SOIL AND WATER MANAGEMENT

Competency Areas

2016 Authors/Instructors for Soil and Water Management

- Larry D. Geohring, Senior Extension Associate, Biological and Environmental Engineering Department, Cornell University
- Dale Gates, Natural Resources Conservation Service (NRCS), Syracuse, New York
- Sjoerd W. Duiker, Associate Professor, Department of Plant Sciences, Pennsylvania State University
- Shawn Bossard, Farm Manager, SUNY Morrisville, New York

With thanks to our past contributors:

- David W. Wolfe, Professor, School of Integrative Plant Sciences, Section Horticulture, Cornell University
- Paul A. Ray, Resource Conservationist, USDA-Natural Resources Conservation Service (NRCS), Syracuse, New York

Lead Editors: Nicole Smaranda, NRCCA Intern, and Quirine Ketterings, NRCCA Co-Chair.

Last Updated 10-26-2016

Competency Area 1: Basic Soil Properties

1. Know the five soil functions.

Soil is a complex matrix of solid materials and void spaces which perform numerous functions essential for life "as we know it" on planet Earth. The solid materials consist of a very intricate array or structure of mineral and organic materials, which interact with the air and water occupying the void (i.e., pore) spaces. The five soil functions include:

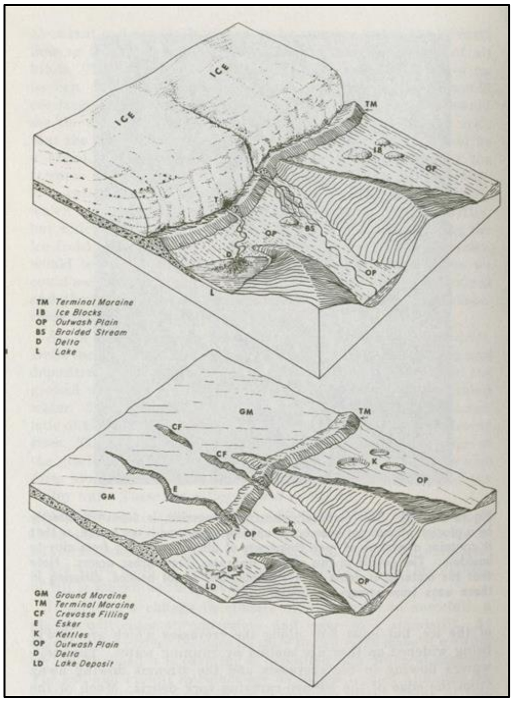
1) A ***Medium*** for plant growth or bio-materials production whereby this medium combines with the other soil functions to anchor roots, and allow for the transport of water and nutrients to the root/soil interface.
2) A ***Habitat*** for soil organisms, making up more than half of all "life" on the planet. The *micro-organisms* are mainly responsible for most of the *bio-chemical* transformations in the soil medium; whereas, the *macro-organisms* primarily affect *physical* soil transformations.
3) A ***Biochemical or Nutrient reactor*** which absorbs, releases (i.e., desorbs), and transforms inorganic and biochemical compounds such as essential plant nutrients, pesticides, minerals, heavy metals, and numerous other compounds.
4) A ***Hydrologic buffer*** which stores (i.e., water holding capacity) and regulates the flow (i.e., drainage) of water in the landscape, allowing for the transport of various inorganic and biochemical compounds within and through the soil medium.
5) A ***Foundation*** for the physical support of structures including everything from plants to skyscrapers.

2. Understand the processes of soil formation in the Northeast.

A. Know the five soil forming processes

All of the New England states and most of New York were once covered by huge expanses of snow and ice, like Antarctica today. These ***glaciations*** have had great effect on the soils we find in the Northeast. We know of four glaciations (in chronological order): the Nebraskan, the Kansas, the Illinoisan, and the Wisconsin glaciations. When large amounts of snow and ice accumulated the ice started to move due to gravity. At the bottom of the ice, rock was picked up. This rock would scrape along the bottom of the ice, be pushed into it, and grind up the rock below. At the end of the ice age, the ice melted and dumped everything in it *in-situ*, as well as caused massive runoff that caused erosion and sedimentation.

The five factors that determine soil formation are: (1) parent material, (2) climate, (3) relief, (4) biota, and (5) time. For example, the influence of vegetation is demonstrated by contrasting the soils formed under Northeast forestil compared to soils formed under prairie grassland in the Midwest. Forest soils typically do not have the higher content of organic matter likely due to the limited turnover of the root systems of trees when compared to soils in regions with higher native vegetation turnover from native grass. Furthermore, some tree species, especially coniferous ones, release significant amounts of organic acids from their leaves upon decomposition. These acids can dissolve organic matter, aluminum and iron oxides and wash these down into the soil profile. This leaves a leached layer (gray or white) near the soil surface, under a dark organic surface layer. The organic acids and



aluminum and/or iron oxides will be deposited below the leached ('E') horizon forming a dark and sometimes orange colored layer. These soils are most common in sandy soils, especially in the outwash plains common in the Northeast.

The influence of parent material has a significant impact on soil formation. Northeastern and Midwestern soils are relatively young and un-weathered having developed from glacial parent material from the last ice age. This compares to soils developed from residual bedrock in un-glaciated areas that tend to be older and more highly weathered, which also interrelates to the time factor for soil formation.

Figure 1. An illustration of the effect of melting of an ice cap on soil formations (From: V.C. Shepps, Pennsylvania and the Ice Age, Commonwealth of Pennsylvania, 1978).

B. Describe glacial till, glacial outwash, lake and marine sediments, organic, and alluvial deposits.

There are three types of alluvial deposits: floodplains, alluvial fans, and deltas. A floodplain is part of a river valley that is inundated during floods. Sediment that is carried by the overflowing stream is sorted – coarser materials are deposited where the water is deeper and flowing faster, while finer materials are laid down further from the channel. Every flood event results in its own layer of sediment, creating stratification characteristic of alluvial soils. Streams may change direction and cut new channels through earlier deposited sediment resulting in complex patterns of alluvial materials. Alluvial fans are formed where streams exit an upland area into a much broader and flatter valley. Sediment is deposited in a fan, with coarse material being deposited first and finer material further from the mouth of the valley as water slows down at becomes shallower. Deltas form as a result of deposition of the finest material beyond floodplains. Deltas are found in oceans, lakes, and reservoirs near the mouth of the river and consist of clayey soils that are often poorly drained.

Two major effects of glaciations on our soils are: (1) the deposition of ***glacial till***, transported and deposited beneath glaciers and left in place as glaciers melted and receded. The basic characteristic of glacial till is that it is *unsorted* containing rocks, gravel, sand, silt and clay all mixed together. Glacial till is often dense with restrictive layers of soil with depth called fragipans (2) the formation of ***glaciofluvial*** (lake and marine) deposits, which formed when the ice melted and the melting water deposited mostly gravel and sand in mounds (called *kames*), ridges (*eskers)*, or flat-topped plains (*outwash plains*). Lakes formed in this period and sediment filled some of the lakes completely. Larger lakes receded or disappeared as ice dams from glaciers melted and meltwater drained. Former lake sediments formed areas of lake plain soils mostly comprised of fine sand, silt and clays. Many shallow lakes filled in with vegetation forming various types of organic soils found throughout the Northeast.. Figure 1 shows block diagrams of an area undergoing glaciations by a continental ice sheet (top) and the resulting topography and deposits after the ice has melted away (bottom).

3. Know the ***particle size fractions*** and size ranges.

A. Sand, silt, and clay; coarse fragments.

- Sand = 2-0.05 mm diameter particles
- Silt = 0.05-0.002 mm diameter
- Clay = <0.002 mm diameter
- Coarse fragments > 2 mm.

B. Understand and use the textural triangle.

The ***textural triangle*** helps determine the ***soil textural*** classification of a soil based on its fine-earth fraction (particles <2mm, that is sand, silt and clay). On the bottom, find the percent sand, on the left hand, percent clay, and on the right hand, percent silt. As an example, a soil has 15% sand, 60% silt, and 25% clay – this soil would be classified as a silt loam (Figure from Soil Survey).

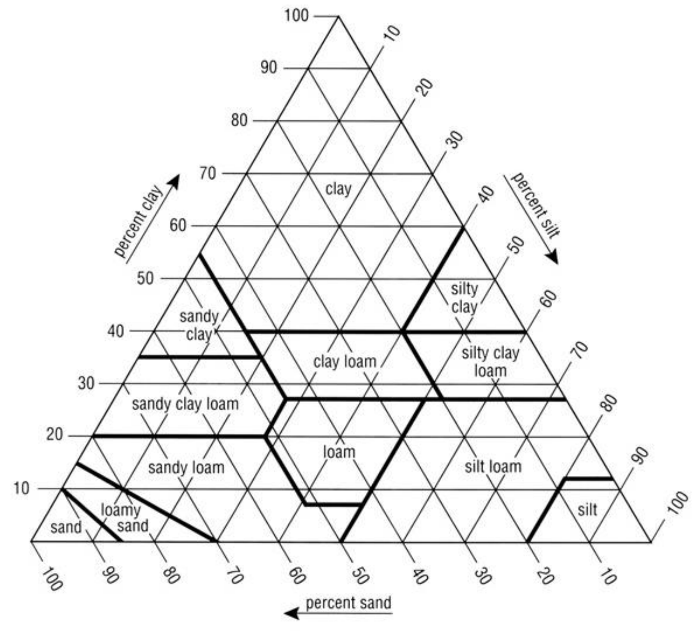


Chart showing the percentages of clay, silt, and sand in the basic textural classes.

4. Understand soil consistency states and the consistency limits.

A. Liquid, plastic, friable, loose, hard, frozen.

A soil is in the liquid state when it acts as a viscous liquid when jarred.
A soil is in the plastic state when it can be molded in different shapes.
A soil is friable when moist soil crumbles into aggregates when crushed with only light pressure.
A soil is loose when it has no consistency at all, typical of dry, structureless sand.
A soil is hard when it can only be crushed with difficulty between crumb and forefinger, typical of dry, structureless clay soils.

B. Liquid limit and plastic limit.

The ***liquid limit*** is the limit between the plastic and liquid state.
The ***plastic limit*** is the limit between the friable and plastic state.

C. "Ball test" to assess conditions for tillage and traffic.

Grab a fistful of field soil in your hand and mold it – if you can form a ball the soil is in the plastic state and highly sensitive to soil compaction by traffic and tillage. In contrast, if the ball breaks into smaller pieces, the soil is in the friable state and resists compaction and can be tilled.

5. Understand and be able to use soil survey publication to:

A. Determine soil type at any location.

Select the soil survey of your County. Soil surveys can be obtained from the USDA-NRCS or Soil and Water Conservation District (SWCD) in your County. Go to the Index to Map Sheets and select the map of your location. On the map, find your location. You will see a Soil Series Symbol designation. Go to the Soil Legend and determine what this symbol stands for. Contact your local NRCS or SWCD office for information on digital soil survey availability. Soils information can be obtained electronically through Web Soil Survey.

B. Interpret soil properties and suitability for agricultural and other purposes.

A general idea of the suitability of soils in your County can be obtained from the General Soil Map Units in the Soil Survey. Each soil association has a short description with most salient potentials and constraints for agricultural production. More specific information about the suitability of each Soil Series for production can be obtained in the Detailed Soil Map Units section. You can also go to the table of yields per acre of crops and pasture to determine the yield potential at high levels of management of each soil type. Absence of a yield indicates that the soil is not suited to that crop or not used for that purpose.

6. Understand soil structure and its importance to crop production and environmental protection.

Soil structure is defined as 'the arrangement of primary soil particles into groupings called ***aggregates or peds'*** (Brady and Weil, 1996). Soil structure determines properties such as total porosity, air-filled and water-filled porosity, pore-size distribution, soil tilth, and aggregate stability. A soil with a well-developed structure will have larger total porosity and greater air-filled porosity and therefore will be better drained and provide a better environment for root growth than the same soil with poor structure. The soil will also absorb water better. This water will be filtered by the soil before it is released to groundwater instead of running off. Runoff causes soil erosion and carries nutrients, organic matter, and pesticides to surface water, causing an environmental threat.

7. Understand different types of soil organic matter, their dynamics, and roles with respect to soil function.

Organic matter largely determines the quality of a soil for crop production. Typical mineral agricultural soils have organic matter contents of 1-6%. ***Organic matter*** consists of three distinctly different parts: living organisms, fresh residues, and well-decomposed residues (i.e., the living, the dead and the very dead organic matter). ***Living organic matter*** is composed of roots, fungi, bacteria, viruses, protozoa, algae, insects, earthworms, and large animals. The living portion represents about 15% of the total soil organic matter. Living organisms play an important role in determining soil quality. Roots stimulate soil aggregation and create pores in the soil. Most other soil organisms live off the 'dead organic matter' and create 'very dead organic matter'. Earthworms completely modify the soil architecture by their burrowing action, and mix soil with organic matter in their intestines which forms stable aggregates upon excretion. Micro-organisms such as fungi contribute to soil structural stability through their hyphae which function as nets around primary soil particles and micro-aggregates. Bacteria produce sticky organic substances that stimulate aggregation. In the process, the living organisms recycle large quantities of nutrients and convert them to forms that are available or unavailable to plants. ***Humus*** is the end product of the decomposition of ‘dead organic matter’. Humus is not food for organisms, but it’s very small (colloidal) size and chemical properties make it an important soil component. Humus has cation and anion exchange capacity, and thus holds on to some essential plant nutrients, storing them for slow release to plants. Humus can ‘neutralize’ certain harmful chemicals, making them unavailable to plants. Humus improves drainage and hence reduces compaction of clay soils and improves water retention in sandy soils.

Competency Area 2: Soil Hydrology

8. Know the components of the hydrologic cycle.

The ***hydrologic cycle*** refers to the fate of water in and on planet Earth, from the time precipitation falls on the Earth’s surface until the water is returned to Earth’s atmosphere. The general principle is simple, and the driving force behind it comes primarily from the Sun’s solar energy. The components and processes of the hydrologic cycle include:

Precipitation – the condensed liquid or crystalline water falling from the atmosphere, in the form of rain, hail, sleet, or snow.
Interception – the process where precipitation is caught and temporarily held in a vegetative canopy before it reaches the land surface. Some of this precipitation may be evaporated directly or adsorbed by the plant, or it occurs as ***throughfall*** (i.e, water dripping off the leaves) or as ***stemflow*** (i.e., the portion that flows down the stem to the ground).
Evaporation - the process where water passes directly from its liquid or solid state to a vapor state. Evaporation can occur from vegetation, soil, or water (and ice) surfaces.
Transpiration – the process where water is extracted from soil by plants, passing up through the plant to the plant leaves and then discharged to the atmosphere through the stomata.
Evapotranspiration – the combined processes of evaporation and transpiration
Condensation – the process where water passes from its vapor state to a liquid or solid state, the opposite of evaporation.
Runoff - the portion of precipitation on a land area that is discharged from the area through streams. The portion lost without entering the soil is called ***surface runoff,*** and the portion which enters the soil before reaching a stream is called ***ground water runoff*** or ***seepage flow*** from groundwater. In Soil Science terminology “runoff” usually refers to any water lost from an area by surface flow; whereas in Geology and Hydrology, “runoff” usually includes both surface and subsurface flow that eventually reaches a stream.
Infiltration – the downward entry of water through the soil surface and into the upper soil layers.

9. Describe the water budget for a soil profile.

The water “budget” for a soil profile refers to the water additions, subtractions, and the amount of water stored or remaining in the soil. The hydrologic cycle component which adds water to the soil is Infiltration, and Evapotranspiration processes are components of water removal. Within a particular volume of soil, such as the plant root zone, is the ***soil water***, the amount of water that the soil volume can store. The ***available soil water holding capacity*** refers to the amount of water the soil can hold, that is considered available to plants for evapotranspiration purposes. Any excess water which infiltrates, and which cannot be retained as the soil water becomes ***deep percolation***, the water that moves downward through the soil profile below the root zone; or if the downward movement is restricted, it's subject to ***interflow***, the horizontal movement of water out of the soil volume. The interflow and deep percolation components produce the seepage flow.

10. Understand characteristics of rainfall and the concept of return periods.

The characteristics of rainfall are the ***amount***, the ***intensity***, the ***duration***, the ***frequency*** or ***return period***, and the ***seasonal distribution***. The amount is of course important to the overall hydrologic cycle and replenishment of the soil water, and the amount is an accumulation or product of the intensity times the duration. For example, the amount may be the same for a high intensity short duration rainfall as it is for a low intensity long duration rainfall. However, the intensity and duration can have a large influence on whether the rainfall infiltrates or becomes surface runoff. Higher rainfall intensity produces larger size raindrops which have more impact energy, and thus higher intensity storms can damage delicate vegetation and bare soil. High intensity storms can literally displace soil particles, causing soil crusting or starting the soil erosion process. High intensity storms may also overwhelm the soils ability to infiltrate the rainfall at the same rate, causing infiltration-excess runoff. The duration refers to the length of time rainfall occurs. A high intensity rainfall for a short duration may affect tender seedlings, but it will not likely have much effect on soil erosion and runoff. Rainfall of longer duration can significantly affect infiltration, runoff, and soil erosion processes.

