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Hydrological Modeling

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ABSTRACT: Hydrological modeling is a vast area of research. Because of high catchment variability and limitation in measurement techniques it is impossible to measure everything we would like to know about hydrological system (Tiwari et al., 2016). Application of hydrological models can reduce these limitations and make calculations much easier. Hydrological model contains spatial and temporal features and behavior of each feature is directed by its own and therefore it makes wide variety for type of hydrological models. This paper review on different types of hydrological model and also it gives brief description on Soil conservation services – curve number model SCS-CN ,Normalized antecedent precipitation index model NAPI, MIKE SHE model, variable infiltration capacity model VIC.SCS-CN and NAPI proves good for runoff calculations. VIC performs ably in moist areas and can be efficiently used in the water management for agricultural purposes. Requirement of large data and physical parameters makes the use of MIKE SHE model confined to smaller size catchments.

KEYWORDS: Hydrological model, Classification, SCS-CN model, NAPI model, MIKE SHE.

I. INTRODUCTION

Hydrology is important area of work as it responsible for availability of water on earth as well as its occurrence, circulation and distribution (Ray, 1975). It deals with each phase of hydrological cycle and describes the relationship of water with environment. The growing urbanization and industrialization are responsible for severe changes occurring in hydrologic system. The changes have direct impact on discharges of many water bodies around the world. In order to estimate these changes it is important to study different hydrologic phenomenon and hydrological cycle thoroughly. Hydrological model proves important and necessary tool for calculation of various impacts occurring on water resources (Chow 1988). The major inputs used by most of the hydrological models are rainfall, air temperature, soil characteristics, vegetation, topography and other physical parameter

II. HYDROLOGICAL MODELING

Hydrological modeling provides sustainable measure for watershed management (Poonia and Tiwari, 2020) .Sorooshian 2008 defines a model as simplest representation of factual world system. The model which provides results nearby to reality using least parameters is considered to be best model. Models are used for determining system behavior and evaluating various hydrological processes. Runoff model can be described as cluster of equations to determine runoff as a function of different factors used to define characteristics of watershed. The rainfall data and drainage area are two major inputs required for all the models. Also watershed characteristics like land use land cover, slope, size, shape, soil conditions, etc are also considered. Hence model characteristic is defined by various parameters which the model consists. Hydrological models are now taken as an important tool for water resource management.

III. BASIS OF HYDROLOGICAL MODELING

The American Society of Civil Engineers (ASCE) introduced the basic terms for different types of mathematical model like analytical models; dynamic models; deterministic models; stochastic models; empirical models; simulation models etc. However, hydrological models are mostly mathematical from four basic categories, simulation basis, temporal basis, spatial basis, and method of solution. Each of these categories is divided into various subcategories. Simulation basis consist of physical, conceptual, empirical or regression and stochastic time series. Spatial representation includes lumped, distributed and coordinate system. Temporal representation

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includes steady state, single-event and continuous representation.

IV. DIFFERENT MODEL TYPES

Rainfall runoff models are majorly classified into lumped and distributed model based on model parameter as a function of space and time and deterministic and stochastic model based on some other criteria. Stochastic model can give different output for single input set but deterministic model will give same result for single set of input. Other type is static and dynamic model. Dynamic model include time while static model does not include time. One of classification given by Sorooshian 2008 is event based and continuous model. Event based model produces one output for specific time period and continuous model gives continuous results. Other major classification is empirical model, conceptual model, and physically based model (Refsgaard 1997).

Empirical model

These models take information from existing data without taking consideration of processes of hydrological system. These models are data driven models. Mathematical equations plays important role in such models and are derived from concurrent input output time series. Mathematical equations have no linkup with physical processes of catchment. Empirical model works within some boundaries. An example of this model is unit hydrograph theory for event based catchment-scale simulation developed by author (Sherman 1932).

Conceptual model

This model explains all component of hydrological process (Jajarmizadeh et al. 2012). The model is formulated with a number of conceptual elements which are simple portrayal of a reference system. Conceptual models advantage is its non linearity which reflect hydrological system's threshold. Further its classification is into event and continuous models. Former simulate single event for period ranging from an hour or less to several days and latter work over an extended period (salarpour et al. 2011).

Physical based model

Real phenomenon is represented by this model. These are mechanist model consisting principles of physical processes. It is based on spatial distribution. This model requires data about initial state of model and morphology of catchment. It does not need extensive meteorological data for calibration but evaluation of large number of parameters for physical characteristic of catchment is required (Abbot et al. 1986 b) .

