3. INFILTRATION, RUNOFF AND HYDROGRAPHS

INFILTRATION

Infiltration is the flow of water into the ground through the soil surface.

- **Horton's Equation:** Horton expressed the decay of infiltration capacity with time as an exponential decay given by

$$f_{ct} = f_{cf} + (f_{co} - f_{cf})e^{-k_h \cdot t_d}$$

where

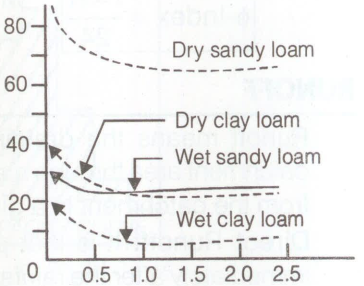
f_{ct} = infiltration capacity at any time t from start of the rainfall

f_{co} = Initial infiltration capacity at t = 0

f_{cf} = Final steady state value

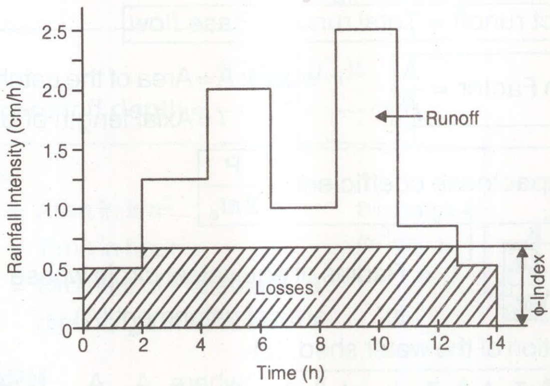
t_d = Duration of rainfall

k_h = Constant depending on soil.



INFILTRATION INDICES

In hydrological calculations involving floods it is found convenient to use a constant value of infiltration rate for the duration of the storm. The defined average infiltration rate is called *infiltration index* and two types of indices are in common use.



(i) **W-Index:** In an attempt to refine the φ-index the initial losses are separated from the total abstractions and an average value of infiltration rate, called W-index, is defined as

$$\boxed{W-\text{Index} = \frac{P - R - I_a}{t_e}}$$

where, P = Total storm precipitation (cm)
R = Total storm runoff (cm)
I_a = Initial losses (cm)
t_e = Duration of rainfall excess
W–Index = Avg. rate of infiltration (cm/hr)

(ii) **φ–Index:** The φ-index is the average rainfall above which the rainfall volume is equal to the runoff volume. The φ-index is derived from the rainfall hyetograph with the edge of the resulting run-off volume.

$$\boxed{\phi\text{-Index} = \frac{I - R}{24}}$$

where, R = Runoff in cm from a 24-h rainfall of intensity I cm/day

RUNOFF

Runoff means the draining or flowing off of precipitation from a catchment area through a surface channel. It thus represents the output from the catchment in a given unit of time.

Direct Runoff: It is that part of the runoff which enters the stream immediately after the rainfall. It includes surface runoff, prompt interflow and rainfall on the surface of the stream. In the case of snow-melt, the resulting flow entering the stream is also a direct runoff. Sometimes terms such as *direct storm runoff* the *storm runoff* are used to designate direct runoff.

Base Flow: The delayed flow that reaches a stream essentially as groundwater flow is called base flow.

(i) Direct runoff = Surface runoff + Prompt Interflow

(ii) Direct runoff = Total runoff – Base flow

(iii) $\boxed{\text{Form Factor} = \frac{A}{l^2}}$ where, A = Area of the catchment
l = Axial length of basin.

(iv) $\boxed{\text{Compactness coefficient} = \frac{P}{2\pi r_e}}$

$\boxed{r_e = \sqrt{\frac{A}{\pi}}}$ r_e = Radius of equivalent circle whose Area is equal to area of catchment (A)

(v) Elevation of the water shed, (z)

$$\boxed{z = \frac{A_1 z_1 + A_2 z_2 + \ldots + A_n z_n}{A_1 + A_2 + \ldots A_n}}$$

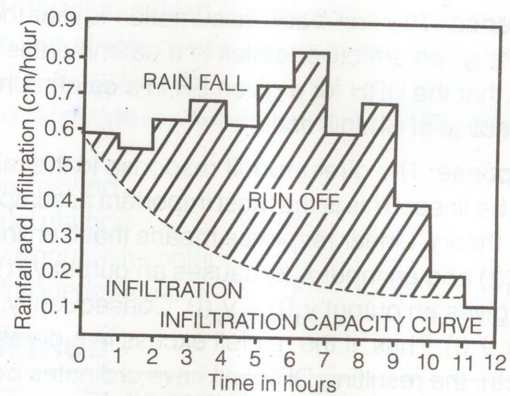
where, A_1, A_2 .... Area between successive contours.
z_1, z_2 ... mean elevation between two successive contrours.

METHOD TO COMPUTE RUNOFF

(i) **By Runoff Coefficient**

$\boxed{Q = KP}$ where, P = Precipitation
K = Runoff coefficient
Q = Runoff

(ii) **By Infiltration Capacity Curve**



Infiltrations capacity curve and run-off

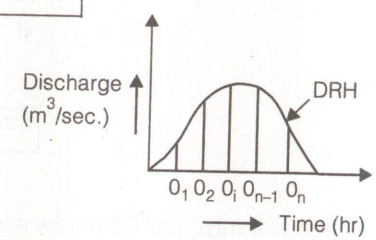
(iii) **By Rational Formula**

$$\boxed{Q_P = \frac{1}{36} \cdot kP_C A}$$

where, k = Runoff coefficient
P_C = Critical design rainfall intensity in cm/hr
A = Area of catchment in hectare
Q_P = Peak discharge in m³/sec.

(iv) $$\boxed{\text{Direct runoff depth} = \frac{0.36\sum_{i=1}^{n}(O_i)t}{A}\text{ cm}}$$

where,
A = Area in km²
t = Time in hour
O_i = Ordinate of i^{th} element i.e., discharge in m³/sec.



HYDROGRAPH

A plot of the discharge in a stream plotted against time chronologically is called a hydrograph.

UNIT HYDROGRAPH

This method was first suggested by Sherman in 1932 and has undergone many refinements since then.

A unit hydrograph is defined as the hydrograph of direct runoff resulting from one unit depth (1 cm) of rainfall excess occurring uniformly over the basin and at a uniform rate for a specified duration (D hours).

Time Invariance: The first basic assumption is that the direct-runoff response to a given effective rainfall in a catchment is time invariant. This implies that the DRH for a given ER in a catchment is always the same irrespective of when it occurs.

Linear Response: The direct-runoff response to the rainfall excess is assumed to be linear. This is the most important assumption of the unit-hydrograph theory. Linear response means that if an input $x_1(t)$ cause an output $y_1(t)$ and an input $x_2(t)$ causes an output $y_2(t)$, then an input $x_1(t) + x_2(t)$ gives an output $y_1(t) + y_2(t)$. Consequently, if $x_2(t) = rx_1(t)$, then $y_2(t) = r_1y_1(t)$. Thus, if the rainfall excess in a duration D is r times the unit depth, the resulting DRH will have ordinates bearing ratio r to those of the corresponding D-h unit hydrograph.

(i) $\boxed{t'_B = t_B + (n-1)D}$

where, t'_B = Base period of T hr U.H

t_B = Base period of D hr U.H

also, $T > D$

$\boxed{T = n \cdot D}$ where 'n' is an integer.

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