DEQ Certification Class Presentations

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July 2024

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

TR55-EB *Tic-Tac-Toe*

Exercise

Exercise Materials

TR55-EB Tic Tac Toe WORKSHEET:

TR55-EB Tic-Tac-Toe WORKSHEET

Use the information given below to complete the blanks for pre-development and post-development conditions for Sites A1, A2, and A3. Assume drainage areas equal site areas.

A1

	Pre	Post
Tc (min)	30	5
Tc (hr)		
CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

Q, in		
Vr, ac-ft		
Fp	1	1
DA (acres)	5.4	5.4
DA (sq mi)		
q(peak), cfs		
q(allowable), cfs		

A2

	Pre	Post
Tc (min)	30	5
Tc (hr)		
CN	78	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

Q, in		
Vr, ac-ft		
Fp	1	1
DA (acres)	5.4	5.4
DA (sq mi)		
q(peak), cfs		
q(allowable), cfs		

A3

	Pre	Post
Tc (min)	15	5
Tc (hr)		
CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

Q, in		
Vr, ac-ft		
Fp	1	1
DA (acres)	5.4	5.4
DA (sq mi)		
q(peak), cfs		
q(allowable), cfs		

Pre = Pre-development condition
Post = Post-development condition
Tc = time of concentration
CN = Curve Number
S = Maximum Potential Retention
Ia = Initial Abstraction
P = Precipitation

qu = Unit Peak Discharge
csm/in = cubic feet per second per square mile per inch
Q, in = Runoff depth in inches
Vr, ac-ft = Runoff volume in ac-ft (total runoff across drainage area)
Vr (ac-ft) = Q(in) x DA(ac) x 1ft/12in
Fp = Pond and Swamp Adjustment Factor
DA, ac or sq mi = Drainage Area in acres or square miles
q(peak), cfs = Peak Discharge Rate in cubic feet per second
q(allowable), cfs = Allowable Peak Discharge Rate in cubic feet per second

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Exercise Materials

In your Participant Guide:

- Module 10

And a calculator

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TR-55 – Module 10, pp.19-31

1. Determine 24-hour rainfall (P) for desired design storm
2. Calculate weighted CN for site
3. Use CN with table to determine initial abstraction (I_a)
4. Calculate expected runoff volume (Q)
5. Determine time of concentration (t_c)
6. Compute I_a/P ratio
7. Use t_c and I_a/P to find q_u from chart
8. Determine pond and swamp adjustment factor (F_p)
9. Combine all above factors and calculate peak discharge (q_p)

TR55 EB TICTACTOE EXERCISE

Virginia Department of Environmental Quality

TR55-EB Tic-Tac-Toe WORKSHEET

Use the information given below to complete the blanks for pre-development and post-development conditions for Sites A1, A2, and A3. Assume drainage areas equal site areas.

A1		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)		
CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

***Use Type II rainfall distribution**

Q, in		
Vr, ac-ft		
Fp	1	1
DA (acres)	5.4	5.4
DA (sq mi)		
q(peak), cfs		
q(allowable), cfs		

A2		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)		
CN	78	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

***Use Type II rainfall distribution**

Q, in		
Vr, ac-ft		
Fp	1	1
DA (acres)	5.4	5.4
DA (sq mi)		
q(peak), cfs		
q(allowable), cfs		

A3		
	Pre	**Post**
Tc (min)	15	5
Tc (hr)		
CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

***Use Type II rainfall distribution**

Q, in		
Vr, ac-ft		
Fp	1	1
DA (acres)	5.4	5.4
DA (sq mi)		
q(peak), cfs		
q(allowable), cfs		

A1		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)		

CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

***Use Type II rainfall distribution**

A1		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

***Use Type II rainfall distribution**

A1		
	Pre	Post
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

3. initial abstraction (I_a)

Finding Ia - Module 10, p. 19

I_a can also be calculated using the following equation:

$$I_a = 0.2 \times \left[\left(\frac{1000}{CN}\right) - 10\right]$$

(TR-55 Eq. 2-2 and TR-55 Eq. 2-4 combined)

CN = Runoff Curve Number

3. initial abstraction (I_a)

Module 10, p. 20

Also:

TR-55 manual

Table 4-1 I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

3. initial abstraction (I_a)

4. Runoff Volume (Q)

$$q_p = q_u A_m Q F_p$$

Runoff Equation

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

Q = Runoff

P = Rainfall (in)

S = Potential maximum retention after runoff begins (in)

$$S = \left(\frac{1000}{CN}\right) - 10$$

CN = Curve number

I_a = Initial abstraction (in)

= 0.2 x S

= (all losses before runoff begins)

3. initial abstraction (I_a)

4. Runoff Volume (Q)

$$q_p = q_u A_m Q F_p$$

$$I_a = 0.2 \times S$$

Module 10, p. 21

$$S = I_a / 0.2$$

A1		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

***Use Type II rainfall distribution**

3. initial abstraction (I_a)

