wo_{10}$	0.101	11.76	2.44	0.246	20.9	Regional Low
$2Wo_1$	0.101	11.76	2.65	0.268	23	Middle
$3Wo_1$	0.101	11.76	2.05	0.207	17.6	Regional High
$3Wo_9$	0.101	11.76	1.97	0.199	17	Regional High

Table 4.6. Recharge as % of Rainfall for different Wells during NE Monsoon Period

Well	Specific yield	NE monsoon rainfall, cm	Actual WT rise, m	Recharge, m	Recharge as % of rainfall	Topography
$1Wo_1$	0.101	10.7	0.75	0.076	0.7	Regional High
$1Wo_2$	0.101	10.7	0.95	0.096	0.89	Middle
$1Wo_7$	0.101	10.7	0.75	0.076	0.7	Middle
$1Wo_{10}$	0.101	10.7	1.06	0.107	1.0	Regional Low
$2Wo_1$	0.101	10.7	0.75	0.076	0.7	Middle
$3Wo_1$	0.101	10.7	0.73	0.074	0.68	Regional High

$3Wo_9$	0.101	10.7	0.5	0.051	0.47	Regional High

Table 4.7. Diffusion of NaCl Concentration with Time ($1Wo_4$ and $1Wo_5$)

Date	Concentration of NaCl in Sample (ppm) in $1Wo_4$	Concentration of NaCl in sample (ppm) in $1Wo_5$
24-1-05	2280	30
25-1-05	2220	90
26-1-05	2140	0
27-1-05	2140	0
28-1-05	2120	60
29-1-05	2110	0
30-1-05	2110	0
31-1-05	2090	30
1-2-05	2080	70
2-2-05	2040	0
3-2-05	2020	20
4-2-05	2010	40
5-2-05	1750	100
6-2-05	1680	70
7-2-05	1470	30
8-2-05	1380	0
9-2-05	1370	30
10-2-05	1360	0
11-2-05	1340	0
12-2-05	1310	0

Table 4.8. Representative Velocity of Ground Water Flow by Tracer Analysis

Time Interval	Ground Water Flow Velocity (m/day)
24-1-05 to 28-1-05	$2.8 * 10^{-4}$
29-1-05 to 2-2-05	$1.5 * 10^{-4}$
3-2-05 to 7-2-05	$1.28 * 10^{-5}$
8-2-05 to12-2-05	$4.5 * 10^{-4}$

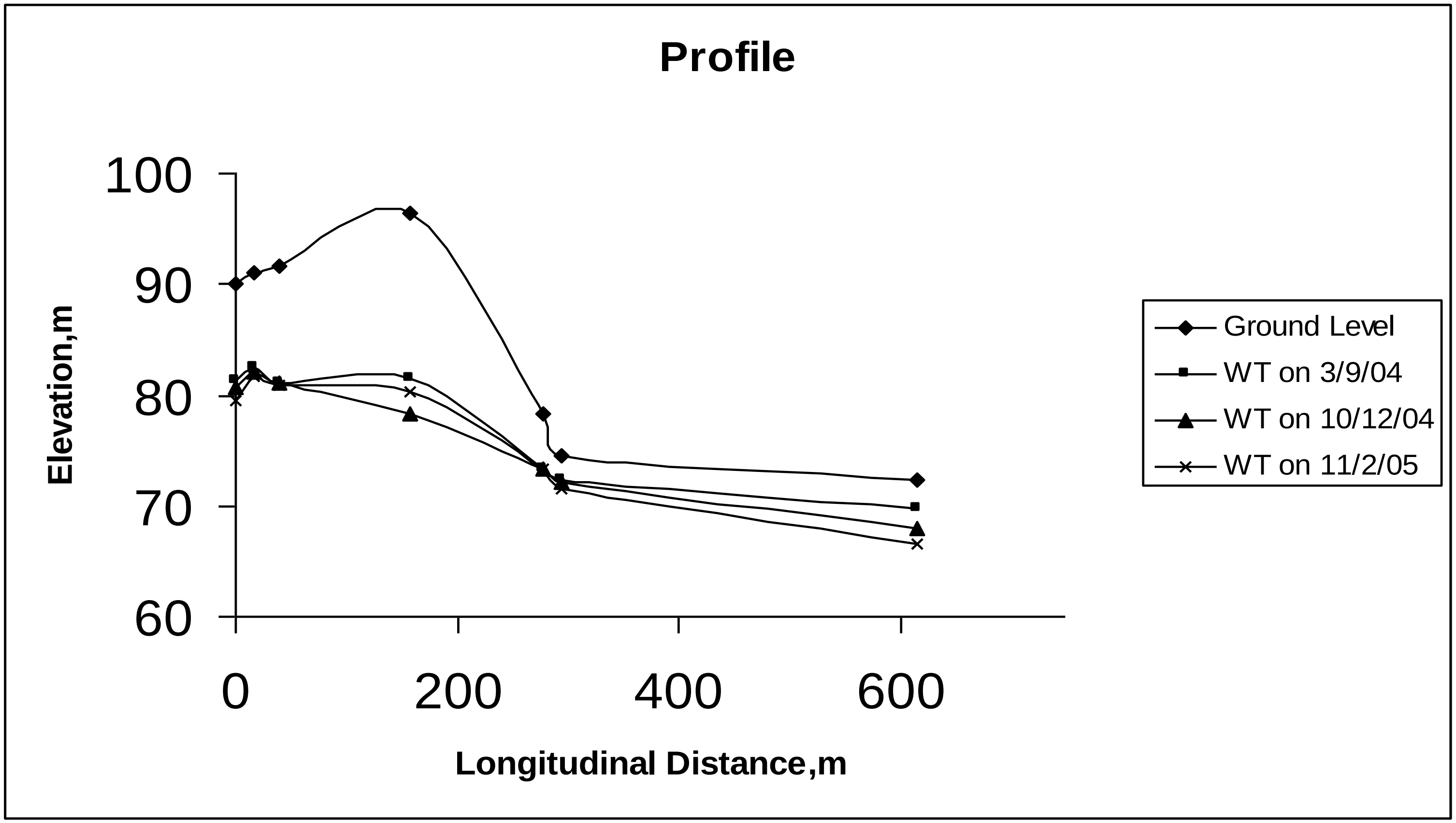

Fig 4.4. Longitudinal Profile of selected wells from Site 1 and Site 2.

