Pennsylvania
Boot Camp – Basic

Hydrology I

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PA Basic Boot Camp Hydrology Lesson Objectives:

- Understand the basics of Hydrology
  - Understand runoff volume & rate for a watershed
- Understand watershed characteristics that affect hydrology
- Be introduced to the EFH-2 program, and other NRCS methods and sources of data

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What is Hydrology?

The science that deals with the occurrence and behavior of water in the atmosphere, on the ground, and underground.

NEH, Part 630 - Hydrology, Chapter 22 - Glossary

In the broadest sense, hydrology deals with the computation of how much water we could expect.

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What is Hydrology?

The study and characterization of water generated in a system

Characterization can include:

- Quantity
- Quality
- Flow rate

For:

- Surface Waters
- Ground Water

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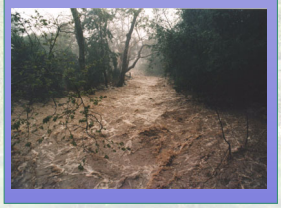
What Hydrology is Not

Study of Weather, *Weather Forecasting*

- Meteorology

Study of Water Flow, Depths, Velocity, etc.

- Hydraulics



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Conservation Practices Requiring Hydrology Calculations

- Waterways
- Diversions & Terraces
- Structures for water control
- Stream Crossing
- Ponds/Wetlands
- Dams/Levees

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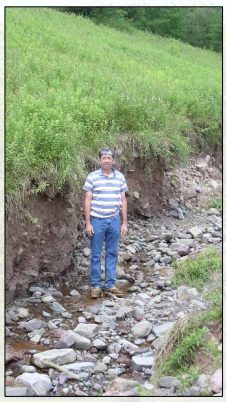

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Types of Hydrology

- **Surface Water Hydrology and Groundwater Hydrology**

We're focusing on surface water hydrology!

- The Prediction of Flow Volumes
- Prediction of Flow Rates at a Given Point of Interest
- Prediction of Timing of the Flow

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Hydrology is Measured As

- **Runoff, V**
  - Surface runoff is the volume of excess water that runs off your drainage area minus losses/abstractions.
  - Acre-inches of runoff
    - May be converted to gallons, cubic feet, etc.
- **Discharge, Q**
  - Peak discharge is the peak rate of runoff from a drainage area for a given rainfall.
  - cubic feet per second

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Factors Affecting Surface Runoff

- Rainfall
- Watershed Size
- Topography
- Hydrologic soil group
- Cover type
- Treatments
- Hydrologic conditions

} Runoff Curve Number

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Factors Affecting Surface Runoff

- **Rainfall**
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} Runoff Curve Number

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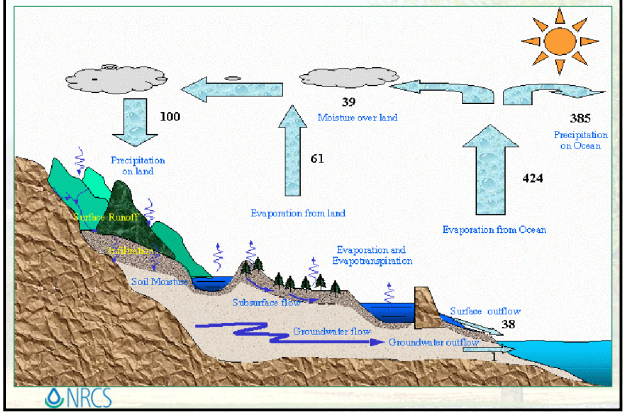
The Hydrologic Cycle



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Precipitation

- Rainfall, Snow, Hail, Sleet
- Measured in Inches

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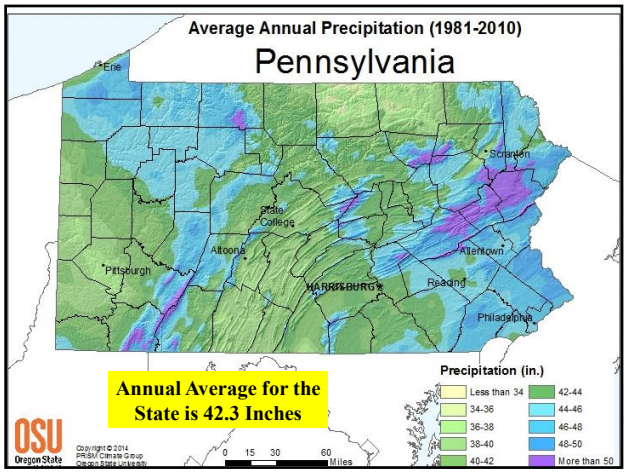

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Hydrology Related Terms

Storm Rainfall Data

Rainfall amounts measured at rain gages, published, and statistically analyzed by NWS.

NEH Part 630, Chapter 4

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Rainfall Events Data Sources

- Information for the US available from:

http://www.nws.noaa.gov/oh/hdsc/studies/prcpfreq.html

- Data for western US from Western Region Climate Center:

http://www.wrcc.dri.edu/CLIMATEDATA.html

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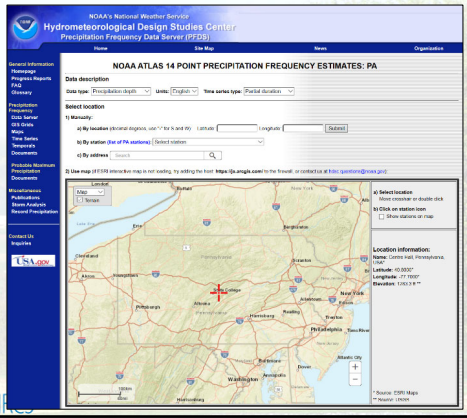
NOAA Atlas 14 Interactive Website Site



