Time of Concentration, Rainfall intensity and Run-off Co-efficient

MCLLMP Virtual Training
By Spring Initiative Partners

Prepared by: People’s Science Institute
Dehradoon

Content

- What is peak discharge?
- Why is it important to know peak discharge?
- What is a hydrograph?
- How to generate a hydrograph?
- How to determine/calculate peak discharge?
- How to design length of Spillway?

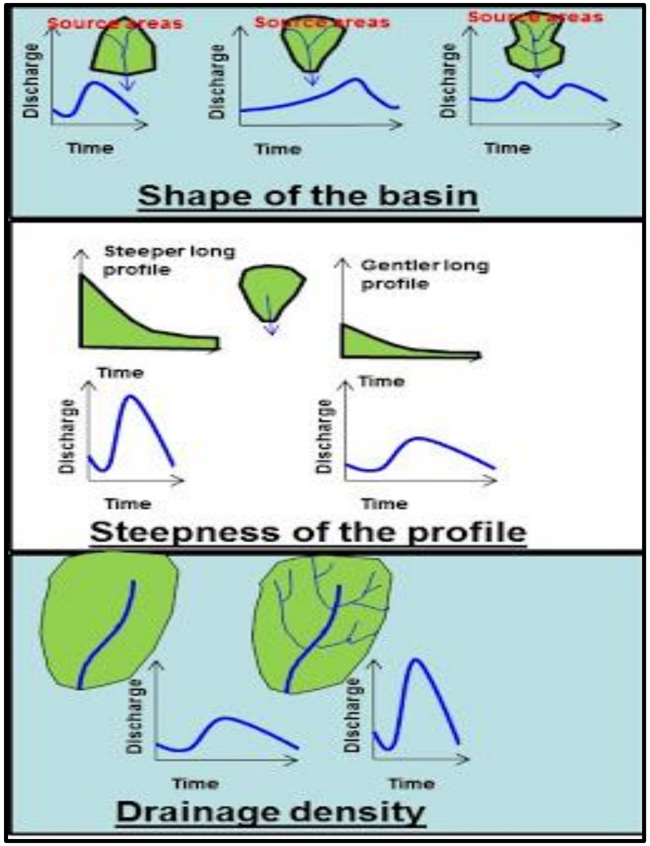
Efforts have been made for explaining simple and cost effective techniques of measuring peak discharge so that even a lay person can understand and measure discharge with minimal support.

Peak Discharge

Peak Discharge : It is the highest concentration of discharge of a stream or a river from its basin or catchment area that occurs. It usually occurs during the monsoon, once in a year.

The peak discharge of a stream may vary from year to year and is a function of

- **Shape of the basin**
- **Drainage Density**
- **Rainfall Intensity**
- **Soil Texture**
- **Vegetation**
- **Slope** and
- **Geology**

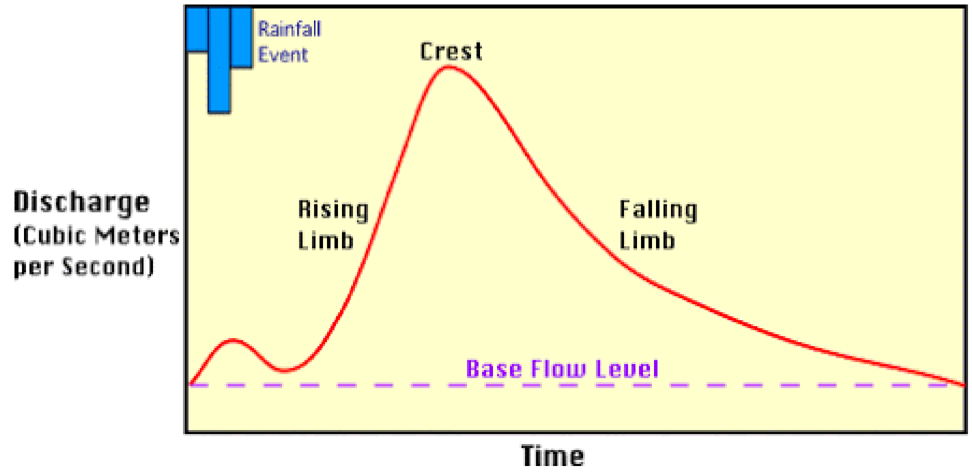


Why Calculate Peak Discharge

Estimation of Peak Discharge is important for designing spillways (for safe disposal of excess or waste water) of all water harvesting structures like dams, reservoirs and ponds, and especially masonry structures like weirs, etc. in a watershed

