



RUN-OFF ESTIMATION

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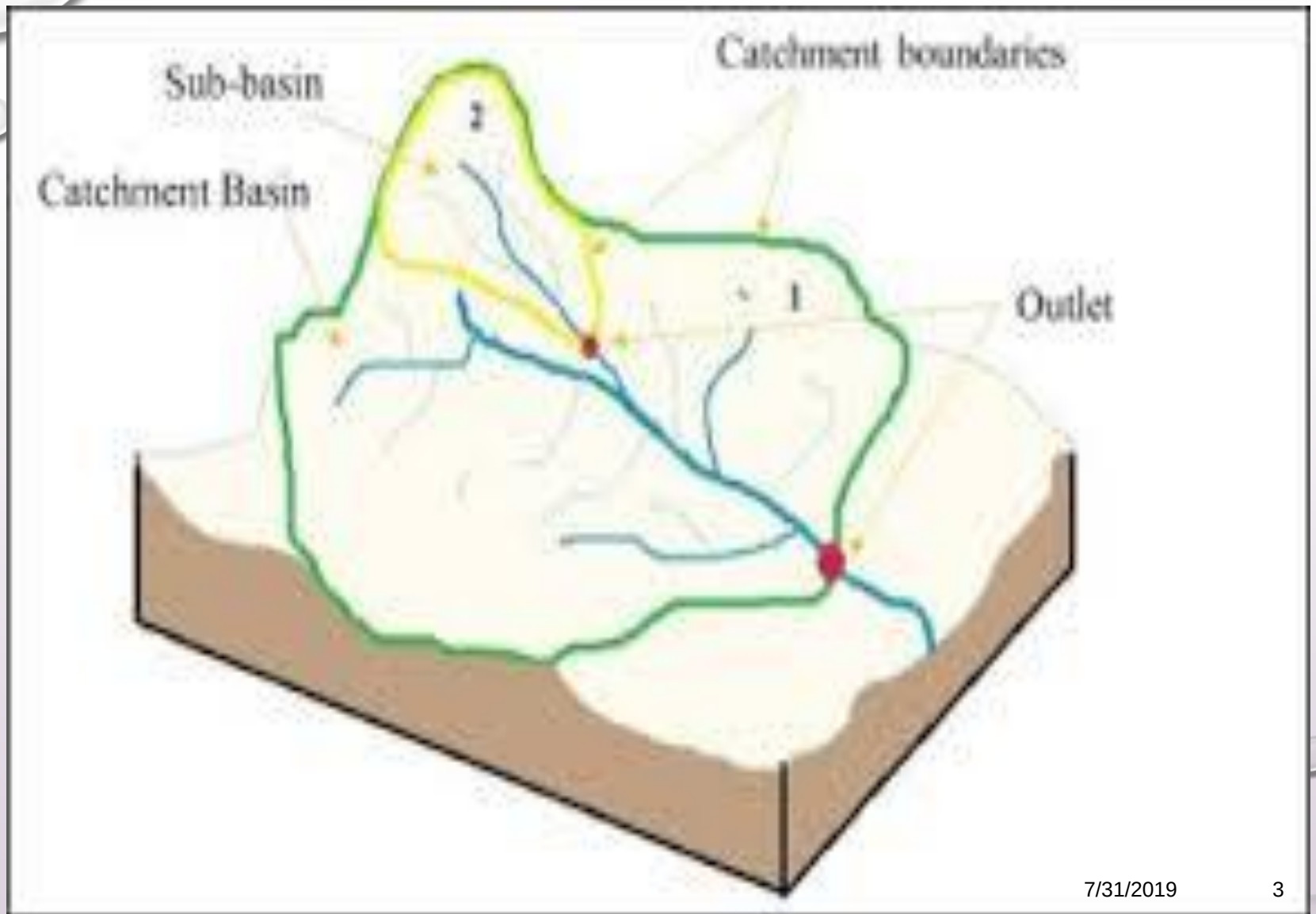
ET 1001
Introduction to Hydrology

