Factors Controlling Erosion

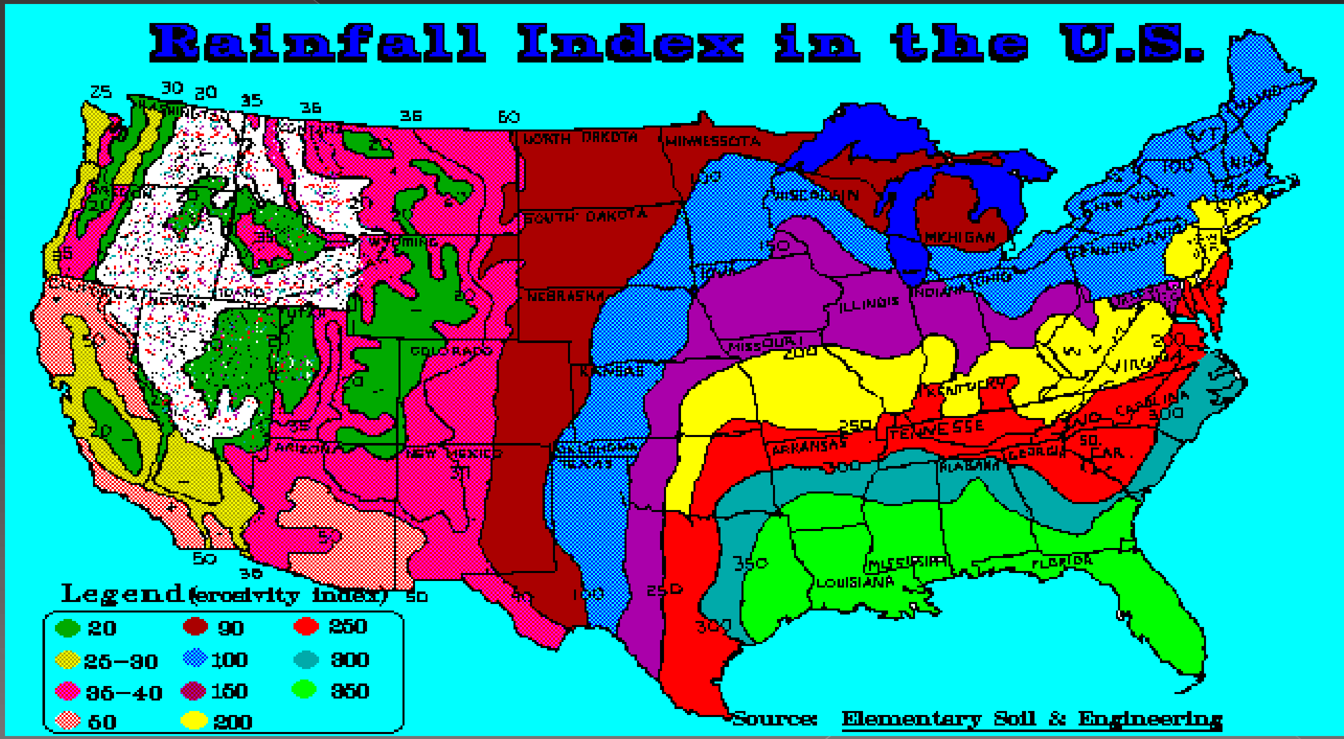
- Precipitation
- Surface Cover
- Topography
- Soil Properties

Rainfall Erosivity

- Intrinsic capacity of rainfall to cause erosion
- Influenced by
  - Amount, intensity, terminal velocity, drop size and drop size distribution of rain.
- High rainfall amounts do not always equate to high erosion rates.

Rainfall Erosivity

- Uniform distribution of rainfall will result in less runoff than seasonal distribution of rain.



