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Development of S Curve for Mini-Watershed of Raichur City Karnataka

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Abstract- Unit Hydrograph (UH) is the most famous and generally utilized technique for analysing and deriving flood hydrograph resulting from a known storm in a basin area. For ungauged catchments, unit hydrograph are derived using either regional unit hydrograph approach. Central Water Commission (CWC) derived the regional unit hydrograph relationships for different sub-zones of India relating to the various unit hydrograph parameters with some prominent physiographic characteristics. The Study Area is located between Latitude 15º57′58″ N to 16º11′25.6″ N and 77º18′1″ E to77º32′5.3″ E Longitude and covers area of 360.97 km^2, having maximum length of 26.17 km. The maximum and minimum elevation of the basin is 533 m and 323 m above MSL, respectively. The Peak discharge of unit hydrograph obtained is 311.469 m^3/s. The final cumulative discharge is 1458.55 m^3/s.

Keywords: *Unit hydrograph, Flood hydrograph, Slope, Synthetic Parameter CWC.*

I. INTRODUCTION

Flood estimation in ungauged catchment is one of the most frequent applications of surface hydrology in general and rainfall-runoff modelling in particular. The geomorphological parameters are mostly time-invariant in nature and therefore, geomorphology based approach could be the most suitable technique for modelling the rainfall-runoff process for ungauged catchments. Unit Hydrographs have been proposed by several engineers as a tool to simulate runoff hydrographs from rainfall for ungauged catchments. Traditional techniques for design flood estimation uses historical rainfall-runoff data for unit hydrograph derivation. Such techniques have been widely applied for the estimation of design flood hydrograph at the sites of gauged Catchment. The estimation of design flood hydrograph is easy if information about runoff at the site is available. In cases where the available runoff data are inadequate for the complete hydrologic analysis, for such cases the available information of the nearby catchment or the information of the region can be used to carry out the further analysis. This approach attempts to establish relationships between model parameters and physically measurable Catchment characteristics for gauged catchments. These relationships are then assumed to hold for ungauged Catchments having similar hydrologic characteristics (CWC, 1986).

Floods are caused by weather phenomena and events that deliver more precipitation to a drainage basin than can be readily absorbed or stored within the basin. Any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream is termed as flood. An overflow or inundation that comes from a river or other body of water and causes damage. The Unit Hydrograph (abbreviated as UH) of a drainage basin is defined as a hydrograph of direct runoff resulting from one unit of effective rainfall which is uniformly distributed over the basin at a uniform rate during the specified period of time known as unit time or unit duration. The unit quantity of effective rainfall is generally taken as 1mm or 1cm and the outflow hydrograph is expressed by the discharge ordinates.

Section I contains the introduction of CWC, Section II contain the Study Area and methodology adopted, Section III contain the result and discussions, Section IV concludes research work with future directions.

II. MATERIALS AND METHODS

A. Study Area

The Study Area is located between Latitude 15º57′58″ N to 16º11′25.6″ N and 77º18′1″ E to77º32′5.3″ E Longitude and covers area of 360.97 km^2, having maximum length of 26.17 km. The maximum and minimum elevation of the basin is 533 m and 323 m above MSL respectively[8]. It is divided into seven subwatersheds as (S2A, S2B, S12C, S2D, S2E, S2F and S2G). Location of the study area is shown in figure 1. The average mean daily temperature varies from 22 to 410C respectively.