The frequency, or more specifically, the return period refers to how often rainfall occurs at a particular amount or intensity and duration. For example, rainfall return periods are referred to as 100 year-1 hour rainfall or 100 year-24 hour rainfall to define the probability that a given amount will fall within a given time period. The 100 year-1 hour rainfall amount will be somewhat less than the 100 year-24 hour rainfall amount for a given location, but the 100 year-1 hour rainfall typically reflects rainfall of higher intensity. Return periods are based on the historical precipitation record, but a 100 year return period does not necessarily mean 100 years will lapse between this type of rain event. The rainfall intensity, duration, and frequency are primary input parameters to soil erosion prediction models such as RUSLE. Return periods are most often used in the design of water management and control structures in order to size them appropriately. Return periods are also being used in a regulatory context, whereby a CAFO facility must meet a no-discharge rule for a 25 year-24 hour rainfall event.

The seasonal distribution of rainfall refers to the time of year when various rainfall amounts occur. The seasonal distribution of rainfall in relation to the evapotranspiration has a major affect on components of the hydrologic cycle and the soil water budget, and also on crop growth in the short term and on what types of crops can be grown. The seasonal distribution determines when surface runoff or deep percolation are most likely to occur or if irrigation is needed. Since the seasonal distribution of rainfall varies in different parts of the country, practices used or recommended in one part of the country may not necessarily be appropriate in another. For example, tillage practices to conserve moisture in Western Kansas are not likely necessary in New York. Or applying anhydrous ammonia in the fall in the upper Midwest may be appropriate, whereas following this same practice in the Northeast often leads to substantial nitrate leaching and little fertility benefit to the next year's crop.

11. Understand factors that affect:

A. Soil infiltration.

Infiltration, the entry of water into soil, occurs as a result of gravity and soil water tension forces. Other terms describing infiltration are ***infiltration rate*** – the rate, or quantity of water per unit time, at which water enters the soil, ***infiltrability*** or ***infiltration capacity*** – how the rate is influenced when water ponds on the surface, and ***cumulative infiltration*** – the total quantity (depth) of water infiltrated with time. A soil may have a high infiltration rate, but if for example the water table is close to the soil surface, it will not have much cumulative infiltration.

Soil infiltration is affected by ***soil surface conditions, subsurface soil conditions***, and other ***influencing factors associated with the liquid to be infiltrated, weather and previous moisture conditions, and the biochemical activity and process byproducts in the soil.*** Soil surface conditions can be predominant factors affecting whether or not infiltration will even occur, and these include surface sealing, the prevalence of cracks and open pores, or the development of crusts and an impermeable layer. Soil roughness, vegetation cover, and land use generally impact what happens at the soil surface by altering the amount of water available at the surface interface, and the condition and openness of the pores at the soil surface. Bare soils may easily develop crusts, or heavily tilled and pulverized soil may destroy the pore size and ability to infiltrate water. An example of how other influencing factors interact with the soil surface conditions are when water containing suspended solids (i.e., liquid manure) is applied, and which can seal the pores. Freezing weather also creates an impermeable soil surface. Soils which are extremely dry do not conduct water very well, at least not until further wetting occurs, so a dry soil surface may initially shed water. This phenomenon explains why runoff can occur in a desert environment. Hydrophobic (water repellent) soil conditions can be induced also such as when a wildfire produces byproduct residue that tends to repel water from infiltrating the soil surface.

There are many factors related to subsurface soil conditions that ultimately influence soil infiltration too. The most common factors are soil type (or more specifically the texture, structure, and size of soil pores), the existence of soil layers that conduct water differently, and the water content of the soil. In general, the ***steady infiltration rates*** for different soil textures are:

- Gravel and coarse sands - > 0.8 inches per hour (iph)
- Sandy loams – 0.4 to 0.8 iph
- Loams – 0.2 to 0.4 iph
- Silty clay loams & clay soils - < 0.2 iph

Exceptions to this list occur when a clay soil has extensive cracks or macropores. Soil layers that conduct water at different rates will influence the cumulative infiltration. A common example of this is when a plowpan is formed by tillage, causing a shallow compacted layer. Some natural soil layering features are fragipans or unfractured bedrock at shallow depth. Infiltration ceases in a soil that is already saturated to the surface, so already wet soils and certainly the presence of a water table will limit cumulative infiltration.

A common approach to classifying a soil's overall infiltration is the ***soil Hydrologic Group***. Soil hydrologic groups are divided into four groups (A,B,C, and D) in which **hydrologic group A has the highest infiltration** rate and cumulative infiltration, and **group D the lowest**. These general groups can be somewhat misleading, however, because they are largely based on the general soil type and texture, and thus fail to consider some of the other many factors that affect infiltration. An example where the hydrologic group classification does not always reflect what may actually happen in the field is where a silt loam soil is given and group C or D classification (because of the fine texture), but this soil is shallow and over limestone or highly fractured bedrock. The shallow soil is soon saturated, allowing the soil to achieve its maximum hydraulic conductivity, and water then flows downward through the bedrock fractures.

Infiltration capacity refers to which force (gravity or soil water tension) controls the infiltration rate. As soil starts to saturate, the predominant force driving infiltration switches from the soil water tension to gravity. For an unsaturated soil, the initial infiltration rate is higher when the soil is dry compared to when it is wet because the drier soil has more negative tension. A good analogy is a dry paper towel versus one that is already partially wet. Because of this phenomenon, initial infiltration rates may be quite similar for unsaturated sand or clay soils. However, once the soil becomes saturated the infiltration rate becomes steady, and this **steady infiltration rate or saturated hydraulic conductivity** for sandy soils is much higher than those for clay soils as given in the above table.

B. Evaporation and transpiration.

The primary factors that affect the ***potential evaporation and transpiration***, if water is readily available from soil and plant surfaces, are:

- Solar radiation
- Temperature
- Humidity
- Wind

Solar radiation and temperature are the thermal (radiation and sensible heat energy) sources that cause water to evaporate from the earth's surface. The amount of heat energy needed to cause water to pass from a liquid to a gaseous state is called the ***latent heat of vaporization***. For a clear sky in the Northeast on the first day of summer, the maximum incoming (extraterrestrial) solar radiation potential provides enough energy to evaporate about a half inch of water per day. However, some of this solar energy is absorbed and diffused by clouds, some is reflected from soil, water, and plant surfaces (the ***albedo***), and some goes into heating the atmosphere and the soil. A heavy cloud cover in the lower atmosphere can significantly affect the amount of solar radiation that reaches the earth's surface. Since the incoming extraterrestrial solar radiation energy is reflected and diffused as it passes through the atmosphere, the net radiation potential reaching the earth's surface is much less. At the earth's surface, the potential evaporation and transpiration is about half to two-thirds the maximum, or generally around one-fourth inch of water per day when summer begins.

Humidity (vapor pressure) and wind are the aerodynamic forces which influence evaporation and transpiration. Humidity affects the vapor pressure gradient of the atmosphere and wind mixes and alters the vapor pressure gradient. At 100% humidity the atmosphere is saturated with as much water vapor as it can hold, so high humidity has the effect of reducing the amount of evaporation and transpiration that occurs. If there is no wind, the water vapor is not transported away from the evaporating or transpiring surface. We feel these same effects as we desire more water on a clear, hot, low humidity, windy day compared to a cloudy, cool, high humidity, still day.

Since the potential assumes water is readily available from soil and plant surfaces, another term, the ***actual evaporation and transpiration***, is used to adjust for when free water is not readily available on the soil surface or on plant surfaces (at the stomata). As the soil surface dries, water is less available at the surface, and dry soil is also not very conductive. On bare soil you may have observed that the soil is still quite moist just below a dry surface. As the soil dries, plant roots also have more difficulty extracting the soil water. Thus, the actual evaporation and transpiration may be less than the potential. The soil water availability (soil coefficient) and type of plant (crop coefficient) further determine the difference between the potential and actual evaporation and transpiration that occurs.

C. Leaching.

Leaching is the removal of soluble material(s) from soil or other permeable material by the passage of water through it. Leaching depends on whether or not there is a soluble material dissolved in the soil water, and whether or not this soil water is moving, such as via deep percolation. Thus, many different soil chemical, physical and biological properties and interactions can influence the degree of leaching. For example, if one adds common table salt ($NaCl$ – sodium chloride) to the soil, it can easily dissolve into separate sodium (cation) and chloride (anion) ions. Since soil (i.e, clay) particles exhibit a negative charge, some of the sodium may bind to the soil, whereas the chloride will not. When percolation occurs, the chloride is then more readily leached (transported) downward through the soil. Different soil types have different percolation (infiltration or hydraulic conductivity) rates. So when adding $NaCl$ to a gravelly soil, as compared to a silt loam, more chloride will be leached through the gravel because it has a higher percolation rate. Also, more sodium will be leached through the gravelly soil, compared to the silt loam because the gravelly soil also binds less of the sodium (has a lower cation exchange capacity). Similarly, nitrate-nitrogen is more subject to leaching than ammonium-nitrogen because of its solubility and availability in the soil water, and more of each will be leached through a gravelly soil because of its higher percolation rate.

D. Runoff.

Surface runoff or overland flow occurs when the soil cannot infiltrate water fast enough or when infiltration ceases, and there is no further capacity to store the water near the soil surface. When the rain intensity is greater than the soils infiltration rate, the excess free water accumulates at the soil surface. This ***infiltration-excess*** may quickly result in overland flow if there is no vegetation or surface depressions that help store it, and the soil surface is sloped. A vegetative cover on the soil is very important to intercepting and dispersing the raindrop impact energy of high intensity rainfall events and in slowing the movement of overland flow when it occurs, but a thick vegetation mat or sod thatch can also provide some water storage.

Surface storage or ***depressional storage*** refers to the amount of water that can be held on the soil surface before overland flow occurs, and small depressions on roughly tilled fields may hold considerable amounts of water, delaying the onset of overland flow. Infiltration-excess runoff depends on the soil's infiltration rate, and may occur anywhere in the landscape where soils with low infiltrability occur. Infiltration-excess type runoff rarely occurs on the coarser textured soils or in soils with extensive macropore development.

When the amount of rainfall is greater than the cumulative infiltration capacity of the soil, infiltration ceases and the excess free water accumulates at the soil surface as a result of ***saturation-excess***. Soils with shallow impermeable layers or poorly drained soils where water tables are close to the surface have limited cumulative infiltration capacity, and are thus quickly vulnerable to saturation-excess runoff. Saturation-excess runoff is not sensitive to rain intensity or soil type (infiltration rate), but depends on where the saturated areas occur in the landscape.

Water that infiltrates and is in excess of the soils available water holding capacity is subject to seepage flow or groundwater runoff. In flat landscapes this excess water causes a rise in the water table, saturates the soil, and this saturation-excess recharges and fills streams, or eventually leads to flooding conditions. In sloping landscapes, the excess deep percolation also raises water tables, concentrating the water to lower portions of the landscape and recharging streams. In sloping landscapes where the subsoil is comprised of layers which conduct water at different rates, interflow above the lesser conductive layers redistributes water laterally to lower parts of the landscape, saturating low lying areas and in some situations producing springs.

Surface runoff from a field can occur anytime as a result of a single high intensity storm on a soil with a low infiltration rate (infiltration-excess). But in the Northeast USA most runoff generally occurs as a result of seasonal excesses of water being redistributed in the landscape, saturating some parts of the landscape and producing runoff (saturation excess) from these areas and which recharges intermittent and perennial flowing streams. Hydrologists refer to this latter process as ***variable source area*** runoff because the runoff is generally derived from the same rapidly saturating areas in some parts of the landscape.

E. Soil Water Storage.

The soil water storage or soil water content can be quantified on the basis of its volumetric or gravimetric water content. The ***volumetric water content*** is the volume of water per unit volume of soil, expressed as a percentage of the volume. The volumetric water content is a convenient and useful way of expressing the soil water content for water budget purposes because the percentage is easily converted into a depth of water for some volume depth per unit area. The ***gravimetric water content*** is the mass of water per unit mass of dry (or wet) soil. The gravimetric water content is a more convenient way to express the amount of stored soil water when making direct water content measurements of the soil. The volumetric water content is equal to the gravimetric water content times the soil's bulk density (on a dry soil basis).

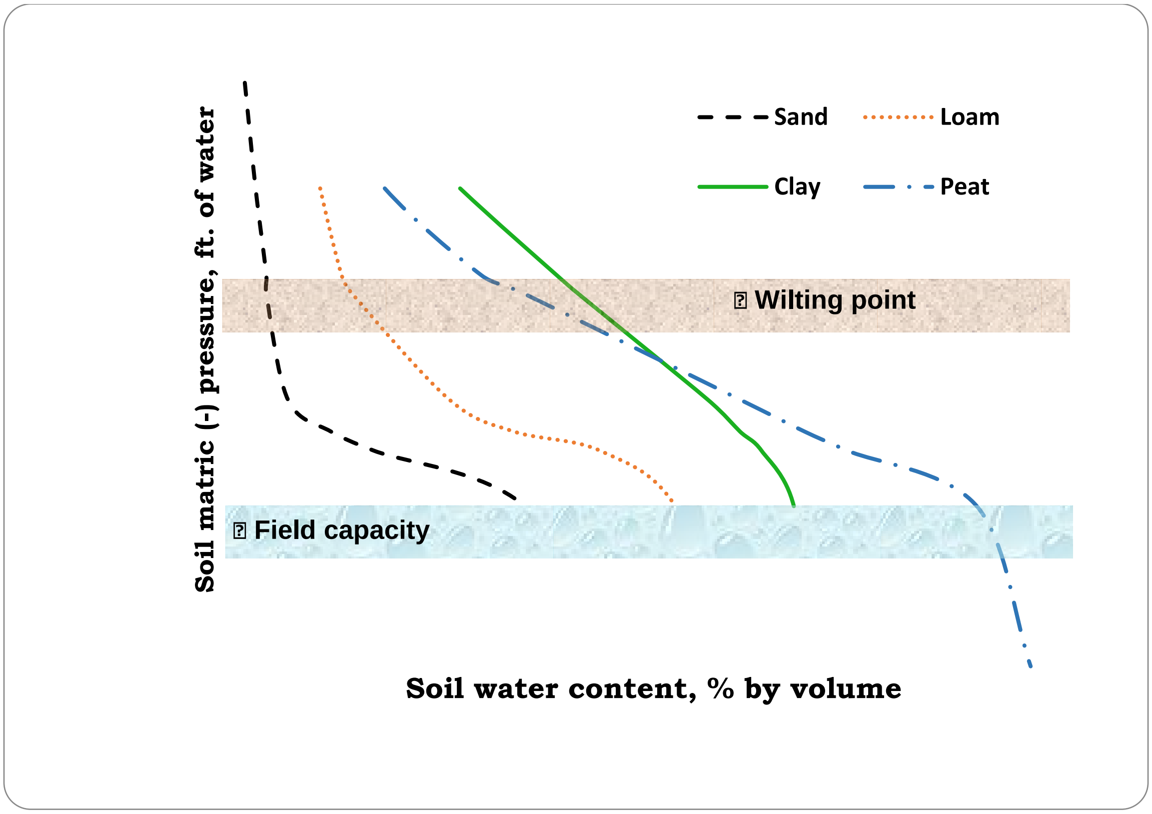
Factors that affect the soil water storage are: (1) the total porosity or void space, (2) the pore-size distribution and connectivity, and (3) the soil water pressure potential or energy status of the soil water.

The ***total porosity*** or void space ultimately establishes the upper limit of how much water can be stored in a given volume of soil. When **all the pores are filled with water the soil is saturated**, and cannot store any more water. The total porosity is a function of the soil's particle size, particle uniformity and packing or structure because the void space that remains between the solid particles determines the extent and distribution of pore sizes and their connectivity. If one fills the same volume with sand and clay sized particles, the total porosity of the clay is somewhat higher, about 50-55% of the volume compared to about 35-40% for sand. The spaces between the sand particles will have larger voids, but there will be fewer of them. The total porosity of medium textured loamy soils is generally around 50% because the smaller silt and clay particles fill some of the voids between the larger sand particles. Soils with good structure will have somewhat higher total porosity than soil that has been compacted (i.e., where the soil particles are forced closer together).

The solid particle density for many mineral soils is about 2.6 grams per cubic centimeter or about 160 pounds per cubic foot. Thus, a dry soil with 50% total porosity will weigh about 80 pounds per cubic foot. The dry weight of an acre-furrow slice, taken to be around 6 to 7 inches depth, then turns out to be about 2 million pounds [(7/12 ft) x (43,560 square feet per acre) x (80 pounds per cubic foot)]. This value is frequently used to convert soil test results, usually reported in milligrams per kilogram (mg/kg or parts per million) to pounds per acre, since the mg/kg result can simply be multiplied times two. Also, since water weighs 62.4 pounds per cubic foot, a cubic foot of soil with 50% total porosity and which is saturated will have a water weight of 31.2 pounds per cubic foot. Consequently, the total weight of this example saturated soil will be a little more than 110 pounds. The volumetric water content of this saturated soil is 50%, and the gravimetric water content of this soil is 31.2 pounds/80 pounds (= 0.39) or 39%. The bulk density of this soil is thus 50%/39% or about 1.3 (grams per cubic centimeter), which is more or less typical of an untilled medium textured soil.