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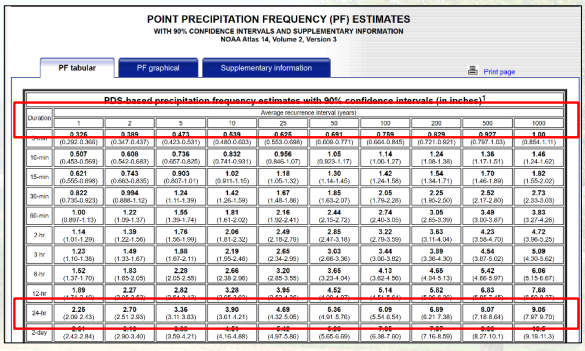
NOAA Atlas 14 Interactive Website Site

https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=pa



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Hydrology Related Terms

Rainfall Depth
Average depth of storm rainfall over the watershed area for a specified storm duration.
NEH Part 630, Chapter 4


Photo courtesy of USDA-NRCS

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Hydrology Related Terms

Rainfall Return Period
The average time interval between rainfall events with a given or greater magnitude.

Described as 2 year, 5 year, 10 year, etc. events

100 - Year Event
An event which has a 1 percent chance of occurrence IN ANY YEAR; NOT ONE event every 100 years.
http://www.srh.noaa.gov/lub/climate/precip-atlas/index.htm

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Hydrology Related Terms

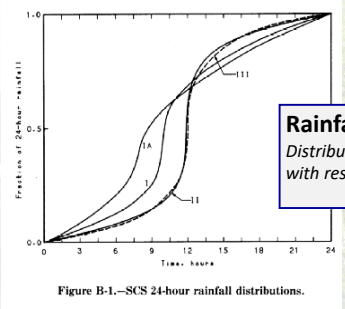

Figure B-1.—SCS 24-hour rainfall distributions.

Rainfall Distribution
Distribution of rainfall with respect to time.
210-VI-TR-55, 2nd ed. June 1986

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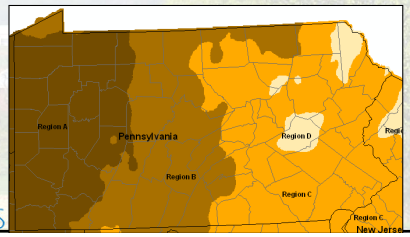
Rainfall Distributions

- Four types of rainfall distributions were developed to cover regional variations in rainfall intensities during storm events across Pennsylvania



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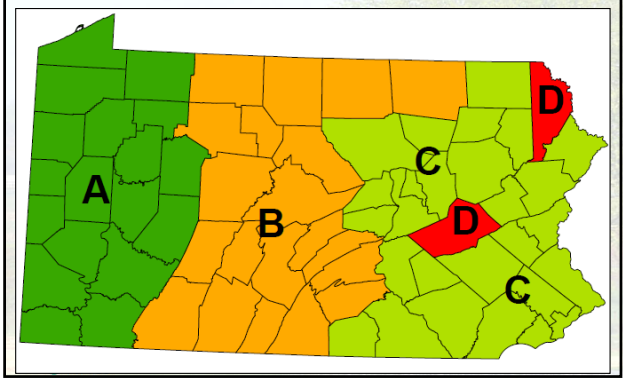
Regional Distribution Types



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Rainfall Frequency Depths

	C	A
Design Storm	Dauphin Co., PA 24-Hr Rainfall (in)	Erie Co., PA 24-Hr Rainfall (in)
2-year	3.1	2.6
10-year	4.6	3.7
25-year	5.6	4.5

- Rainfall frequency amounts differ by county
- Available automatically in EFH-2

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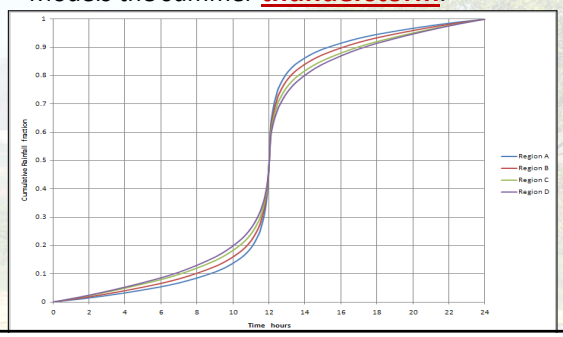
Rainfall Intensity

- Models the summer **thunderstorm**.



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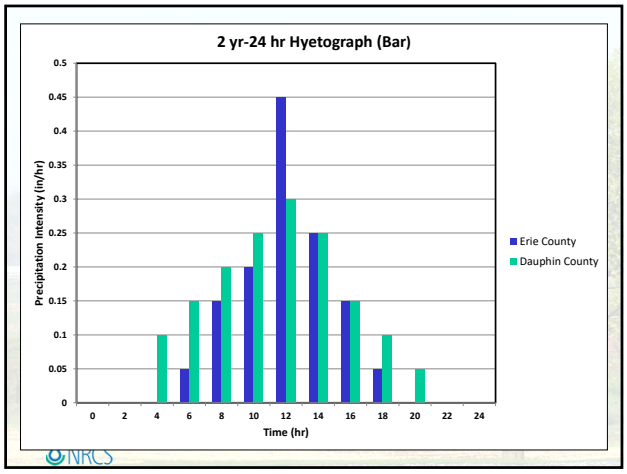

