DERIVATION OF UNIT HYDROGRAPH & S CURVE FOR HARIDRA RIVER CATCHMENT USING CWC METHOD

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***Abstract*: Unit Hydrograph (UH) is the most popular and widely used method for analysing and deriving flood hydrograph resulting from a known storm in a basin area. Traditional techniques for design flood estimation use historical rainfall-runoff data for unit hydrograph derivation. 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. In this study, the lately developed UH model is applied to Haridra river catchment located between Latitude 14º07′12″ N to 14º31′12″ N Latitude and 75º41′24″ E to76º13′12″ E Longitude. The study area covers an area of 1422.77 km2, having maximum length of 85.03 km. The maximum and minimum elevation of the basin is 525 m and 900 m above MSL, respectively. The Peak discharge of unit hydrograph obtained is 199.19m^3/sec. The final cumulative discharge is 4241.19 m^3/sec. From this study 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. Using very limited data makes this model very useful for ungauged catchments.**

***Keywords:* Unit hydrograph, Unguaged, Haridra, CWC.**

1. Introduction

Estimation of design flood for various water resources structures, particularly for medium and major water resources schemes, has been one of the most active areas of research for the hydrologists and water resource engineers. 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). One of the most popular approaches for the simulation of flood hydrograph for the ungauged catchments is based on the application of the developed regional unit hydrograph utilizing the rainfall – runoff records of the gauged catchments. However, this approach has somewhat limited scope since the hydrological behaviour of many nearby catchments have to be ascertained for establishing the regional formula for the unit hydrograph parameters. The second approach, which may be utilized for developing the unit hydrograph for ungauged catchments, utilizes geomorphological characteristics. This approach has many advantages over the regionalization approach as it avoids the requirement of data and computations in the neighbouring gauged catchments in the region (NIH 1998).

2. Study Area

The study area is Haridra River catchment, which is a small catchment in Karnataka State, India. Figure 1 shows map of Catchment area of Haridra River, which is a main tributary of Tungabhadra. Tungabhadra is a Sub-Basin of Krishna River. The study area is located between 14º07′12″ N to 14º31′12″ N Latitude and 75º41′24″ E to 76º13′12″ E Longitude. The study area covers an area of 1422.77 sq.km, having maximum length of 85.03 km and the study area elevation varies from 525 m to 900 m. Catchment area is delineated from SOI toposheets 48N/10, 48N/11, 48N/12, 48N/14, 48N/15, 48N/16, 57B/2, 57B/3, 57B/4 on 1:50,000 scale using Arc GIS software.

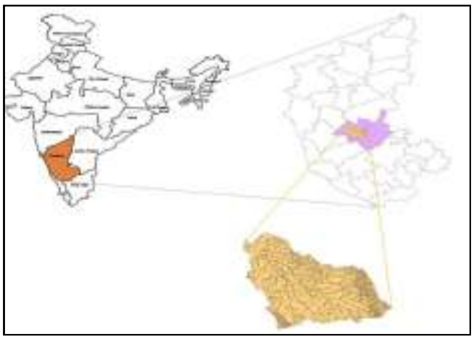

Fig 1 : Location map of Study area

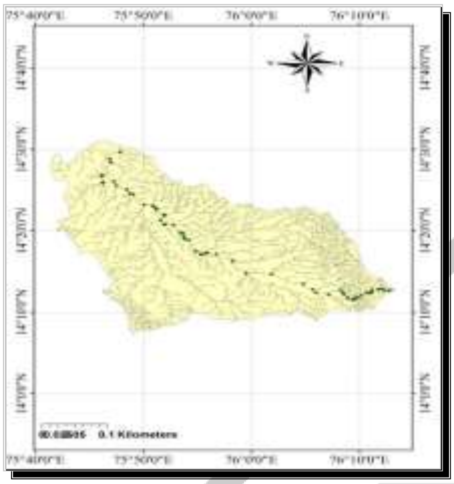

Fig. 2: Map of Study area with Streams

Table 1: Data used

Data	Source - Survey of India	Year
Toposheets Scale- 1:50000	No.48N/10	2009
	No.48N/11	2009
	No.48N/12	2009
	No.48N/14	2009
	No.48N/15	2009
	No.48N/16	2009
	No.57B/2	2009
	No.57B/3	2009
	No.57B/4	2009
ArcGIS	Version 9.3	2008