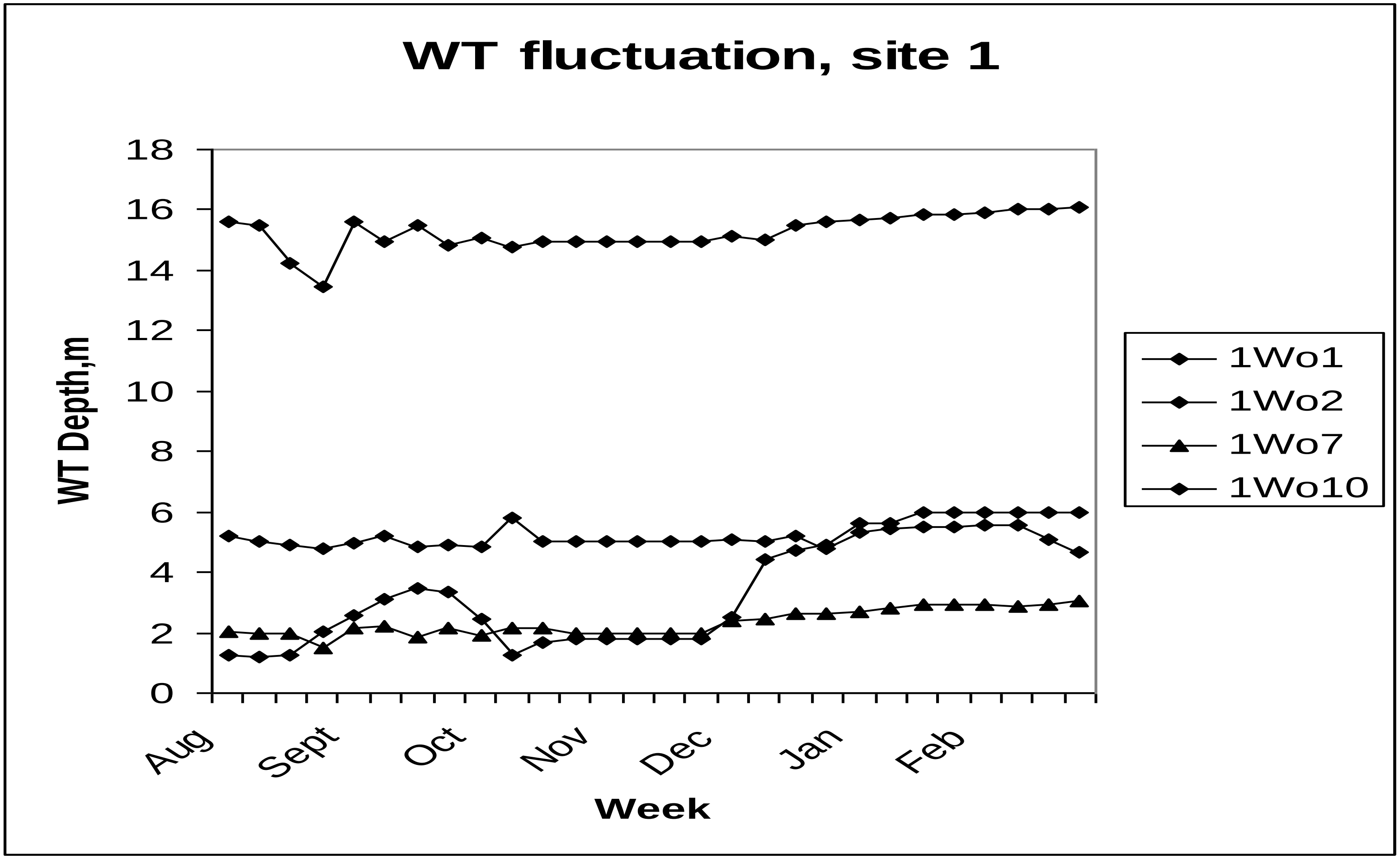

Fig. 4.5.1. Variations of water Table Depths with Time for site 1.

