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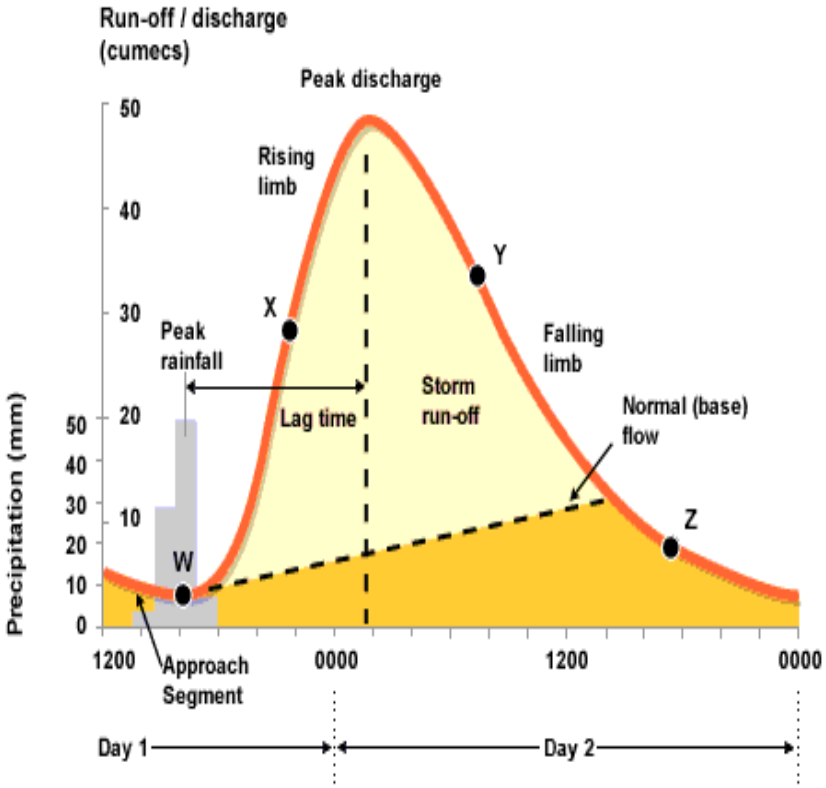
The Hydrograph

1-Definition

The hydrograph is a graph of flow rate versus time. It is also referenced as a listing of flow rate data versus time. It is one of the more useful concepts of hydrology and is used frequently in stormwater management.



A typical surface runoff is shown in the figure, the hydrograph consists of three general parts, (1) rising limb, (2)crest segment, and (3)falling limb, the runoff hydrograph will have the following properties:

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a-Time of peak(t_p).

b-Recession time(t_r).

c-Time of base(t_b).

The shape of the hydrograph depends on many factors, watershed shape,area, slope,depth, the earth impervious, the land use, the rainfall intensity, evaporation …etc.

2-Hydrograph separation:

Several techniques exist to separate DRO from B.F based on the analysis of groundwater recession curves or type and amount of measured data available. The direct runoff hydrograph is the difference between the total runoff and the base flow function.

1-Straight line (constant slope)method. $N=0.83\ A^{0.2}$(N days and A area km^2)

2-Fixed-based (concave baseflow) method.