Hydrograph

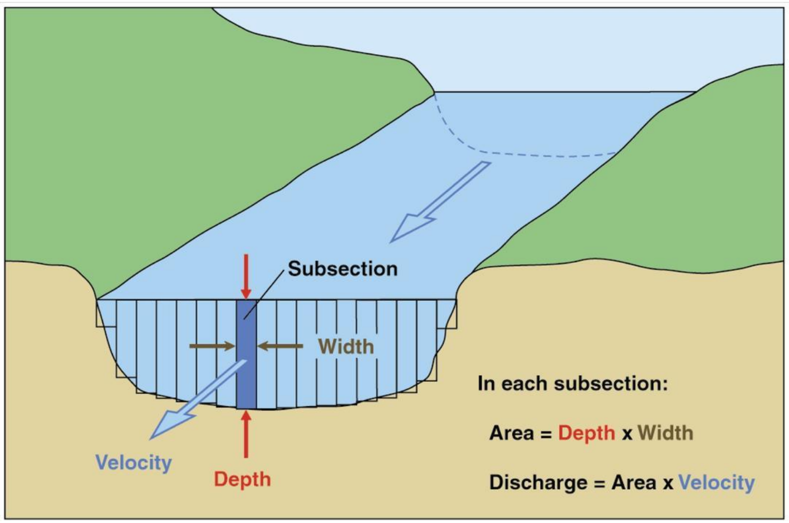
A graph which shows the discharge of a river (related to rainfall), over a period of time.



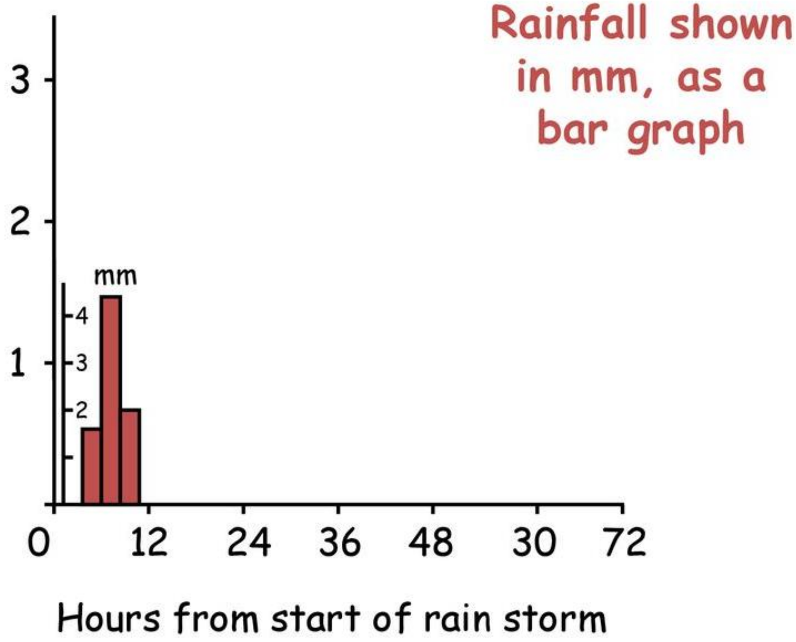
River Discharge

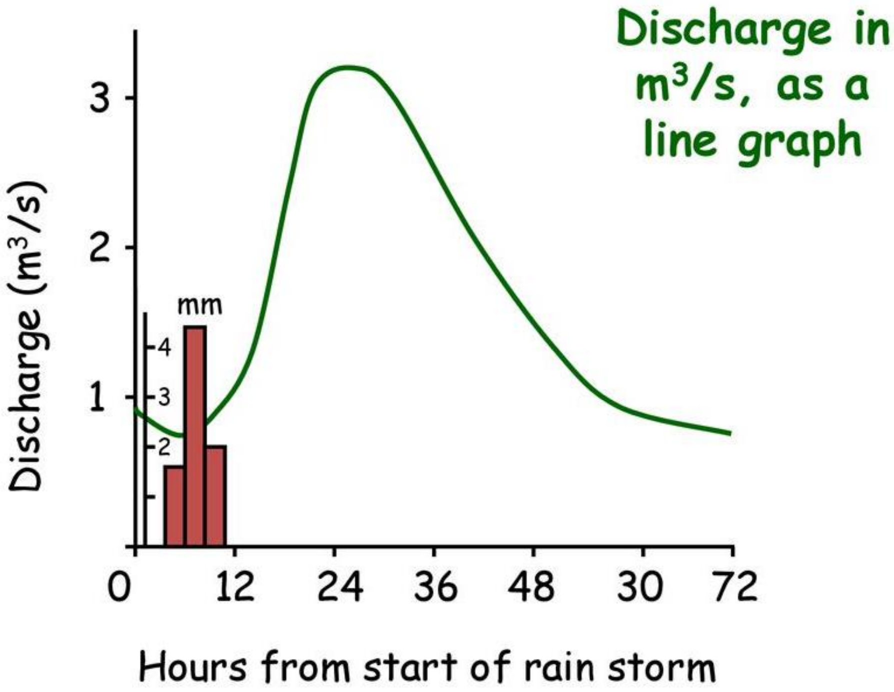
= cross sectional area X rivers mean (average) velocity

(at a particular point in its course)