Methodology

The extracted Catchment and its parameters are used for the derivation of unit hydrograph using CWC method and its methodology is shown in below flow chart.

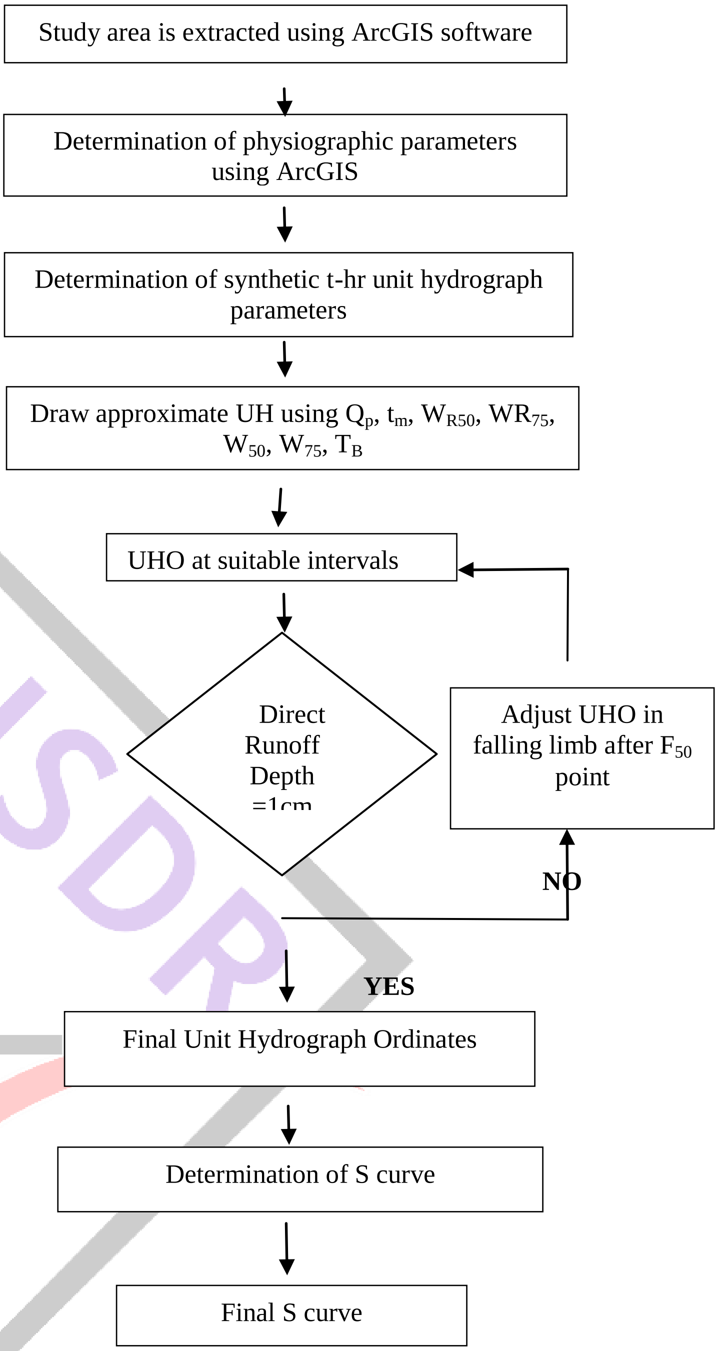

Fig 2: Methodology adopted to derive a CWC Unit Hydrograph Ordinates and S-curve.

