Estimation of runoff

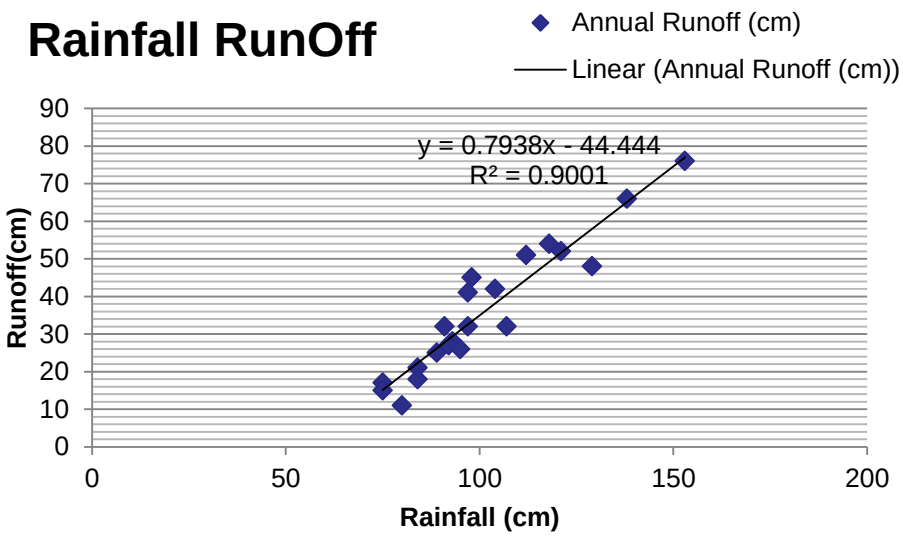
Empirical formulae

Usually, $R = aP + b$

sometimes, $R = aP^n$

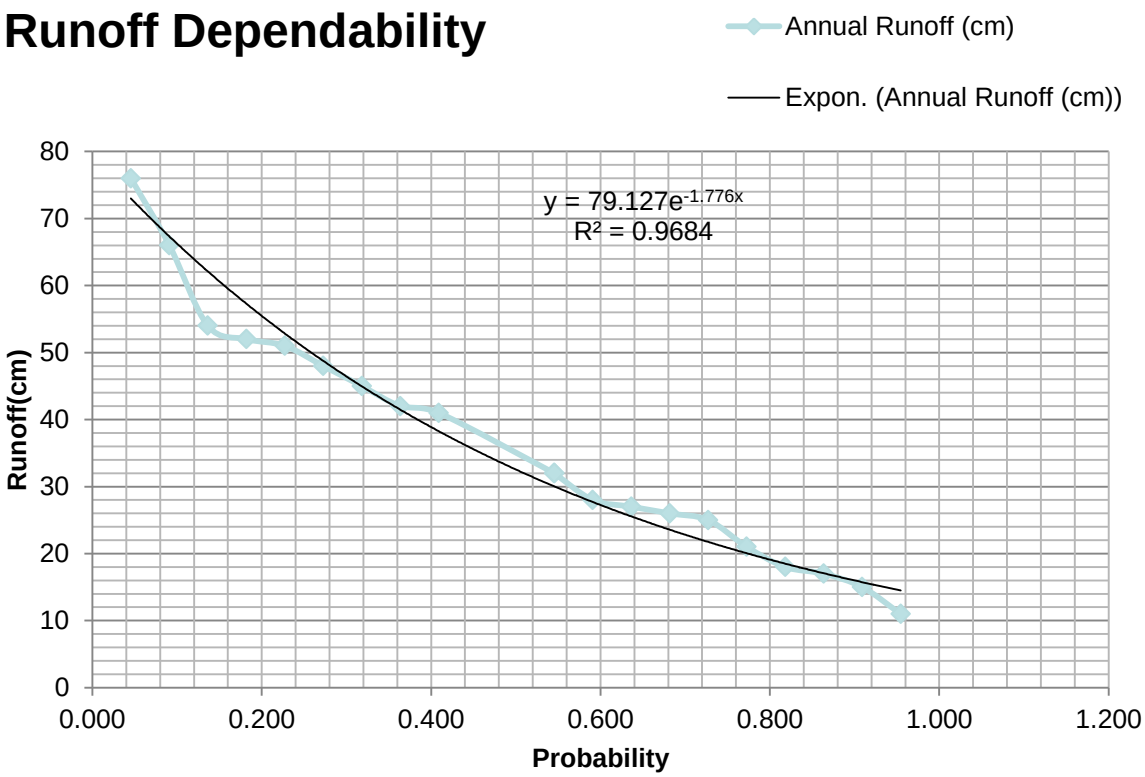
where R = runoff, P = rainfall, a, b, and n, are constants.

