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EVALUATION OF MODIFIED CHIENG MODEL FOR IRRIGATED REGION OF PAKISTAN

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Waterlogging is one of the main problems besetting agriculture in Pakistan. The paper presents a modification and evaluation of Chieng's model for Rechna Doab area of the Punjab, Pakistan, for existing tile drainage system. The model in its original form considers only rainfall as inflow, whereas the study area inflow comprises rainfall, irrigation supplies and seepage from canal. Thus the need for modification was evident. This modified model analyzed the response of ground water to various recharge and discharge parameters. Daily data of twenty-nine months were used for the identification of the model parameters and for verification of the model applicability by making coincidence between computed and observed water table depth. The results showed a good agreement between the comparison of computed and observed water table depths.

Key words: Chieng model, evaluation, irrigated region

INTRODUCTION

There are a wide array of criteria for use in selecting water balance model for drainage discharge. In actual practice the model input data and its availability, operational and computational time requirements, accuracy and simplicity are all equally important. Accuracy and simplicity are generally listed to be the objectives with which water balance model is analyzed. Ribbens and Shaffer (1976) developed a simulation model that approximates processes in the soil water system and is more process oriented than others. Chieng *et al.* *(1978)* developed a subsurface drainage model which was utilized to evaluate the drainage coefficient. Chang *et al.* (1981) used "DRAINMOD" water management model originally developed by Skaggs (1980) in irrigated areas. The water table depths derived from the model simulation underestimated the water loss from the soil profile.

Since presently the analytical formulation of drainage problem does not provide a complete solution, therefore, a versatile model is the need of time to work with soil-water-plant and climatic properties as inputs applicable for different field conditions. In the Chieng model, the rainfall is only considered as inflow, whereas in the study area, the inflow comprised rainfall, irrigation supplies and seepage from canal.

This paper presents a modification in the Chieng model to accommodate the contribution of irrigation supplies and seepage from canal as an inflow to make the model useful for local conditions. The paper further explains its validity comparing the computed and observed water table depths for the "Rechna Doab" area of Pakistan.

Description of the Modified Model

The water content at any time depends on the balance between water inflow, outflow and change in soil water storage. The inflow in this modified model consists of rainfall, irrigation water and seepage from the canal towards the area. The soil profile above the drain depth is divided into four zones to allow the adjustment for change in soil properties with depth. The processes involved are shown in Fig. I. Each zone is assumed to have two distinct storage capacities i.e. available soil moisture storage, the difference between field capacity and wilting point, and transient storage, the drainable pore spaces or the difference between saturation and field capacity. The depletion from available water takes place by evapo-transpiration and depletion from transient storage is by drainage. When the inflow water first fills the available storage capacities, the excess water goes to transient storage causing the water table to rise. The outflow from the drains is assumed to deplete the water from the transient storage.

The actual quantity drained from each zone is dependent upon the drainable porosity and the depletion from transient storage causes the water table to fall. The water table fluctuation in the soil is related to the changes in the transient water contents in the soil. Although the entire transient water is considered drainable, the actual quantity drained is dependent upon the suction applied and is variable.

In the water balance approach for subsurface drains design, the changes in soil moisture are computed by balancing input of precipitation, irrigation water and seepage from the canals into the soil and the outputs of evapotranspiration and outflow from the soil. The change in storage of water is given as:

Change in storage = Inflow + outflow

Inflow = Rainfall + irrigation water + seepage from the canal

Outflow = Actual evapotranspiration

The equation used in the water balance modified model is as follows:

$$SMCT = SMC(k.IJ + VF(k.,l- AE(k.,) + TR(k.IJ \quad (I)$$

Where,

SMCT = Soil moisture Content (tentative),

SMC(I) = Soil moisture content at time I,

$VF_{(I)}$ = Inflow at time I.
$AE_{(I)}$ = Actual evapotranspiration at time I.
$TR_{(I)}$ = Transient storage at time I.
I = Number of time interval, and
K = Number of zones.

The evapotranspiration takes place from each zone which depends upon temperature, rainfall, irrigation water applied, cropping pattern, cropping intensity, root zone of the crops grown and available soil moisture in each zone.

Two approaches may be considered for the contribution of seepage from the canals.