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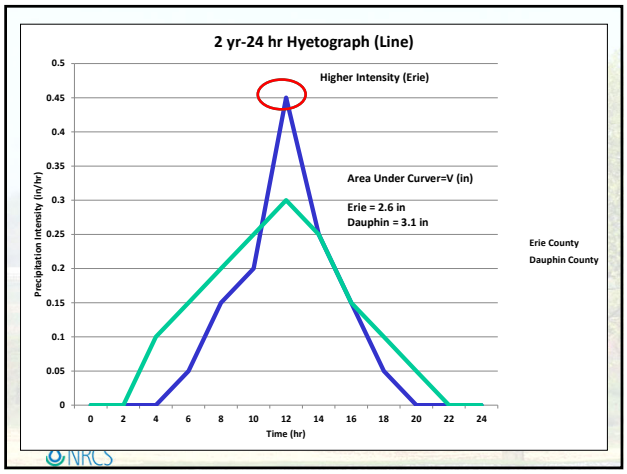

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Factors Affecting Surface Runoff

- Rainfall
- **Watershed Size**
- Topography
- Hydrologic soil group
- Cover type
- Treatments
- Hydrologic conditions

} Runoff Curve Number

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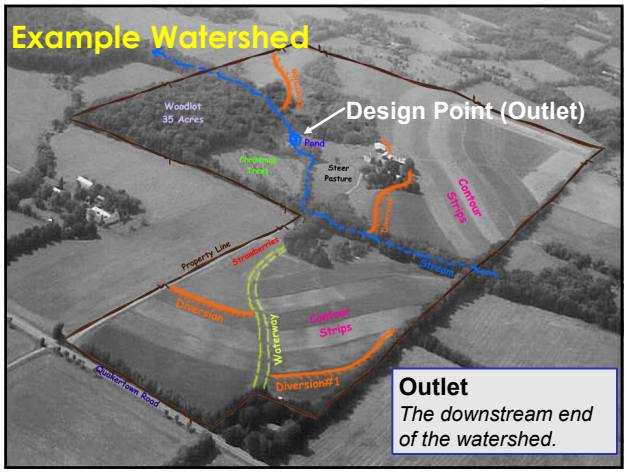
Example Watershed



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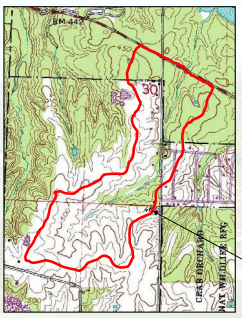
Hydrology Terms



The area contributing direct runoff to a stream is called the "*watershed*" or "*drainage area*".

NEH Part 630, Chapter 22

Watershed Boundary

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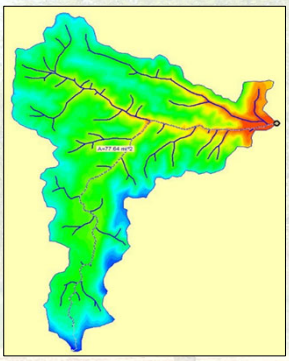
Hydrology Terms

- Watershed Boundary
  - the outline of the watershed on a map or the divide between watersheds
- Boundary defines the area water cannot escape except at the point of concentration/point of outflow.
- We determine the watershed from a Topographic Map



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What is a topo map?

- They render the three-dimensional ups and downs of the terrain on a *two-dimensional surface*.

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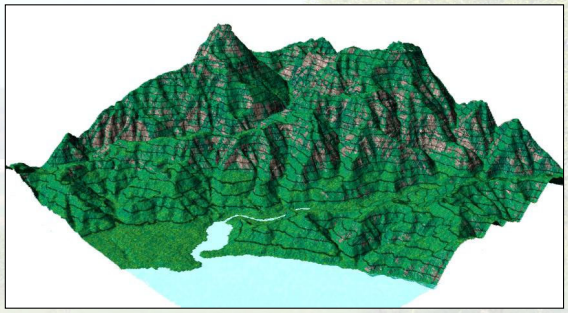
What is a topo map?



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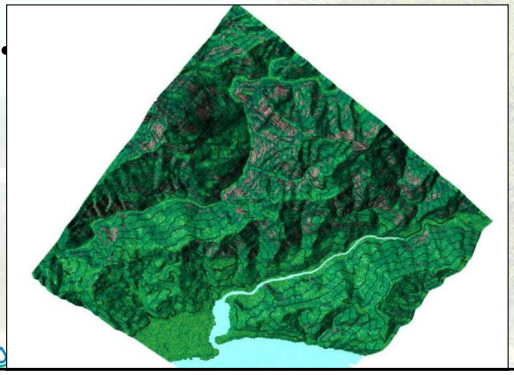
What is a topo map?



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What is a topo map?

- They render the three-dimensional ups and downs of the terrain on a *two-dimensional surface*.
- **Topo Maps usually show:**
  - Both natural and manmade features.
  - Works of nature including mountains, valleys, plains, lakes, rivers, and vegetation.
  - Principal works of man, such as roads, boundaries, transmission lines, and major buildings

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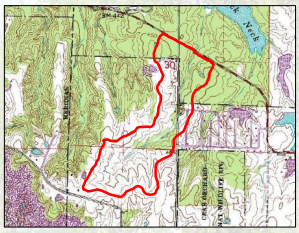
Hydrology Terms

- Contours
  - Represent lines of **equal** elevation
  - Reference to height above sea level
  - Interval is always constant.
- Shape of contours determines:
  - Slope
  - Flow paths
  - Hydraulic travel time through watershed



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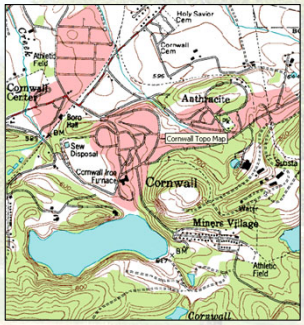
Interpreting Topographic Maps – Colors

- Brown – Contours
- Blue – Water
- Green – Forests
- Pink – Urban Areas
- Black – Cultural
- Black/Red – Roads
- Purple – Photo-revisions