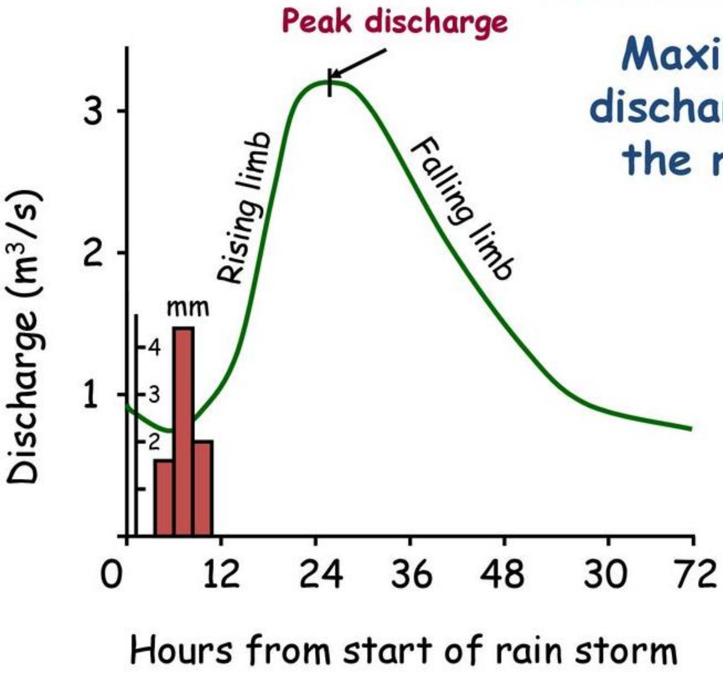


Generating Hydrographs



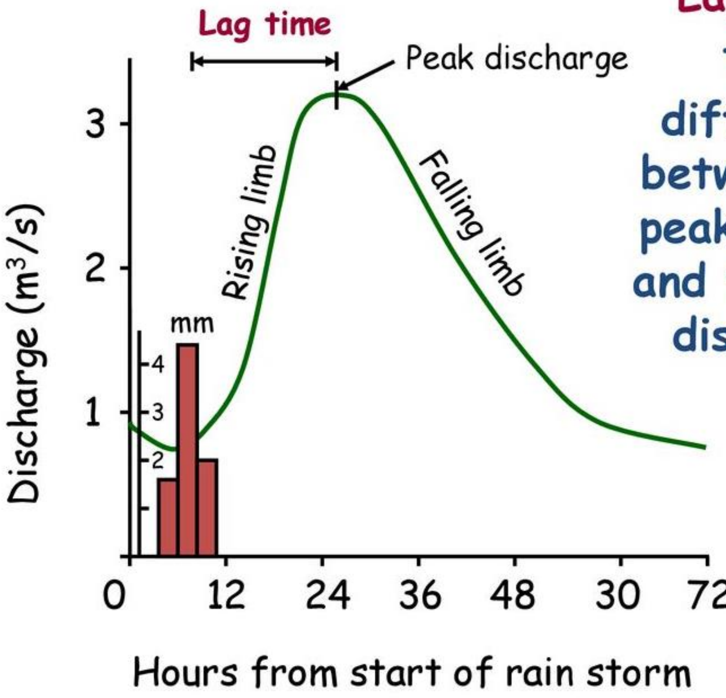


Basic Features of Hydrographs



Peak Discharge

Maximum discharge in the river



Lag time

Time difference between the peak rainfall and the peak discharge

Plotting Hydrographs (Exercise I)

Use the table below to create your own hydrograph and label the points below

Hours	1	2	3	4	5	6
Rainfall (mm)	10	30	40	25	15	5

Time (hrs)	0	2	4	6	8	10	12	14	16	18	20
Discharge (cumecs)	30	35	45	80	130	100	70	50	40	35	30

Peak Rainfall

The hour of greatest rainfall during a storm

Peak Discharge

The time of maximum discharge by the river

Lag Time

The period of time between peak rainfall and peak discharge

Rising Limb

The period of rising river discharge following a period of rainfall.

Falling Limb

The period of time when the rivers discharge is falling

Plotting Hydrographs (Exercise II)

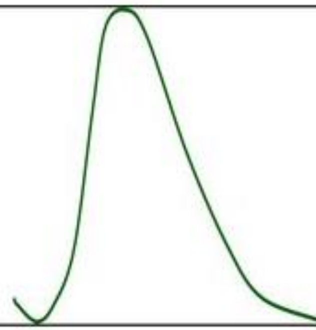
Plot the following two discharge graphs

Time (hrs)	0	2	4	6	8	10	12	14	16	18	20
Discharge 2 (cumecs)	20	25	30	40	47	50	47	42	35	27	20
Discharge 3 (cumecs)	40	50	100	140	120	80	65	55	50	45	40

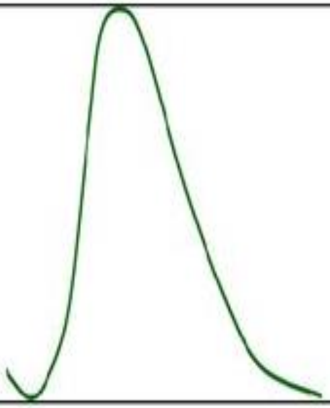
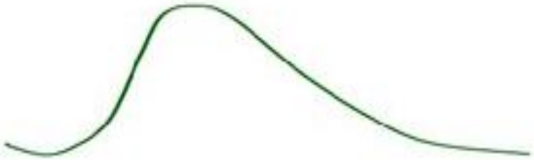
- Try and give reasons for the different shape of the discharge graphs. Think about the physical and human process at work as well as the rainfall

Interpreting Hydrographs

How can hydrographs help in interpreting features of watershed or basin ?

