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Watershed Modelling Using Control System Concept

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Abstract

Watershed modelling is an essential component for water resources management. Surface hydrologic response in a watershed can be thought as a combination of routing elements and runoff production units. This study develops a watershed model using control system concept in MATLAB Simulink module. It is built as a combination of routing elements and runoff production units. Routing is carried out by using non-linear form of Muskingum method whereas runoff generation is by means of linear/non-linear reservoirs. The developed model is tested for four events which are selected such that there exists extreme flows. The performance of non-linear model was slightly better than that of linear model. Though the simulated and observed discharges follow the same trend, there exists discrepancy between simulated and measured flows which indicates the need for further improvement in the model.

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1. Introduction

Watershed models are essential for water resources assessment and management. They are used to analyse the quantity and quality of surface and groundwater resources, and groundwater development and protection. Watershed model can be considered as a combination of routing elements and runoff generation modules. The excess rainfall will get converted to surface runoff, which then routed through the streams or channels to become the runoff at the outlet of watershed.

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River Routing is a methodology to trace the changes in shape of water wave (expressed as discharge v/s time) as it moves through a river/ channel. In general, there are two types of routing, viz., reservoir routing and channel routing. In reservoir routing, the storage was a unique function of the outflow discharge. However, in channel routing the storage is a function of both inflow and outflow discharges and hence a different routing method is needed [1]. In very long channels/rivers, the entire flood wave changes its shape, owing to the storage available in the long stretches of the channels/river. Muskingum method is one of the popular lumped flow routing techniques and its modest data requirements make it attractive for practical use [2].

Runoff generation process in watershed modelling is considered as one of the most important and fundamental process in hydrology. Researchers have developed numerous methods to simulate the rainfall runoff process. However, most of the methods are lumped in nature. The conversion of rainfall to runoff is a very complex process due to unsteady occurrence and distribution pattern of rainfall. Basically, the hydrological processes are non-linear in both time and space. The linear representation of these processes is simple but may not offer a true representation of the processes.

The control system concepts were utilized for representing dam and river system so as to control the flow in the system to meet certain criteria [3]. Romanowicz and Osuch [4] developed an integrated Data Based Mechanistic (DBM) rainfall-flow/flow-routing model for applying in the Upper River Narew catchment by using Simulink. A representation of non-linear Muskingum models in MATLAB Simulink module is carried out by using control system concept [5]. Mehra (2014) conducted a study on Watershed Modelling using Control System Concept. A model for the rainfall-runoff process, both including runoff generation and routing process, was developed in Simulink as a combination of linear reservoir and linear Muskingum method. Though, the general trend of the computed discharge matches with that of the observed, there was discrepancy between these values. This discrepancy might be due to the assumption of linearity. The current study envisages the development of a control system model by a combination of Muskingum non-linear routing model and nonlinear reservoirs in the MATLAB Simulink module and its comparison with linear model.

2. Materials and Methods

2.1. MATLAB and Simulink

MATLAB and its graphical tool Simulink can be used to design, develop, and implement computational intensive complex science and engineering problems. Simulink is a graphical tool in MATLAB for the modelling and simulation of systems and it enables rapid construction of a system process. One of the main advantages of Simulink is the capability to model a nonlinear system, which a transfer function is unable to do. Models components are represented graphically as block diagrams and their interaction as connecting lines among them in Simulink.

2.2. Arc SWAT

ArcSWAT is an extension and graphical user input interface for Soil and Water Assessment Tool (SWAT) in ArcGIS. The SWAT is a physically-based continuous hydrologic model which can be used for simulating rainfall-runoff process, erosion and sediment transport, agricultural processes, and their management on complex watersheds with varying soils, land use, and management conditions over long periods of time [6]. The Arc SWAT can be used for variety of applications and is used in the current study for identifying sub basins and stream links.

2.3. Study Area

Achenkovil watershed is selected as study area. Watershed lies between $9^{\circ}00'$ to $9^{\circ}20'$ north latitudes and $76^{\circ}20'$ to $77^{\circ}20'$ east longitude. It spreads over the districts of Kollam, Pathanamthitta, and Alappuzha of Kerala State, India and covers an area of 1340 km^2 .

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