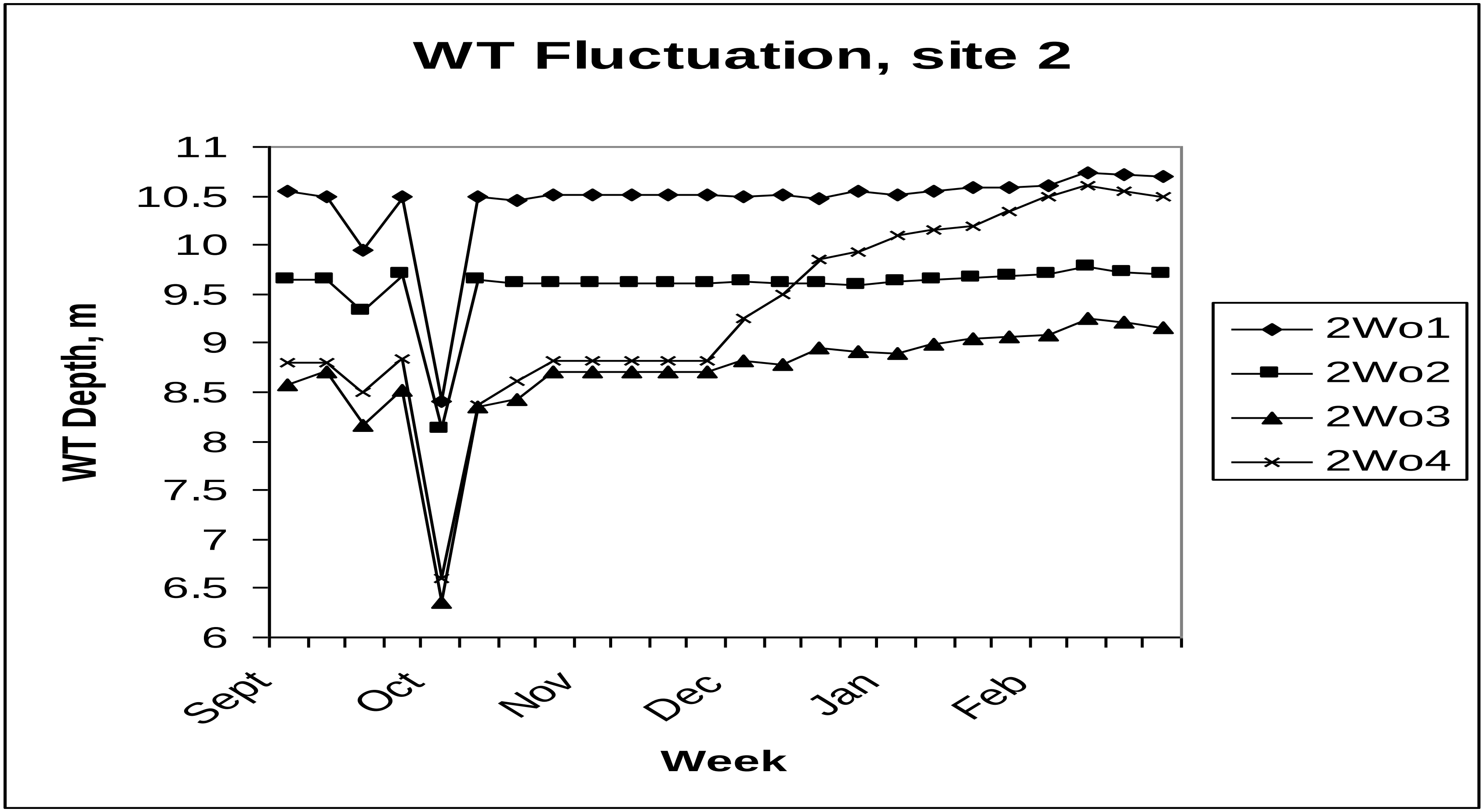

Fig.4.5.2. Variations of water Table depths with time for site 2

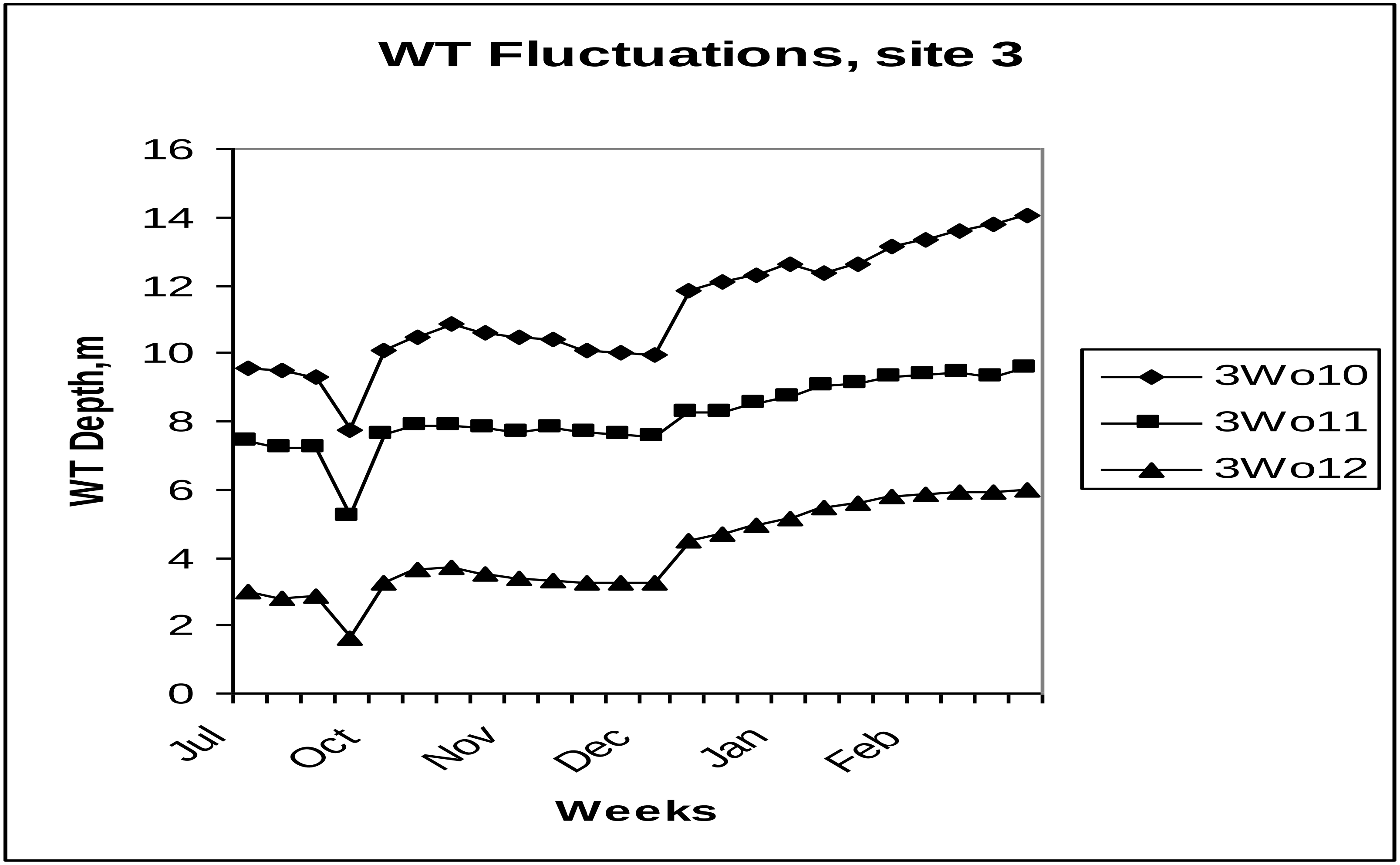

Fig.4.5.3. Variations of water Table depths with time for site 3

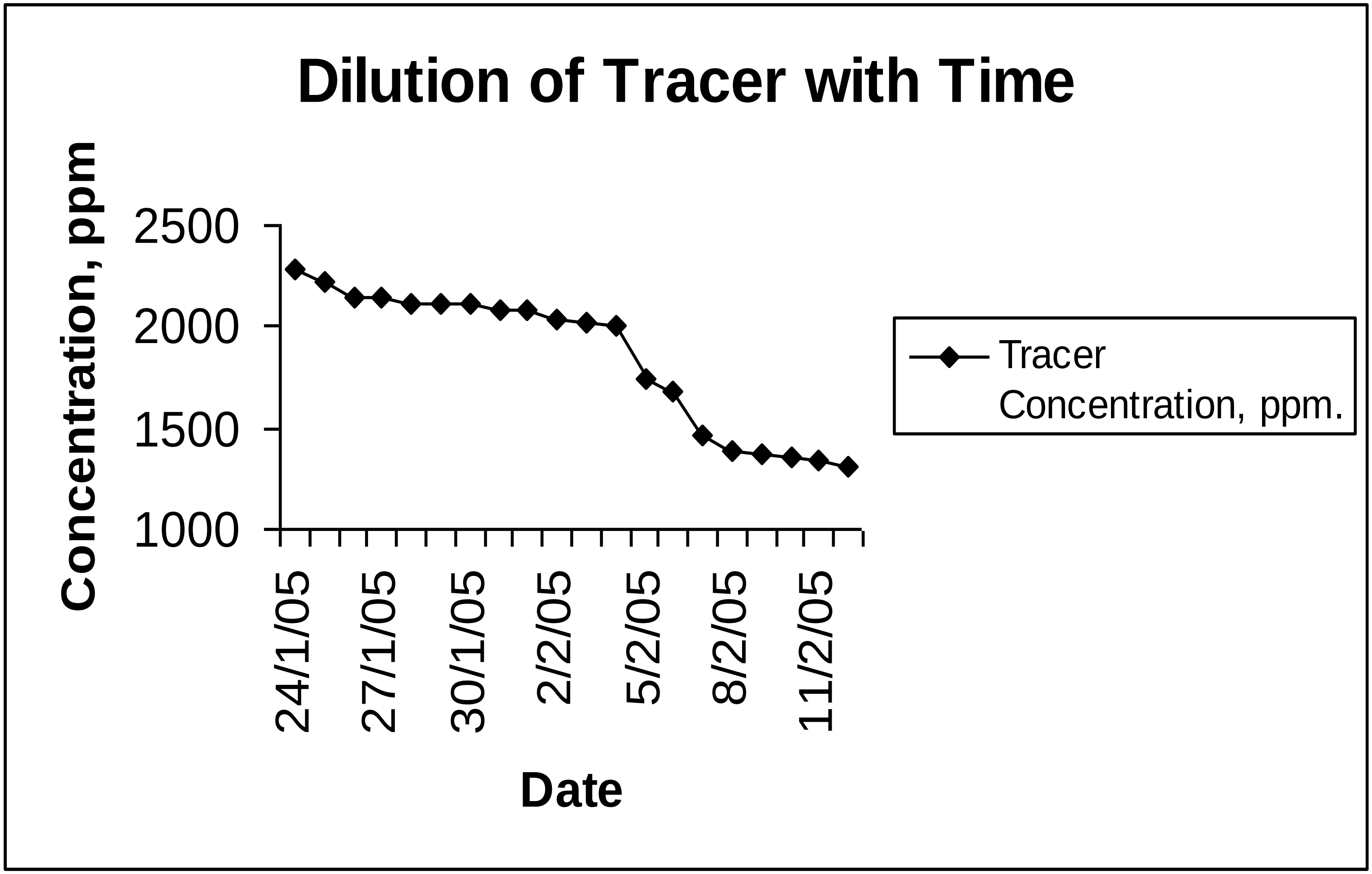

Fig.4.7. Diffusion of NaCl Concentration with Time.

Summary and Conclusion

SUMMARY AND CONCLUSION

This study is aimed at the estimation of recharge and discharge in laterites, a major soil type of the state of Kerala. The study was conducted in three adjoining locations in Tavanur, Malappuram district during the period from August 2004 to February 2005. Many information pertaining to the nature and rate of recharge, discharge, effects of artificial recharge and movement of ground water have been provided by the study.

The major findings of the study are summarized below:

(1) Direction and the pattern of ground water flow was analysed by plotting water table contour map for the monsoon and post monsoon seasons using surfer software. It had appreciable similarities with ground contour.

(2) The profile of water table showed very close resemblance with that of ground surface.

(3) The ground water recharge estimated by monitoring water level fluctuation was found to be 0.26m for the higher altitude areas in the KCAET campus whereas it was 0.29m and 0.35m in the middle and lower altitude areas respectively. In the site 2, the recharge was 0.35m and corresponding to Site 3 it was 0.25m. The higher recharge in KCAET campus for the lowest altitude areas was due to the alluvial aquifer which as a relatively higher infiltration factor of 15.1. Higher recharge for the Site 2 was contributed by the recharge measures undertaken in KCAET campus.

(4) In the KCAET campus, the average water table deletion rate of the highest altitude area was 5cm/week during the months of January to February. The water table depletion rate for the middle altitude areas and lower altitude areas were 10 cm/week and 25 cm/week respectively. In the second study area, the depletion rate of water table was about

15 cm/week during the same summer months and the depletion rate in the third study area was in the range 15 cm/week to 22 cm/week for the higher and lower altitude areas respectively.

(5) The rejected recharge for the shallow water table areas was found to be 3 cm for the KCAET campus.

(6) Artificial recharge had a great impact on the ground water table rise of the open wells, as was indicated by the study wells in site 2. Ground table rose more than 2 m within a time span of 1 week corresponding to a rainfall of 7 cm in the areas influenced by the artificial recharge works done at KCAET campus.

(7) The velocity of ground water flow of the lateritic aquifer of KCAET campus was estimated by tracer analysis adopting single borehole dilution method and was found to range from $1.28 * 10^{-5}$ to $4.5 * 10^{-4}$ m/day.

(8) Future works may be done with mere elaborate tracer studies for longer period to obtain better reliable results in the velocity of ground water movement for a complete one year period.

References

REFERENCES

Asare, S.N., Rudra, R.P., Dickinson, W.T. and Wall, G.J. 1993. Seasonal Variability of Hydraulic Conductivity. *Trans*.*ASAE*. 36(2):451-455

Balek, J. 1989. Ground Water Resources Assessment. Elsevier, Amsterdam

.

Boyd, R.A. 1998. Characterizing Ground Water Flow in the Municipal Well Fields of Ceder Rapids, IOWA with selected Environmental Tracers. *J. American Water Resources Association.* 34(3):507-514.

