A Synthesis of Post-Fire Road Treatments for BAER Teams: Methods, Treatment Effectiveness, and Decision-Making Tools for Rehabilitation

Appendix D: NRCS Curve Number Method

Final Report to the Joint Fire Sciences Program

JFSP Project # 06-3-4-03

Randy B. Foltz, Research Engineer
Peter R. Robichaud, Research Engineer
Hakjun Rhee, Post-doctoral Associate

October 31, 2008

Rocky Mountain Research Station

Rocky Mountain Research Station
1221 S. Main St
Moscow, ID

Phone 208 882-3557
FAX 208 883-2318

Appendix D—NRCS Curve Number Method

The curve number method was developed by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), to estimate runoff and peak flow. The following steps were modified from SCS Engineering Field Handbook: Chapter 2—Estimating Runoff (USDA SCS; 1991) and used to apply the NRCS curve number method for estimation of post-fire peak flow.

1. Determine rainfall type among type I, IA, II, and III (figure 4) and design storm recurrence interval (e.g., 2, 5, 10, 25, 50, and 100 year), based on the location of the watershed. Then the rainfall amount (P) is determined using NOAA Atlas (NOAA, 2007).
2. Classify the watershed soil among soil groups (A, B, C, and D) (table 14).
3. Determine the average watershed slope, which is the slope of the land, not the water course. The following relationship can be used, or any adequate method can be used:

$$Y = \frac{100CI}{A} \qquad \text{(Equation D.1)}$$

where

Y = average watershed slope in percent;
C = total contour length in feet;
I = contour interval in feet; and
A = drainage area in square feet.

4. Determine the runoff curve number (CN), based on cover type, treatment, hydrologic conditions, and hydrologic soil group determined above (table D.2; table D.3; figure D.1). A representative curve number for a watershed can be estimated by area weighting with different curve numbers.
5. Estimate time of concentration using the following empirical relationship:

$$T_c = \frac{l^{0.8}\left[\left(\frac{1000}{CN}\right) - 9\right]^{0.7}}{1140Y^{0.5}} \qquad \text{(Equation D.2)}$$

where

T_c = time of concentration in hours;
l = flow length in feet;
CN = runoff curve number; and
Y = average watershed slope in percent.

6. Calculate potential maximum retention after runoff begins in inches (S) using the following relationship:

$$S = \frac{1000}{CN} - 10. \qquad \text{(Equation D.3)}$$

7. Calculate the runoff (Q) in inches, with a given total rainfall amount (P) in inches, and the S-value calculated above using figure D.2 or the following relationship:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}. \qquad \text{(Equation D.4)}$$

8. Calculate initial abstraction (I_a) in inches, which includes the portion of the rainfall that is not available for either infiltration or runoff and is used to wet surfaces prior to reaching the ground (interception). The initial abstraction is generally returned to the atmosphere by evaporation (Chin, 2000). The initial abstraction is found to be approximated by table D.4 or the following equation:

$$I_a = 0.2\ S \qquad \text{(Equation D.5)}$$

9. Calculate I_a/P using the values determined above.
10. Determine unit peak flow (q_u) in cfs/acre/inch, using T_c and I_a/P in figure D.3 to D.6.
11. Estimate peak flow (q_p) using the following relationship:

$$q_p = \frac{q_u \times A \times Q}{43{,}560} \qquad \text{(Equation D.6)}$$

where

q_p = peak flow in cfs;
q_u = unit peak flow in cfs/ac/in;
A = drainage area in square feet; and,
Q = runoff in inches.

Limitations and notations for using the NRCS curve number method are as follows:

- This method only considers rainfall-generated runoff, and not runoff generated from snowmelt. Runoff and peak flow from snowmelt or rain on frozen ground cannot be estimated.
- The watershed drainage area must be greater than 1.0 acre and less than 2,000 acres (3.1 mi^2).