		
Total Rainfall		
Intensity of Rain		
Wetness of Ground		
Rock Type		
Ground Cover		
Slope Angle		

Interpreting Hydrographs (Contd.)

		
Total Rainfall	High	Low
Intensity of Rain	High	Low
Wetness of Ground	Saturated	Un-Saturated
Rock Type	Impermeable	Permeable
Ground Cover	Urban/Deforested (Surface run-off)	Vegetation (Intercept and allow infiltrations)
Slope Angle	Steep (Quicker run-off)	Gentle (Slower)

Peak Discharge Calculation: Dicken's Formula

Although there are several methods of estimating peak discharge only two methods are discussed below:

1. Dicken's formula:

It was formerly adopted only in Northern India but now it can be used in most of the states in India after proper modification of the constant.

$$Q = KA^{3/4}$$

Where Q is discharge in m^3/sec.

A is area of catchment in km^2.

K is Dicken's constant.

According to the area of catchment (terrain, vegetation, etc) and amount of rainfall, the value of K for North and North East India is 11.37. In other parts it may be higher upto 22.04 in Western India.

Peak Discharge Calculation: Rational Formula

2. Rational formula:

The Peak discharge by Rational formula is given by

$$Q_p = \frac{CIA}{360}$$

Where Q_p is the peak discharge in m^3/sec.(or cumec)

A is catchment area in hectares (ha)

C is Coefficient of run off and varies with slope, soil texture and vegetation. A table is provided for different values of C

I is the Intensity of rainfall equivalent to the **time of concentration** of the watershed in mm/hr and

A is the area of watershed in hectares (ha)

Run-off Coefficient C

S. No.	Type of Area	Value of C		
	Slope	Plains 0-5%	Rolling 6-10%	Hilly 11-30%
1	Agricultural land			
	Sandy soil	0.30	0.40	0.52
	Loamy soil	0.50	0.60	0.72
	Clayey soil	0.60	0.70	0.72
2	Grassland			
	Sandy soil	0.10	0.16	0.22
	Loamy soil	0.30	0.36	0.42
	Clayey soil	0.40	0.55	0.60
3	Forest			
	Sandy soil	0.10	0.25	0.30
	Loamy soil	0.30	0.35	0.50
	Clayey soil	0.40	0.50	0.60

Time of Concentration: Kirpich Formula

Time of concentration is a concept used in hydrology to measure the response of a watershed to a rain event. It is defined as the **time** taken by the water to travel (flow) from the most distant or remote point in a watershed to the lowest point or watershed outlet. It is therefore a function of length and slope.

The time of concentration is determined by the **Kirpich Formula** where

$$\mathbf{Tc = 0.0195\, L^{0.770}\, S^{-0.385}} \quad \text{or} \quad \mathbf{Tc = \frac{0.0195\, L^{0.770}}{S^{0.385}}}$$

Where

Tc = the time of concentration, in minutes

L = The length of flow or travel distance in m

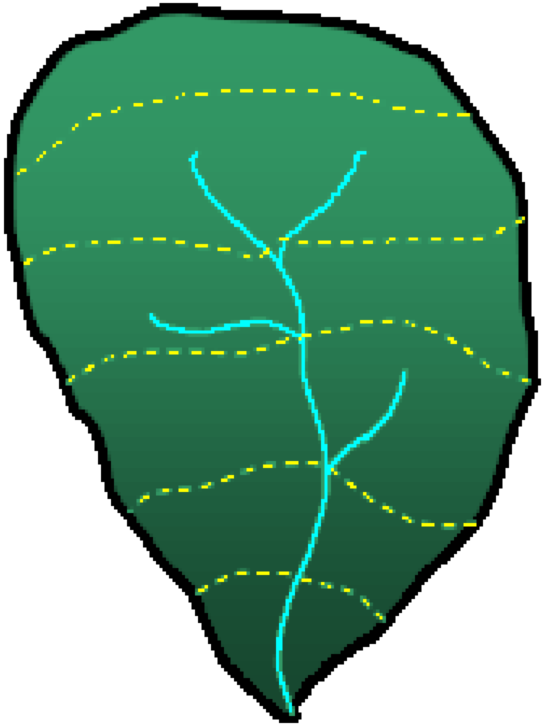
S = The slope of the flow length in absolute term (m/m)

Time of Concentration: Kirpich Formula (Contd.)