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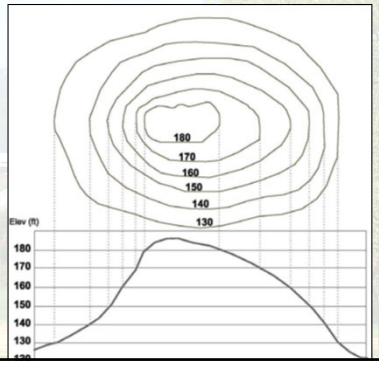
Interpreting Topographic Maps – Contours



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Interpreting Topographic Maps – Contours

- Closer Contours = Steeper Site
- Further Apart Contours = Flatter Site

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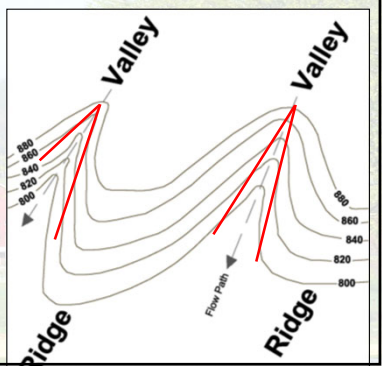
Interpreting Topographic Maps – Contours – Features

- Looking Uphill
  - Ridges – "U"
  - Valley/Gully – upside-down "V"



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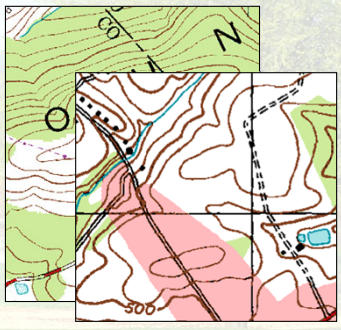
Interpreting Topographic Maps – Contours – Features

- Peaks
- Saldles



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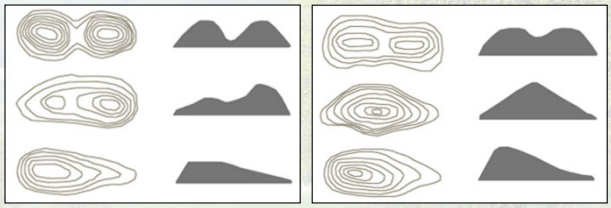
Interpreting Topographic Maps – More Features



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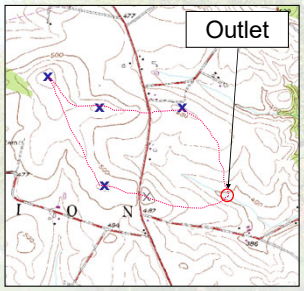
Delineating a Watershed

1. Draw an "O" at the outlet
2. Mark high points along both sides of watercourse with an "X".
3. Starting at "O", **connect** "X's on right to highest point.
   1. Cross contours on perpendicular
   2. **DO NOT CROSS BLUE LINES!!!**
   3. Do not cross the same contour line more than once.
4. Repeat for "X's on left



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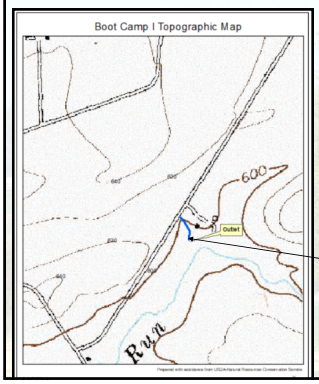
Delineating a Watershed – Your Turn



- Delineate the waterway's watershed

Outlet

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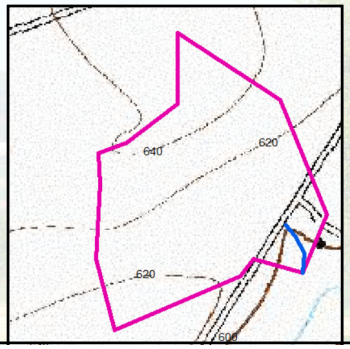
Delineating a Watershed – Your Turn



- Watershed delineation

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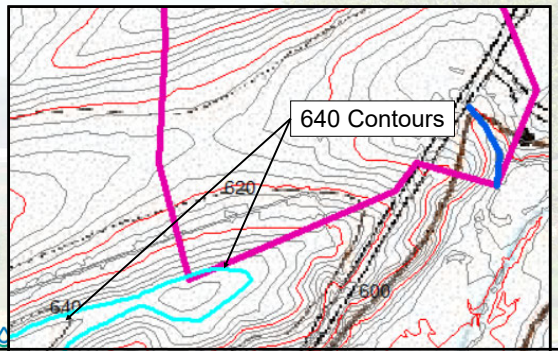
Delineating a Watershed – Your Turn

THE REST OF THE STORY…



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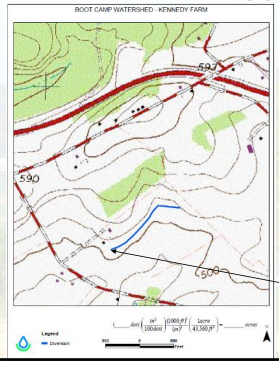
Delineating a Watershed – Your Turn



- Delineate the watershed for the outlet of the diversion.

