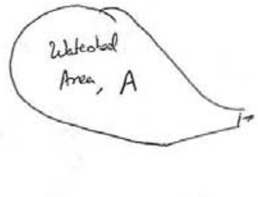
LECTURE – 16
14-FEB-2012

SCS Method

Yesterday, we introduced to you the SCS method to evaluate direct runoff.
For a watershed subjected to a rainfall (which is measured in units of length → P), there will be some amount that flows along the surface.



$$P_e = \frac{(P - I_a)^2}{P - I_a + S}$$

→ Again please note that here in the expression ~~there~~ all the quantities are in units of length

→ Therefore, you need to envisage that if the runoff is given as P_e

* this means that volume of runoff due to rainfall P is = P_e × Watershed area.

→ The maximum potential abstraction is given as S (in units of length). This means that from the available volume of water that is precipitated (i.e. P × Watershed Area), a maximum volume of = S × Watershed Area can get abstracted (or deducted).

→ Similarly the meaning of initial abstraction I_a (again in units of length) is that a volume = I_a × Watershed Area has to be deducted initially even before the runoff process begins.

→ When the runoff begins, due to ponding, on the surface there will be still some volume of water that is abstracted and this is $= F_a \times$ Watershed Area.

→ So F_a is not depth of ponding. It signifies the volume of water that is to be deducted.

i.e. why we were able to write

$$P = P_e + I_a + F_a$$

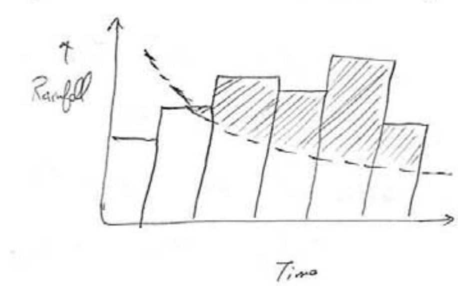
Actual volume conservation equation is

$$P \times \text{Watershed Area} = (P_e + I_a + F_a) \times \text{Watershed Area}$$

* Using curve numbers for the respective land use and soil category, we can get the potential abstraction ~~volume~~ S.

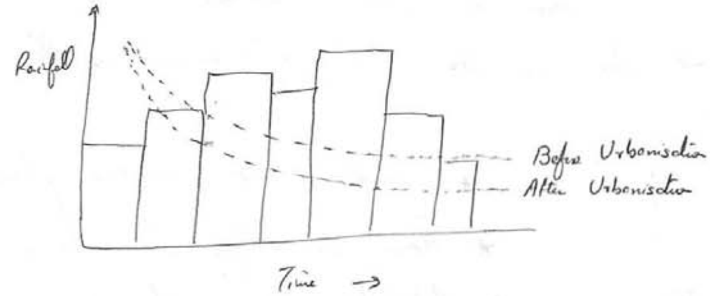
Effect of Urbanisation

Due to urbanisation, the watershed properties change. You have seen that infiltration rate decreases with time



The shaded area is effective rainfall (or excess rainfall).

Due to urbanisation, the hyetograph can change



→ Volume of water available for surface runoff increases due to increase in imperviousness ~~on~~ surface.

→ Also the provision of drainage channels and canals (man made) can increase efficiency of surface runoff.

If you recall, in the beginning of surface water system we have stated that surface water — either stored or flowing.

→ Till now we have seen how much amount (or volume) of surface runoff can occur for a given rainfall.

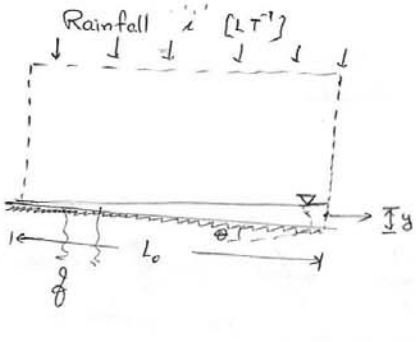
→ How the flow occurs and its velocity are not studied yet

Flow Depth and Velocity

→ Flow of water begins when the surface starts getting ponded.

→ We have briefly seen overland flow
||ly there are channel flows also.

Overland Flow → The thin sheet of flow occuring over a wide surface.
→ This is the first mechanism of flow.



* Consider a uniform plane
* Rain is falling at intensity i.
* Infiltration occurs at any instant at the rate f.
* Let us assume that sufficient time is elapsed and the process are in steady state conditions.

→ The length of plane considered $= L_o$
Width considered = Unit width
Slope of the plane, $S_o = \tan\theta$

→ The continuity equation for water in liquid state for the control volume considered:

$$\iint_{cs} \vec{v}\cdot\hat{n}\, dA = 0 \quad \text{(Steady state problem)}$$

* Inflow to control volume in any time interval Δt

$$= i\, \Delta t\, L_o \cos\theta \times 1$$

∴ Rate of inflow to control volume $= i\, L_o \cos\theta$
Rate of outflow from control volume $= f\, L_o \cos\theta + V_y$

∴ Continuity equation is:

$$\iint_{cs} \vec{v}\cdot\hat{n}\, dA = f L_o \cos\theta + V_y - i L_o \cos\theta = 0$$

Let us consider discharge per unit width = q_0

Now $q_0 = Vy$

But $Vy = (i - f) L_0 \cos\theta$ (from continuity eqn)

$\therefore \quad q_0 = (i - f) L_0 \cos\theta$

⇒ In fluid mechanics you have studied Darcy-Weisbach friction equation

The friction head $h_f \approx f \dfrac{L V^2}{8 R g}$

where $R \rightarrow$ hydraulic radius

$\dfrac{h_f}{L} \rightarrow$ friction slope, here $= S_0$ (assuming uniform flow)

Hydraulic radius $R \approx y$.

$$\therefore \quad h_f = f \frac{L V^2}{8 y g}$$

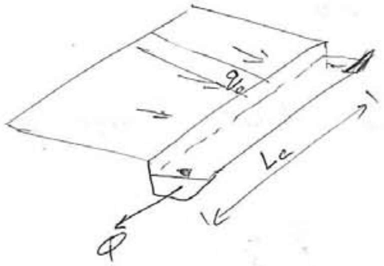
$$\text{or} \quad y = \frac{f V^2}{8 g S_0}$$

or ~~y~~= considering $q_0 = Vy$

we get
$$y = \left[\frac{f q_0^2}{8 g S_0} \right]^{1/3}$$

This is depth of sheet flow on a uniform plane (Please note that this is actual depth and not related to volume depth considered in SCS method).

Channel Flow → The overland flow along surfaces merges in some channels and causes channel flow.



* Consider a channel of length L_c
* There is a uniform overland flow into the channel with discharge per unit width $= q_o$

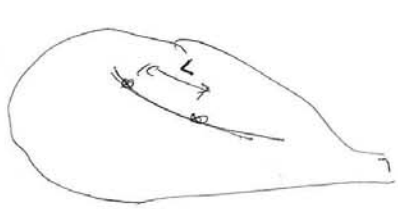
∴ Discharge Q at channel end $= q_o L_c$

Also from Manning's eqn.

$$Q = \frac{1}{n} A R^{2/3} S_o^{1/2}$$

you can identify the depth of flow in channels.

Travel Time



If two points in a stream = L distance

Velocity of flow along path = $v(l)$

Then $dl = v(l)\,dt$

$$\int_0^t dt = \int_0^L \frac{dl}{v(l)} \quad \text{or} \quad t = \int_0^L \frac{dl}{v(l)}$$