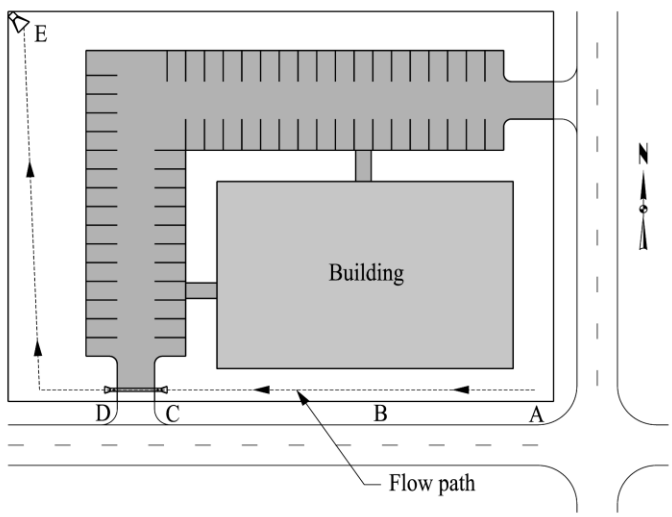
Runoff Examples

A. Rational Method Example

1. **Problem Statement:** A 2 acre commercial site (350 feet by 250 feet) is being developed with a new building and parking lot. The site drains to a culvert located at the northwest corner of the property. The hydraulically most distant point is located at the southeast corner of the property. Runoff from the SE corner of the property flows west, through a driveway culvert under the south drive, and then north to the main culvert. The average slope along this route is 3%. All runoff drains to the northwest corner and the site does not have any off-site drainage.

   Assuming this site is located in Iowa Climactic Section 4, with Group C soils; use the Rational Method to determine the peak runoff from the property.

Figure 2B-6.01: Example Commercial Development



2. **Time of Concentration:** The first step in calculating the peak runoff rate is determining the Time of Concentration. For the Rational Method, the Velocity Method, as described in Section 2B-3, is typically used to calculate T_c.

   The velocity method consists of three components, sheet flow, shallow concentrated flow, and open channel flow.

Table 2B-6.01: Site Conditions for Rational Method Example

Segment	Flow Type	Segment Properties
A-B	Sheet	Dense Grass, Slope = 2.0%, Length = 100’
B-C	Shallow Con. Flow	Grassed Waterway, Slope = 2.0%, Length = 140’
C-D	Pipe Flow	12” RCP, Assume 1/2 pipe flow, Slope = 1.0%, Length = 140’
D-E	Open Channel	Earth channel with short grass, Slope = 2.0%, Length = 275’ Assume a rectangular channel with 6’ bottom and flow depth of 4”

Worksheet 2B-6.01: 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

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

Sheet flow (Applicable to T_c only)

	Segment ID		AB				
1.	Surface description (Table 2B-3.01)		Dense Grass				
2.	Manning's roughness coeff., n (Table 2B-3.01)		0.24				
3.	Flow Length, L (Total 100' max.)	ft	100				
4.	2 year 24 hour rainfall, P_2 (Section 2B-2)	in	3.01				
5.	Land slope, s	ft / ft	0.02				
6.	Travel Time, $T_t = \frac{0.007(nL)^{0.8}}{(\sqrt{P_2})(S)^{0.4}}$, (Eq. 2B-3.03)	hr	0.25	+		=	0.25

Shallow concentrated flow

	Segment ID		BC				
7.	Surface description (Figure 2B-3.01)		Grassed waterway				
8.	Flow length, L	ft	140				
9.	Watercourse slope, s	ft / ft	0.02				
10.	Average velocity, V (Fig. 2B-3.01 or Table 2B-3.02)	ft / s	2.3				
11.	Travel Time, $T_t = \frac{l}{3600V}$, (Eq. 2B-3.01)	hr	0.02	+		=	.02

Open channel / pipe flow

	Segment ID		CD		DE		
12.	Cross sectional flow area, A (Section 2F-2)	ft^2	0.39		2		
13.	Wetted perimeter, P_w (Section 2F-2)	ft	1.57		6.67		
14.	Hydraulic radius, $R = \frac{A}{P_w}$ (Section 2F-2)	ft	0.25		0.30		
15.	Channel slope, s	ft / ft	0.01		0.02		
16.	Manning's roughness coefficient, n		0.013		0.027		
17.	Velocity, $V = \frac{1.49\left(r^{2/3}\right)\left(s^{1/2}\right)}{n}$, (Eq. 2B-3.04)	ft / s	4.55		3.5		
18.	Flow length, L	ft	140		275		
19.	Travel Time, $T_t = \frac{l}{3600V}$, (Eq. 2B-3.01)	hr	0.01	+	0.02	=	0.03
20.	Watershed or subarea T_c or T_t (add T_t in steps 6, 11 and 19)					**hr**	**0.30**

From Worksheet 2B-6.01, the time of concentration is 0.30 hours (18 minutes).

