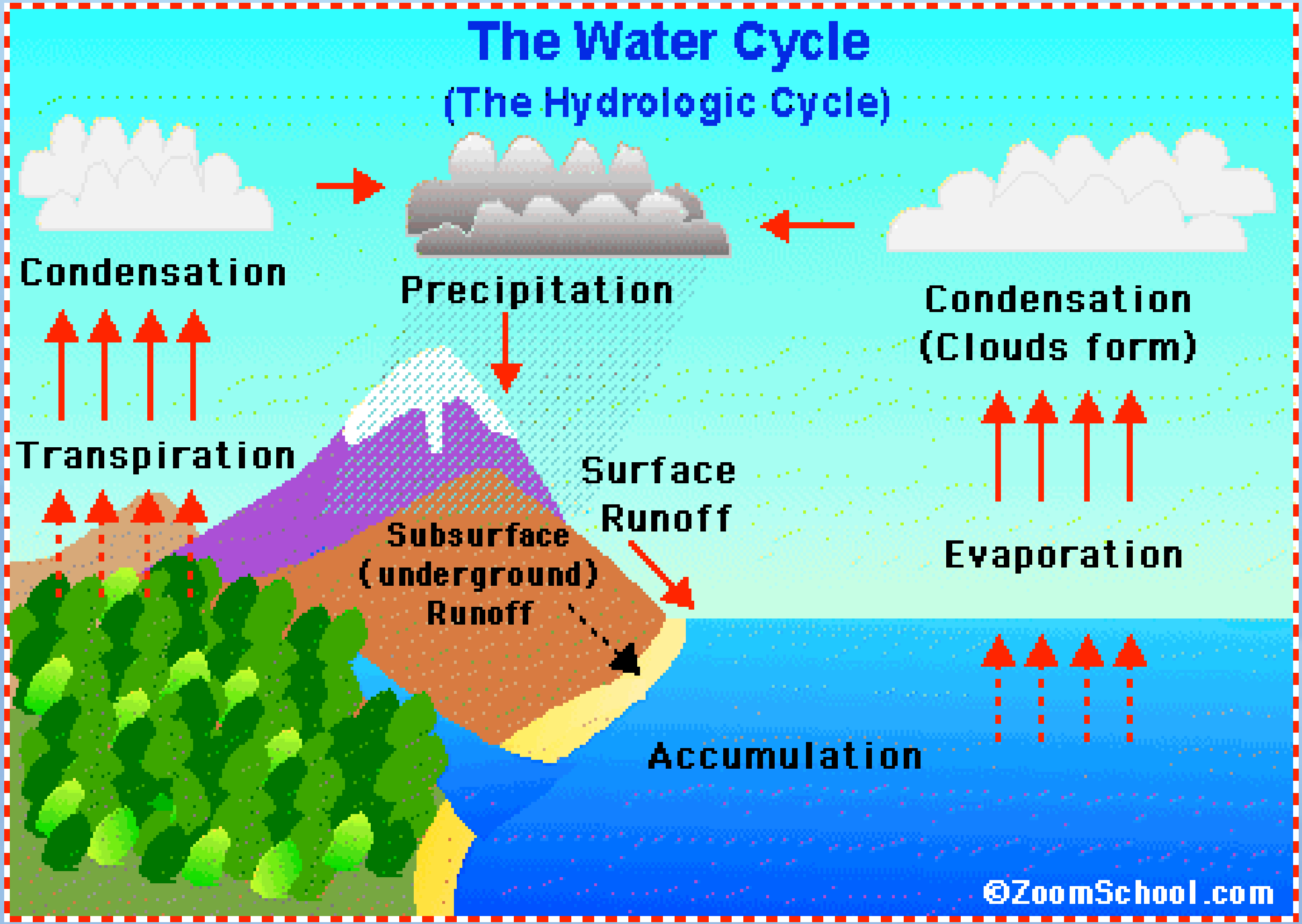
Sjoerd W Duiker and Larry D. Geohring

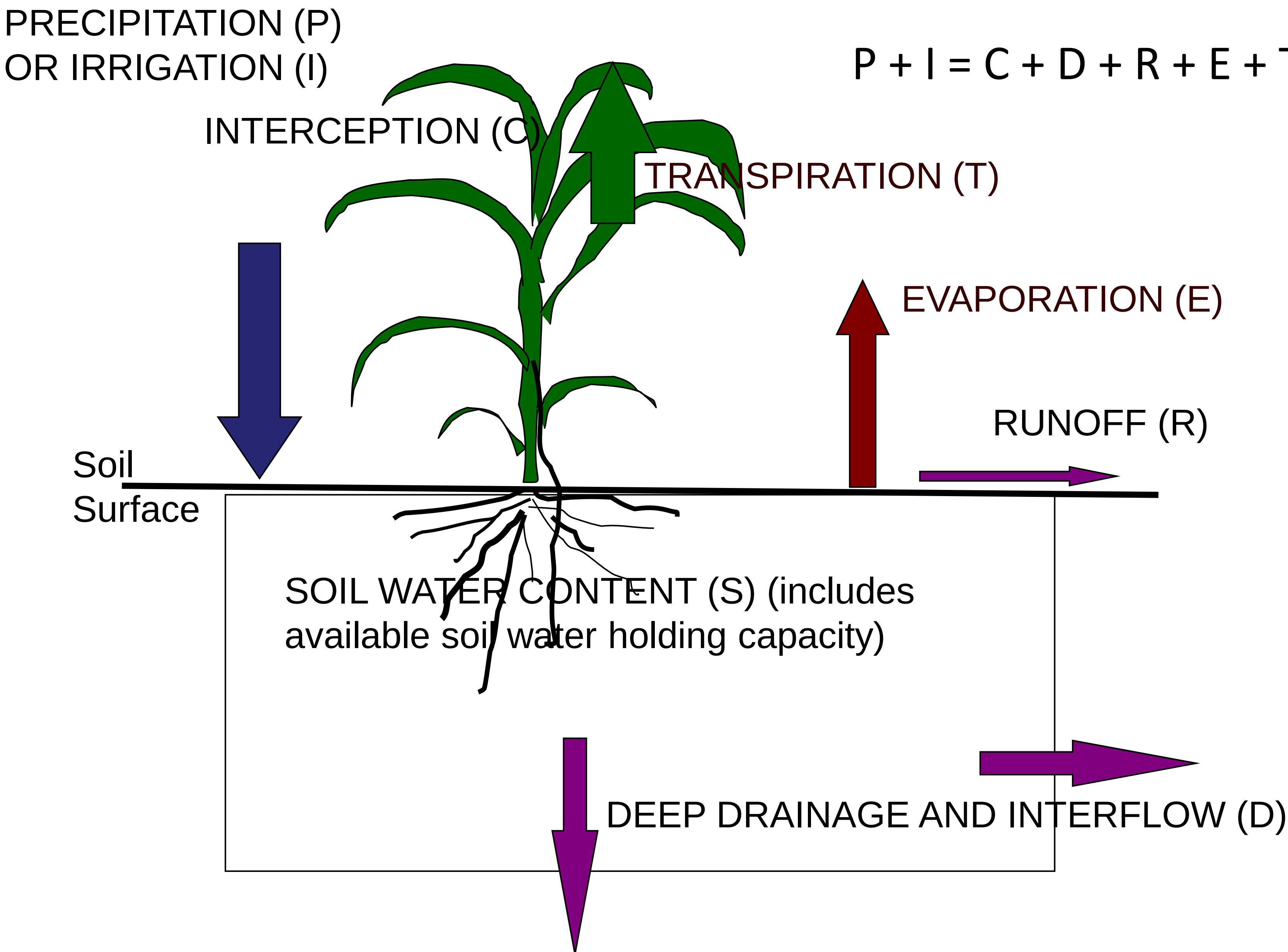
SOIL HYDROLOGY, DRAINAGE AND IRRIGATION

Know the components of the hydrologic cycle



Describe the water budget for a soil profile