4. Runoff Volume (Q)

$$q_p = q_u A_m Q F_p$$

A1 Pre

$I_a = 0.703$

Module 10, p. 21

$S = I_a / 0.2$

$= 0.703/0.2$

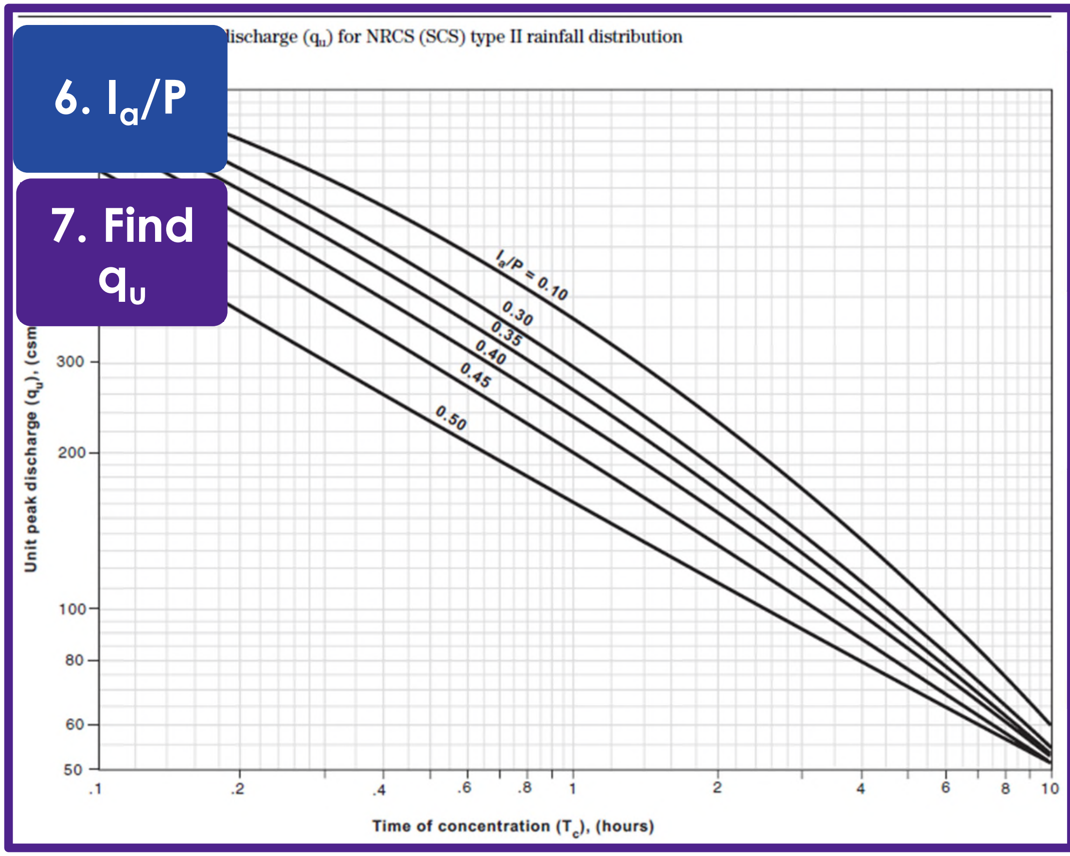
$= 3.514$

A1		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	74	79
S	3.514	2.658
Ia	0.703	0.532
P, in	2.6	
Ia/P		
qu (csm/in)*		