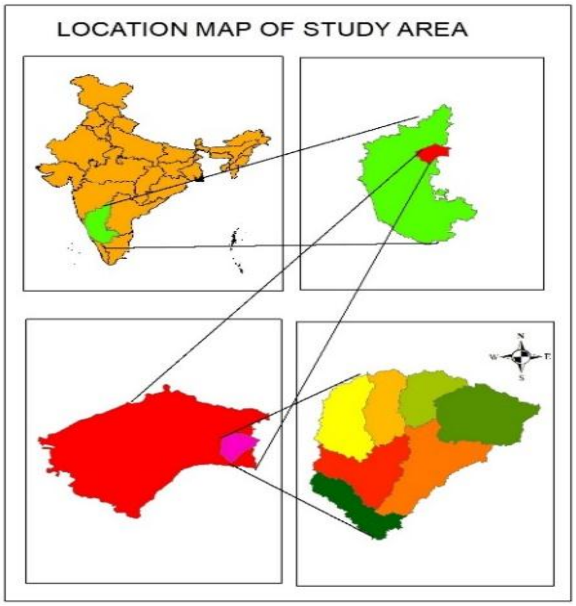


Figure 1 Location Map of Study Area

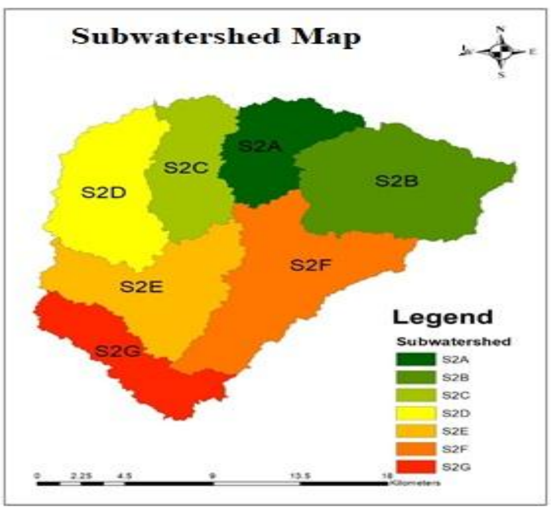
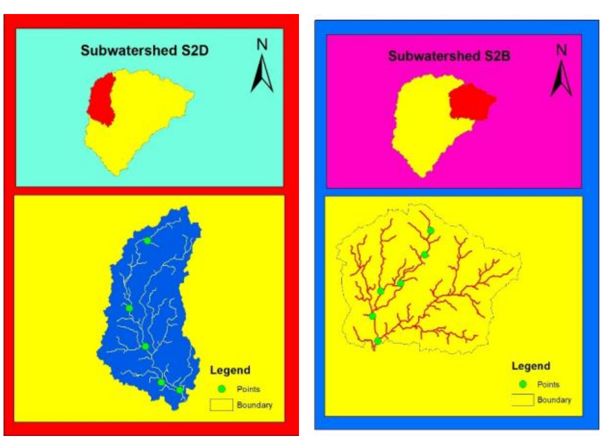


Figure 2 Subwatershed



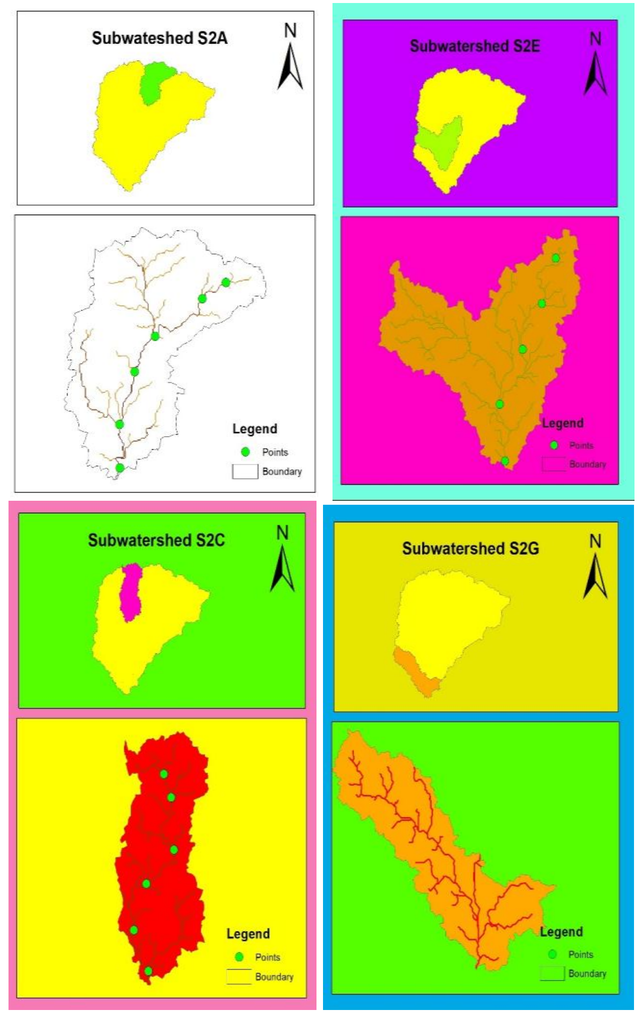


Figure 3 Points selected

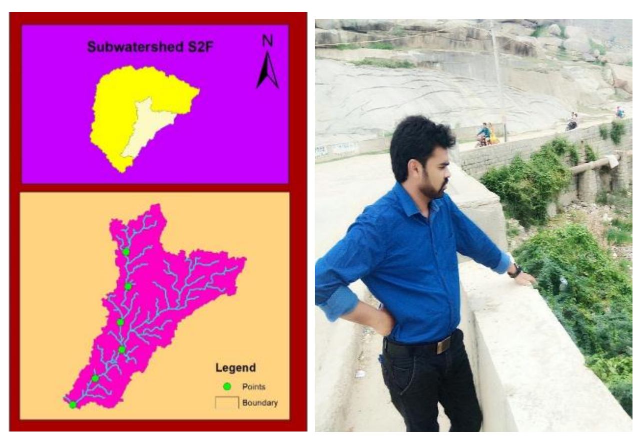


Figure 4 Location

B. Methodology

Snyder (1938) gave some empirical relationships for development of synthetic unit hydrograph for a ungauged catchment based on his studies carried out in USA for several catchments in the Appalachian Highland relating shape of the UH to physiographic characteristics of the catchment and information of the nearby gauged catchments. The characteristics of the watersheds and their Unit hydrographs, prepared for several watersheds in a sub-zone, is correlated by regression analysis and the equations for synthetic unit hydrograph are derived for estimating design flood for ungauged watersheds. (CWC, 1986) The unit hydrograph characteristics such as peak (Qp), time to peak (tp), width of hydrograph at 50% of peak volume (W50), width of hydrograph at 75% of peak volume (W75), width of the rising side of unit hydrograph in hours at ordinate equal to 75% of UH peak (WR75), time base (t_B) etc. has been computed on the basis of physiographic features.