The important influence of pore-size and distribution on soil water storage is in regards to how different pore sizes respond to energy forces or the ***soil water pressure potential***. Under saturated conditions, large pores drain more easily in response to ***gravity potential***. Also, when the soil is unsaturated, large pores are less subject to ***capillary (or matric potential)*** forces. In unsaturated soil conditions, the soil water pressure potential becomes negative (suction), and the degree to which this occurs greatly influences the soil water storage (retention) or water content in different sized pores. The ***soil water characteristic (retention) curve*** defines the relationship between the soil water pressure potential or energy status (matric or suction potential) and the soil water content. It's important to note that soil water moves in direct response to the energy or pressure potential forces acting upon it (i.e., moving from a higher to lower energy status), and not necessarily in response to different soil moisture contents (i.e., from higher to lower soil moisture content). The soil water characteristic curve(s) and definitions are used to establish and further refine and quantify the general availability of soil water which is often referred to as (1) ***gravitational water*** (water subject to drainage), (2) ***capillary water*** (water available to plants), and (3) ***hygroscopic water*** (water that is not available to plants). The following figure shows general soil water characteristic curves for various soil types.

Differences in soil water pressure potentials from one point to another in the soil and throughout the larger landscape determine how water will move. Engineers often use the terminology of pressure in fluid flow, or ***hydraulic head***, which is the sum of the gravity potential and the pressure potential. For water movement in soil, the water table is used as a convenient reference because below the water table the total porosity of the soil is saturated, and above the water table, the soil porosity is unsaturated (the soil water content is less than the total porosity). The ***water table*** is defined as the upper surface of groundwater (saturated zone) or that level in the ground below the soil surface where the water is at (and in equilibrium with) atmospheric pressure. At the water table reference, the pressure potential is set equal to zero. Thus, below the water table, the pressure potential becomes positive, and above the water table the pressure potential becomes negative. This negative pressure in unsaturated soil is termed matric, tension or suction pressure potential so as not to confuse it with positive pressures. A typical ***pressure gauge*** is also referenced to the atmosphere so a ***vacuum gauge*** is used to measure the negative pressure on the suction side of a centrifugal pump. Similarly in soil, a ***tensiometer***, equipped with a vacuum gauge, is used to measure the negative pressure potential exerted in unsaturated soil. The ***standard atmospheric pressure or bar***, as measured with a barometer, is 29.5 inches of mercury which is equivalent to 14.5 pounds per square inch, 33.5 feet of water, 1020 centimeters of water, or 100 kilopascals. The atmospheric pressure is what pushes on the free water surface and allows one to easily draw (vacuum) liquid up through a straw, or similarly allows for a centrifugal water pump to be placed above a water surface. Plants are also able to extract (transpire) the soil water that is held at a negative pressure in unsaturated soil because the plant water energy status produced at the opening of the stomata in the leaves is even more negative (around – 15 atmospheres or bars) in response to atmospheric conditions.



12. Know the relationship between the listed soil parameters and soil water content, soil water tension, soil pore size, plant growth and the fate and transport of nutrients and pesticides. Qualitatively understand how these parameters vary for different soil types.

A. Field capacity.

The ***field capacity*** is the amount of water remaining in the soil a few days after having been wetted and after free drainage (the downward water flow due to gravity - the gravitational water) has ceased. The matric potential at this soil moisture condition is around - 1/10 to – 1/3 bar. In equilibrium, this potential would be exerted on the soil capillaries at the soil surface when the water table is between 3 to about 10 feet below the soil surface, respectively. The larger pores drain first so gravity drainage, if not restricted, may only take hours, whereas in clay soils (without macropores), gravity drainage may take two to three days. The volumetric soil moisture content remaining at field capacity is about 15 to 25% for sandy soils, 35 to 45% for loam soils, and 45 to 55% for clay soils.

B. Permanent wilting point.

The ***permanent wilting point*** is the water content of a soil when most plants (corn, wheat, sunflowers) growing in that soil wilt and fail to recover their turgor upon rewetting. The matric potential at this soil moisture condition is around -10 to -20 bars, or commonly estimated at -15 bar. Most agricultural plants will generally show signs of wilting long before this moisture potential or water content is reached (more typically at around -2 to -5 bars) because the rate of water movement to the roots decreases and the stomata tend to lose their turgor pressure and begin to restrict transpiration. This water is strongly retained and trapped in the smaller pores and does not readily flow. The only way to remove the remaining hygroscopic water is to add heat energy and evaporate it out. The volumetric soil moisture content at the wilting point will have dropped to around 5 to 10% for sandy soils, 10 to 15% in loam soils, and 15 to 20% in clay soils.

C. Available water capacity.

The ***total available water (holding) capacity*** (or capillary water) is the portion of water that can be absorbed by plant roots. By definition it is the amount of water available, stored, or released between in-situ field capacity and the permanent wilting point water contents. The average amount of total available water in the root zone for various soil types is given in the table below.

Soil Type	Total Available Water, %	Total Available Water, In./ft
Coarse sand	5	0.6
Fine sand	15	1.8
Loamy sand	17	2.0
Sandy loam	20	2.4
Sandy clay loam	16	1.9
Loam	32	3.8
Silt loam	35	4.2
Silty clay loam	20	2.4
Clay loam	18	2.2
Silty clay	22	2.6
Clay	20	2.4
Peat	50	6.0

The soil types with higher total available water content are generally more conducive to high biomass productivity because they can supply adequate moisture to plants during times when rainfall does not occur. Sandy soils are more prone to drought and will quickly (within a few days) be depleted of their available water when evapotranspiration rates are high. In fact, the ***readily available soil water*** before plants will begin showing signs of wilting and stress is only about half of the total available water content values shown in the above table. For example, for a plant growing on fine sand with most of its roots in the top foot of soil, there is ½ x 1.8 inch, or less than one inch of readily available water. A plant transpiring at the rate of 0.25 inches per day will thus start showing stress symptoms within four days if no rainfall occurs. Shallow rooted crops have limited access to the available soil water, and so shallow rooted crops on sandy soils are particularly vulnerable to drought periods. Irrigation may be needed and is generally quite beneficial on soils with low available water capacity.

D. Total soil water storage capacity.

The total soil water storage capacity or total porosity refers to when all the soil pores or voids are filled with water. This occurs when the soil is saturated or flooded. A peat soil usually has the highest total soil water storage capacity of around 70 to 85% by volume. Sands and gravels will have the lowest total porosity of around 30 to 40% by volume. Total porosity for silt soils ranges from 35 to 50%, and clay soils typically range from 40 to 60%. Restricted drainage conditions can cause the soil to attain its total porosity water content, at which time free water is observed and perched water tables develop (in layered soils) or the apparent water table is found near the surface.

When the total soil water storage capacity is reached, air is pushed out of the pores or void spaces and oxygen and other gaseous diffusion in the soil is severely restricted. Most agricultural plants cannot tolerate this condition very long (usually no more than a day or two) as plant root respiration requires some oxygen diffusion to the roots. Without air-filled pores, the concentration of carbon dioxide and other gases like ethylene increase, producing toxic conditions and limiting plant growth. Root cells switch to anaerobic respiration, which is much less efficient than aerobic respiration in converting glucose molecules to ATP (Adenosine triphosphate – the chemical energy within cells for metabolism and cell division). As anaerobic (reduced) conditions develop in the soil, nitrification ceases and denitrification is enhanced. Corn plants will quickly yellow in response to this saturated soil state as nitrogen becomes limiting, and the plant tries to adjust by producing more adventitious roots. Prolonged anaerobic conditions in the soil starts to reduce manganese, iron (causing phosphorus to be more soluble), sulfur (producing hydrogen sulfide), and eventually methane gases. Hydrophytic (wetland type) plants are adapted to saturated soils because they are able to obtain oxygen through other forms of plant structure adaptations (i.e., pneumataphores, lenticels, aerenchyma).

E. Drainable porosity.

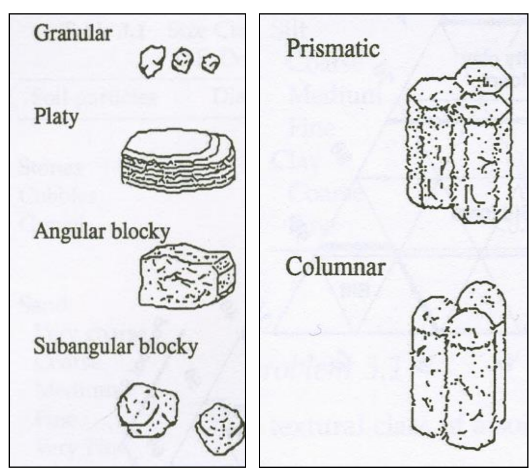
The ***drainable porosity*** or effective porosity is the pore volume of water that is removed (or added) when the water table is lowered (or raised) in response to gravity and in the absence of evaporation. At its maximum, it’s essentially the amount of water available, stored, or released between the total soil water storage capacity and the in-situ field capacity, and is generally referred to as the gravitational water. In hydrogeology, this water is referred to as the ***specific yield*** in unconfined aquifers. Some average values for the drainable porosity on a volumetric water content percent basis are 2% for clays (with no macropores), 5% for clays with macropores, 7% for sandy clay, 10% for silt, 15% for sandy silt, 20% for fine sand, 25% for medium sand and fine gravel, 30% for coarse sand, and 20% for coarse gravel and pebbles. The drainable porosity tends to decrease for coarse gravel and cobbles because the total porosity is also low for these materials.

Consider a soil that is saturated with the water table at the surface. If this soil has a subsurface drainage pipe (tile) buried several feet down and it is discharging to the atmosphere (above a water surface) at some lower elevation, the drainable porosity water content will be released to the tile drain until the water table is lowered to the depth of the drain. The soil water content at the depth of the drain will be still at its total porosity water content, but at the soil surface, the soil water content will now be decreased, potentially to the field capacity water content. The actual soil water content over this profile depth will vary, based upon the shape of the soil water characteristic curve in response to the varying soil matric pressure potential.

Since at low matric pressure potentials the big pores empty first, sandy soils will have a larger drainable porosity compared to a loam or clay soil. Macropores or good soil aggregation in loam and clay soils will increase the drainable porosity of these soils, and facilitate the drainage removal of this excess water. Any nutrients or pesticides dissolved or suspended in this readily drainable pore space will also be carried along with this water, either flowing to a tile drain or continuing downward to the water table via deep percolation if no drainage restriction exists. In large pores, nutrients that might otherwise adsorb to the soil particles (ammonium or phosphate) will bypass the soil because of limited time for contact and chemical reactions to occur with the soil surface area. Soils with a wide range of different pore sizes (sandy loams) or soils with mostly small sized pores are better at filtering nutrients and pesticides as they leach through the soil profile.

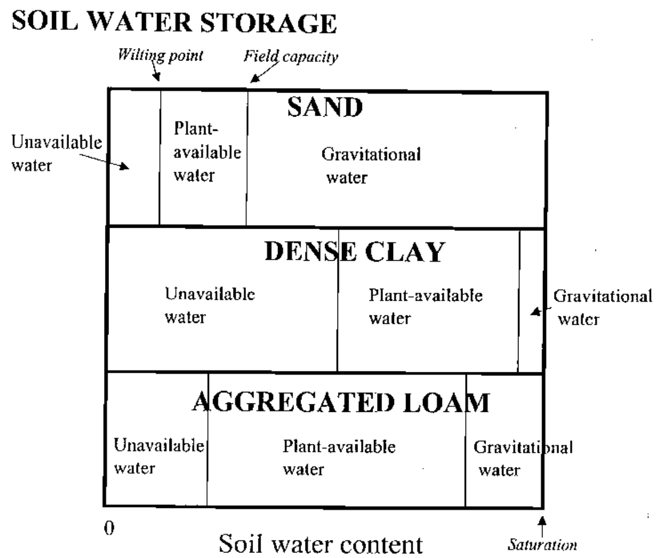
The combined aspect of low available water holding capacity and high drainable porosity for sandy soils causes these soils to have a high leaching potential. It will not take much rain or irrigation (or application of liquid manure) to replenish the available soil water and to raise the soil water content to a drainable state. If there is no drainage restriction, deep percolation will quickly move soluble nutrients like nitrate below the root zone. Applying the proper amount (depth) of irrigation to these soils will both conserve water and enhance irrigation and nutrient use efficiency. In soils with shallow (low permeability) layers, these may also soon be overwhelmed with high rainfall or irrigation application amounts. However, in this case, the soil will soon become saturated, reducing plant growth, and enhancing the opportunity for surface runoff to occur. Since phosphorus is mostly available near the soil surface, it can readily be transported then if surface runoff occurs.

F. Soil texture, structure.



The size and percentage of individual soil particles determines a soil's *texture*, but when the bulk arrangement of these particles is considered, the term *structure* is used. The clustering or ***aggregation*** of primary soil particles into compound particles of naturally formed peds or separate soil aggregates can greatly modify the textural influence on soil air and moisture relationships. The soil texture and structure fundamentally determines the number and sizes of soil pores, which will influence the fate and transport of air (gas) and water exchange. Various soil forming processes lead to natural structural ped features, and soil scientists classify these into ***granular, crumb, platy, angular blocky, subangular blocky, prismatic, and columnar*** types as shown here. Pores exist around these structure types, and some (i.e., crumb, subangular blocky) will also contain interstitial porosity (smaller micro-pores within the aggregate or ped). A platy structure usually impairs permeability because the horizontal plates often overlap, but a blocky structure may lead to even larger pore sizes than would be found between individual soil particles. The blocky structure affect on pore space is particularly important in clay soils, and is generally what provides the drainable porosity. Angular and subangular blocky structures are commonly found in B horizons of soils developed in humid regions. Sands are often considered structureless, because aggregation in sands occurs less frequently. The breakdown of structure by raindrop impact or tillage is what may lead to soils forming crusts or for puddling to occur. Root growth, the actions of microorganisms, and the availability of nutrients are all influenced by structural conditions. Fine roots and many microorganisms utilize, and probably hide in the interstitial porosity, whereby biochemical reactions and nutrient exchanges occur. Consequently, structure is of fundamental importance to good soil health.

Soil structure can be modified naturally by soil microorganisms. The effect of worm burrows in forming macropores is perhaps best known because it can be easily visualized. However, modern tillage implements also greatly modify the soil structure within, and sometimes below (plowpan), their range of depth influence. The following figure provides an illustration of how various parameters of soil water storage may be influenced by different texture and structure aspects (From H.M. van Es).



G. Macroporosity/Preferential flow.

Macropores or macroporosity commonly refers to those soil pores through which water flows primarily in response to gravity. Macropores are thus less influenced by capillarity, and will exhibit low (near zero) soil matric pressure potentials. Macropores occur in coarse sands and gravels, soil structural cracks, or may form as the result of worm holes, other small burrowing microorganisms, decaying roots, and some tillage operations. The influence of macropores on drainable porosity has long been known, but it only has been in recent decades that its importance to soil water and contaminant movement has received close attention. Since water can be infiltrated quickly and flows rapidly downward in macropores, it is also termed ***preferential flow***. The significance of macroporosity and preferential flow is that nutrients and other dissolved and suspended substances can be rapidly transported down past the root zone without substantial filtration or other biochemical remediating interactions. Although the magnitude of macroporosity in soils is generally small (usually less than 5% of the total porosity), when only a small concentration amount of a nutrient, pesticide or other contaminant creates great risk to water quality, the environmental threat may still be significant. Macroporosity is generally beneficial to air and water exchange, soil health, and to providing more optimum conditions for plant growth, but it has also lead to water quality impacts when dissolved and suspended materials are transported to tile drain outlets or groundwater.

The deleterious effects of contaminant transport in preferential flow may be modified to some degree using tillage to disturb macropore continuity, but the impact is usually limited where macropore features extend well below the depth of tillage influence. Since water flow into and through macropores is most prevalent when soils are already in their wettest state, avoidance of applying potential contaminants during this time and prior to rainfall is one method of minimizing unwanted impacts. Applying nutrients or other materials at lower rates will also reduce concentrations of contaminants occurring in preferential flow.

13. Understand permeability and infiltrability, and how they are affected by soil type, weather, and management practices.

Permeability is the ease with which gases, liquids, or plant roots can penetrate or pass through a layer of soil or porous media. Permeability is thus both a feature of the soil pore size and distribution for allowing something to pass through it; and a feature of the gas, liquid, or plant root in its ability to diffuse, flow, or penetrate through these soil pore openings. The term ***intrinsic permeability*** refers to the property of the soil pores or any porous material to let something pass through it. One analogy of intrinsic permeability is screens with different size openings. The screen with the biggest opening is more intrinsically permeable than one with the smallest opening. The opening size may have little effect on a gas passing through, may effect on how water can move through, and a major effect on what size roots might grow through.