***Use Type II rainfall distribution**

Finding Ia/P and q_u– Mod. 10, pp. 21-23



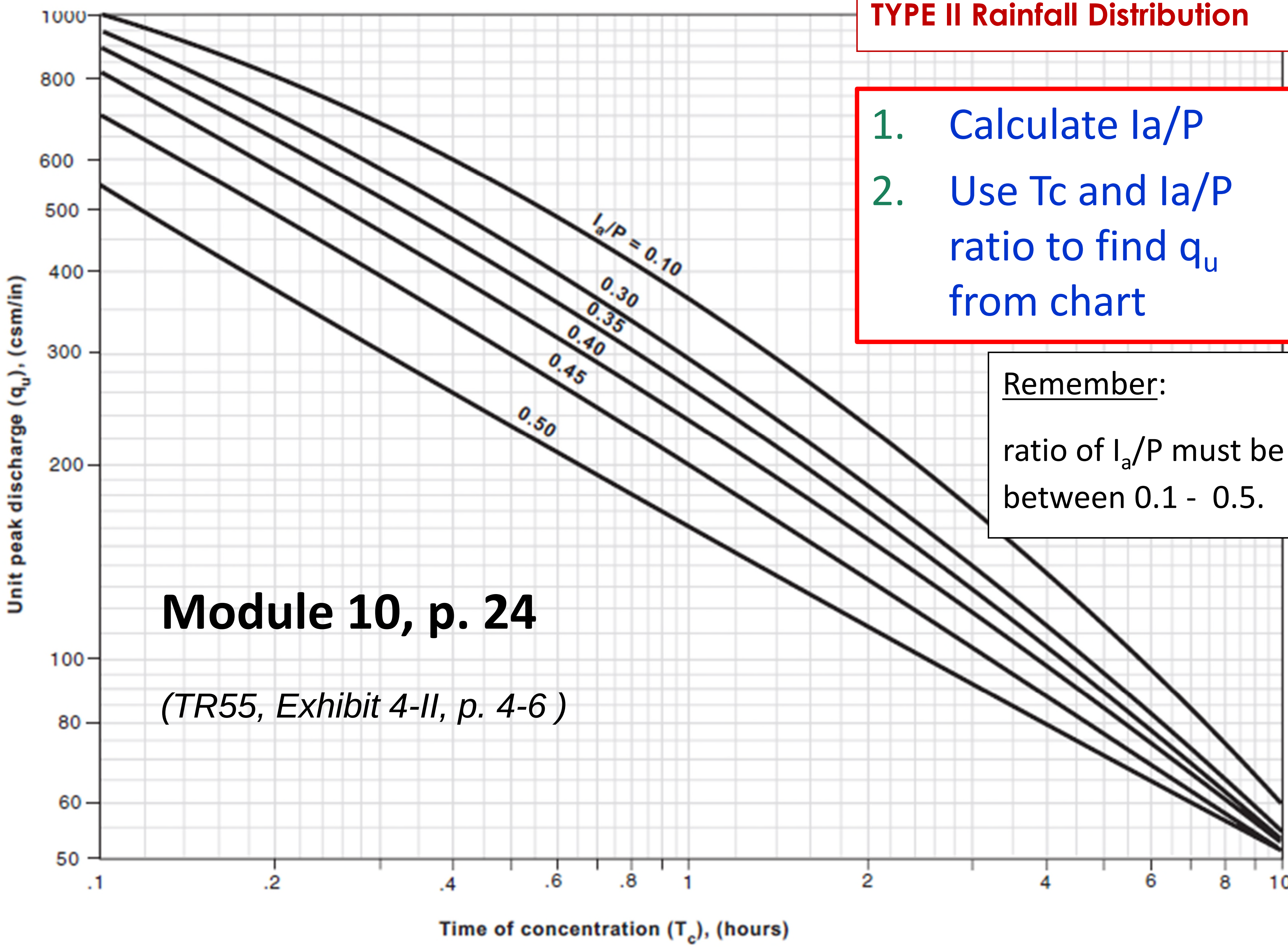
6. Ia/P

7. Find q_u

Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution

TYPE II Rainfall Distribution

1. Calculate Ia/P
2. Use Tc and Ia/P ratio to find q_u from chart



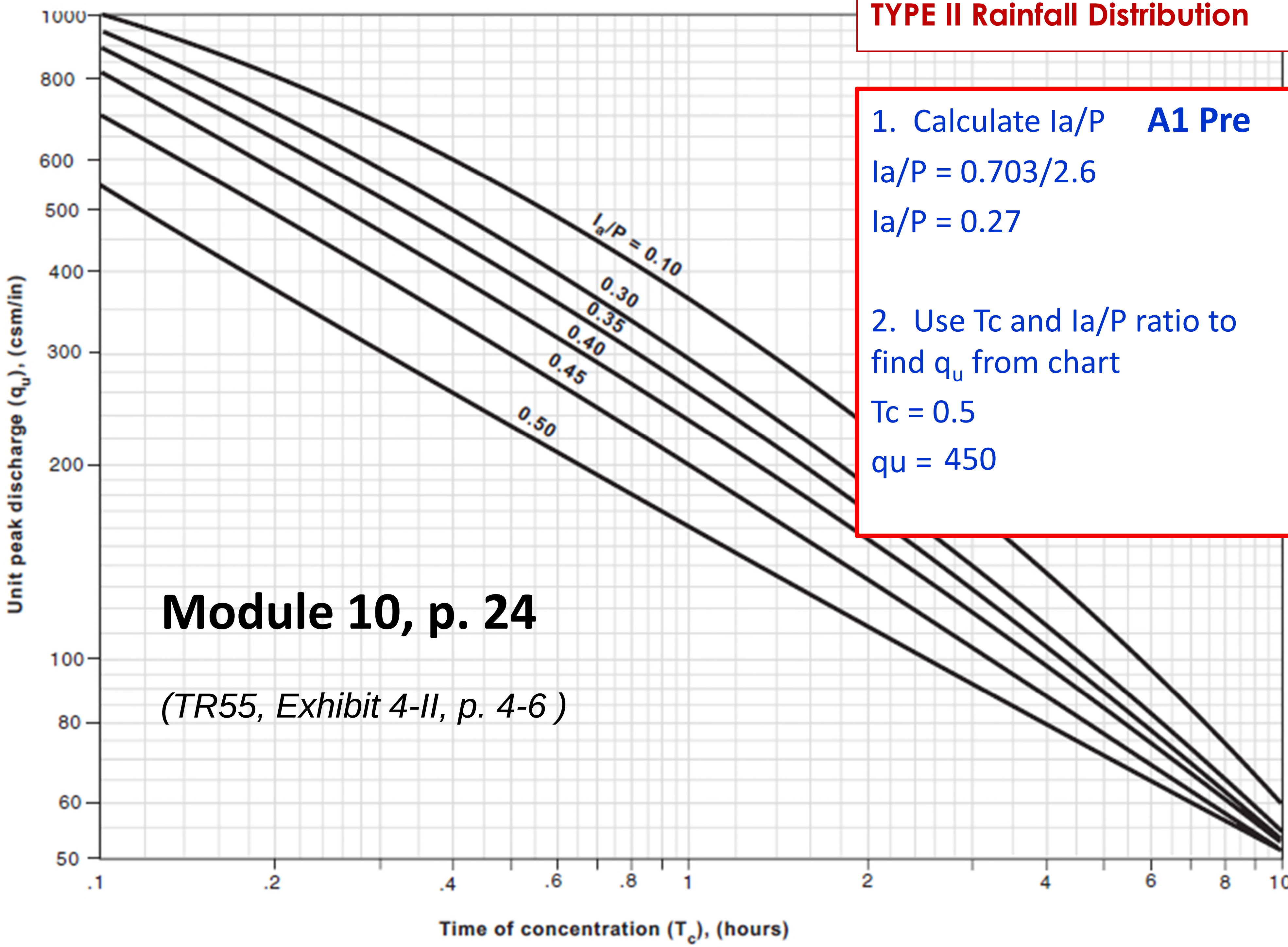
<u>Remember</u>:

ratio of I_a/P must be between 0.1 - 0.5.

Module 10, p. 24

(TR55, Exhibit 4-II, p. 4-6)

Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution



TYPE II Rainfall Distribution

1. Calculate Ia/P **A1 Pre**

Ia/P = 0.703/2.6

Ia/P = 0.27

2. Use Tc and Ia/P ratio to find q_u from chart

Tc = 0.5

qu = 450

Module 10, p. 24

(TR55, Exhibit 4-II, p. 4-6)

A1		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	74	79
S	3.514	2.658
Ia	0.703	0.532
P, in	2.6	
Ia/P		
qu (csm/in)*		

***Use Type II rainfall distribution**

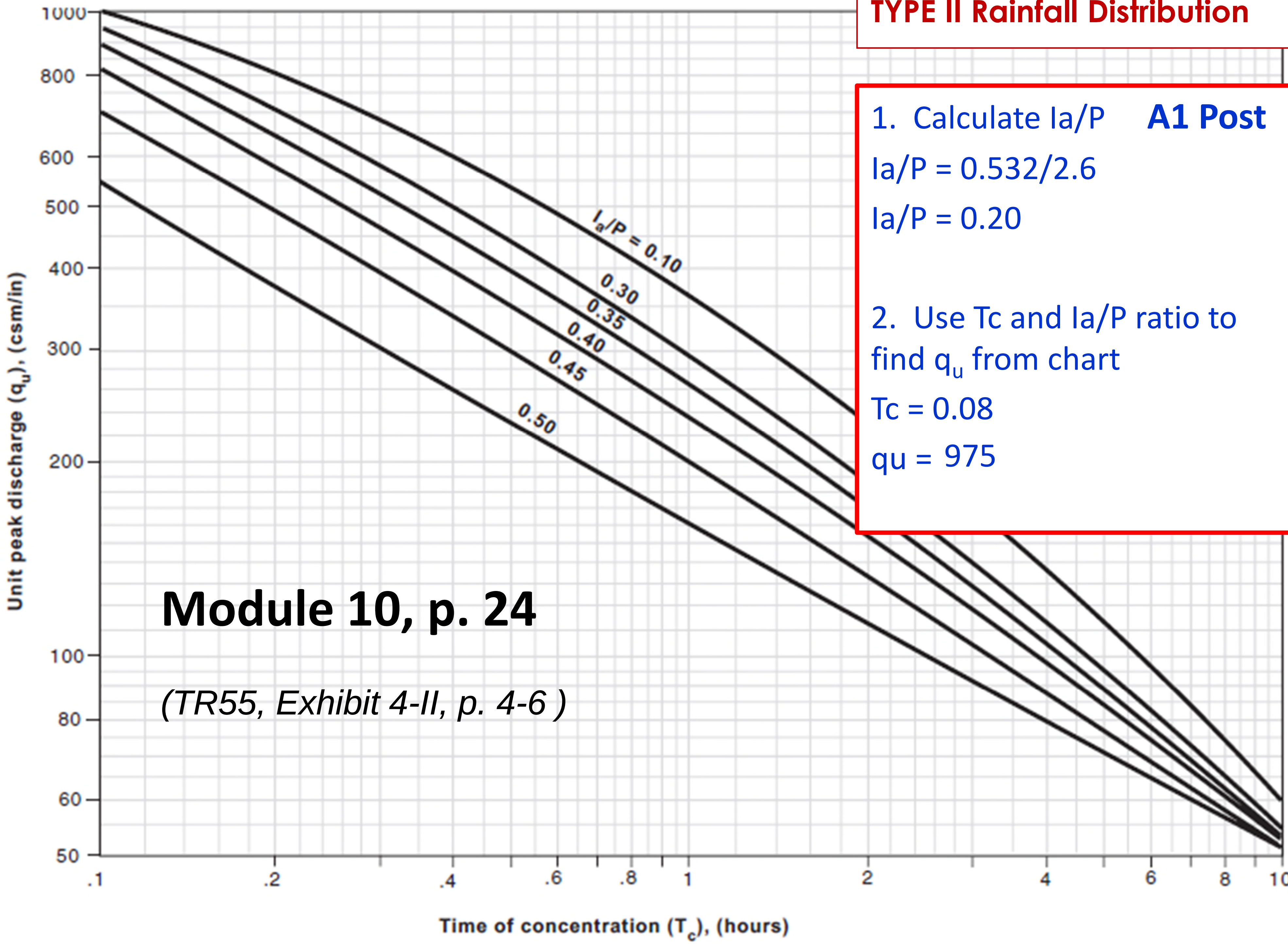
A1		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	74	79
S	3.514	2.658
Ia	0.703	0.532
P, in	2.6	
Ia/P	0.27	?
qu (csm/in)*	450	?

