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Statistical Validation of Synthetic Unit Hydrograph for Ungauged Basin

Gunjagi D.A[1], Chaudhari A.S.[2], Deshmane P.H.[3], Khedekar A.D.[4], Jadhav P.S.[5], Mangutkar T.N.[6]
[1] *Asst. Professor, Dept. of Civil Engineering, Sanjay Ghodawat Group of Institutions, Kolhapur, Maharashtra, India.*
[2, 3 ,4 ,5, 6] *Student of BE, Dept. of Civil Engineering, Sanjay Ghodawat Group of Institutions, Kolhapur, Maharashtra, India.*

Abstract: ***For design of culverts, bridges, barrages, small dams, embankments, protective works and water supply schemes, the peak flood discharge is of greatest concern on the basis of which the sizes, capacities, location, and outlets of these structures are fixed. The magnitude of floods is described by flood discharge, elevation and volume, each of which is important for design of a structure. For design of important structures, complete flood hydrograph at the site is also an important requirement. This project include study of ungauged basin to derive Synthetic Unit Hydrographs (SUH) from empirical relations between the salient Hydrograph characteristics and basin characteristics and statistical validation. Results indicated that for this basin, Direct Runoff Hydrograph (DRH) prediction using average Unit Hydrograph (UH) from storm 5 provided minimum Error Root Mean Square (ERMS) of 4.11m3/s and η of 95.06%. Therefore, average storm UH5 from 10 storm event was considered an average representative UH for the Dhamani basin. It is the best UH representing the basin with minimum ERMS and maximum efficiency shows the computed and observed DRHs.***

Keywords: Synthetic unit hydrograph, ungauged basin, statistical methods, PUB, peak discharge

I. INTRODUCTION

For design of important structures, complete flood hydrograph at the site is also an important requirement. It is possible to compute floods to a reasonable extent by adopting various types of structural and non-structural measures. However, this requires accurate prediction or forecasting of flooding events in the region of interest on the basis of which protection measures may be designed. In India, practicing engineers in the field of hydrology are facing the problem of inadequate information about the quantity and quality of water resources data that arises from poorly developed hydrological networks. Like most of the developing countries India too lacking in financial, human and technical resources for developing and maintaining networks that can provide data for sustainable water resources planning, design and management. This leads to unplanned depletion of water resources and degradation of the ecosystem, consequently affecting the quality of human life. The problems arising from lack of data will persist in the foreseeable future. It is also not possible to set up an ideal network, as some sites are inaccessible. Predictions in Ungauged Basins (PUB) was an IAHS initiative operating throughout the decade of 2003-2012, established with the primary aim of reducing uncertainty in hydrological predictions. Predictions of ungauged basins under these conditions are highly uncertain. The IAHS Decade on Predictions in Ungauged Basins, or PUB, is a new initiative launched by the International Association of Hydrological Sciences (IAHS).

II. OBJECTIVES OF STUDY

A. To prepare catchment maps for the selected study area and to find the geomorphological characteristics of the basins.
B. To derive 1-hour unit hydrograph from the observed data for catchment of river Dhamani.
C. To examine the predictive capability of unit hydrographs derived for various statistical methods.
D. To develop average representative unit hydrograph from the Dhamani basin.
E. To test empirical methods by which a representative basin could be used to develop synthetic unit hydrograph for the un-gauged basin.

III. METHODOLOGY

A. To use GIS techniques to prepare catchment maps and to evaluate the geomorphological characteristics for the study area.

The Dhamani basin comprised of horizontally disposed dark gray massive and Amygdaloidal basalts of the Deccan trap formation. This basalt at higher levels have been lateralized. The length (L) of the river considered for study is about 33.53 km and the catchment area (A) is about 156km^2. It lies on latitude 16037' north and longitude 73059' east. Figure 1 shows the location map and of Dhamani basins.The GIS software is used in present study the boundaries of the catchments and all the streams have been mapped at a scale of 1:50,000 from survey of India topo sheets 47-H/14, 15.