Example

If the length of the longest drainage line is 500m and difference in elevation is 44m in a selected catchment of 20ha, then

$$\text{Slope } S = \frac{44}{500} = 0.088 \text{ and } L = 500\text{m}$$



$$T_c = \frac{0.0195\, L^{0.770}}{S^{0.385}} = \frac{0.0195\,(500)^{0.770}}{(0.088)^{0.385}}$$

$$= \frac{0.0195 \times 119.73}{0.39}$$

$$= \mathbf{6\ min}$$

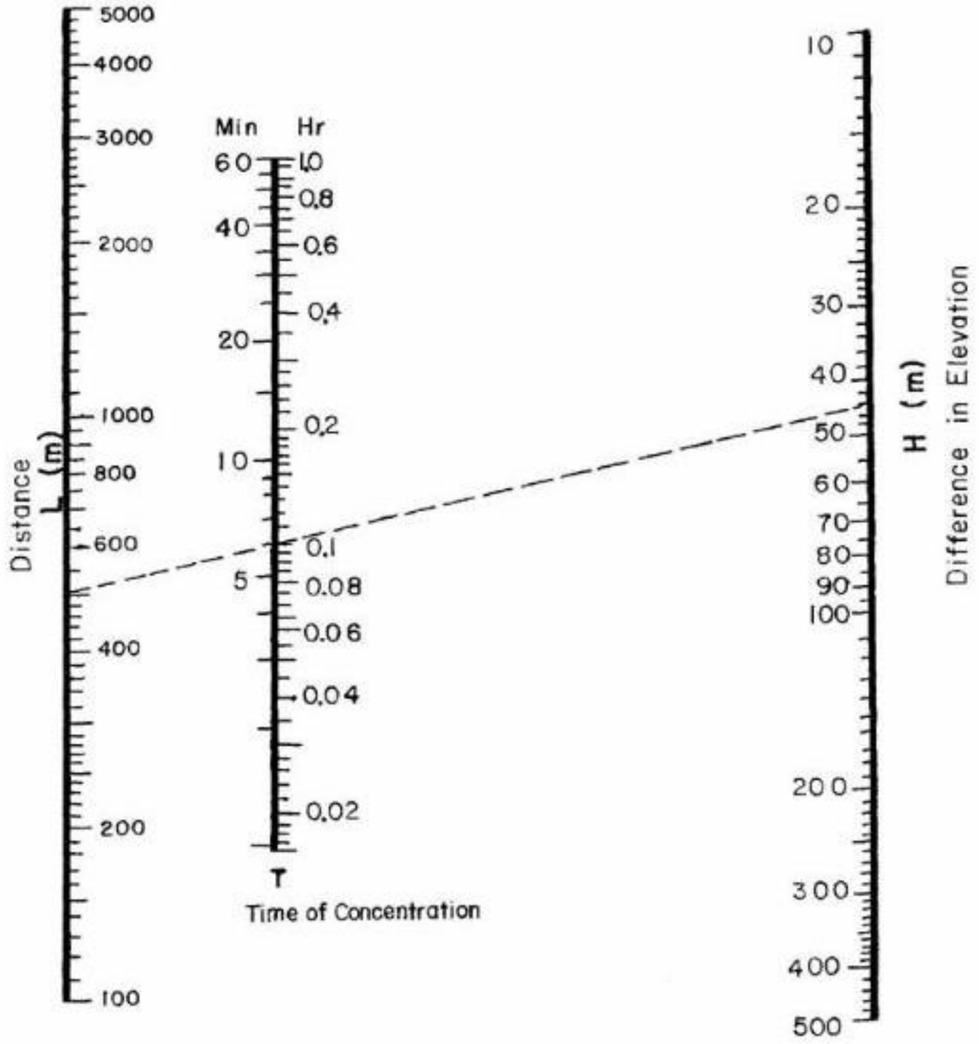
Time of Concentration using Nomograph

Example

This can also be calculated with the help of a **Nomograph.**

On the left is the length of the longest drainage line and on the right is the difference in elevation.