3-Variable slope (constant discharge) method

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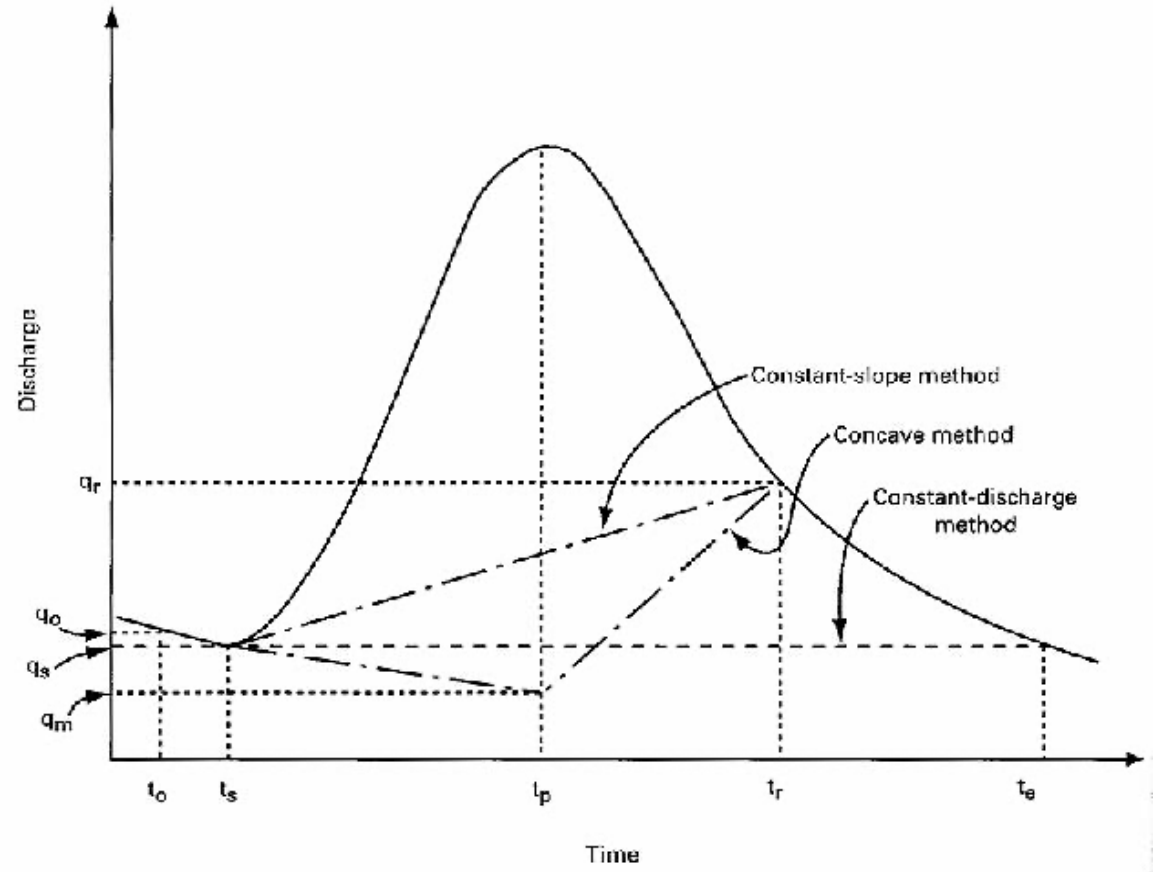

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3-The Unit Hydrograph

U.H is defined as A basin outflow resulting from **one centimeter** or **one inch** of direct runoff generated uniformly over the drainage area at a uniform rainfall rate during a specified period.

For a specific watershed, the U.H for a given quantity of rainfall excess can be used to generate another Hy. If the storm duration is the same.

The following general rules should be observed in developing U.H:

1-Storms should be selected with a simple structure with relatively uniform spatial and temporal distribution.

2-Watershed size should generally fall 1000 ac. -1000 mi^2.

3-Direct runoff should range from 0.5-2 inches.

4-Duration of rainfall excess should be 25-30% of t_p.

5-Anumber of storms of similar duration should be analyzed to obtain an average unit hydrograph for that duration.

The following are essential steps for developing a U.H from a single storm hydrograph.

1-Analyze the hydrograph and separate the base flow.

2-Measure the total volume of direct runoff (DRO) under the hydrograph and convert this to in ,cm ,over the watershed.

3-Convert the total rainfall to rainfall excess and evaluate duration for the DRO and U.H.

4-Divide the ordinate of the DRO hy. By the volume and plot these results as the U.H for the basin. The time is assumed constant for storms of equal duration and thus it will not change.

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.$t_1 = t_2$

.$i_1 = i_2$

$Q_1 / Q_2 = d_1 / d_2$ $\qquad d = \frac{\sum DRO * \Delta t}{A}$

Examples

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Ex.1:

Given the ordinate of a flood hy. For 1700 km^2 during 12 hrs.drive 12 hrs.U.H?

T(hr)	Q1(YH.)	Q2(U.H.)
0	0	0
12	30	3
24	100	10
36	365	36.5
48	645	64.5
60	700	70
72	585	58.5
84	475	47.5
96	360	36
108	275	27.5
120	180	18
132	125	12.5
144	85	8.55
156	50	5
168	25	2.5
180	0	0

$$\frac{Q_{UH}}{Qhy} = \frac{d_{UH}}{d_{HY}}$$

so $Q_{UH} = Q_{hy} * \frac{d_{UH}}{d_{HY}}$

$$d = \frac{\sum DRO * \Delta T}{A} = \frac{4000 * 12 * 3600}{1700 * 10^6} = 0.1 \text{ m}$$

Q1=Q2 * =0.1 * Q2

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Ex.2:

Two storms of 6-hr duration for each, with 2 and 3 cm depth respectively, the storm of 3 cm occurred after 12 hrs. from the first ,drive the total hy. For the two storms from U.H. given below?