3. Results and Discussion

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.

Catchment area, (A) = **1422.77 sq.km**

Length of the main stream, (L) = **85.03 km**

Length of the main stream from centre of gravity of the catchment, (Lc) = **43.84 km**

4.1 Calculation of stream slope

Some important tributary points which are joining to mainstream are selected for finding out the equivalent slope

S of the Catchment. The equivalent stream slope for Catchment is given table 2.

3.2 Determination of synthetic t_r-hr Unit graph parameters.

tp	$= 0.553(LLc/\sqrt{s})^{0.405}$	**= 22.49 hrs**
q_p	$= 2.043/(tp)^{0.872}$	**= 0.14 m³/sec/km²**
W_{50}	$= 2.197/(qp)^{1.067}$	**= 17.90 hrs**
W_{75}	$= 1.325/(qp)^{1.088}$	**= 11.25 hrs**
W_{R50}	$= 0.799/(qp)^{1.138}$	**= 7.49 hrs**
W_{R75}	$= 0.536/(qp)^{1.109}$	**= 4.74 hrs**
T_B	$= 5.038(tp)^{0.733}$	**= 49.35 hrs**
T_m	= tp+ (tr/2)	**= 22.99 hrs**
Q_p	= qp x A	**= 199.19 m³/sec**

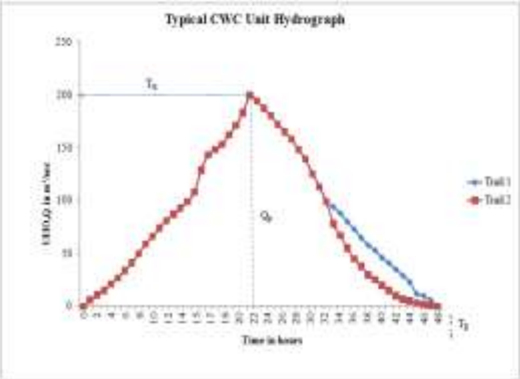

Fig 3: Unit hydrograph of Catchment area

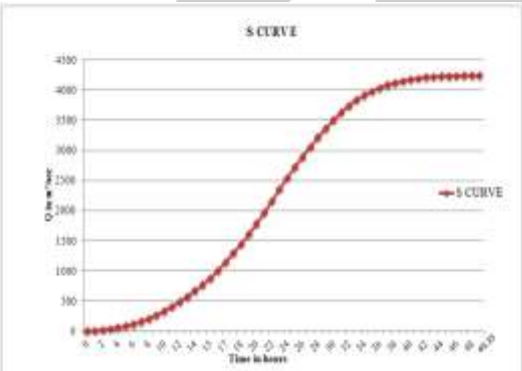

Fig 4: S curve of catchment area

Conclusion

The final cumulative discharge is compared with central water commission discharge details and the result obtained is about 97.53 % accuracy. 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.

Table 2: Calculation of Equivalent Stream Slope for Catchment.