Kinetic Energy (E)

$E=1/2mv^2$

m=mass, v= velocity

- Given a terminal velocity of a raindrop is 8 m s^{-1}
- Kinetic energy of a rain storm
- (½)m*64 = 32*m
- Increase velocity to 10 m $s^{-1}$with wind and E increases to 50*m

Runoff

- Runoff occurs only after water:
  - Is adsorbed by the soil
  - Fills up the soil pores and surface depressions
  - Accumulates on the soil surface to a given depth (dictated by slope)
- Generally, runoff represents a small fraction of total rainfall

Runoff

- There are a lot of factors working against the production of runoff
  - Runoff Inputs=rain, irrigation, snowmelt
  - Runoff outputs=infiltration, evaporation, canopy interception, transpiration, surface retention
- These are some of the factors that we will seek to influence when controlling erosion

Runoff Erosivity

- Kinetic energy of runoff is much lower than rainfall primarily because its velocity is so low
- Mass is also generally much lower
- Assume that 25% of rainfall is runoff and that runoff velocity is 1 m s^{-1}
- Runoff energy $=0.25(½)m(1)^2 = 0.125m$
- Recall rainfall energy = 32m

Estimating Runoff

- Useful when:
- Designing mechanical erosion control structures
  - Ponds, terraces, waterways, vegetative filters, etc.
- Estimating the probable amount of sediment and chemicals transported

Estimating Runoff

- Factors to consider
  - Vegetative cover
    - Influences interception
  - Topography
    - Slope, slope length, and shape
  - Soil surface condition
    - Surface roughness, crusting
  - Soil texture
    - Infiltration rate

Time of Concentration

- Tc is the time it takes for runoff to travel from the most distant point of the watershed to the outlet
- Influences the peak discharge
- The shorter the Tc the larger the peak discharge

Peak Discharge

- Important in the design of erosion control structures
  - Terraces, grass water ways, etc.
- Rational equation is a simple equation for determining peak discharge
- Only useful for watersheds that are 200 acres or smaller in size

$$q = CIA$$

  - q= peak runoff rate (ft^3/s or m^3/s)
  - C=Runoff coefficient dimensionless
  - I=rainfall intensity
  - A=drainage area (ft^2, or m^2)

Runoff Coefficients for Rational Method

	Runoff Coefficient, C					
	Soil Group A			Soil Group B		
Slope:	< 2%	2-6%	> 6%	< 2%	2-6%	> 6%
Forest	0.08	0.11	0.14	0.10	0.14	0.18
Meadow	0.14	0.22	0.30	0.20	0.28	0.37
Pasture	0.15	0.25	0.37	0.23	0.34	0.45
Farmland	0.14	0.18	0.22	0.16	0.21	0.28
Res. 1 acre	0.22	0.26	0.29	0.24	0.28	0.34
Res. 1/2 acre	0.25	0.29	0.32	0.28	0.32	0.36
Res. 1/3 acre	0.28	0.32	0.35	0.30	0.35	0.39
Res. 1/4 acre	0.30	0.34	0.37	0.33	0.37	0.42
Res. 1/8 acre	0.33	0.37	0.40	0.35	0.39	0.44
Industrial	0.85	0.85	0.86	0.85	0.86	0.86
Commercial	0.88	0.88	0.89	0.89	0.89	0.89
Streets: ROW	0.76	0.77	0.79	0.80	0.82	0.84
Parking	0.95	0.96	0.97	0.95	0.96	0.97
Disturbed Area	0.65	0.67	0.69	0.66	0.68	0.70

Rational Method Runoff Coefficients - Part I

	Runoff Coefficient, C					
	Soil Group C			Soil Group D		
Slope:	< 2%	2-6%	> 6%	< 2%	2-6%	> 6%
Forest	0.12	0.16	0.20	0.15	0.20	0.25
Meadow	0.26	0.35	0.44	0.30	0.40	0.50
Pasture	0.30	0.42	0.52	0.37	0.50	0.62
Farmland	0.20	0.25	0.34	0.24	0.29	0.41
Res. 1 acre	0.28	0.32	0.40	0.31	0.35	0.46
Res. 1/2 acre	0.31	0.35	0.42	0.34	0.38	0.46
Res. 1/3 acre	0.33	0.38	0.45	0.36	0.40	0.50
Res. 1/4 acre	0.36	0.40	0.47	0.38	0.42	0.52
Res. 1/8 acre	0.38	0.42	0.49	0.41	0.45	0.54
Industrial	0.86	0.86	0.87	0.86	0.86	0.88
Commercial	0.89	0.89	0.90	0.89	0.89	0.90
Streets: ROW	0.84	0.85	0.89	0.89	0.91	0.95
Parking	0.95	0.96	0.97	0.95	0.96	0.97
Disturbed Area	0.68	0.70	0.72	0.69	0.72	0.75