***Use Type II rainfall distribution**

Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution

TYPE II Rainfall Distribution



1. Calculate Ia/P **A1 Post**

Ia/P = 0.532/2.6

Ia/P = 0.20

2. Use Tc and Ia/P ratio to find q_u from chart

Tc = 0.08

qu = 975

Module 10, p. 24

(TR55, Exhibit 4-II, p. 4-6)

A1		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	74	79
S	3.514	2.658
Ia	0.703	0.532
P, in	2.6	
Ia/P	0.27	0.20
qu (csm/in)*	450	975

***Use Type II rainfall distribution**

A1		
	Pre	**Post**
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	74	79
S	3.514	2.658
Ia	0.703	0.532
P, in	2.6	
Ia/P	0.27	0.20
qu (csm/in)*	450	975

***Use Type II rainfall distribution**

Q, in		
Vr, ac-ft		
Fp	1	1

DA (acres)	5.4	5.4
DA (sq mi)		

q(peak), cfs		

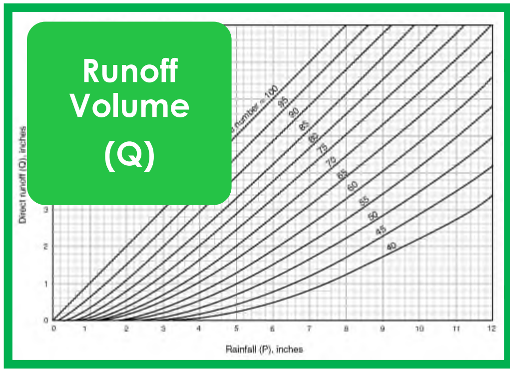
A1

Q, in		
Vr, ac-ft		

DA (acres)	5.4	5.4
DA (sq mi)		

q(peak), cfs		

Finding Q – Module 10, pp. 21-23



4. Runoff Volume (Depth)

Q

4. Runoff Volume (Q)

- Solve for Q (runoff depth):
  - SCS Runoff equation (p.21)
  - Tabular method (p.23), TR-55 Manual
  - Graphical method (p.22), TR-55 Manual

3. initial abstraction (I_a)

4. Runoff Volume (Q)

$$q_p = q_u A_m Q F_p$$

Runoff Equation

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

Q = Runoff

P = Rainfall (in)

S = Potential maximum retention after runoff begins (in)

$$S = \left(\frac{1000}{CN}\right) - 10$$

CN = Curve number

I_a = Initial abstraction (in)

= 0.2 x S

= (all losses before runoff begins)

Module 10, p. 23

Table 2-1 Runoff depth for selected CN's and rainfall amounts [1/]

Rainfall	Runoff depth for curve number of—												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

[1/] Interpolate the values shown to obtain runoff depths for CN's or rainfall amounts not shown.

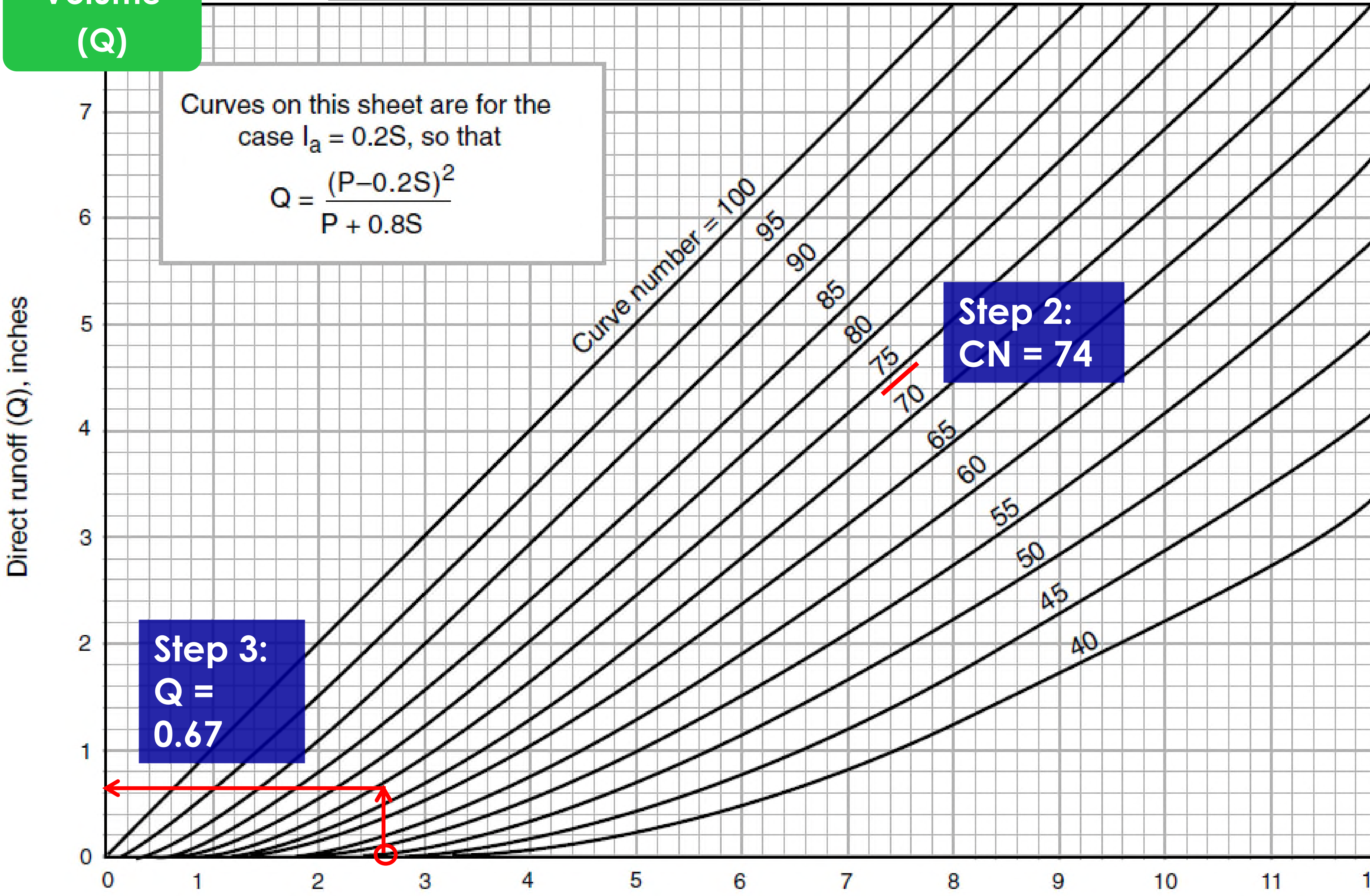
4. Runoff Volume (Q)

unoff depth for selected CN's and rainfall amounts 1/

Rainfall	Runoff depth for curve number of—												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