Year	Annual Rainfall (cm)	Annual Runoff (cm)
1975	118	54
1976	98	45
1977	112	51
1978	97	41
1979	84	21
1980	91	32
1981	138	66
1982	89	25
1983	104	42
1984	80	11
1985	97	32
1986	75	17
1987	107	32
1988	75	15
1989	93	28
1990	129	48
1991	**153**	76
1992	92	27
1993	84	18
1994	121	52
1995	95	26



Rainfall Runoff Relation					
Year	Annual Runoff (cm)	m(Rank)	T(n+1)/m	Frequency(1/T*100	Probability F/100
1991	76	1	22.00	4.55	0.045
1981	66	2	11.00	9.09	0.091
1975	54	3	7.33	13.64	0.136
1994	52	4	5.50	18.18	0.182
1977	51	5	4.40	22.73	0.227
1990	48	6	3.67	27.27	0.273
1976	45	7	3.14	31.82	0.318
1983	42	8	2.75	36.36	0.364
1978	41	9	2.44	40.91	0.409
1980	32	12	1.83	54.55	0.545
1985	32	12	1.83	54.55	0.545
1987	32	12	1.83	54.55	0.545
1989	28	13	1.69	59.09	0.591
1992	27	14	1.57	63.64	0.636
1995	26	15	1.47	68.18	0.682
1982	25	16	1.38	72.73	0.727
1979	21	17	1.29	77.27	0.773
1993	18	18	1.22	81.82	0.818
1986	17	19	1.16	86.36	0.864
1988	15	20	1.10	90.91	0.909
1984	11	21	1.05	95.45	0.955

Probability F/100	Annual Runoff (cm)
0.045	76
0.091	66
0.136	54
0.182	52
0.227	51
0.273	48
0.318	45
0.364	42
0.409	41
0.545	32
0.545	32
0.545	32
0.591	28
0.636	27
0.682	26
0.727	25
0.773	21
0.818	18
0.864	17
0.909	15
0.955	11



Strange Table

CATCHMENT (good / average / bad)	RAINFALL (MM)	RUNOFF (%)	YIELD per 1 sq.km (mcm)	YIELD per 1 sq.mile (mcm)
good	454.00	**12.8**	**0.058112**	**0.0929792**
		STRANGE TABLE		
RAINFALL (mm)	GOOD	AVERAGE	BAD	
100	0.7	0.5	0.3	
125	1	0.7	0.5	
150	1.5	1.1	0.7	
175	2.1	1.5	1	
200	2.8	2.1	1.4	
225	3.5	2.6	1.7	
250	4.3	3.2	2.1	
275	5.2	3.9	2.6	
300	6.2	4.6	3.1	
325	7.2	5.4	3.6	
350	8.3	6.2	4.1	
375	9.4	7	4.7	
400	10.5	7.8	5.2	
425	11.6	8.7	5.8	
450	12.8	9.6	6.4	
475	13.9	10.4	6.9	

ESTIMATION OF RUNOFF & YIELD OF BASIN(1)