Rational Method Runoff Coefficients - Part II

Hydrologic Soil Groups

A	Low runoff potential Sands, loamy sands, or sandy loams Infiltration rates >0.3 inches/hr
B	Moderately low runoff potential Silt loams and loams Infiltration rate between 0.15 and 0.3 inches/hr
C	Moderately high runoff potential Sandy Clay loams infiltration rate between 0.05-0.15 inches/hr
D	High runoff potential Clay loams, silty clay loams, sandy clays, silty clays, or clays infiltration rates between 0-0.05 inches/hr

Hydrologic Soil Groups

- Other soil variable that influence hydrologic soil groups
  - Depth to water table
  - Depth to clay pan
  - Depth to bed rock
  - Soil structure
  - Shrink-swell capacity

Modified Rational Equation

- Provides peak runoff estimates for larger watersheds, or for rain events that are shorter than time of concentration.

$$q = \frac{C(R_{tc})A}{Tc}$$

  - q= peak runoff rate (ft^3/s or m^3/s)
  - C=Runoff coefficient dimensionless
  - R_{tc}=depth of rain occurring prior to Tc (ft or m)
  - A=drainage area (ft^2, or m^2)
  - T_C=Time of Concentration

$q = CIA$

Using Curve Numbers (CN) to Estimate Runoff

- Simple calculation that can be used to estimate runoff

$$Q = \frac{(R-0.2S)^2}{(R+0.8S)}$$

- Q= Depth of runoff(mm, inches)
- R=Rainfall (mm, inches)
- S=Retention Parameter (mm, inches)
  - S accounts for losses of water before runoff begins, such as water retained in depressions, water intercepted by vegetation, and water lost to evaporation and infiltration.

Using Curve Numbers (CN) to Estimate Runoff

- Curve numbers (CN) are used to estimate S
- Curve numbers are influenced by hydrologic soil group, land use, soil management, cropping system, conservation practices and antecedent water content.

$$S = \frac{25400}{CN} - 254$$

Equation use for mm of rainfall

$$S = \frac{1000}{CN} - 10$$

Equation use for inches of rainfall

CN Table for Cropland

Cover description			Curve numbers for hydrologic soil group—			
Cover type	Treatment[2]	Hydrologic condition[3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row + CR	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured + CR	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

[1] Average runoff condition.
[2] *Crop residue cover (CR)* applies only if residue is on at least 5% of the surface throughout the year.
[3] Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good ⩾ 20%), and (e) degree of surface roughness.
Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

CN Table for Other Ag Lands

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	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

[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% ground cover.
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.