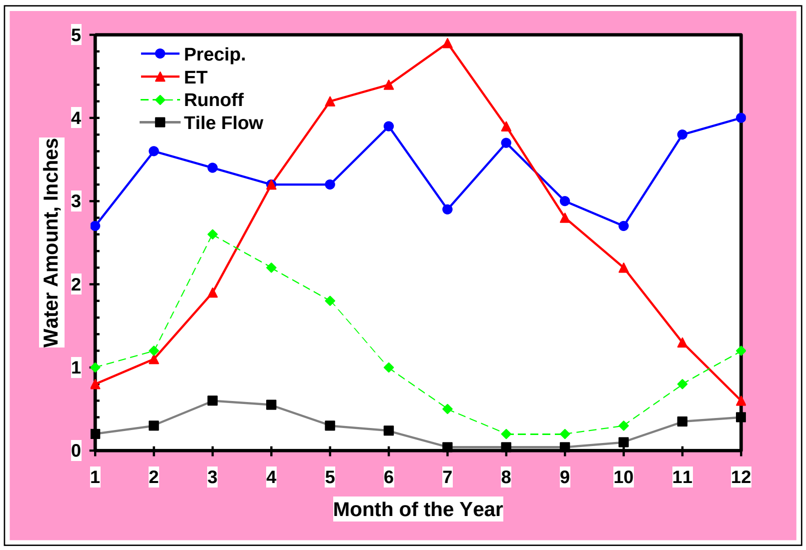
Temperature, pressure, molecular size and activity, density, and dynamic viscosity properties of gases all influence the ability of a gas to flow and diffuse through soil pores. Higher temperatures and pressures increase gas flow. Gases like carbon dioxide and ammonia are denser than air (oxygen) so these will diffuse (move) more slowly through soil pores. Methane will diffuse faster than air. Since soil gases primarily move through the larger (non-water filled) pores, compaction which compresses the larger pores first can substantially diminish the soils ability for gaseous exchange. Saturation of the pores also severely restricts gas permeability and the exchange of soil air with the atmosphere.

Liquids differ greatly from air with regards to flow properties. Water is much denser than air, and water viscosity changes more dramatically over normal environmental temperatures. Because of changes in density and viscosity, water at 35 degrees Fahrenheit will not infiltrate soil quite as quickly as warmer water. Water is also incompressible so it is less sensitive to pressure changes in the soil. Water conductivities are typically an order of magnitude greater than air conductivity because of the density and viscosity differences, but because of molecular diffusion properties of gas, gas diffusive fluxes are much greater than water. A change in barometric pressure or wind will affect gas exchange in the soil, without having much effect on water. For a soil with the same intrinsic permeability properties, gasoline will move faster than water through the soil, and water will move faster than crude oil. Liquid manure is thought to move more quickly than water through soil via gravity because it has a higher density and the suspended organics alter its viscosity. Management practices which reduce the soil's intrinsic permeability at the surface (makes soil pores smaller or causes them to be blocked or less connected) will reduce infiltrability. Practices such has heavy traffic loads or compressive tillage (plow, disk) which reduce pore size or connectivity at deeper depths may also reduce the soils overall permeability at deeper depths in the soil.

Management practices that reduce the soil's intrinsic permeability often have an effect on the ease with which plant roots can penetrate the soil and grow too. Plant roots may have difficulty penetrating and thriving in soils with smaller pores, not only because of changes in air-water relationships, but also because of alterations to the soils bulk density and soil strength. Plant roots have a more difficult time penetrating dry soils, compared to moist soils, because of differences in soil strength at different soil water contents. However, even the strength of moist compacted soils may limit root penetration. Compared to wheat or corn, tap rooted plants like alfalfa can exert greater root penetration forces to pass through compacted horizons, so plants also differ in their conductive ability to get through soil.

14. Understand how seasonal soil conditions and landscape position affect runoff and leaching.

Seasonal soil conditions change in response to the seasonal distribution of precipitation relative to the distribution of the potential evapotranspiration. In the Northeast, the distribution of the annual precipitation is similar from month to month, but the evapotranspiration peaks in July and diminishes significantly in the colder months. During the months when the rainfall is higher than the evapotranspiration, the soil will be gaining water. When the rainfall is lower than evapotranspiration, the soil water is extracted. As the soil water content increases, there is a limit to how much it can hold, the field capacity. Any rain after the soil reaches its field capacity will either drain or saturate the soil (if drainage is restricted). The water that drains becomes deep percolation and increases the opportunity for leaching in deep soils, or it will be redistributed by interflow over less permeable layers in the subsoil to lower parts of the landscape. The redistributed water generally causes soil saturation in some areas in the landscape (often at the toe of concave slopes), which eventually runs off. Although some surface runoff can occur anytime in response to large storms, most of the runoff (and tile drain discharge) begins after evapotranspiration ceases in the fall, and it peaks in late winter/early spring in response to all the additional water from snowmelt. Runoff starts to decrease in late spring in response to increasing evapotranspiration, which again begins to extract water from the soil. Runoff and leaching are minimal during the late summer months because the soil water content is usually less than field capacity, and the soil can store rains that occur at this time. In fact, during the summer months, irrigation may be needed to maintain the soil water content from dropping below critical thresholds. The following figure shows the distribution of the average water balance for Central NY.



15. Know simple field methods to assess soil water conditions.

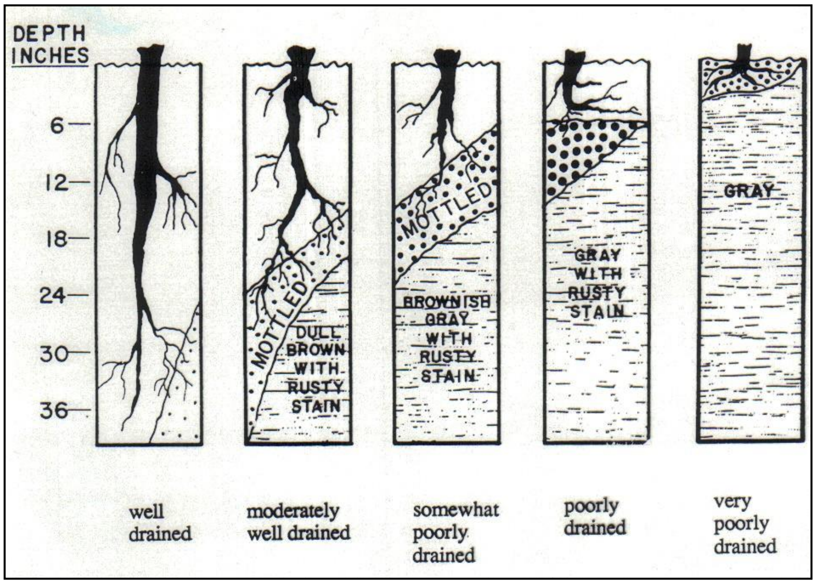
One simple method to assess soil water conditions in the field is the ***"Feel" method***, a somewhat more specific approach to the "ball test". Soil will either feel wet, moist, or dry. When the soil is wet, it will leave water on your hand (about field capacity). When the soil feels moist, it likely will be somewhere in the plant available water content range. A soil that feels dry is usually below the critical threshold of the readily available water moisture content. With some practice and experience with different soil types, one can reasonably gage the soil water content. Sandy soils may rarely feel wet because of their high drainable porosity. Sandy soils at or even above field capacity will also generally support vehicle traffic. However, a silt loam or clay soil at field capacity will often be too wet for traffic without some slippage. If your 4x4 SUV is making ruts, the soil is often above field capacity for all but the coarse sand/gravelly type soils, and a water table will likely be present within 2 feet below the surface. For a more detailed description of the "Feel" method see http://www.wy.nrcs.usda.gov/technical/soilmoisture/guideline.html. Other simple tools for monitoring soil water content include: (1) ***Capacitance probe*** - a single probe that is inserted into the soil and that provides a relative indication of soil wetness, (2) ***Tensiometer*** – a ceramic tipped probe attached to a tube filled with water that directly measures the matric (vacuum) tension or energy status of the soil, and then along with information about the soils characteristic curve, gives the volumetric water content, (3) ***Resistance (porous) blocks*** – made with gypsum or ceramic material that measures the electrical conductance of the soil, and then is calibrated to the matric tension or volumetric water content, and (4) ***Time Domain Reflectometry (TDR)*** – consisting of two or more probes inserted into the soil providing a measure of the volumetric water content. All of these tools are relatively inexpensive. The capacitance probe is very easy to use but requires some interpretation to convert relative soil wetness to volumetric water content. The tensiometer has a limited (low tension) range of measurement for soils near saturation so is not well suited to coarse textured soils. The resistance type measurement blocks are suitable for all soil types but excessive salts may interfere with obtaining accurate and consistent readings. Depending on the length of the probes, the TDR probes measure the soil water content over a slightly larger volume (rather than at a point), but may be subject to interference or inaccuracies in stony or high organic matter content soils. Another method that utilizes a much more expensive tool is the ***Neutron Probe***. It's most often used in research where the probe access tubes can be installed and left undisturbed for long time periods.

A relatively simple and very accurate method to determine the soils gravimetric water content is to extract samples from the field, weigh them, dry them in an oven, and weigh them again. This ***oven method***, however, requires an accurate scale, is a bit tedious and doesn't provide an instantaneous result.

Competency Area 3: Drainage and Irrigation

16. Understand the relationship between soil drainage class and productivity.

The ***soil drainage class*** and some characteristic features associated with each class are depicted in the following figure (from Soil Survey). One characteristic feature in the figure is the depth of rooting that typically occurs in each drainage class, providing there are no other restrictions (i.e., compacted layer) to root penetration. Deeper rooting depths are associated with well drained soils, because the depth of the water table below the surface is not restricting root growth and oxygen exchange. Although not all plant species respond the same, for most common agricultural crops, a deeper and healthy root environment translates into higher biomass productivity. Studies in New York have shown 2 to 3 fold yield increases in corn and forage production on well drained soils as compared to those grown on somewhat poorly to poorly drained soils. Another major benefit of well drained soils that affects



productivity is that the soil is more conducive to timely tillage operations without creating structural damage. This is particularly important in the Northeast, where the seasonal moisture distribution causes soils to be wet in the spring and fall, and the growing season is limited.

17. Qualitatively understand how hydrology and soil and landscape properties influence drainage class and drainage criteria.

The soil drainage classification is based on a variety of physical, chemical and biological indicators and interactions that occurred over a long time period. From a hydrology perspective, the depth of the water table below the surface, the extent of the rise and fall (fluctuation) of the water table, and the time of duration that the water table is near the surface are important indicators. The water table may reach the surface of a well drained soil, but if this happens very infrequently, it doesn't cause it to be a poorly drained soil. A very poorly drained soil classification arises out of the criteria that the water table not only reach or even exceed the surface (flood), but also that it remain close to the surface for the entire year duration, even during the summer months when evapotranspiration rates are high. The water table will rise and fall in all soils in response to rain events and seasonal water distributions, but the 'average' depth and duration of the water table position below the surface increases for each better drained condition. The 'presence' of the high water table condition is partly a function of the soil type (texture), but more importantly it is a function of the most restricting (impermeable) soil layer and the depth of this layer below the surface. For example, there are sandy soils that are classified as poorly drained. Thus, even though a sand texture (with big pores) would normally have good internal drainage, if it is underlain by clay which prevents the water from percolating away, it may still be classified as poorly drained. Poorly drained soils can also occur on the top of a hill, so although landscape position might suggest that a soil in that position should be well drained and water should easily run off, that may not always be the case. A poorly drained soil on the top of a hill is usually caused by the presence of some impermeable underlying layer. Nevertheless, poorly drained soils are more likely to be found at the base of hills and in low-lying areas of a watershed where water collects.

Noting the above figure, the important chemical and biological indicators that also help determine soil drainage classifications have to do with the ***aerobic*** (air-filled pores) versus ***anaerobic*** (saturated or water-filled pores) status. Long term anaerobic soil conditions reduce manganese and iron which results in grey/green/blue staining of soil peds as shown in the poorly drained classification. Where the water table rises and falls, the soil goes through brief periods of anaerobic and aerobic conditions respectively, which cause iron to oxidize and produce the red/brown/yellow/orange staining (***mottles***) on soil ped interfaces. The respiration and biochemical processes of soil microorganisms facilitate the aerobic/anaerobic conditions.

18. Know the advantages and disadvantages of:

A. Surface drainage.

Surface drainage is the shaping, grading, or management of the land surface to provide gradual removal or diversion of water off of the land surface. Surface drainage is accomplished by smoothing out small depressions (land smoothing) or regrading an undulating land surface to a uniform slope, and directing water to a natural or improved, constructed channel. Ridge tillage is a form of surface drainage, providing excess water that accumulates between the ridges can flow away. Soil aeration or coring is also a form of surface drainage if it facilitates infiltration of water into an unsaturated subsoil. Surface drainage refers to the orderly removal of water, both within a field or to the removal of excess water off site. Advantages of surface drainage are to minimize the duration of ponded water that inundates crops, and to minimize the prolonged saturation of soil which restricts gas (oxygen and carbon dioxide) exchange with the soil and plant root system or which prevents cultural operations. Surface drainage is most advantageous on flat lands where slow infiltration, low permeability, or restricting soil layers prevent the ready infiltration of high intensity rainfall.

A disadvantage of surface drainage is that it has a minimal affect on reducing the saturated subsoil occurring as a result of high water table conditions, especially where the source of the water is emerging from lower horizons. Other disadvantages are that if the water is not removed in an orderly manner, soil erosion may occur, and nutrient and other contaminants may be carried off in the runoff. Phosphorus and many herbicides are normally bound near the soil surface, and these may be transported in the surface drainage water.

B. Subsurface drainage.

Subsurface drainage is the removal of excess drainable porosity water in the subsoil, with the aim of lowering or controlling the water table depth below the crop root zone. Subsurface drainage is usually implemented with the use of buried corrugated (and perforated) plastic or clay (***tile***) conduits, but it can be done also by creating an unlined pore (***mole drain***), constructing ***blind (or French) drains***, excavating deep open drains, or by the use of ***tubewells*** (shallow groundwater wells). A subsurface drain must be installed below the water table (so water can flow from higher to lower energy state) or it will not work. Once the water table drops to the same elevation as the drain, the drain will no longer flow. The primary advantage of subsurface drainage in humid regions is the water table can be lowered so soils classified as poorly drained can be improved to respond more like well drained soils, with the benefits of improved productivity and trafficability. In arid regions, the advantage is mainly to minimize the buildup of excess salinity in the crop root zone.

A disadvantage of subsurface drainage is that it is often more costly to implement per unit area compared to surface drainage, especially for fine textured soils. Also, if water ponds on the surface because of surface sealing or a shallow compact layer (plowpan, fragipan), subsurface drainage is not effective in removing this excess water. The environmental disadvantages related to drainage implementation are poorly drained, wetland type habitats may be modified, and the drainage discharge water may carry unacceptable contaminants. Since subsurface drainage lowers the water table and facilitates aerobic soil conditions, nitrification is enhanced and high nitrate concentrations may occur in the drain discharge water.

C. Random layout.

A ***random layout*** refers to the irregular pattern in which surface and subsurface drainage systems are implemented into the landscape. A random layout mimics and takes advantage of natural drainage patterns, and thus surface ditches and/or subsurface drains are randomly arranged in depressional topography to improve the wettest areas of the landscape. Random systems are well suited to undulating landscapes, where the higher areas of the topography are already adequately drained. Random systems are less costly to install per unit land area improved, and generally facilitate more efficient cultural operations by reducing turns (around wet areas), allowing for larger areas to be managed as a single unit. A disadvantage of a random layout is that it may not adequately and uniformly drain the area.

D. Pattern layout.

A ***pattern layout*** is a well organized regular spacing of surface and/or subsurface drains across an area. The pattern can be ***parallel*** or ***herringbone*** shaped (at angles to a slope, channel, or field boundary). Pattern layouts are well suited to long, uniformly sloping fields where the land slope is generally less than 5 to 8%. In land slopes of 3% or less, the pattern can be oriented in any direction to take advantage of optimal field shapes. A pattern layout provides more uniform drainage improvements, but will be more costly per unit land area improved.

19. Understand the potential impacts of the following factors affecting soil drainability and the installation of drainage systems:

A. Location of bedrock.

Bedrock that is massive and un-fractured creates an impermeable boundary which can restrict soil drainage. Soils that are shallow over this type of bedrock will saturate quickly, producing interflow and surface runoff. When this type of bedrock is within less than three feet of the surface, subsurface drains are ineffective and difficult to install. Subsurface drains can be beneficial if this type of bedrock is deeper than three feet, and does not interfere with installation. Surface drainage can be used to facilitate the removal of ponding or shallow perched interflow water (i.e., water accumulated above a restrictive but otherwise unsaturated soil layer), but the benefit is marginal in fine textured soils where the soil water capillary tension sustains high water content in the soil.

On the other hand, limestone bedrock that is highly fractured and has solution cavities does not necessarily restrict drainage. Shallow soils over limestone bedrock may have a limited water storage capacity because of the shallow depth, but the excess water can usually drain away through the fractures. Water tables are usually not present and subsurface drains are ineffective. Surface drainage to remove ponded water provides some benefit on low permeability fine textured soils.