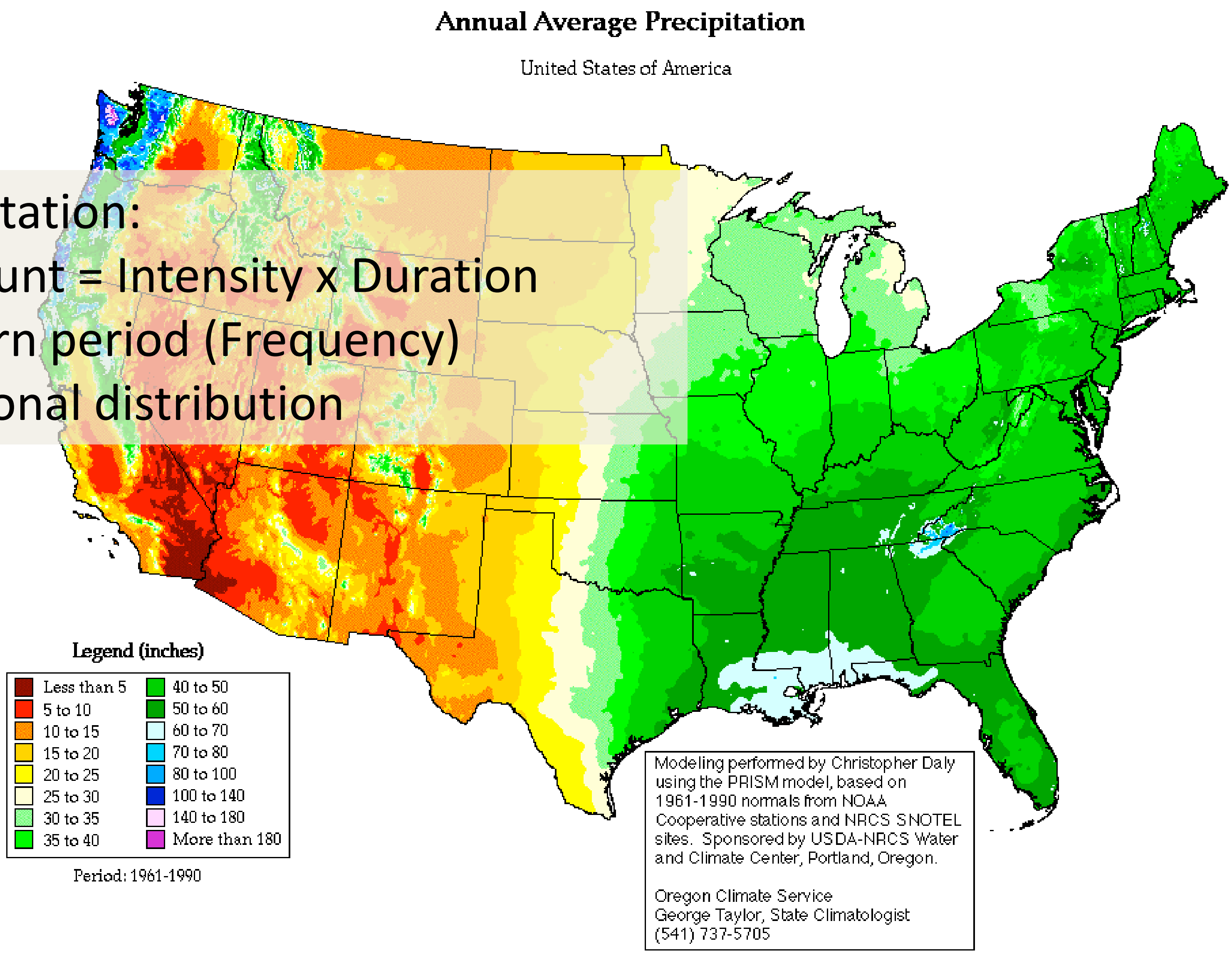
$$P + I = C + D + R + E + T \pm \Delta S$$



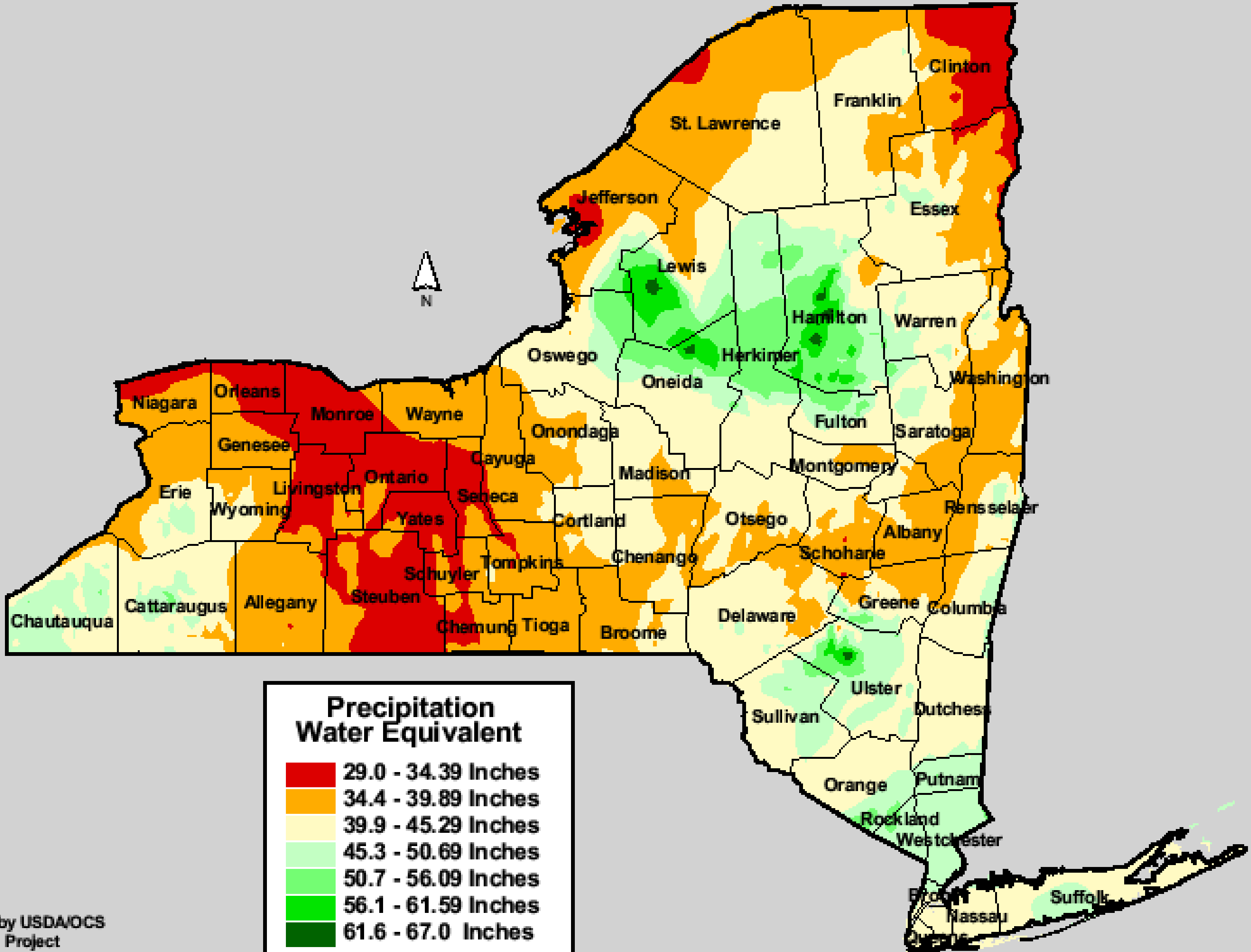
Understand characteristics of rainfall and the concept of return periods

Precipitation:

- Amount = Intensity x Duration
- Return period (Frequency)
- Seasonal distribution



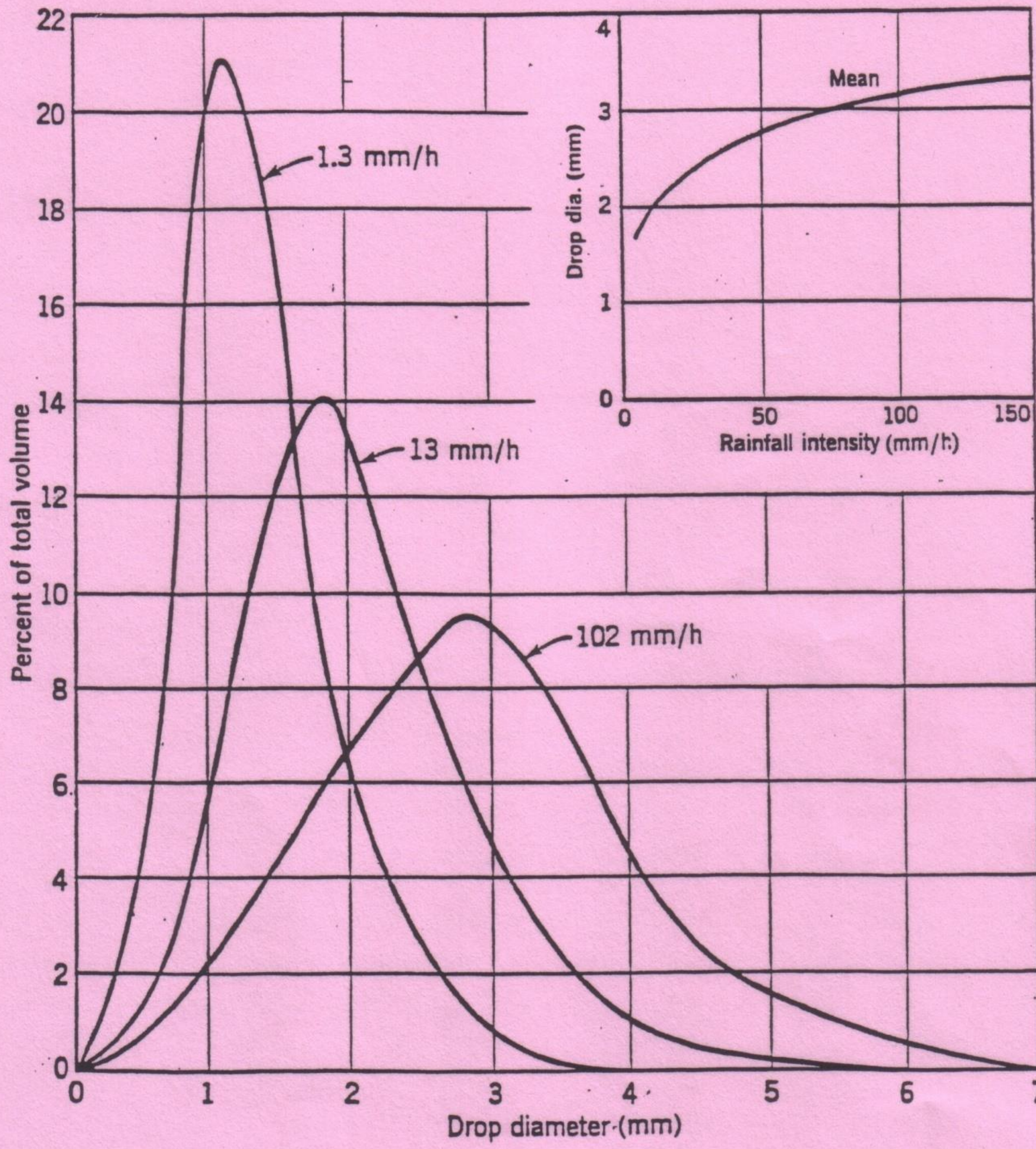
30 Year (1961-1990) Mean Annual Precipitation for New York



Data Provided by USDA/OCS
Prism Mapping Project
Middle Atlantic River Forecast Center

Raindrop size distribution for different rainfall intensities:

Higher intensity = larger raindrops = higher impact



Effect of rainfall intensity on raindrop size and its contribution to total rainfall. (Redrawn from Laws and Parsons, 1943, and Wischmeier and Smith, 1958.)

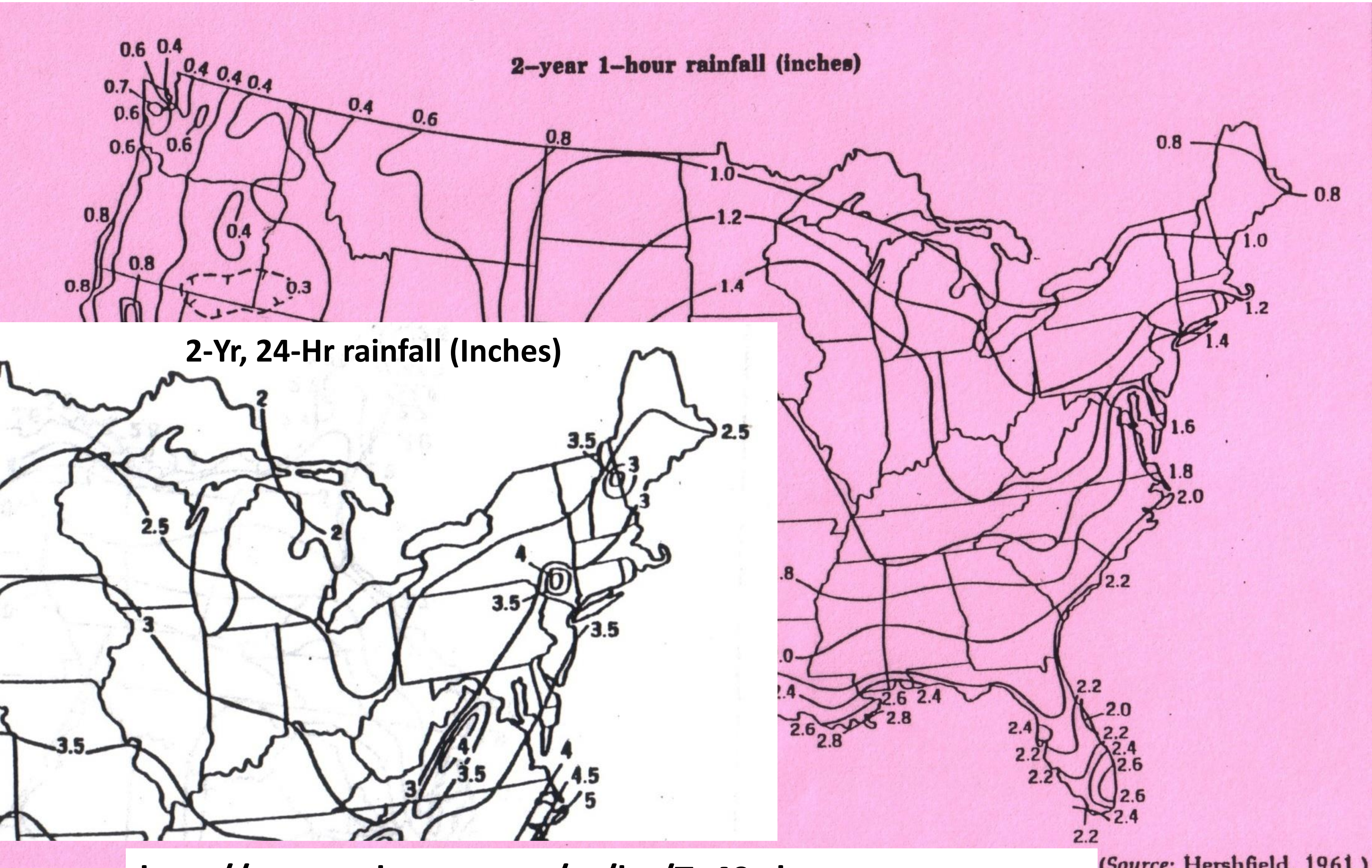
Return periods

“Return period, sometimes called recurrence interval, is defined as the period within which the depth of rainfall for a given duration will be equaled or exceeded once on the average”