4. Runoff Volume (Q)

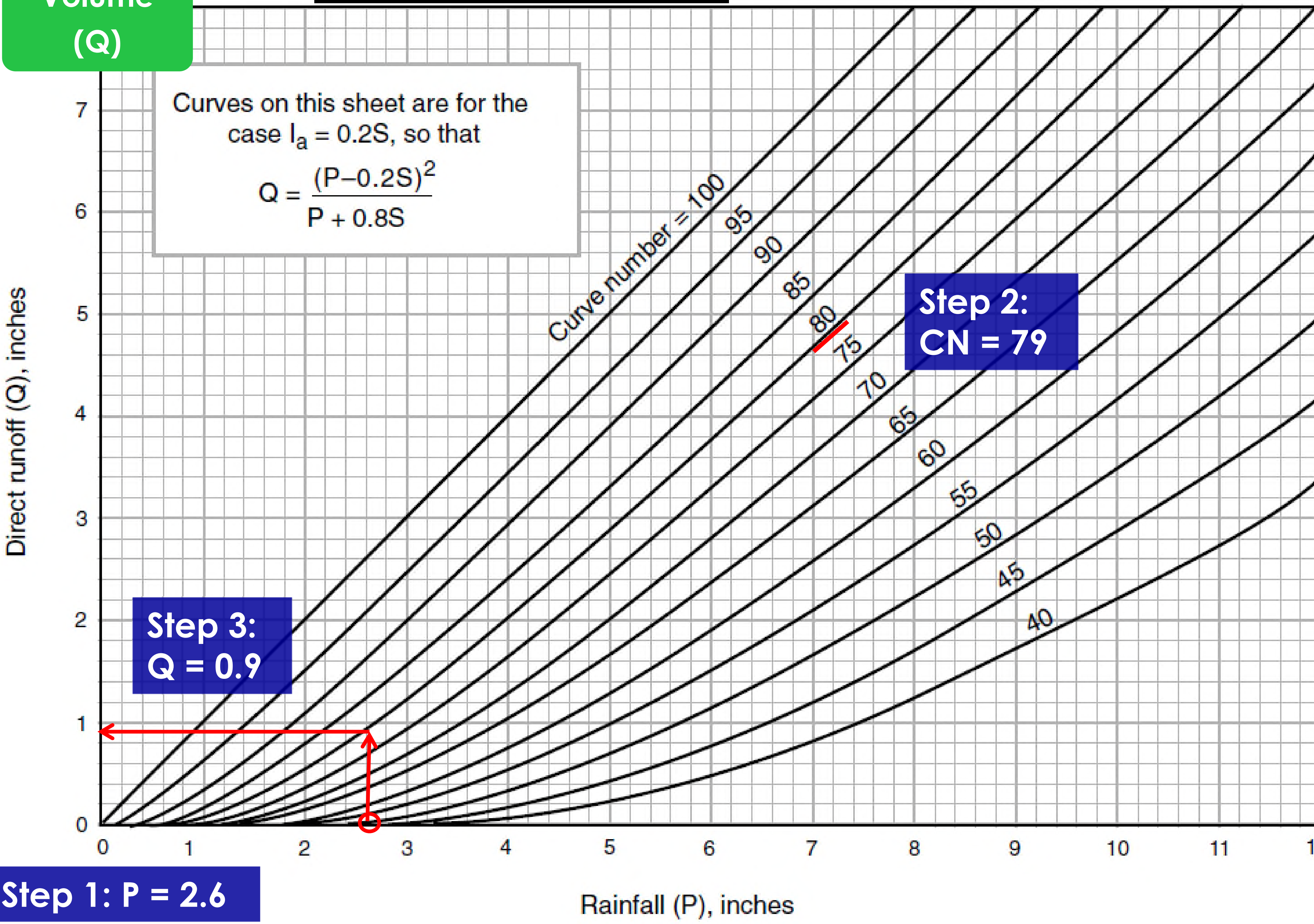
A1 Pre



Step 1: P = 2.6

4. Runoff Volume (Q)

A1 Post



Step 1: P = 2.6

3. initial abstraction (I_a)

4. Runoff Volume (Q)

Finding Ia and Q

A1 Pre

$$S = \left(\frac{1000}{CN}\right) - 10 = \left(\frac{1000}{\mathbf{74}}\right) - 10 = \mathbf{3.514}$$

P = rainfall (in)

CN = runoff curve number

S = potential maximum retention after runoff begins (in)

I_a = initial abstraction (in)
= 0.2 x S
= 0.2 x **3.514**
= **0.703**

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

$$= \frac{\mathbf{(2.6 - 0.703)^2}}{\mathbf{(2.6 - 0.703) + 3.514}} = \mathbf{0.665}$$

3. initial abstraction (I_a)

4. Runoff Volume (Q)

Finding Ia and Q

A1 Post

$$S = \left(\frac{1000}{CN}\right) - 10 = \left(\frac{1000}{\mathbf{79}}\right) - 10 = \mathbf{3.514}$$

P = rainfall (in)

CN = runoff curve number

S = potential maximum retention after runoff begins (in)

I_a = initial abstraction (in)
= 0.2 x S
= 0.2 x **2.658**
= **0.532**

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

$$= \frac{\mathbf{(2.6 - 0.532)^2}}{\mathbf{(2.6 - 0.532) + 2.658}} = \mathbf{0.905}$$

A1

Q, in	0.665	0.905
Vr, ac-ft		

DA (acres)	5.4	5.4
DA (sq mi)		

q(peak), cfs		

Q, in	0.665	0.905
Vr, ac-ft		

Q, in = Runoff depth in inches

Vr, ac-ft = Runoff volume in ac-ft (total runoff across drainage area)

Vr (ac-ft) = Q(in) x DA(ac) x 1ft/12in

Finding DA (square miles)

A1		
Q, in	0.665	0.905
Vr, ac-ft	0.299	0.407

DA (acres)	5.4	5.4
DA (sq mi)		

$$DA\ (mi^2) = acres/640$$
$$= 5.4/640$$
$$= 0.008438$$

Mod 10, p. 33
TR55 worksheet 4

Finding q(peak)

A1		
Q, in	0.665	0.905
Vr, ac-ft	0.299	0.407

DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438

q(peak), cfs		

9. peak discharge (q_p)

Finding q_p – Module 10, p. 30

$$q_p = q_u \times A_{mi} \times Q \times F_p$$

q_p (cfs)

q_u (csm/in) from previous step

Q (in) from previous step

A_{mi} (mi^2)

F_p given as 1

9. peak discharge (q_p)

Finding q_p – Module 10, p. 30

$$q_p = q_u \times A_{mi} \times Q \times F_p$$

q_u = 450

Q (in) = 0.665

A_{mi} (mi^2) = 0.00844

F_p = 1

A1 Pre
q_p = 2.5 cfs

q_u = 975

Q (in) = 0.905

A_m (mi^2) = 0.00844

F_p = 1

A1 Post
q_p = 7.4 cfs

TR55-EB Tic-Tac-Toe WORKSHEET

Use the information given below to complete the blanks for pre-development and post-development conditions for Sites A1, A2, and A3. Assume drainage areas equal site areas.