B. Soil gradation and porosity.

Soil gradation, texture, and porosity influence the drainabilty and the saturated hydraulic conductivity of soil. Compared to fine textured soil, coarse textured soils have higher drainable porosity and can conduct water more readily once they become saturated. Surface drainage is not usually necessary on a coarse textured soil, whereas it can be quite beneficial on fine textured soil. If a single subsurface drain tile line is installed in coarse and fine textured soils where both have a water table present, the drain in the coarse textured soil will receive more water and will respond quicker to a rain event. Because of the higher saturated conductivity, the drain in the coarse textured soil will also have a wider lateral effect on lowering the water table. For this reason, a pattern layout of parallel subsurface drains can be placed farther apart in a coarse textured soil, and still achieve a uniform drainage response. Subsurface drain spacing guidelines for different soil types are often made available in Drainage Design Guides for different states. For example, see pages 5 to 16 in the NY Drainage Guide [ftp://ftp-fc.sc.egov.usda.gov/NY/ Engineering/publications/drainage_guide_ny.pdf].

C. Topography.

Slope or changes in topography tend to facilitate the overall drainability of soils as excess water has an opportunity to flow to lower elevations. Soils on convex type slopes are often better drained than those within concave slopes (particularly those at the toe of the slope) because rain and excess water tends to be dispersed rather than concentrated in the landscape. The topography has a significant influence on the type of drainage systems and methods used because the installation of a drainage system by necessity also must have a place to dispose of or discharge the water that is collected. Since excess water collects at low points in the topography, the drainability of soils in this position is also made worse because outlets may be difficult to find for the water. Dikes and the use of pumping systems may be the only alternative remaining to enhance soil drainage in low lying areas. Thus, topography determines the layout of a drainage system (i.e., interceptor, random, pattern), and the outlet situation (i.e., natural, constructed open ditch, or pump).

D. Organic soils.

The internal drainability of deep organic soils is rarely a problem because of their prevalence for large pores and high drainable porosity. Some organic soils are shallow over an impermeable clay or marl, which may restrict the internal drainage. However, the larger difficulty with draining most organic soils in the Northeast is usually a result of their landscape position. Organic soils have mostly developed in low lying parts of the landscape where the natural drainage of excess water away from these areas is minimal. The installation of drainage systems in organic soils often requires constructing improved open channel outlets to remove surface and subsurface water, diverting water entering from upslope, and dike and pump systems to isolate and dewater soil areas. Both surface and subsurface drainage methods can be used but subsurface methods are frequently limited by a lack of a suitable outlet. Since organic soils are most often used and developed for growing high value agricultural crops, more intensive drainage systems are installed to reduce water stress risk. Drains are often installed at closer spacing, and the design is adjusted to remove larger volumes of water in short periods of time.

E. Type of crop.

The type of crop and its sensitivity to poor drainage conditions establishes the criteria of whether drainage improvements are needed, and to what extent. The rooting depth of a crop is one important factor, as shallow rooted crops may be able to withstand water tables closer to the surface. Although onions, which are shallow rooted, are an interesting example whereby they may be able to withstand a water table close to the surface, but if there is a deep water table and water ponds on the surface, they do not fare well. This is partly why they are well suited to organic soils, which can infiltrate a high intensity rain, as opposed to many mineral soils. For a soil of the similar drainability, one crop may do well whereas another can't compete. This is often observed when a mixed forage seeding of alfalfa, birdsfoot trefoil, and timothy are grown.

F. Outlet.

A soil may have a high drainable porosity, but its drainability depends on whether or not this gravitational water has a place to flow. Impermeable layers or a water table within the soil determine whether the drainable water will flow vertically downward, or laterally through the soil. The impermeable layer and water table also need to have some slope, or the water may not move laterally either. Without an outlet of some sort, soils saturate, water accumulates, and eventually landscapes flood. In order for a subsurface drain to lower the water table in the soil, the outlet of the pipe has to discharge to a water surface elevation that is below the elevation of the water table in the soil. If this cannot be achieved by gravity utilizing changes in topography, then pumps are required.

20. Understand the benefits and risks to the environment that are potentially inherent from a drainage system and potential for management of outlet control.

The major positive environmental effects and concerns with drainage implementation are:

- Increased productivity and value of land – wet soils can be used for more intensive land uses
- Improved trafficability, timeliness, and cost efficiency
- Reduced erosion – saturated soils cannot adsorb additional water so these may induce more surface runoff and erosion, and saturated sloping soils are less stable. Increased plant canopy from higher crop yields have a higher capacity to intercept raindrops and reduce erosion.

The major negative environmental effects and concerns with drainage implementation are:

- Land use conversion – wet soils and wetlands converted to agricultural land or other intensive (industrial, urban) land uses
- Habitat conversion – bio-diverse areas converted to mono-culture ecological systems (corn, soybean fields or houses and lawns)
- Water quantity manipulations – drainage water discharges may alter receiving stream hydrographs (i.e., extensive uncontrolled surface drainage may increase downstream peak flows and induce flooding)
- Water quality alterations – water discharged from drainage systems may contain undesirable concentrations of sediment and/or other contaminants that may enter receiving waters, as compared with runoff and leaching which occurs naturally

Potential for management of outlet control:

- Negative impacts from tile drainage can be mitigated to some extent by controlling drain tile outlets and storing water back in the field during critical periods or during the non-growing season. Other outlet controls can route tile water through various treatment systems to remove any excess nutrients that may be contained in tile outflows from cropland.

21. Understand the concept of hydric soils, hydric soil indicators, and the regulatory aspects associated with wetlands and the installation of drainage systems.

Hydric soils are defined as soils formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. Inclusion of the growing season in the definition is to assure that soil temperature and moisture conditions are favorable for microbial activity, so that anaerobiosis occurs. The hydric soil indicators may vary by region and for organic or sandy soils as opposed to loam and clay soils, but they generally must include observations of pronounced organic matter accumulation since plant decomposition is slower under saturated conditions. Mottled soil near the surface and color hue are key indicators also. The very poorly drained and poorly drained soil drainage classifications usually fit the hydric soil delineation. The hydric soil component is a key criteria of wetland delineation for regulatory purposes because soils are the most stable, long-term indicator of the three delineation criterion components (the other two being hydrology and vegetation). Vegetation can easily be removed, and hydrology is subject to seasonal fluctuations. The wetland protection rule requires permits be secured prior to draining and altering a delineated wetland. The Federal rule (implemented by the US Army Corps of Engineers) may be more stringent than state regulations, so it is best to check with both jurisdictions prior to implementing a drainage project on suspect wetland areas.

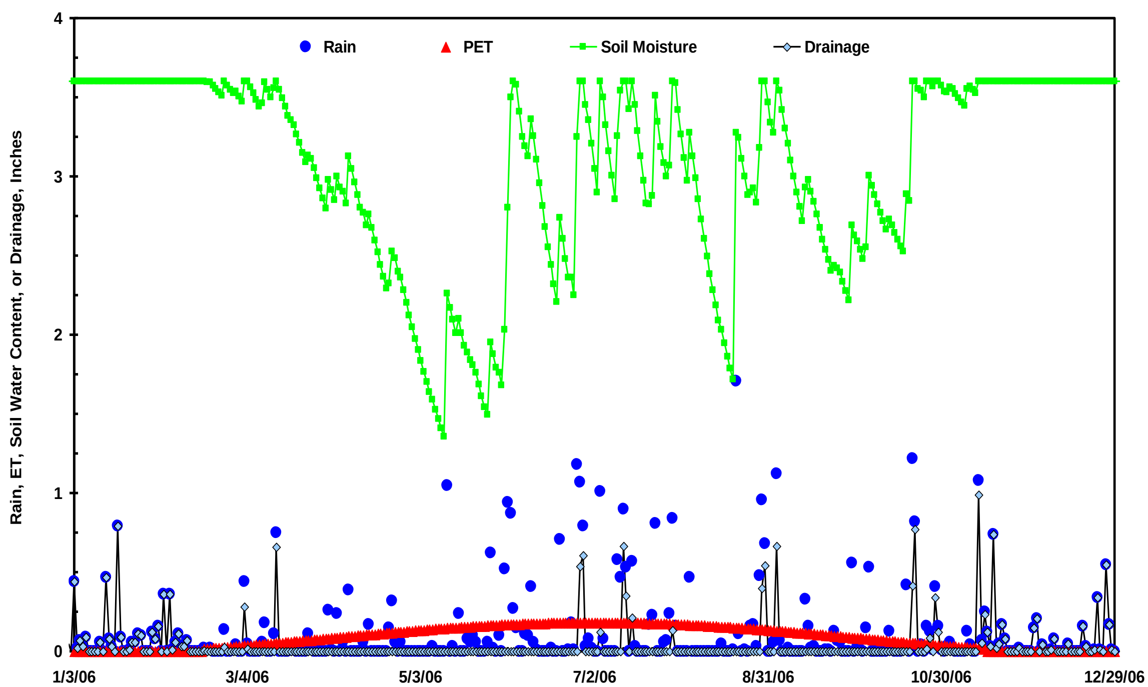
22. Explain the factors that influence the potential and actual evapotranspiration of crops.

As indicated in Item 11. B., the potential evaporation and transpiration, if water is readily available from soil and plant surfaces, is influenced by solar radiation (cloud cover), temperature, humidity, and wind factors. The actual evaporation and transpiration or evapotranspiration are also functions of the soil water content and the plant's ability to extract the soil water. For evapotranspiration, the plant root system extracts soil water from below the surface. So as discussed in Item 12. C., the total available soil water (depth reservoir) depends on the plant's rooting depth. In the same soil type, plants with deeper rooting depths will have more total water available, or similarly, for the same plant the amount of soil water available increases as it grows a larger root system. As the soil dries, plants have a more difficult time of extracting the available water, so a soil coefficient is often used to adjust the potential evapotranspiration to obtain the actual evapotranspiration. Also, plants vary in their ability and sensitivity to access the total available soil water so a depletion factor is assigned to arrive at the amount of readily available water. In the example in Item 12. C., the value of half (0.5) was used (typical of many field crops), but this may vary from 0.2 (for celery, spinach) to 0.65 (for sugar beets and sweet potato). Crop coefficients, which vary by crop and stage of maturity, are often used to adjust the actual evapotranspiration, relative to the potential, for soil water budget and irrigation scheduling purposes. For many crops at full maturity, the crop coefficient is one, but it may even be slightly more than one for tall crops like corn. In other words, at full maturity, the actual evapotranspiration of a crop is the same or slightly more than the potential evapotranspiration. The factors that influence the actual evapotranspiration of crops, and the overall (seasonal) water requirements and irrigation management decisions are:

- Type of plant
- Rooting depth and distribution
- Adaptation ability to water stress
- Growth and development stage
- Plant health

23. Understand the relationships of hydrology, the soil water budget, and crop water requirements as these pertain to irrigation system water requirements and the potential benefits of irrigation.

The soil water budget and balance is similar to balancing one's checking account. In fact one of the simple methods for irrigation scheduling is called the "checkbook" method. Rain is a deposit to the soil water budget, and the actual evapotranspiration is a withdrawal. The field capacity water content sets the upper limit (balance) of what the soil can absorb, or for the checking account analogy it is the minimum balance one may need to sustain. The daily rainfall (deposits) relative to the actual daily evapotranspiration (withdrawals) determines whether the soil water budget is wetting or drying. If the rainfall exceeds the actual evapotranspiration, the soil water increases. If the soil water is already at its field capacity water content when this occurs, then the excess is drainable (deep percolation or runoff) water. When the soil water content is less than field capacity, the soil absorbs the rain, and the soil water content increases. However, if the rain amount is more than the evapotranspiration and the amount needed to raise the soil to its field capacity, the extra must drain. When there is no rain, the evapotranspiration gradually depletes the soil water. This can go on for awhile, until the readily available water is gone, and then the plant starts to stress and stops evapotranspiring. Either rain or irrigation must occur at this time to replenish the soil water, preferably enough to raise the water content back to the field capacity. An example of a typical daily soil water budget for a loam soil with grass cover in Central NY is shown in the following figure, showing the soil moisture storage at field capacity in early March, drying down in early May, moisture fluctuation with summer thunderstorms, and then rewetting back to field capacity in November.



The crop water requirements partly depend on the potential evapotranspiration demand, but generally some minimum amount of water is needed to obtain good yields. In other words, it takes slightly more water per pound of dry plant biomass to produce a crop in a humid climate as compared to an arid (low humidity) one, but a certain minimum amount is still needed to obtain reasonable yields. Alfalfa is a low efficiency water user, transpiring about 100 gallons of water per pound of dry matter, whereas corn transpires about one-third as much, and small grains, soybeans, and most vegetables about one-half as much as alfalfa.

In the Northeast, the annual or growing season irrigation system water requirements range from about 4 to 12 inches (or acre-inches volume) to offset the difference between the rainfall and actual evapotranspiration amounts. However, for crops which have a low depletion factor (sensitive to soil water stress), are shallow rooted, and which are grown on sandy soils, these can rapidly deplete the readily available soil water during times of high evaporative demand. During mid-summer in the Northeast, the average weekly potential evapotranspiration demand is about 1 to 1.5 inches per week. Thus, for the more sensitive crops (potatoes, vegetables, dwarf rootstock trees), only a few days without rain may be detrimental. Supplemental irrigation may be quite beneficial for these crops, especially when grown on coarse textured soils.

24. Know the four methods of irrigation and the advantages and disadvantages of each with respect to different soil conditions and crop types.

The four methods of irrigation are:

- Surface
- Sprinkler
- Drip/trickle
- Subsurface

Surface irrigation consists of a broad class of irrigation methods in which water is distributed over the soil surface by gravity flow. The irrigation water is introduced into level or graded furrows or basins, using siphons, gated pipe, or turnout structures, and is allowed to advance across the field. Surface irrigation is best suited to flat land slopes, and medium to fine textured soil types which promote the lateral spread of water down the furrow row or across the basin. Surface irrigation is not well suited to soils with water tables near the surface. Surface irrigation is suited to most all types of crops providing the irrigation water can be distributed uniformly without prolonged inundation of the crop. It may be harmful to root crops which do not tolerate inundation. For small grains and forage crops where individual plants are closely spaced providing a complete cover, surface irrigation must be carried out while the plants are still small.

Sprinkler irrigation is a method of irrigation in which water is sprayed, or sprinkled through the air in rain like drops. The spray and sprinkling devices can be permanently set in place (solid set), temporarily set and then moved after a given amount of water has been applied (portable set or intermittent mechanical move), or they can be mounted on booms and pipelines that continuously travel across the land surface (wheel roll, linear move, center pivot). Sprinkler irrigation systems are adaptable to all soil types providing the application rate of the spray or sprinkler device is matched to not exceed the soil's infiltration rate. Sprinklers with large nozzles operating at too low pressures tend to produce large droplets, potentially causing soil erosion and runoff on medium and fine textured soils. Sprinkler systems are better suited to shorter crops because of the need to have the sprinkler positioned above the crop for adequate spray coverage. Seedlings and some crops may be sensitive to drop impact if drop size is not controlled, and the sprinkler drops may promote fungi and spread disease on foliage and fruit. Sprinkler systems can also be used for frost prevention, crop cooling, and fertigation.

Drip/trickle irrigation systems are methods of micro-irrigation wherein water is applied through emitters to the soil surface as drops or small streams. The discharge rate of the emitters is low so this irrigation method can be used on all soil types. The placement of individual emitters can be such that individual widely spaced plants can be watered without watering areas in between, which can provide considerable water savings in widely spaced row and orchard crops. The emitters can also be spaced to water continuous row strips (line-source emitters), but the emitters need to be positioned closer together on sandy soils to achieve lateral spread of the water. Small grain and forage crops where the entire soil surface needs to be wetted are less suited to drip irrigation, mostly because of the cost to achieve this type of irrigation coverage. Drip irrigation is well suited to fertigation if clogging of the emitters can be minimized, and the micro-sprayers can provide some frost protection or crop cooling.

Subsurface irrigation consists of methods whereby irrigation water is applied below the soil surface. The specific type of irrigation method varies depending on the depth of the water table. When the water table is well below the surface, drip or trickle irrigation emission devices can be buried below the soil surface (usually within the plant root zone). The buried drip/trickle method is best suited to medium and fine textured soils which promote the lateral spread of the irrigation water throughout the crop root zone, and it is well suited to all crop types. When the water table is close to the surface, ***sub-irrigation*** is the application of irrigation water below the ground surface by managing the water table level to within or near the root zone. ***Controlled drainage*** is a means of regulating the discharge from a subsurface drainage system to manage the water table level. However, if the water table drops below the level of the subsurface drainage system during dry periods, true sub-irrigation requires the need for adding irrigation water back into the subsurface drainage system. Sub-irrigation using water table control is best suited to organic and coarse and medium textured soils, to take advantage of the high saturated hydraulic conductivity, but minimal capillary rise, of these soils. Sub-irrigation requires soils with underlying restrictive layers, preferably positioned between 3 to 6 feet below the soil surface, so a water table can be sustained. Sub-irrigation is not well suited to shallow rooted crops or to irrigate transplanted seedlings, and it cannot provide fertigation or frost protection.

