# Infiltration

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# definition

- ***Infiltration:*** is the process of water entry into a soil
- ***Soil water movement (percolation)*** **:**is the process of water flow from one point to another point within the soil.
- ***Infiltration rate:*** *is the rate at which the water actually infiltrates through the soil*
- ***Infiltration capacity****:the maximum rate at which the ground can absorb water*
- ***Field capacity****:is the volume of water the ground can hold.*

# Infiltration capacity(f) relation with rainfall intensity(i)

$f = f_c$, when $i >= f_c$ or $f = I$, when $i < f_c$

# FACTORS AFFECTING INFILTRATION

- condition of the land surface (cracked, crusted,compacted) land vegetation cover,
- surface soil characteristics (grain size & gradation),
- storm characteristics (intensity, duration & magnitude),
- surface soil and water temperature,
- chemical properties of the water and soil.

# MEASUREMENT OF INFILTRATION

Infiltration varies temporally and spatially

Could be measured as

- Areal Infiltration (from analysis of rainfall-runoff data)
- Point infiltration

  Infiltrometer is the instument used to measure point infiltration

# ESTIMATION INFILTRATION

- **Horton infiltration**

basd on hortons conclusion that infiltration begins at some rate $f_o$ *and exponentially decreases until it reaches a constant* $f_c$.

$$f_p = f_c + (f_0 - f_c)e^{-kt}$$

- Note that infiltration takes place at capacity rates only when the intensity of rainfall i equals or exceeds $f_p$

$$F(t) = f_c t + \frac{(f_0 - f_c)(1 - e^{-kt})}{k}$$

# The ϕ-index method

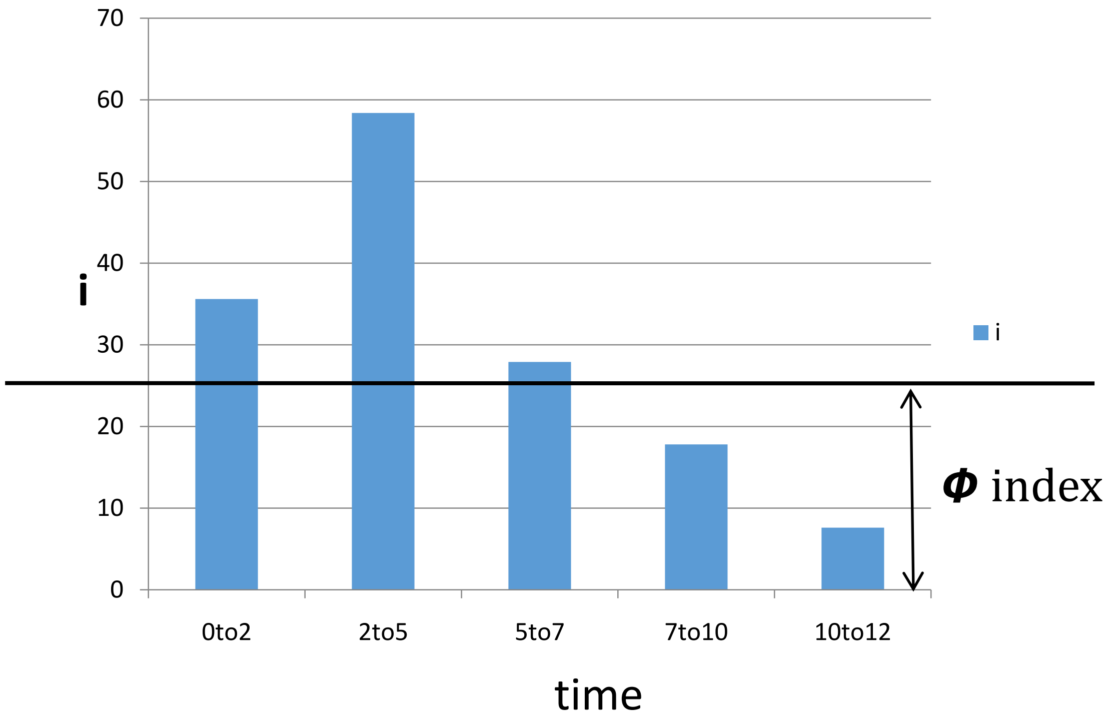
- The **ϕ**-index is the simplest method and is calculated by finding infiltration as a difference between gross rainfall and observed surface runoff.
- It is an average RF above which the RF volume is equal to RO volume
- *The* ϕ-index method gives *better estimate when losses is calculated after heavy rainfall and the soil profile is saturated.*

# Example:

- Estimate **ϕ**-index of the catchment having an area 2.26 km2.The observed runoff caused by the rainfall given in the Table is 282.097 m3.

| Time (hr) | Rainfall (mm/h |
| --- | --- |
| 00 to 2 | 35.6 |
| 2 to 5 | 58.4 |
| 5 to 7 | 27.9 |
| 7 to 10 | 17.8 |
| 10 to 12 | 7.6 |

