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Research Article

Synthetic Unit Hydrograph for Un-gauged Basins using Geomorphologic Instantaneous Unit Hydrograph (GIUH) based Nash model

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ABSTRACT

The present study examines one of the most widely used flood hydrograph modelling approach for gauged and un-gauged basins and efforts have been made to produce Synthetic Unit Hydrograph (SUH) with the help of Nash Model, which has a low relative error and based on the Geomorphological Instantaneous Unit Hydrograph (GIUH). Under the suggested methodology forty one tributaries of Narmada basin were selected from the state of Madhya Pradesh and Gujarat for study purpose. Arc-GIS 10.2.2 software was used for analysis purpose. SRTM Image popularly known as Digital Elevation Model (DEM) was used as an input. Various Geomorphological characteristics of the streams as output were derived from Arc GIS software: Stream Order, Total number of streams of different order, Stream Length, Area of the catchment, Slope of the area, etc. The complete data was derived through Arc-GIS 10.2.2 software and various parameters were extracted. From the Geomorphological parameter obtained, the Nash parameters were derived and synthetic Unit Hydrograph was produced and was found smooth and time saving. The result shows that Bifurcation Ratio=4.17779, Stream Length Ratio=2.890911, Stream Area Ratio=2.55258, Main stream Length (km) =56.66, average slope (S) = 0.077068 (m/m) = 7.7 %, Dynamic velocity (m/s) = 3.956173766, Nash parameter (n) =5.2412, Nash parameter (K in hr.) = 1.30188, Peak Time (t_P) = 5.521533456 hr, Peak Discharge (q_P) = 335.1370794 cumec.

KEYWORDS : Geomorphologic Instantaneous Unit Hydrograph, GIUH, Nash Model, GIS, Arc-GIS, DSRO, rainfall-runoff, Un-gauged Catchment, SRTM, DEM, Digital Elevation Model.

1 INTRODUCTION

Water is seen as a fundamental component for all forms of survival. To keep the demand and supply in balance, a lot of technical effort is required. These engineering skills are necessary for the planning, design, and construction of dams and barrages, among other things. The safety measures are mostly based on the discharge flow, but they must also be safeguarded against a flurry flood. These structures are extremely useful during floods because they are built on the basis of a chosen design flood and effective reservoir functioning.

In comparison to other approaches, GIUH has the advantage of not requiring rainfall and meteorological data for catchments in that region. Through empirical relationships, the basin

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geomorphology and hydrology link was better understood. The usefulness of a parametric approach for the derivation of unit hydrograph to build a relationship between the Unit Hydrograph with basin characteristics is highlighted in this study. The GIUH was created using a stream with a specific order and a linear response function. In circumstances where rainfall data is available but no runoff data available, the GIUH technique would be use. By assuming that the GIUH model's peak runoff is known, the approach comprises finding Nash model parameters. In the current study, GIUH-based Nash model is utilized to estimate floods in un-gauged watersheds with an acceptable degree of accuracy.

2 OBJECTIVES

Following are the objectives of the study:

1. To find out an optimum technique for developing Synthetic Unit Hydrograph for un-gauged basins.
2. To find out the suitable area for the study purpose to achieve the program objectives.
3. To derive various input parameters for GIUH based Nash model with the help of Geomorphological techniques using Arc-GIS software.
4. To extract various parameters for SUH using Nash model.
5. To develop Synthetic Unit Hydrograph for un-gauged basin

3 STUDY AREA AND DATA COLLECTION

For the purpose of the study, forty one tributaries of Narmada basin were taken from the state of Madhya Pradesh and Gujarat. In the Narmada basin, most of the tributaries are un-gauged. These tributaries flow in two directions, one on the southern side and the other on the northern side. There are roughly 22 on the southern side and 19 on the northern side. Study area selected for the present study has one of the tributaries of Narmada basin i.e. Uri watershed, situated on the right bank of basin. Table 1 shows basin characteristics of Narmada River and Uri watershed. Fig. 1 shows the DEM map of the Uri watershed to determine the relevant Geo-morphological characteristics of the watershed.

Table 1: basin characteristics of Narmada River and Uri watershed.

S.no.	Parameters	Properties or Value
1	Study Area	The Narmada River flow in the Amarkantak plateau in the shahdol district of Madhya Pradesh.
2	Elevation of origin of Narmada River	1057 meter above mean sea level (msl)
3	Geographical Location of Uri Watershed	74° 47' E longitude
		22° 36' N latitude
4	The total distance travelled by the Narmada River before it falls in Arabian sea.	1312 km
5	Origin of Uri Watershed	Vindhya range of Madhya Pradesh
6	Nature of Uri Watershed	Un-gauged
7	An elevation of Uri Watershed	450 m
8	Total length of Uri Watershed	74 km

Figure 1: DEM map of the Uri watershed

4 METHODOLOGY AND DATA ANALYSIS

Digital Elevation model has been used and various Geomorphological characteristics have been extracted and synthetic Unit Hydrograph has been developed through various steps as mentioned below.