Outlet

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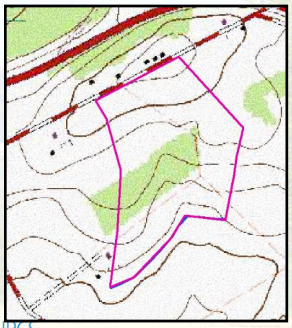
Delineating a Watershed – Your Turn



- Watershed delineation

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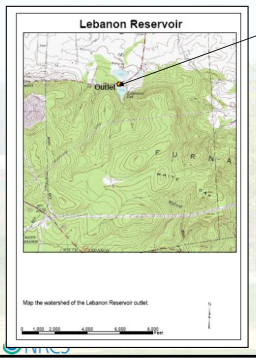
Delineating a Watershed – Your Turn



Outlet

- Delineate the watershed for the outlet of the Lebanon Reservoir

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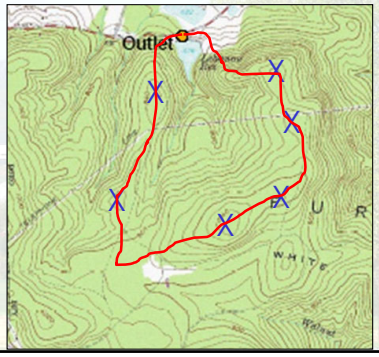
Delineating a Watershed – Your Turn



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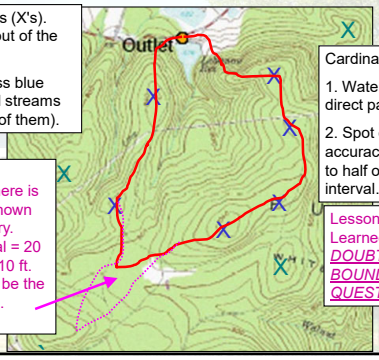
Delineating a Watershed – Your Turn

THE REST OF THE STORY…

More high spots (X's). Are they in or out of the watershed?

Hint: Don't cross blue lines, perennial streams (or extensions of them).

Tricky – but it's possible that there is more DA, as shown by this boundary. Contour interval = 20 ft, accuracy to 10 ft. One foot could be the difference here.



Cardinal Rules:

1. Water flows most direct path down.

2. Spot elevation accuracy on map equal to half of contour interval.

Lesson To Be Learned: *WHEN IN DOUBT - WALK THE BOUNDARY IN QUESTION.*

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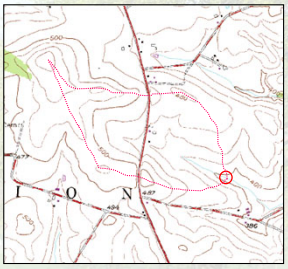
Delineating a Watershed – Determining Acreage

- Dot Counter
- Planimeter
- Conservation Desktop
- ArcGIS Tools



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Factors Affecting Surface Runoff

- Rainfall
- Watershed Size
- **Topography**
- Hydrologic soil group
- Cover type
- Treatments
- Hydrologic conditions

} Curve Number

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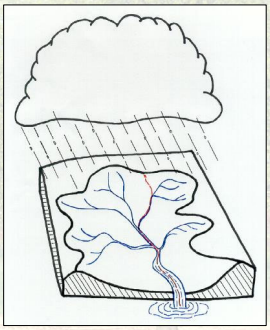
Topography is best defined by the slopes and flow length in the watershed…

- Topography controls **where** and **how fast** the water flows.
- As slopes increases,
  - Discharge rate ⇧
- As flow length increases,
  - Discharge rate ⇩



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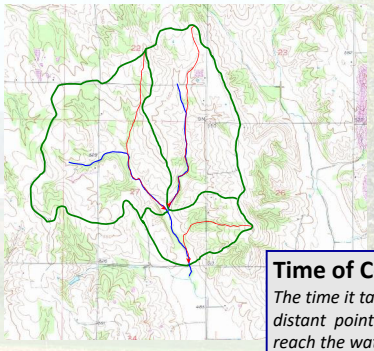
Hydrology Related Terms



Time of Concentration (Tc)

The time it takes water from most distant point (hydraulically) to reach the watershed outlet.

NEH Part 630, Chapter 15

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Time of Concentration

- The time it takes water from the most distant point (hydraulically) to reach the watershed **outlet**.
  - Example – Rush Hour Traffic
- Based on Flow Length, Slope, and Curve Number

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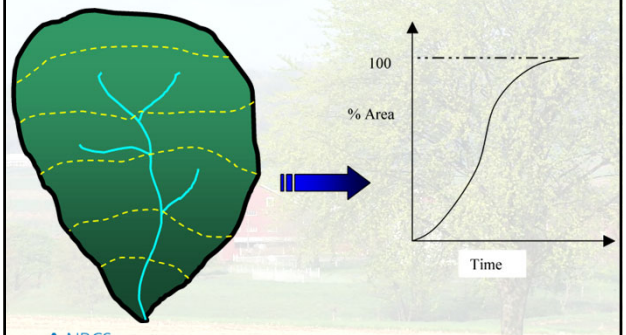
Time of Concentration



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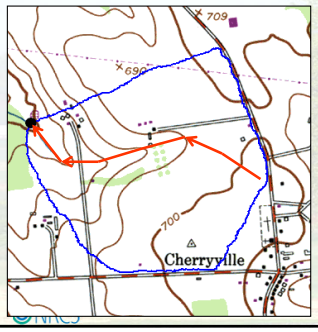
Watershed Length



- Longest flow path through the watershed
- The longer the length, the **smaller** the peak flow that occurs, relative to the watershed size.
- Example
  - Length = 3900 ft

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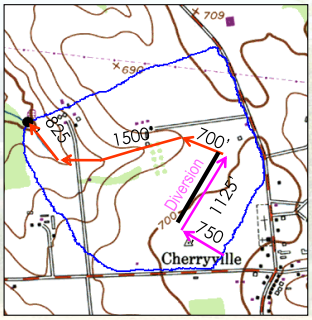
Watershed Length with Conservation



- Increase length by adding certain conservation practices
  - Diversion Length = 750' + 1125' = 1875'
  - Total Watershed Length = 1875'+700'+1500'+825' = 4900'
  - 1000' INCREASE!