# Computation of $\boldsymbol{\Phi}$ index from hyetograph



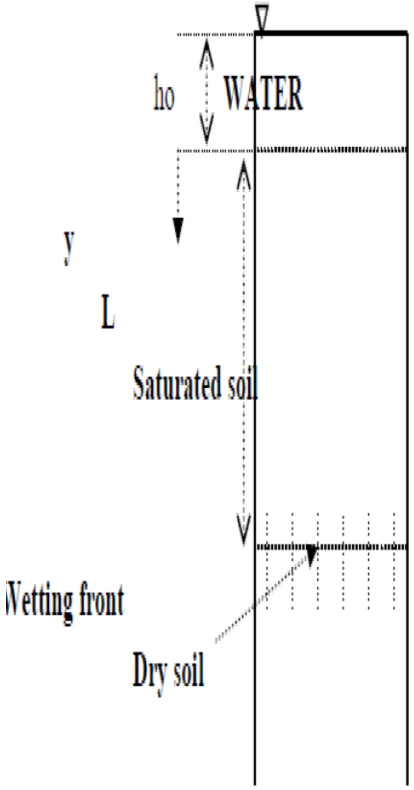
# The Green-Ampt method

Assumes that water is pounded on the ground surface. Consider a vertical column of soil of unit horizontal cross-sectional area and let a control volume be defined around the wet soil between the surface and depth L.

$$F(t) = L(n - \theta_i)$$

$$F(t) = Kt + \psi\Delta\theta \ln(1 + \frac{F(t)}{\psi\Delta\theta})$$

- *Θ $_I$ -initial moisture content*
- *n – porosity*
- *K- hydraulic conductivity*



# After simplification

$$F(t) - \psi\Delta\theta \ln(1 + \frac{F(t)}{\psi\Delta\theta}) = Kt$$

$$f = K(\frac{\psi\Delta\theta}{F(t)} + 1)$$

The attraction soil exerts on the water

**Table 4.1** USDA Soil Texture Green-Ampt Infiltration Parameters (Maidment, 1993)

| Soil texture classes | Porosity n | Wetting front soil suction head ψ (cm) | Saturated hydraulic conductivity Ks (cm/hr) |
|---|---|---|---|
| Sand | 0.437<br>(0.374-0.500) | 4.95<br>(0.97-25.36) | 23.56 |
| Loamy sand | 0.437<br>(0.363-506) | 6.13<br>(1.35-27.94) | 5.98 |
| Sandy loam | 0.453<br>(0.351-0.555) | 11.01<br>(2.67-45.47) | 2.18 |
| Loam | 0.463<br>(0.375-0.551) | 8.89<br>(1.33-59.38) | 1.32 |
| Silt loam | 0.501<br>(0.420-0.582) | 16.68<br>(2.92-95.39) | 0.68 |
| Sandy clay loam | 0.398<br>(0.332-0.464) | 21.85<br>(4.42-108.0) | 0.30 |
| Clay loam | 0.464<br>(0.409-0.519) | 20.88<br>(4.79-91.10) | 0.20 |
| Silty clay loam | 0.471<br>(0.418-0.524) | 27.30<br>(5.67-131.5) | 0.20 |
| Sandy clay | 0.430<br>(0.370-0.490) | 23.90<br>(4.08-140.2) | 0.12 |
| Silty clay | 0.479<br>(0.425-0.533) | 29.22<br>(6.13-139.4) | 0.10 |
| Clay | 0.475<br>(0.427-0.523) | 31.63<br>(6.39-156.5) | 0.06 |

**Table4.2**: Mean steady-state matric potential drop $\Psi i$ across seals by soil texture (Maidment 1993)

| Soil texture | Matric, potential drop $\Psi i$ (cm) | Reduction factor for sub-crust conductivity SC |
|---|---|---|
| Sand | 2 | 0.91 |
| Loamy sand | 3 | 0.89 |
| Sandy loam | 6 | 0.86 |
| Loam | 7 | 0.82 |
| Silt loam | 10 | 0.81 |
| Sandy clay loam | 5 | 0.85 |
| Clay loam | 8 | 0.82 |
| Silty clay loam | 10 | 0.76 |
| Sandy clay | 6 | 0.80 |
| Silty clay | 11 | 0.73 |
| Clay | 9 | 0.75 |

# Example

- Compute the infiltration rate f and cumulative infiltration F after one hour of infiltration into a silt loam soil that initially had an effective saturation of 30 %. Assume water is pounded to a small but negligible depth on the surface.

For a silt loam soil $\Psi = 16.7$ cm, $K = 0.65$ cm/hr, $n = 0.501$, $\theta i = 30\% \times 0.501$

$$\Delta\theta = n - \theta i = 0.501 - 30\% \times 0.501 = 0.35.$$

$$\Psi\Delta\theta = 16.7 \times 0.35 = 5.84 \text{ cm}.$$

The cumulative infiltration at t = 1 hour is calculated employing Eq. (4.10), taking a trial value of F(t) = Kt =0.65 cm.

$$F(t) = Kt + \psi\Delta\theta \ln(1 + \frac{F(t)}{\psi\Delta\theta})$$

= 1.27 cm

$$F(1) = 0.65 * 1 + 5.68 \ln(1 + \frac{0.65}{5.68})$$

Substituting F = 1.27 cm in Eq(4.10) we get 1.79 cm and aftera number of iteration F converges to a constant value of 3.17 cm.

Infiltration rate after one hour is estimated by Eq. (4.11)

$$f = K(\frac{\psi\Delta\theta}{F(t)} + 1)$$

$$f = 0.63(\frac{5.68}{3.17} + 1)$$

= 1.81 cm/hr.

# The Phillip method

Phillip proposed an equation to estimate cumulative infiltration F(t) by

$$F(t) = St^{0.5} + Kt \qquad (4.3)$$

Where:

$S$ = sorpitivity which is a function of the soil suction potential (representing soil suction head

$K$ = the hydraulic conductivity of the soil (representing gravity head)

$t$ = time from the beginning of the rainfall.

Noting that $f(t) = dF(t)/dt$, the Phillip equation for infiltration rate is

$$f(t) = 0.5St^{-0.5} + K \qquad (4.4)$$