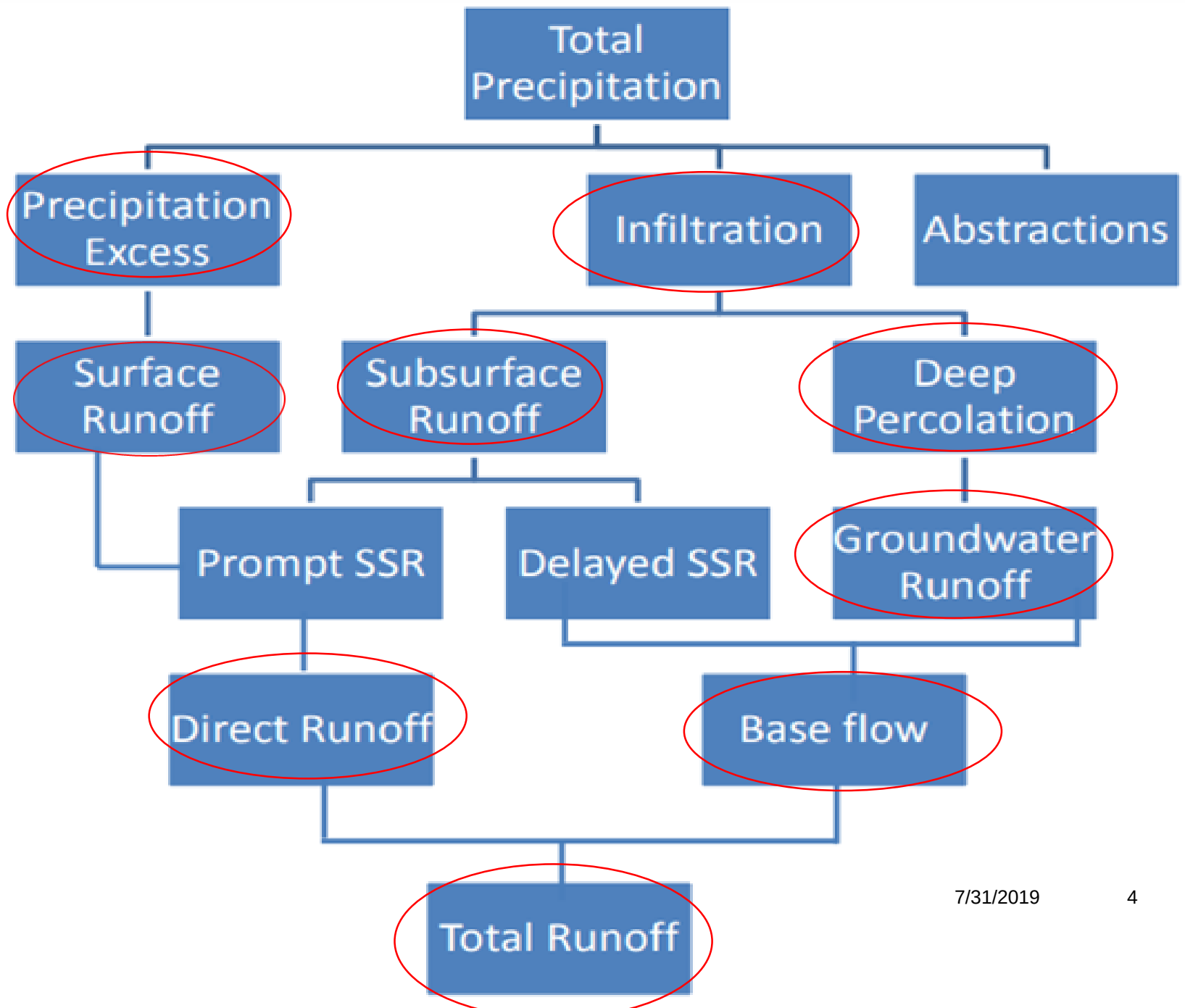


Learning outcomes

On successful completion of this course students will be able to:

1. To apply concepts of rainfall losses, unit hydrograph theory to predict surface runoff responses.
2. Will provide undergraduates with the basic concepts in unit hydrograph application. These concepts can be used in the design of hydraulic and flood control structures to convey drainage and to minimize flood impacts in adjacent land areas.
3. Compare and evaluate (EX; How they work, what their limitations are) a number of methods for determining peak flows and flood hydrographs, including flood intensity frequency analysis, the probabilistic and deterministic rational methods





Factors Affecting Runoff

- 1. Precipitation characteristics**
- 2. Meteorological characteristics**
- 3. Catchment characteristics**
- 4. Storage characteristics (Pools, lakes, channel in the catchment reduce the run off).**