Chen, J., Chen, C., Gau, H. and Liu, C. 1999. A Two Well Method to Evaluate Transverse Dispersivity for Tracer Test in a Radially Convergent Flow Field. *J.Hydrology*. 223:175-197.

Davidson, J.M. and Neilson, D.R. 1969. Field Measurement and Use of Soil Water Properties. *J. Water Resources Research*. 5:1312-1321

.

Dorsey, J.D., Ward, A.D., Fausey, N.R. and Bair, E.S. 1990. A Comparison of Four Field Method for Measuring Saturated Hydraulic Conductivity. *Trans. ASAE*. 33(6):1925-1932.

Fedler, C.B., Rainwater, K.A., Yueyang, D., Dvracek, M.J. and Ramsey, R.H. 1989. Field Study of Tracer Movement in a Shallow Alluvial Aquifer. *Trans. ASAE*.32(3):857-861.

Gupta, R.K., Rudra, R.P., Dickinson, W.T., Patni, N.K. and Wall, G.J. 1993. Comparison of Saturated Hydraulic Conductivity Measured by Various Field Methods. *Trans. ASAE*. 36(1): 51-60.

Hillel, D., Krentos, B.D. and Styllanon, Y. 1972. Procedure and Test of an Internal Drainage Method for Measuring Soil Hydraulic Characteristics in situ. *J. Soil Science*. 114:395-400.

Jabro, J.D. 1992. Estimation of Saturated Hydraulic Conductivity of Soil from Particle Size Distribution and Bulk Density Data. *Trans. ASAE*.35(2):557-563.

Jabro, J.D., Lotse, E.G., Simons, K.E. and Baker, D.E. 1991. A Field Study of Macropores Flow under Saturated Condition Using Bromide Tracer. *J. Soil and Water Conservation.* 23(5): 376-381.

Jackson, R.E. 1995. Partitioning Tracer Test for Detection, Estimation, and Remediation Performance Assessment of Subsurface Nonaquous Phase Liquids. *J. Water Resources Research.* 31(5):1201-1211.

Lall, U. 1995. Yield Model for Screening Surface and Ground water Development. *J. Water Resources Planning and Management.* 121(1):9-15.

Langsholt, E. 1994. Water Balance Modelling in Lateritic Terrain. *J. Hydrological Processes.* 8: 83-99.

Lesaffre, B. 1990. Field Measurements of Saturated Hydraulic Conductivity and Drainable Porosity Using Guyon's Pumping Test. *Trans. ASAE*. 33(1):173-177.

Noble, A. and Tiwari, K.N. 1999. Modelling Hydrological Processes in Hill slope Watershed of Humid Tropics. *J.Irrigation and Drainage Engineering*. 125(4): 197-204.

Pesti, G., Kelly, W.E., Bogardi, I. and Kalanski, R.J. 1966. Combining Geophysical and Well Data for Identifying Best Well Location. *J. Water Resources Planning and Management.* 122(2):97-104.

Ranfrez, J.A. and Finnerty, B. 1996. Precipitation and Water Table Effects on Agricultural Production and Economics. *J. Irrigation and Drainage Enginerring* 122(3): 164-172.

Ruprecht, J.K. and Schofielt, N.J. 1991. Infiltration Characteristic of a Complex Lateritic Soil Profile. *J.Hydrological Processes*. 7(1): 87-97.

Smith,M.C., Vellidis, G., Thomas, D.L. and Breve, M.A. 1992. Measurement of water table Fluctuation in Sandy Soil Using Ground Penetrating Radar. *Trans*. *ASAE.* 35(4):1161-1170.

Tabrizi, M.H.N., Jamaluddin, H., Billings, S.A. and Skaggs, R.W. 1990. Use of Identification Technique to Develop a Water Table Prediction Model. *Trans. ASAE*.33(6): 1913-1917.

ABSTRACT

A study was conducted in three locations in Tavanur, Malappuram District, Kerala to study the ground water recharge, discharge and movement of water in the lateritic aquifer. The field data were collected during August 2004 to February 2005. To estimate the ground water recharge and discharge, weekly water table depth were collected for the available open wells and bore wells in the study area. The effect of artificial recharge was monitored by observing the water table positions of open wells near to the recharge site. The velocity of ground water was estimated by performing borehole dilution method with NaCl as the Tracer.

The Ground water recharge and discharge were found to vary with altitude, slope and thickness of the aquifer. Ground water recharge for different locations varied from0.26 to 0.35m for the study period. Average summer period ground water recharge was estimated as 5 cm/week, 10 cm/week and 25 cm/week for highest, mid and lower most altitude positions of the first study area. The impact of artificial recharge was highly significant; a water table rise of 2.2m was obtained corresponding to rainfall of 7 cm, near the wells influenced by the recharge measures. Rise in water table in other wells which are outside the perview of artificial recharge for the same rainfall magnitude was mere 10 cm. The Tracer studies give a ground water velocity varying from 1.28 * 10-5 to 4.5 * 10-4 m/day.

Appendices

Appendix: 1

Date	R.F(mm)	Dry bulb temp©	wet bulb Temp©	Max Temp©	Min temp©	Evaporation (mm)
8/1/04	6.4	24.5	24	29.5	24	4.7
8/2/04	13.4	27	25	29	24.5	4.25
8/3/04	13.2	23.25	23	27.25	22	10.68
8/4/04	60.4	24	24	26	22.5	34.7
8/5/04	43.2	24	23.5	27	23	20.7
8/6/04	45	24	24	27	22.75	21.5
8/7/04	11.2	24.5	24.5	28	23	1.4
8/8/04	4.4	25	24.5	29	22	3
8/9/04	1.6	25	24.25	29.5	23	3.5
8/10/04	0	25.5	25.25	30	24	3.9
8/11/04	18.3	24.5	24.5	29.5	23.5	5.35
8/12/04	3.9	22.5	22.5	30	22.5	1.3
8/13/04	26.4	23.25	23	29	22	6.4
8/14/04	30.5	23.5	23	29.5	23	6.8
8/15/04	14.1	23	22.5	29.5	22.5	3.4
8/16/04	2.7	25	24	30	22.5	4.4
8/17/04	6.9	25	24.5	29.5	22.5	2.9
8/18/04	2	24	23.5	28	23	2.3
8/19/04	4.6	23.5	23.5	27	22.75	2.6
8/20/04	0.4	25	24.5	29.5	23.5	1.7
8/21/04	0.4	25	25	29	23.5	4.3
8/22/04	3.6	26.5	25	29.5	23.5	0
8/23/04	2.5	24.5	24.5	30	24	4

8/24/04	0	26	24.5	29.5	24	4
8/25/04	0	27	25.5	30	24	4
8/26/04	0.2	26	24	29.5	23	4
8/27/04	0	26	24.5	29.5	24	5
8/28/04	0	26.5	24.5	30	23	5.2
8/29/04	0	26	25	30	23.5	5.4
8/30/04	0	26	24.5	33.5	23.5	2
8/31/04	0	24.5	23.5	30	23.25	5.4
9/1/04	0	24.5	23.5	30	22.5	5.6
9/2/04	0	25.5	24.5	30	23	5.2
9/3/04	0	25.5	24.5	30	24	5.6
9/4/04	0	26	24.5	30	24	3.5
9/5/04	1.3	24.5	24	29.5	24	5.3
9/6/04	0.8	24.25	23.5	29.5	23.25	1
9/7/04	1.8	26	24.5	31	23.5	4.9
9/8/04	2.3	25	25	30.5	24	2.3
9/9/04	0	25	24.5	30	23	2
9/10/04	19	24.25	23.75	27.5	23.25	0
9/11/04	0	25.1	24.5	30	23.5	4.2
9/12/04	0	26.5	24.75	30	23.25	4.1
9/13/04	0	26.5	25.5	30.5	25	0
9/14/04	5.2	25.5	25	30	24	0
9/15/04	0	27.25	25	30	25	4
9/16/04	0.8	27	25.5	31	25	4.6
9/17/04	29.2	26	25	31	24	15.2
9/18/04	39.2	28	26.25	31	20	21.6
9/19/04	0.3	25.25	25	32	25	0
9/20/04	0	25.5	25	30.5	25	4
9/21/04	0	27	25	30	24	5.3
9/22/04	0	27	25.5	31	24.5	2.14
9/23/04	0	28	26	31	24	3