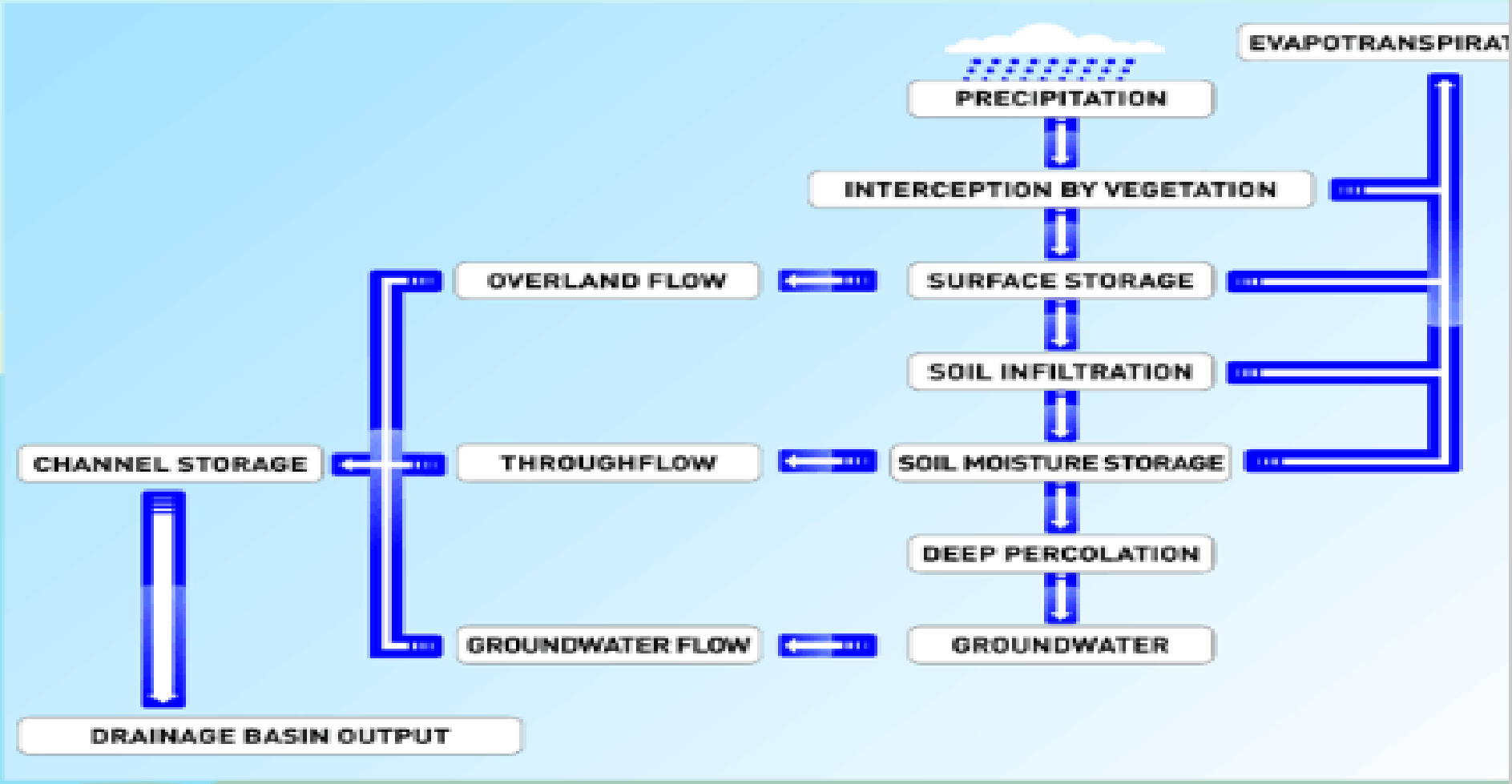
- **Englis**
  - for ghat R= 0.85P-30.5
  - for non Ghat areas R={P-17.8}*P/254
  - R= Run off (cms), P= Precipitation(cms)
- **Khosla'formula**
  - R= P-T/3.74 T= Temp F , R & P in cms
- **Barlow & Lacey**
  - R= k P where k is constant depending on catchment and rainfall characters.

Lacey's formula for Indo-Gangetic plain

$$R = \frac{P}{1 + \frac{304.8}{P}\left(\frac{F}{S}\right)} \qquad \ldots(4.11)$$

where F is a monsoon duration factor varying between 0.5 to 1.5 and S is the catchment factor depending upon the slope and varies from 0.25 for flat areas to 3.45 for hilly areas

- Runoff= Precipitation - Losses



Rational Method

$$Q = C^* I * A$$

Q = C I A

Where: Q = peak flow (m3/hr)

C = runoff coefficient (dimensionless)

I = precipitation intensity (m/hr)

A = effective drainage area (sq.m)