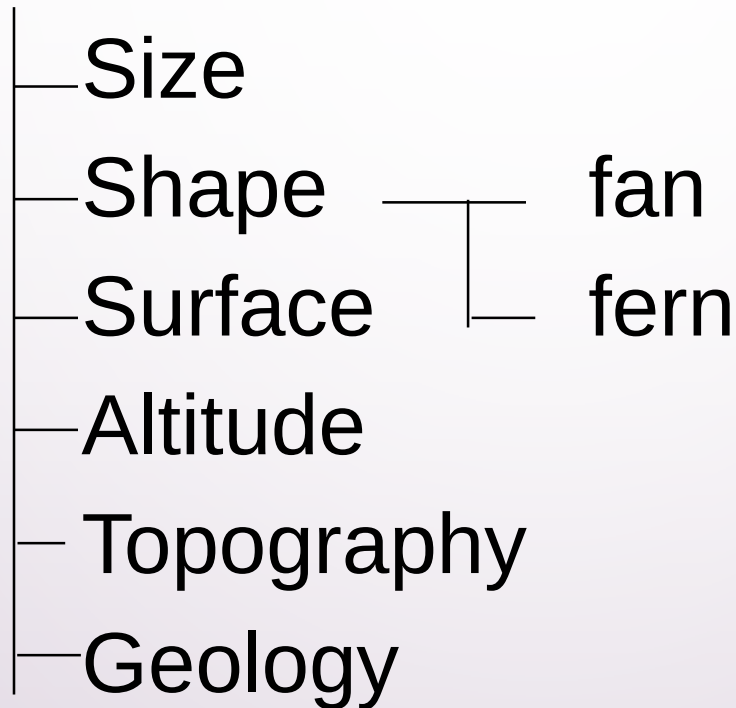
1. PRECIPITATION CHARACTERISTICS

- Type or nature of storm
- Intensity
- Extent
- Duration

2. METEOROLOGICAL CHARACTERISTICS

- Temperature
- Humidity
- Wind
- Pressure Variation

3. CATCHMENT CHARACTERISTICS



IMPORTANCE

- * Rate of runoff
 - in order to design dams, drains and Bridges.
- * Amount of surface runoff
 - In order to plan water storage and Irrigation.
- **Runoff is the portion of rainfall over a catchment which is discharged from the area to the form of streams or rivers.**

Estimating rates of surface runoff

PEAK RUNOFF :-

Peak runoff is the maximum rate of runoff which would be expected by rainfall of a given intensity and magnitude of the area.

METHODS:

- 1. RATIONAL METHOD**
- 2. HYDROGRAPH ANALYSIS.**
- 3. COOK'S METHOD**

1. Rational Method

Q P (precipitation)

$$\cancel{Q} = KP \quad ; \quad Q = CIA$$

Q = Peak runoff (m^3 / s)

C = Co-efficient of runoff

Depend on the - Soil surface of the catchment

- Topography

- Soil texture

I = Rainfall intensity during the time of
Concentration and the given recurrence interval (mm/h)

A = Catchment area. (Ha)

$$C = \frac{\sum C_i A_i}{A_t}$$

Rainfall intensity depends on

1. Time of concentration (gathering time)
2. Recurrence interval (return period)

Time of concentration (T_c)

If a rainfall on an impervious surface at a constant rate at the result in runoff in finally reach a rate equal to the rate of RF.

The time required to reach this stage is called T_c .

The finite time taken by the water to flow through the stream channel to the control section.

The time of concentration can be defined as the longest time taken by surface runoff to reach the outlet from any point at the catchment.

$$\mathbf{TC = 0.02L^{0.77} \times S^{0.385}}$$

L - Maximum length (m)

S - Slope

$$\mathbf{I = RF\ Depth\ (cm/mm)\ /\ Tc}$$

Recurrence Interval

RI is the time interval between two events which equal or exceed particular level. Generally a series of RF data are used to calculate a recurrence interval.

$$N = TM$$

N - No of years

T - Recurrence interval

M - Ranking number

Assumptions of Rational Method

- Rainfall occur with uniform intensity at least to the tc.
- rainfall intensity is uniform throughout catchment.

Limitations of rational method

- Uniform rainfall throughout the watershed never satisfied.
- Initial losses (interception, depression storage, etc). are not considered

Example 01.

The land use pattern of a watershed is given in the following table. The hydrologic soil group of the watershed is B. Calculate the peak rate of runoff for rainfall intensity of 100 mm/h for the duration of t_c of watershed.