Longer return period = higher precipitation events
Shorter events = higher intensity

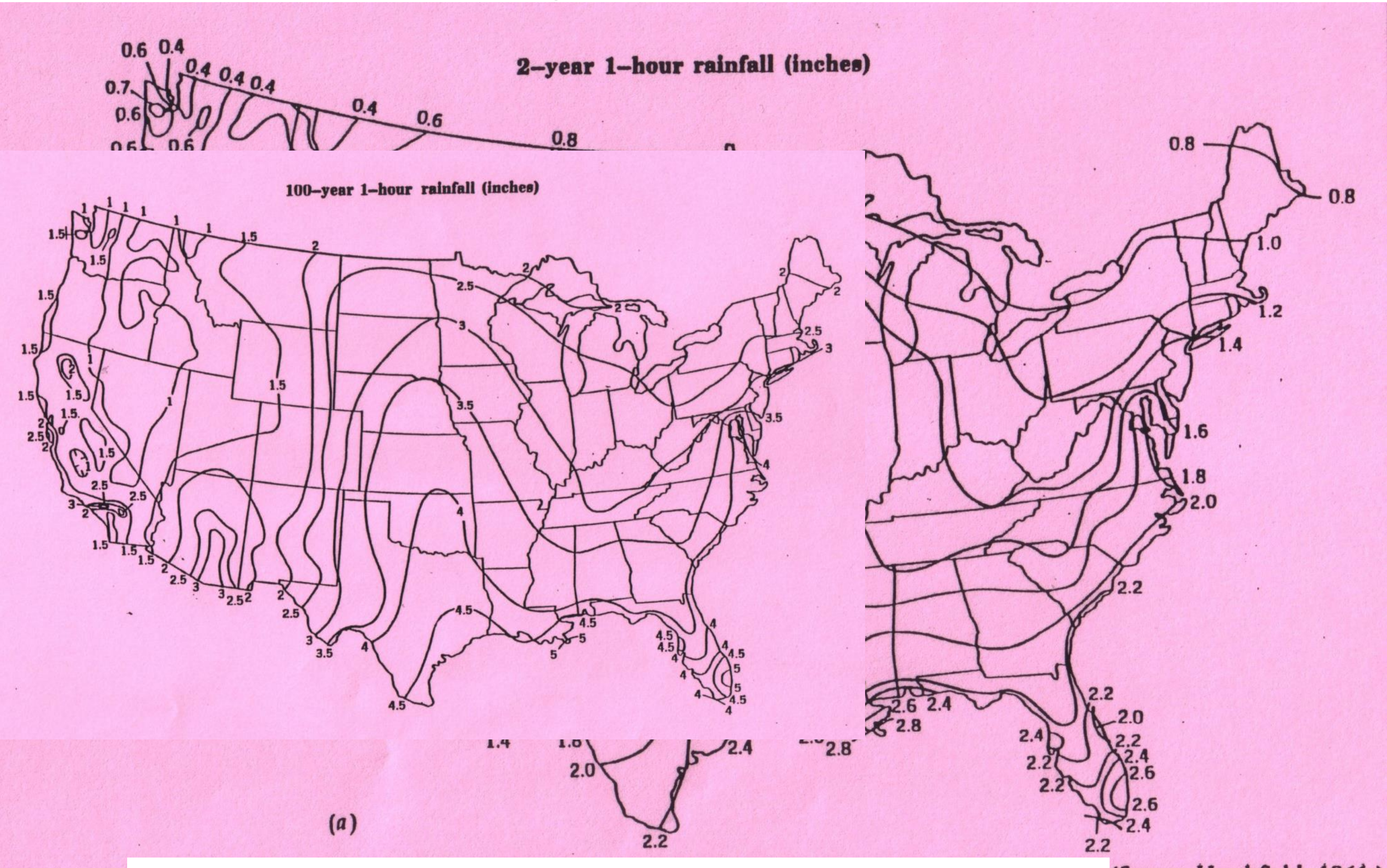
G.O. Schwab, D.D. Fangmeier, W.J. Elliott, and R.K. Frevert. 1993. Soil and Water Conservation Engineering 4th Ed. John Wiley & Sons, New York.

The effect of length of an event on rainfall amount



http://www.erh.noaa.gov/er/hq/Tp40s.htm

The effect of return period on rainfall amount



http://www.erh.noaa.gov/er/hq/Tp40s.htm

(*Source:* Hershfield, 1961.)

Precipitation Characteristics – Why are they important?

1. RUSLE – Revised Universal Soil Loss Equation
   Storm totals, intensity and frequency used to calculate Erosivity (R)

2. Design of water management and control structures
   uses return periods – the longer the return period, the greater the protection, but the higher the cost

3. CAFOs need to have no-discharge for a 25 year, 24 hr rainfall event.

Understand Factors that Affect Infiltration and Runoff

Infiltration – the entry of water into the soil
Permeability – the movement of water through the soil

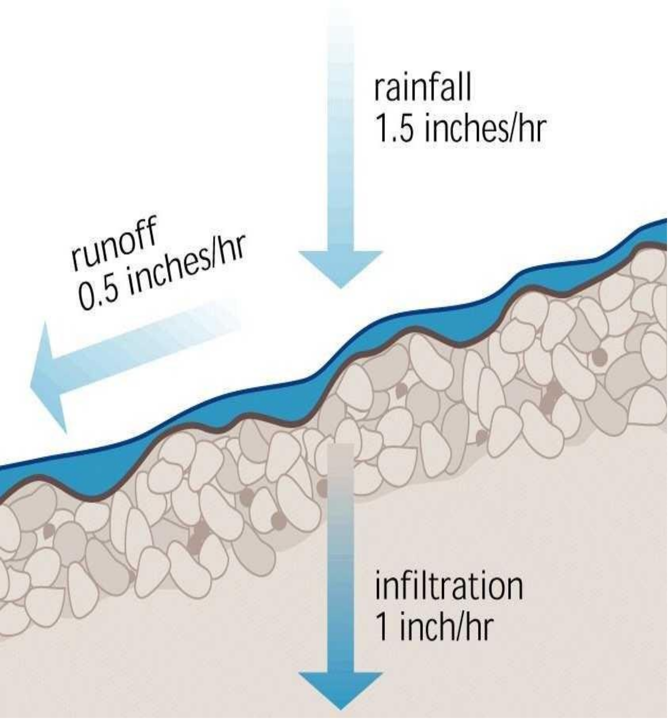
Infiltration rate – the rate at which water enters the soil
Infiltration capacity (infiltrability) – rate of water entry when water is freely available at soil surface
Cumulative infiltration – total water infiltrated over a period of time

Affected by:
Surface conditions: Sealing and crusting at soil surface, cracks and pores, soil roughness and cover

Subsurface conditions: Soil texture, macroporosity (bypass flow), soil moisture content, temperature

Soil Hydrologic Group – based on soil type and texture (A= lowest runoff potential, D = highest runoff potential)

Infiltration Excess runoff vs Saturation Excess Runoff



Infiltration excess – rain intensity greater than soil infiltrability – governed by surface characteristics

Greatly affected by surface cover
Can occur on any soil type
Common when rainfall intensity is high

Saturation excess – runoff occurs because soil is saturated. Infiltration rate dependent on where saturated areas occur in landscape