Table E.2: Rational Method Values

LAND USE	C	LAND USE	C
BUSINESS		**LAWNS**	
Downtown areas	0.70-0.95	Sandy soil, flat 2%	0.05-0.10
Neighbourhood areas	0.50-0.70	Sandy soil, average 2-7%	0.10-0.15
		Sandy soil, steep 7%	0.15-0.20
RESIDENTIAL		Heavy soil, flat 2%	0.13-0.17
Single family areas	0.30-0.50	Heavy soil, average 2-7%	0.18-0.22
Multi units, detached	0.40-0.60	Heavy soil, steep	0.25-0.35
Multi units, attached	0.60-0.75		
Suburban	0.25-0.40	**AGRICULTURAL LAND, 0-30%**	
		BARREN PACKED SOIL	
INDUSTRIAL		Smooth	0.30-0.60
Light areas	0.50-0.80	Rough	0.20-0.50
Heavy areas	0.60-0.90		
Parks, cemeteries	0.10-0.25	**CULTIVATED ROWS**	
Playgrounds	0.20-0.35	Heavy soil, no crop	0.30-0.60
Railroad yard areas	0.20-0.40	Heavy soil, with crop	0.20-0.50
Unimproved areas	0.10-0.30	Sandy soil, no crop	0.20-0.40
		Sandy soil, with crop	0.10-0.25
STREETS			
Asphalt	0.70-0.95	**PASTURE**	
Concrete	0.80-0.95	Heavy soil	0.15-0.45
Bricks	0.70-0.85	Sandy soil	0.05-0.25
Drives and walks	0.75-0.85	Woodlands	0.05-0.25
Roofs	0.75-0.95		
		BARREN SLOPES > 30%*	
		Smooth, impervious	0.70-0.90
		Rough	0.50-0.70

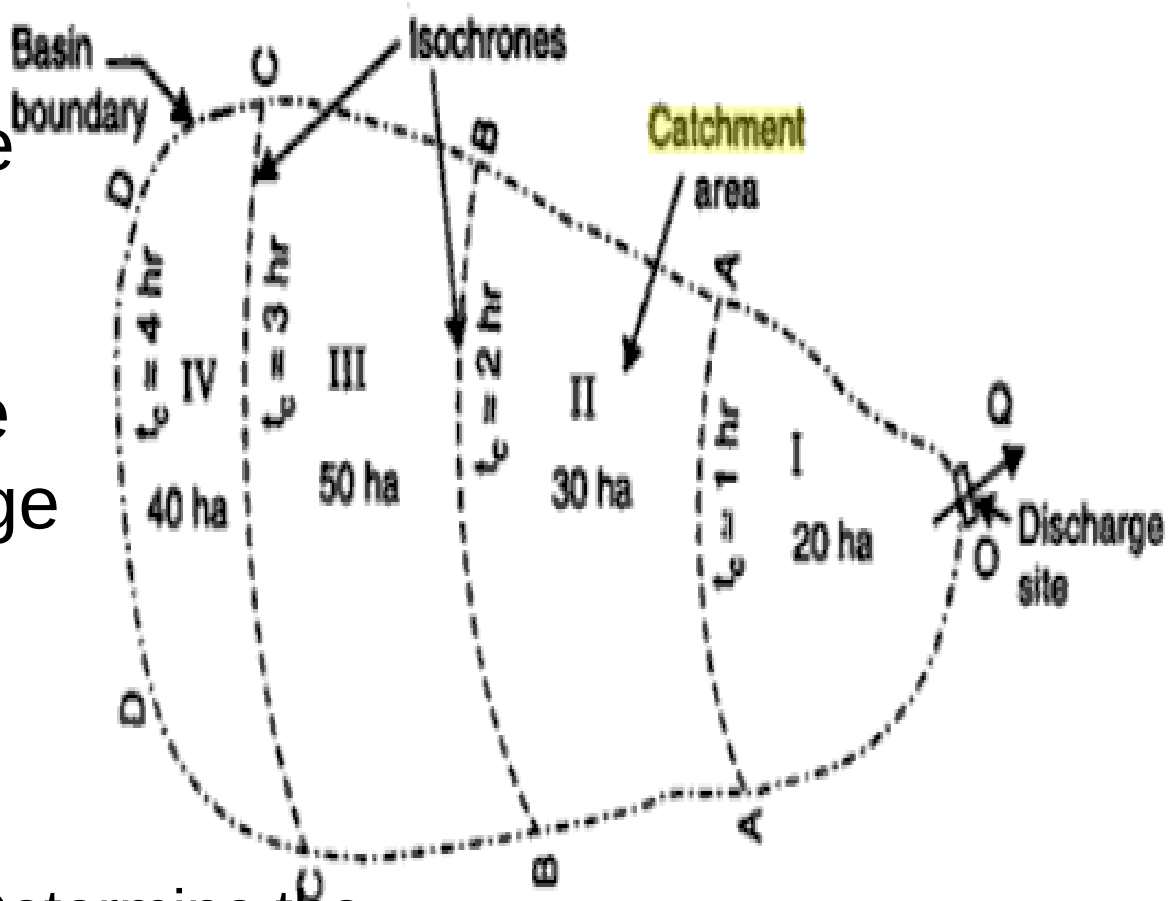
Note: The Designer must use judgment to select the appropriate value of C within the range