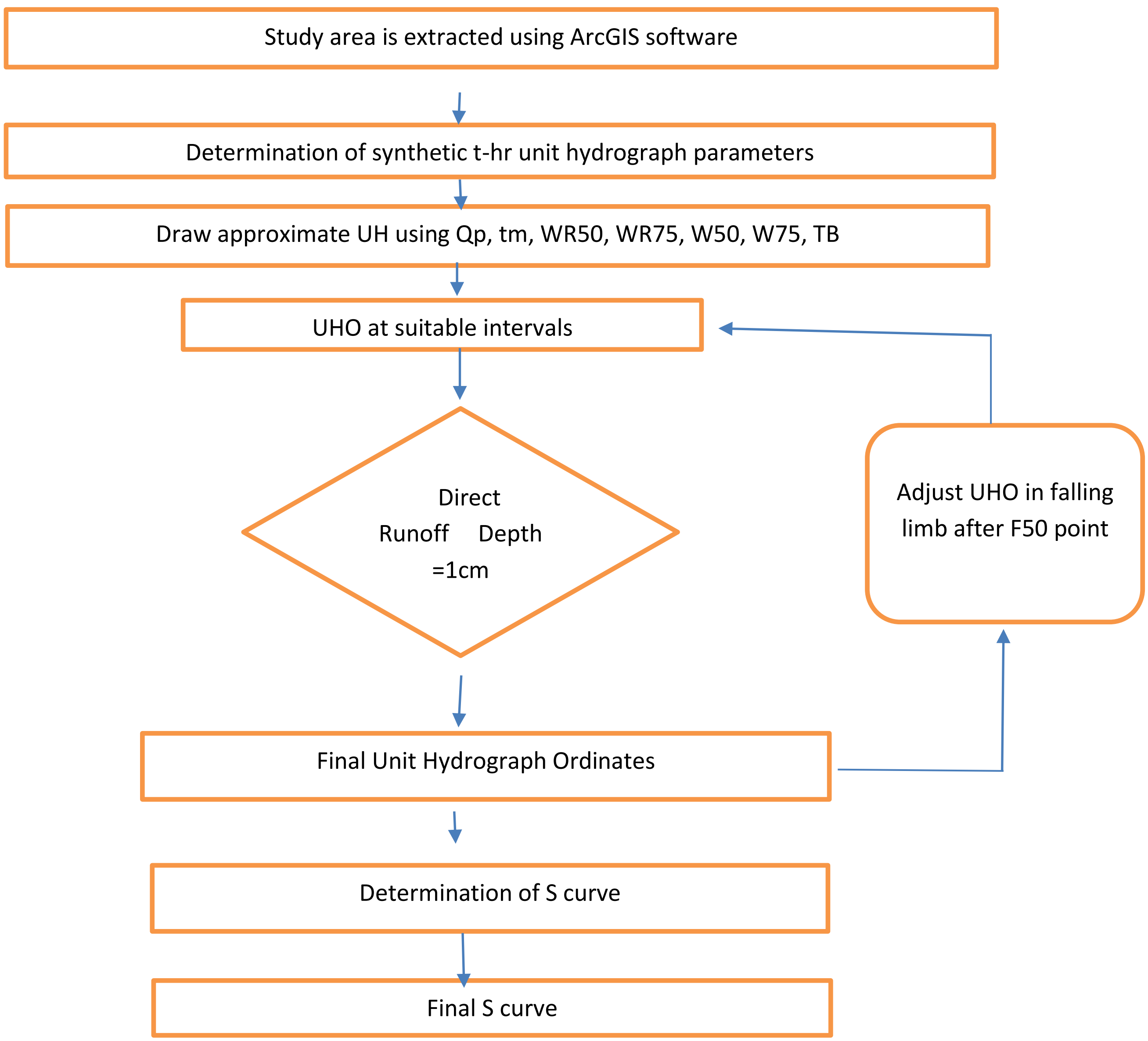


Figure 5: Methodology adopted to derive a CWC Unit Hydrograph Ordinates and S-curve

III. RESULTS AND DISCUSSIONS

No information of flood runoff is readily available for the study area, hence, to derive flood runoff or flood hydrographs, unit hydrographs were derived by CWC method by using following parameters below

A. Determination of physiographic parameters

The point of interested area is extracted from SRTM DEM 30m using ARCHYDRO software. S is to be determined using the elevation of the main stream at a number of significant points along it. Usually, the length of the stream from a point where an important tributary joins it up to another where the next tributary joins it called as a stream segment. S calculated as the average slope of all the stream segments and calculated using the expression

$S = (\sum L_i (D_{i-1}+D_i))/L^2$	… (3.10)

Where L_i is the length of i^{th} segment in km, D_i, D_{i-1} are the height above the datum (RL of the outlet of the basin) with respect of RL of contour at the i^{th} and $(i-1)^{th}$ locations in meters, L is the length of the longest stream in km

tp = 0.553(LLc/√s)0.405 …(3.11)
qp = 2.043/(tp)0.872 …(3.12)
W50 = 2.197/(qp)1.067 …(3.13)
W75 = 1.325/(qp)1.088 …(3.14)
WR50 = 0.799/(qp)1.138 …(3.15)
WR75 = 0.536/(qp)1.109 …(3.16)
TB = 5.038(tp) 0.733 …(3.17)
Tm = tp+(tr/2) …(3.18)
Qp = qp x A … (3.19)