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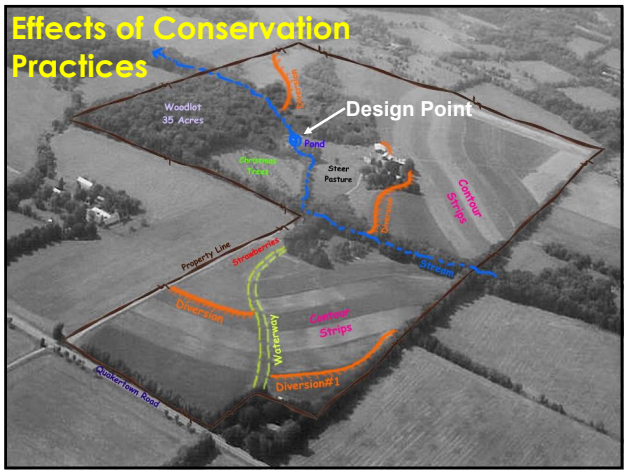
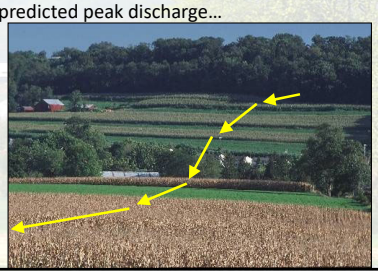
Effects of Conservation Practices



75

Time of Concentration – Slope

- Average land slope of the **uplands** above the stream.
  - Generally, the steeper the watershed slope, the greater the predicted peak discharge…



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Average Watershed Slope

- Best determined from the hillside slopes that drain to the stream.
- **It is NOT the Slope of the streambed!**
  - It is not the total **elevation** change divided by the flow length.

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Factors Affecting Surface Runoff

- Rainfall
- Watershed Size
- Topography
- **Hydrologic soil group**
- **Cover type**
- **Treatments**
- **Hydrologic conditions**

} Curve Number

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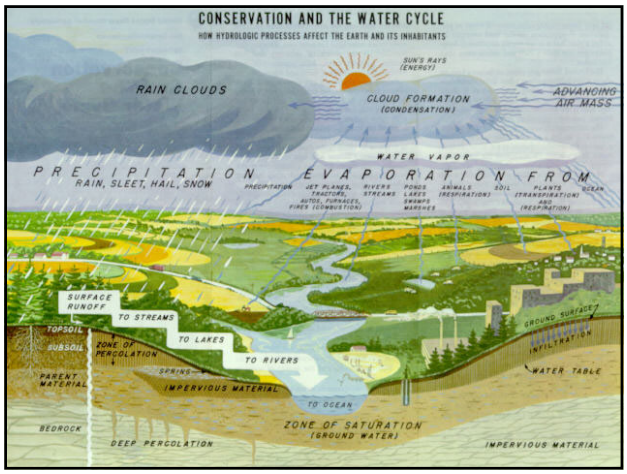

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Runoff Curve Numbers

- An index of the amount of runoff from a watershed
- Any value from 0 to 100
  - Practical applications are limited to a range of 40-98
- The higher the CN, the higher the runoff
  - CN of 100 would equal TOTAL RUNOFF
  - CN **IS NOT** % of rainfall that **becomes** runoff

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Runoff Curve Numbers

- **Hydrologic Soil Group**
  - A group of soils having the same runoff potential
- **Land Cover**
- **Land Treatment**
  - Hydrologic Condition

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Hydrologic Soil Group

- Groups of A, B, C, or D
  - from low to **high** runoff potential
- Based on rate of infiltration for bare soil after prolonged wetting
- A group of soils having the same runoff potential under similar storm and cover conditions
- May have dual classification
  - Example: A/D, B/D, or C/D (the first letter is for drained areas and second is for undrained areas)

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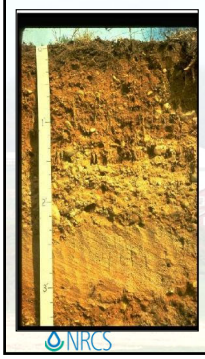
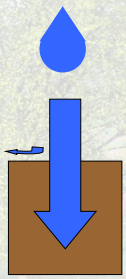
Hydrologic Soil Group A



- High infiltration rates
- Deep, well drained
- Soil Types: Sands/Gravels
- **Lowest Runoff Potential**



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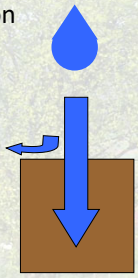
Hydrologic Soil Group B

- Moderate infiltration rates
- Moderately deep, moderately well drained soils
- Sandy Loams & Loamy **Sands**
- **Moderate Runoff Potential**



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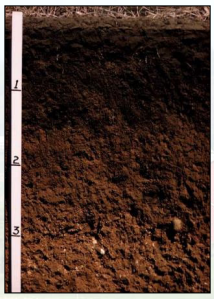
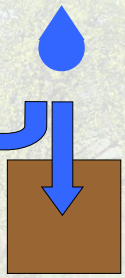
Hydrologic Soil Group C



- **Slow** infiltration rates
- Shallow soils
- Loams & Clay Loams
  - moderately fine to fine texture
- **Moderately High Runoff Potential**



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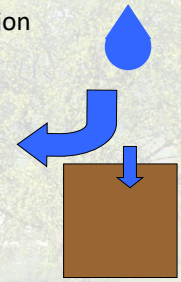
Hydrologic Soil Group D

- Very slow infiltration rates
- Clays
- High water tables
- Shallow soils over nearly impervious material
- **Highest Runoff Potential**



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Dual Hydrologic Soil Group

- Example: Bowmansville – "B/D"
  - High water table (Undrained) – "D"
  - With subsurface drainage system (Drained) – "B"
- **Use "D" unless you know there is subsurface drainage operating properly!**