1. All the seepage contribution may be considered in the first zone only.
2. Contribution of seepage may be divided in all zones.

In the first approach when the seepage is not distributed in the zones, the inflow for the first zone is given by the following equation:

$$VF_{(I)} = PRE_{(I)} + IR_{(I)} + SP_{(I)} \qquad (2)$$

Where,

$VF_{(I)}$ = Inflow at time I.
$PRE_{(I)}$ = Rainfall (precipitation) at time I.
$IR_{(I)}$ = Irrigation water applied at time I, and
$SP_{(I)}$ = Seepage from the canal at time I.

Whereas the inflow for the second, third and fourth zones is the water exceeding the storage capacities of the upper adjacent zones respectively.

In the second approach, the inflow for the second, third and fourth zones is the water exceeding the storage capacities of the upper zones plus the contribution of seepage from the canals. Tentative soil moisture contents for the zones is calculated by the equation (3). If the tentative soil moisture does not exceed the field capacity of a zone then all water is stored in the zone as available soil moisture content and no water goes down or in the transient storage of the zone as given in the following equation:

$$SMC_{(K, I+1)} = SMCT \qquad (3)$$

Where,

$SMC_{(K, I+1)}$ = Soil moisture content of zone K at time + I, and
SMCT = Soil moisture contents (tentative) of a zone.

In this model it is assumed that if the soil moisture exceeds the available soil moisture of a zone, the water exceeding the field capacity comes at tentative transient storage of the zone, which is calculated using the following equation:

$$TRT = SMCT - SMC_{(K, I+1)} \qquad (4)$$

$$SMC_{(K, I+1)} = F.C_{(K)} * DPT_{(K)} \qquad (5)$$

Where,

TRT = Tentative transient storage,
SMCT = Soil moisture storage (tentative).
$SMC_{(K, I+1)}$ = Available soil moisture contents of zone K at time I + I.
$F.C_{(K)}$ = Field capacity of zone K, and
$DPT_{(K)}$ = Depth of zone K.

If the calculated tentative transient storage of a zone exceeds the drainable porosity of the respective zone, the water satisfies the available drainable porosity of the zone and the remainder is drained quickly as the part of inflow for the lower adjacent zone as given in the following equation:

$$VFT = TRT - F_{(K)} * DPT_{(K)} \qquad (6)$$

Where,

VFT = Excess water from the zone,
TRT = Tentative transient storage,
$F_{(K)}$ = Drainable porosity of zone K, and
$DPT_{(K)}$ = Depth of zone K.

A large percentage of water which was held in the transient storage of the zone is also drained as an inflow for the lower adjacent zone and this percentage may vary for different zones. Total inflow for the lower adjacent zone is calculated as follows:

$$VF_{(K+1)} = TRT * PARA_{(K)} + VFT \qquad (7)$$

Where,

$VF_{(K+1)}$ = Inflow for the lower adjacent zone.
TRT = Tentative transient storage.
$PARA_{(K)}$ = Drain water factor for the zone K, and
VFT = Excess water.

On the other hand, if the tentative transient storage does not satisfy the drainable porosity of the zone then some water contents are stored in the drainable pore spaces and all other water contents are drained as an inflow for the lower adjacent zone as calculated by the following equation:

$$VF_{(K+1)} = TRT * PARA_{(K)} \qquad (8)$$

Where,

$VF_{(K+1)}$ = Inflow for the lower adjacent zone,
TRT = Tentative transient storage, and
$PARA_{(K)}$ = Drain water factor for zone K.

If the inflow satisfies the water holding capacity of whole soil profile, excess moisture enters transient storage in the drainable pore spaces and a part of this is discharged through subsurface drains and the rest contributes to the groundwater and gives a rise to groundwater level. The discharge through the drain depends on the water present in the transient storage of the

Tahk I. Paralm:ters used for the verification of the model

Parameter	Zone-1	Zone-2	Zone-3	Zone-4
Fidd capacity	0.201	0.196	0.190	0.189
Drainable porosity	0.111	0.114	0.116	0.119
Initial SMC	70.0	70.0	80.0	90.0
Initial TR	0.0	0.0	10.0	ISO
Evapotranspiration	0.7	30.0	0.0	0.0
Seepage	0.2	(IA	OA	0.0
Para	1.0	1.0	1.0	0.0