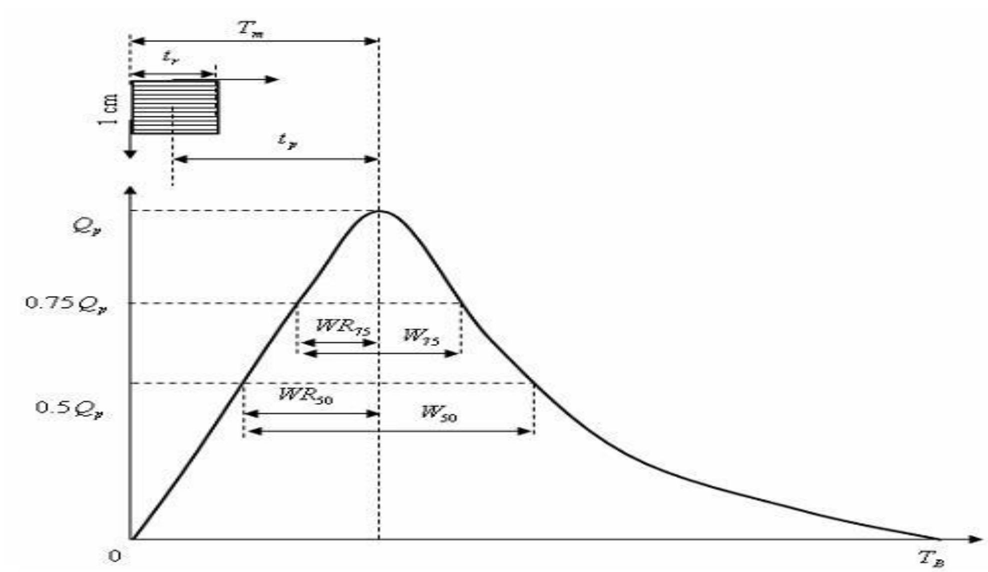


Figure 6: Typical CWC Unit Hydrograph

Table 1

S2A				
Point No	*Segment length Li in Km*	*Elevation from outlet Di in m*	*(Di + Di-1)*	*Li(Di+Di-1)*
0				
1	1.1	47	104	114.4
2	1.17	42	89	104.13
3	2.39	25	67	160.13
4	1.63	17	42	68.46
5	2.01	9	26	52.26
6	1.87	4	13	24.31
Σ Li(Di+Di-1)				523.69
S = Σ Li (Di+Di-1)/L^2			4.985	

S2C				
Point No	*Segment length Li in Km*	*Elevation from outlet Di in m*	*(Di + Di-1)*	*Li(Di+Di-1)*
0				
1	1.84	53	104	191.36
2	1.07	48	101	108.07
3	3.05	36	84	256.2
4	2.67	21	57	152.19
5	2.86	12	33	94.38
6	2	5	17	34
Σ Li(Di+Di-1)				836.2
S = Σ Li (Di+Di-1)/L^2			3.094	

S2D				
Point No	*Segment length Li in Km*	*Elevation from outlet Di in m*	*(Di + Di-1)*	*Li(Di+Di-1)*
0				
1	3.07	48	104	319.28
2	5.43	22	70	380.1
3	3.19	12	34	108.46
4	2.84	7	19	53.96
5	1.38	1	8	11.04
Σ Li(Di+Di-1)				872.84
S = Σ Li (Di+Di-1)/L^2			3.160	

S2E				
Point No	*Segment length Li in Km*	*Elevation from outlet Di in m*	*(Di + Di-1)*	*Li(Di+Di-1)*
0				
1	0.65	29	104	67.6
2	3.09	18	47	145.23
3	3.17	12	30	95.1
4	3.1	5	17	52.7
5	3.11	1	6	18.66
Σ Li(Di+Di-1)				379.29
S = Σ Li (Di+Di-1)/L^2			2.315	

S2F				
Point No	*Segment length Li in Km*	*Elevation from outlet Di in m*	*(Di + Di-1)*	*Li(Di+Di-1)*
0				
1	3.61	37	104	375.44
2	2.96	29	66	195.36
3	3.2	19	48	153.6
4	1.84	13	32	58.88
5	3.43	8	21	72.03
6	3.02	5	13	39.26
Σ Li(Di+Di-1)				894.57
S = Σ Li (Di+Di-1)/L^2			3.318	

S2B				
Point No	Segment length Li in Km	Elevation from outlet Di in m	(Di + Di-1)	Li(Di+Di-1)
0				
1	1.54	42	104	160.16
2	1.71	33	75	128.25
3	3	19	52	156
4	1.53	14	33	50.49
5	1.84	8	22	40.48
6	1.59	2	10	15.9
Σ Li(Di+Di-1)				551.28
S = Σ Li (Di+Di-1)/L^2			3.528	

S2G				
Point No	*Segment length Li in Km*	*Elevation from outlet Di in m*	*(Di + Di-1)*	*Li(Di+Di-1)*
0				
1	2.89	25	104	300.56
2	1.91	16	41	78.31
3	2.73	8	24	65.52
4	2.15	3	11	23.65
5	1.65	1	4	6.6
Σ Li(Di+Di-1)				474.64
S = Σ Li (Di+Di-1)/L^2			5.429	