Land Use classification	Crop and management practice	Area(ha)
Land use A	Forest with matured woodland	25
Land use B	Row crop, good practice	30
Land use C	Small grain, good practice	20
Land use D	Grassland with rotating species, good practice	10

Table 5.1: Typical values of runoff coefficient, C for different land use and rainfall intensity for hydrologic soil group B

Crop and Hydrologic conditions	Coefficient C for rainfall rates of		
	25 mm/h	100 mm/h	200 mm/h
Row crop, poor practice	0.63	0.65	0.66
Row crop, good practice	0.47	0.56	0.62
Small grain, poor practice	0.38	0.38	0.38
Small grain, good practice	0.18	0.21	0.22
Grassland with rotating species good practice	0.29	0.36	0.39
Permanent pasture under good practices	0.02	0.17	0.23
Forest with matured woodland	0.02	0.1	0.15

(Source: Schwab et al., 1993)

• **Type of area** **runoff coefficient**
(Increases with slope)

- **Urban area**
 - **More than 70% paved (down town)** **0.7 - 0.95**
 - **50 - 70% paved (neighbour hoods)** **0.5 - 0.7**
 - **less than 30% paved (residential)** **0.3 - 0.5**
- **Industrial area**
 - **Heavy area** **0.6 - 0.9**
 - **Light area** **0.5 - 0.8**
- **Agricultural area**
 - **Sandy loam soil** **0.1-0.35**
 - **Clay and silt loam soil** **0.3 - 0.6**
 - **tight clay soil** **0.4-0.7**
- **Parks, cemeteries, play grounds** **0.1 - 0.35**
- **Streets, roads** **0.7 - 0.95**
- **Roofs** **0.8 - 0.95**

2. Cook's Method

- This method is based on,
 1. Kind of vegetation
 2. Soil permeability
 3. Slope of the land

$$Q = PRFS$$

Q = Peak runoff m^3/s

P = Unadjusted peak runoff m^3/s

R = Recurrence interval conversion factor

F = Recurrence interval factor (Figures for Sri Lanka)

S = Shape factor

Vegetation	Soil Type	Slope	Catchment Characteristics
1. Heavy grass 10	Deep well drained 10	Very flat 5	25
2. Medium grass 10	Moderable Permeable 20	Moderable 10	45
3. Cultivated land 20	Low Permeability 25	Rolling 15	65
4. Bare land 25	Shallow soil with impeded drain 30	Hilly 20	75

3. Hydrograph

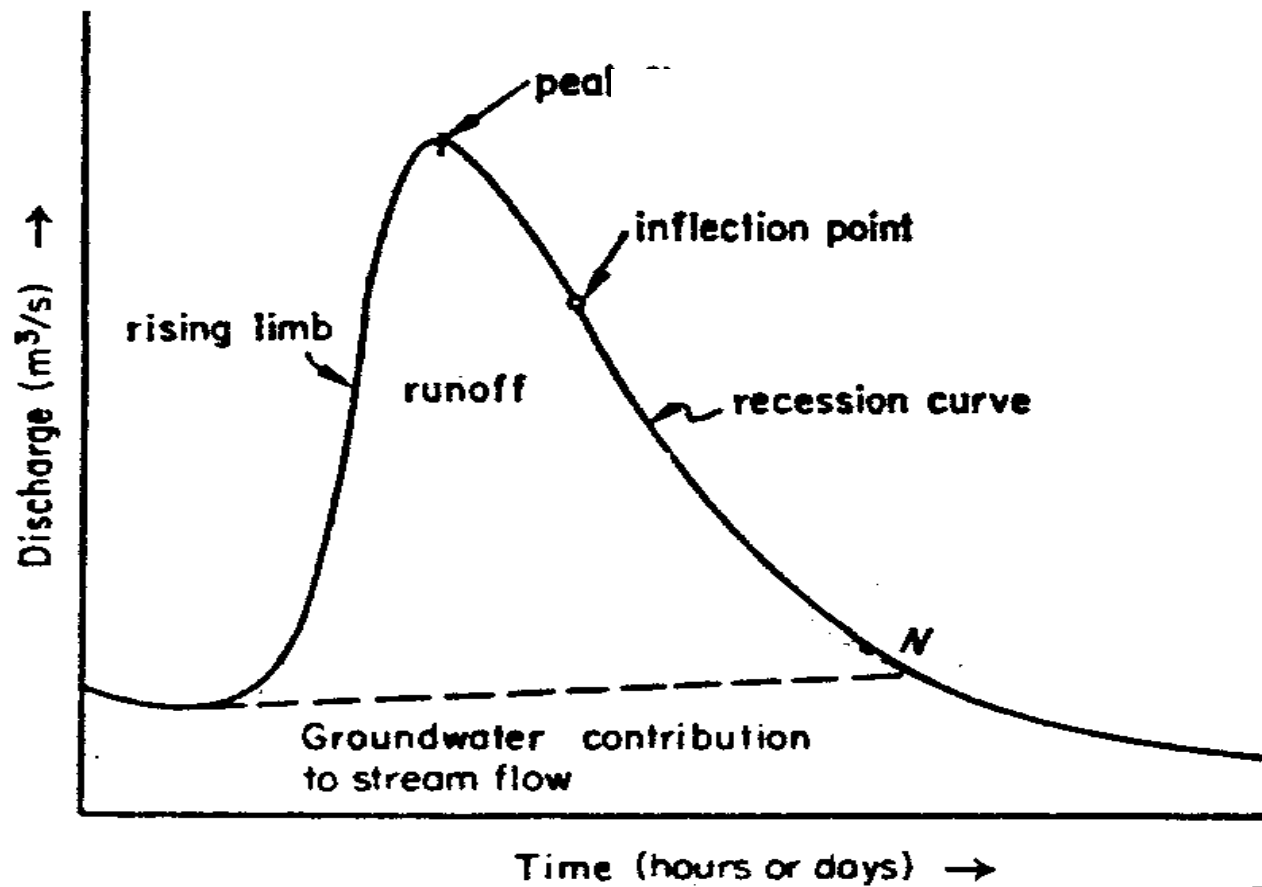
- Hydrograph is a plot of discharge versus time.
- Hydrograph is a graph showing variations of discharge with time at a particular point of a stream.