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Where to Find the HSG

Map symbol and soil name	Hydrologic group
BrB2:	
Brecknock	B
BrC2:	
Brecknock	B
KaC2:	
Klinesville	C/D
PeB2:	
Penn	C
PeC2:	
Penn	C

- EFH-2 Tables
- "Water Features" Report
  - Web Soil Survey
    http://websoilsurvey.nrcs.usda.gov

Drained/Undrained

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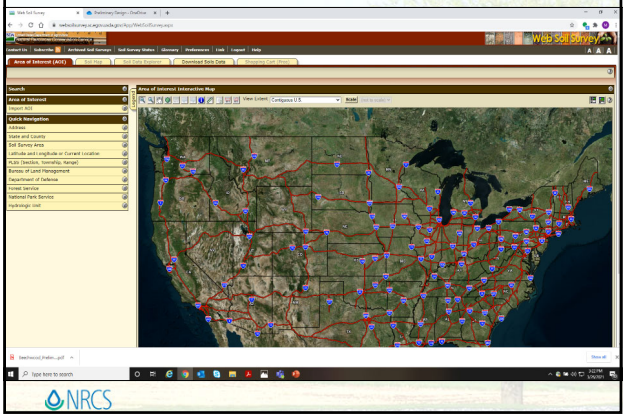
Web Soil Survey



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How land cover affects runoff…

- Raindrop impact on soil is lessened
  - Retention increases evaporation.
  - Vegetation **uses** soil water.
- Interception delays start of runoff.
  - Roughness slows water down.

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Curve Number – Terminology

- Row Crops – Corn, Beans, Vegetables
  - Field crops planted in rows far enough apart so most of the soil surface is exposed to the impact of rainfall
- Small Grains – Wheat, oats, barley, flax, etc
  - Rows close enough so that the soil surface is not exposed except during or shortly after planting
- Close-seeded legumes or rotation meadow
  - Alfalfa, sweet clover, timothy, or a combination, which are planted in close rows or broadcast.
- Meadow – continuous grass, not **grazed**, generally mown for hay

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Curve Number – Terminology

- Pasture/Grassland – based on native pasture or range cover effect, not forage production
  - Poor: heavily grazed – plant cover on ½ of the area
  - Fair: not heavily grazed – plant cover on ½ - ¾ of the area
  - Good: lightly grazed – plant cover on over ¾ of the area
- Woods
  - Poor: **heavily** grazed or regularly burned; litter, small trees, brush are destroyed
  - Fair: grazed but not burned; some litter, but woods are unprotected
  - Good: protected from grazing; litter and shrubs cover the soil

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Curve Number – Cover Types

- Row Crops
  - Corn, Beans, Vegetables

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Curve Number – Cover Types

- Row Crops
  - Corn, Beans, Vegetables
- Small Grains

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Curve Number – Cover Types

- Row Crops
  - Corn, Beans, Vegetables
- Small Grains
- Close-Seeded Legumes

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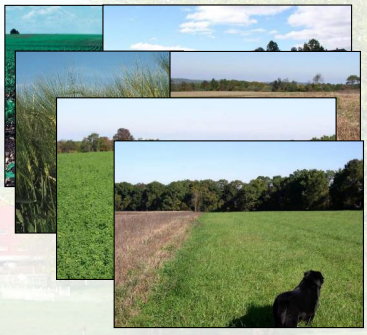
Curve Number – Cover Types

- Row Crops
  - Corn, Beans, Vegetables
- Small Grains
- Close-Seeded Legumes
- Rotation Meadow
  - In sequence with other crops



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Curve Number – Cover Types

- Row Crops
  - Corn, Beans, Vegetables
- Small Grains
- Close-Seeded Legumes
- Rotation Meadow
  - In sequence with other crops
- Pasture

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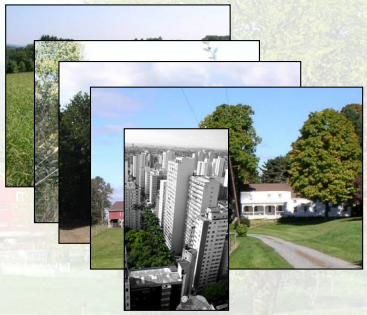
Curve Number – Cover Types

- Meadow
- Brush
- Woods
- Farmsteads
- Urban
  - Over 10% of area, use TR-55



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Cover Treatments – Terminology

- Straight Row – fields farmed in straight rows either up and down or across the slope.
  - If the land slope is less than 2%, equivalent to contouring.
- Contouring – farmed on the contour
  - Hydrologic effect increases surface storage by providing furrows
- Terracing – graded or open-end terraces with outlets
  - Hydrologic effect is to increase storage and infiltration opportunity.

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Curve Number – Cover Treatments

- Affect flow path of runoff
- Straight Row
- Crop Residue
  - Residue on ≥5% of surface throughout year
- Contoured
- Terraced
- Combination of treatments

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Curve Number – Hydrologic Condition

- Affect infiltration
  - Canopy and density of vegetation
  - Amount of year-round cover
  - Amount of grass/close-seeded legumes in cover
  - Percent of residue on surface (good ≥ 20%)
  - Degree of surface roughness
- **POOR** – infiltration **impaired**, increasing runoff
- **GOOD** – average or better infiltration, decreasing runoff