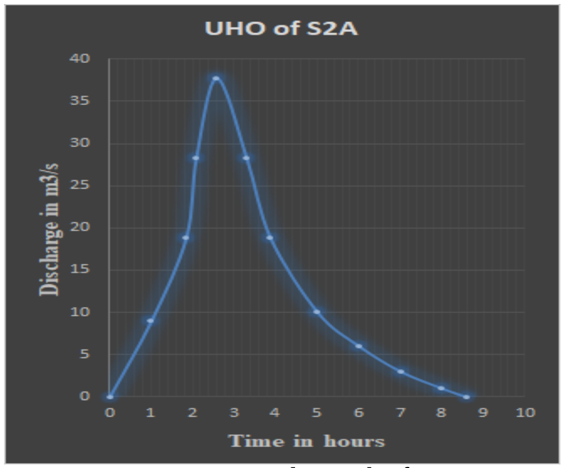


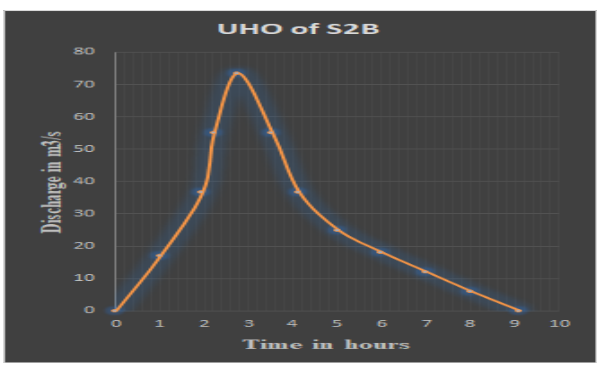
Figure 7 Unit Hydrograph of S2A

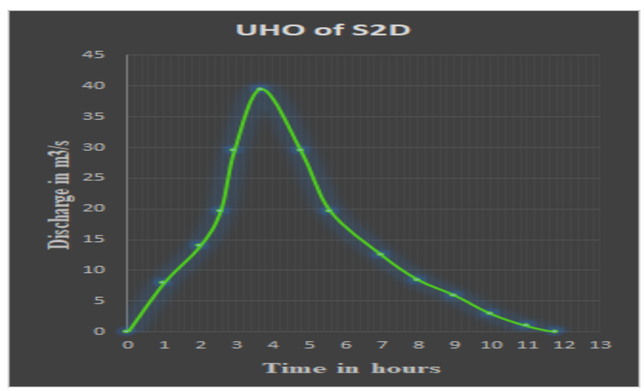
B. Determination of synthetic t_r-hr Unit graph parameters

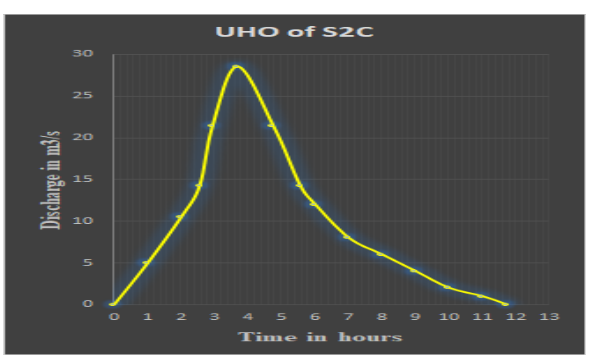
Table 2 Parameters of t_r- hr. Unit Hydrograph

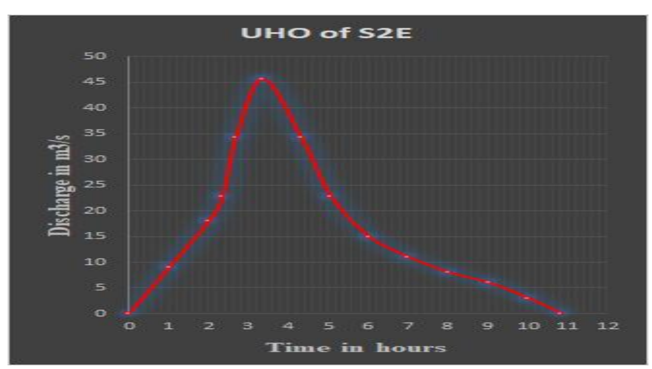
Subwatershed	Area Sq_km	t_p (hr)	q_p $m^3/s/km^2$	W_{50} (hr)	W_{75} (hr)	W_{R50} (hr)	W_{R75} (hr)	T_B (hr)	Tm (hr)	Q_p m^3/s
S2A	34.820	2.069	1.084	2.016	1.214	0.729	0.490	8.583	2.569	37.741
S2B	72.600	2.240	1.011	2.171	1.309	0.789	0.529	9.097	2.740	73.429
S2C	38.180	3.167	0.748	2.997	1.818	1.113	0.740	11.729	3.667	28.542
S2D	52.960	3.181	0.745	3.008	1.826	1.117	0.743	11.765	3.681	39.447
S2E	55.530	2.839	0.822	2.707	1.639	0.998	0.666	10.825	3.339	45.668
S2F	71.510	3.521	0.682	3.307	2.011	1.236	0.820	12.676	4.021	48.743
S2G	35.220	2.086	1.076	2.032	1.223	0.735	0.494	8.636	2.586	37.899
Total Qp										311.469