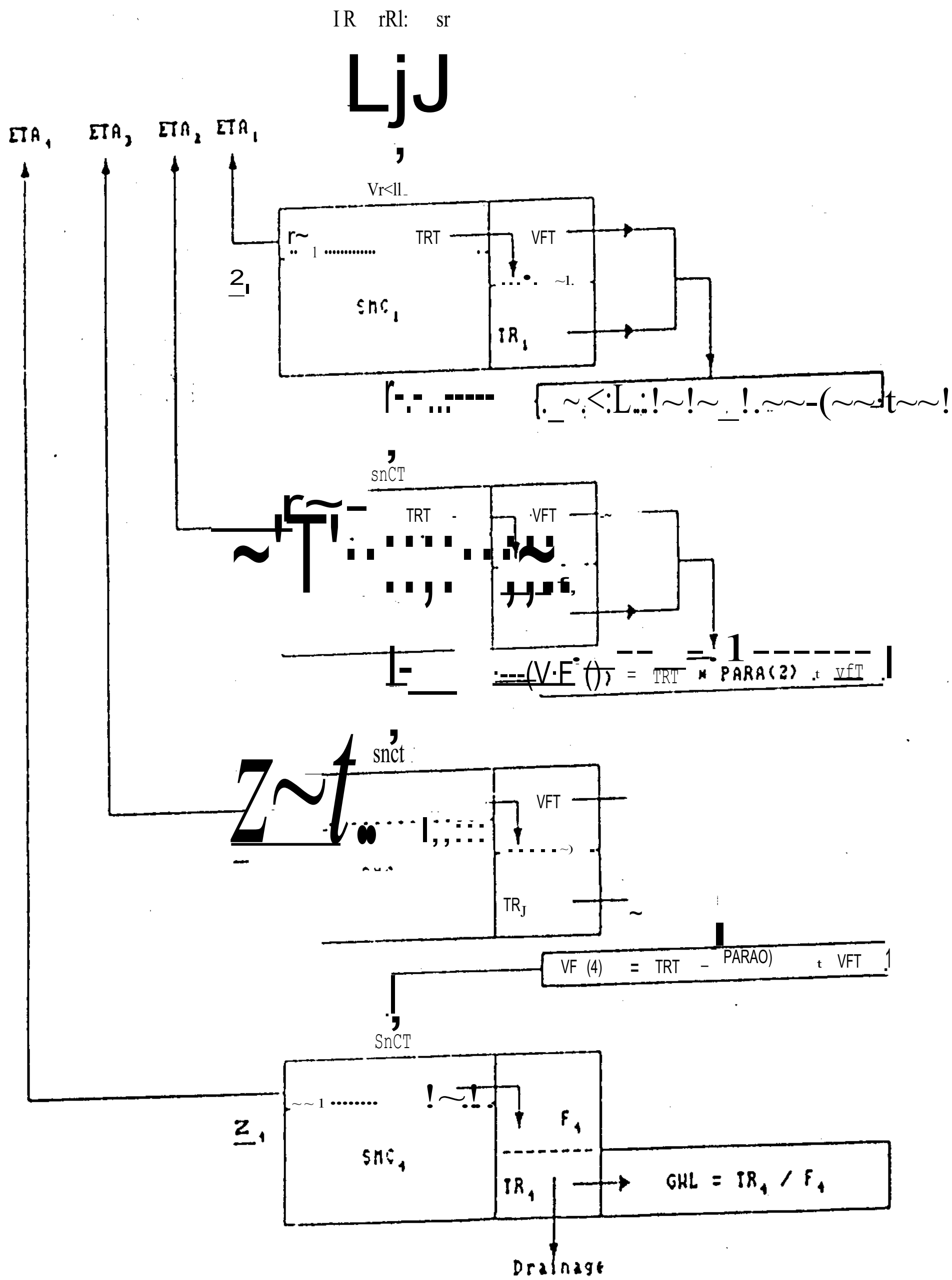

Fig. I. Diagram of modified Chieng model .