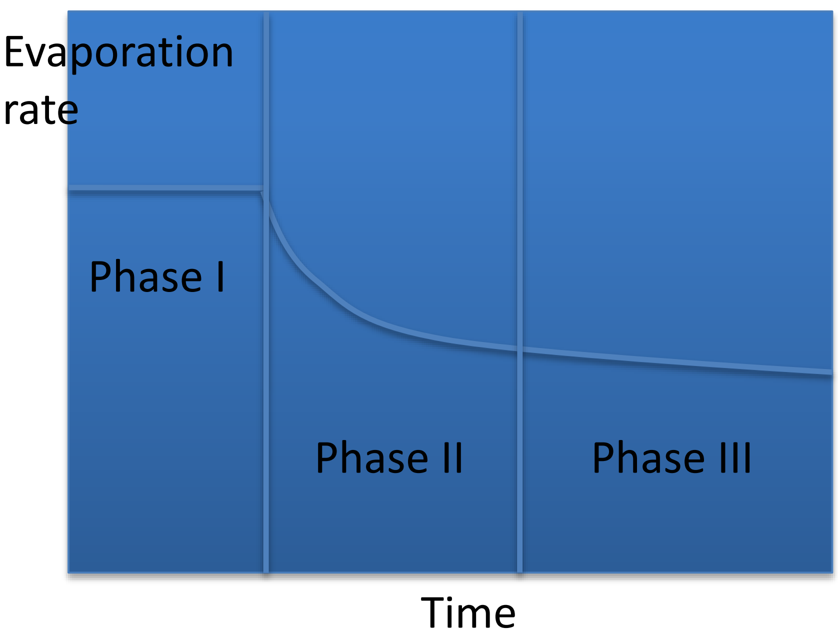
Not impacted by surface cover
Common on poorly drained soils
Common in spring
Common on soils with impervious layers
Common on lower parts of landscape (variable source area)

Evaporation

the process by which a liquid or a solid enters the gas phase.

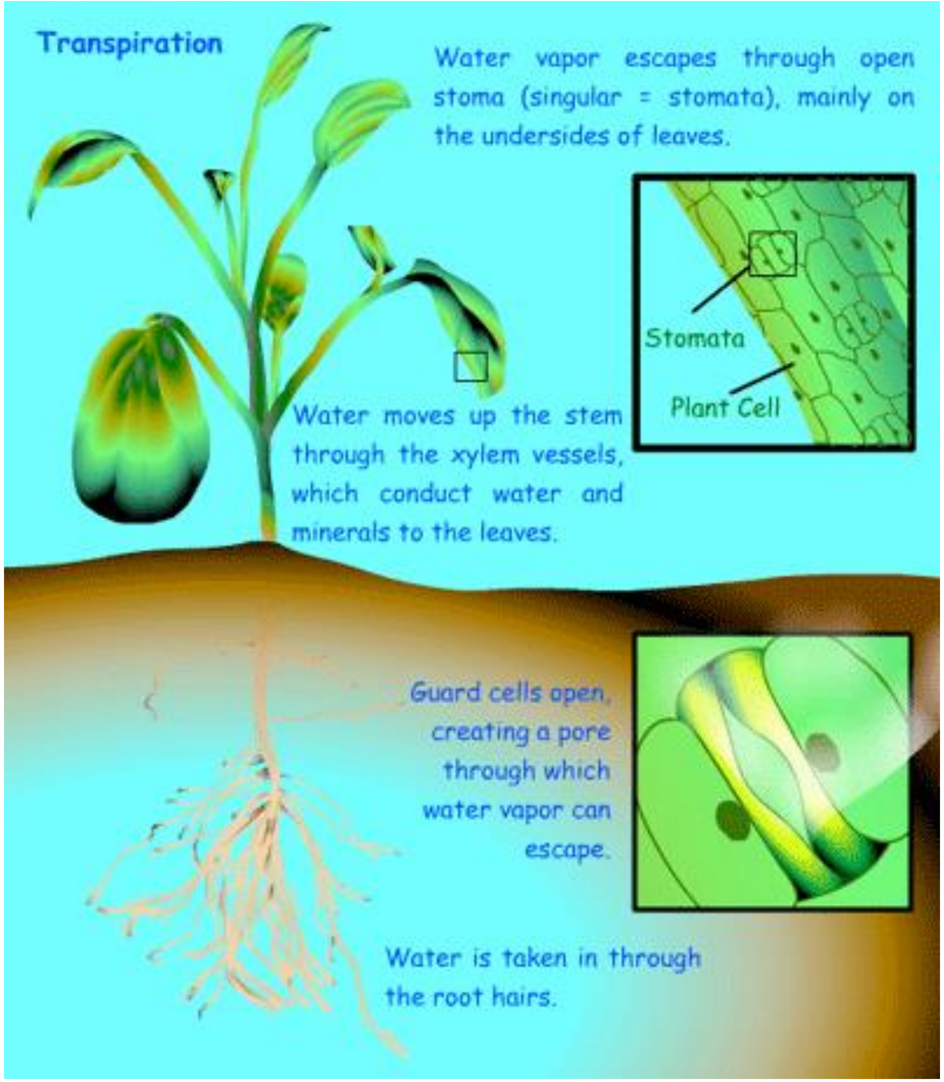
Evaporation

Evaporation is measured using a Class A Evaporation Pan at Weather Stations. Actual evaporation from soil will be less because soil is not saturated all the time and evaporation decreases rapidly when soil surface dries (low conductivity)



TRANSPIRATION

the process where water is transported from the soil through the plant, and then lost through the leaves



http://water.me.vccs.edu/courses/SCT112/lecture3b.htm

Understand Factors that Affect Evapotranspiration

- ET = Evaporation + Transpiration
- Potential ET = ET from an extended surface of uniform height of an actively growing short green crop that completely shades the ground and is not short of water
- ET depends on:
  - Crop growth stage (leaf area)
  - Solar radiation
  - Temperature
  - Humidity
  - Wind
  - Mulch Cover
- Actual ET can be higher than pan evaporation b/c of large leaf surface area