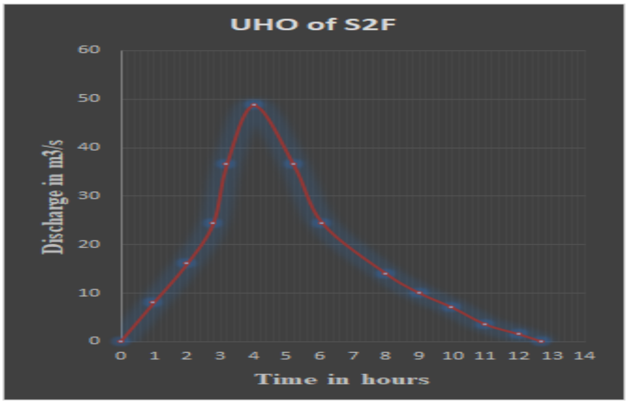
C Preparation of t_r-hr Synthetic unit graph

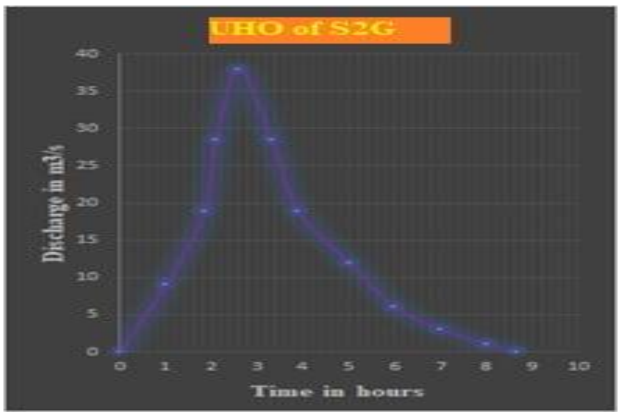


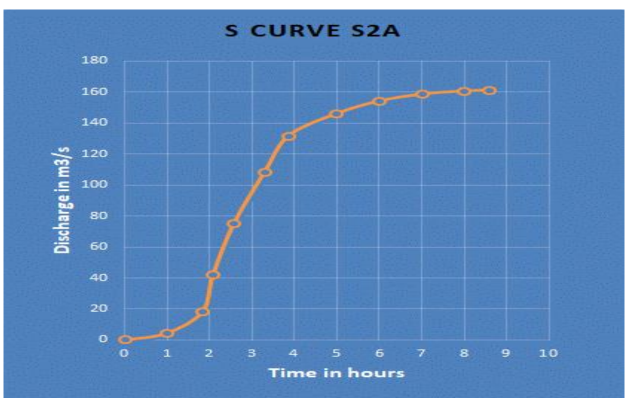


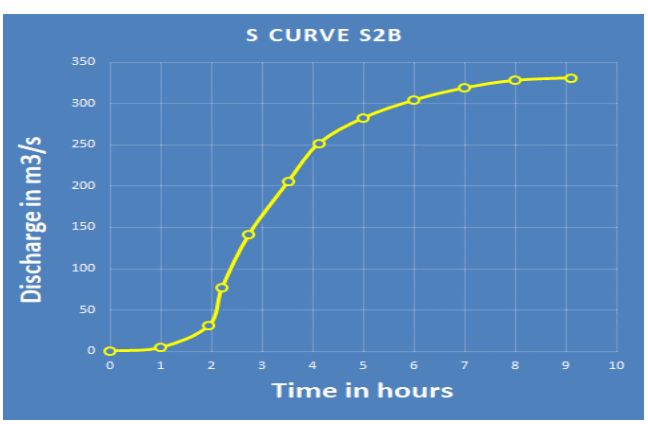


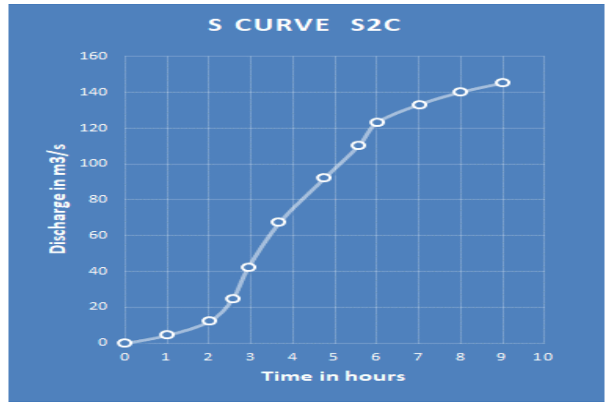


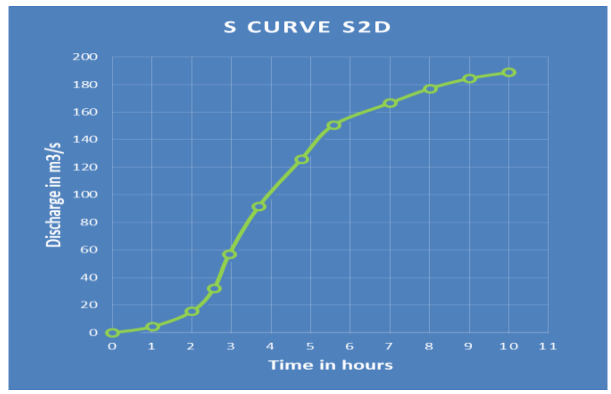


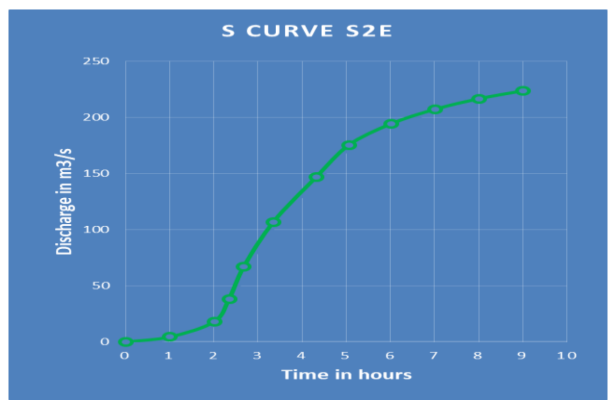












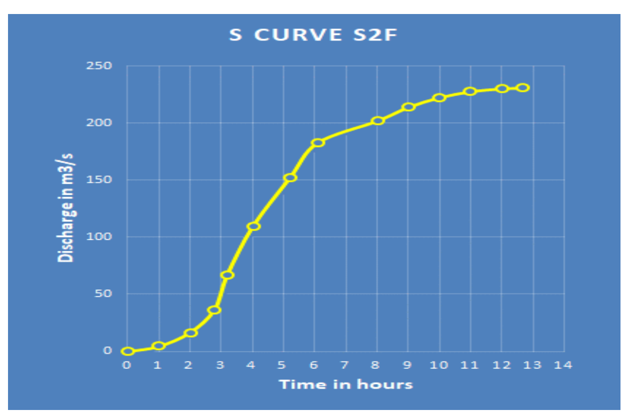


Figure 8 Unit Hydrograph and S Curve

Table 3: CWC Unit Hydrograph ordinates

Sl No	S2A						S2B					
	Time in hours	UHO in m3/s	(Qi+Qi+1)/2	volume in m3	Depth (m)	Cumulative discharge in m3/s	Time in hours	UHO in m3/s	(Qi+Qi+1)/2	volume in m3	Depth (m)	Cumulative discharge in m3/s
1	0.00	0.00				0.00	0.00	0.00				0.00
2	1.00	9.00	4.50	16200.00	0.00047	4.50	1.00	17.00	8.50	30600.00	0.00042	4.50
3	1.84	18.87	13.94	42139.44	0.00121	18.44	1.95	36.71	26.86	91844.10	0.00127	31.36
4	2.08	28.31	23.59	20381.76	0.00059	42.03	2.21	55.07	45.89	42953.04	0.00059	77.25
5	2.57	37.74	33.03	58256.10	0.00167	75.05	2.74	73.43	64.25	122589.00	0.00169	141.50
6	3.29	28.31	33.03	85600.80	0.00246	108.08	3.52	55.00	64.22	180315.72	0.00248	205.71
7	3.86	18.87	23.59	48406.68	0.00139	131.67	4.12	36.70	45.85	99036.00	0.00136	251.56
8	5.00	10.00	14.44	59241.24	0.00170	146.10	5.00	25.00	30.85	97732.80	0.00135	282.41
9	6.00	6.00	8.00	28800.00	0.00083	154.10	6.00	18.00	21.50	77400.00	0.00107	303.91
10	7.00	3.00	4.50	16200.00	0.00047	158.60	7.00	12.00	15.00	54000.00	0.00074	318.91