- The watershed must be hydrologically similar; i.e., able to represented by a weighted CN. Land use, soils and cover are distributed uniformly throughout the watershed. The land use must be primarily rural. The NRCS curve number method is not applicable if urban conditions represent more than 10 percent of the watershed.
- The computed time of concentration (T_c) should be less than 10 hours. If the computed T_c is less than 0.1 hour, 0.1 hour is used.
- The flow length (l) should be greater than 200 feet and less than 26,000 feet.
- Potholes (storage) should be less than one third of the total drainage area, and should not intercept the drainage.
- The average watershed slope should be greater than 0.5 percent and less than 64 percent.
- The weighted CN should be greater than 40 and less than 98.
- If I_a/P is less than 0.1, 0.1 is used; and if I_a/P is greater than 0.5, 0.5 is used.

Table D.1. Runoff depth for selected CN/s and rainfall amounts[1] (USDA SCS, 1991).

Rainfall	Runoff (Q; inches) for curve number of—											
	40	45	50	55	60	65	70	75	80	85	90	95
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
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41
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
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
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
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
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
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
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
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
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

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

Table D.2. Runoff curve numbers for other agricultural lands[1] (USDA SCS, 1991).

Cover description			Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition		A	B	C	D
Bare soil	—		77	86	91	94
Pasture, grassland, or range—continuous	Poor		68	79	86	89
forage for grazing.[2]	Fair		49	69	79	84
	Good		39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—		30	58	71	78
Brush—brush-weed-grass mixture with brush	Poor		48	67	77	83
the major element.[3]	Fair		35	56	70	77
	Good		30[4]	48	65	73
Woods-grass combination (orchard	Poor		57	73	82	86
or tree farm).[5]	Fair		43	65	76	82
	Good		32	58	72	79
Woods[6]	Poor		45	66	77	83
	Fair		36	60	73	79
	Good		30[4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—		59	74	82	86

[1] Average runoff condition.
[2] *Poor*: < 50% ground cover or heavily grazed with no mulch.
Fair: 50% to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
[3] *Poor*: < 50%.
Fair: 50% to 75% ground cover.
Good: > 75% ground cover.
[4] Actual curve number is less than 30; use CN = 30 for runoff computations.
[5] CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
[6] *Poor*: Forest, litter, small trees, and brush have been destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table D.3. Runoff curve numbers for arid and semiarid rangelands[1] (USDA SCS, 1991).

Cover description			Curve numbers for hydrologic soil group—			
Cover type	Hydrologic Condition[2]		A[3]	B	C	D
Herbaceous—mixture of grass, weeds, and	Poor			80	87	93
low-growing brush, with brush the	Fair			71	81	89
minor element.	Good			62	74	85
Oak-aspen—mountain brush mixture of oak	Poor			66	74	79
brush, aspen, mountain mahogany, bitter brush,	Fair			48	57	63
maple, and other brush.	Good			30	41	48
Pinyon-juniper—pinyon, juniper, or both;	Poor			75	85	89
grass understory.	Fair			58	73	80
	Good			41	61	71
Sagebrush with grass understory.	Poor			67	80	86
	Fair			51	63	70
	Good			35	47	55
Desert shrub—major plants include saltbush,	Poor		63	77	85	88
greasewood, creosotebush, blackbrush, bursage,	Fair		55	72	81	86
palo verde, mesquite, and cactus.	Good		49	68	79	84

[1] Average runoff condition. For rangelands in humid regions, use table x.
[2] *Poor*: < 30% ground cover (litter, grass, and brush overstory).
Fair: 30% to 70% ground cover.
Good: > 70% ground cover.
[3] Curve numbers for group A were developed only for desert shrub.

Table D.4. I_a values for runoff curve numbers (USDA SCS, 1991).