LOCATION MAP

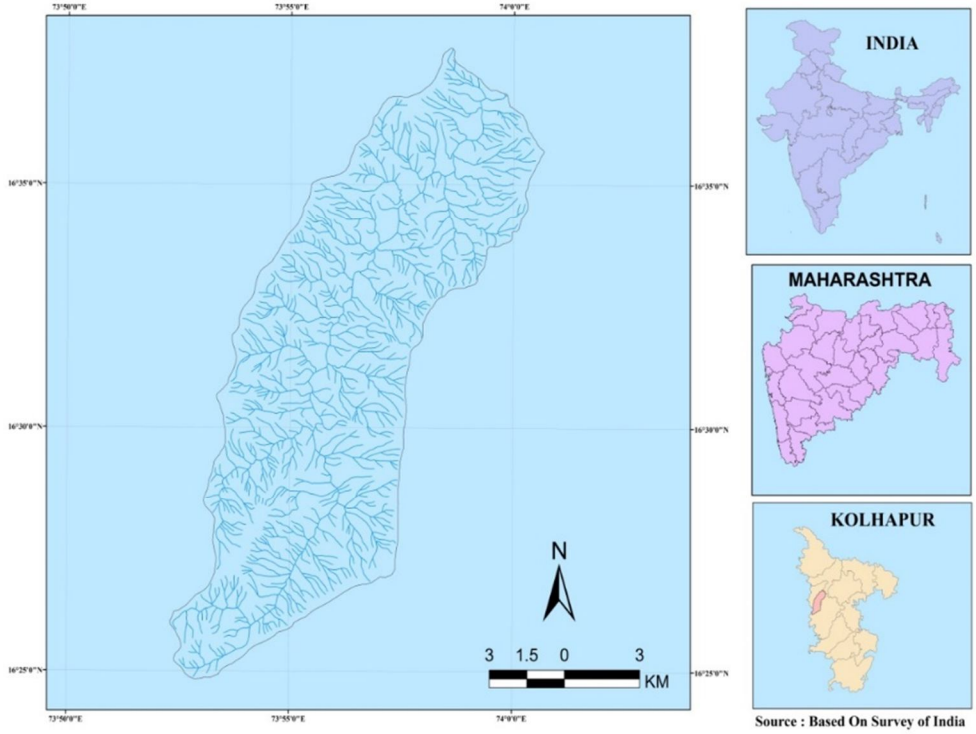

Table I: Catchment characteristics of Dhamani basins

CATCHMENT CHARACTERISTICS	SYMBOL	SI UNIT	DHAMANI BASIN
Drainage area of the basin	A	Km^2	156
Watershed perimeter	P_W	Km	64
Watershed length	L_W	Km	25.05
Watershed width	W_W	Km	7.184
Length of main channel	L	Km	33.53
Length between outlet and centroid of the basin	L_V	Km	16.46
Slope of main channel	S_0	m/km	0.218
Number of 1^{st} order streams	N_1	No.s	613
Length of 1^{st} order streams	L_1	Km	356.659
Number of 2^{nd} order streams	N_2	No.s	131
Length of 2^{nd} order streams	L_2	Km	106.551
Number of 3^{rd} order streams	N_3	No.s	33
Length of 3^{rd} order streams	L_3	Km	50.842
Number of 4^{th} order streams	N_4	No.s	4
Length of 4^{th} order streams	L_4	Km	11.437
Number of 5^{th} order streams	N_5	No.s	1
Length of 5^{th} order streams	L_5	Km	21.809

B. To derive one hour unit hydrographs for the selected basin from the available rainfall-runoff data using single event method.

One hour unit hydrograph is derived by using single event method for the selected basin (DHAMANI). The records of hourly rainfall from single self-recording rain gauge station at PATRYACHIWADI (PT) for DHAMANI basin are collected from hydrology project circle, Nasik. For the chosen storms, the hourly discharges at gauging station PATRYACHIWADI corresponding to the recorded stages are noted.

Table II: Hourly discharge from 07/09/2007(1.00 hr.) to 08/09/2007(1.00 hr.)

TIME	DISCHARGE	GAUGE
07/09/2007 01:00:00	52.81	2.90
02:00:00	55.83	2.96
03:00:00	65.15	3.14
04:00:00	98.85	3.74
05:00:00	118.28	4.06
06:00:00	115.80	4.02
07:00:00	112.72	3.97
08:00:00	106.03	3.86
09:00:00	103.02	3.81
10:00:00	99.44	3.75
11:00:00	88.92	3.57
12:00:00	81.53	3.44
13:00:00	77.06	3.36
14:00:00	74.31	3.31
15:00:00	71.58	3.26
16:00:00	71.58	3.26
17:00:00	69.42	3.22
18:00:00	69.42	3.22
19:00:00	68.89	3.21
20:00:00	67.81	3.19
21:00:00	67.28	3.18
22:00:00	67.28	3.18
23:00:00	65.68	3.15
08/09/2007	65.15	3.14
01:00:00	66.21	3.16

C. Use statistical validation method viz.; leave one out cross validation, leave half cross validation with replication, bootstrap validation and 0.632 estimator methods etc. To find to best average unit hydrograph which gives minimum Root Mean Square Error (RMSE) and can represent basins with similar hydrological conditions. Following result is obtained from leave one out cross method, EFFICIENCY=95.06, RMSE= 4.11

D. To process the data by different methods of empirical synthesis of hydrograph viz. Snyder, Soil Conservation Services, CWC etc. and then compare with average unit hydrograph.

