Lecture 16

14-September-2016

NRCS METHOD TO DETERMINE SURFACE RUNOFF:

In the last class, we introduced to you the NRCS method.

Recalling the terms,

P= the depth of rainfall.

P_e=Depth of excess rainfall

F_a=Depth of water retained in watershed.

I_a=Depth of water for initial obstruction

S=potential maximum retention for the watershed,

Then P-I_a=potential runoff possible

The SCS method suggest that the ratio of two actuals (i.e. F_a and P_e) to the two potentials (i.e. S and P-I_a) are equal

$$\therefore \frac{F_a}{P_e} = \frac{S}{P - I_a}$$

$$or\ \frac{F_a}{S} = \frac{P_e}{P - I_a}$$

$$P = P_e + I_a + F_a$$

Rearranging and solving, we get

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

This is the basic equation for computing the depth of excess rainfall or direct runoff from a storm using NRCS method

- It is seen that through many observations, empirically

$$I_a = 0.2S$$

$$\therefore P_e = \frac{(P - 0.2S)^2}{P + 0.8S}$$

Further empirical studies suggest that the potential maximum retention S in inches is

$$S = \frac{1000}{CN} - 10$$

Where CN is runoff curve number, which is a function of land use, antecedent soil moisture etc.

- Curve number, CN is dimensionless $0 \leq CN \leq 100$
- For impervious surface and/ or water surface , $CN = 100$
- For natural surface $CN < 100$

ANTECEDENT MOISTURE CONDITION

The curve number obtained through various experiment are plotted for P_e(in inches) verses cumulative rainfall P (in inches)

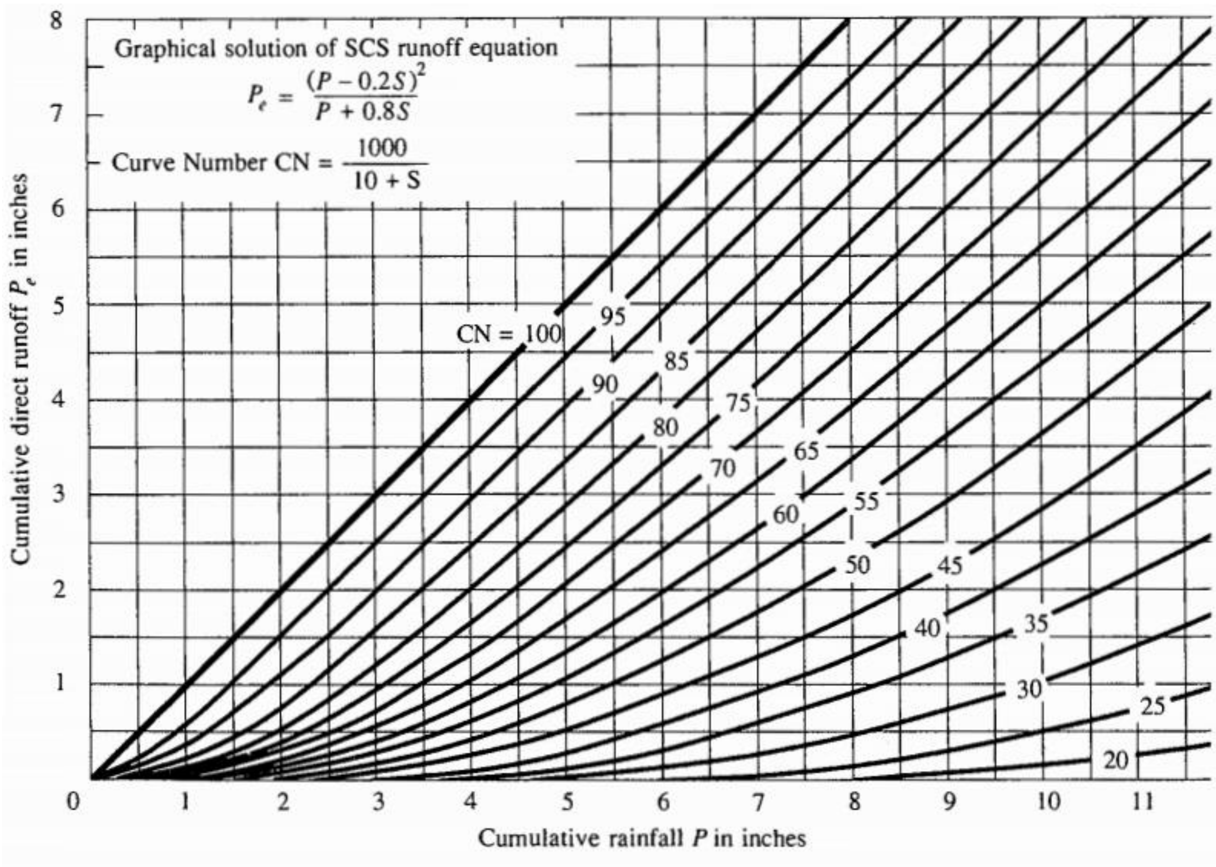


Figure: Solution of NRCS Runoff equation (provided by SCS)

(The snapshot image copied from the course text book Chow et al. (1988))

- This curve number is for antecedent moisture condition II (AMC II)
- For dry condition, you can use AMC I and for wet conditions you can use AMC III

$$CN(I) = \frac{4.2CN(II)}{10 - 0.058CN(II)}$$

$$CN(III) = \frac{23\ CN(II)}{10 + 0.13CN(II)}$$

- So in graphs and tables you are actually provided with curve number for AMC II.
- Empirically, it is observed that the initial abstraction $I_a = 0.2S$ for many small watersheds in USA.