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

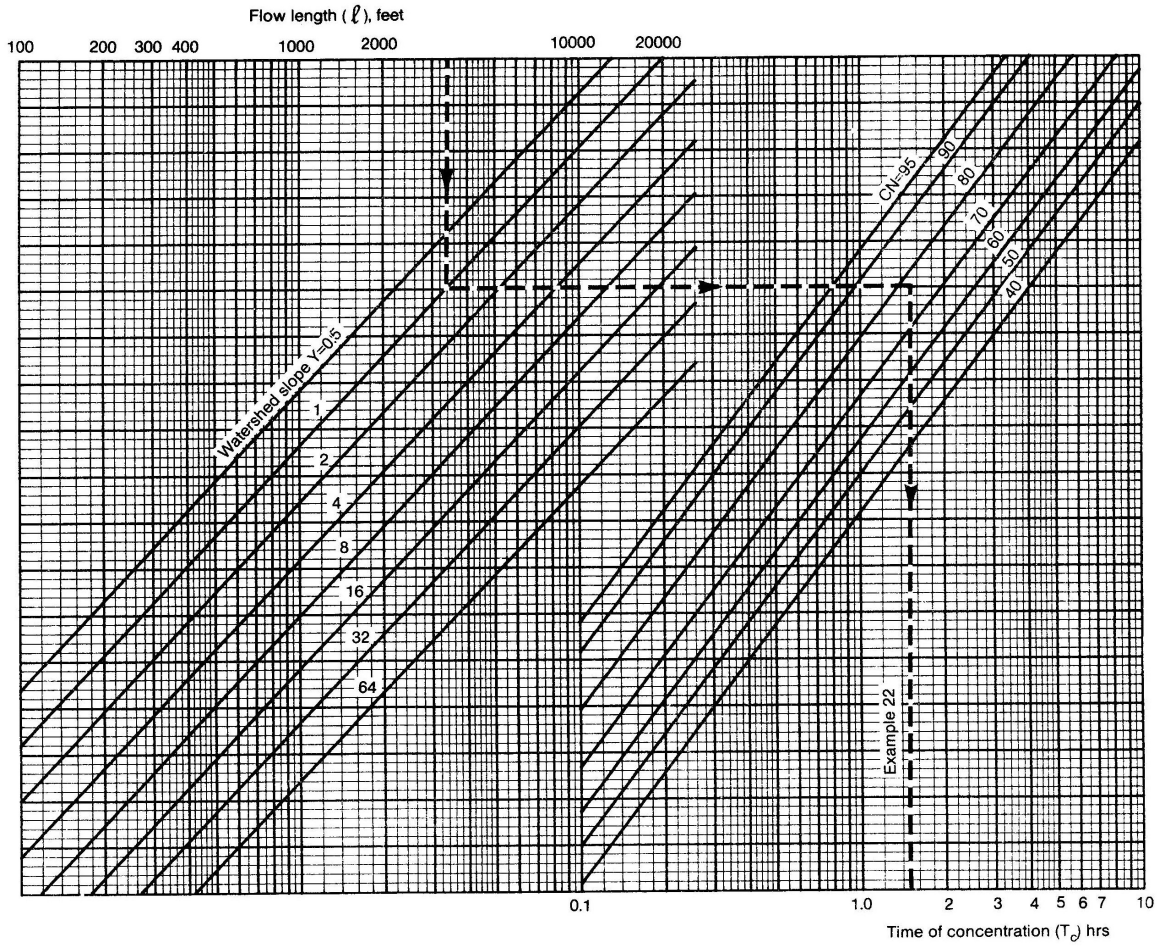

Figure D.1. Time of concentration (T_c) nomograph (USDA SCS, 1991).