25. Understand the sources of water for irrigation and how water quantity and quality affects irrigation methods.

The sources of water for irrigation can include ***surface water*** sources, ***groundwater*** sources, ***municipal water*** supplies, ***grey-water*** sources, and other agricultural and industrial ***process wastewaters***. Surface water sources include ‘flowing’ water supplies (i.e., creeks, streams, canals) and ‘standing’ or stored water supplies (i.e., ponds, reservoirs, lakes). The distinction is important because this may affect the allowable rate of water withdrawal (pumping rate) and which irrigation method may be more appropriate. For example, a flowing water supply may not have adequate flow when irrigation is needed most, and thus the amount of water that can be withdrawn at any given time may be limited. A standing or stored water supply does not limit the pumping rate, unless the supply becomes depleted (drawn-down). A small creek may be suited for drip irrigation, but not to supply the high flow rate required of a big gun sprinkler. A flowing water supply may carry sediments and be of more variable water quality. However, both types of surface water supplies are generally of poorer quality than a groundwater supply, and often filtration is required when used with drip irrigation. Groundwater supplies may come from springs and wells, and although the quality is usually good, the available quantity that can be pumped at any time may again limit the irrigation method. It takes a very good yielding well to supply a large sprinkler system, or the duration of pumping may be limited because of excessive drawdown. Poorly developed wells pumped to excessive drawdown either collapse or go dry.

Municipal water supplies are good quality sources but are also usually limited in the amount one can withdraw at any time. Tap size or water use restrictions have to be considered, and backflow prevention of some type is required. Municipal sources are already pressurized, which makes them convenient for drip and small sprinkler irrigation systems, without the need for a pump. Grey-water is domestic wastewater, other than that containing human excreta, such as sink drainage, washing machine discharge or bath water. Quantities of grey-water may be limited for any large scale field irrigation, but may be an important source for helping to recharge ponds during drought periods. Excessive soap residues tend to prevent direct application, especially to fruit and vegetable crops.

The quality of agricultural or industrial process wastewaters often limits their use to surface or sprinkler irrigation methods, and in their suitability for fruit and vegetable crop irrigation. Agricultural wastewaters can be an important source of nutrients, but this may also cause them to be unsuited for supplying the entire season's irrigation requirement.

26. Describe the components of irrigation scheduling.

Irrigation scheduling is a soil water budget accounting process to determine when irrigation is needed and the amount of irrigation water to apply. The important components of irrigation scheduling include:

- Rainfall amount
- Potential evapotranspiration amount
- Field capacity soil water content
- Wilting point soil water content
- Allowable crop depletion factor
- Crop rooting depth
- Time of planting

As discussed in Items 22 and 23, this information allows one to determine the readily available amount of water in the plant root zone, estimate the actual evapotranspiration depletion, and account for rain replenishment. The time of planting is important relative to the potential evapotranspiration amount, and is used to account for the changes in root growth and crop canopy development (crop coefficient).

Competency Area 4: Soil Health and Compaction

---

27. Understand the concept of soil health, and know and identify some indicators.

Soil health (also called 'soil quality') is "the capacity of a soil to function, within ecosystem and land use boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health" (Doran and Parkin, 1994). Soil health is an aggregate concept affected by chemical, physical and biological factors.

A. Chemical indicators.

Total organic carbon, total organic nitrogen, pH, mineral N, available P, K.

B. Physical indicators.

Soil texture, depth of soil and rooting, soil bulk density and infiltration, water holding capacity, water retention, water content, soil temperature.

C. Biological indicators.

Microbial biomass C and N, potentially mineralizable N, soil respiration, biomass C/biomass ratio.

28. Describe different types of soil compaction, and understand their agronomic and environmental implications.

A. Plow layer.

A plow layer is created by repeated use of moldboard or disk plows at the same depth. The soil just below the tillage tool is compacted and becomes denser than the rest of the soil below or above it. Penetration resistance peaks at the depth of the plow pan, then decreases below it. Soils with high clay contents at tillage depth are especially sensitive to this type of compaction. One of the consequences is inhibition of root penetration through the plow pan. Roots can grow horizontal if they are unable to grow through the plow pan. Water will stagnate on top of the plow pan. This causes problems with trafficability, aeration, and compromises the effectiveness of artificial drainage systems. Increased runoff can ensue.

B. Subsoil.

Subsoil compaction is caused primarily by heavy machinery traffic at times when the soil is moist (in the plastic state). Subsoil compaction is primarily related to axle load. It affects root penetration and water percolation.

C. Crusts.

Crusts are caused by the impact of raindrops on the soil surface. If the soil is unprotected and has poor structural stability, soil fines will disperse and fill large pores. Infiltration capacity is reduced quickly. When wet, this thin layer is called a seal, and when it dries up it becomes a crust. Crusts can significantly harm germination of young seedlings which have trouble breaking through the crust. Increased runoff due to crusts and seals is a threat to surface water quality.

D. Surface.

Surface compaction is the compaction of the soil surface and is mostly due to surface pressure. Surface compaction results in reduction of pore space in the topsoil that causes increased runoff, reduced aeration, planting problems and reduced root growth. It can indirectly lead to nutrient deficiencies in the young plant such as potassium and phosphorus deficiency due to restricted root systems.

29. Understand the processes and management practices that cause soil compaction and their relative significance under Northeast conditions.

A. **Equipment traffic and load distribution:** Surface compaction is primarily caused by surface pressure, which can be the result of animal hoofs, tires inflated to high pressures, steel wheels, etc. The threat of this type of compaction is primarily within the top 12 inches of the soil. Subsoil compaction is primarily due to axle load. When axle load exceeds 10 tons the threat of subsoil compaction is great. If the load can be distributed over a larger footprint area, surface compaction is reduced. If the load can be distributed over multiple axles, subsoil compaction is reduced.

B. **Timing of tillage and traffic as it relates to soil water conditions**: When soils are tilled or trafficked in their plastic state they are highly sensitive to compaction, while the soils are sensitive to rutting in their liquid state. In the friable state soils are less sensitive to compaction.

C. **Tillage methods**: The moldboard and disk plows are probably the two tillage tools that pose the greatest threat to soil compaction because they are the most likely to cause formation of a plow pan. In-furrow moldboard plowing is the worst because, in addition to the tillage tool causing compaction, the tires or animal hoofs cause direct subsoil compaction.

30. Understand the negative effects of long-term tillage-intensive crop production on overall soil health and compaction in the plow layer and subsoil.

Intensive tillage leads to destruction of soil structure and reduction of residue cover. This leads to increased potential of soil erosion and runoff which negatively affect soil productivity and water quality. Intensive tillage leads to break-up of soil aggregates, which exposes occluded organic matter to decomposition. Surface organic matter content therefore decreases. Intensive tillage negatively affects soil organisms such as earthworms (especially vertically burrowing earthworms such as nightcrawlers), mycorrhizal fungi and detrital fungi which play important roles in aggregation by creating fungal hyphae which bind soil particles together and through their production of glomalin, an important substance that acts as a glue for aggregation. Intensive tillage also negatively affects many beneficial organisms that leave near the soil surface, such as ground beetles, daddy long-legs, lady-bird beetles, and spiders. Because continuity of macropores is disrupted, intensive tillage reduces drainability of the soil. Repeated and frequent tillage at the same depth with a tool such as a moldboard plow or disk will cause compaction below the tillage tool. When this is repeated year after year, a tillage pan may form. High intensity traffic at times when the soil is above the plastic limit will cause compaction. Heavy equipment such as grain carts and manure spreaders can cause subsoil compaction.

31. Understand the relation between soil compaction and the following factors. Understand each factors' relation to plant growth and important soil chemical and biological processes.

A. Aeration.

Soil compaction reduces pore volume, especially of the larger pores. This reduces air-filled porosity and aeration. This affects root function, because most crop roots start malfunctioning below 10% air-filled porosity. A poorly aerated soil leads to greater denitrification losses. Iron oxides will be reduced to ferric iron (Fe^{2+}), which is colorless and mobile. The soil will take on the color of the soil matrix (usually gray). Many soil organisms will suffocate and die in poorly aerated soils. The microbial community may go predominantly anaerobic.

B. Aggregation/structure.

Soil structure will degrade upon compaction. Most damage is done when soils are trafficked or tilled in their liquid state. When these soils dry out they tend to become hard. Roots will have problems penetrating this hard soil. Water will tend to stagnate, causing aeration problems.

C. Soil strength.
Soil strength increases in a compacted soil. Roots will have difficulty penetrating compacted soil.

D. Runoff and erosion.
Runoff and erosion will increase as an effect of compaction because of the reduced pore volume and especially macro-pores.

E. Drainage.
Drainage will be compromised because of the reduced pore size and subsequent water percolation rate in compacted soils.

32. Understand variable susceptibility to compaction among soil types due to:

A. Drainage.
A poorly drained soil will be in the liquid or plastic state for longer periods of time of the year and therefore will be more susceptible to compaction.

B. Texture.
Soils with high clay content are highly sensitive to soil compaction. This is partly due to the fact that they dry out slowly and this causes them to be in the liquid or plastic state for long periods of time, and partly because the clay platelets easily slide over each other causing them to pack more easily than sand or silt particles which are not plate-like.

33. Understand the effect of soil compaction on root and shoot growth, and crop yield.

Root growth is restricted, and shoot growth may be compromised. Seedlings will have difficulty emerging in compacted soils, while shoot growth will be reduced after emergence due to the effects of a reduced root system, nitrogen deficit due to denitrification, and inhibited root function due to lack of aeration. Crop yields can be reduced 50% in very severely compacted soils, but usually compaction losses will be hard to perceive because they are in the 2-5% range. Effects of surface compaction on crop yields can last for many years, but can usually be remediated in 1 (sandy soils) to 5 years (clay soils). Subsoil compaction, on the other hand, can affect crop yields for more than 10 years.

34. Understand the relation between soil strength and soil water content and its implication for root growth.

Soil strength is highly correlated with water content. When the soil is dry, soil strength is high, and when it is wet, soil strength is low. The effects of soil compaction on soil strength are especially severe on root penetration in dry periods of the year (summer).

35. Understand the appropriate use of a soil penetrometer and how to detect compaction layers.

The penetrometer can be a useful tool in soils that don’t have many rocks. It needs to be used when the soil is at field capacity (thoroughly moistened to depth of penetration resistance measurement). The penetrometer needs to be pushed into the soil at a rate of about 1 inch/second. Most penetrometers have indentations on the rod every 3 inches. Use this to determine at what depth the penetration resistance increases above 300 psi. Push the penetrometer in further, and record at what depth the penetration resistance decreases below 300 psi. If there is a mild plow pan, penetration resistance might not quite increase to 300 psi, but even above 200 psi root penetration is affected.

36. Understand how compaction leads to soil and water degradation. Understand the broader environmental consequences of soil degradation from compaction affecting:

A. Energy requirements.
Energy requirements of soil engaging tools such as tillage implements increase significantly due to compaction.

B. Pesticide use.
Because crops are less vigorous, they are more likely to suffer from weed infestations, disease pressure, and insect attacks.

C. Runoff and water quality.
Compaction increases runoff and compromises surface water quality.

37. Know how to prevent or minimize soil compaction.

- Prevent compaction by avoiding traffic in the field or tillage when the soil is wetter than the plastic limit.
- Reduce tire pressure to increase tire footprint and to avoid surface compaction.
- Use tracks to increase footprint and avoid surface compaction.
- Use doubles on the tractor and reduce tire pressure in them to avoid surface compaction.
- Reduce axle load to avoid subsoil compaction (don't exceed 10 tons/axle)
- Reduce use of moldboard and disk plows.
- Don't run tractor wheel in furrow
- Increase organic matter content to make soil resist compaction more
- Increase root occupation in times when soil is moist (winter period)
- Reduce the field portion impacted by tires by increasing swath width
- Avoid trafficking the whole field by respecting field roads and traffic lanes.
- Try precision traffic, driving in same traffic lanes always.

38. Describe approaches for remediation of soil compaction, and understand when they are appropriate.

A. Deep tillage (subsoil compaction).
Deep tillage can help to remediate subsoil compaction and can break through plow pans. The effects of deep tillage are usually short lived unless management adopts strategies to avoid further compaction, and to make soil resist compaction better.

B. Organic matter additions and cover crops (plow layer compaction; subsoil compaction when using deep-rooted cover crops).
Organic matter can make the soil resist compaction better, whereas growing cover crops in the fall and winter when the soil is moist can help create pathways for the roots of summer crops to follow. The roots also make pores that improve infiltration and aeration.

C. Reduced tillage (plow layer compaction).

Shallow tillage in the top 0-12 inches can help to remediate rutted soil and to address surface compaction. The effects of compaction are not typically completely eliminated, and follow-up needs to make sure compaction is not caused again.

Competency Area 5: Soil Conservation

Erosion Aspects:

39. Understand the three stages of water soil erosion and their relation to soil properties.

The three stages of soil erosion are: ***dislodgement, transportation, sedimentation***. Silt is usually preferentially dislodged and transported because clay particles tend to be flocculated and combined in aggregates which increase their mass, and sand particles are larger and heavy. Aggregation of course also affects this process: a well-aggregated soil is less sensitive to dislodgement and transportation than a poorly aggregated soil. Soil cover dramatically affects dislodgement by protecting the soil from raindrop impact. Soil cover also reduces transportation by providing physical barriers and opportunities for ponding and velocity reduction. Infiltration affects transportation. Hence a soil with high infiltration will have less transportation. Sedimentation occurs when the velocity and carrying capacity of runoff decreases. This may happen if soils change in slope or infiltration capacity.

40. Understand the main agronomic and environmental consequences of soil erosion and sedimentation.

Agronomic:

- Organic-matter rich surface soil is removed.
- Nitrogen, phosphorus, potassium, and other nutrients in mineral and organic form are lost from the field.
- Herbicides and other pesticides attached to soil particles will be removed from the field.
- Since silt particles are preferentially removed in erosion, the soil tends to either become more clayey or sandier.
- Soil depth is reduced, leading to reduced root volume and increased moisture stress.
- Rill and gully formation will compromise field work.
- Deposition can cause newly planted crops to be lost.

Environmental:

- Increased need for channel dredging.
- Adverse impacts on the recovery of underwater grass beds because the sediment reduces the amount of light reaching plants.
- Benthic (bottom-dwelling) organisms suffer increased mortality and reduced reproduction.
- Fish may be affected as increased sediment affects their feeding, clogs gill tissues, and smothers eggs.
- Siltation can alter the habitat of aquatic organisms.
- Increased turbidity may change the abundance of plankton, a prey which is important for larval and juvenile fish.

- Nitrogen and Phosphorus are carried with the sediment, contributing to eutrophication, algae blooms, hypoxia, and overall water quality degradation.
- Persistent pesticides are potentially carried to surface water where they can enter the ecosystem.

41. Understand the different types of soil erosion.

There are four types of water erosion:

- ***Inter-rill erosion***: the movement of soil by rain-splash and its transport by thin surface flow whose erosive capacity is increased by turbulence generated by raindrop impact. The term sheet erosion is frequently used instead of inter-rill erosion, but it omits the concept of rain-splash and conveys the erroneous concept that runoff commonly occurs as a uniform sheet.
- ***Rill erosion***: erosion by concentrated flow in small rivulets.
- ***Gully erosion***: erosion by runoff scouring large channels (deeper than 1 foot).
- ***Streambank erosion***: erosion by rivers or streams cutting into banks.

42. Understand how soil types differ in soil erodibility.

Soil texture, organic matter, and soil structure all affect erodibility. Silt particles are most easily removed by erosion, as sand particles are larger and can resisted movement to some degree, while clay particles are typically better aggregated than silt particles in macro-aggregates. Higher levels of organic matter causes soils to become less erodible due to the impact of organic matter on over all soil structure. Improved soil aggregate stability causes soils to be less erodible.

43. Understand how climatic factors affect soil erosion.

Rainfall quantity and intensity are important. Greater rainfall amounts per year increase the potential for erosion, but the intensity of rainfall is more important. Gentle, drizzling rain from frontal storms is not highly erosive, whereas convectional storms in summer or fall produce downpours with large droplet size which can cause severe erosion. Hurricanes also typically produce high intensity rainfall events.

44. Know how the topographic factors of slope and slope length affect soil erosion.

Erosion increases with increasing slope and slope length.

45. Explain the Revised Universal Soil Loss Equation (RUSLE).

The Natural Resources Conservation Service (NRCS) uses the ***Revised Universal Soil Loss Equation (RUSLE)*** or the Water Erosion Prediction Program (WEPP) to calculate soil loss by erosion as a function of 5 factors:

$A = R \times K \times LS \times C \times P$

Where:

A = annual soil loss (tons/acre/yr)
R = erosivity of rainfall
K = erodibility of the soil
LS = slope length/steepness
C = cropping and management factors
P = erosion control practices

46. Understand how agronomic management practices can reduce erosion.

A. Vegetation type and growth stage.

Perennial vegetation typically helps reduce potential for erosion cf annual crops because soil is continually protected by the living vegetation. However, with no-till practices that maintain high residue cover and include cover crops, continuous high soil cover can be maintained with annual crops as well. Sometimes, a perennials such as pure alfalfa can still exhibit high soil erosion because bare patches between plants increase in side as the stand ages. A mix of alfalfa and grass is therefore much more effective in limiting erosion. Closely-spaced crops such as wheat tend to provide quicker soil cover than widely spaced crops such as corn. The soil is especially sensitive to soil erosion until canopy closure with can be 6 weeks for a crop like corn.

B. Tillage and crop residue management.

Clean tillage leaves the soil unprotected by burying all crop residue. Leaving more residue at the surface will protect the soil from erosion. All tillage disturbs and loosens soil and this make the soil more sensitive to erosion.