9/24/04	4	27	25	30	24.5	2.6
9/25/04	15	27	25.5	30.5	24	9.8
9/26/04	0	28	26	31	24	3
9/27/04	33.1	25	29.5	33	23.5	5.5
9/28/04	3	24.5	26	31	23	6.6
9/29/04	0	26	27	32	22.5	2
9/30/04	0	25.5	27	32	22	1.9
10/1/04	1	24.5	24	31	23.5	2.9
10/2/04	104	25.5	24	29.5	22.5	82.8
10/3/04	110	23	23	29	23	88.2
10/4/04	23.5	23	23	26.5	22.5	3.5
10/5/04	0.2	26	25	30	23	2.2
10/6/04	0	25	23.5	30	21	3.9
10/7/04	0		24.5	30	21.5	3.2
10/26/04	0	26	24	32.5	23.6	2
10/27/04	0	26	23.5	34	24	4
10/28/04	0	25.5	24	32.5	24	3
10/29/04	0	26.5	23.5	30	23.5	1.4
10/30/04	0	25.5	24	33	24	1.2
10/31/04	0	25.5	25	32.5	23	1.58
11/1/04	3.6	29	25	30	22	1.6
11/2/04	0	28	25	32.5	23.5	3
11/3/04	0	27	24.5	33.5	22.5	2.5
11/4/04	0	26.5	24	32	24	2.2
11/5/04	0	25.5	23	30	22.5	2
11/6/04	0	26	25	32	24	2.2
11/7/04	0	29	28	33	24.5	3
11/8/04	0	28.5	27.5	32	23	2.45
11/9/04	3.3	27	26	34	24	3.2
11/10/04	38.2	25.5	25	32	24	3.1
11/11/04	0	26.5	26.5	34	24	3.1

11/12/04	4.2	27	25.5	32.5	23	3.1
11/13/04	0	27	26.5	33.5	23.5	2.6
11/14/04	0	27.5	27	33	24.5	3.2
11/15/04	1.2	28	26.5	30	23.5	2
11/16/04	0	27	24	33	23	2
11/17/04	0	27	24.5	33.5	24	3.3
11/18/04	0	26	23.5	33	23.5	2.65
11/19/04	0	25	21	33	20	4
11/20/04	0	27	26	33.5	22.5	4
11/21/04	0	26.5	26	34.5	23.5	3.5
11/22/04	0	27	23.5	34	23.5	4
11/23/04	0	27	23	34.5	23.5	3.8
11/24/04	0	27	24	33.5	23.5	3.7
11/25/04	0	26.5	22.5	33.5	22.5	4.4
11/26/04	0	27	23	35	23.5	4.1
11/27/04	0	27.5	27	34.5	23.5	4
11/28/04	0	25.5	25.5	33.5	21	4.5
11/29/04	0	24.5	21	33	21	4.7
11/30/04	0	24.5	21	33	20.5	3.5
12/1/04	0	25	22	34	20.5	3.5
12/2/04	0	27	23.5	33.5	23	3.1
12/3/04	0	25.5	23	33.5	23	3.4
12/4/04	0	25.5	22.5	33.5	22.5	3.2
12/5/04	0	28	28	34	23	4.4
12/6/04	0	25	20	33	19.5	4
12/7/04	0	25	21	33	20.5	4
12/8/04	0	25	23	34.5	22	3.2
12/9/04	0	25.5	22.5	35	22.5	3.2
12/10/04	0	25	25	33.5	23	5
12/11/04	0	26	25.5	34	22	3.6
12/12/04	0	26.5	26	34.5	23	4.1

12/13/04	0	26	25	33	24	4.9
12/14/04	0	26.5	23	33.5	24	5
12/15/04	0	25	20	33.5	22.5	4.9
12/16/04	0	24.5	24	33	20	4
12/17/04	0	25	20.5	34	20.5	5.1
12/18/04	0	25	20	34.5	22	3.9
12/19/04	0	24	23	34	23	3.6
12/20/04	0	23	22.5	32.5	20.5	4
12/21/04	0	23	20.5	31	20	3.7
12/22/04	0	24	21	33	20.5	3
12/23/04	0	24	21	33	20	4
12/24/04	0	25	22.5	33	20	3.1
12/25/04	0	24	21	34	22.5	4
12/26/04	0	26.5	22	34	21.5	4
12/27/04	0	27	22.5	34.5	23.5	4.7
12/28/04	0	24.5	21	33	23	6
12/29/04	0	24.5	21	34.5	22.5	6
12/30/04	0	25.5	21.5	33.5	23	4
12/31/04	0	27	24	34.5	25	4
01/01/05	0	26	22	32	23	2.4
02/01/05	0	25	25	33	23	4
03/01/05	0	26	22	33	23.5	4.1
04/01/05	0	25.5	21	34	23.5	4
05/01/05	0	25	20.5	33.5	21.5	4
06/01/05	0	25	20.5	35	20.5	4.2
07/01/05	0	24.5	21.5	34.5	21.5	4.1
08/01/05	0	24.5	20.5	33	21.5	3.6
09/01/05	0	26	21	33.5	20.5	4
10/01/05	0	23.5	20	33	20.5	6
11/01/05	0	23.5	22.5	32	21	9
12/01/05	0	22.5	19.5	33	19	11

13/01/05	0	23.5	19	32	21	9
14/01/05	0	24	22	34	20.5	9
15/01/05	0	23.5	21.25	34	21.5	4.6
16/01/05	0	24	21	33	22	10.8
17/01/05	0	23.5	22	33.5	23	12
18/01/05	0	23.5	22.5	32.5	22	11.2
19/01/05	0	25	22.5	33.5	22.5	13.8
20/01/05	0	25	23	35	23	13.4
21/01/05	0	27	25	36	23.5	11
22/01/05	0	26	23	35.5	25.5	8.3
23/01/05	0	26	22.5	36	24	5
24/01/05	0	27.5	23	35.5	27	4.6
25/01/05	0	25.5	22	34	25	4
26/01/05	0	27	25.5	33.5	22.5	4
27/01/05	0	24.5	23.5	33	23.5	4
28/01/05	0	25	23	32	22	4
29/01/05	1	24.5	23	33	20.5	6.8
30/01/05	2.4	24	23.5	32.5	24	5.6
31/01/05	1.2	25.5	23.5	30.5	22	8.4
01/02/05	0	26	23.5	35	22.5	9.95
02/02/05	0	26.5	23	35	24.5	10
03/02/05	0	26	22	35	23	0
04/02/05	0	26	22.5	35	24.5	4.6
05/02/05	0	27	26	35	27	4.6
06/02/05	0	26	25.5	34	23	4.13
07/02/05	0	25	25	35	22.5	4.7
08/02/05	0	25	21	35.5	22	6.25
09/02/05	0	25	23	35	22	6
10/02/05	0	25	19.5	36.5	20	6
11/02/05	0	24	21	36	21	6
12/02/05	0	25	24.5	37	25	6.8

13/02/05	0	24	23.5	36	18.5	7
14/02/05	0	23	22	35	20	5.7
15/02/05	0	24.5	23	33	22	5.4
16/02/05	0	27	25	33	23	4
17/02/05	0	27	25.5	33.5	24	9.8
18/02/05	0	27.5	25	33	24	12.1
19/02/05	0	25.5	24	33.5	23	11.4
20/02/05	0	25	24.5	33	23.5	11.6
22/02/05	0	28	26.5	34.5	23	11.5
23/02/05	0	27	24	35	23.5	8
24/02/05	0	27	23	33	22.5	9.3
25/02/05	0	25.5	24	37	23	7.1
26/02/05	0	27	24	36	22.5	7.3
27/02/05	0	27	24	35	22.5	6.3
28/02/05	0	27	22.5	37	22.5	5.6