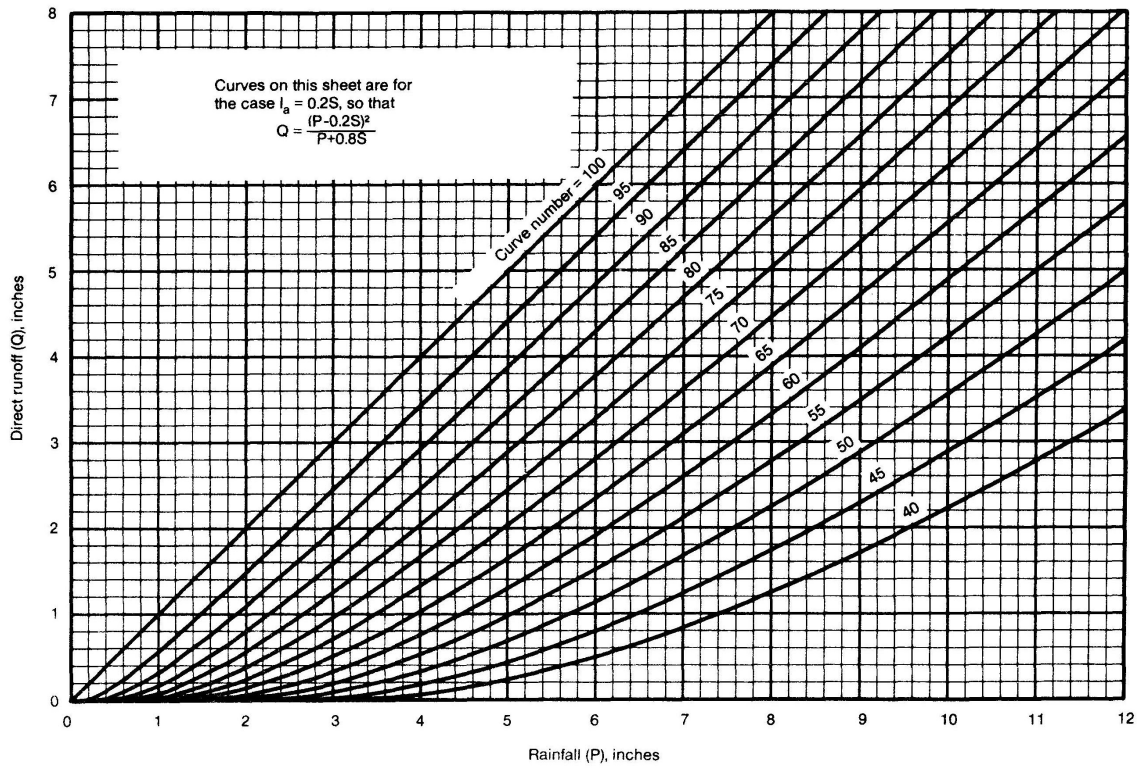

Figure D.2. Solution for runoff equation (USDA SCS, 1991).