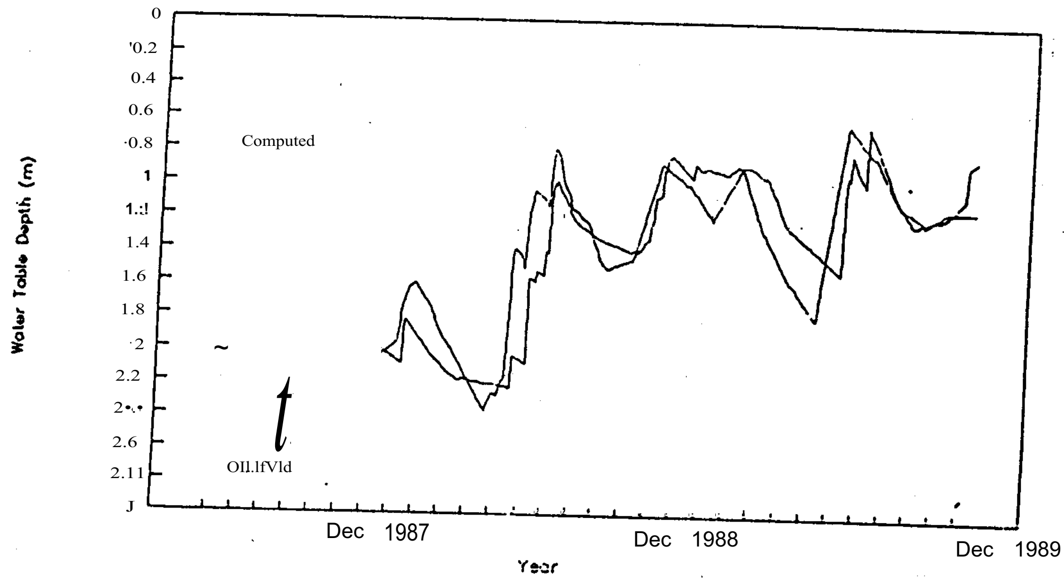

Fig. 2a. Observed and computed water table depth (parameter of 1.0)

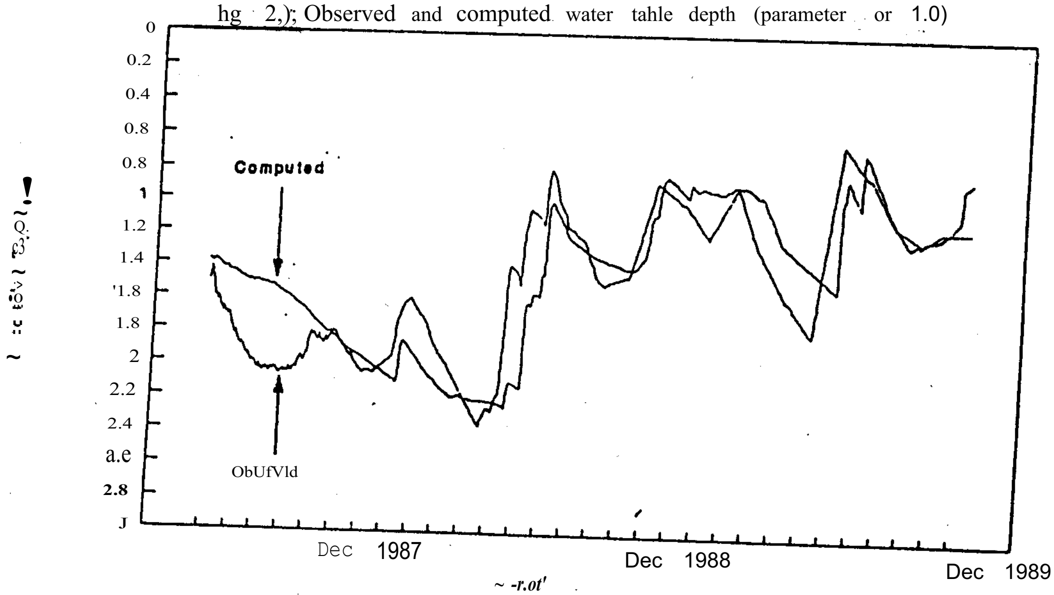

Fig. 2b. Observed and computed water table depth (parameter of U.7).

fourth zone. If the water stored in the transient storage is greater than the drainage rate capacity then the water is drained following the drainage rate capacity and rest of the water contributes to the groundwater and subsequently the water table level rises. Transient storage for the fourth zone is calculated as follows:

$$TR_{(4,I+1)} = TR_{(4,I)} - R \qquad (9)$$

Where.

