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Rainfall Runoff Modelling of Madhura Watershed Using Snyder's Model

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Abstract—*Derivation of unit hydrograph for an ungauged watershed having no rainfall records is important for planning and management of water resources. Usually, models that rely on geomorphological characteristics of a catchment are used to define rainfall-runoff relationships of an ungauged catchment. Accuracy in predicting run off response by an established model such as SCS, IUH, NASH depend on the accuracy of the estimated geomorphological parameters and can be improved by using GIS techniques. In this paper a study is carried out to ascertain the effectiveness of GIS in deriving unit hydrograph of an ungauged watershed by employing Snyder model. Madhura watershed in Barak basin, an ungauged catchment, of area 349.43 sq. km, is the selected as the study area. Geomorphological features of the watershed are estimated by applying GIS technique and are used to determine the Snyder model parameters C_p, the peak flow factor, and C_t, the lag factor. Unit hydrograph for the catchment is obtained by using computed Snyder parameters are compared with the known values to determine efficiency of the model. Results obtained indicate satisfactory model performances.*

1. INTRODUCTION

Water is one of the most basic requirements for life on planet Earth and also, one of the most important available natural resources. With the fast paced growth in population, urbanization, industrialisation, and advanced agricultural practises, it has become a prime concern for proper management and utilisation of the available water resources. Hydrologic modelling, primarily rainfall-runoff modelling is an effective means of utilisation and management of the available water resources. In most of the countries, watersheds are ungauged or very poorly gauged with hardly any record of rainfall or stream flow data, as a result, establishment of rainfall runoff relation in such poorly gauged or completelyungauged catchments become very difficult and sometimes, quite impossible.Derivation of unit hydrographs for ungauged catchments, which are required for modelling purpose also become complicated.And so was Synthetic Unit hydrograph introduced. Synthetic unit hydrographs were derived by using established relations between the basin parameters and unit hydrograph parameters of the gauged basins to the ungauged basin in the hydro-meteorologically homogenous area.Some common synthetic unit hydrograph techniques for ungauged basins are Snyder's SUH, SCS Dimensionless hydrograph, Instantaneous Unit Hydrograph (IUH) and Geomorphological Instantaneous Unit Hydrograph (GIUH). Hydrologic models that rely on geomorphological parameters can be applied to derive synthetic unit hydrographs. Geographic Information System (GIS), a rapidly advancing tool, in the field of spatially varying objects can be used in calibrating geomorphological parameters. Incorporation of GIS techniques in existing hydrologic models ensures superior model accuracy and applicability. In this paper, a study has been has been carried out in the Madhura watershed of Barak basin. Snyder's Synthetic unit hydrograph technique has been used. The geomorphological parameters required are obtained using GIS.

2. SNYDER SYNTHETIC UNIT HYDROGRAPH

The Snyder method is the precursor to all synthetic unit hydrographs. Snyder proposed a synthetic unit hydrograph model based on relationships found between characteristics of a standard unit hydrograph and descriptors of basin morphology. Since peak flow and time of peak flow are two of the most important parameters characterizing a unit hydrograph, the Snyder method employs factors defining these parameters, which are then used in the synthesis of the unit graph (Snyder, 1938). The basic assumption in this method is that basins which have similar physiographic characteristics are located in the same area will have similar values of $\mathbf{C_t}$, the lag factor, and$\mathbf{C_p}$, the peak flow factor. The hydrograph characteristics are the effective rainfall duration, t_r, the peak direct runoffrate, q_p, and the basin lag time, t_p. From these relationships, five characteristics of a requiredunit hydrographfor a given effective rainfall duration, viz., the peak discharge per unit of watershed area, q_{pR}, the basin lag, t_{pR}, the base time, t_b, and the widths, W (in time units) of the unit hydrograph at (W_{50}) 50% and (W_{75})75%of the peak discharge**,** may be calculated.A standard unit hydrograph is associated with specific effective rainfall duration, *tr*, defined by the following relationship with basin lag, *tp*,

$$T_p=5.5tr \quad (a)$$

For a standard unit hydrograph the basin lag, *tp*, and the peak discharge, q_p, are given by,

$$t_p= C_1C_t(L*L_c)^{0.3} \quad (b)$$

$$q_p= (C_2C_pA)/t_p \quad (c)$$

The basin lag time of the standard unit hydrograph is in hours, *L* is the length of the main stream in kilometres from the outlet to the upstream divide, $L_c$is the distance in kilometres from the outlet to a point on the stream nearest the Centroid of the watershed area, and C_1 = 0.75 (1.0 for English units).The peak discharge of the standard unit hydrograph is in m^3/s, *A* is the basin area in km^2, and C_2= 2.75 (640 for English units).If t_p is different from 5.5*tr*, then basin lag for the required unit hydrograph is calculated as

$$T_{pR}= t_p-\{(t_r-t_R)/4\} \quad (d)$$

The peak discharges of the standard and required UH are related as

$$Q_{pR}= (q_p*t_p)/t_{pR} \quad (e)$$

Assuming a triangular shape for the UH, and given that the UH represents a direct runoff volume of 1 cm (1 in), the base time of the required UH may be estimated by,

$$T_b= (C_3*A)/q_{pR} \quad (f)$$

Where, *C3* is 5.56 (1290 for the English system).