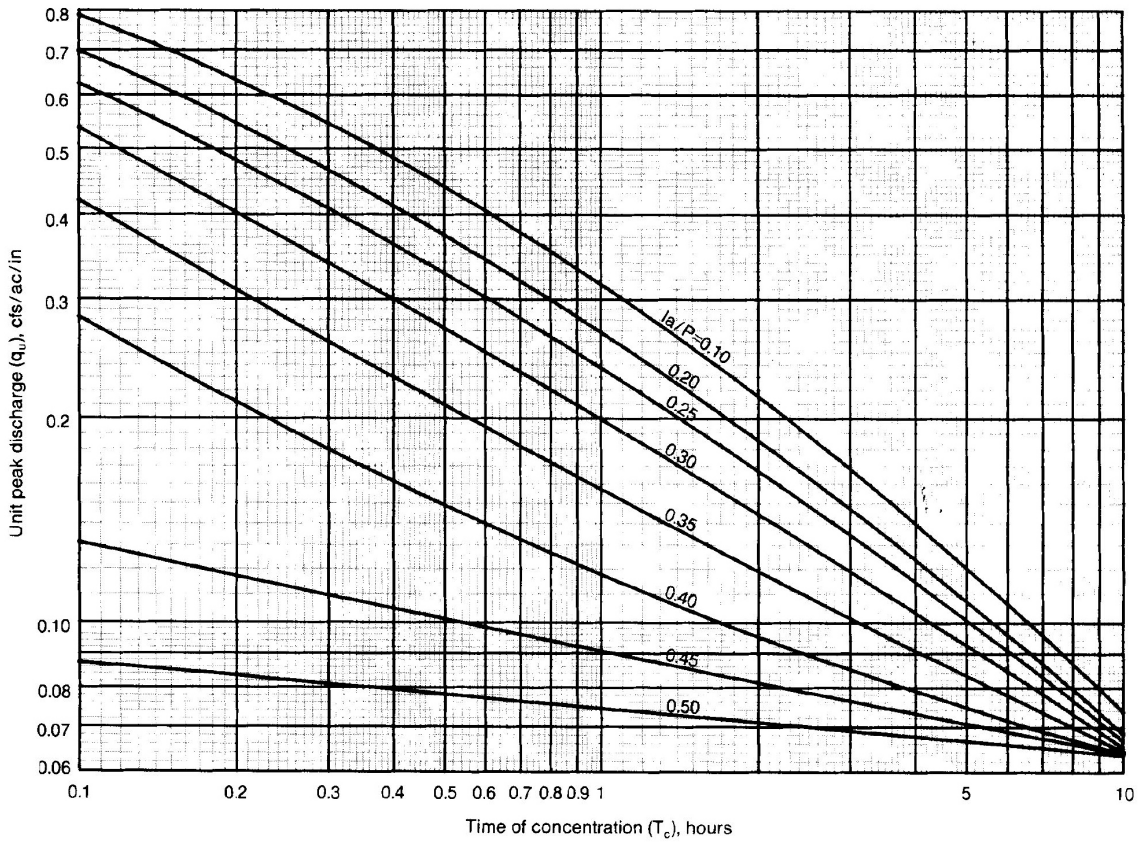

Figure D.3. Unit peak flow (q_u) for SCS Type I rainfall distribution (USDA SCS, 1991).

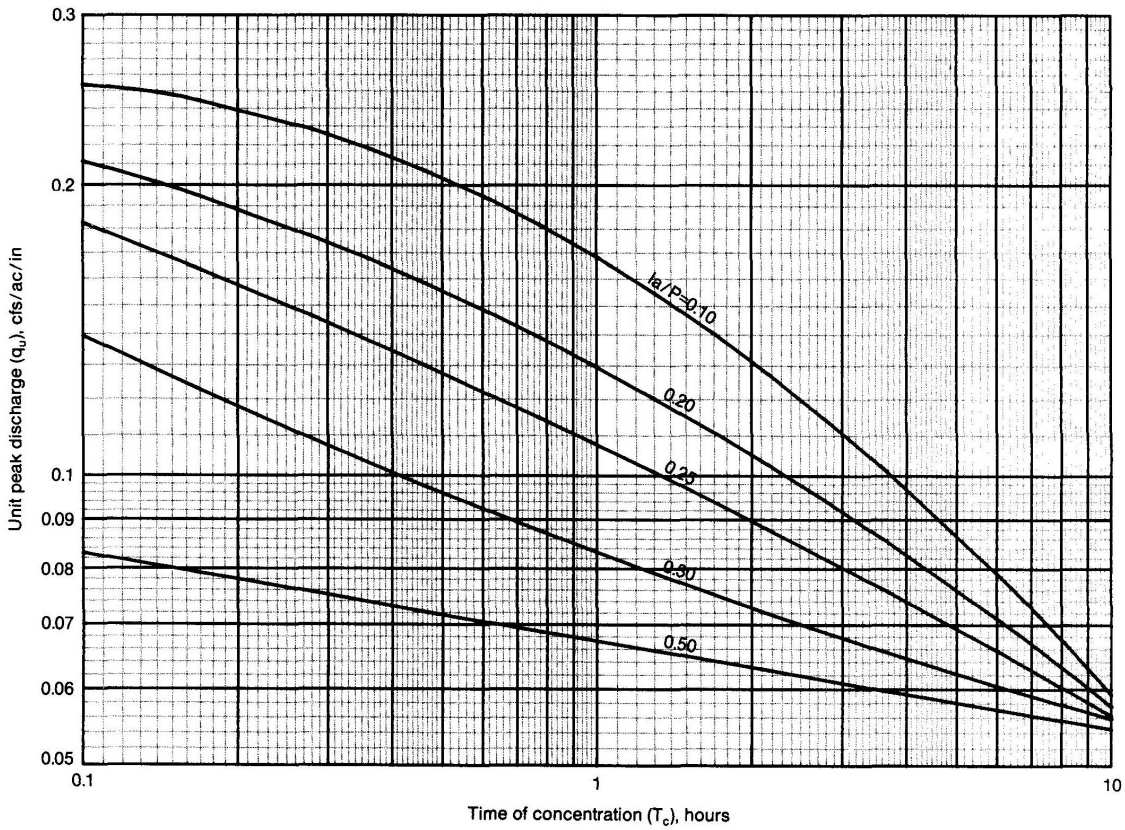

Figure D.4. Unit peak flow (q_u) for SCS Type IA rainfall distribution (USDA SCS, 1991).

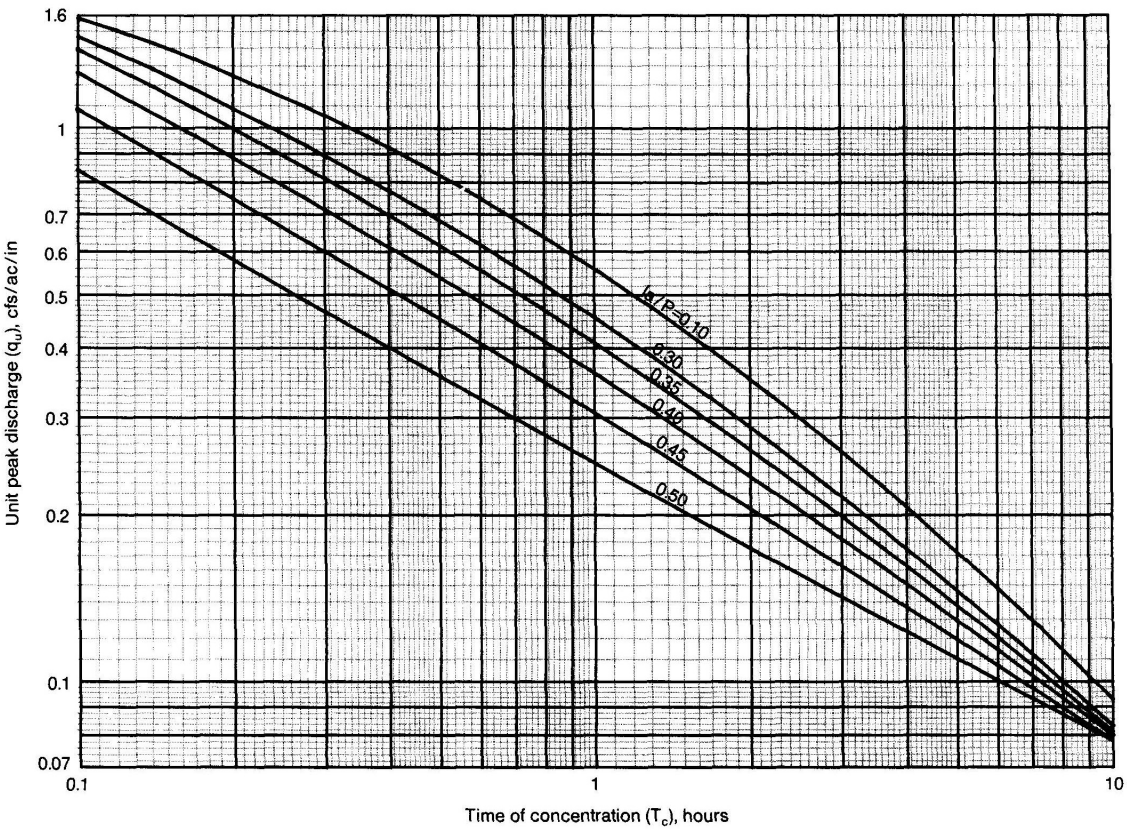

Figure D.5. Unit peak flow (q_u) for SCS Type II rainfall distribution (USDA SCS, 1991).

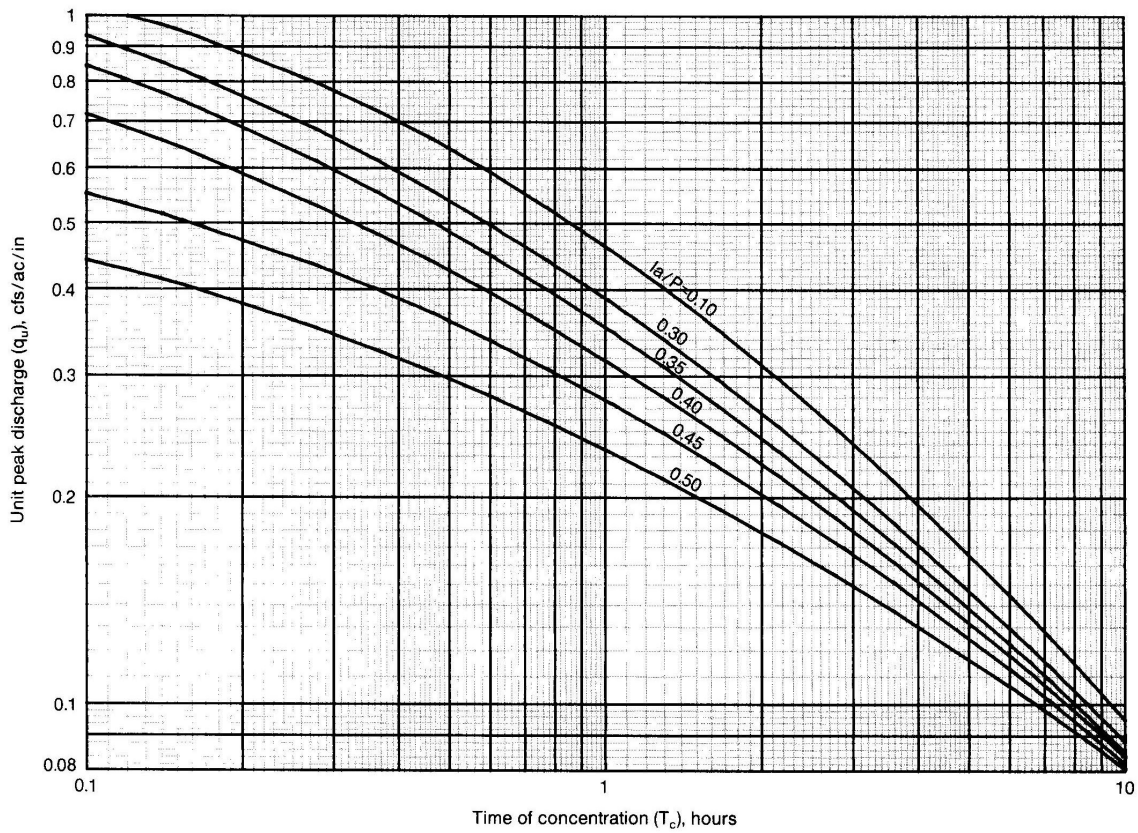

Figure D.6. Unit peak flow (q_u) for SCS Type III rainfall distribution (USDA SCS, 1991).