CN Tables for Urban Lands

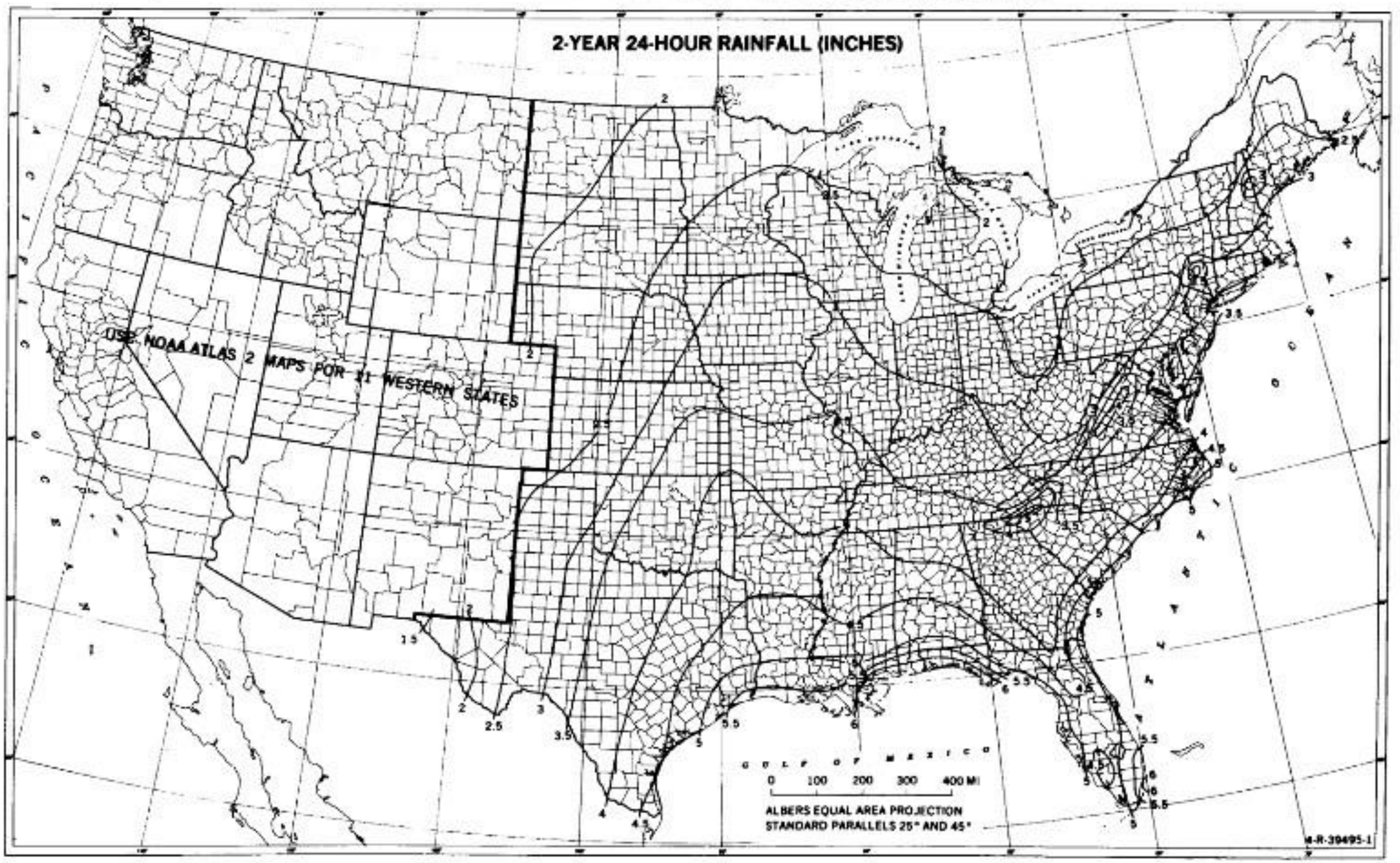
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
		Curve numbers for hydrologic soil group—			
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair 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
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
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)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2a).					

Cover description

[1] Average runoff condition.
[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.
[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4] Composite CN's for natural desert landscaping should be computed based on the impervious area (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Rainfall from a 2 year 24 hour rain event

