II -145 A Simplified Urban Hydrologic Model and its Application

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1. Introduction

Urban hydrologic cycle consists of natural water cycle and the human water use which gives rise to an artificial water cycle. The simulation of complete water cycle in urban areas requires simulation of both natural water cycle which is governed by the physical laws and the artificial water cycle which is determined by different usage patterns. Herath et al (1996)[1] presented a distributed hydrologic model in a GIS environment for simulation of the complete urban water cycle. However, due to the excessive computational requirements, the model is not well suited for repeated simulations required in urban policy decision making. As the urban water cycle analysis is carried out with high resolution spatial and temporal data, it is possible to simplify the governing equations and still obtain adequate results. Storage based equations instead of pressure based equations were found to provide adequate results (Hearth et al, 1996)[2] for such simulations. In the present study , this storage based distributed model is extended to incorporate groundwater flow and artificial drainage flow paths, and is applied for long term simulation in an urban catchment.

2. Model Description

The catchment is described by a uniform grid network. The flow routing is carried out by determining the excessive amount through the successive application of conservation law for different hydrologic processes as given below.

$$\frac{\partial . Ss}{\partial . t} = H_{k-1} + R_k - E_k - I_k \quad (1)$$

$$\frac{\partial . S_T}{\partial . t} = Int_{K-1} + I_K - e(1 - impf_k) - R_k - Int_k \quad (2)$$

$$R_k = \int K(\theta)dt \quad (3)$$

$$Int_k = \int slope.K(\theta)dt \quad (4)$$

$$\frac{\partial . S_g}{\partial t} = R_k + 0.5K_g(h_{k+1} + h_k)\frac{[h_k - h_{k+1}]}{\Delta X} \quad (5)$$

Surface and Subsurface storage are given in equation (1) and (2) respectively. Recharge and Interflow are computed using equation (3) and (4) respectively. Complete description about those equations are given in Herath et. al (1996).[1]
Ground water storage is computed using Darcy's equation (5).

All the above equations are applied explicitly in the direction of flow for each component. The subscript k denotes the current grid and k+1 denotes the next grid in the flow direction. The model for artificial water cycle is the same as that described in Herath et. al (1996).[1]

3. Application

This model has been applied to the Maehara sub catchment in the Ebi river basin located in Chiba Prefecture, where the catchment area is 3.25 sq km. The population is around 27750. The following data sets were prepared for the analysis. 1) DEM, 2) Land use map, 3) Soil distribution map, 4) Water supply data, 5) Population data. Using above data GIS maps were prepared for 50 m grids. The land use map was used to compute the impervious ratios of each grids where as population data and water supply data were used to estimate the artificial water supply and drainage at each grid. Details of catchment and spatial data are given in Herath et al (1996)[1].

4. Results and Discussion

4.1 Discharge comparison

Simulations were carried out for the rainfall and evaporation parameters for the year 1995. Fig. (1) shows the comparison of observed and computed discharge hydrograph for the month of October, 1995. Fig (2) and Fig. (3) show the enlarged segments of Fig.(1) for the non rainy and rainy days respectively. The results show that the model can simulate both artificial and natural components of the hydrological cycle well for both short term and long term simulations.

4.2 Ground Water comparison

The groundwater head is measured at a location in the high ground about 500m from the river gauging station. Comparison of measured groundwater head and the computed water head of the nearest grid is shown in Fig. (4). The trend of ground water fluctuation is captured by the model, but the model sensitivity appears to be less than the actual ground water head fluctuations.

4.3 Water balance

The annual input to the catchment and the different discharge components through model estimates are shown in Fig.(5).

Key Words: Urban Hydrology, Distributed catchment model.

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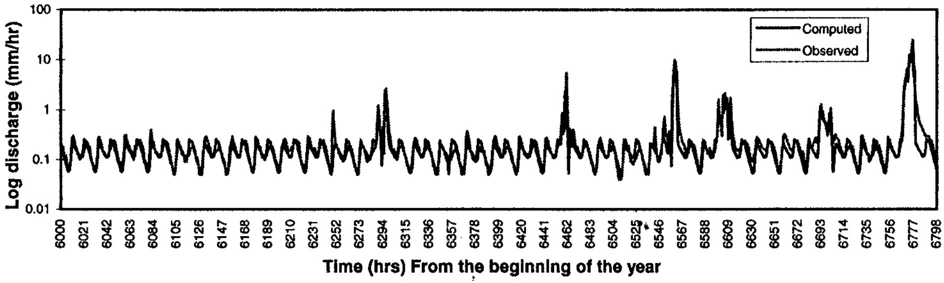

Figure (1) Observed and Computed hydrograph at the river outlet

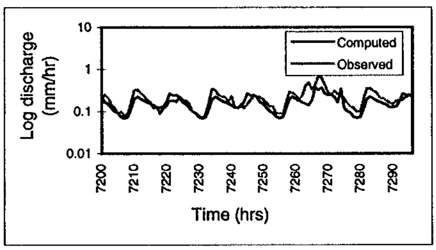

Figure (2) Comparison of observed and computed discharges for non rainy period

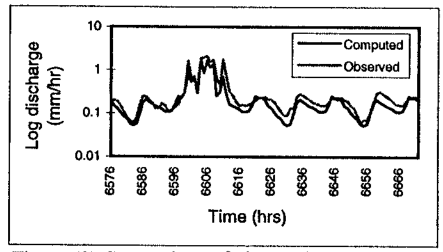

Figure (3) Comparison of observed and computed discharges for rainy period

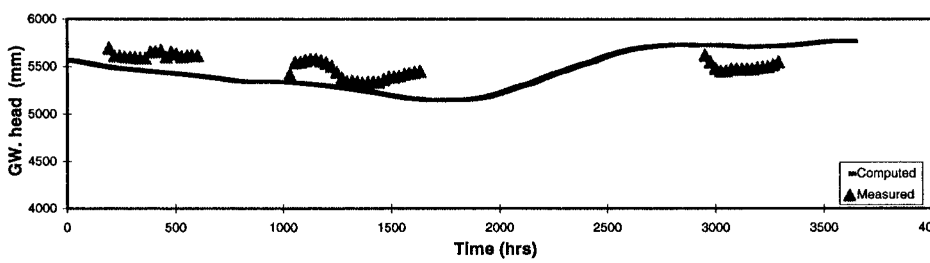

Figure (4) Comparison of observed and computed Ground Water heads from January to May, 1995

5. Conclusion

The storage based distributed catchment model was seen to provide adequate description of catchment wide distribution of artificial and natural hydrologic cycle components. The model required only about 7 min for one year simulation in a 300 MHz PC computer, for 72x46 grids at 50 m resolution with one hour time steps. Therefore it is possible to use the modeling approach to carryout analysis related to long term effects of urbanization and effect of different measures to improve the urban environment.

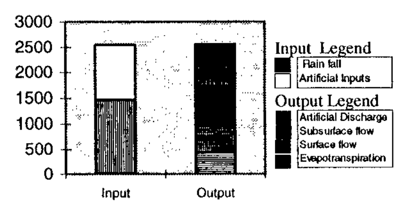

Figure (5) Annual Water balance

6. References

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2. S. Herath and K. Musiake (1996): *Analysis and Modeling of Urban Hydrological Cycle*, International Conference on Urban Engineering in Asian Cities in the 21st Century, Bangkok, Thailand, pp. F251-F256