3. **Runoff Coefficient:** The county soil survey indicates the existing soils are Group C. Because this site is being regraded and developed, it is assumed that the resulting soil profile will more closely resemble Group D soils due to compaction during construction.

   Because the drainage area contains multiple surfaces, a composite runoff coefficient must be determined. The values for the Rational coefficient are provided in Table 2B-4.01. A summary of the surface areas and associated Rational coefficients for the site is provided in Table 2B-6.02 below.

   The 5 year composite runoff coefficient (C_5) for the site is calculated by finding the overall average:

$$C_5 = \frac{(27{,}282 \times 0.95) + (22{,}800 \times 0.95) + (36{,}818 \times 0.5)}{87{,}500} = 0.75$$

   The 100 year is found in a similar manner.

Table 2B-6.02: Summary of Surface Areas for Rational Method Example

Proposed Surface	**Area (sf)**	**Rational Coefficient**	
		5 year	***100 year***
Parking Lot and Sidewalk	27,282	0.95	0.98
Building	22,800	0.95	0.98
Lawn (good condition)	36,818	0.50	0.65
Total / Composite	87,500 (2 acres)	0.75	0.83

4. **Peak Runoff:** The Rational method requires three components to calculate peak runoff: runoff coefficient, rainfall intensity, and drainage area. The runoff coefficient was determined in number 3 above and the area was given above as 2 acres. The only missing component is the rainfall intensity (i).

   The rainfall intensity is found in the rainfall depth and intensity tables in Section 2B-2. This site is located in Iowa climactic zone 4 so Table 2B-2.05 is utilized. The time of concentration was calculated as 18 minutes. For design, the T_c is typically rounded down to the next standard duration; in this case is 15 minutes. From Table 2B-2.05, the 5 year and 100 year intensities for a 15 minute T_c are 3.96 and 7.46 inches/hour respectively.

   The peak runoff rate is determined from Equation 2B-4.01 as follows:

   $Q_5 = 0.75 \times 3.96 \times 2.0 =$ 5.9 cfs

   $Q_{100} = 0.83 \times 7.46 \times 2.0 =$ 12.4 cfs

B. SCS Method Example

1. **Problem Statement:** A watershed covers 180 acres in Carroll County, Iowa. The current land use is agricultural with 60 acres in pasture and 120 acres in active corn and soybean production (row crops). The cultivated portion has been contoured and terraced and is farmed utilizing no-till farming practices (crop residue). The entire watershed is in good hydrologic condition and the county soil survey indicates that this area contains group B soils.

   A new, 60 acre development near the upstream end of this watershed is being considered for construction of single family one-acre lots. This development is being proposed in the cultivated portion of the watershed. It is estimated that the development will contain approximately 35% impervious area (streets, driveways, homes, outbuildings, etc.)

   Determine the peak runoff rates for the watershed before and after development.

2. **Curve Number:** The first step is to determine the existing and proposed curve number (CN) for the watershed. CN values are provided in Tables 2B-4.03 through 2B-4.05. The value for row crops, contoured and terraced with crop residue is 70 for a good hydrologic soil condition and soil group B (from Table 2B-4.04). For pasture, the value is 61 (Table 2B-4.05).

   The value for the proposed developed condition must also be obtained. The original land was assessed as a group B soil; however, given the compaction that occurs as a result of mass grading and construction, it is likely that the soil condition will be reduced to a Group C or D soil. A Group C soil is assumed for this example. Table 2B-4.03 includes CN values for 1 acre residential lots; however, these values assume and impervious area of 20%. The assumed impervious are of this development 35% as stated above. Therefore the impervious and pervious (lawn) areas will be assessed separately.

   A composite CN must be determined to represent the average CN of the entire watershed. This is done by determining a weighted average, based upon ground area. This is shown in Worksheets 2B-6.02 and 2B-6.03.

3. **Time of Concentration:** The time of concentration may be determined with either the Velocity or Lag methods. In this example the Lag method, as described in Section 2B-3, will be used.

   Assume the watershed has a flow length of 4,700 feet and an average land slope of 8.0 percent. The example calculation for T_c is shown in Worksheets 2B-6.02 and 2B-6.03.

   For the developed example in Worksheet 2B-6.03, an adjustment for urbanization was applied. This process is necessary when utilizing the lag method in developed areas.

4. **Runoff:** The total runoff, in inches, from the watershed and the peak rate of runoff is then determined as shown in the worksheets below.