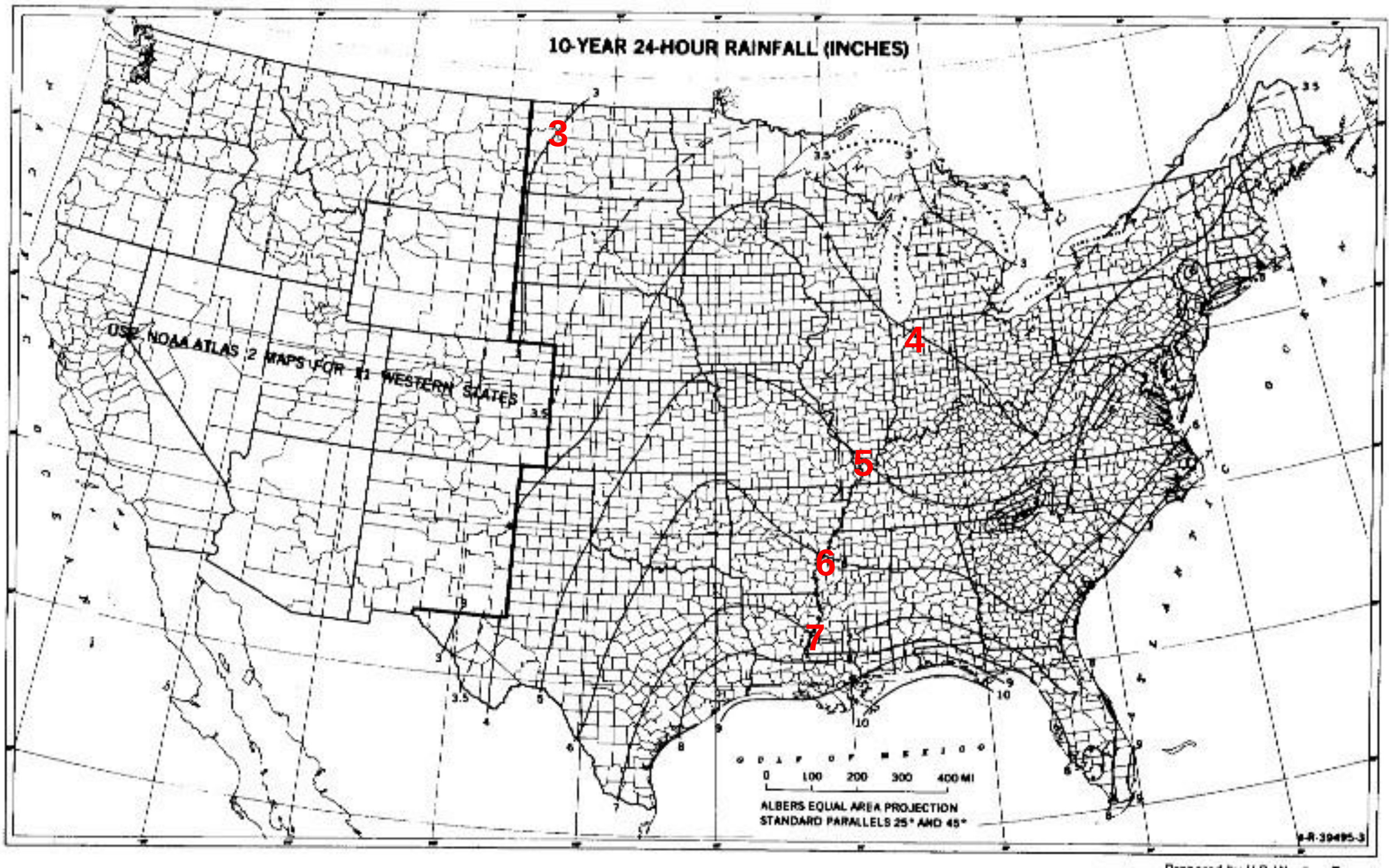
Figure 2-2 —**Precipitation values for the Eastern United States—2-year 24-hour rainfall (inches)**



Prepared by U.S. Weather Bureau

Rainfall from a 10-year 24 hour rain event

Figure 2-4 —**Precipitation values for the Eastern United States—10-year 24-hour rainfall (inches)**



How much runoff would a 10 year storm produce on Cropland

- Use the CN Calculations for estimate

$$Q = \frac{(R-0.2S)^2}{(R+0.8S)}$$

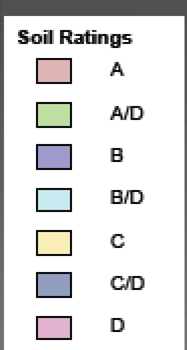
$$S = \frac{1000}{CN} - 10$$

Equation use for inches of rainfall

- Payne county 10-year storm produces 4.5 inches in 24 hours
  - R=4.5inches

Map of Field West of town showing Hydrologic Groups

- 55% of field is Group B
- 45% is Group D



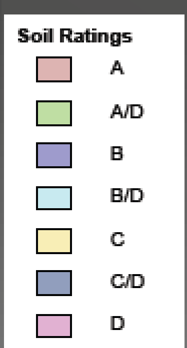
Calculating the Average CN

Cover description			Curve numbers for hydrologic soil group—			
Cover type	Treatment²	Hydrologic condition³	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row + CR	Poor	64	75	83	86
		Good	60	72	80	84

- Straight row wheat with poor hydrologic condition
  - Group B=76, Group D= 88

Map of Field West of town showing Hydrologic Groups

- Group B portion of CN=0.55*76=41.8
- Group D portion of CN=0.45*88=39.6
- Add these portions together to get average CN of 81.4