Hydrograph analysis

The basic requirement in hydrograph analysis is to separate the **base flow** & the **direct runoff**.

Types of hydrograph

- **Storm hydrographs** - Storm hydrographs are graphs that show how a drainage basin responds to a period of rainfall.
- **Flood hydrographs** - Flood hydrographs is a visual representation of the variation in the stream or river depth over time.
- **Annual hydrographs** - An annual hydrograph shows the average daily flow of a river over the course of one year rather than a period of hours.



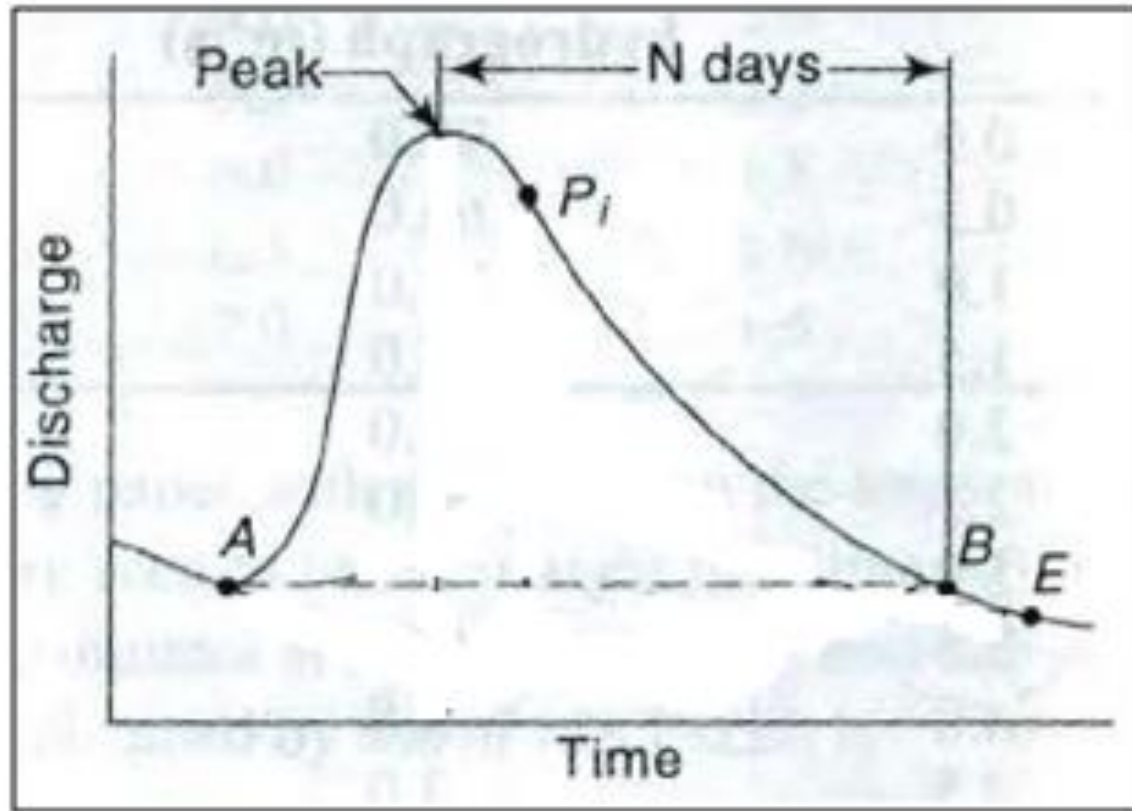
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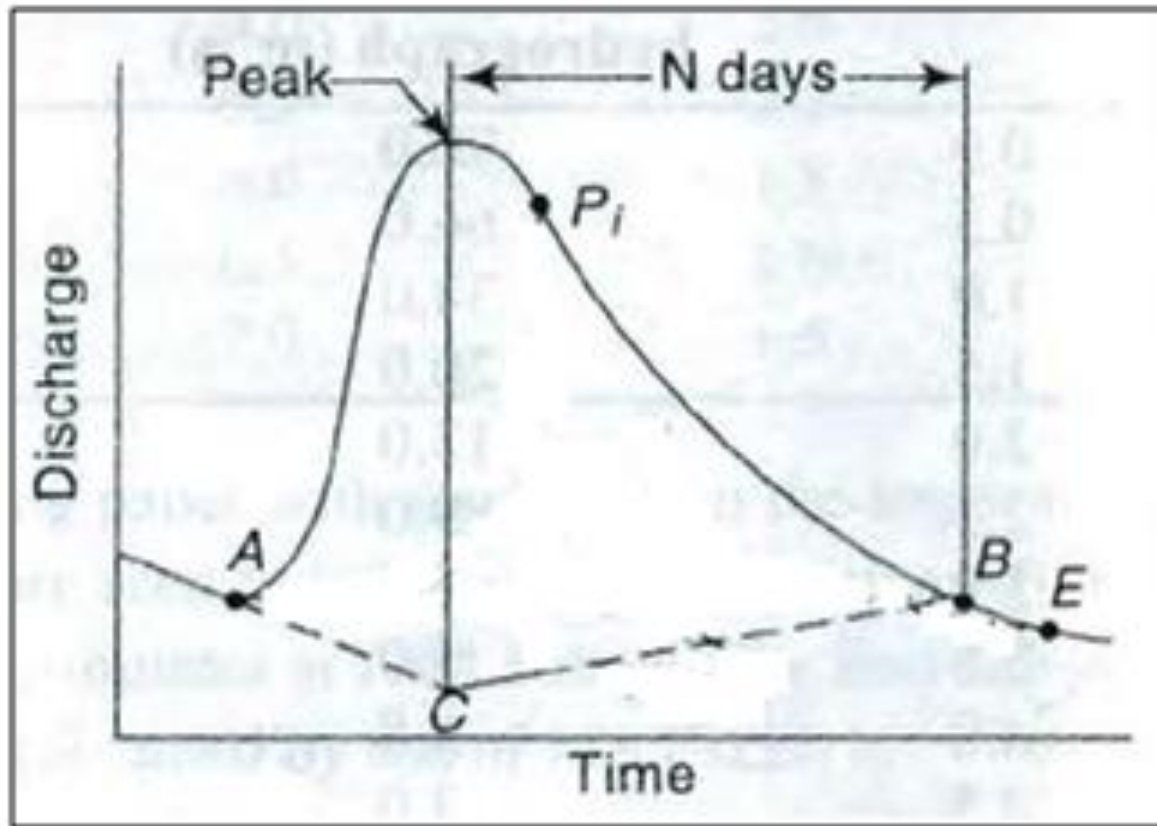
Component parts of a natural hydrograph