Rational method Example

•A 4-hour rain of average of intensity of 1cm/hr falls over the catchment.

Q= CIA

•The time of concentration from the lines AA,BB,CC, and DD are 1,2,3,4 hours respectively to the site O. Where the discharge measurements are made.

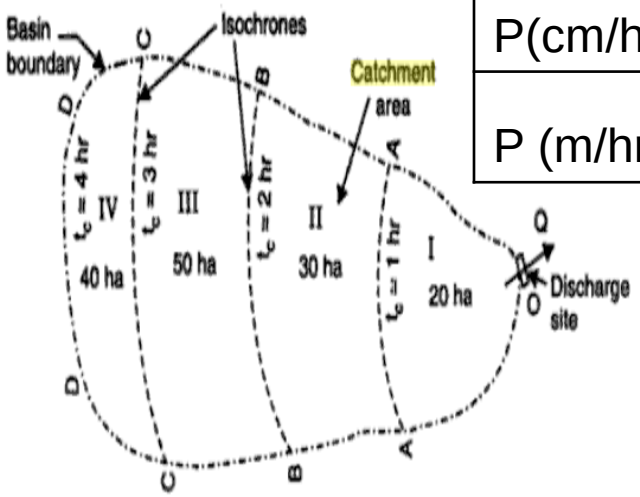


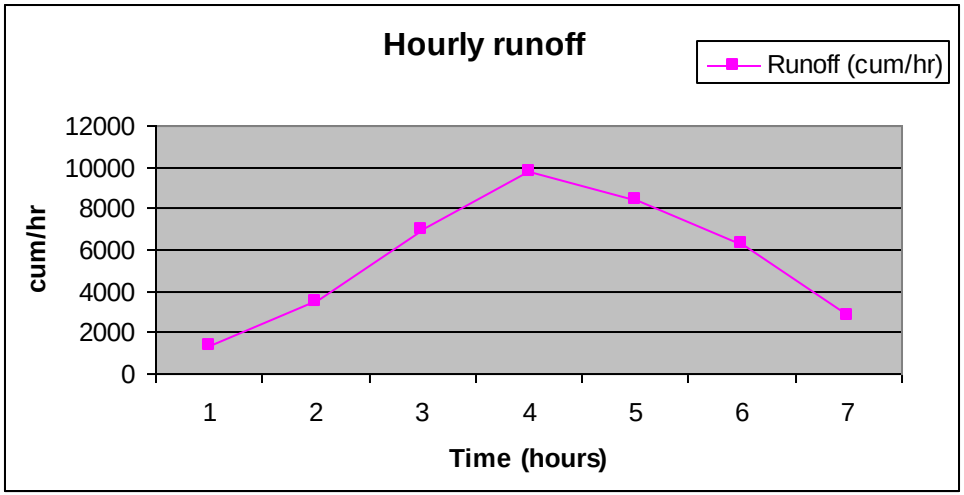
•Take value of C=0.7. Determine the discharge at site O.