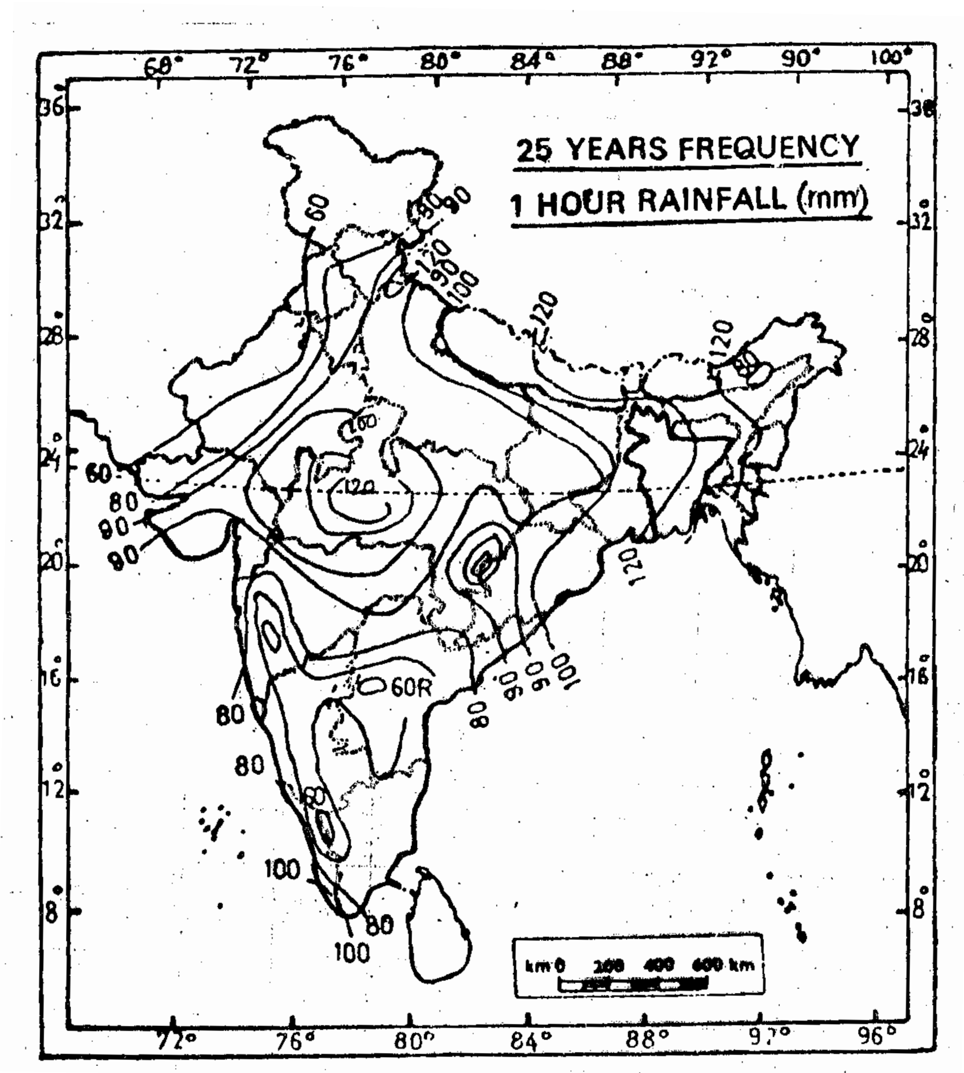
If we join the elevation difference i.e. 44 m with drainage length i.e. 500m it will cut the middle line of time of concentration at **6min**.



One Hour Rainfall Intensity

For estimation of the rainfall intensity equivalent to the time of concentration following is done.

Get an **isohyetal map** of 25 yrs frequency and find **one hour rainfall intensity** of the region. For Meghalaya it is **120mm**.