Separation of base flow

METHOD 1



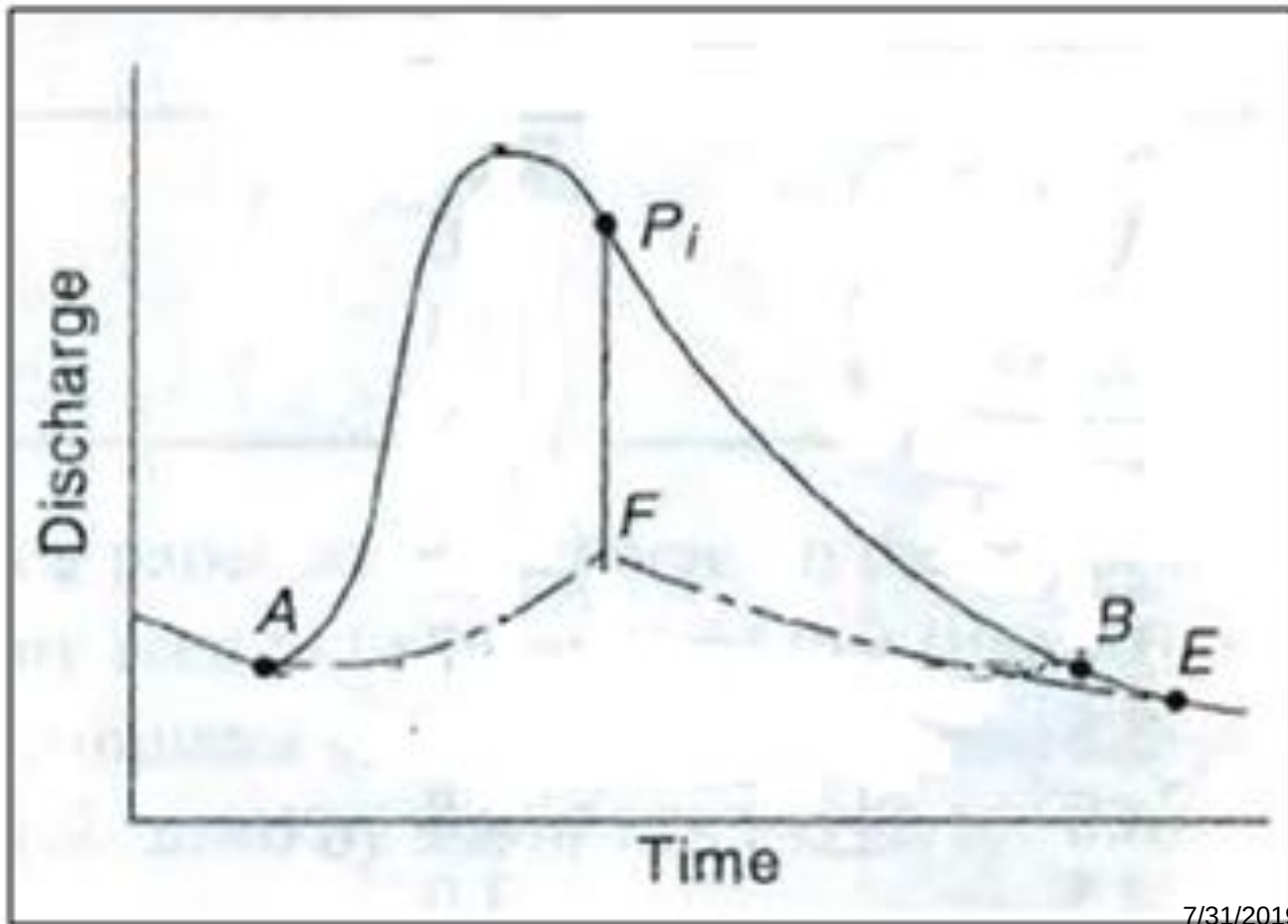
METHOD 2



$$N = 0.84A^{0.2}$$

N - No. of Days
A - Catchment Area (Km^2)

METHOD 3



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EXAMPLE 02

- The following are the ordinates of the hydrograph of flow from a catchment area of 770 km^2 due to a 6-h rainfall.
- Derive the ordinates of Direct Runoff Hydrograph (DRH). Make suitable assumptions regarding the base flow.

Time from beginning of storm	(h)	0	6	12	18	24	30	36
Discharge	(m ³ /s)	42	65	215	360	400	350	270
Time from beginning of storm	(h)	42	48	54	60	66	72	
Discharge	(m ³ /s)	205	145	100	70	50	42	

The unit hydrograph

- The quantity and intensity of rain both have a direct effect on the hydrograph.
- But it has not yet been made clear how, and to what extent, each of these affects it.
- The method of doing this, is a part-empirical technique that uses the concept of the unit hydrograph, first described by sherman I.K. (1932).
- It should be emphasized that the correlation sought in between the rainfall excess (the rain remaining as runoff after all losses by evaporation, interception and infiltration have been allowed for) and the surface runoff (the hydrograph of runoff minus base flow).

- **Definition :-** *The direct runoff hydrograph corresponding to an effective unit rain (such as 1cm RF) in a specific time duration.*

Construction of the UHG.