$TR_{(4,I+1)}$ = Transient storage of 4th zone at time I + I.

$TR_{(4,I)}$ = Transient storage of 4th zone at time I. and

R = Drainage rate.

If the water held in the transient storage of the fourth zone is less than the drainage rate capacity. then all the water coming in the transient storage is drained and no water contributes to the groundwater level rise and the transient storage becomes zero for the following day as given in the following equation:

$$TR_{(4,I+1)} = 0.0 \qquad (10)$$

Where.

$TR_{(4,I+1)}$ = Transient storage in the fourth zone for the time I + I.

The groundwaier level rise and fall is calculated by the following equation:

$$GWL = DL + TR_{(4,I+1)}/F_{(4)} \quad (11)$$

Where,

GWL = Groundwater level,
DL = Drain level,
$TR_{(4,I+1)}$ = Transient storage in the fourth zone for the time I+1, and
$F_{(4)}$ = Drainable porosity of the fourth zone.

If the water after satisfying the drainage rate capacity exceeds the capacity of the transient storage of the fourth zone, the water comes in the third zone and gives a water level rise to the third zone and the same process is done for the water rise in the upper zones but for simplicity only water level rise in the fourih zone is shown in Fig. 1. The groundwater level is cakulated using the following equation:

$$GWL = DL + DPT_{(4)} + TR_{(3,I+1)}/F_{(3)} \quad (12)$$

Where,

$DPT_{(4)}$ = Depth of fourth lone,
$TR_{(3,I+1)}$ = Transient storage in the third zone at time I+I, and
$F_{(3)}$ = Drainable porosity of the third zone.

The groundwater table depth is calculated by the following equation:

$$GWD_{(I+1)} = DD - GWL \quad (13)$$

Where,

$GWD_{(I+1)}$ = Groundwater table depth at time I+1,
DD = Drain level, and
GWL = Ground water level.

Model Verification: The validity of the model should be checked by comparison of cakulated water table changes with the observed ones. The results were then evaluated in order to improve the model further for best simulation.

The observed data on water table changes, which were collected from the field had a spatial distribution. These data were manipulated to get an average value of water table changes. Then the. model was verified by comparing the calculated and observed data. The veritication of the model in actual field situation was obtained by comparing the simulation results against the ohserved field data for 29 months, in which groundwater depth, rainfall, irrigation evapotranspiration and discharge were known for a suitable study area. The parameters used for the veritication of the model are shown in Table 1.

The input parameters used in the model were based on the lumping of the measured data for the region. Good agreement hctwccu the computed and observed water table was found as exemplitied by Fig. 2a and 2b. The discrepancy between actual, observed and computed results occurred at the start when gradual fall was not simulated well with a sudden fall of the observed water table depth. It is believed that this happened due to the initial adjustment of the parameters.

Another discrepancy between the observed and computed water table depths was found much later. The reason for this discrepancy was that the actual data related to discharge for 3rd year were not available, thus an average rate (on trial and error basis) for the whole year was considered. Fig. 2a and 2b show the comparison of observed and computed results for the drainage rates of 0.8 mm/day for the 3rd year and the parameter values of 1.0 and 0.7 (Fig. 2a and 2b) show that if the parameter is changed from 1.0 to 0.7 then there is no effect on the water table depth.

After the verification of the model it was applied to simulate the drainage rate in the study area. In order to determine the drainage rate, it was necessary to simulate the water table depth regime over a long period. The computer model was run using 20 years climatic data trorn the study area.

Conclusion: A water balance model developed by Chieng was moditied and applied to simulate the ground water table changes in an irrigated region of Pakistan. The model was verified by comparing the computed and observed water table depth which showed a good agreement. The concept of using the transient storage in a soil column of a known depth, as a predictor of water table depth, is considered useful in subsurface design work. Through the sensitivity analysis of the model it was found that water table movement is most affected by the value of the drain depth.

Recommendation: While the model used in this study is conceptual and lumped. a physically distributed model which may be able to improve the design parameters should be developed and evaluated.

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$$GWL = DL + TR_{(4,t+1)}/F_{(4)} \quad (11)$$

Where.
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