Appendix 2

REDUCED LEVEL READING BY THEODOLITE SURVEYING

POINT												
		BS			IS			FS			HI	RL
	UP	MIDDLE	DOWN	UP	MIDDLE	DOWN	UP	MIDDLE	DOWN	V ANGLE		
X1	0.455	0.385	0.315							2	99.89321	100
P1				1.705	1.7	1.64				2	99.89321	98.42341
P2				2	1.905	1.805				2	99.89321	98.67183
P3				2.455	2.305	2.155				2	99.89321	98.63805
P4					1.5					0	99.89321	98.39321
P5					1.62					0	99.89321	98.27321
P6					1.745					0	99.89321	98.14821
P7					1.85					0	99.89321	98.04321
P8					1.87					0	99.89321	98.02321
P9					0.845					0	99.89321	99.04821
P10					0.255					0	99.89321	99.63821
P11					0.35					0	99.89321	99.54321
P12					0.16					0	99.89321	99.73321
P13					0.125					0	99.89321	99.76821
P14				1.535	1.235	0.935				2	99.89321	100.7544
P15				1.805	1.444	1.105				2	99.89321	100.8942
P16				2.225	1.825	1.425				2	99.89321	100.862
X2				1.4	1.14	1.025				2	99.89321	100.0646
X3				1.42	1.27	1.11				2	99.89321	99.70793
X4				1.86	1.655	1.44				2	99.89321	99.70659

CP1							2.23	1.795	1.355	2	99.89321	101.1536
P8	1.495	1.535	1.575							0	99.55821	98.02321
P17					0.975					0	99.55821	98.58321
P18				0.77	0.675	0.575				1	99.55821	99.22523
P19				0.975	0.825	0.675				1	99.55821	99.25845
P20				1.155	0.955	0.755				1	99.55821	99.30295
P21				2.005	1.755	1.555				2	99.55821	99.37622
CP2							1.815	1.545	1.275	2	99.55821	99.90012
P21	2.385	2.335	2.285							2	101.3589	99.37622
P22				2.45	2.35	2.25				2	101.3589	99.71
P23				2.625	2.525	2.425				2	101.3589	99.535
CP3							2.95	2.875	2.75	0	101.3589	98.48395
P23	1.255	1.2	1.145							3	100.1549	99.535
P24					1.855					0	100.1549	98.29986
P25					2.105					0	100.1549	98.04986
P26					2.615					0	100.1549	97.53986
P27					3.105					0	100.1549	97.04986
CP4								3.165		0	100.1549	96.98986
P28					1.18					0	100.1549	98.97486
P29					1.025					0	100.1549	99.12986
P30					0.75					0	100.1549	99.40486
P31					0.36					0	100.1549	99.79486
P32				1.13	0.88	0.63				1	100.1549	100.1491
P33				1.08	0.78	0.48				1	100.1549	100.4236
P34				1.38	1.02	0.68				1	100.1549	100.3581
P35				1.66	1.26	0.86				1	100.1549	100.2926
CP5							1.72	1.28	0.85	1	100.1549	100.3947
CP3	0.78	0.7	0.62							-1.5	99.60526	98.48395
P36					1.75					0	99.60526	97.85526
P37					1.865					0	99.60526	97.74026
P38					1.855					0	99.60526	97.75026

P39					1.96					0	99.60526	97.64526
P40					1.87					0	99.60526	97.73526
P41					1.72					0	99.60526	97.88526
P42					1.395					0	99.60526	98.21026
CP6								1.3		0	99.60526	98.30526
CP4		3.05								0	100.0399	96.98986
P43					1.42					0	100.0399	98.61986
P44					1.14					0	100.0399	98.89986
CP7								1.255		0	100.0399	98.78486
CP6		1.1								0	99.40526	98.30526
X5				1.58	1.505	1.43				0	99.40526	97.90026
X6				1.615	1.4	1.19				0	99.40526	98.00526
X7				1.89	1.78	1.67				0	99.40526	97.62526
P45					1.63					0	99.40526	97.77526
P46					1.79					0	99.40526	97.61526
P47					1.71					0	99.40526	97.69526
P48					1.93					0	99.40526	97.47526
P49					1.69					0	99.40526	97.71526
P50					2.35					0	99.40526	97.05526
P51					2.36					0	99.40526	97.04526
P52					2.745					0	99.40526	96.66026
CP8								2.96		0	99.40526	96.44526
CP7	1.465	1.405	1.345							0	100.1899	98.78486
X8				1.1	0.975	0.95				0	100.1899	99.21486
X9				1.11	1	0.88				0	100.1899	99.18986
X10				1.19	1.155	1.12				0	100.1899	99.03486
X11				1.615	1.58	1.48				0	100.1899	98.60986
X12				2.325	2.225	2.125				0	100.1899	97.96486
X13				2.425	2.285	2.145				0	100.1899	97.90486
X14				2.575	2.4	2.225				0	100.1899	97.78986
X15				2.5	2.44	2.38				0	100.1899	97.74986

X16				2.525	2.465	2.405				0	100.1899	97.72486
X17				1.98	1.88	1.78				-5.67	100.1899	96.33482
X18				2.72	2.57	2.4				-5.67	100.1899	94.46572
X19							2.12	2.045	1.97	-5.67	100.1899	98.78486
CP7		0.54								0	99.32486	98.78486
P53				2.55	2.45	2.35				-5	99.32486	96.44526
CP9							2.275	2.23	2.19	-13	99.32486	95.20929
CP8	0.5	0.455	0.41							10	95.3438	96.44526
P54				2.5	2.48	2.46				-10	95.3438	92.1624
P55				2.5	2.46	2.42				-18	95.3438	90.50176
P56				2.705	2.63	2.555				-19	95.3438	88.06379
P57				2.1	2	1.9				-20	95.3438	86.88173
CP10							1.58	1.45	1.31	-20	95.3438	85.18197
CP9	1.01	0.88	0.75							18	88.41718	95.20929
X20				1.1	1.08	1.06				0	88.41718	87.33718
X21				1.86	1.82	1.78				0	88.41718	86.59718
X22				0.82	0.76	0.7				8	88.41718	89.32492
X23				1.82	1.76	1.67				8	88.41718	88.73838
X24				2.98	2.88	2.68				8	88.41718	89.68566
X25				2.42	2.27	2.12				3.3333	88.41718	87.89439
X26				2.45	2.34	2.23				5.6667	88.41718	88.24874
P58					2.41					0	88.41718	86.00718
P59				3.36	3.3	3.24				-5	88.41718	84.06658
P60				3.78	3.705	3.63				-5	88.41718	83.4011
P61				3.38	3.28	3.18				-7	88.41718	82.70577
P62				3.34	3.22	3.1				-7	88.41718	82.28193
P63				3.58	3.45	3.31				-7	88.41718	81.68905
P64				3.87	3.7	3.52				-7	88.41718	80.47136
CP11							3.8	3.68	3.41	-7	88.41718	80.00752
CP10	0.98	0.77	0.56							8	80.14967	85.18197
P65					1.85					0	80.14967	78.29967

P66					2.14					0	80.14967	78.00967
P67					2.2					0	80.14967	77.94967
CP12								2.4		0	80.14967	77.74967
CP11		2.89								0	82.89752	80.00752
1Wo5					1.655					0	82.89752	81.24252
P68					1.735					0	82.89752	81.16252
P69					1.8					0	82.89752	81.09752
1Wo4				0.61	0.55	0.49				0	82.89752	82.34752
CP13							1.84	1.68	1.54	2	82.89752	82.26736
CP12		1.97								0	79.71967	77.74967
1Wo3				1.77	1.75	1.73				0	79.71967	77.96967
P70					1.52					0	79.71967	78.19967
P71					1.68					0	79.71967	78.03967
P72					1.72					0	79.71967	77.99967
P73					1.64					0	79.71967	78.07967
X27				1.52	1.43	1.32				0	79.71967	78.28967
X28				1.4	1.29	1.18				0	79.71967	78.42967
CP14							2.45	2.15	1.85	0	79.71967	77.56967
X29				1.89	1.54	1.21				0	79.71967	78.17967
CP13	2.19	1.89	1.59							0	84.15736	82.26736
P74					1.09					0	84.15736	83.06736
P75					0.6					0	84.15736	83.55736
P76				1.41	1.26	1.1				3	84.15736	84.52278
CP15							0.92	0.72	0.52	3	84.15736	85.53316
CP14	1.35	1.15	0.95							-5	82.20135	77.56967
P77					1.41					0	82.20135	80.79135
CP16								1.725		0	82.20135	80.47635
X30				0.615	0.59	0.565				5	82.20135	82.05419
X31				1.102	1.056	1.01				12	82.20135	83.03713
X32				1.84	1.79	1.74				25	82.20135	84.28383
X33				0.98	0.88	0.78				0	82.20135	81.32135