11	8.00	1.00	2.00	7200.00	0.00021	160.60	8.00	6.00	9.00	32400.00	0.00045	327.91
12	8.58	0.00	0.50	1044.00	0.00003	161.10	9.10	0.00	3.00	11880.00	0.00016	330.91

Sl No	S2C						S2D					
	Time in hours	UHO in m3/s	(Qi+Qi+1)/2	volume in m3	Depth (m)	Cumulative discharge in m3/s	Time in hours	UHO in m3/s	(Qi+Qi+1)/2	volume in m3	Depth (m)	Cumulative discharge in m3/s
1	0.00	0.00				0.00	0.00	0.00				0.00
2	1.00	5.00	2.50	9000.00	0.00024	4.50	1.00	8.00	4.00	14400.00	0.00027	4.50
3	2.00	10.50	7.75	27900.00	0.00073	12.25	2.00	14.00	11.00	39600.00	0.00075	15.50
4	2.55	14.27	12.39	24522.30	0.00064	24.64	2.56	19.72	16.86	33989.76	0.00064	32.36
5	2.93	21.41	17.84	24405.12	0.00064	42.48	2.94	29.59	24.66	33728.04	0.00064	57.02
6	3.67	28.54	24.98	66533.40	0.00174	67.45	3.68	39.45	34.52	91961.28	0.00174	91.54
7	4.75	21.41	24.98	97102.80	0.00254	92.43	4.76	29.59	34.52	134213.76	0.00253	126.06
8	5.55	14.27	17.84	51379.20	0.00135	110.27	5.57	19.72	24.66	71893.98	0.00136	150.71
9	6.00	12.00	13.14	21278.70	0.00056	123.40	7.00	12.50	16.11	82934.28	0.00157	166.82
10	7.00	8.00	10.00	36000.00	0.00094	133.40	8.00	8.50	10.50	37800.00	0.00071	177.32
11	8.00	6.00	7.00	25200.00	0.00066	140.40	9.00	6.00	7.25	26100.00	0.00049	184.57
12	9.00	4.00	5.00	18000.00	0.00047	145.40	10.00	3.00	4.50	16200.00	0.00031	189.07
13	10.00	2.00	3.00	10800.00	0.00028	148.40	11.00	1.00	2.00	7200.00	0.00014	191.07
14	11.00	1.00	1.50	5400.00	0.00014	149.90	11.77	0.00	0.50	1386.00	0.00003	191.57
15	11.73	0.00	0.50	1314.00	0.00003	150.40						