4.1 Digital Elevation Model (DEM)

The DEM data for this study has been extracted from the SRTM. Using the ArcGIS tool, the catchment of the Uri watershed basin was delineated using a DEM map of India.

4.2 Extraction of Geomorphological Characteristics from DEM

Various sequential steps has been mentioned in the flow chart mentioned below for DEM processing.. The Horton's ratio and other Geomorphological parameters were calculated using Arc GIS after using the above approach. Fig.2 shows flow chart for DEM processing

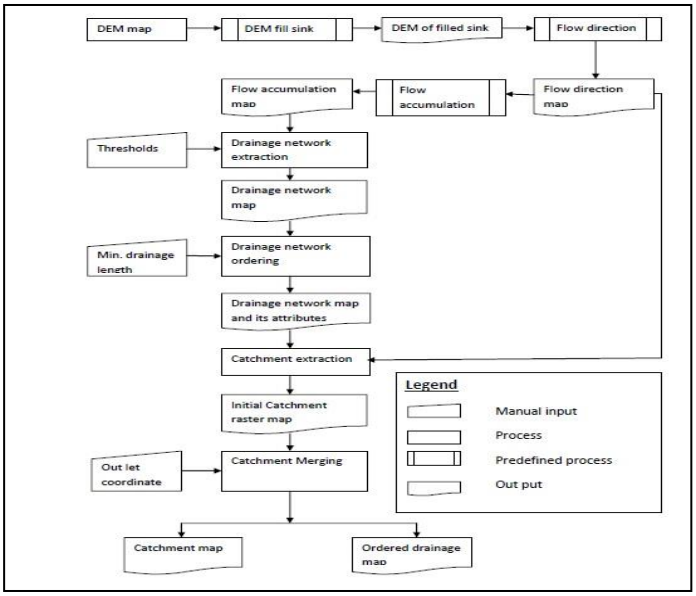

Figure 2: Flowchart for DEM Processing

4.3 GENERATION OF GIS DATABASE

Data has been classified from the above process. Geomorphological data has been measured and derived. Stream networks and water bodies are depicted on the drainage map for the research region. Soil Map which provides information on the several types of soils found in the watershed. This information has been be used to predict the runoff capacity of various soils and Contour Map, that connects places of equal elevation. Table 2 & 3 show Measured Geomorphological data& Derived Geomorphological data respectively.

Table 2: Measured Geomorphological data

Stream Order	Total number of streams	Total Length (km)	Mean stream length of highest order = L_W (km)
1	282	377.298	56.66
2	68	164.327	
3	13	94.723	
4	3	32.2821	
5	1	56.66	

Table 3: Derived Geomorphological data

Stream Order	Mean stream Length (km)	Mean stream area (A_w)	Bifurcation Ratio (R_B)	Stream Length Ratio (R_L)
1	1.33793617	4.008	4.147058824	
2	2.416573529	18.011	5.230769231	1.806194932
3	7.286384615	54.671	4.333333333	3.015171906
4	10.7607	184.58	3	1.476822947
5	56.66	826.34		5.265456708
Average			**4.177790347**	**2.890911623**

4.4 DERIVATION OF NASH MODEL PARAMETERS FROM PEAK DISCHARGE (q_P) AND PEAK TIME (t_P) OF GIUH

The drainage map shown below, depicts the area's drainage pattern, as well as stream density and existing tank information. It also provides information on tank status, such as water distributed area, silted portion, and so on. This data will be aid in the preparation of plans for the rehabilitation of these degraded tanks. The GIS database has been utilized to understand the activities in the watershed and to evaluate the temporal variations in this area. The land capability map has been generated using the soil map. The land capability map created in this way is used to create a land adjustment map, which provides information on cropping pattern adjustments required for improved agricultural production. The most suitable method is a quantitative morphometric examination of the drainage basin since it allows us to comprehend the relationship between various features of a drainage basin's drainage pattern and numerically defined a lot of good drainage basin parameters for the purpose of comparing the development of different drainage basins under diverse geology and climatic conditions. Fig. 3 shows drainage map. Fig. 4 shows equation to derive Nash model parameter through flowchart. Table 4 shows different parameters derived. Table 5 shows GIUH ordinates based on Nash model parameters. Fig. 5 shows Synthetic Unit Hydrograph (SUH) derived for Uri Watershed.