C. Crop rotations.

Crop rotations can help control erosion by rotating perennials with annuals because the soil will not be tilled during the growth of the perennial. Rotations of crops with wide row spacing such as corn with crops with narrow row spacing such as small grains also helps combat erosion because the latter protect the soil better. If crops are planted in strips, the soil that is eroded from a bare strip will be caught in the strip with living vegetation below it.

D. Cover cropping.

Keeping the soil covered in the fall and winter protects it from erosion. The mulch left by the cover crop can protect the soil from erosion (if not plowed under). The cover crops help improve soil aggregate stability.

47. Understand the basic approaches to structural soil conservation practices.

A. ***Filter strips*** are strips or areas of permanent vegetation used to filter sediment, organic materials, nutrients, pesticides, and other contaminants from runoff.

B. ***Grassed waterways*** are natural or constructed swales of permanent vegetation where water usually concentrates as it runs off a field.

C. ***Diversions*** are cross-slope channels used to intercept surface runoff and divert it to a safe or convenient discharge point. They are usually placed above the area to be protected and are permanently vegetated with grass. They are often used on steeper slopes where a terrace would be too expensive or difficult to build, maintain, or farm. They can also be used to protect barnyards or farmsteads from runoff.

D. Ponds, surface inlets, and WASCOB's.

Ponds can act as sedimentation basins. ***Surface (open tile) inlets*** allow movement of surface runoff water into underground tile drains and safely direct discharge into surface waters. ***WASCOBs*** (water and sediment control basins) are short earthen dams built across a drainage way that trap sediment and water.

E. ***Terraces*** are broad cross-slope channels similar to diversions, used to control erosion on cropland and built so that crops can be grown on the terrace. ***Storage terraces*** store water until it can be absorbed by the soil or released to stable outlet channels or through underground outlets. Storage terraces are usually designed to drain completely in 48 hours to avoid waterlogging within the terrace. **Gradient terraces** are gently sloping channels constructed almost perpendicular to the natural field slope to reduce field slope lengths, and collect runoff water and carry it to a stable outlet like a waterway. Various different types (constructed shapes) of terraces include bench, broad-base, channel-type, conservation bench, graded, level, Mangum, narrow-base, parallel, nonparallel, ridge-type, ridgeless-channel, and steep-backslope terrace.

G. ***Drop structures*** are hydraulic structures for safely transferring water in a channel to a lower level channel without causing erosion. They can be vertical or slanting and are typically built with a vertical riser conduit (drop-inlet spillway) or an apron (drop spillway) with a plunge pool at the base. The plunge pool acts to dissipate flow and reduce erosion of the stream bottom.

Tillage Aspects:

48. Understand the purposes of tillage.

Tillage can be defined as any mechanical manipulation of soil. The goal of proper tillage is to provide a suitable environment for seed germination, root growth, weed control, soil-erosion control, and moisture control (John Deere, 1993).

49. Describe the basic components and workings of tillage systems, and understand their agronomic and environmental benefits.

Distinctions are made between primary and secondary tillage. Primary tillage is usually the deepest operation in the system, which loosens and fractures the soil to reduce soil strength, invert and cover previous crops or weeds and to bring or mix residues and fertilizers in the tilled layers. The implements for primary tillage include moldboard, chisel, and disk plows, heavy tandem, offset and one-way disks, subsoilers and heavy-duty, powered rotary tillers. Secondary tillage is used to kill weeds, cut and cover crop residues, incorporate herbicides, and prepare a well pulverized seedbed. Secondary tillage tools include light- and medium-weight disks, field cultivators, row cultivators, rotary hoes, drags, powered and unpowered harrows or rotary tillers, rollers, ridge- or bed-forming implements, and numerous variations of those.

A. ***Plow-till.***

Typically consists of primary tillage with a moldboard plow, followed by one or more passes with a disk and another type of harrow. The moldboard plow is the best weed controlling tillage tool. It also thoroughly inverts the soil, incorporating and covering residue, fertilizer or manure. Thus, it reduces ammonia volatilization if performed immediately after manure or urea application, and it reduces odor nuisance. However, the plow-till system is one of the more soil degrading tillage practices because of its aggressive disturbance and reduction of mulch cover. This system uses the most fossil fuel for field operations and takes the most labor.

B. *No-till*.

No primary or secondary tillage is performed. Crops are direct seeded with a no-till planter or drill, and weeds are controlled without tillage. Manures and fertilizers are applied to the soil surface or may be injected with low-disturbance injectors. If left at the surface, ammonia volatilization and odor are a concern. No-tillage systems conserve soil and build soil organic matter. They also have a beneficial effect on soil organisms. Fossil fuel use for field operations is low as well as labor needs. Odor from manure, planting issues through heavy residue, and weed control are the greatest challenges with this system. Even crop residue spread at harvest is extremely critical for success with no-tillage.

C. *Mulch-till.*

A type of conservation tillage which includes a form of field-wide tillage which leaves a planned amount of residue on the soil surface (generally more than 30% crop residue cover after planting). Common tillage tools used with this system are chisel plows, disk harrows and field cultivators. Erosion control is much better than that obtained with moldboard plowing due to the increased mulch cover, but not as great as that obtained with no-tillage. Organic matter content is typically higher than with plow-till, but lower than with no-till. Mixing of manure and urea fertilizers is usually sufficient to reduce ammonia volatilization (if done quickly after application) and odor nuisance.

D. *Ridge-till*.

A tillage system in which no tillage is done from harvest until planting, except for nutrient injection. Crops are grown on preformed ridges. The ridges are usually formed in the previous crop with in-row cultivators. Ridge tillage is a way to reduce use of in-crop herbicide inputs, and it is a form of precision traffic because all traffic takes place between rows. Manure is typically not incorporated, which increases ammonia volatilization losses and odor nuisance. Organic matter content is typically similar to mulch-till systems, and erosion control is good due to the high residue cover after planting. All crops need to be planted on the same row-spacing, and equipment needs to be redesigned to run between the ridges.

E. *Zone/Strip tillage*.

A system that is similar to no-tillage, except narrow tilled zones are formed either during planting or previous to planting for seed placement. The major benefit of zone tillage over no-tillage is the faster emergence of early planted summer crops such as corn. Zone tillage takes more tractor power, and equipment costs are higher than with no-tillage. Erosion control is excellent as there is no full width tillage performed

50. Understand the adaptability of tillage systems to common soil types in the Northeast based on:

A. Texture.

Light-textured soils benefit from heavy crop residue cover because of its moisture savings. These soils dry out quickly and are well-drained. No-tillage is therefore the system of choice on these soils. Heavy clay soils dry out slowly in the spring and may cause corn to emerge slowly in no-tillage with heavy crop residue cover. Mulch-till, ridge-till or zone tillage may be the optimum choice, although some attachments on the planter may achieve satisfactory results in no-tillage as well. Slope and stoniness are also factors that determine which system is optimal. On steeply sloping soils erosion control is more acute and greater residue cover more important. Stony soils are most suitable to no-tillage crop production.

B. Drainage class.

In the soil survey, soils are classified as being excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. In general, the better drained a soil is, the more suitable it is to high-residue or no-tillage farming. In well-drained soils moisture conservation is a benefit, and soil warming is generally not a big problem. In poorly drained soils, however, excessive moisture does not evaporate under a mulch layer, and early warming of the soil may be problematic, especially for corn production and other early planted crops, but not for fall-seeded crops or crops planted later than corn. High residue systems are more challenging on poorly drained soils, but can be implemented successfully with some planting equipment modifications and proper planning of crop rotations. High residue systems on poorly drained soils may help facilitate non soil disturbing types of trafficability.

C. Climate.

The major determinant of variations in climate in the Northeast is temperature and the onset of the seasons. High residue and no-tillage systems tend to have slower soil drying and warming in spring and are therefore more challenging in the northern parts of the Northeast.

51. Understand the adaptability of tillage systems to various cropping systems.

A. Livestock-based systems.

The following applies primarily to dairy and beef farms, while hog and poultry farms usually only produce grain (see next section).

- Residue return– Many times all above-ground biomass is removed in hay, silage, or straw. This puts much pressure on the soil resource (promotes soil erosion and organic matter decline). Therefore, care needs to be taken to return organic residues (manure) to the soil, grow cover crops in fallow periods, and to minimize further organic matter losses through intensive tillage.
- Crop diversity – Many crops can be grown for forage, and therefore, there is much opportunity to increase crop diversity (corn, soybeans, sorghum, sorghum-sudangrass, sudangrass, rye, wheat, barley, oats, alfalfa, several perennial grasses, red clover, annual ryegrass, kale, etc.). High crop diversity and cropping intensity can be used to great advantage in permanent no-tillage systems due to the time savings, soil erosion control, and soil improvement. Since different crops are planted at different row spacings, ridge tillage is not a favored tillage system.
- Soil compaction – Manure application and timely harvest operations during fall, winter, and spring when soils are still wet can pose a significant compaction risk. It is important to respect principles of compaction avoidance. If compaction is caused, surface or deep tillage may be required to alleviate its effects.
- Soil erosion – It is important to maintain living vegetation on the land to protect the soil from erosion and compaction, and to take up nutrients that may be released when organic matter from manure applications is decomposing. Cover crops can be established with no-tillage practices, which protects the soil when they are established.

- Soil warming – Soil warming may be a concern with no-till systems when corn is planted into a high residue cover that remains from the previous corn grain harvest. In this case, zone-tillage may be a practical alternative. In most other cases, soil warming in the spring is of minor concern.
- Weed control – It is important to manage weeds with crop diversity in permanent no-tillage systems. If perennial weeds get established and become a problem, early fall applications of burn-down herbicides may be needed, or tillage may be required. Plow tillage is the best weed control option besides herbicides to control perennials and many annuals.
- Nutrient management – Some nitrogen from manure will volatilize if it is not incorporated immediately (at least within 7 days, but more realistically speaking within 48 hours). If nitrogen conservation is a major goal, injection may be the best option. Alternatively, plow or mulch tillage may achieve the same goal (but is often challenging immediately after manure application). The same holds for odor control.

B. Conventional cash grain systems.

Primarily limited to corn, soybeans, and small grains.

- Residue return - with the exception of small grains, most residue is left in the field, which helps with organic matter conservation and erosion control. The return of crop residues to soil can compensate for some of the organic matter losses due to tillage.
- Crop diversity – Crop diversity may be low, as in continuous corn or corn-soybean systems. This poses a problem for soil quality and successful no-tillage, which may then need to be addressed by tillage. In the latter case, mulch tillage is preferred over plow tillage to limit soil impacts. Ridge tillage is an option in crops planted at the same row spacing. Zone tillage can be used for corn if early soil warming is a concern (after corn grain).
- Soil compaction – Large grain carts with high axle loads pose a subsoil compaction threat and need to be used judiciously. Grain trucks with road tires pose a severe surface compaction threat and should be kept out of the fields for successful soil management. Continuous no-tillage may be impossible if ruts are created in much of the field, although often ruts are localized and can be addressed in those parts of the field.
- Soil erosion – Because mulch is left in field, excellent erosion control is possible, especially if no-tillage, zone tillage or ridge tillage are used. Mulch tillage may not be possible after soybeans or small grains harvested for grain because residue cover will be reduced to <30% (in which case this type of tillage is classified as conventional or reduced tillage).
- Weed control – Can be challenging in continuous no-tillage that lack crop diversity. In that case plow tillage may be required to eliminate severe weed problems.
- Nutrient management – Urea fertilizers are subject to volatilization similarly to manure (see A above). Anhydrous ammonia needs to be injected with low disturbance knives, and secondary tillage may be required prior to planting.

C. Low-input and organic cash grain systems.

- Residue return – Similar to B above.
- Crop diversity – Often crop rotations are more diverse than on other cash grain farms. Permanent no-tillage is possible in low-input systems with high crop diversity, but not on organic grain farms due to weed control problems. If small grains or forages are part of the cropping system, ridge tillage is not an option.
- Soil compaction – These operations may be small (although not necessarily so) and therefore the threat of compaction may be limited, in which case no-tillage is an excellent option in low-

input systems. In organic systems, farmers may attempt to plow as shallow as possible to reduce tillage intensity.

- Soil erosion – A significant threat if plow tillage is used. The effects of plow tillage need to be compensated by return of crop residues, cover crops, composts and manure additions to maintain soil quality.
- Soil warming - Not usually a major issue on these farms because crops are typically not planted as early (to allow control of early emerging weeds).
- Weed control – The major reason to do tillage, especially in organic systems. Plow tillage is the best weed control around, but may be alternated with less intensive tillage such as mulch tillage or occasional no-tillage, even on organic farms.
- Nutrient management – Often manure is applied to supply nutrients (for manure management, see A above). If compost is applied, ammonia volatilization is not of concern in the field, and no incorporation is required.

D. Horticultural and vegetable production systems.

- Residue return – These cropping systems often include low residue crops and sometimes the whole plant is removed. This puts much pressure on the soil resource. If the crops are produced on level ground (often the case), erosion threat may be small. But soil quality degradation is still a significant concern that needs to be addressed by reducing or eliminating tillage.
- Crop diversity – Cropping diversity is often high to manage plant diseases. This opens up an opportunity for continuous no-tillage. However, in these crops no-tillage or zone tillage is not widespread yet, while ridge tillage is often impractical. However, precision traffic needs to be considered seriously, and ridge till might be an option to do that. Therefore, mulch tillage would be recommended. To help with soil improvement it is recommended to plant cover crops and to rotate with field and forage crops that are grown without tillage and return large quantities of crop residue to the soil.
- Soil compaction – Soil compaction is a very serious threat on these farms due to the importance of timely harvest which often forestalls the ability to respect soil moisture conditions for traffic. While compaction avoidance needs to be first, it may be necessary to do deep tillage to alleviate subsoil compaction (if high axle loads are used), or to do shallow tillage if surface compaction is prevalent.
- Soil erosion – Wind erosion may be a concern on peat soils used for vegetable production. The solution is wind breaks and/or residue cover. Another issue is subsidence of peat soils, which should be addressed with regulating the water table. On very gentle slopes water erosion can also be a concern on peat soils. Therefore no-tillage and mulch tillage need to be developed but are often not practiced in these systems. Whatever can be done to reduce tillage intensity will be beneficial to improve soil quality.
- Soil warming – Mulch may be an issue in specialty crop production. Mulch cover keeps soils cool, and this doesn't help to get the early crop up. To alleviate this, zone tillage or clean tillage should be considered.
- Weed control – The repertoire of herbicides for specialty crops is much smaller than in field crops. Therefore, it may be more challenging to do continuous no-tillage in these systems. It is important to reduce the production of viable weed seeds and to deplete the weed seed bank. In addition, it is important to prevent perennials from getting a foothold in continuous no-tillage. In practice, no-till may be practiced for a few years, but often needs to be followed by inversion tillage (plow till) to control weeds.

- Nutrient management – Tillage is not a major concern for nutrient management in vegetables, except to reduce volatilization when urea is used.

52. Understand the relation between tillage practices and:

A. Residue cover

Almost every tillage pass reduces residue cover. It is possible to estimate the effect of a tillage system on residue cover based on the percent cover after harvest, overwinter residue decomposition, and estimates of percent cover remaining after different tillage operations. Tables have been published in Midwest Plan Service – publication 45 (Conservation Tillage Systems and Management, 2nd Ed. 2000, chapter 7).

B. Soil roughness

The soil surface can be smoothened by soil tillage. However, subsequent traffic creates more soil roughness after tillage, and the danger of rut formation is greater on a previously tilled soil than a long-term no-tillage soil. Ridge tillage leaves the soil in ridges. Higher ridge height can reduce erosion potential.

C. Soil quality

Soil tillage degrades soil quality because of its negative effects on soil structure.

D. Residue fragility and persistence

Fragile and non-fragile residue are terms used to distinguish the different decomposition rates of crop residues. Fragile residue is from crops such as soybeans, canola, dry beans, and potatoes. Non-fragile residue is from crops such as corn, alfalfa, and small grains. The reduction in residue cover due to tillage is much greater in fragile residue than in non-fragile residue, and the persistence of fragile residue is less than that of non-fragile residue (see chapter 7 of MWPS, 2000).

53. Understand the relation between tillage systems and:

A. Soil structure and compaction.

Tillage destroys soil structure, although in cases it may enable crop roots to occupy compacted soil, which could help to build soil structure. Soil compaction is created below various tillage tools (i.e., plows, disks, powered rotary tillers), but it can also be alleviated by other types of tillage tools (i.e., subsoilers, chisels).

B. Runoff and erosion.

Soil tillage increases runoff and erosion because of its effect on residue cover and soil aggregation. In certain cases where soil structure is poor or compaction is present, soil tillage may increase infiltration and reduce erosion. The goal of soil management should be however, to avoid relying on a cycle of tillage to remediate poor soil structure caused by tillage.

C. Use of fertilizers and pesticides.

The major goal of tillage is to control weeds. In the absence of tillage, herbicides are needed to control weeds in permanent no-tillage. However, herbicides are only one tool in the box of weed control. Judicious use should be made of different herbicide modes-of-action, timing of applications, crop rotations, crop vigor, nutrient placement, mowing, reducing weed dispersal, etc., instead of relying on herbicides alone for weed control in continuous no-tillage. In reality, herbicides are used by almost all non-organic farmers, and herbicide use is not increased greatly in no-tillage. Use of other pesticides is not greatly affected by tillage.