Rational method

Time from beginning of storm, Hours								
Zone (ha)	1	2	3	4	5	6	7	
1	20	20	20	20				5600
2		30	30	30	30			8400
3			50	50	50	50		14000
4				40	40	40	40	11200
Q1(cum.hr)	1400	3500	7000	9800	8400	6300	2800	39200

C	0.7
P(cm/hr)	1
P (m/hr)	0.01





SCS-CN Method (Soil Conservation services (SCS) of US)

	Q=(P-λS)^2/((P+(1-λ)*S) for P >λS
	Q= 0 for P<=λS
Q(mm)	River flow
P(mm	Precipitation
S(mm)	Retention
t(day)	Time

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)} \qquad (3)$$

S= (25400/CN)-254

Curve Number(CN)ranges from 0 to 100

CN=25400/(S+254)

CN=0 means complete retention

CN=100 means Zero retention

λ	0.2 Average conditions
λ	0.1 For black soils under AMC of type II and III
λ	0.3 AMC of type I and for all other soils having AMC of type I, II, III.

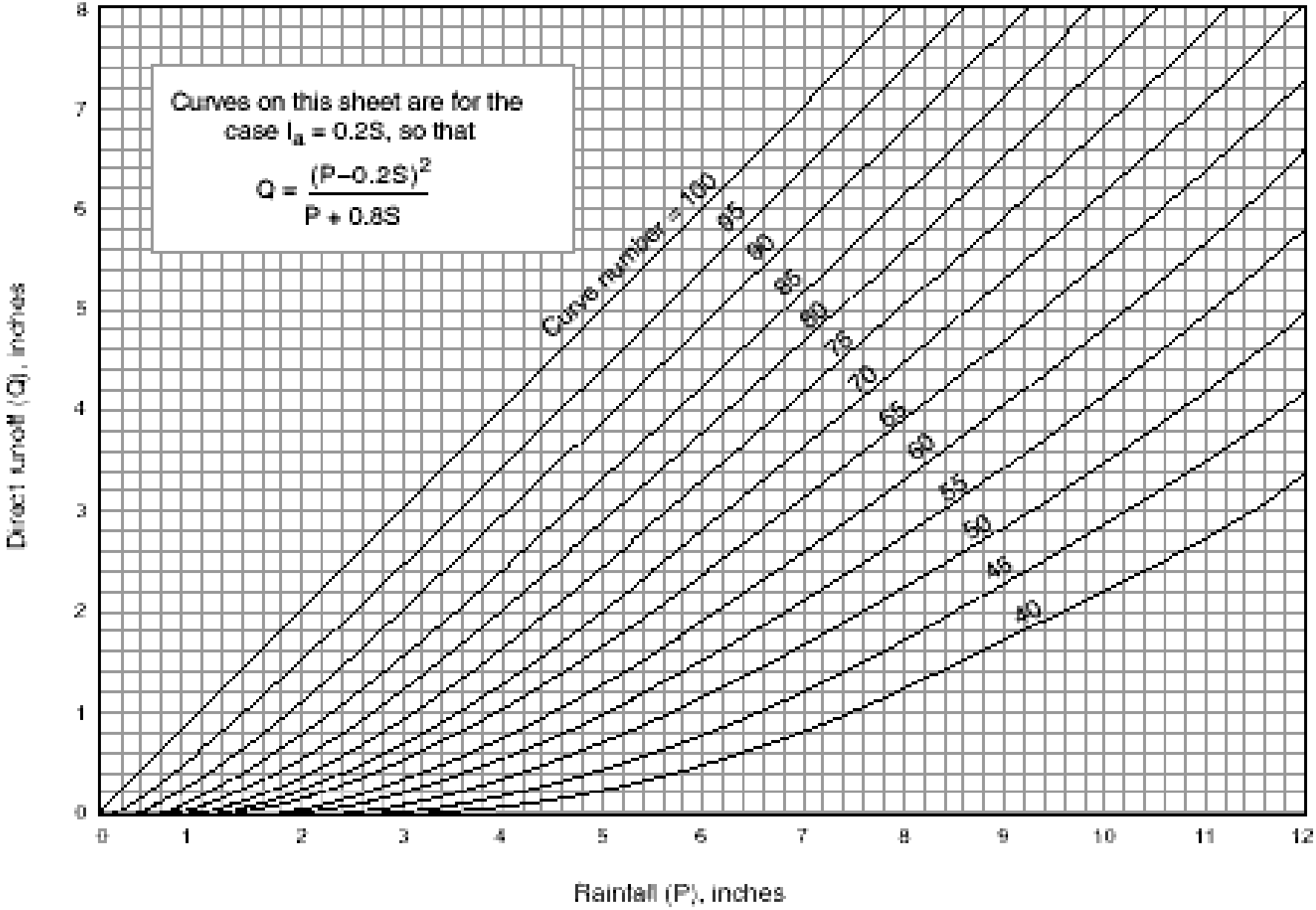
SOIL (GROUPS)	
A	Low runoff potential
B	Moderately low runoff potential
C	Moderately high runoff potential
D	High runoff potential