Back to Calculation

$$S = \frac{1000}{CN} - 10$$

$$Q = \frac{(R-0.2S)^2}{(R+0.8S)}$$

Equation use for inches of rainfall

- Payne county 10-year storm produces 4.5 inches in 24 hours
  - R=4.5inches
- CN=81.4

$$S = \frac{1000}{81.4} - 10 = 2.28$$

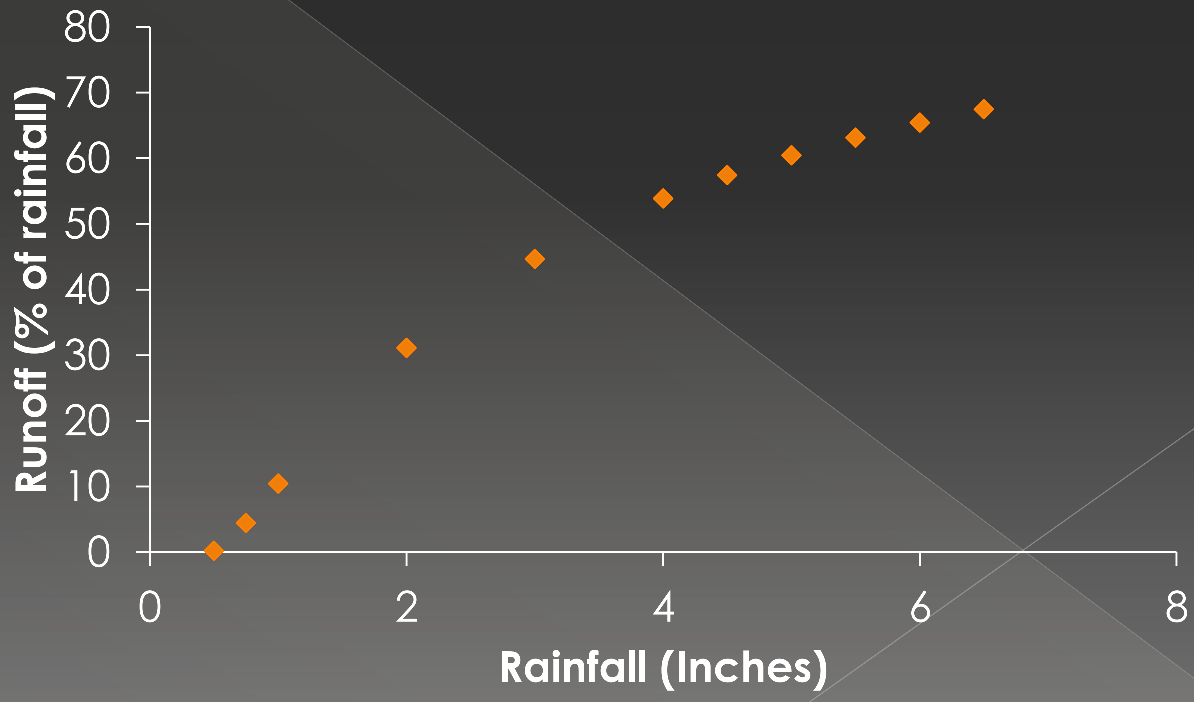
$$Q = \frac{(4.5-0.2*2.28)^2}{(4.5+0.8*2.28)} = 2.6 \text{ inches}$$

Equation use for inches of rainfall

- Runoff(Q) = 57% of rainfall
  - High due to permeability of soil and cultivation and quantity of rainfall

Relationship between Rainfall and Runoff from CN Estimates

- Runoff as a % of rainfall increases with the quantity of rainfall



Relative Energy of rainfall and runoff

- 4.5 inches of rainfall at 8 m/s
  - Equivalent to 462555 L/acre(kg /acre)
- VS. 2.60 inches of runoff moving at 1 m/s
  - 267254 L/acre (kg /acre)

Rainfall

$E=1/2mv^2=1/2*462555*(8)^2=15$ MJ/acre

Runoff

$E=1/2mv^2=1/2*267254*(1)^2=0.134$ MJ/acre