Worksheet 2B-6.02: Runoff Curve Number and Runoff - *Existing Conditions*

Project: SCS Example – Existing Conditions	By	Date
Location: Carroll County, Iowa	Checked	Date
Check one: ☑ Present ☐ Developed		

1. Runoff Curve Number

Soil name & hydrologic group (County soil survey)	Cover Description (cover type, treatment and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN[1] Tables 2B-4.03, 4.04, & 4.05	CN[1] Figure 2B-4.01	CN[1] Figure 2B-4.02	Area ☑ac ☐mi² ☐%	CN x Area
Marshall, B	Row crops with contouring, terracing, and crop residue.	70			120	8,400
Marshall, B	Pasture, continuous forage	61			60	3,660
				Totals ➡	180	12,060

[1]Use only one CN source per line

CN (weighted) = $\frac{Total\ product}{total\ area} = \frac{12060}{180} = 67$ Use CN ➡ 67

Potential max. retention, S = $\frac{1000}{67} - 10 = 4.9$ (Eq. 2B-4.07) S ➡ 4.9

2. Time of Concentration

Watershed Lag, L = $\frac{4700^{0.8}(4.9+1)^{0.7}}{1900(8.0)^{0.5}} = 0.56$ (Eq. 2B-3.05)

$T_c = \frac{0.56}{0.6} = 0.93$ hr (Eq. 2B-3.05) T_c ➡ 0.93

3. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	5	100	
Rainfall, P (24-hour) ('D' from tables in Section 2B-2)......	in	3.74	7.67	
Runoff, Q = $\frac{(P-0.2S)^2}{(P+0.8S)}$ (Eq. 2B-4.06)............	in	1.0	3.8	

4. Peak Runoff Rate

		Storm #1	Storm #2	Storm #3
Ratio of Initial abstraction to Rainfall $\frac{I_a}{P} = \frac{0.2\times S}{P}$		0.26	0.13	
Coef. for Peak Discharge (Table 2B-4.06 - interpolated)	C_0	2.48290	2.54004	
	C_1	-0.62108	-0.62630	
	C_2	-0.12606	-0.15691	
Unit peak runoff, q_u (Eq. 2B-4.09)	ft³/s/mi²	318	363	
Peak Runoff $q_p = q_u \times \frac{Area(ac)}{640\ ^{ac}/_{mi^2}} \times Q \times F_p$ (Eq. 2B-4.08)	cfs	**89**	**388**	

Worksheet 2B-6.03: Runoff Curve Number and Runoff - *Proposed Conditions*

Project: SCS Example – Existing Conditions	By	Date
Location: Carroll County	Checked	Date
Check one: ☐ Present ☑ Developed		

1. Runoff Curve Number

Soil name & hydrologic group (County soil survey)	Cover Description (cover type, treatment and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN[1] Tables 2B-4.03, 4.04, & 4.05	CN[1] Figure 2B-4.01	CN[1] Figure 2B-4.02	Area ☑ac ☐mi² ☐%	CN x Area
Marshall, B	Row crops with contouring, terracing, and crop residue.	70			40	2,800
Marshall, B	Pasture, continuous forage	61			60	3,660
Marshall, C	Open space, lawn in good condition	74			52	3,848
Marshall, C	Impervious area (streets, roofs, etc).	98			28	2,744
				Totals ➡	180	13,052

[1]Use only one CN source per line

CN (weighted) = $\frac{Total\ product}{total\ area} = \frac{13052}{180} = 73$ Use CN ➡ 73

Potential max. retention, S = $\frac{1000}{73} - 10 = 3.7$ (Eq. 2B-4.07) S ➡ 3.7

2. Time of Concentration

Watershed Lag, L = $\frac{4700^{0.8}(3.7+1)^{0.7}}{1900(8.0)^{0.5}} = 0.48$ (Eq. 2B-3.05)

$T_c = \frac{0.48}{0.6} = 0.80$ hr (Eq. 2B-3.05)

For lag method, adjust for urbanization: % impervious = 28 ac / 180 ac = 16%
From Figure 2B-3.03, Imp. Factor = 0.9. No channel improvements assumed.
$T'_c = 0.80 \times 1.0 \times 0.9 = 0.72$ (Eq. 2B-3.07) T_c ➡ 0.72

3. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	5	100	
Rainfall, P (24-hour) ('D' from tables in Section 2B-2)	in	3.74	7.67	
Runoff, $Q = \frac{(P-0.2S)^2}{(P+0.8S)}$ (Eq. 2B-4.06)	in	1.3	4.5	

4. Peak Runoff Rate

		Storm #1	Storm #2	Storm #3
Ratio of Initial abstraction to Rainfall $\frac{I_a}{P} = \frac{0.2\times S}{P}$		0.20	0.10	
Coef. for Peak Discharge (Table 2B-4.06 - interpolated)	C_0	2.50928	2.55323	
	C_1	-0.61885	-0.61512	
	C_2	-0.1403	-0.16403	
Unit peak runoff, q_u (Eq. 2B-4.09)	ft³/s/mi²	390	438	
Peak Runoff $q_p = q_u \times \frac{Area(ac)}{640\ ^{ac}/_{mi^2}} \times Q \times F_p$ (Eq. 2B-4.08)	cfs	**143**	**554**	