A1

	Pre	Post
Tc (min)	30	5
Tc (hr)		
CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

Q, in		
Q, ac-ft		
Fp	1	1

DA (acres)	5.4	5.4
DA (sq mi)		

q(peak), cfs		

q(allowable), cfs	

A2

	Pre	Post
Tc (min)	30	5
Tc (hr)		
CN	78	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

Q, in		
Q, ac-ft		
Fp	1	1

DA (acres)	5.4	5.4
DA (sq mi)		

q(peak), cfs		

q(allowable), cfs	

A3

	Pre	Post
Tc (min)	15	5
Tc (hr)		
CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

Q, in		
Q, ac-ft		
Fp	1	1

DA (acres)	5.4	5.4
DA (sq mi)		

q(peak), cfs		

q(allowable), cfs	

Turn to Module 11

Energy Balance and Sheet Flow

TR55-EB Tic Tac Toe - Preparation

Complete allowable release rate, q(allowable), for A1-A3.

$$q_{1\,post} \leq q_{1\,pre}\left(\frac{Vr_{pre\,1}}{Vr_{post\,1}}\right)(IF)$$

p. 8, Mod. 11 in PG

TR55-EB Tic Tac Toe - Preparation

Given:

P = 2.6 inches is 1-yr, 24-hr rainfall

Vr = Q, ac-ft

$$q_{1\,post} \leq q_{1\,pre}\left(\frac{Vr_{pre\,1}}{Vr_{post\,1}}\right)(IF)$$

p. 8, Mod. 11 in PG

Complete allowable release rate, q(allowable), for A1-A3.

$$q_{allowable} = q_{1,pre} \times \left(\frac{Vr_{1yr,pre,ac-ft}}{Vr_{1yr,post,ac-ft}}\right) \times IF$$

A1

Q, in	0.665	0.905
Vr, ac-ft	0.299	0.407

DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438

q(peak), cfs	2.5	7.4

$$q_{1\,post} \leq q_{1\,pre}\left(\frac{Vr_{pre\,1}}{Vr_{post\,1}}\right)(IF)$$

A1

Q, in	0.665	0.905
Vr, ac-ft	0.299	0.407

DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438

q(peak), cfs	2.5	7.4

$$q_{1\,post} \leq q_{1\,pre}\left(\frac{Vr_{pre\,1}}{Vr_{post\,1}}\right)(IF)$$

$$q_{peak,1yr(allowable)} = q_{pre,1yr} \times \frac{Vr_{pre,1yr}}{Vr_{post,1yr}} \times IF$$

A1		
Q, in	0.665	0.905
Vr, ac-ft	0.299	0.407
DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438
q(peak), cfs	2.5	7.4

$$q_{peak,1yr(allowable)} = q_{pre,1yr} \times \frac{Vr_{pre,1yr}}{Vr_{post,1yr}} \times IF$$

$$= 2.5\ cfs \times \frac{0.299}{0.407} \times 0.8$$

$$= 1.5\ cfs$$

A1

Q, in	0.665	0.905
Vr, ac-ft	0.299	0.407

DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438

q(peak), cfs	2.5	7.4

q(allowable), cfs	1.5

Questions?

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

TR55-EB Tic-Tac-Toe WORKSHEET

Use the information given below to complete the blanks for pre-development and post-development conditions for Sites A1, A2, and A3. Assume drainage areas equal site areas.

A1		
	Pre	Post
Tc (min)	30	5
Tc (hr)		
CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

Q, in		
Q, ac-ft		
Fp	1	1

DA (acres)	5.4	5.4
DA (sq mi)		

q(peak), cfs		

q(allowable), cfs	

A2		
	Pre	Post
Tc (min)	30	5
Tc (hr)		
CN	78	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

Q, in		
Q, ac-ft		
Fp	1	1

DA (acres)	5.4	5.4
DA (sq mi)		

q(peak), cfs		

q(allowable), cfs	

A3		
	Pre	Post
Tc (min)	15	5
Tc (hr)		
CN	74	79
S		
Ia		
P, in	2.6	
Ia/P		
qu (csm/in)*		

*Use Type II rainfall distribution

Q, in		
Q, ac-ft		
Fp	1	1

DA (acres)	5.4	5.4
DA (sq mi)		

q(peak), cfs		

q(allowable), cfs	

3. initial abstraction (I_a)

4. Runoff Volume (Q)

$$q_p = q_u A_m Q F_p$$

Runoff Equation

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

Q = Runoff

P = Rainfall (in)

S = Potential maximum retention after runoff begins (in)

$$S = \left(\frac{1000}{CN}\right) - 10$$

CN = Curve number

I_a = Initial abstraction (in)

= 0.2 x S

= (all losses before runoff begins)

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

Finding Ia - Module 10, p. 19

I_a can also be calculated using the following equation:

$$I_a = 0.2 \times \left[\left(\frac{1000}{CN} \right) - 10 \right]$$

(TR-55 Eq. 2-2 and TR-55 Eq. 2-4 combined)

CN = Runoff Curve Number

3. initial abstraction (I_a)

Module 10, p. 20

Also:

TR-55 manual

Table 4-1 I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

3. initial abstraction (I_a)