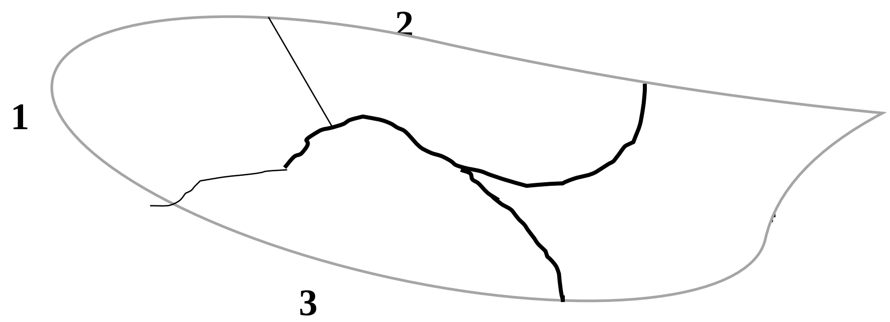
Table: Runoff curve numbers for selected agricultural, suburban, and urban land uses (Antecedent Moisture Condition II and $I_a = 0.2S$)

Land Use Description		Hydrologic Soil Group			
		A	B	C	D
Cultivated land[1]: without conservation treatment		72	81	88	91
with conservation treatment		62	71	78	81
Pasture or range land: poor condition		68	79	86	89
good condition		39	61	74	80
Meadow: good condition		30	58	71	78
Wood or forest land: thin stand, poor cover, no mulch		45	66	77	83
good cover[2]		25	55	70	77
Open Spaces, lawns, parks, golf courses, cemeteries, etc.					
good condition: grass cover on 75% or more of the area		39	61	74	80
fair condition: grass cover on 50% to 75% of the area		49	69	79	84
Commercial and business areas (85% impervious)		89	92	94	95
Industrial districts (72% impervious)		81	88	91	93
Residential[3]:					
Average lot size	Average % impervious[4]				
1/8 acre or less	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.[5]		98	98	98	98
Streets and roads:					
paved with curbs and storm sewers[5]		98	98	98	98
gravel		76	85	89	91
dirt		72	82	87	89

(The table is taken as snapshot from the course text book Chow et al. (1988))

For a watershed if the areas are divided based on curve numbers, a weighted curve number can be evaluated.

Weighted curve number,



$$CN = \frac{1}{100}[L_1 * CN_1 + L_2 * CN_2 + \cdots]$$

L_1, L_2, L_3,…percentage of land use

- The soils are classified by SCS as:
- Group A that may consist of Deep sand, Deep loess, aggregated silts, etc.
- Group B that consist of Shallow loess, sandy loam, etc.
- Group C that consist of clay loams, shallow sandy loam, soils low in organic content, etc.
- Group D consist of soils that swell significantly, heavy plastic clays, etc.

EXAMPLE:

Determine weighted curve number for a watershed with 40% residential,25% open space(good condition),20% commercial and business(i.e. 85% impervious) 15 % industrial (i.e. 72% impervious) the soil group are C,D,C and D.

From the runoff curve number table provided in the text book:

For residential area with soil group C and ¼ is CN=83

For open space, for soil D, the CN=80

For commercial place soil C, the CN =94

For industrial location in soil D, the CN=93

Therefore weighted curve number,

CN = 0.40×83 + 0.25×80 + 0.20×94 + 0.15×93

= 86

To get runoff volume for a 6 inch rainfall:

$$P_e = \frac{(P - 0.2\,S)^2}{P + 0.8S}$$

$$S = \frac{1000}{86} - 10$$

=1.63 inches

$$P_e = \frac{(6 - 0.2 * 1.63)^2}{6 + 0.8 * 1.63}$$

= 4.41 inch

To evaluate Abstractions using Infiltration equations

- Recall, we had studied Green-Ampt equation; Horton's equation; etc. to find the rate of infiltration.
- Using these equations also, we can determine the abstractions (assuming that other abstractions like retention storage; trapping; etc are negligible)
- If we use, Green-Ampt equation, then we need to determine the time required for ponding.
- You have to estimate, what will be the time required for ponding (t_p)?
- As you are aware, till ponding occurs, the infiltration rate and rainfall intensity will be same.
- Substitute these facts in non-linear cumulative infiltration equation of Green-Ampt and subsequently determine the ponding time.
- Once, the infiltration quantity is identified, the surface runoff can be estimated by deducting the abstractions from the total rainfall.