Understand Factors that Affect Leaching

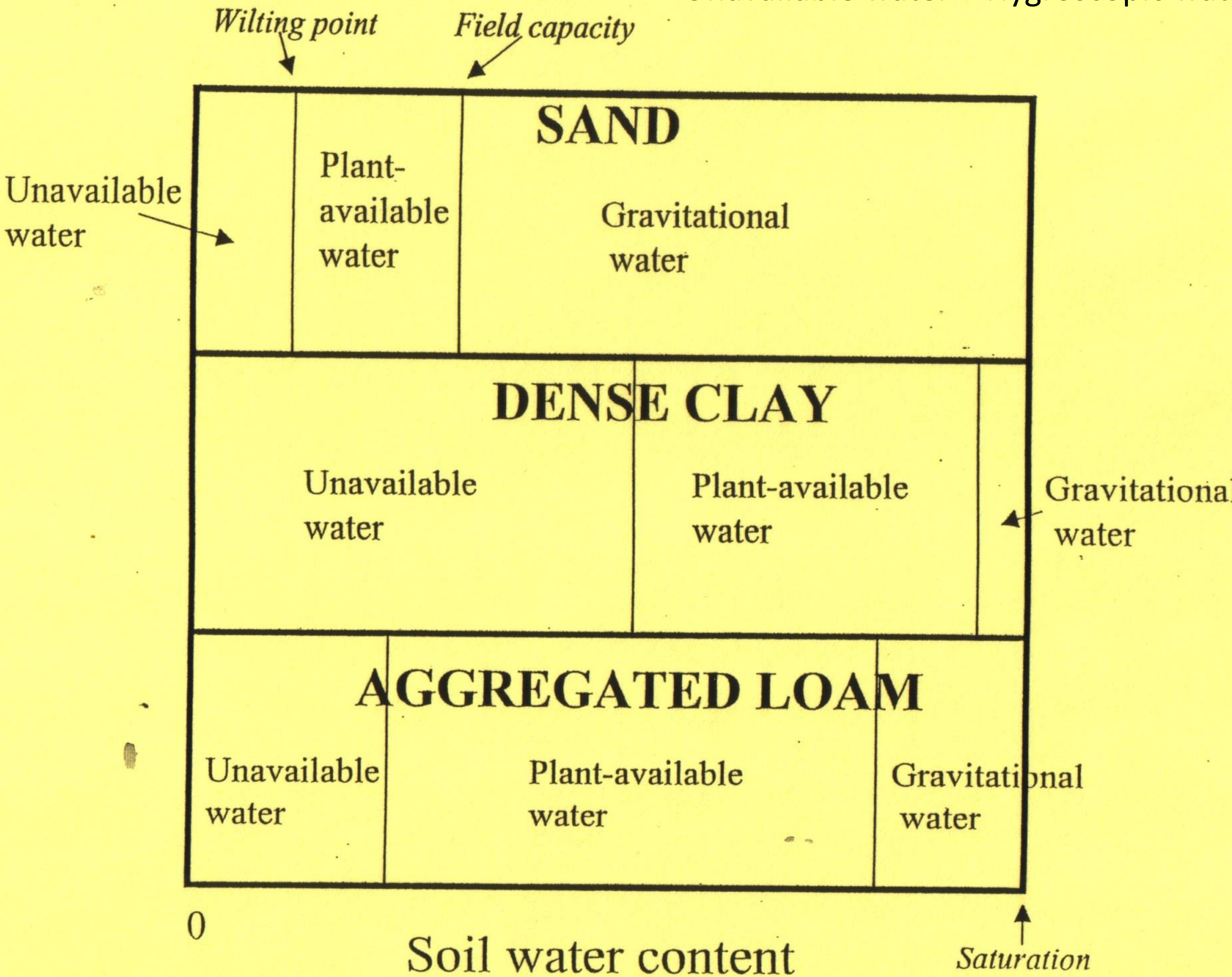
- Does the substance dissolve in water
- Does the substance get retained by soil
- Soil texture (clay less than sand)
- Structure (well-structured soil more than poorly structured)
- Macro-pores (no-tillage, high biological activity)
- Impervious layers in soil (reduce leaching)
- Time of year (high soil water content = more leaching)

Understand Factors that Affect Soil Moisture Storage

- Need to distinguish between volumetric and gravimetric water content
- Total soil water storage capacity – all pores filled with water (peat – 70-85vol%, sand – 30-40vol%, silt 35-50, clay 40-60)
- Available water holding capacity = moisture content at field capacity – that at permanent wilting point
- Field capacity – water remaining few days after complete wetting and after free drainage has stopped (1/10- 1/3 bar).
- Drainable porosity – water in soil between field capacity and complete saturation. It would be the water removed when drainage pipe is installed in a soil with high water table.
- Permanent wilting point – water content of soil when most plants wilt and fail to recover (15 bar)

SOIL WATER STORAGE

PAW = Capillary water
Unavailable water = Hygroscopic water



Organic matter increases water holding capacity at field capacity – and hence available water holding capacity (B.D. Hudson. 1994. Soil organic matter and available water capacity. J. Soil Water Cons. 49(2): 189-194.)

Coarse fragments decrease PAW

Increasing OM by 1% increases PAW by 3.4% - 5539 gal/A for 6" depth

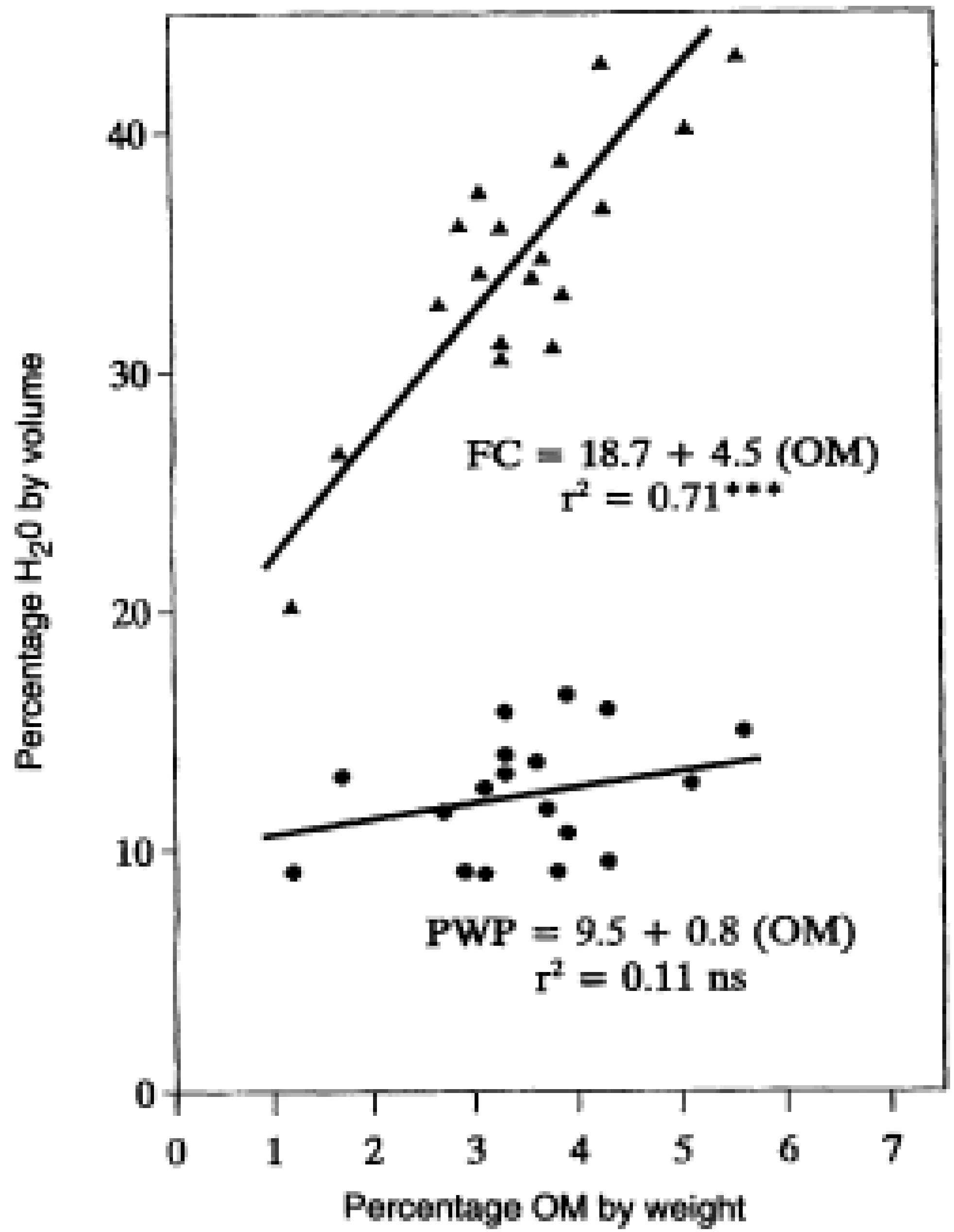
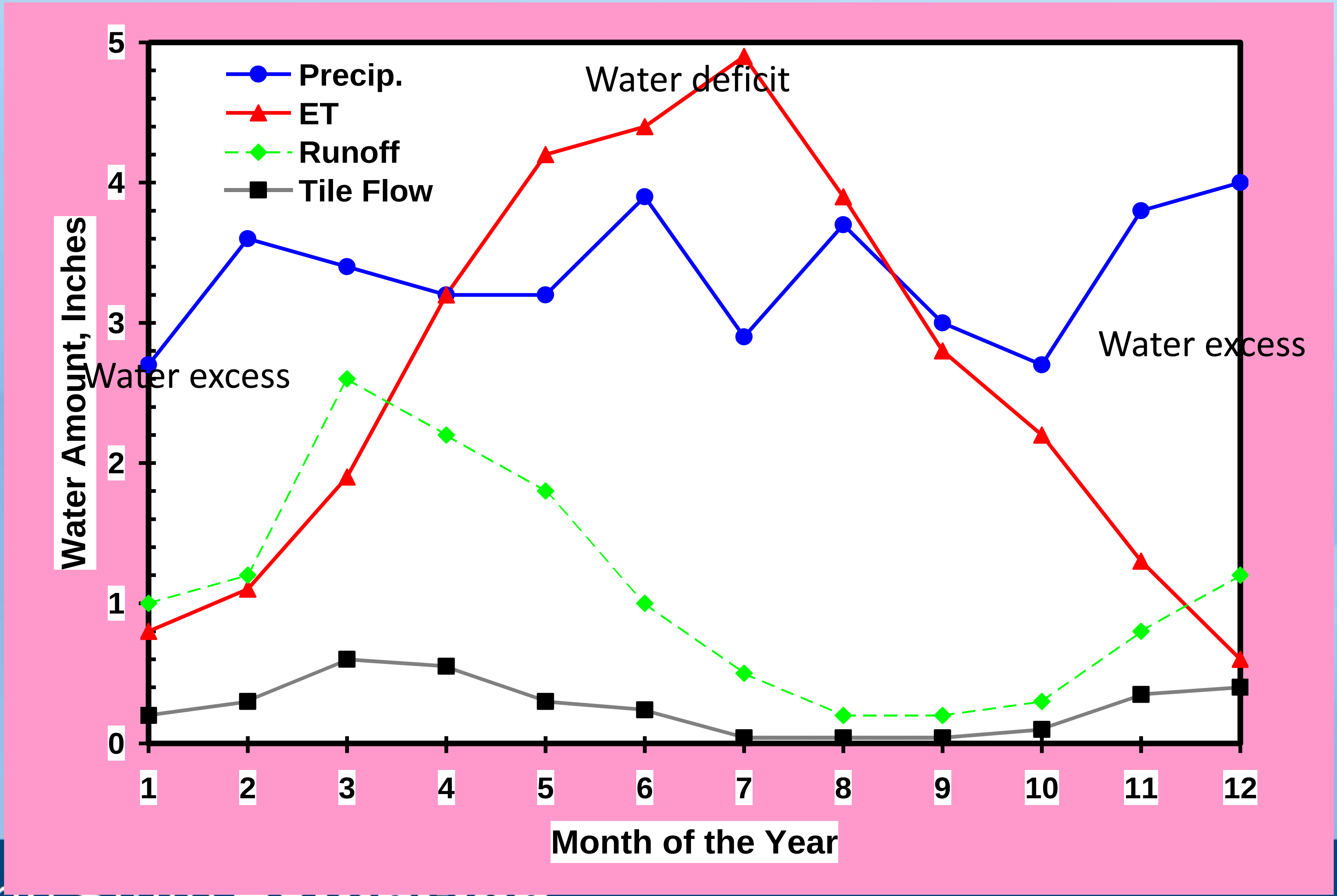