Sl No	S2E						S2F					
	Time in hours	UHO in m3/s	(Qi+Qi+1)/2	volume in m3	Depth (m)	Cumulative discharge in m3/s	Time in hours	UHO in m3/s	(Qi+Qi+1)/2	volume in m3	Depth (m)	Cumulative discharge in m3/s
1	0.00	0.00				0.00	0.00	0.00				0.00
2	1.00	9.00	4.50	16200.00	0.00029	4.50	1.00	8.00	4.00	14400.00	0.00020	4.50
3	2.00	18.00	13.50	48600.00	0.00088	18.00	2.00	16.00	12.00	43200.00	0.00060	16.50
4	2.34	22.83	20.42	24987.96	0.00045	38.42	2.79	24.37	20.19	57406.14	0.00080	36.69
5	2.67	34.25	28.54	33905.52	0.00061	66.96	3.20	36.56	30.47	44966.34	0.00063	67.15
6	3.34	45.67	39.96	96383.52	0.00174	106.92	4.02	48.74	42.65	125902.80	0.00176	109.80
7	4.31	34.25	39.96	139540.32	0.00251	146.88	5.21	36.56	42.65	182712.60	0.00256	152.45
8	5.05	22.83	28.54	76030.56	0.00137	175.42	6.09	24.37	30.47	96513.12	0.00135	182.92
9	6.00	15.00	18.92	64689.30	0.00116	194.33	8.00	14.00	19.19	131916.06	0.00184	202.10
10	7.00	11.00	13.00	46800.00	0.00084	207.33	9.00	10.00	12.00	43200.00	0.00060	214.10
11	8.00	8.00	9.50	34200.00	0.00062	216.83	10.00	7.00	8.50	30600.00	0.00043	222.60
12	9.00	6.00	7.00	25200.00	0.00045	223.83	11.00	3.50	5.25	18900.00	0.00026	227.85
13	10.00	3.00	4.50	16200.00	0.00029	228.33	12.00	1.50	2.50	9000.00	0.00013	230.35
14	10.83	0.00	1.50	4482.00	0.00008	229.83	12.68	0.00	0.75	1836.00	0.00003	231.10

Sl No	S2G					
	Time in hours	UHO in m3/s	(Qi+Qi+1)/2	volume in m3	Depth (m)	Cumulative discharge in m3/s
1	0.00	0.00				0.00
2	1.00	9.00	4.50	16200.00	0.00046	4.50
3	1.85	18.95	13.98	42763.50	0.00121	18.48
4	2.09	28.42	23.69	20463.84	0.00058	42.16
5	2.59	37.90	33.16	59688.00	0.00169	75.32
6	3.32	28.42	33.16	87144.48	0.00247	108.48
7	3.88	18.95	23.69	47748.96	0.00136	132.17
8	5.00	12.00	15.48	62395.20	0.00177	147.64
9	6.00	6.00	9.00	32400.00	0.00092	156.64
10	7.00	3.00	4.50	16200.00	0.00046	161.14
11	8.00	1.00	2.00	7200.00	0.00020	163.14
12	8.64	0.00	0.50	1152.00	0.00003	163.64

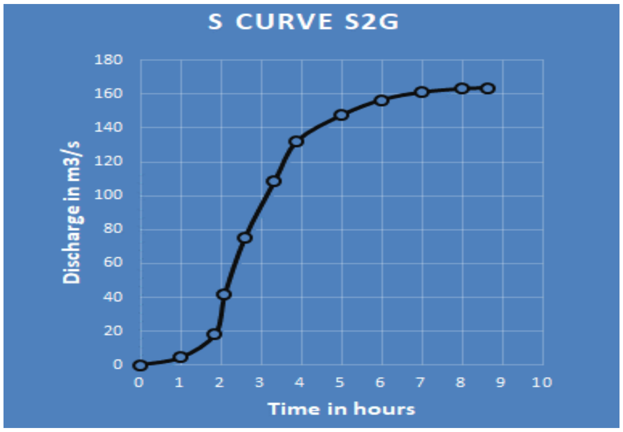


Figure 9 S Curve of S2G

IV. CONCLUSIONS

Using very limited data makes this model very useful for an ungauged catchment aiming at event prediction. Equivalent discharge is the maximum discharge that takes place in a Catchment which can be used to design hydraulic structures. To derive flood runoff or flood hydrographs, unit hydrographs were derived by central water commission method. This information is useful to derive flood hydrograph along the stream. This drainage network analysis and application of the UH can provide a significant contribution towards flood management program. Thus, the present model could be applied to simulate flood hydrographs for the catchments that have not been studied yet. The Peak discharge of unit hydrograph obtained is 311.469m^3/s. The final cumulative discharge is 1458.55 m^3/s.

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