Sl No.	L_i in km	D_i in m	D_i+D_{i-1}	$L_i (D_i+D_{i-1})$
0	-	-	-	-
1	1.365	1.42	1.42	1.94
2	3.090	3.21	4.63	14.31
3	0.755	0.78	3.99	3.01
4	3.754	3.89	4.67	17.49
5	0.330	0.34	4.23	1.40
6	1.815	1.88	2.22	4.03
7	0.195	0.20	2.08	0.41
8	1.896	1.97	2.17	4.11
9	1.077	1.12	3.09	3.33
10	2.411	2.50	3.62	8.73
11	1.102	1.14	3.64	4.01
12	0.687	0.71	1.85	1.27
13	3.583	3.72	4.43	15.87
14	1.426	1.48	5.20	7.42
15	0.614	0.64	2.12	1.30
16	0.529	0.77	1.41	0.75
17	2.410	3.49	4.26	10.27
18	0.177	0.26	3.75	0.66
19	1.365	1.98	2.24	3.06
20	1.229	1.78	3.76	4.62
21	0.315	0.46	2.24	0.71
22	1.652	2.39	2.85	4.71
23	2.038	2.95	5.34	10.88
24	0.696	1.01	3.96	2.76
25	1.090	1.58	2.59	2.82
26	0542	0.78	2.36	1.28
27	0.730	1.06	1.84	1.34
28	3.040	4.40	5.46	16.60
29	1.119	1.62	6.02	6.74
30	0.330	0.47	2.09	0.69
31	0.660	1.63	2.10	1.39
32	0.330	0.81	2.44	0.81
33	1.499	3.70	4.51	6.76
34	3.466	8.56	12.26	42.49
35	4.169	10.30	18.86	78.63
36	4.884	10.19	20.49	100.07
37	7.094	14.81	25.00	177.35
38	2.527	17.94	32.75	82.76
39	0.994	7.06	25.00	24.85
40	2.417	11.33	18.39	44.45
41	2.918	13.67	25.00	72.95
42	0.573	6.94	20.61	11.81
43	0.314	3.80	10.74	3.37
44	1.177	14.26	18.06	21.26
45	1.213	9.72	23.98	29.09
46	0.324	2.60	12.32	3.99
47	0.490	3.93	6.53	3.20

48	0.135	1.08	5.01	0.68
49	0.959	7.67	8.75	8.39
50	1.350	10.73	18.40	24.84
51	0.625	4.97	15.70	9.81
52	0.409	3.25	8.22	3.36
53	0.761	6.05	9.30	7.08
54	1.247	25.00	31.05	38.72
55	0.650	13.30	38.30	24.90
56	0.572	11.70	25.00	14.30
57	0.791	25.00	36.70	29.03
58	1.129	75.00	100.00	112.90
($\sum L_i$ ($D_{i-1}+D_i$)) =				1135.76
Equivalent stream slope, S ($\sum L_i$ ($D_{i-1}+D_i$))/L^2 =				0.157 m/km

Table 3: CWC Unit Hydrograph ordinates

Sl No.	Time in hours	Trail 1				Trail 2			
		UHO in m^3/s	$(Q_i+Q_{i+1})/2$	Volume	Depth	UHO in m^3/s	$(Q_i+Q_{i+1})/2$	Volume	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	0	0				0			
2	1	6	3	10800	0.00001	6	3	10800	0.00001
3	2	11	8.5	30600	0.00002	11	8.5	30600	0.00002
4	3	15	13	46800	0.00003	15	13	46800	0.00003
5	4	21	18	64800	0.00005	21	18	64800	0.00005
6	5	27	24	86400	0.00006	27	24	86400	0.00006
7	6	34	30.5	109800	0.00008	34	30.5	109800	0.00008
8	7	41	37.5	135000	0.00009	41	37.5	135000	0.00009
9	8	50	45.5	163800	0.00012	50	45.5	163800	0.00012
10	9	59	54.5	196200	0.00014	59	54.5	196200	0.00014
11	10	66	62.5	225000	0.00016	66	62.5	225000	0.00016
12	11	74	70	252000	0.00018	74	70	252000	0.00018
13	12	81	77.5	279000	0.00020	81	77.5	279000	0.00020
14	13	87	84	302400	0.00021	87	84	302400	0.00021
15	14	93	90	324000	0.00023	93	90	324000	0.00023
16	15	99	96	345600	0.00024	99	96	345600	0.00024
17	15.50	108	103.5	186300	0.00013	108	103.5	186300	0.00013
18	16	129	118.5	213300	0.00015	129	118.5	213300	0.00015
19	17	143	136	489600	0.00034	143	136	489600	0.00034
20	18	148	145.5	523800	0.00037	148	145.5	523800	0.00037
21	18.25	153	150.5	135450	0.00010	153	150.5	135450	0.00010
22	19	162	157.5	425250	0.00030	162	157.5	425250	0.00030
23	20	171	166.5	599400	0.00042	171	166.5	599400	0.00042
24	21	183	177	637200	0.00045	183	177	637200	0.00045
25	22	190	186.5	671400	0.00047	190	186.5	671400	0.00047
26	22.99	199.19	194.595	693536.58	0.00049	199.19	194.595	693536.58	0.00049
27	24	187	193.095	702093.42	0.00049	187	193.095	702093.42	0.00049
28	25	180	183.5	660600	0.00046	180	183.5	660600	0.00046
29	26	172	176	633600	0.00045	172	176	633600	0.00045
30	27	165	168.5	606600	0.00043	165	168.5	606600	0.00043
31	28	158	161.5	581400	0.00041	158	161.5	581400	0.00041
32	29.502	148	153	827301.6	0.00058	148	153	827301.6	0.00058
33	30	139	143.5	257266.8	0.00018	139	143.5	257266.8	0.00018
34	31	125	132	475200	0.00033	125	132	475200	0.00033
35	32	113	119	428400	0.00030	113	119	428400	0.00030
36	33.4	99	106	534240	0.00038	99	106	534240	0.00038
37	34	94	96.5	208440	0.00015	78	88.5	191160	0.00013
38	35	88	91	327600	0.00023	67	72.5	261000	0.00018
39	36	80	84	302400	0.00021	55	61	219600	0.00015
40	37	73	76.5	275400	0.00019	45	50	180000	0.00013