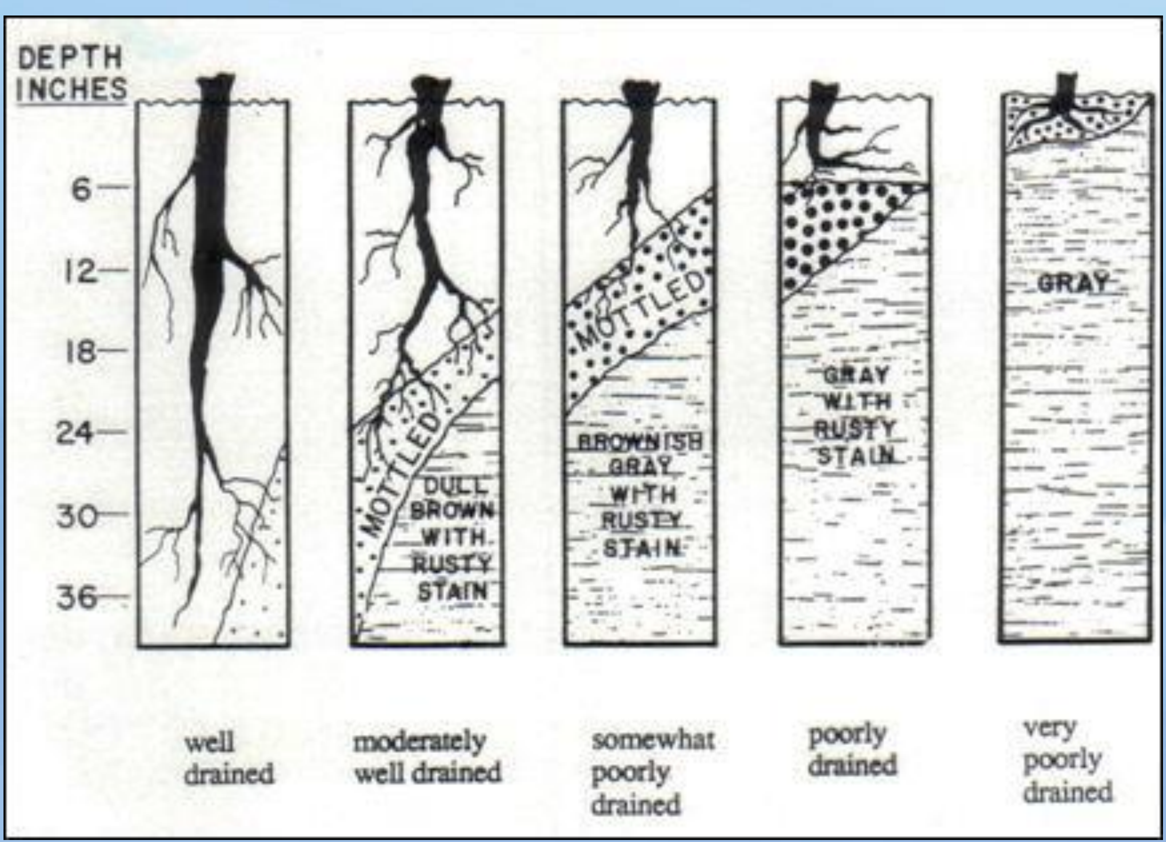
Figure 2. Water content at FC and PWP versus OM content of silt loam surface horizons