CP15		1.53								0	87.06316	85.53316
X34				0.275	0.25	0.225				8	87.06316	87.51617
X35				0.83	0.8	0.77				22.667	87.06316	88.43532
X36				2.44	2.39	2.34				0	87.06316	84.67316
X37				3.305	3.245	3.18				0	87.06316	83.81816
X38				2.8	2.74	2.665				0	87.06316	84.32316
X39				2.925	2.85	2.78				0	87.06316	84.21316
X40				2.24	2.14	2.05				0	87.06316	84.92316
P78					1.15					0	87.06316	85.91316
P79					0.8					0	87.06316	86.26316
P59							1.4	1.25	1.1	2	87.06316	84.345
CP4	2.7	2.25	1.8							1	97.66734	96.98956
P80					1.61					0	97.66734	96.05734
P81					1.73					0	97.66734	95.93734
P82					1.95					0	97.66734	95.71734
P83					2.09					0	97.66734	95.57734
P84					2.12					0	97.66734	95.54734
1Wo1				1.35	1.265	1.19				0	97.66734	96.40234
TANK				1.65	1.49	1.34				0	97.66734	96.17734
P16				1.65	1.57	1.51				0	97.66734	96.09734
X41				2.04	1.96	1.88				0	97.66734	95.70734
X42				2.25	2.17	2.085				0	97.66734	95.49734
X43				2.75	2.59	2.44				0	97.66734	95.07734
X44				3.32	3.05	2.78				0	97.66734	94.61734
CP17								2.23		0	97.66734	95.43734
CP5	0.425	0.27	0.12							0	100.6607	100.3907
P85					1.905					0	100.6607	98.7557
P86					2.425					0	100.6607	98.2357
P87					2.81					0	100.6607	97.8507
CP18								2.85		0	100.6607	97.8107
CP17		0.33								0	95.76734	95.43734

X14				1.52	1.51	1.5				0	95.76734	94.25734
X45				2.65	2.575	2.5				11	95.76734	96.02097
P88				1.86	1.835	1.81				-9	95.76734	93.14415
P89				2.805	2.565	2.505				-11	95.76734	87.56416
P90				2.95	2.8	2.65				-12	95.76734	86.8455
CP19							2.45	2.35	2.25	-14	95.76734	88.69843
CP18	0.44	0.34	0.24							12	94.06264	97.8108
P91				1.16	1.14	1.11				0	94.06264	92.92264
P92					0.76					0	94.06264	93.30264
X46				1.4	1.36	1.32				0	94.06264	92.70264
X47				1.8	1.71	1.61				0	94.06264	92.35264
X48				1.23	1.2	1.17				-7.67	94.06264	92.056
X49				2.05	2.02	1.19				-7.67	94.06264	80.65863
X50				2.6	2.55	2.5				-9	94.06264	89.95191
X51				2.56	2.48	2.42				-13	94.06264	88.49155
X52				2.58	2.5	2.42				-13	94.06264	88.03318
X53				1.76	1.7	1.65				-12	94.06264	90.1048
X54				1.2	1.16	1.13				-12	94.06264	91.45827
CP20								1.075		0	94.06264	92.98764
CP19		2.1								3	90.7932	88.69843
X55					0.6					0	90.7932	90.1932
1WB16				0.64	0.595	0.55				10	90.7932	91.75465
X56				1.18	1.12	1.06				14	90.7932	92.51422
X57				1.27	1.25	1.19				14	90.7932	91.44527
P93					1.745					0	90.7932	89.0482
P94					1.98					0	90.7932	88.8132
1WB15					1.92					0	90.7932	88.8732
P95					2.07					0	90.7932	88.7232
P96					2.43					0	90.7932	88.3632
CP21								2.66		0	90.7932	88.1332
CP20		0.89								0	90.7932	89.9032

X58				1.32	1.28	1.24				-15.67	90.7932	87.40613
X59				1.75	1.7	1.65				-15.67	90.7932	86.46611
X60				2.13	2.05	1.94				-13	90.7932	84.55618
X61				2.68	2.62	2.56				-12	90.7932	85.71199
X62				1.88	1.8	1.72				-14	90.7932	85.21323
X63				1.43	1.39	1.35				8	90.7932	90.51966
X64				1.325	1.294	1.265				10	90.7932	90.54262
X65				2.44	2.4	2.36				-14	90.7932	86.49112
X66				2.54	2.48	2.4				-10	90.7932	85.90169
X67				2.14	1.99	1.84				-14	90.7932	81.73693
1WB13				1.99	1.95	1.91				0	90.7932	88.8432
X68					1.73					0	90.7932	89.0632
X69				0.87	0.84	0.81				0	90.7932	89.9532
X70				0.7	0.65	0.6				7	90.7932	91.36499
CP22							1.92	1.875	1.83	0	90.7932	88.9182
CP21	1.21	1.165	1.1							0	89.2982	88.1332
P97				2.425	2.39	2.354				-7	89.2982	86.03719
CP23							2.29	2.24	2.19	-7	89.2982	85.8364
CP22	0.32	0.27	0.22							4	88.48536	88.9182
X71				1.305	1.28	1.255				0	88.48536	87.20536
X72				1.325	1.28	1.245				0	88.48536	87.20536
X73				1.89	1.85	1.81				0	88.48536	86.63536
X74							1.75	1.68	1.6	0	88.48536	86.80536
CP23	0.805	0.7	0.595				.			0	86.6536	85.8364
X75				1.96	1.93	1.9				0	86.6536	84.7236
X76				1.94	1.89	1.85				0	86.6536	84.7636
X77				0.88	0.85	0.82				0	86.6536	85.8036
X78				0.855	0.83	0.805				6.5	86.6536	86.3973
X79				0.85	0.8	0.75				10.333	86.6536	87.63619
CP22	0.32	0.27	0.22							4	88.48536	88.9182
P98				1.6	1.57	1.54				-17.33	88.48536	85.17916

P99				0.79	0.73	0.67				-17	88.48536	84.37096
CP24							0.94	0.86	0.78	-17	88.48536	83.12258
CP23	1.77	1.7	1.63							15	84.01052	85.8364
X80				0.82	0.79	0.76				2.3333	84.01052	83.46867
X81				0.555	0.522	0.495				0	84.01052	83.48852
P100				2.72	2.7	2.68				-11.67	84.01052	80.49814
P101				3.21	3.165	3.11				-11.67	84.01052	78.8449
P102				3.41	3.35	3.29				-9.33	84.01052	78.72393
CP25							3.39	3.295	3.2	-8.33	84.01052	77.97639
CP24	1.02	0.92	0.82							11.333	80.16924	83.12258
X82				0.67	0.57	0.47				0	80.16924	79.59924
X83				0.4	0.29	0.18				0	80.16924	79.87924
X84				0.54	0.48	0.42				0	80.16924	79.68924
X85				1.27	1.13	0.99				0	80.16924	79.03924
X86				0.53	0.32	0.11				0	80.16924	79.84924
X87				1.6	1.41	1.19				1	80.16924	79.47642
X88				1.65	1.35	1.05				1	80.16924	79.86797
P103					1.45					0	80.16924	78.71924
P104					1.15					0	80.16924	79.01924
P105					1.24					0	80.16924	78.92924
P106					1.36					0	80.16924	78.80924
1WB14				2.35	2.24	2.13				12	80.16924	82.42413
W2				1.89	1.781	1.68				0	80.16924	78.38824
X89				1.51	1.45	1.39				0	80.16924	78.71924
X90				1.07	0.95	0.83				0	80.16924	79.21924
X91				1.07	1	0.93				0	80.16924	79.16924
CP26								1.65		0	80.16924	78.51924
CP25		1.95								0	79.92639	77.97639
1WB11				1.66	1.44	1.32				0	79.92639	78.48639
X92				1.22	1.15	1.08				0	79.92639	78.77639
X93				1.95	1.85	1.75				0	79.92639	78.07639