The width in hours of the UH at a discharge equal to a certain percentage of the peak discharge $q_{pR}$is given by Chow et al. (1988) as,

$$W_{\%}=C_w*(q_{pR}/A)^{-1.08} \quad (g)$$

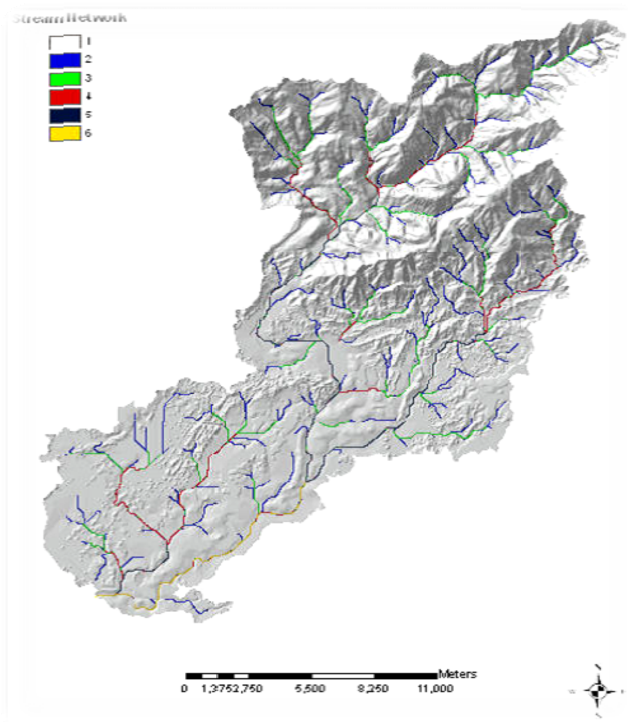
Where, the constant $C_w$is 1.22, for the 75% width and 2.14, for the 50% width.

3. STUDY AREA

Madhura watershed, located in Barak basin, is the selected study area. It is the second largest river system in the north eastern region of India. Madhura watershed is an ungauged catchment spreaded over an area of 349.43 sq. km with highest elevation of 1740 m from main sea level. The length of the main stream is 52.61 km and the highest ordered stream is 6^{th} of length 14.59 km. the watershed lies between latitudes 24°45' N and 25°15'N, and longitude 92°45E and 93°15E.

4. MODEL APPLICATION

Hydrologic responses of a watershed are found to depend on the geomorphological characteristics of the watershed. For deriving UH using Snyder's technique watershed characteristics such as stream order, stream length, watershed area, etc. are required. These characteristics can be estimated using Geopgraphic Information System. Topomaps of scale 1:50,000 are collected from survey of India and is processed and georeferenced using Arcgis 10.1. The georeferenced map is then used to calculate the area and length. ASTER (Advanced Spaceborne Thermal and Reflection Radiometer) with resolution 30m x30 m and SRTM (Shuttle Radar Topography Mission) with resolution 90m x 90 m providesdigital elevation model (DEM) for a watershed and are readily available in the websites(http:// www. gdem.aster.ersdac.or.jp) and (http://srtm.usgs.gov/) respectively. The DEMs are further processed to prepare drainage network. On the basis of the drainage network, stream lengths of different stream order are determined. The estimated watershed parmeters are then applied in the Snyder equations to derive the Synthetic Unit hydrograph. The derived SUH is then compared to an already existing UH to check the validity of the model.



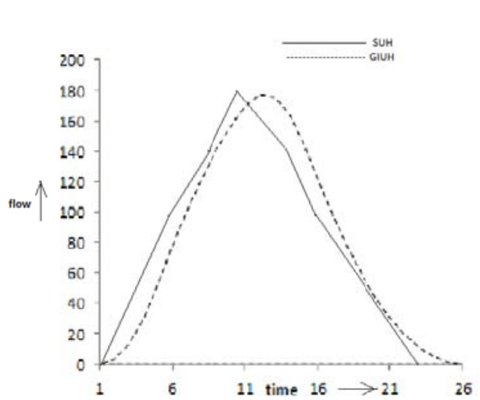
4.1.: Figure: Madhura watershed showing streams of different stream order

5. RESULT

From a derived Geomorphological Instantaneous Unit Hydrograph with discharge of q_{pR}= 2.27 $m^3/s.km^2.cm$, the synder synthetic unit hydrograph technique is initiated. The area of the watershed, A, length of the main stream in kilometres from the outlet to the upstream divide, L and the distance in kilometres from the outlet to a point on the stream nearest the Centroid of the watershed area, $L_c$are determined using GIS as 349.43 sq. km, 14.56 km and 52.661 km respectively. The regionally varying parameters viz., $\mathbf{C_t}$, the lag factor, and $\mathbf{C_p}$, the peak flow factor are then calculated using the above ascertained parameters in equations (b) and (c), and are found to be as .12 and .55 respectively.The calibrated C_t and C_p are then used to derive Synthetic Unit hydrograph of a sub watershed of Madhura to check the efficacy of the model. The sub watershed is of area 72.78 sq. km., L= 4.23 and L_c= 17.31.

5.1 Table: Model Comparision of Madhura sub watershed

MODEL	Time to peak(hours)	Peak Discharge	Base Time(hours)
GIUH	1.1	177.1	2.5
SUH	.9	179.33	2.26



5.2 Figure: Comparison of 1 Hour UH using GIUH and SUH for Madhura sub watershed.

6. CONCLUSION

The present study provides a report on estimation of Snyder parameters viz., $\mathbf{C_t}$, the lag factor, and $\mathbf{C_p}$, the peak flow factor. The estimated Snyder parameters can be used in similar geographic locations to derive UH of ungauged watersheds. The described method is very cost effective, time saving and quite accurate. The results obtained indicate satisfactory model performance. The Snyder parameters can be further improved with more number of model performances.

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