II-88 1-D SIMULATION of ANNUAL HYDROLOGIC CYCLE for the purpose of simplified hydrologic modeling

Graduate School University of Tokyo Student Member Guangheng NI
I.I.S. University of Tokyo Member A. HERATH
I.I.S. University of Tokyo Member K. MUSIAKE

1. INTRODUCTION

Search for simplified cathment process models has become an important topic in hydrology. The present paper investigates the influence of soil hydraulic properties and groudwater on annual hydrological processes at a point.

2. NUMERICAL MODEL DESCRIPTION

Richards equation is used to describe the unsaturated-saturated soil water flow with the upper boundary defined by flux due to rainfall and evaporation. When ponding occurs, a constant water pressure is assigned to the surface and rainfall excess is taken as direct runoff. The lower boundary is determined by leakage to deeper aquifer from the unconfined groundwater under constant deep aquifer piezometric head. Finite-difference method employing mass-conservation discritization form is adopted in the numerical model to ensure a good mass balance. The simulation time step is allowed to vary linearly from 30 second initial value. At the begining of rainfall events, time step is automatically set to the minimum value.

Rainfall data sets of different resolutions were made from observed precipitation data of 1 minute resolution for years 1986 and 1987 for simulaions. Daily potential evaporation rates were calculated from the observed meteorological data for year 1986 and 1987, using Penman equation. The actual evaporation from the potential value is computed in the simulation model based on the averaged volumetric soil moiture upto 5cm from surface by the following formula, $Ea = EP * A * (1.0 - exp(-B * (\theta - \theta_r)))$.

Homogeneous Kanto Loam soil medium was treated with soil hydraulic properties described using Van Genuchten equations derived from moisture-water head relation measured in the laboratory.

3. RESULTS AND DISCUSSION

3.1 Impact of rainfall data

Usually, lower the resolution of the rainfall data is, the smaller the rainfall accumulation with intensity larger than some value. Therefore with the same rainfall, larger infiltration may result for lower resolution of rainfall data. Figure 1, shows this effect for the case for saturated conductivity, $k_s = 0.0001 cm/sec$ and initial depth to groundwater 12.0m. When rainfall data resolution changes from 5min to 60.0 min, the runoff decreases about 5 percent of annual precipitation.

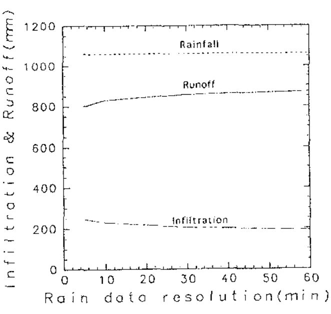

Figure 1. Impact of rainfall data resolution

3.2 Impact of soil parameter

Simulation results for soils of different k_s values, 0.00001, 0.0001, 0.001, 0.005, 0.01 cm/sec respectively, are shown in Figure 2.

With lower k_s runoff is higher due to the lower infiltration capacity, but this also depends on the distribution of rain intensity . Figure 3 shows the distribution of annual rainfall intensities for different data resolutions. When rain intensity decreases from 0.001 to 0.00001cm/sec, rain accumulation increases fast, resulting in a relatively bigger increase in runoff as seen in figure 2 when k_s changes from 0.001 to 0.00001cm/sec. However, when k_s changes from 0.01 to 0.001 cm/sec, there is not such a large increase of runoff (Fig. 2), for there is almost no addition of rain accumulation when rain intensity changes from 0.01 to 0.001cm/sec (Fig. 3).

Following infiltration, redistribution of soil moisture takes place affecting evaporation and recharge to groundwater. If k_s is larger, the amount of infiltrated rainfall is bigger, and downward movement of infiltrated rainfall is faster, so more water can reach groundwater and induce more leakage to deeper aquifers. However this decreases the soil water amount available for evaporation. Therefore, as k_s increases, evaporation shows some decrease(Fig. 2) although to a smaller degree. On the other hand, when the groundwater is shallow, such as when groundwater table is around 2.0-3.0 m, due to the influence of capillary rise more soil moisture is available for evaporation, making annual evaporation volume to increase with k_s.