4. Runoff Volume (Q)

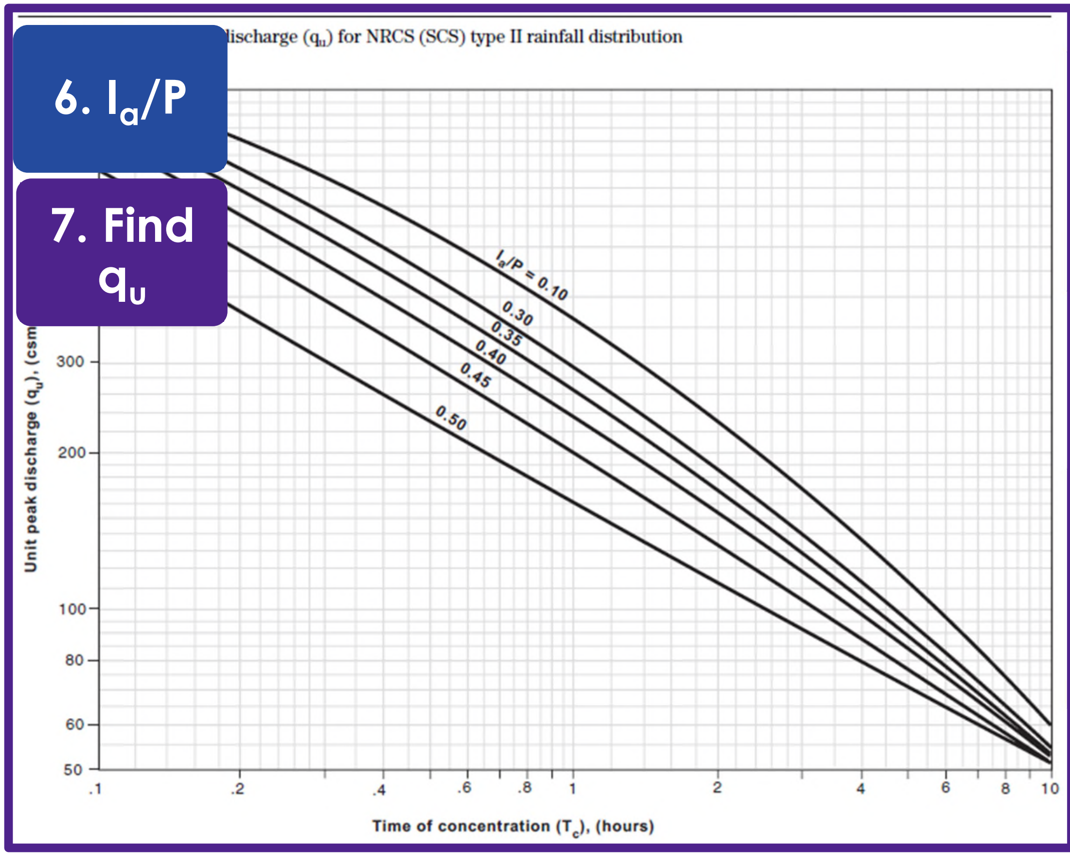
$$q_p = q_u A_m Q F_p$$

$$I_a = 0.2 \text{ x } S$$

Module 10, p. 21

$$S = I_a / 0.2$$

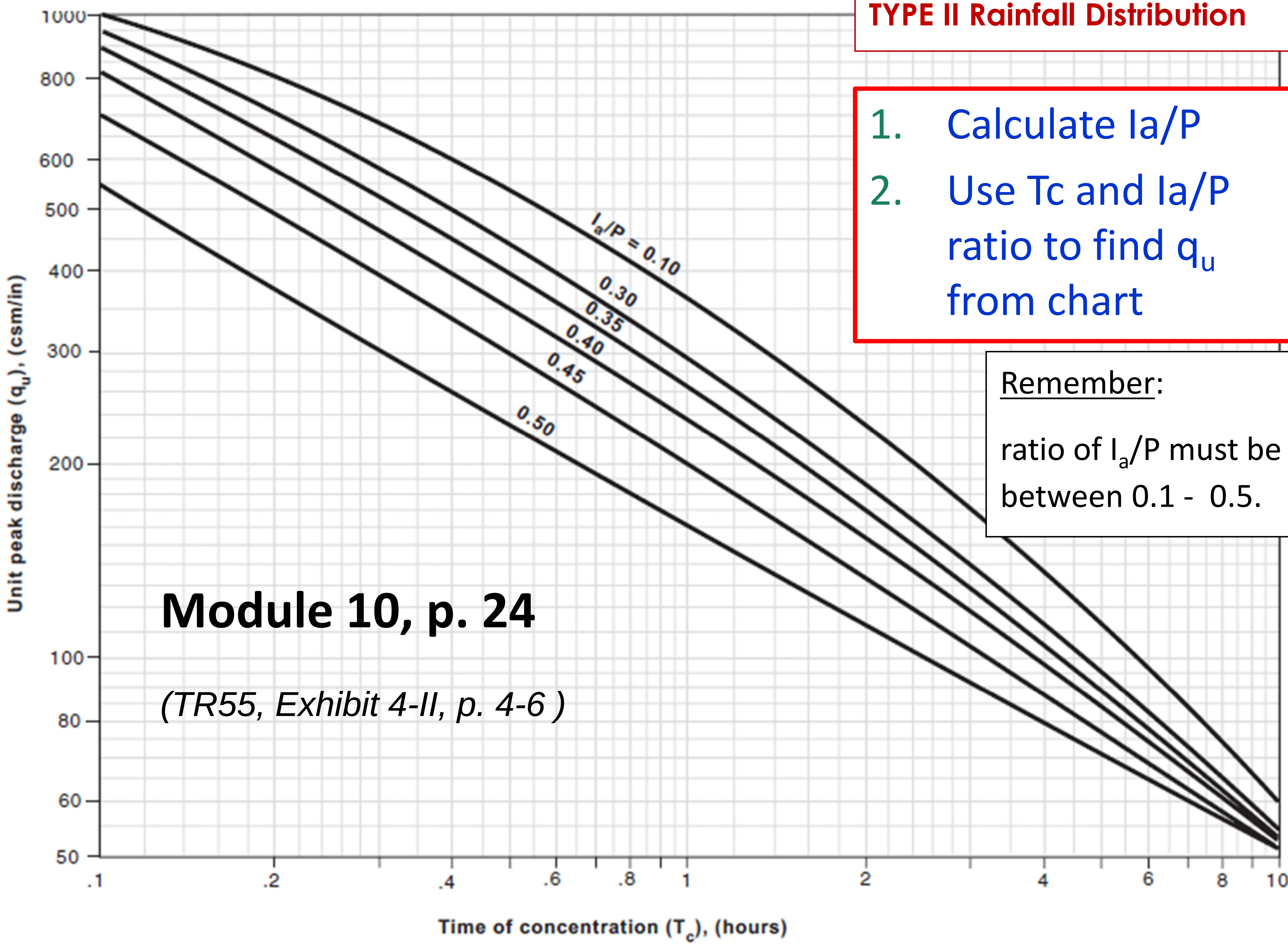
Finding Ia/P and q_u – Mod. 10, pp. 21-23



6. Ia/P

7. Find q_u

Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution



TYPE II Rainfall Distribution

1. Calculate Ia/P
2. Use Tc and Ia/P ratio to find q_u from chart

Remember:

ratio of I_a/P must be between 0.1 - 0.5.