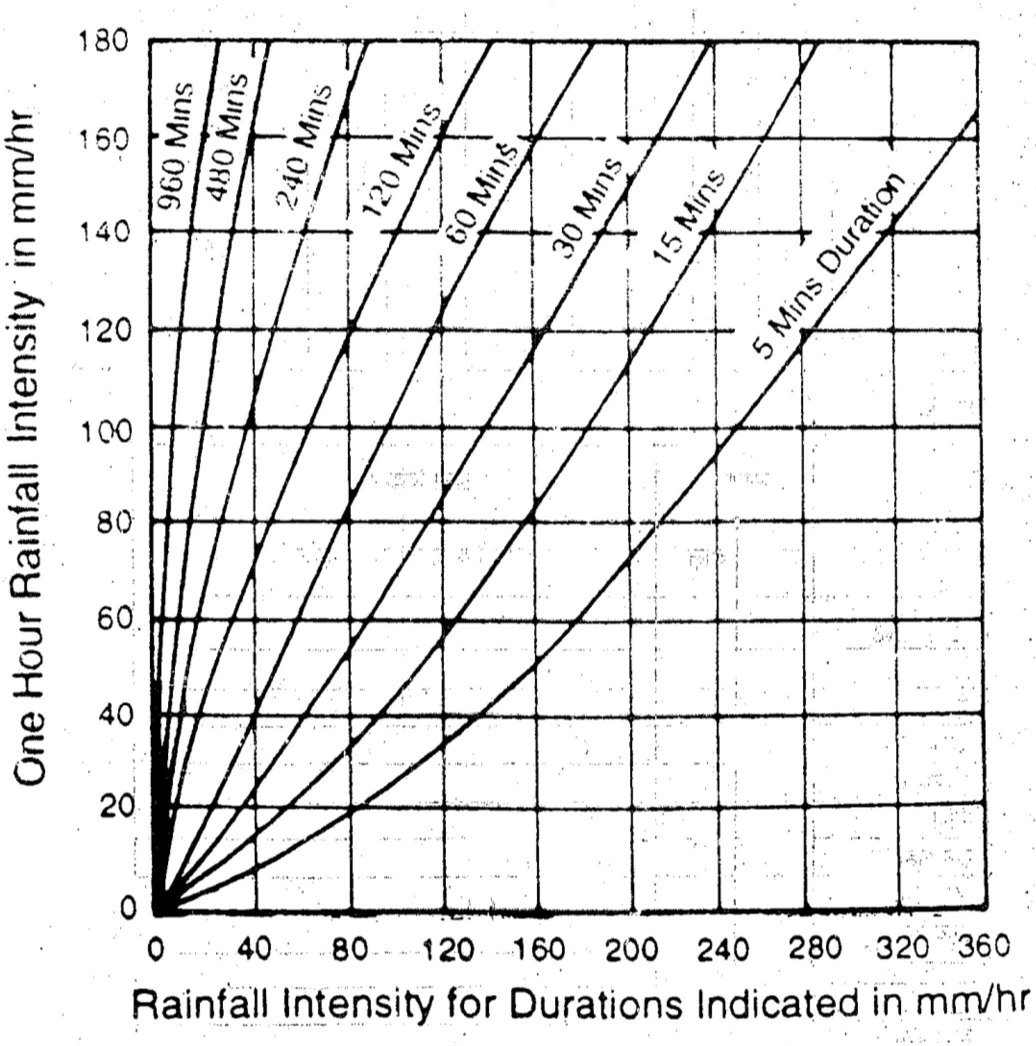


Rainfall Intensity

In the graph on Y Axis is the one hour rainfall intensity. There are different graphs of Tc for different time.

Draw a horizontal line from Y axis to Tc of the area.

Then draw a vertical line from the point of intersection to get the **Rainfall intensity in mm/hr for the required Tc.** For the selected watershed it is about **260 mm/hr**



Estimation of Run-off coeficient

Assuming that the soil texture in the selected watershed is loamy and the land use is Agricultural land = 4ha (A_1) with 10%, pasture land = 6ha (A_2) with 20% slope and forest land = 10ha (A_3) with 30% slope, then

As per table C for Ag Land = 0.60 (C_1),
for Pasture Land = 0.42 (C_2) and
for Forest Land = 0.50 (C_3) then

average run-off Coefficient is given by:

$$\mathbf{C} = \frac{A_1 C_1 + A_2 C_2 + A_3 C_3}{A_1 + A_2 + A_3}$$

$$= \frac{4 \times 0.6 + 6 \times 0.42 + 10 \times 0.50}{4 + 6 + 10}$$

$$= \frac{2.4 + 2.52 + 5.0}{20}$$

$$= \mathbf{0.496}$$

S. No.	Type of Area	Value of C	
	Slope	Rolling 6-10%	Hilly 11-30%
1	Agricultural land		
	Sandy soil	0.40	0.52
	Loamy soil	0.60	0.72
	Clayey soil	0.70	0.72
2	Grassland		
	Sandy soil	0.16	0.22
	Loamy soil	0.36	0.42
	Clayey soil	0.55	0.60
3	Forest		
	Sandy soil	0.25	0.30
	Loamy soil	0.35	0.50
	Clayey soil	0.50	0.60

Estimation of Peak discharge (By Rational Formula)

Now Peak Discharge Qp is given by

$$\mathbf{Qp = \frac{CIA}{360}}$$

For the selected watershed

C = 0.496

I = 260 mm/hr and

A = 20 ha then

$$\mathbf{Qp} = \frac{0.496 \times 260 \times 20}{360}$$

= 7**.16 cumec**

Estimation of Spillway Length

Suppose a water harvesting structure like a **check dam** is proposed at the outlet point of the catchment area. To make the dam **safe** it is important that the water should **not overtop** the dam. For this a spillway is constructed. These are usually **rectangular** in section. The discharge over the rectangular section is given by

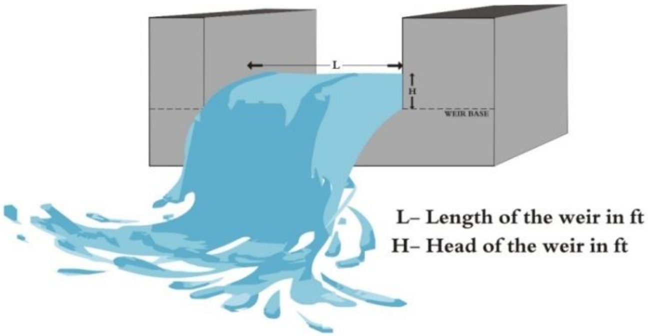
$$Q = 1.84\ L\ H^{3/2}$$

where,

Q= Discharge in m^3 */sec*

L= Length of the weir (or channel width)in m

H= Head of water over of the weir in m



The height of spillway is usually not kept more than 0.75m. Therefore for the selected catchment length of the spillway

$$\mathbf{L} = \frac{Q}{1.84\ H^{3/2}} = \frac{7.16}{1.84 \times 0.75^{3/2}} = \frac{7.16}{1.95} = \mathbf{5.99\ m}$$