V. BRIEF DESCRIPTION OF FEW MODELS

SCS-CN model:

This is considered as conceptual model. Soil conservation services – curve number model is developed by USDA (U.S department of agriculture). The model is used for calculation of runoff depth especially in catchments ranging from 0.25 hectare to 1000kmsq.This method uses triangular synthetic unit hydrograph and peak rates of surface runoff to estimate the storm runoff (Williams et al., 1976). The parameters considered in this model slope, vegetation cover, area of watershed (Balvanshi et al. 2014) .The accurate curve number is also needed to be calculated. This actually defines the runoff potential. Parameters used for curve number calculations are hydrologic soil group, land use type, vegetation cover, soil conservation measures, antecedent soil moisture condition etc (Kumar and Tiwari, 2015). Runoff by this model is given by equation $Q = \frac{(P-I_a)^2}{(P-I_a+S)}$ if P> I_a where I_a is initial abstraction, S is potential maximum retention, P is precipitation (Ara et al. 2018). With the help of GIS techniques, this model shows more appropriate results (Balvanshi and Tiwari, 2006)

NAPI model:

Normalized antecedent precipitation model is developed based on water balance equation. This model is modification over antecedent precipitation index in three aspects, it includes antecedent precipitation earlier in the day of event; normalized station mean; and normalized antecedent series length. Hagen, 2001 proposed the following equation for computation of runoff $\frac{Q}{P} = 1 - e^{a+bP+cNAPI}$ where Q is runoff due to rainfall event P; a is dimensionless quantity; b is a dimensional quantity of dimension inverse of P; and c is dimensionless quantity and NAPI is ratio of API extended to precipitation on the day, but before storm, to the average daily precipitation multiplied by the weighted sum due to decay constant in the respective day. This model is less data driven, simple to use and less subjective to physical conditions and can be potential candidate for runoff prediction.

MIKE SHE model

It is physical based model and requires extensive physical parameters. This model was developed in 1990. The model describes different hydrological cycle processes such as precipitation, evapotranspiration, interception, river flow, saturated ground water flow etc. it can simulate surface and ground water movement, sediment transport etc. DHI-WE provides full and detailed manual of MIKE SHE. Code consists of all pre-processing and post-processing modules. MIKE SHE take care of the major processes in the hydrologic cycle and incorporate process models for evapotranspiration, overland flow, unsaturated flow, groundwater flow, and channel flow and their interactions. Each of these processes can be represented at various levels of spatial distribution and complexity, according to the goals of the modeling study, the availability of field data and the modeler's choices (Buttes, 2004).

VIC model

Variable infiltration capacity model is semi distributed grid based model which uses energy equation and water balance equation. Major inputs for this model are precipitation; minimum and maximum daily temperature and wind speed. Processes like runoff, base flow, infiltration are based on various empirical relations. Soil heterogeneity and precipitation is considered for simulation of excess runoff. It includes three layers. Top most layers allow soil evaporation, middle layer show dynamic response of soil to rainfall events and lower layer is used to describe the behavior of soil moisture. Modified VIC model consist of both infiltration excess runoff and saturation excess runoff and effect of variability of soil heterogeneity on surface runoff characteristics. The model is applied to number of river basins and helps in predicting climate and land changes.

VI. DISCUSSION

Original SCS-CN has many limitations over curve number calculations and moisture condition consideration. sharply and Williams modified the model and gave slope correction for curve number. NAPI can be used for calculation of runoff of ungauged catchment by predicting its geomorphologic parameters using cumulative geomorphologic index developed by geomorphologic parameters of gauged and ungauged catchment (Ghosh et al. 2021). Nijssen 1997 coupled VIC model with simple grid based network and stated that it perform well in moist areas. Author used this model for irrigation planning in a small watershed and found out that it can be efficiently used for the water management for agricultural purposes (Singh et al. 1999).Yang et al, 2000 compared 3 models and recommended that MIKE SHE model can be used in smaller size catchments. MIKE SHE model requires extensive model data and physical parameter which may not be obtainable all the time and make it tough to set up the model. Also users are unable to modify and adjust the code but it had high processing ability compared to other models. It has large-scale graphical capabilities for pre and post processing and thus makes the modeling easier. Abu al Nasar ,2005 found that it will produce models of equal or superior ability compared to other codes. The sensitivity analysis is done so as to understand how sensitive a model is to certain parameters. This is important to identify with how the model functions and also what parameters need more consideration and importance than others (Chouhan et al., 2006).

VII. CONCLUSION

Rainfall-runoff models are the standard tools used for examining different hydrological processes. A large number of models with different applications been developed. These model ranges from small to large catchments. Each model has got its own exclusive characteristics and respective applications. Some of them are comprehensive and depend on the physics of underlying hydrological processes and are distributed in space and time. The models are used for the modeling of both gauged and ungauged catchments, helps in flood forecasting, proper water resource management and evaluation of water quality, erosion and sedimentation, land use and climate change etc. Each model has various limitations like lack of user friendliness, extensive data requirements, absence of clear statements of their drawbacks etc. Involvement of technologies like remote sensing and artificial intelligent has reduced these limitations to much extent. There are many choices available for hydrological models, its classification helps experts to select and apply most appropriate model for required work. Reviewing of models ensures deeper understanding of model characteristics.

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