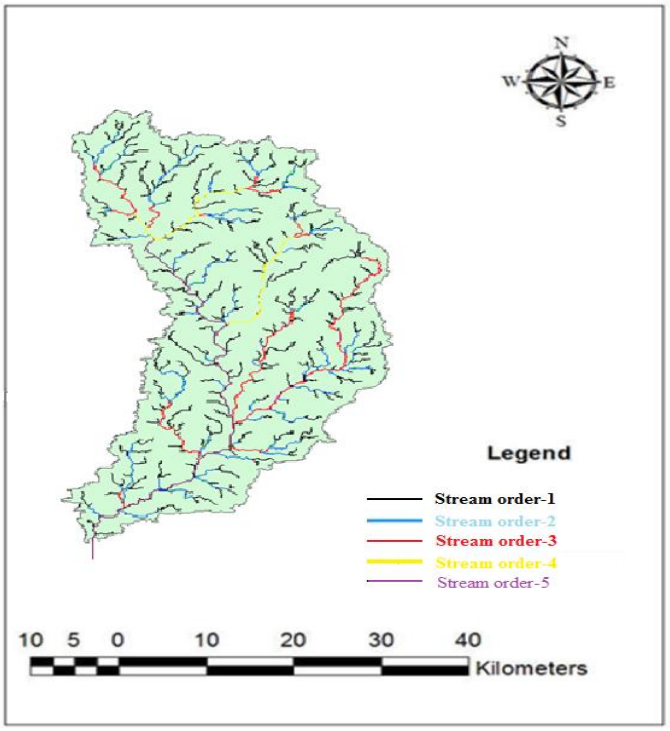

Figure 3: Drainage Map with stream order

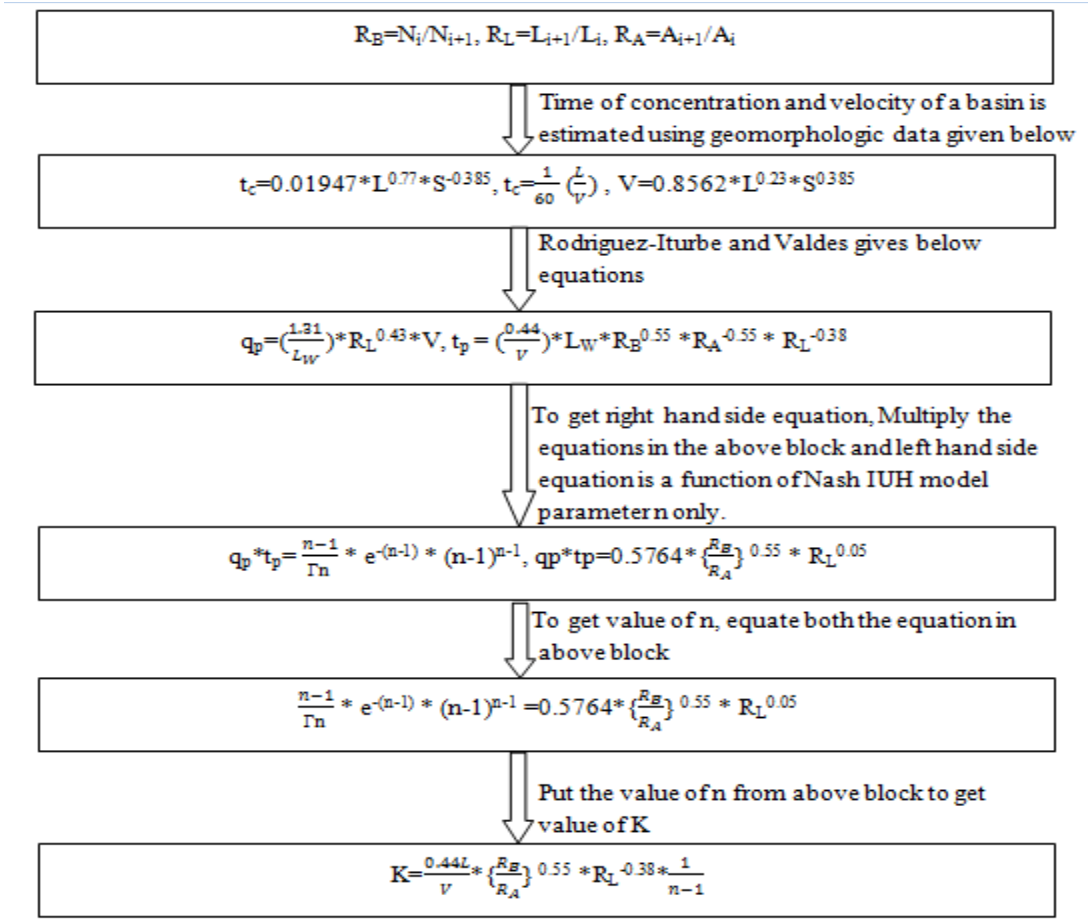

Figure 4: equation to derive Nash model parameter through flowchart.