Typical Water budget for Central NY



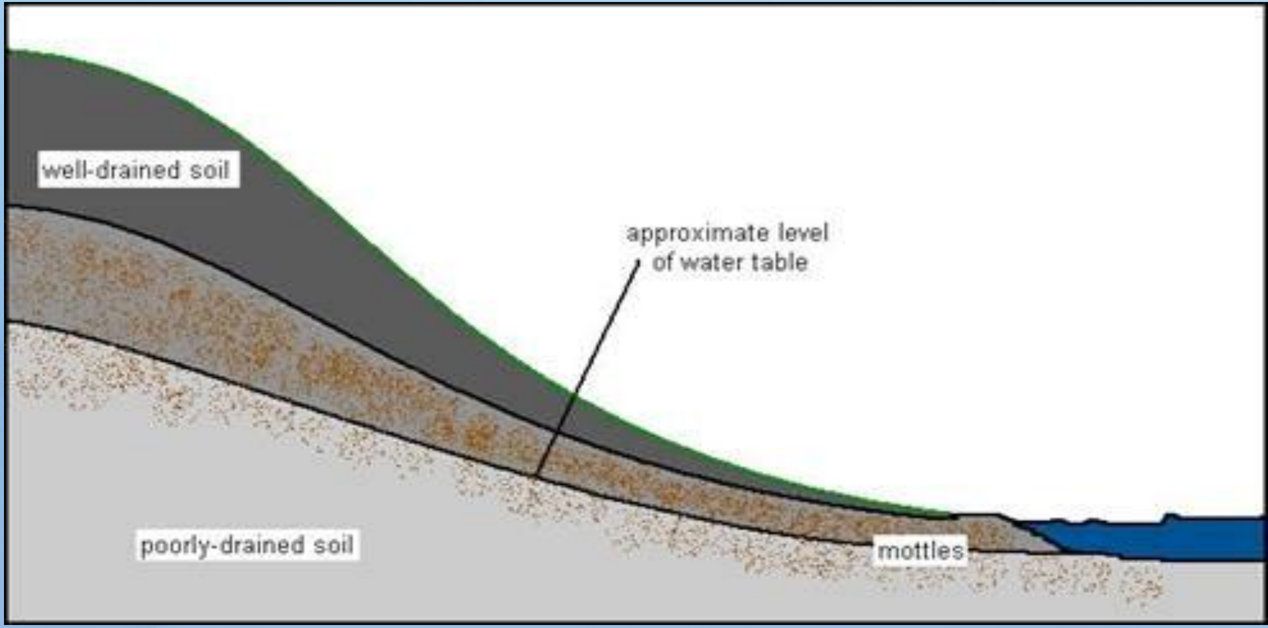
Drainage Classification in Soil Survey

- Frequent depth to water table
- Affects rooting depth and soil suitability for field work
- Yields 2-3 times higher on well-drained than poorly drained soils



Understand how hydrology and soil and landscape properties influence drainage

- Soils higher on hillslope usually better drained (except in case of impervious layers)



Removing Excess Water: Surface Drainage

- Shaping, grading, management of surface to allow water to drain off surface
- Examples, ditches, land smoothing, ridge till, aeration, coring
- Application: flat lands with slow infiltration
- Advantages: minimize duration of ponding
- Disadvantages: doesn't address subsoil saturation, erosion and nutrient loss may occur

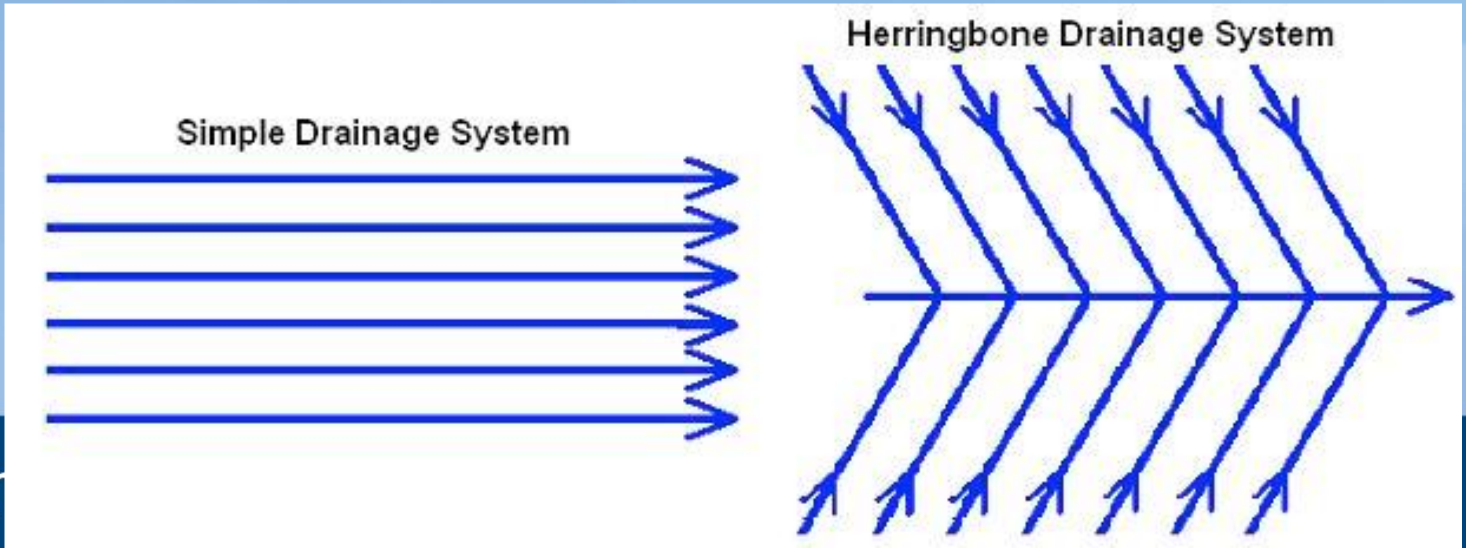
Removing Excess Water: Subsurface Drainage

- Lowers water table
- Examples: tile drains, mole drains, french drains
- Advantages: makes poorly drained soils act like well-drained soils
- Disadvantages:
  - Costs
  - Doesn't address surface
  - Wetland destruction
  - Increased nitrate leaching
  - Rapid movement of nutrients to surface waters

Subsurface drainage types

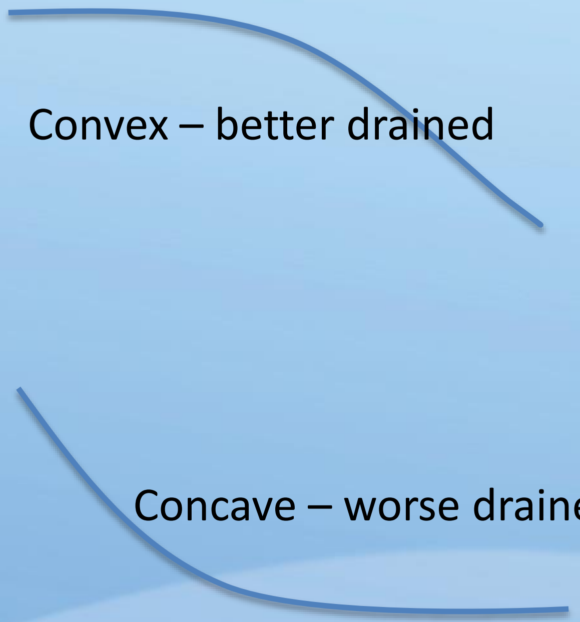
- Random
  - Undulating terrain
- Pattern
  - Uniform terrain
  - Gentle slopes (<8%)

Random



Factors Affecting Drainage

- Bedrock – if at < 3ft depth subsurface drainage ineffective
- Slope – determines drainage system, outlet
- Texture – surface drains may work in fine textured soils. Subsurface drainage works well in coarser textured/well structured soils.
- Organic soils – large drainable porosity, but often in depressions in landscape so water may need to be pumped out – still may be profitable for production of high value crops- but land subsidence is a problem.



Drainage – pros and cons

Pros	Cons
Increased land productivity	Land use conversion
Trafficability / timeliness	Wetland loss - habitat
Removal of salts, contaminants	Water quality
Vector control, public health	Water quantity
Erosion control	

Additional aspects of drainage

- Hydric soils: soils anaerobic in upper part, especially during growing season
- Indicators: generally organic matter accumulation, gray color, mottling
- Regulations: Freshwater Wetlands Act (NY)
- Clean Water Act (US)
- Prior Converted soils usually exempt

Adding Water to Avoid Deficiencies: Irrigation

- One method to schedule irrigation is the checkbook method – based on water budget
  - Inputs: precipitation and irrigation
  - Outputs: evapotranspiration
  - Field capacity: maximum available water content
  - Daily addition = precip – ET
  - If field capacity is exceeded – deep drainage
  - Total irrigation requirements – 4-12 inches /season in NE

Other Components of Irrigation Scheduling to Determine when Irrigation is Needed

- Crop depletion factor – depletion of PAW when crops start experiencing undue stress (e.g. 0.2 of PAW for celery, spinach, 0.65 for sugar beet, sweet potato, or 0.5 for most other crops)
- Crop rooting depth
- Time of planting

Irrigation types

- Surface – flat slopes, medium-heavy textured soils
- Sprinkler – permanent, movable, travelling
- Drip/trickle – efficient, can be used on all soil types
- Subsurface – below surface, e.g drip.