1. Draw the total hydrograph and separate base flow.
2. Find the ordination of direct runoff by Subtracting the ordinates of total Hydrograph and ordinates of base flow.


$$\text{Ordinates of UHG} = \frac{\text{Ordinates of direct runoff}}{\text{Depth of direct runoff}} \\ \text{(Rainfall excess)}$$

$$\text{Direct runoff depth(D)} = \frac{\text{Total volume of direct runoff}}{\text{Area of the catchment}}$$

$$D \text{ (cm)} = \frac{0.36 \text{ t } \Sigma X}{A}$$

- **T** = Time interval between successive ordinates (hrs)
- **A** = Area of the catchment (km²)
- **EX** = Sum of discharge ordinates
[Direct runoff (m³/s)]

The area under the curve of the hydrograph has the dimensions of discharge multiplied by time.

$$\frac{L^3}{T} \times t = l^3 = \text{volume of runoff}$$

Assumptions of unit hydrograph theory

1. The effective RF is uniformly distributed within its duration of specified period of time.
2. The effective RF is uniformly distributed throughout the whole area of the drainage basin.
3. The base of time duration of the hydrograph of direct runoff due to an effective RF of unit duration is constant.

4. The ordinates of direct runoff common base time are directly proportional to the total amount of direct runoff represented by each hydrograph.
5. For a given drainage basin the hydrograph of runoff due to a given period of RF reflects all the combined physical characteristics of the basin.

REFERENCES

- [Http://www.Seu.Ac.Lk/ft/lm/FT0_099/hydrology/5.0%20runoff.Pdf](http://www.Seu.Ac.Lk/ft/lm/FT0_099/hydrology/5.0%20runoff.Pdf)
- [Https://mail.Google.Com/mail/ca/u/0/#inbox?Projector=1](https://mail.Google.Com/mail/ca/u/0/#inbox?Projector=1)
- [Https://nptel.Ac.In/courses/105101002/downloads/module3/lecture3.Pdf](https://nptel.Ac.In/courses/105101002/downloads/module3/lecture3.Pdf)
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ASSIGNMENT

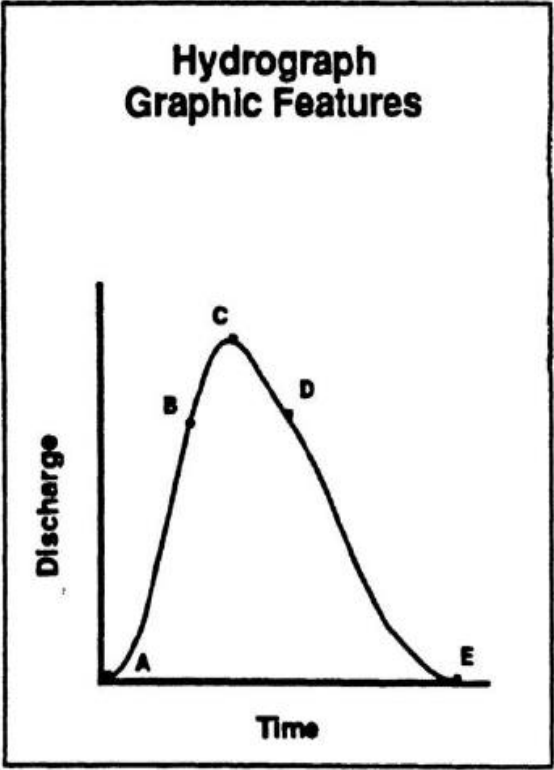
Activity 1

1. A hydrograph is a graph showing _____, _____
_____ or other properties of water flow with respect to time. When the
stage is plotted against time, the graph is a _____ hydrograph. When the discharge is
shown against time, the graph is a _____ hydrograph. The latter being the most
commonly used form, is simply called a _____.

2. List the various types of hydrographs.

- a. _____ hydrograph
- b. _____ hydrograph
- c. _____ hydrograph
- d. _____ hydrograph
- e. _____ hydrograph

3. Identify the various hydrograph components shown on the following hydrograph:



A. _____

B. _____

C. _____

D. _____

E. _____

A-C _____

C-E _____

B-D _____

A-E _____

ABCDEA _____

4. The daily stream flow data at a site having a drainage area of 6500 km² are given in the following table. Separate the base flow using the above three methods.

Time (days)	Discharge (m ³ /s)
1	1600
2	1550
3	5000
4	11300
5	8600
6	6500
7	5000
8	3800
9	2800
10	2200
11	1850
12	1600
13	1330
14	1300
15	1280