Table 4: value of different parameter derived

S.No.	Parameter	Value
1	Bifurcation Ratio	4.17779
2	Stream Length Ratio	2.890911
3	Stream Area Ratio	2.55258
4	Main stream Length (km)	56.66
5	average slope S (m/m)	0.077068
6	Dynamic velocity (m/s)	3.956173766
7	Nash parameter (n)	5.2412
8	Nash parameter (K in hr)	1.30188
9	Peak Time = t_P (hr)	5.521533456
10	Peak Discharge = q_P (cumec)	335.1370794

Table 5: GIUH ordinates based on Nash model parameters.

Time t in hr	U(t) in cumec	Time t in hr	U(t) in cumec
0.25	0.038431	13	40.48234
0.5	0.599317	14	25.71215

0.75	2.759854	15	15.98057
1	7.713097	16	9.746388
2	67.60919	17	5.846395
3	175.0018	18	3.45581
4	274.9112	19	2.016134
5	328.4737	20	1.162468
5.521533	335.1371	21	0.663183
6	330.0949	22	0.374719
7	294.3764	23	0.209879
8	240.5462	24	0.116613
9	183.8633	25	0.064317
10	133.3265	26	0.035234
11	92.64698	27	0.019181
12	62.15334		

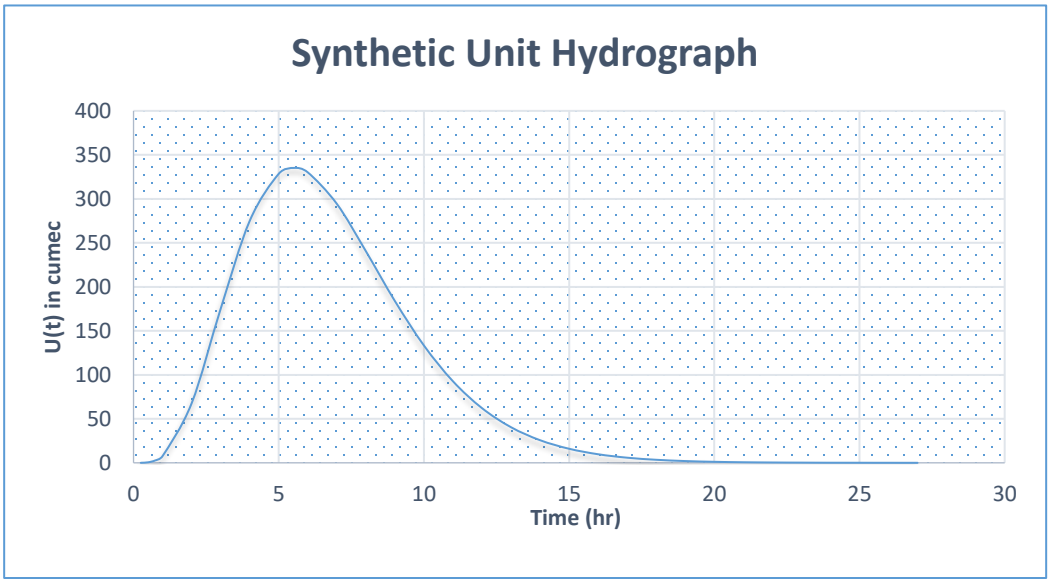

Figure 5: SUH for Uri Watershed

5 CONCLUSIONS

1. The study shows that GIUH based Nash Model is found to be highly effective for developing Synthetic Unit Hydrograph since the majority of the required basin parameters are retrieved from DEM data.

2. The study shows that Uri Watershed, tributary of Narmada River is lies in the range between 200 hectares to 5000 km^2 and has been found highly suitable for study purpose, since the limitation of the unit hydrograph will automatically be the limitation of suggested model as well.
3. The study indicates that all input parameters: Stream Order, Total number of streams of different order, Stream Length, Area of the catchment, Slope of the area, etc., have been successfully derived using Geomorphological techniques with the help of Arc-GIS software to achieve the program objectives**.** The Geomorphological data found are: Bifurcation Ratio=4.17779, Stream Length Ratio=2.890911, Stream Area Ratio=2.55258, Main stream Length (km) =56.66, average slope (S) = 0.077068 (m/m) = 7.7 %.
4. The study shows that various parameters required for developing SUH extracted successfully with help of input parameters obtained through Geomorphological techniques used in GIUH based Nash model: Dynamic velocity (m/s) = 3.956173766, Nash parameter (n) =5.2412, Nash parameter (K in hr) = 1.30188, Peak Time (t_P) = 5.521533456, Peak Discharge (q_P) = 335.1370794.
5. The overall study shows that Synthetic Unit Hydrograph developed is found to be smooth and effective.

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