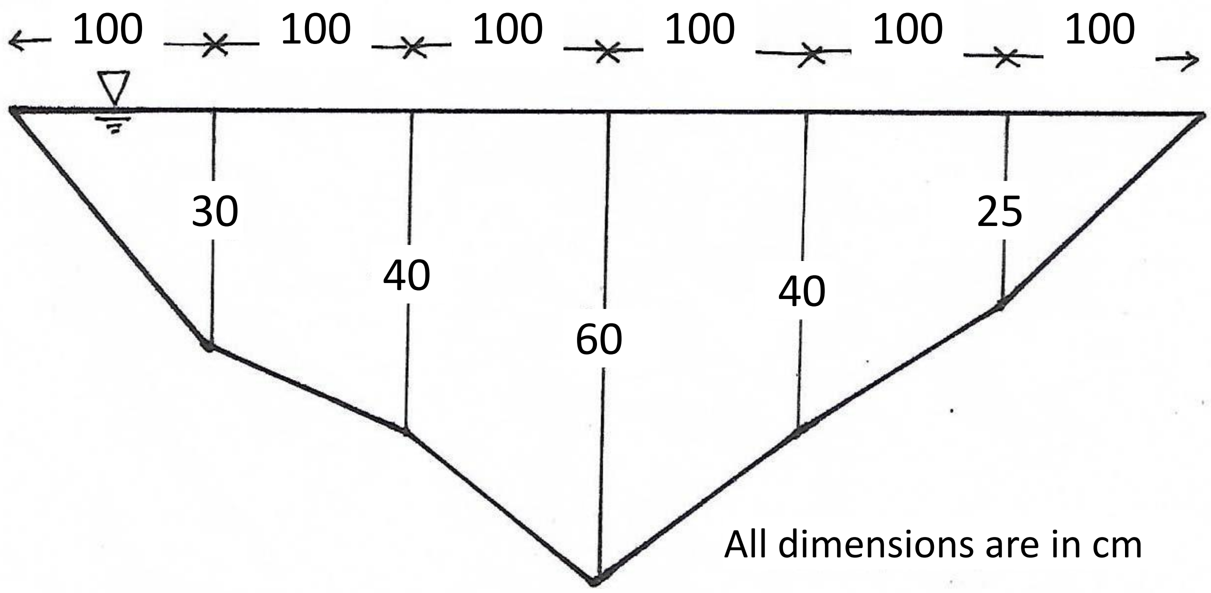
Estimation of Spillway Cross Section

A thumbs rule process to assess the cross-sectional area during peak discharge is as follows.

- Go to the approximate location of the drainage point where a structure will be constructed.
- Enquire with the villagers (preferably experienced elderly person) the maximum level of water in the drainage line in the last 20 years or so. He/she might say the water reached the toe of a tree on the left bank some 15 yrs back or the rock on the right bank was submerged.
- Take a rope and placing it horizontally, place two pegs on either side of the banks.
- Measure depth of the drain at regular interval
- Calculate the area of cross section as was discussed in discharge measurement session earlier.

Estimation of Spillway Cross Section (Contd.)

- Draw the section on a plain paper or graph paper
- Calculate the area of different sections



Estimation of Spillway Cross Section (Contd.)

The areas of different sections are:

Section 1: Triangle Area A1 = ½ 100 x 30 = 1500cm^2.

Section 2: Trapezoid Area A2 = ½ (30+40) x 100 = 3500cm^2

Section 3: Trapezoid Area A3 = ½ (40+60) x 100 = 5000cm^2

Section 4: Trapezoid Area A4 = ½ (60+40) x 100 = 5000cm^2

Section 5: Trapezoid Area A5 = ½ (40+25) x 100 = 3250cm^2

Section 6: Triangle Area A6 = ½ 25x100 = 1250cm^2.

Total cross sectional area

A = (A1+A2+A3+A4+A5+A6) = 19,500cm^2 = **1.95 m^2**

This is the cross sectional area for peak discharge. If the depth of spillway is fixed at 0.75 the length **(L)** of the spillway would be 1.95/0.75 = **2.6**m

Questions

- What is a peak discharge?
- Why is peak discharge important?
  a) For selecting watershed activities
  b) For designing a spillway of the structure in a watershed
  c) For determining the height of the structure
  d) For determining the storage capacity of the structure
- What is time of concentration?
  a) Time taken by the float to reach from one point to a specific point.
  b) Time taken by the water to travel from farthest point to watershed outlet.
  c) Time taken by the water to travel from highest elevation to watershed outlet.
- Peak discharge is a function of
  a) Rainfall intensity
  b) Vegetation cover
  c) Slope
  d) Geology
  e) All of these

Links for Videos

- https://www.youtube.com/watch?v=DnZLLgLjVt0
- https://www.youtube.com/watch?v=gb9JvFfo3vc

Thank You

ITBP Road, Niranjanpur, Near Hotel Sun Park Inn
Dehra Doon – 248001 (Uttarakhand)
Tel. : 0135-2971954, 55
E-mail : psiddoon@gmail.com
Website : www.peoplesscienceinstitute.org