Antecedent Moisute Condition (AMC)	
AMC-I	Soils are dry but not to the wilting point. Satisfactory cultivation has taken place
AMC-II	Average conditions
AMC-III	Sufficient rainfall occurred within the immediate past 5 days. Saturated soil conditions prevail

AMC For determining the Value of CN		
AMC type	Dormant season	Growing season
I	Less than 13 mm	less than 36 mm
II	13 to 28 mm	36 to 53 mm
III	More than 28 mm	More than 53 mm

CN values for Suburban and Urban land use				
Cover and treatment	Soil Group			
Type of area	A	B	C	D
1. Open space, lawns and parks				
i. In good condition. Grass cover is more than 75%	39	61	74	80
ii. In the fair condition. Grass cover is 50 to 75%	49	69	79	84
2. Commercial and business areas (85% impervious)	89	92	94	95
3. Industrial districts (72% impervious)	81	88	91	93
4.Residential (Average 65% impervious)	77	85	90	92
5. Paved parking lots, paved drive ways , roads, streats etc	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89

Land Use Description on Input Screen	Description and Curve Numbers					
	Cover Description		Curve Number for Hydrologic Soil Group			
	Cover Type and Hydrologic Condition	% Impervious Areas	A	B	C	D
Agricultural	Row Crops - Staight Rows + Crop Residue Cover- Good Condition (1)		64	75	82	85
Commercial	Urban Districts: Commerical and Business	85	89	92	94	95
Forest	Woods(2) - Good Condition		30	55	70	77
Grass/Pasture	Pasture, Grassland, or Range(3) - Good Condition		39	61	74	80
High Density Residential	Residential districts by average lot size: 1/8 acre or less	65	77	85	90	92
Industrial	Urban district: Industrial	72	81	88	91	93
Low Density Residential	Residential districts by average lot size: 1/2 acre lot	25	54	70	80	85
Open Spaces	Open Space (lawns, parks, golf courses, cemeteries, etc.)(4) Fair Condition (grass cover 50% to 70%)		49	69	79	84
Parking and Paved Spaces	Impervious areas: Paved parking lots, roofs, drivesways, etc. (excluding right-of-way)	100	98	98	98	98
Residential 1/8 acre	Residential districts by average lot size: 1/8 acre or less	65	77	85	90	92
Residential 1/4 acre	Residential districts by average lot size: 1/4 acre	38	61	75	83	87
Residential 1/3 acre	Residential districts by average lot size: 1/3 acre	30	57	72	81	86
Residential 1/2 acre	Residential districts by average lot size: 1/2 acre	25	54	70	80	85
Residential 1 acre	Residential districts by average lot size: 1 acre	20	51	68	79	84
Residential 2 acres	Residential districts by average lot size: 2 acre	12	46	65	77	82
Water/ Wetlands		0	0	0	0	0


Curves on this sheet are for the case $I_a = 0.2S$, so that
$Q = \frac{(P-0.2S)^2}{P+0.8S}$
Curve number = 100
95
90
85
80
75
70
65
60
55
50
45
40
Direct runoff (Q), inches
Rainfall (P), inches
0
1
2
3
4
5
6
7
8
9
10
11
12

Example

area(ha)	350
CN FOR AMC III	70
λ	0.2

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)} \qquad (3)$$

Estimate the value of direct runoff for the following rainfall

Date	Rainfall (mm)	λS	Q(mm)
1-Jul	50	21.77	5.81
2-Jul	20	21.77	0.00
3-Jul	30	21.77	0.58
4-Jul	18	21.77	0.00
S= (25400/CN)-254	118		6.39
S= (25400/CN)-254	=(25400/70)-254	108.86	
Q=(P-λS)^2/((P+(1-λ)*S) for P >λS			
Q= 0 for P<=λS			
Total Runoff volume(cum)	=350*10000*6.39/1000		22368.8

End