By studying UHs for 58 watersheds ranging in area from 10 to 3090 m^2, Mitchell (1948) established an SUH method based on the basin lag and summation curve according to classification area less than 175m^2, area of 175m^2 to 750m^2 ,and area over 750m^2.

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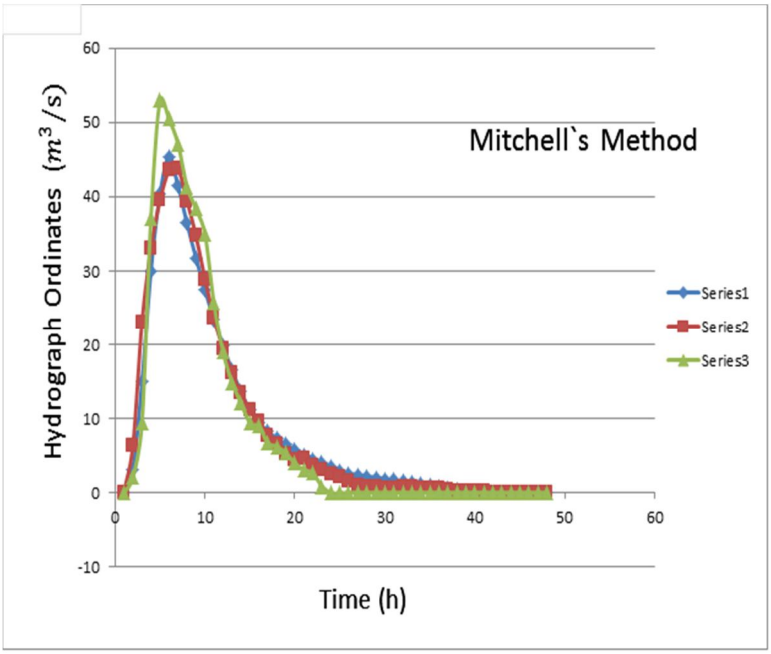

Fig. 1 - SUH for Mitchell's Method

E. To see whether and to what extent there is any compatibility between them and to check whether there is any impact of geomorphological parameters on the results.

IV. RESULT AND DISCUSSION

For the Dhamani basin, 10 average UHs were determined by the leave one out cross validation method. Thus, 10 DRHs were computed and then compared with the corresponding observed DRHs in the validation test. Results indicated that for this basin, DRH prediction using average UH from storm 5 provided minimum ERMS of 4.11m3/s and η of 95.06%. Therefore, average storm UH5 from 10 storm event was considered an average representative UH for the Dhamani basin. It is the best UH representing the basin with minimum ERMS and maximum efficiency shows the computed and observed DRHs derived From UH 5 by the leave one out cross validation method and the observed UH derived from actual storm data for the Dhamani basin.

Table III - Synthetic unit hydrograph results with error function (%)

UNIT HYDROGRAPH METHOD	Tp	TB	Qp	ERROR Tp %	ERROR TB %	ERROR QB %
Obs. UH	4	47	52.95	0	0	0
Avg. UH	6	23	43.8	-50	51.064	17.280
A.R. Thorvat	4.075	51.742	55.989	-1.875	-10.089	-5.739
Snyder's case A	3.132	79.89	101.941	21.7	-69.979	-92.523
Snyder's case B	4	82.5	75.501	0	-75.532	-42.589
Mitchel's case A	6.195	41	45.365	-54.875	12.766	14.325
Mitchel's case A	4	28.5	76.14	0	39.362	-43.796
Common's case A	7.67	21.49	56.316	-91.75	54.277	-6.357
Common's case B	4	28.5	76.14	0	39.362	-43.796
CWC	7.67	21.49	56.316	-91.75	54.277	-6.357

V. CONCLUSION

A. Unit hydrographs are related directly to excess rainfall and characteristics of each storm causing that specific runoff. Therefore, and based on the results of this research, it observed that Patel & Thorvat method is more suitable for application on this region than Snyder method, Common's method and the CWC methods.

B. The synthetic unit hydrograph method was applied for the estimation of runoff for Dhamani basin caused by selected storms.

C. The percentage error in peak discharge prediction using this novel approach was 5.739% for the Dhamani basin. Other important characteristics of the unit hydrographs were also found from the developed unit hydrographs including: peak discharge per unit of watershed area, basin leg, and the base time of the unit hydrographs.

D. The results obtained from this approach were compared with those from other methods, and these comparisons also indicated good proximity.

E. As these results show, the method gives a good indication of the expected magnitude of the UH. We within the range of error that could be expected in a study of this nature.

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