Module 10, p. 24

(TR55, Exhibit 4-II, p. 4-6)

3. initial abstraction (I_a)

4. Runoff Volume (Q)

$$q_p = q_u A_m Q F_p$$

Runoff Equation

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

Q = Runoff

P = Rainfall (in)

S = Potential maximum retention after runoff begins (in)

$$S = \left(\frac{1000}{CN}\right) - 10$$

CN = Curve number

I_a = Initial abstraction (in)

= 0.2 x S

= (all losses before runoff begins)

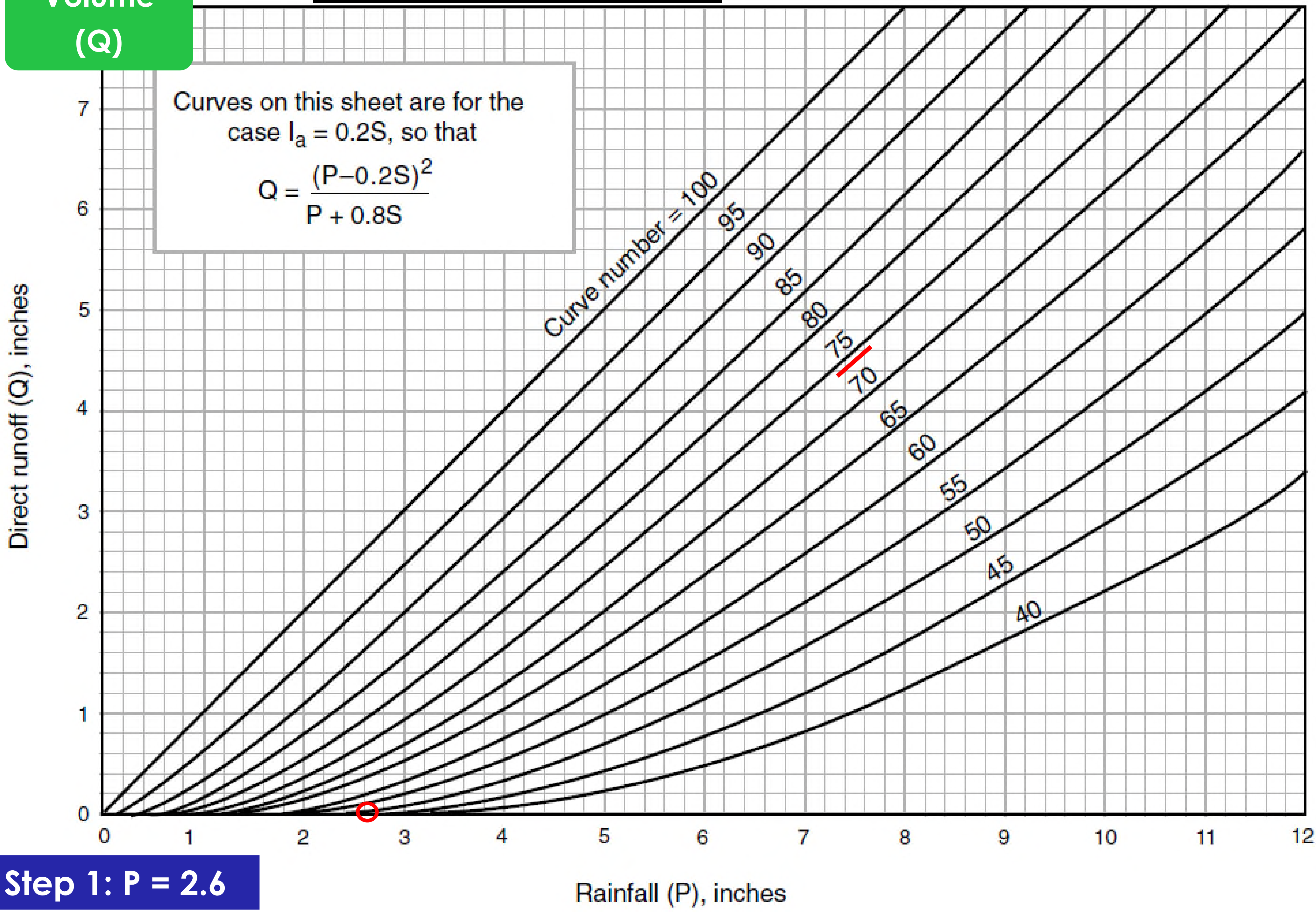
4. Runoff Volume (Q)

unoff depth for selected CN's and rainfall amounts 1/

Rainfall	Runoff depth for curve number of—												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

4. Runoff Volume (Q)

A1 Pre



Step 1: P = 2.6

3. initial abstraction (I_a)

4. Runoff Volume (Q)

Finding Ia and Q

P = rainfall (in)

CN = runoff curve number

S = potential maximum retention after runoff begins (in)

A1 Pre

$$S = \left(\frac{1000}{CN}\right) - 10 = \left(\frac{1000}{\quad}\right) - 10 = $$

I_a = initial abstraction (in)
= 0.2 x S
= 0.2 x
=

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

$$= \frac{(2.6 - Ia \quad)^2}{(2.6 - Ia) + S} = $$

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

9. peak discharge (q_p)

Finding q_p – Module 10, p. 30

$$q_p = q_u \times A_m \times Q \times F_p$$

q_p (cfs)

q_u (csm/in) from previous step

Q (in) from previous step

A_m (m^2)

F_p given as 1

Solutions to A2 and A3

A2		
	Pre	Post
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	78	79
S	2.821	2.658
Ia	0.564	0.532
P, in	2.6	
Ia/P	0.22	0.20
qu (csm/in)*	475	975

*Use Type II rainfall distribution

A2

Q, in	0.853	0.905
Q, ac-ft	0.384	0.407

DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438

q(peak), cfs	3.4	7.4

q(allowable), cfs	2.6

A3		
	Pre	Post
Tc (min)	15	5
Tc (hr)	0.25	0.0833

CN	74	79
S	3.514	2.658
Ia	0.703	0.532
P, in	2.6	
Ia/P	0.27	0.20
qu (csm/in)*	650	975

*Use Type II rainfall distribution

A3

Q, in	0.665	0.905
Q, ac-ft	0.299	0.407

DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438

q(peak), cfs	3.6	7.4

q(allowable), cfs	2.1

A1		
	Pre	Post
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	74	79
S	3.514	2.658
Ia	0.703	0.532
P, in	2.6	
Ia/P	0.27	0.20
qu (csm/in)*	450	975

*Use Type II rainfall distribution

Q, in	0.665	0.905
Q, ac-ft	0.299	0.407

DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438

q(peak), cfs	2.5	7.4

q(allowable), cfs	1.5

A2		
	Pre	Post
Tc (min)	30	5
Tc (hr)	0.5	0.0833

CN	78	79
S	2.821	2.658
Ia	0.564	0.532
P, in	2.6	
Ia/P	0.22	0.20
qu (csm/in)*	475	975

*Use Type II rainfall distribution

Q, in	0.853	0.905
Q, ac-ft	0.384	0.407

DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438

q(peak), cfs	3.4	7.4

q(allowable), cfs	2.6

A3		
	Pre	Post
Tc (min)	15	5
Tc (hr)	0.25	0.0833

CN	74	79
S	3.514	2.658
Ia	0.703	0.532
P, in	2.6	
Ia/P	0.27	0.20
qu (csm/in)*	650	975

*Use Type II rainfall distribution

Q, in	0.665	0.905
Q, ac-ft	0.299	0.407

DA (acres)	5.4	5.4
DA (sq mi)	0.008438	0.008438

q(peak), cfs	3.6	7.4

q(allowable), cfs	2.1

Questions?

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY