ESTIMATING RUNOFF VOLUME = ROCKET SCIENCE

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Why Runoff Volume?

- Many stormwater programs have a volume control requirement; that is, capturing the first 1 or 1.5 inches of stormwater and retaining it for 2 to 5 days.
- Similarly, Erosion Control measures are required to capture a volume and discharge it over a 2 to 5 day period.

Hydrologic Components

- Watershed Characteristics – Drainage Area, Land Use, Types of Soil, and Time of Concentration.
- Storm Characteristics – Type, Duration, Total Volume, Intensity, and Distribution.

SELECTING THE RIGHT METHOD!

- Acceptable methods to calculate peak discharge.
  1. Rational Method
  2. NRCS,TR-55 Graphical Peak Flow Method(also known as the SCS Method)

- Which method do I use?
  1. Rational Method: drainage area is less than 50 acres
  2. SCS Method: drainage area is greater than 20 acres, also the SCS method should only be used when the Curve Number exceeds 50 and the time of concentration is greater than 0.1 hr and less than 10 hr.

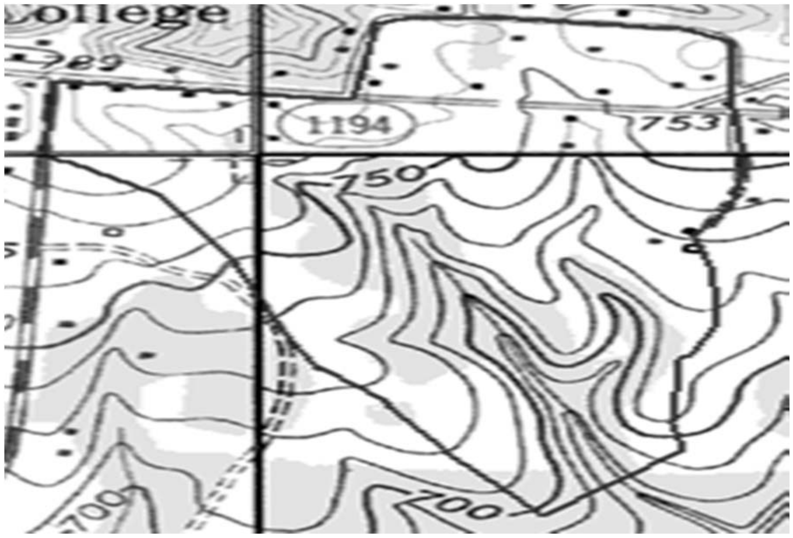
USING THE NRCS METHOD

- Step 1. Determine the drainage area.
- Step 2. Determine a weighted Curve Number and Tc
- Step 3. Select appropriate Rainfall amounts. (Depth, not intensity)
- Step 4. Determine peak discharge.

Example #1

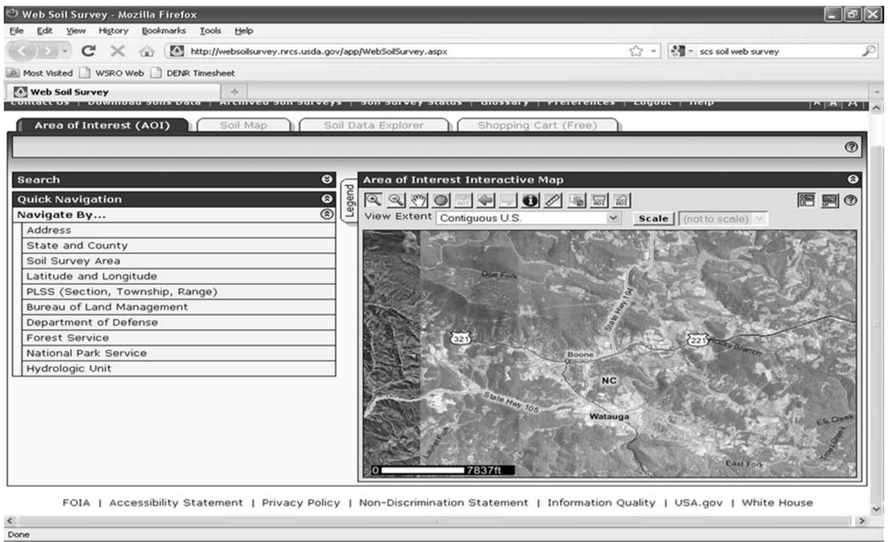
- Using the SCS Method, determine the total amount of runoff volume produced from a 10 year storm event that is located in Boone, NC. Two-thirds of the site is to be cleared and graded, while one-third will be left alone as dense woods.
- Drainage area of 45 acres
- Assume all soils are Hydrologic Group B
- The time of concentration:
  - Sheet flow of 50' with a slope of 8% made of Dense Woods.
  - Shallow concentrated flow of 250' with a slope of 6.5% unpaved.
  - Channel flow of 450' with a slope of 3.5% using a bankfull flow area of 4.5 ft^2 and a wetted perimeter of 5.0'. (Use n = 0.055)
- *http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm*

Hydrologic Components

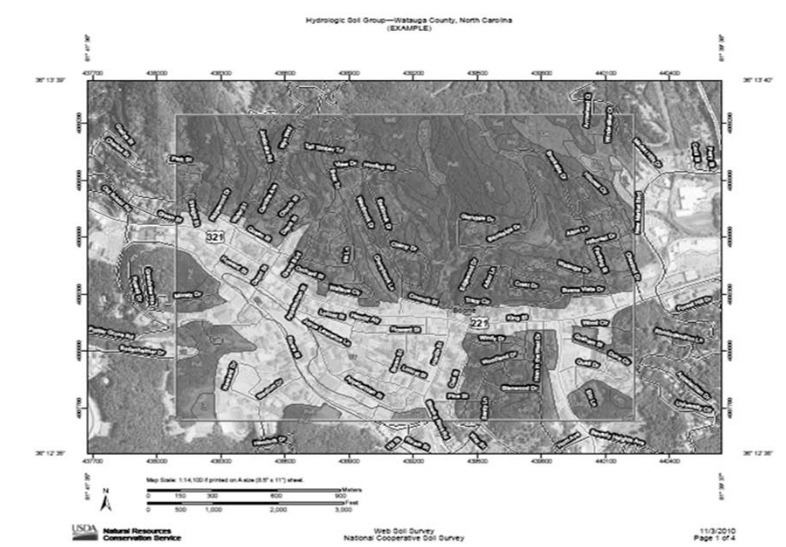


NRCS SOIL WEB SURVEY

NRCS SOIL WEB SURVEY



NRCS SOIL WEB SURVEY



Four Hydrologic Soil Groups as Defined by the SCS (1986)

Group A - A soils have low runoff potential and high infiltration rates and have a high rate of water transmission (greater than 0.30 in/hr). The textures of these soils are typically sand, loamy sand, or sandy loam.

Group B - B soils have moderate infiltration rates and have a moderate rate of water transmission (0.15-0.30 in/hr). The textures of these soils are typically silt loam or loam.

Group C - C soils have low infiltration rates and have a low rate of water transmission (0.05-0.15 in/hr). The texture of these soils is typically sandy clay loam.

Group D - D soils have high runoff potential and have a very low rate of water transmission (0-0.05 in/hr). The textures of these soils are typically clay loam, silty clay loam, sandy clay, silty clay, or clay.

NRCS SOIL WEB SURVEY

RUSLE2 Related Attributes–Iredell County, North Carolina

Map symbol and soil name	Pct. of map unit	Slope length (ft)	Hydrologic group	Kf	T factor	Representative value		
						% Sand	% Silt	% Clay
ToC2—Tomlin sandy clay loam, 6 to 10 percent slopes, moderately eroded								
Tomlin, moderately eroded	90	230	B	.10	5	55.1	14.9	30.0
ToD2—Tomlin sandy clay loam, 10 to 15 percent slopes, moderately eroded								
Tomlin, moderately eroded	80	—	B	.10	5	55.1	14.9	30.0
ToE2—Tomlin sandy clay loam, 15 to 25 percent slopes, moderately eroded								
Tomlin, moderately eroded	80	—	B	.10	5	55.1	14.9	30.0

Data Source Information

Soil Survey Area: Iredell County, North Carolina
Survey Area Data: Version 18, Jul 6, 2012

Table 8.03e Runoff curve numbers of urban areas[1]

Cover Description: Cover type and hydrologic condition	Average percent impervious area[2]	Curve number for hydrologic soil group: A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	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
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[4]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

Table 8.03g Runoff curve numbers for other agriculture lands[1]

Cover description: Cover type	Hydrologic conditions[3]	Curve numbers for hydrologic soil groups: A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	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 the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	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

LAND USE

- Total Drainage area = 45 acres
  - (2/3) * 45 = 30 acres cleared
  - (1/3) * 45 = 15 acres dense woods

- CN Values (These values can be found in the Manual, Chapter 8.)
- CN = 86 for Newly Graded Areas
- CN = 55 for Dense Woods

- Weighted CN-Value
- CN*A = (86)*(30 ac) + (55)*(15 ac) = 3405 (Divide by total Acreage)
- Weighted CN-Value = $\sum CN*A/A_T$ >>> 3405/45 = 75.67

TR-55

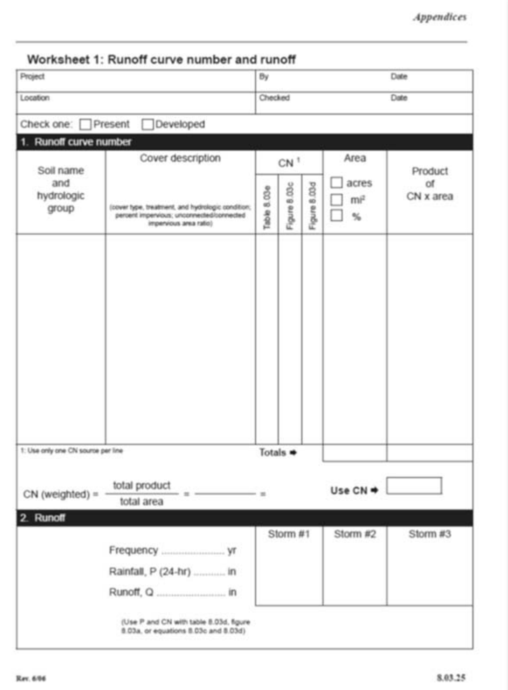
MBPOLING

Spring Workshop
NRCS Method
Wake County, North Carolina

Sub-Area Land Use and Curve Number Details

Sub-Area Identifier	Land Use		Hydrologic Soil Group	Sub-Area Area (ac)	Curve Number
Basin #1	Newly graded area (pervious only)		B	30	86
	Woods	(good)	B	15	55
	Total Area / Weighted Curve Number			45	76
				==	==

The curve number, CN, describes the characteristics of the drainage area that determines the amount of runoff generated by a given storm: hydrologic soil group and groundcover. Soils are classified into four hydrologic soil groups (A, B, C, and D) based on their minimum infiltration rate, with A having the highest infiltration potential and D having the lowest.



Appendices

Worksheet 1: Runoff curve number and runoff

Project		By			Date	
Location		Checked			Date	
Check one: ☐ Present ☐ Developed						
1. Runoff curve number						
Soil name and hydrologic group	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1]			Area ☐ acres ☐ mi² ☐ %	Product of CN x area
		Table 8.03e	Figure 8.03c	Figure 8.03d		
1: Use only one CN source per line		Totals ➡				

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ________ = Use CN ➡ ☐

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr			
Rainfall, P (24-hr) .... in			
Runoff, Q .... in			

(Use P and CN with table 8.03d, figure 8.03a, or equations 8.03c and 8.03d)

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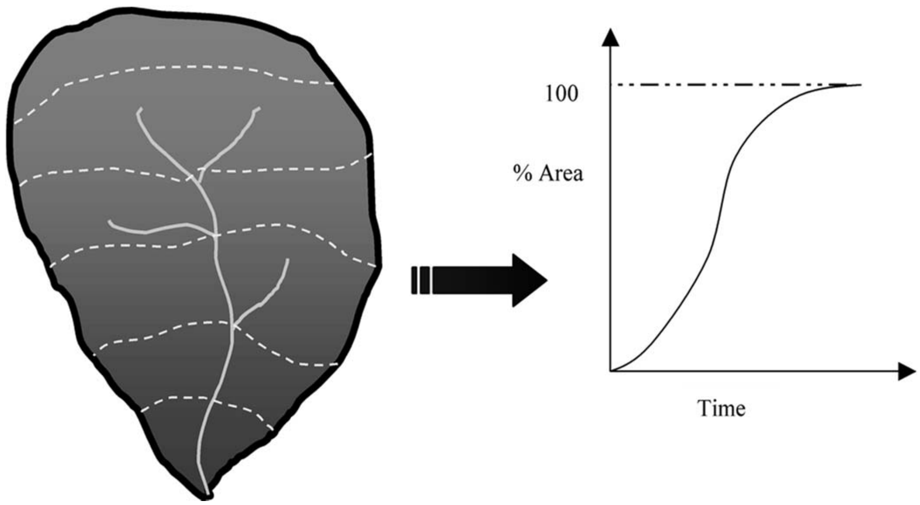
Hydrologic Components

- **Time of concentration** is a concept used in hydrology to measure the response of a watershed to a rain event. It is defined as the time needed for water to flow from the most remote point in a watershed to the watershed outlet. It is a function of the topography, geology, and land use within the watershed. (Wikipedia)
  - $t_c = t_{sheet} + t_{shallow} + t_{channel}$

Time of Concentration



Worksheet 2: Time of Concentration (T_c) or travel time (T_t)

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

Check one: ☐ T_c ☐ T_t through subarea

Note: Space for as many as two segments per flow can be used for each worksheet.
Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

Segment ID:

1. Surface description (table 8.03h) ....
2. Manning's roughness coefficient, n (table 8.03h)
3. Flow length, L (total L + 300ft) .... ft
4. Two-year 24-hour rainfall, P_2 .... in
5. Land slope, s .... ft/ft
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t .... hr ☐ + ☐ = ☐

Shallow concentrated flow

Segment ID:

7. Surface description (paved or unpaved) ....
8. Flow length, L .... ft
9. Watercourse slope, s .... ft/ft
10. Average velocity, V (figure 3-1) .... ft/s
11. $T_t = \frac{L}{3600\,V}$ Compute T_t .... hr ☐ + ☐ = ☐

Channel flow

Segment ID:

12. Cross sectional flow area, a .... ft^2
13. Wetted perimeter, P_w .... ft
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r .... ft
15. Channel slope, s .... ft/ft
16. Manning's roughness coeficient, n ....
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V .... ft/s
18. Flow length, L .... ft
19. $T_t = \frac{L}{3600V}$ Compute T_t .... hr ☐ + ☐ = ☐
20. Watershed or subarea or (add in step 6,11, and 19) .... Hr ☐

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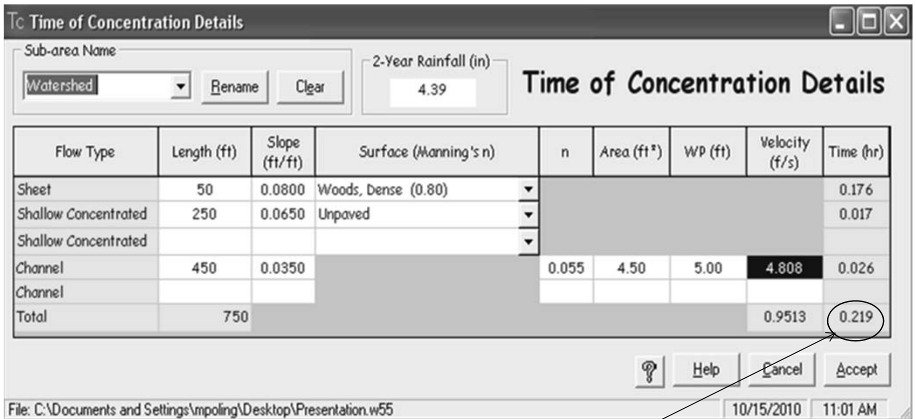
TIME OF CONCENTRATION TR-55


Tc Time of Concentration Details

Sub-area Name: Watershed | Rename | Clear

2-Year Rainfall (in): 4.39

Time of Concentration Details

Flow Type	Length (ft)	Slope (ft/ft)	Surface (Manning's n)	n	Area (ft²)	WP (ft)	Velocity (f/s)	Time (hr)
Sheet	50	0.0800	Woods, Dense (0.80)					0.176
Shallow Concentrated	250	0.0650	Unpaved					0.017
Shallow Concentrated								
Channel	450	0.0350		0.055	4.50	5.00	4.808	0.026
Channel								
Total	750						0.9513	0.219

Help | Cancel | Accept

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~ 13.14 Minutes

RAINFALL

Boone, North Carolina 36.2167N, 81.6667W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.48	0.76	0.96	1.32	1.66	2.00	2.18	2.85	3.77	4.39
10	0.62	1.00	1.26	1.83	2.39	2.92	3.18	4.10	5.28	6.61
25	0.72	1.14	1.45	2.14	2.85	3.55	3.87	4.94	6.21	8.07
100	0.86	1.38	1.74	2.66	3.67	4.69	5.15	6.47	7.82	10.65

SCS Peak Discharge Method

- $Q = \frac{(P-0.2S)^2}{(P+0.8S)}$
- Q = Depth of Runoff (in) over the entire watershed.
- P = Rainfall (Depth in inches of a 24 hour event)
- S = Potential maximum retention after run off begins (in)
- $S = \frac{1000}{CN} - 10$; S = 3.22
- $Q = \frac{(6.61 - (0.2*3.22))^2}{(6.61 + (0.8*3.22))}$; Q = 3.88 Inches of Runoff

Graphical Peak Discharge Method

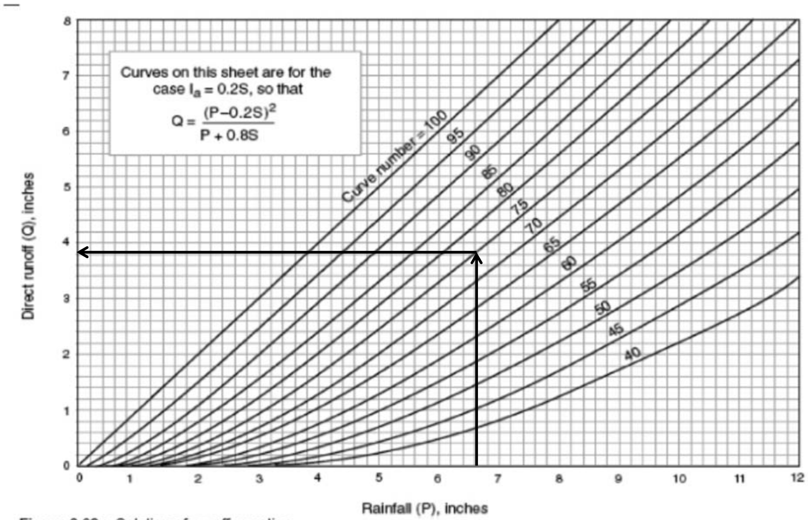


Figure 8.03a Solution of runoff equation

Table 8.03d 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	0.00	0.00	0.00	0.00	0.00	0.00	.03	.07	.15	.27	.46	.74	.99
1.4	0.00	0.00	0.00	0.00	0.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	0.00	0.00	0.00	0.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	0.00	0.00	0.00	0.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	0.00	0.00	0.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	0.00	0.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	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.

SCS Peak Discharge Method

- Peak Discharge (Q_p) = $q_u * A_m * F_p * Q$ = CFS
- Unit Peak Discharge (q_u) From figure 8.03k in the sediment manual (CFS / Square Mile per Inch of Rainfall)
- Drainage Area (A_m) = mi^2
- Pond and Swamp Factor (F_p) = 1.0 ~ 0%
- Runoff (Q) = Depth in inches

INITIAL ABSTRACTION

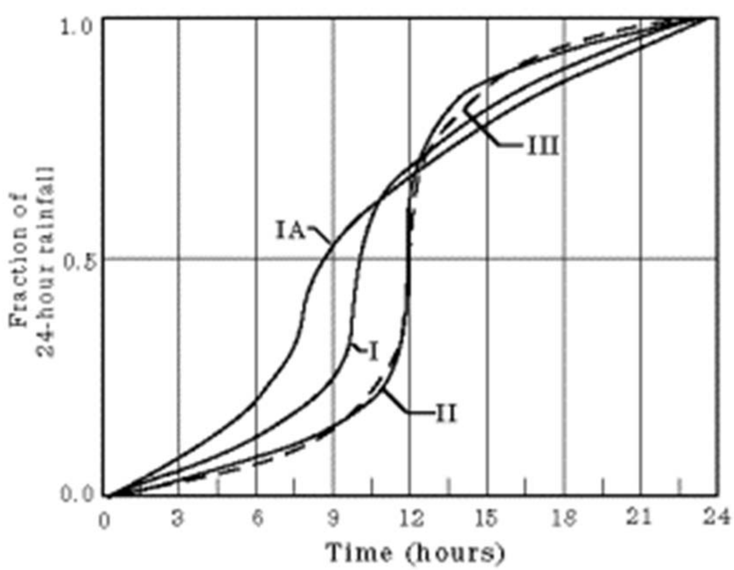
Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500

CN = 75.67

Initial abstraction (Ia) is all losses before runoff begins. It includes water retained in surface depressions, water being intercepted by vegetation, evaporation, and infiltration.

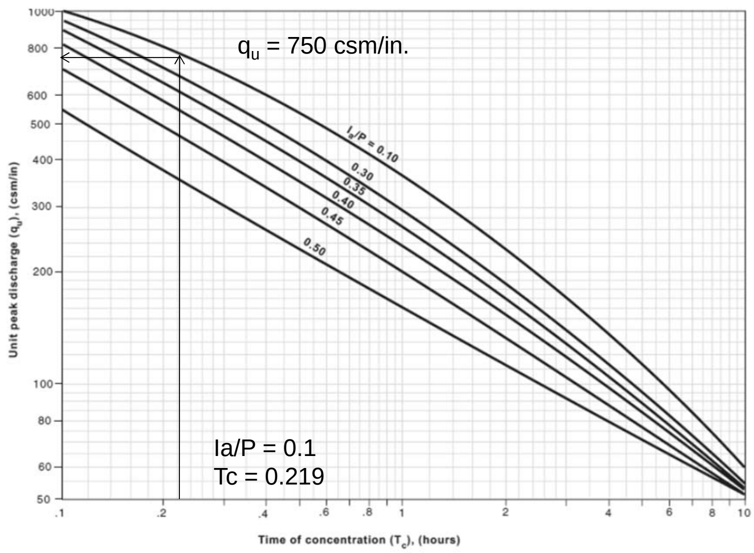
- Average (Ia) = 0.65”
- Ia/P = 0.65 / 6.61 = 0.1

Unit Hydrograph



UNIT PEAK DISCHARGE

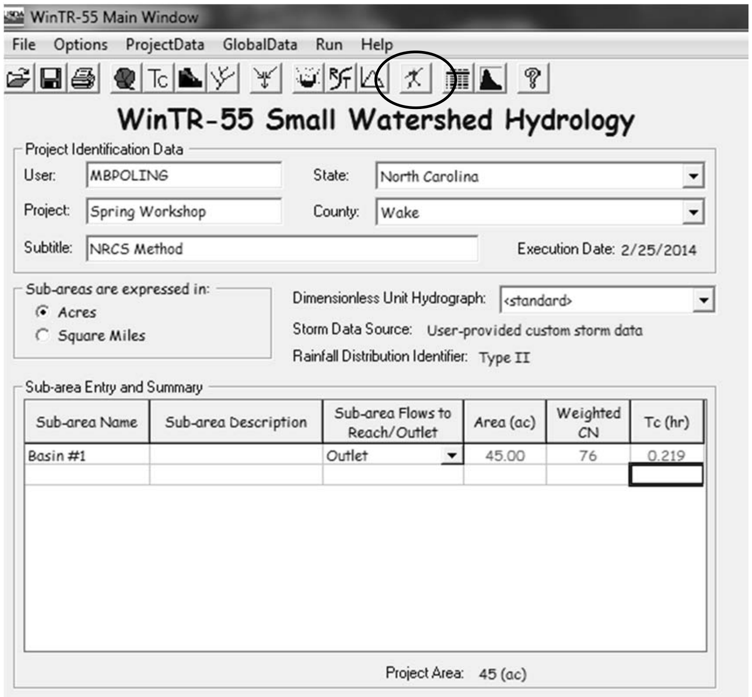
Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution



SCS Peak Discharge Method

- Peak Discharge (Q_p) = $q_u * A_m * F_p * Q$ = CFS
- Unit Peak Discharge (q_u) = 350 csm/in (figure 8.03k in the sediment manual) (CFS / Square Mile per Inch of Rainfall)
- Drainage Area (A_m) = 45 Acres/640 ac/mi^2 = 0.07 mi^2
- Pond and Swamp Factor (F_p) = 1.0 ~ 0%
- Runoff (Q) = 3.88 inches

- Q_p = 750 * 0.07 * 1.0 * 3.88 = 204 cfs

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MBPOLING                         Spring Workshop
                                   NRCS Method
                           Wake County, North Carolina

                         Hydrograph Peak/Peak Time Table

 Sub-Area        Peak Flow and Peak Time (hr) by Rainfall Return Period
 or Reach       10-Yr
Identifier      (cfs)
             (hr)
------------------------------------------------------------------------
SUBAREAS
Basin #1       227.48
           12.03


REACHES

OUTLET         227.48
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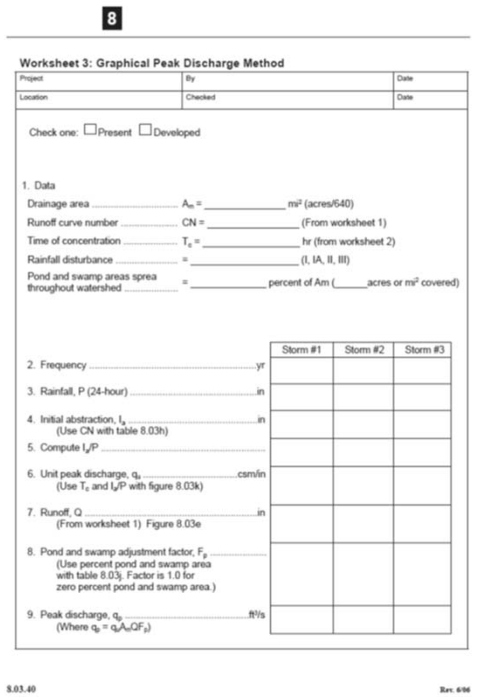

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Worksheet 3: Graphical Peak Discharge Method

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Data

Drainage area .... A_m = ________ mi² (acres/640)

Runoff curve number .... CN = ________ (From worksheet 1)

Time of concentration .... T_c = ________ hr (from worksheet 2)

Rainfall disturbance .... = ________ (I, IA, II, III)

Pond and swamp areas sprea throughout watershed .... = ________ percent of Am (______ acres or mi² covered)

	Storm #1	Storm #2	Storm #3
2. Frequency .... yr			
3. Rainfall, P (24-hour) .... in			
4. Initial abstraction, I_a .... in (Use CN with table 8.03h)			
5. Compute I_a/P			
6. Unit peak discharge, q_u .... csm/in (Use T_c and I_a/P with figure 8.03k)			
7. Runoff, Q .... in (From worksheet 1) Figure 8.03e			
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 8.03j. Factor is 1.0 for zero percent pond and swamp area.)			
9. Peak discharge, q_p .... ft³/s (Where $q_p = q_u A_m Q F_p$)			

8.03.40 Rev. 6/06

RUNOFF VOLUME

- Q = 3.88 Inches of Runoff
- Area = 45 Acres
- Volume = Depth x Area
- Volume = 627,264 Cubic Feet of Runoff
- Volume = 14.4 ac-ft

EXAMPLE #2

- Using the Rational Method in conjunction with the SCS Triangular Unit Hydrograph Method, determine the total amount of runoff volume produced from a 10 year storm event. Two-thirds of the site is to be cleared and graded, while one-third will be left alone as dense woods.
- Drainage area of 45 acres
- Weighted Runoff Coefficient
- The time of concentration:
  - Sheet flow of 50' with a slope of 8% made of Dense Woods.
  - Shallow concentrated flow of 250' with a slope of 6.5% unpaved.
  - Channel flow of 450' with a slope of 3.5% using a bankfull flow area of 4.5 ft^2 and a wetted perimeter of 5.0'. (Use n = 0.055)

RATIONAL METHOD

- Step 1. Determine the Land Use "C" Values.
- Step 2. Determine your time of concentration, time to peak, and time of base.
- Step 3. Select Appropriate Storm

8

Table 8.03b
Value of Runoff Coefficient (C) for Rational Formula

Land Use	C	Land Use	C
Business:		Lawns:	
Downtown areas	0.70-0.95	Sandy soil, flat, 2%	0.05-0.10
Neighborhood areas	0.50-0.70	Sandy soil, ave., 2-7%	0.10-0.15
Residential:		Sandy soil, steep, 7%	0.15-0.20
Single-family areas	0.30-0.50	Heavy soil, flat, 2%	0.13-0.17
Multi units, detached	0.40-0.60	Heavy soil, ave., 2-7%	0.18-0.22
Multi units, Attached	0.60-0.75	Heavy soil, steep, 7%	0.25-0.35
Suburban	0.25-0.40	Agricultural land:	
Industrial:		Bare packed soil	
Light areas	0.50-0.80	Smooth	0.30-0.60
Heavy areas	0.60-0.90	Rough	0.20-0.50
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
Streets:		Sandy soil with crop	0.10-0.25
Asphalt	0.70-0.95	Pasture	
Concrete	0.80-0.95	Heavy soil	0.15-0.45
Brick	0.70-0.85	Sandy soil	0.05-0.25
Drives and walks	0.75-0.85	Woodlands	0.05-0.25
Roofs	0.75-0.85		

NOTE: The designer must use judgement to select the appropriate C value within the range for the appropriate land use. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest C values. Smaller areas with slowly permeable soils, steep slopes, and sparse vegetation should be assigned highest C values.

Source: American Society of Civil Engineers

LAND USE

- Total Drainage area = 45 acres
  - (2/3) * 45 = 30 acres cleared
  - (1/3) * 45 = 15 acres dense woods

- C Values (These values can be found in the Manual, Chapter 8.)
- C = 0.6 for Newly Graded Areas
- C = 0.25 for Dense Woods

- Weighted CN-Value
- CN*A =(0.6)*(30 ac) + (0.25)*(15 ac) = 21.8 (Divide by total Acreage)
- Weighted CN-Value = $\sum CN*A/A_T$ >>> 21.8/45 = 0.48

Time of Concentration and the Jarrett Method

- Jarrett (2005) determined that the time of concentration, t_c, is approximated as 5 minutes for watersheds smaller than the Jarrett Maximum Area.

Jarrett Method for Small Drainage Areas

- $A_{jarrett}$ = Jarrett Maximum Area (ac)
  - $A_{jarrett}$ = 460 * (S)
- S = H / L
  - S = Average Slope Length (ft)
  - H = Change in Elevation (ft)
  - L = Flow Length (ft)

Jarrett Method for Small Drainage Areas

- Drainage Area = 45 acres
- $A_{jarrett}$ = 460 * (S)
  - S = 0.048 ft/ft
- $A_{jarrett}$ = 460 * (0.048) = 22.08
- 45 > 22.08 Therefore cannot assume 5 minute time of concentration

TIME OF CONCENTRATION

The Kinematic Wave Theory

SOLVED THROUGH ITERATIONS

$$T_C = \frac{\left[\frac{L}{\left(\frac{1.49 * S^{1/2}}{n} \right) \left(\frac{I_i * C}{43{,}200} \right)^{2/3}} \right]^{3/5}}{60}$$

where:

L = length of overland flow plane (feet)

S = slope (ft/ft)

n = Manning's roughness

Ii = rainfall intensity

C = rational runoff coefficient

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**Watershed Basin Number**	A			**Solving for Time of Concentration**										
2	**Total Drainage Area**	45			**Kinematic Wave Theory**										
3	**Rational Method for Flow**		**RUNOFF COEFFICIENT**						User Data	Calculated Value					
4	Subarea A (acres)	30			Length of overland flow			50.000	feet	Surface Mannings n					
5	Subarea A Runoff Coefficient	0.6	**LAND USE**	**C**	Mannings "n" for surface			0.800		Smooth Surface			0.011		
6										Bare Earth			0.020		
7	Subarea B (acres)	15	**BUSINESS:**		Average watershed slope			0.080	ft./ft.	Fallow			0.050		
8	Subarea B Runoff Coefficient	0.25	DOWNTOWN AREAS	0.7-0.95	Constant alpha			0.527		Cultivated, <= 20% Residue			0.060		
9	Subarea C (acres)		NEIGHBORHOOD AREAS	0.5-0.7	Constant m			1.667		Cultivated > 20% Residue			0.170		
10	Subarea C Runoff Coefficient		**RESIDENTIAL:**		Weighted Runoff Coefficient			0.48		Grass, Short			0.150		
11	Subarea D (acres)		SINGLE FAMILY AREAS	0.3-0.5						Grass, Dense			0.240		
12	Subarea D Runoff Coefficient		MULTI UNITS, DETACHED	0.4-0.6						Grass, Bermuda			0.410		
13	Weighted Runoff Coefficient	**0.4833**	MULTI UNITS, ATTACHED	0.6-0.75						Woods, Light			0.400		
14	2-year Rainfall Intensity (IDF)	3.83	SUBURBAN	0.25-0.4						Woods, Dense			0.800		
15	10-year Rainfall Intensity (IDF)	5.06	**INDUSTRIAL:**												
16	**Q2 Flow**	**83.3**	LIGHT AREAS	0.5-0.8	Trail Time of Duration				Rainfall Intensity(IDF)			Calculation of Time of Concentration			
17	**Q10 Flow**	**110.1**	HEAVY AREAS	0.6-0.9	tr (minutes)				i (inches/hour)			tc (minutes)			
18			PARKS, CEMETARIES	0.1-0.25	http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html										
19			PLAYGROUNDS	0.2-0.35	5				7.5			10.98			
20			RAILROAD YARD AREAS	0.2-0.4	10				6			12.01			
21			UNIMPROVED AREAS	0.1-0.3	15				5.06			12.86			
22			**STREETS:**		30				3.67			14.62			
23			ASPHALT	0.7-0.95	60	(1 hour)			2.39			17.36			
24			CONCRETE	0.8-0.95	120	(2 hours)			1.46			21.14			
25			BRICK	0.7-0.85	180	(3 hours)			1.06			24.03			
26			DRIVES AND WALKS	0.75-0.85	360	(6 hours)			0.69			28.54			
27			ROOFS	0.75-0.85	720	(12 hours)			0.44			34.17			
28			**LAWNS:**		1440	(24 hours)			0.28			40.94			
29			SANDY SOIL, FLAT, 2%	0.05-0.1											
30			SANDY SOIL, AVE., 2-7%	0.1-0.15	**Enter the Rainfall Intensity Values for the Corresponding Times of Duration from the NWS hyperlink provided.**										
31			SANDY SOIL, STEEP, 7%	0.15-0.2	**Select the smallest Trial Time of Duration that is equal to or less than the calculated Time of Concentration, or the Calcu**										
32					**Time of Concentration if it is less than 5 minutes. This is the overland flow component of the Time of Concentration.**										
33															
34					**Overland Flow**		tc (minutes)	**12.86**							
35			HEAVY SOIL, FLAT, 2%	0.13-0.17											
36			HEAVY SOIL, AVE., 2-7%	0.18-0.22	**Calculate the shallow concentrated flow component of the Time of Concentration.**										
37			HEAVY SOIL, STEEP, 7%	0.25-0.35	**Calculate the channel flow component of the Time of Concentration.**										
38			**AGRICULTURAL LAND:**		**Sum these three components.**			**This is the total Time of Concentration.**							
39			*BARE PACKED SOIL*												
40			SMOOTH	0.3-0.6	**Shallow Concentrated Flow**				**Channel Flow**						
41			ROUGH	0.2-0.5											
42			*CULTIVATED ROWS*		**Paved**										
43			HEAVY SOIL NO CROP	0.3-0.6	Flow Length			0	Flow Length		450				
44			HEAVY SOIL WITH CROP	0.2-0.5	Slope			0	Slope		0.035				
45			SANDY SOIL NO CROP	0.2-0.4	tc (minutes)			**0.0**	Hydraulic Radius		0.9				
46			SANDY SOIL WITH CROP	0.1-0.25	**Unpaved**				Mannings n		0.055				
47			*PASTURE*		Flow Length			250	tc (minutes)		**1.6**				
48			HEAVY SOIL	0.15-0.45	Slope			0.065							
49			SANDY SOIL	0.05-0.25	tc (minutes)			**1.0**		**Al Jarrett Shortcut, for Bare Soil**					
50			WOODLANDS	0.05-0.25						Average Watershed Slope			4.8	%	
51					**Total Time of Concentration**			**15.5**		Total Drainage Area A			45	acres	
52	Revised 11/25/2008	TGH								4.6*S			22.08		
53										If A<4.6*S, Assume Tc=5 minutes					

STORM DURATION

By setting the storm duration equal to the time of concentration, you are producing a storm event with the maximum peak discharge.

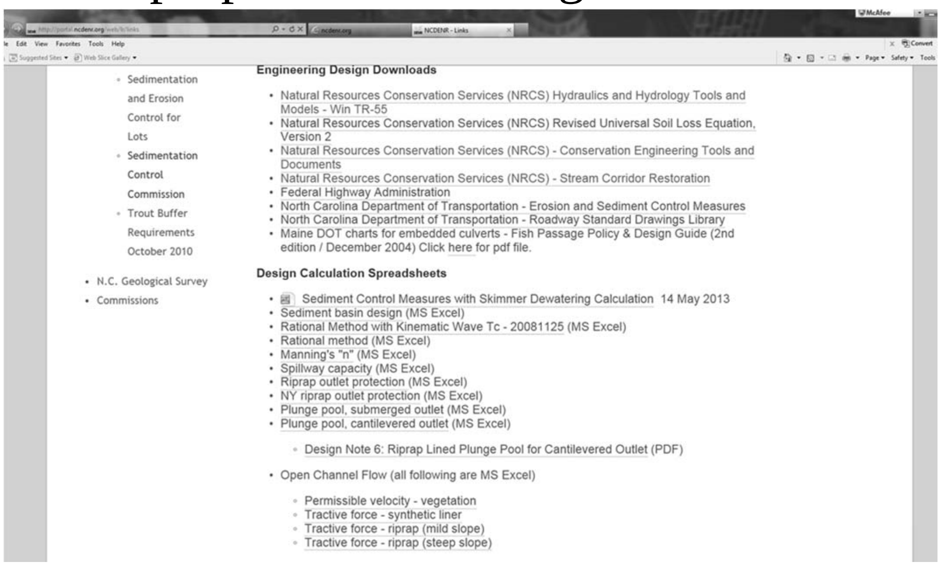
Q: Why did you set the storm duration greater than the time of concentration?

A: You want to make sure that all of the drainage area is contributing.

Tc = 15.5 min.

Boone, North Carolina 36.2167N, 81.6667W										
ARI* (years)	**5 min.**	**10 min.**	**15 min.**	**30 min.**	**60 min.**	**120 min.**	**3 hr.**	**6 hr.**	**12 hr.**	**24 hr.**
2	5.71	4.57	3.83	2.64	1.66	1.00	0.72	0.48	0.31	0.18
10	7.50	6.00	5.06	3.67	2.39	1.46	1.06	0.69	0.44	0.28
25	8.59	6.85	5.78	4.28	2.85	1.77	1.29	0.83	0.52	0.34
100	10.38	8.25	6.95	5.32	3.67	2.35	1.72	1.08	0.65	0.44

http://portal.ncdenr.org/web/lr/links



ESTIMATING PEAK FLOW

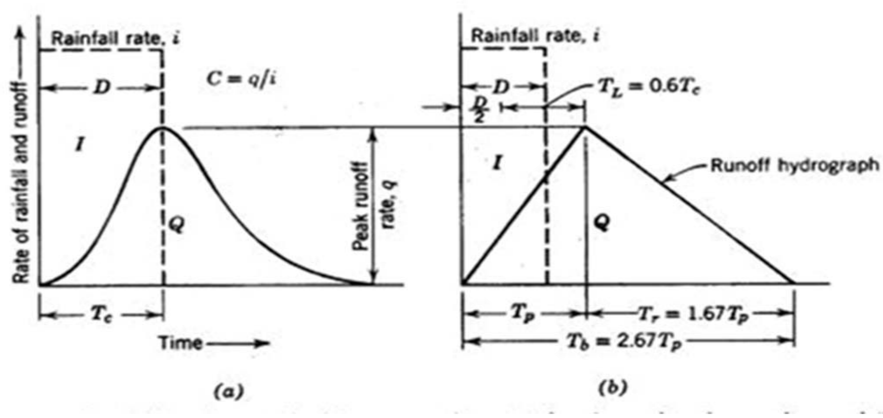
- RATIONAL EQUATION, Q = CIA
- C = 0.48
- I = 5.06 in/hr
- A = 45 Acres

- Q = 109 cfs

SCS TRIANGULAR HYDROGRAPH METHOD

- Step 1. Solve for Peak Flow and time to peak
- Step 2. Apply values to the SCS Triangular unit Hydrograph
- Step 3. Find the area of the triangle! (.5 * Base * Heights)

SCS TRIANGULAR HYDROGRAPH

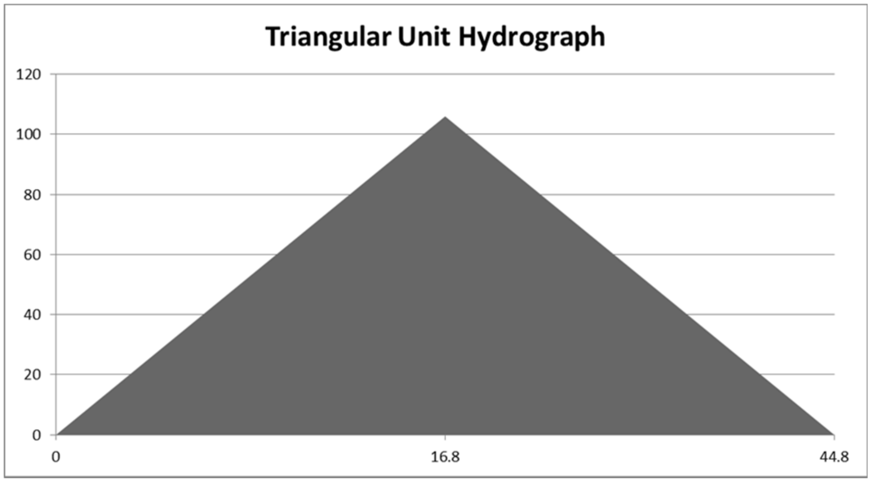


Time to Peak, Time of Base

- Lag Time (T_L) = T_C * 0.6 (SCS Empirical Equation)
- Time to Peak (T_P) = D/2 + T_L
- T_P = D/2 + T_C * 0.6
- T_P = (15/2) + (15.5 * 0.6) = 16.8 Minutes

- Time of Base (T_R) = 1.67 * T_P
- $T_{R\,=}$ 1.67 * 16.8 = 28 Minutes

AREA UNDER THE TRIANGLE



RUNOFF VOLUME

- Solving for the area under the triangles!

(0.5*106*16.8*60) + (0.5*106*28*60)

53,424+89,040 = 142,464 Cubic Feet of Runoff!

Also, Volume = 3.3 Acre-Feet

WHY IS THE VOLUME SO DIFFERENT?

- Volume 24 hr event = 14.4 Acre-Feet
- Volume 15 min. event = 3.3 Acre-Feet

- Peak Flow 24 hr event = 204
- Peak Flow 15 min. event = 106

From a depth perspective!

Boone, North Carolina 36.2167N, 81.6667W

ARI* (years)	5 min.	10 min.	15 min.	30 min.	60 min.	120 min.	3 hr.	6 hr.	12 hr.	24 hr.
2	0.48	0.76	0.96	1.32	1.66	2.00	2.18	2.85	3.77	4.39
10	0.62	1.00	1.26	1.83	2.39	2.92	3.18	4.10	5.28	6.61
25	0.72	1.14	1.45	2.14	2.85	3.55	3.87	4.94	6.21	8.07
100	0.86	1.38	1.74	2.66	3.67	4.69	5.15	6.47	7.82	10.65

Why Runoff Volume?

- Sediment traps and basins are using total runoff volume and peak discharge rate.
- Designing with Peak discharge does not account for increased amounts of volume. This leads to traps and basins being over topped!
- Is a type II storm distribution unreasonable for sediment trap and basin design?