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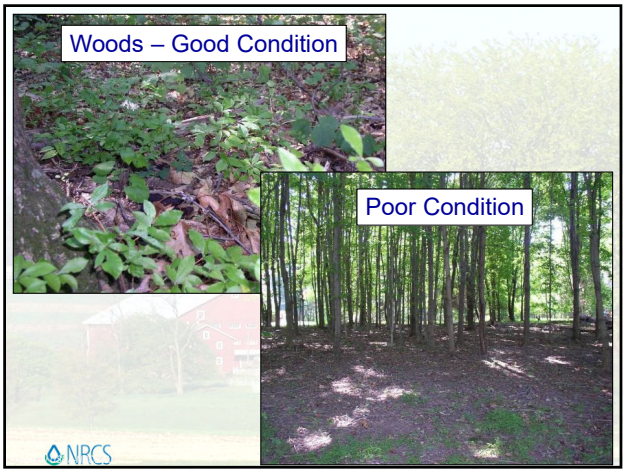

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Runoff Curve Number

Cover Type	Treatment	Condition	A	B	C	D
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

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Runoff Curve Number Charts EFH Ch 2-85

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Curve Number Examples

1.
- Pasture
- 75% cover
- HSG = B/D
- CN = ____

2.
- Residential
- 30% impervious
- HSG = C
- CN = ____

3.
- Corn, Beans, Wheat rotation
- No till & Cover crop
- Farms up & down the slope
- HSG = B
- CN = ____

4.
- Cemetery (well maintained)
- HSG = A
- CN = ____

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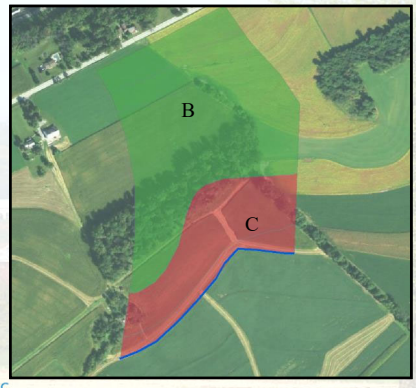
RCN Example – Diversion



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RCN Example - Diversion

Soil name and hydrologic group (table 2-1)	Cover description (cover type, treatment, and hydrologic condition)	CN (table 2-3)	Area (acres or %)	Product of CN × area
C	Woods, Good	70	x 1	= 70
C	Hay (Rot. Meadow), C, good	78	x 3	= 234
C	Row, C, CR, good	81	x 6	= 486
C	Pasture, Good	74	x 2	= 148
B	Row, C, CR, good	74	x 12	= 888
B	Woods, Good	55	x 10	= 550
B	Rotat. Meadow, C, good	69	x 6	= 414
			Totals = 40	2790

CN (weighted) = $\frac{2790}{40}$ = 69.8 Use CN = 70

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Time of Concentration

$$T_c = \frac{l^{0.8}[(\frac{1000}{CN}) - 9]^{0.7}}{1140Y^{0.5}}$$

T_c	=	*Time of Concentration*
l	=	*Watershed Length*
CN	=	*Runoff Curve Number*
Y	=	*Average Watershed Slope*

The good news is…
EFH-2 Computer Program will do the math for you!

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Peak Rate of Runoff, Q_p

- Rainfall Intensity
- Curve Number
- Watershed Length
- Drainage Area
- Watershed Slope

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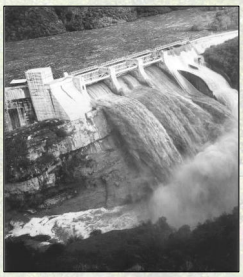
Hydrology

- For conservation practices, V and Q determine type, and size of conservation practices.



Gibraltar Reservoir 1969

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National Engineering Handbook (NEH)

- Part 630, Hydrology
  - Portion of the NEH pertaining to hydrology
  - Source document for all NRCS hydrology methods
- Part 650, Engineering Field Handbook
  - Chapter 2, Estimating Runoff and Peak Discharges
  - Computer Model EFH-2.

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Field Exercise

- **Objective:** Further understand watershed parameters to that determine peak runoff rates.
- **Location:** Oberholtzer Farm – Union Co.

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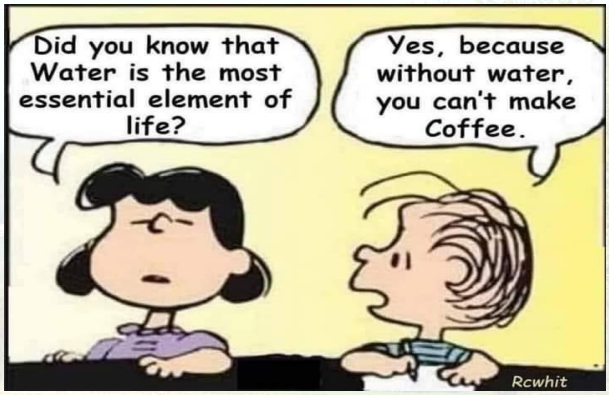

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Get Ready for the Field…

- *Clipboard*
- *Pencil & Eraser*
- *Clinometer/Hand Level*
- *LUNCH & SNACKS!*
- *Handouts (from Binder)*
  - *RCN Tables*
  - *Directions*
  - *Terraces Handouts*
  - *Contour Handouts*
- *Oberholtzer Farm Aerial Map/Soils Handout*

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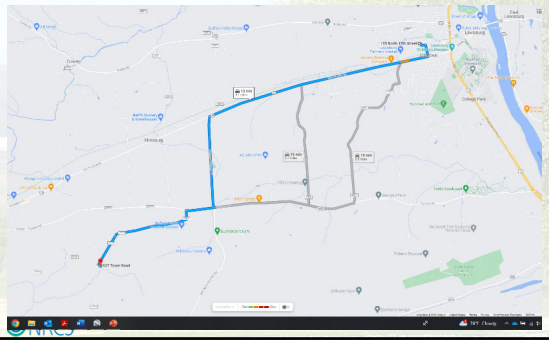
Oberholtzer Farm
527 Tower Road,
Mifflinburg, PA 17844



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