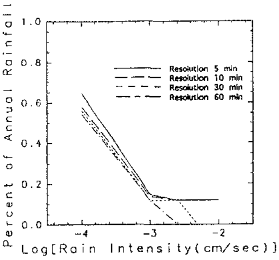

Figure 2. Annual rainfall intensity distribution for 1986

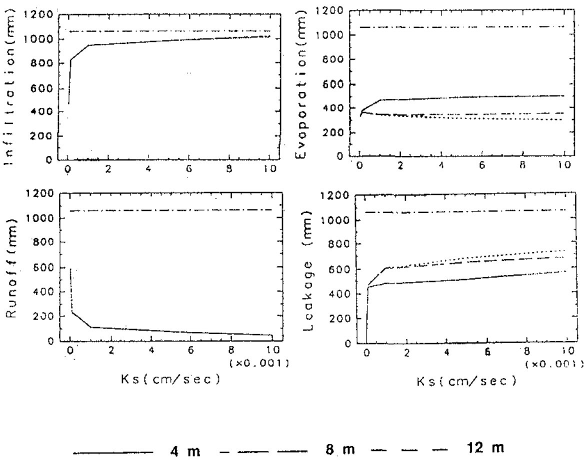

Figure 3. Simulation results for different K_s and depth to groundwater

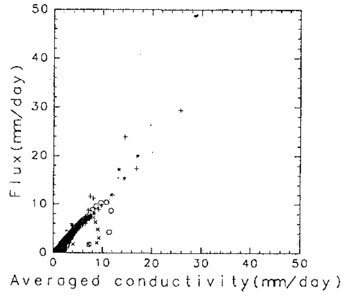

Figure 4. Relation between averaged conductivity and flux for different soil layers

3.3 Impact of depth to groundwater

When depth to groundwater table is larger than some value, capillary rise has no effect. Infiltration capacity is mainly determined by surface layer characteristics. Therefore, even when the depth change, amounts of infiltration, runoff, evaporation are almost stable, as well as the leakage to deeper aquifer. Figure 2 shows the effect on these quantities when the initial depths to groundwater table is 4.0, 8.0 and 12.0m.

3.4 Flux in unsaturated zone

Flux distribution in unsaturated zone is important as it determines the interaction between surface water and groundwater. However, it is very difficult to describe it in a simple way which reflect the soil properties and depths to groundwater table, without using a large number of parameters. By dividing the soil domain into a number of layers with equal thickness of 1.0 meter, the relation between soil storage and flux at the bottom of each layer was investigated. The results shows that there is a good relation between the averaged soil conductivity (calculated from the averaged moisture of the layer) and flux from the bottom of each layer. Results for one simulation case is shown in Figure 4, and the relation between flux, $flux_i$ at bottom and averaged conductivity k_i for i_{th} soil layer can be described as, $flux_i = \alpha * k_i$ and α is approximately equal to 1.0. By using this formula the flux distribution within the unsaturated zone can be simplified.

Employing this observation a series layer model described below was used to simulate the annual moisture movement in the unsaturated zone at daily scale. $S_{t+dt} = S_t + dt * (Flux_{in} - Flux_{out})$. The computations were found to agree very well with numerical simulation results. Due to lack of space these results would be shown during the presentation.

4. CONCLUSION

For physically based modeling, rainfall is a very important input data. The resolution of it and its effect on simulation result should be investigated prior to simulations. Soil parameters have important effect on hydrological processes.Infiltration, runoff and evaporation are mainly determined by the condition of surface layer and are not affected so much by the depth to groundwater table when the depth is larger than some value. Unsaturated soil water flux at any depth can be related with the averaged conductivity of a soil layer above this depth, which can be used to simplify modeling flux distribution within the unsaturated zone.