1WB12				0.835	0.77	0.705				4.3333	79.92639	80.1434
X94				1.04	0.98	0.92				0	79.92639	78.94639
X95				2.03	1.98	1.95				0	79.92639	77.94639
X96				1.49	1.39	1.29				8.6667	79.92639	81.53076
CP14							2.5	2.4	2.3	-4	79.92639	77.5696
CP26	2.01	1.9	1.77							6.3333	77.77687	78.51924
P107					1.83					0	77.77687	75.94687
P108					1.36					0	77.77687	76.41687
P109					1.5					0	77.77687	76.27687
X97				2.76	2.67	2.55				0	77.77687	75.10687
X98				2.95	2.86	2.78				0	77.77687	74.91687
W6				3.16	3.1	3.05				0	77.77687	74.67687
X99				0.74	0.685	0.62				0	77.77687	77.09187
X100				1.11	1.08	1.05				0	77.77687	76.69687
CP27								1.63		0	77.77687	76.14687
CP14		1.14								0	78.7096	77.5696
P110				1.59	1.54	1.49				0	78.7096	77.1696
P111					1.47					0	78.7096	77.2396
X101				3.43	3.29	3.15				0	78.7096	75.4196
X102				3.41	3.21	3.09				0	78.7096	75.4996
X103				3.28	3.08	2.88				0	78.7096	75.6296
1WO6				2.56	2.525	2.49				0	78.7096	76.1846
P112					1.8					0	78.7096	76.9096
P113					0.595					0	78.7096	78.1146
P114					0.13					0	78.7096	78.5796
P115					1.12					1	78.7096	77.59135
CP28								1.38		1	78.7096	77.33135
CP27	2.2	1.85	1.5							1	76.77362	76.14685
1WO7				2.83	2.7	2.57				1	76.77362	74.52906
X104				2.22	2.02	1.82				3	76.77362	76.84943
X105				2.91	2.775	2.64				1	76.77362	74.47151

P116					2.1					0	76.77362	74.67362
P117					2.04					0	76.77362	74.73362
P118					1.78					0	76.77362	74.99362
P119					1.35					0	76.77362	75.42362
P120					1.28					0	76.77362	75.49362
CP29								1.32		0	76.77362	75.45362
CP28	1.15	0.75	0.45							1	76.85812	77.33135
X106				2.305	2.145	1.965				-3	76.85812	72.9309
X107				1.975	1.875	1.775				5	76.85812	76.72832
X108				2.01	1.81	1.61				-4	76.85812	72.25768
X109				1.7	1.6	1.5				7.6667	76.85812	77.9158
X110				2.32	2.19	2.06				9	76.85812	78.70099
X111				1.16	1.09	1.01				0	76.85812	75.76812
P121					1.14					0	76.85812	75.71812
P122					1.6					0	76.85812	75.25812
P123					2.14					0	76.85812	74.71812
P124					2.84					0	76.85812	74.01812
CP30								3.02		0	76.85812	73.83812
CP29	2.17	1.93	1.68							2	75.6711	75.45362
X112				2.92	2.78	2.63				0	75.6711	72.8911
X113				2.5	1.98	1.46				0	75.6711	73.6911
X114				2.55	2.465	2.355				0	75.6711	73.2061
X115				1.58	1.45	1.34				0	75.6711	74.2211
X116				1.4	1.375	1.35				12.333	75.6711	75.3608
X117				0.71	0.65	0.59				4.6667	75.6711	76.0023
CP31							3.56	3.36	3.16	11	75.6711	79.82231
CP30	3.48	3.28	3.08							-6	81.28681	73.83812
P125				1.71	1.66	1.67				0	81.28681	79.62681
P126					2.12					0	81.28681	79.16681
X118				2.38	2.3	2.22				0	81.28681	78.98681
X119				2.97	2.81	2.65				0	81.28681	78.47681

X120				3.74	3.645	3.55				0	81.28681	77.64181
X121				3.45	3.37	3.29				0	81.28681	77.91681
X122				0.78	0.66	0.59				0	81.28681	80.62681
X123				0.46	0.36	0.26				0	81.28681	80.92681
X124				0.28	0.15	0.05				0	81.28681	81.13681
X125				3.4	3.23	3.04				5	81.28681	81.19119
X126				1.45	1.21	0.97				2.3333	81.28681	82.03349
CP32							2.13	1.935	1.75	9	81.28681	85.23877
CP31	3.24	3.15	2.88							-10	89.14604	79.82231
X127				2.47	2.4	2.325				-2.33	89.14604	86.15212
X128				3.775	3.675	3.54				-2.667	89.14604	84.37422
X129				3.68	3.44	3.2				-2.33	89.14604	83.74936
X130				2.775	2.625	2.465				-5	89.14604	83.82078
P127					0.965					0	89.14604	88.18104
P128					0.92					0	89.14604	88.22604
P129					0.45					0	89.14604	88.69604
P130				0.82	0.72	0.62				3	89.14604	89.47656
P131				0.8	0.675	0.55				3	89.14604	89.78288
P132				0.88	0.74	0.6				3	89.14604	89.87467
P133				0.97	0.8	0.63				3	89.14604	90.12825
CP33							1.28	1.15	0.83	3	89.14604	90.35316
CP32	1.32	1.05	0.78							-5	90.98599	85.23877
P134					1.04					0	90.98599	89.94599
P135					0.52					0	90.98599	90.46599
P136					0.14					0	90.98599	90.84599
P137				0.695	0.495	0.295				1	90.98599	91.19072
P138				0.7	0.45	0.2				1	90.98599	91.41022
P139				1.98	1.68	1.38				3	90.98599	92.44707
P140				2.39	1.92	1.45				3	90.98599	93.98406
P141				2.98	2.58	2.18				3.3333	90.98599	93.05552
P142				0.15	0.11	0.07				3.6667	90.98599	91.39295

CP34							1.6	1.44	1.2	4	90.98599	92.33642
CP33	1.055	0.66	0.265							-4	96.51747	90.35316
X131				0.52	0.42	0.32				0	96.51747	96.09747
X132				0.96	0.86	0.765				0	96.51747	95.65747
X133				0.8	0.66	0.53				0	96.51747	95.85747
CP35							1.25	1.04	0.84	1	96.51747	96.19466
CP34	1.65	1.45	1.25							2	95.18504	92.33642
X134				2.2	1.84	1.44				1	95.18504	94.67297
P143					1.21					0	95.18504	93.97504
P144					0.77					0	95.18504	94.41504
P145					0.46					0	95.18504	94.72504
P146					0.24					0	95.18504	94.94504
P147					0.12					0	95.18504	95.06504
P148				0.67	0.57	0.47				1	95.18504	94.96578
CP36							0.78	0.6	0.43	1	95.18504	95.19753
CP35	0.62	0.44	0.26							-5	99.76904	96.19466
P149					0.795					0	99.76904	98.97404
P150					0.67					0	99.76904	99.09904
CP5								0.356		0	99.76904	100.394
CP7	1.73	1.59	1.45							1	99.88452	98.78486
X135				1.56	1.48	1.4				1	99.88452	98.68546
X136							1.122	1.13	1.04	0	99.88452	98.75452
X135	1.89	1.8	1.71							0	100.4855	98.68546
X137				1.65	1.6	1.54				0	100.4855	98.88546
X138				1.68	1.6	1.52				0	100.4855	98.88546
X139				1.92	0.78	1.64				0	100.4855	99.70546
X140							3.61	3.51	3.41	0	100.4855	96.97546
CP35	1.2	1.23	1.26							0	97.42466	96.19466
X143				1.61	1.57	1.53				0	97.42466	95.85466
X144				3.06	2.93	2.8				0	97.42466	94.49466
X145				2.94	2.85	2.76				0	97.42466	94.57466

X146				2.875	2.675	2.475				-2	97.42466	93.35104
X147							2.6	2.3	2	-2	97.42466	93.02848
CP35	1.96	1.66	1.36							3	94.71357	96.19466
X148				2.36	2.21	2.06				0	94.71357	92.50357
X149				0.82	0.71	0.6				0	94.71357	94.00357
X150				1.65	1.57	1.49				0	94.71357	93.14357
X151				2.015	1.935	1.855				0	94.71357	92.77857
X152				3.08	2.98	2.88				0	94.71357	91.73357
X153				3.12	2.97	2.82				0	94.71357	91.74357
X154				2.55	2.35	2.13				0	94.71357	92.36357
X155				3.05	2.94	2.83				0	94.71357	91.77357
X156				3.5	3.37	3.24				0	94.71357	91.34357
X157							2.68	2.62	2.58	0	94.71357	92.09357
										0		