41	38	65	69	248400	0.00017	38	41.5	149400	0.00011
42	39	58	61.5	221400	0.00016	30	34	122400	0.00009
43	40	53	55.5	199800	0.00014	25	27.5	99000	0.00007
44	41	46	49.5	178200	0.00013	20	22.5	81000	0.00006
45	42	41	43.5	156600	0.00011	15	17.5	63000	0.00004
46	43	35	38	136800	0.00010	10	12.5	45000	0.00003
47	44	29	32	115200	0.00008	7	8.5	30600	0.00002
48	45	23	26	93600	0.00007	5	6	21600	0.00002
49	46	12	17.5	63000	0.00004	3	4	14400	0.00001
50	47	10	11	39600	0.00003	2	2.5	9000	0.00001
51	48	06	8	28800	0.00002	0.5	1.25	4500	0.00000
52	49.35	0	3	14580	0.00001	0	0.25	1215	0.00000
Total depth in m					0.010880	Total depth in m			0.010080

Nomenclature

UHO : Unit hydrograph ordinates; CWC: Central Water Commission; A= Area of catchment; D_i= Elevation from outlet; F_{50}= Falling limb at 50% of peak discharge; F_{75}= Falling limb at 75% of peak discharge; L=Length of the main stream; L_i= Length of i^{th} segment; L_c= Length of the main stream from centre of gravity of the catchment; Q= Discharge; Q_p= Peak discharge of Unit hydrograph; q_p= Peak discharge of unit hydrograph per unit area in cumecs/km^2; R50= Rising limb 50% of peak discharge; R75= Rising limb 75% of peak discharge; S= Slope; T_B=Base width of unit hydrograph;T_m=Time from the start of rise to the peak of unit hydrograph; t_p= Time from the centre of rainfall excess (1.0 cm) in 1 hr unit duration to the unit hydrograph peak in hours; t_r=Unit rainfall duration adopted in specific study; W_{50}= Width of uunit hydrograph measured at 50% of peak discharge ordinates; W_{75}= Width of unit hydrograph measured at 75% of peak discharge ordinates;W_{R50}= Width of rising limb unit hydrograph measured at 50% of peak discharge ordinate; W_{R75}= Width of rising limb unit hydrograph measured at 75% of peak discharge ordinate

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