T(hr)	U.H	Q1	Q2	TOTAL
0	0	0	-	0
6	50	100	-	100
12	125	250	0	250
18	185	370	150	520
24	160	320	375	625
30	110	220	555	775
36	60	120	480	600
42	36	72	330	402
48	25	50	180	230
54	16	32	108	140
60	8	16	75	91
66	0	0	48	48
			24	24
			0	0

$$\frac{Q_{UH}}{Qhy} = \frac{d_{UH}}{d_{HY}}$$

$$\frac{Q_{UH}}{Qhy} = \frac{1}{2}$$

$Q_{hy}=2 * Q_{U.H}$

$Qhy=3* Q_{U.H}$

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Ex. 3

Convert the DRO hy. Into a 2 hrs. U.H. .The rainfall is 1.5 in/hr, and the Φ index for the storm was 0.5 in/hr.The base flow in the channel was 100 cfs. what are the t_p (time of peak) and t_b(time of base) ?

1.5 in/hr* 2 hr -0.5 in /hr *2= 2 in

$$\frac{Q_{UH}}{Qhy} = \frac{d_{UH}}{d_{HY}}$$

$$Q_{UH} = Q_{hy} * \frac{d_{UH}}{d_{HY}}$$

T_p =4 hrs.

T_b=10 hrs.

T(HR.)	Q(CFS)	DRO	2hr.U.H
0	0	0	0
1	100	0	0
2	300	200	100
3	700	600	300
4	1000	900	450
5	800	700	350
6	600	500	250
7	400	300	150
8	300	200	100
9	200	100	50
10	100	0	0
11	100	0	0

4- Convert the duration of the unit hydrograph (U.H)

The linear property of U.H. can be used to generate U.H. of a larger or smaller duration. There are two methods to convert U.H. duration"

4.1-Superposition method:

It is applied to convert duration from shot to long time, and t_2/t_1=integer number.

To generate the U.H. of t_2 , the U.H. of t_1 is legged till it reaches t_2, then by taking the summation of the lagged unit hydrographs.

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Ex 4:

Given the ordinate of 2 hr. U.H..Drive the ordinate of 6 –hr U.H,?

-Lagging 2-hr.

-Lagging 2-hr.

-The summation of three storms.

-Multiply by 2/6.

T(hr.)	2-hr.U.H	LAG.2-HR	LAG.2 HR.	SUM	6HR.U.H.
0	0	-	-	0	0
2	300	0	-	300	100
4	720	300	0	1020	340
6	800	720	300	1820	606.6
8	540	800	720	2060	686.6
10	300	540	800	1640	546.6
12	170	300	540	1010	336.6
14	100	170	300	570	190
16	50	100	170	320	106.6
18	10	50	100	160	53.3
20	0	10	50	60	20

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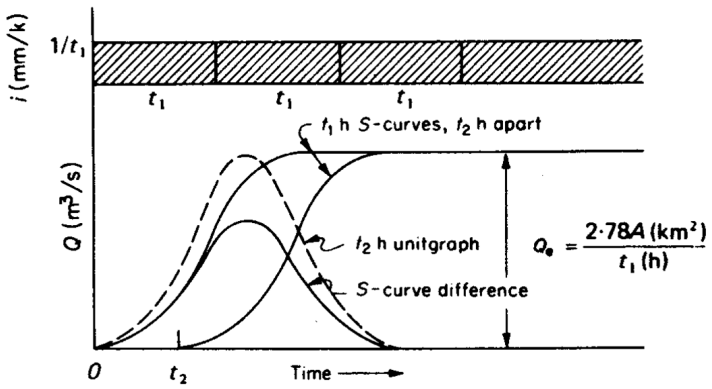
4.2-S-curve method:

Allows construction of a U.H. of any duration. Assume that a U.H. of duration t is known and that we wish to generate a U.H. of t', the first step by adding a series of unit hydrographs of duration t, each lagged by t, then by shifting the S-curve by t', subtract the accumulated U.H. finally, we must multiply all hydrograph by t/t'.

-Shift by t_1 with accumulation.

-Add the last two columns.



-Shift by t_2 without accumulation.

-subtract the last two columns.

-Multiply by t_1/t_2.

Ex.5:

Convert the following tabulated 2-hr. U.H. To 3-hr U.H. using the S-curve method?

T	2-hr U.H	Lag.2hr.	Sum.	Lag 3hr	Sub.	*2/3
0	0	-	0	-	0	0
1	75	-	75	-	75	50
2	250	0	250	-	250	166.6
3	300	75	375	0	375	250
4	275	250	525	75	450	300
5	200	375	575	250	325	216.6
6	100	525	625	375	250	166.6
7	75	575	650	525	125	83.3
8	50	625	675	575	100	66.6
9	25	650	675	625	50	33.3
10	0	675	675	650	25	16.6
11		675		675	0	0