D. Infiltration and percolation.

Crop residue cover helps to improve infiltration by the reduction of sealing and crusting. Percolation is improved when a well-developed, continuous macro-pore systems is present. Because macro- and microbial activity is significantly higher in permanent no-tillage systems than in plow-tillage, percolation is also customarily increased. Mulch till and ridge till would be intermediate, whereas zone-till is similar to no-tillage.

54. Understand the concept of soil tilth and the roles of soil texture, organic matter, structure/aggregation, and bulk density as they affect tilth.

Soil tilth refers to the physical condition of the soil in relation to plant growth. Tilth tends to decrease with particle size (sand>silt>clay), and organic matter content. Soils with good tilth have high aggregate stability, and low bulk density.

55. Understand the relationship between soil consistency and tillage conditions; the "ball test", and the effects of soil freezing.

Soils with high clay content tend to have high consistency. They tend to be in a plastic state much of the year (as judged with the 'ball test' described in 4C) which makes tillage operations challenging. One strategy to address this is to do primary tillage on these soils in the fall, let the freezing-thawing action crumble the clods, and then to do secondary tillage in the spring to prepare a seedbed. This is a way to avoid cloddy seedbeds in the early spring. Fall tillage, however, may lead to increased erosion potential.

Competency Area 6: Watershed Hydrology

---

56. Describe a watershed and its main functions.

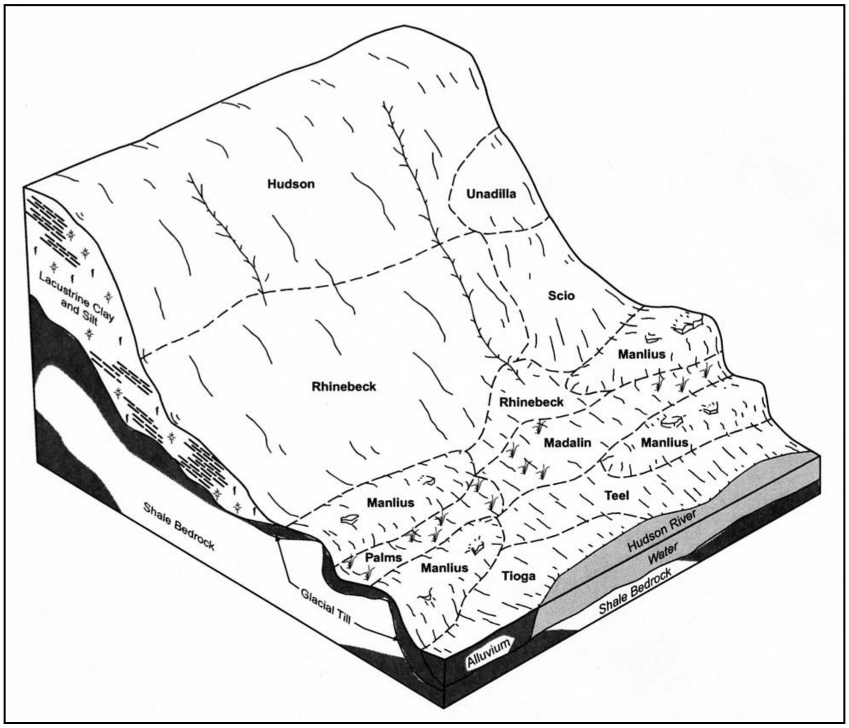
A ***watershed***, drainage basin, or catchment is an area of land from which surface runoff (and subsurface recharge, and groundwater usually) flows to a common discharge outlet. The main functions of a watershed are the collection and redistribution of water (as per the hydrologic cycle), providing a diversity of soils, vegetation, and landscape features or scenic views to support life functions of insects, animals and humans. A watershed's development and basic features or ***morphology characteristics*** result from climate and geologic interactions over long time periods.

Characteristics features of watersheds are:

- Boundary (topographic divide between other watersheds)
- Outlet and base (common discharge point and type of termination)
- Size and Shape (total area, and its general extent and arrangement)
- Elevation and Gradient (elevations of boundary and outlet and distance between)
- Aspect and Orientation (watershed slope and direction it faces)
- Drainage network (pattern of runoff concentration and streamflow)

- Soils and Geology (soil types, parent materials, arrangement, bedrock and aquifers)
- Land Use and Vegetation (rural, urban, industry, agriculture, and forestry)
- Cultural Activities (settlement, history, heritage, and recreation)

57. Understand the major inputs and outputs of water in a watershed.



Similar to the concepts discussed in Competency Area 2: Soil Hydrology, the components of the hydrologic cycle and the water budget for the soil profile can be extrapolated and applied to watersheds. Some differences in these concepts need to be considered, however, because of the larger scale and spatial variations that occur in watersheds, especially as they become larger. In watersheds, the spatial distribution of elevations, soils, geology, vegetation, and land use interact with the hydrologic cycle, causing variations with how water collects, drains, and is redistributed within soil associations and throughout the landscape. In the Soil Survey, distinctive patterns of soils, elevation relief, and drainage are commonly grouped by their association. For example, the following figure shows a typical relationship of soils and underlying geologic material in the Hudson-Rhinebeck-Manlius general soil association map unit (From Soil Survey of Saratoga County, New York).

This general soil association is further described in the survey as gently sloping to hilly with scattered rock outcrops in the Manlius part of the unit. Large watersheds commonly consist of a composite of these general soil associations, creating further complexity in watershed hydrology. The following terms are thus described in the context of watersheds.

A. **<u>Precipitation</u>** – often varies across a watershed, and the spatial variation tends to be even greater in watersheds with significant topographic relief because the cooler air at higher elevations has a lower saturation vapor pressure and the humidity condenses easily. The amount of precipitation also varies more with convective type storms as compared to broadly occurring frontal storms.

B. **<u>Storms</u>** – are classified as ***frontal, convective, and orographic***. Frontal storms occur as warm or light air masses meet cold or heavy air masses. This is the dominant type of precipitation that occurs in the Northeast, generally producing the low intensity, long duration rainy days. Convective storms occur as a result of air expanding when heated by solar energy, and the lighter air moistened with evapotranspiration rises, cools, and condenses. In the Northeast, this produces the summer thunderstorms, often delivering high intensity but short duration rains. Orographic storms occur as wind forces warm, moist air masses to rise over hills and mountains, so although this occurs in conjunction with frontal and convective storm types in high relief watersheds, this type of storm process better explains why watersheds in the western side of the Adirondacks (the Tug Hill Plateau) gets more precipitation than the eastern side (Hudson Valley and Lake Champlain). Some important considerations of watersheds in regards to storm direction are the watershed size, shape, gradient, and aspect. Storms moving slowly over large, elongated, steep gradient watersheds in the opposite direction of the aspect are likely to create flashy increases in stream flow and depth, often leading to flooding conditions in the lower end of the watershed.

C. **Infiltration and percolation** – will vary substantially across a watershed. Generally, infiltration and percolation tend to be higher in soils that are higher in elevation than the other soils in the same association in the watershed, or higher in soils that straddle convex slopes. However, there are numerous exceptions to this because of the variation in soils, soil layering and geologic material. For example, the infiltration and percolation is less on many soils at higher elevations in watersheds of New York's Southern Tier, compared to the lower lying soils in the alluvial valleys.

D. **Storage** (Depression, Detention, Channel, Groundwater, Retention) – refers to the locations in the watershed where surface runoff or excess drainage water is held, at least temporarily. ***Depression storage*** is the water stored in field surface depressions and therefore not contributing to surface runoff. ***Detention storage*** refers to the water in excess of the depression storage which is temporarily stored somewhere in the watershed while enroute to streams. Wetlands are a good example of detention storage. Both depression and detention storage can have a significant effect on reducing stream flow peaks. ***Channel storage*** is the water temporarily stored in channels while enroute to an outlet, or it also refers to the drainage water that can be stored above the start pumping level in ditches and floodways without flooding adjacent land. Channel storage provides for more uniform stream flow, smoothing out rapid increases in stream flow and depth. The drainable (porosity) water that cannot be absorbed by the soil, and which continues to flow downward as deep percolation, recharges the groundwater and gradually causes a rise in the water table. If the water table is below the elevation of an adjacent stream, the ***groundwater is stored*** until such time that the water table starts to rise above the stream. ***Retention*** is the precipitation on an area that does not escape as runoff. Essentially it's the difference between the total precipitation and total runoff. The more precipitation that can be evapotranspired and absorbed by the soil's water holding capacity and these different storage processes, the less is lost as runoff. Thus, the seasonal distribution of precipitation relative to the evapotranspiration greatly affects the total runoff that occurs.

E. **Vegetation** – plays an important role in the amount of retention, both in terms of interception and transpiration. Interception, the amount of precipitation caught by vegetation canopy, and that which is evaporated directly back to the atmosphere, varies spatially with different vegetative types in the watershed. The effect of interception on retention is more significant when precipitation comes in low intensity, small amounts. A tall dense alfalfa canopy can intercept about 0.20 inches of rain, and under the right conditions it can evaporate directly with little of this ever hitting the ground. However, transpiration is the primary component of retention, and thus generally combined as evapotranspitation.

F. **Base Flow** – occurs when the stored groundwater raises the water table elevation above that of an adjacent ditch or stream. When this occurs, the hydraulic head (soil water pressure potential plus the gravity potential energy status) of the water table begins to exceed that of the adjacent stream, and the groundwater flows to recharge the stream. In a ***perennial stream*** (always flowing), base flow is a continuous process of transferring temporarily stored groundwater into surface water. For an ***intermittent stream*** (one that only flows part of the year), the groundwater is stored until the deep percolation recharge raises the water table, and then the excess groundwater is transferred to the stream causing it to flow.

G. **Storm Flow** – is most often considered to be the *direct* surface water runoff that flows to and recharges a stream following a precipitation event. Some hydrologists, however, consider storm flow as both the direct surface water runoff plus the increase in base flow (over pre-storm event) that occurs in a stream in response to a rain event. The distinction and separation of storm flow and base flow in a stream is very important to stream water quality, as the quality of the storm flow and the base flow is usually quite different. An ***ephemeral stream*** is one that flows only during and immediately after a rain event, carrying only surface water runoff with no base flow contribution. This type of stream channel is above the water table at all times. The term ***concentrated flow path*** is often used in reference to a channel carrying only storm flow.

H. **Runoff** (Surface, Channel and Subsurface) – as described in 8. and above, varies from point to point in a stream within a watershed. Since these different sources of runoff contribution to a stream can vary as one traverses the stream, the water quality of a stream can vary substantially from one location to another, both within and for different watersheds. Runoff tends to accumulate as one approaches the outlet of a watershed, and larger watersheds generally exhibit more runoff. Land use can greatly impact the different components of runoff, and subsequently the water quality of the stream(s) within the watershed. Large areas of impervious surface will increase the surface runoff component by reducing the opportunity for infiltration, percolation, and storage. Converting large areas of forest to other land uses often increases surface runoff by changing interception and evapotranspiration, and perhaps infiltration and percolation components. Channel alterations and modifications impact the amount of channel storage.

I. **Evaporation and Transpiration** – varies spatially in watersheds with respect to the extent of open water, types of vegetation, and impervious surfaces. Even more importantly, evaporation and transpiration vary temporally (or seasonally throughout the year), causing major shifts in retention and runoff.

58. Understand a stream hydrograph and its relation to pollution. Understand the relation between a pollutograph and a hydrograph.

A stream ***hydrograph*** is a graphical or tabular representation of the stream flow rate (cubic feet per second) with respect to time. A ***pollutograph*** would be a similar graphical or tabular representation of the concentration of pollutants or contaminants with respect to time. When the stream flow rate and pollutant concentrations are graphed or tabulated together with respect to the same time, one can observe how the stream flow and pollutant concentrations vary with respect to each other. By multiplying the stream flow rate times the pollutant concentration, the total load (i.e., pounds) of pollutant delivery is determined, and can be accumulated for some stream flow time period.

Some characteristic features of a stream hydrograph are its rising limb, peak flow, and falling limb or recession curve. The ***rising limb*** portion is where the stream flow rate is increasing. The ***peak flow*** represents the maximum flow rate that occurs, and the ***falling limb or recession curve*** is the portion showing how the stream flow rate decreases. When the rise and subsequent fall of the stream flow rate happens quickly as a result of a rain event, the stream is referred to as ***flashy***. In contrast, if this rise and fall takes a long time, the stream is ***sluggish***. At the outlet of a small, steep gradient watershed, stream hydrographs tend to be flashy in response to thunderstorms because the runoff (storm flow) concentrates and then dissipates quickly. A watershed with extensive impervious surface or compacted soils will also have a flashy response, compared to a similar watershed that is forested.

Some pollutant concentrations increase quickly with increasing stream flow, and the concentration may peak before the flow rate peak. Suspended sediments, phosphorus, fecal coliforms, pesticides and other typically sediment bound type pollutants (with high soil-water adsorption partitioning coefficients) would be examples of this type of response. This is often referred to as the first-flush of pollutant delivery. The concentration of other dissolved pollutants such as nitrate-nitrogen and chloride salts are less affected with increases in stream flow rate, and may actually decline somewhat during the stream flow rate peak, but then gradually increase during the recession of the flow. The delayed increase in concentration of dissolved pollutants is often a result of the base flow (flushed groundwater) contributions.

59. Explain the pollutant delivery process, and describe the relationship of nutrient budgets and total maximum daily loads (TMDL) to non-point source pollutant loading.

Pollutant delivery requires a pollutant to be 'available' when water is moving over or through the soil and landscape. Soil erosion is an example of soil being available (by dislodgement) when water is flowing. Generally, pollutants that are readily soluble in water and that have a ***low soil-water adsorption partition coefficient (do not readily attach to soil)*** can be transported in either surface runoff or in water percolating through the soil. Nitrate-nitrogen is an example of this and can thus easily be leached to groundwater. Pollutants that have ***high soil-water adsorption partition coefficients (easily attach to soil)*** are more readily transported in surface runoff, but are typically removed as water infiltrates and percolates through the soil. Phosphorus would be an example of a pollutant with a high adsorption partition coefficient. However, soils with macropores may have a limited ability to absorb pollutants with high adsorption partition coefficients because of the limited interaction of the percolating water with the soil particles. Thus, the importance of nutrient budgets is to minimize nutrient pollutant availability when water is flowing over or through the landscape. It is typically easier to manage nutrients, than to manage excess flowing water. When nutrients are applied in excess of crop nutrient requirements, the opportunity increases for pollutants to be available and transported off-site to other receiving water bodies. The off-site transport and diffuse loss of pollutants from storm water runoff (from agriculture and other sources) is termed nonpoint source pollution.

The ***total maximum daily load (TMDL)*** is the maximum amount of a pollutant that a water body can receive and still meet water quality standards. Federal and state regulatory agencies establish the maximum allowable point and nonpoint source loading for designated stream reaches, based on characteristics of stream flow, ability of the stream to process pollutants, and designated uses. Nutrient budgets or developing and implementing comprehensive nutrient management plans (CNMP's) is a methodology for agricultural producers to minimize the off farm loss of excess available nutrients to reduce nutrient pollutant loads to designated receiving streams and waterbodies. With implementation of CNMP's, nutrient losses and nonpoint source pollutant loads can be reduced, and TMDL targets can be achieved.

60. Understand precipitation return periods and define a 25-year, 24-hour precipitation event and list sources for identifying this event in various parts of the Northeast.

Precipitation return periods were discussed in Item 10. The following figure shows contour lines of the 25-year, 24-hour precipitation amounts for the Northeast (note precipitation amounts in inches on the right hand side of the contour lines). The 25-year, 24-hour precipitation amount varies between 4 to 5 inches for much of the Northeast, and increases to 6 inches for Long Island, NY, and southern areas of Connecticut. Information for many different frequency-duration storms can be obtained via the National Oceanic Atmospheric Administration (NOAA) web site http://www.erh.noaa.gov/er/hq/Tp40s.htm.

61. Describe the main agricultural point and non-point sources of contaminants in a typical rural watershed in the Northeast.

The main agricultural point or concentrated sources from livestock-based systems are from barnyards, feedlots, silage storage and milkhouse wastewater discharges. For conventional cash grain, horticultural and vegetable production systems, the point sources arise from fertilizer, pesticide and fuel storage areas. The main non-point sources of contaminants from agricultural operations are sediments (largest on a mass basis), phosphorus, pesticides, pathogens, and nitrate-nitrogen (usually from tile drain discharges).

62. Understand and describe aquifers (confined, unconfined) and the geologic conditions that affect water yield from wells.

Aquifers are geologic formations that store groundwater in the saturated pores of these sediment or rock formations, and are sufficiently permeable to transmit economic quantities of water to wells or springs. Aquifers consist of two types, confined and unconfined, as distinguished by differences in their hydraulic behavior. A ***confined aquifer*** has an upper, and perhaps lower natural soil or rock layer boundary that does not transmit water readily, and thus, the stored water is confined within the permeable layer materials. The importance of this hydraulically is the stored water can then develop a hydraulic head pressure that exceeds the level of the upper confining layer. A well that is drilled into this type of aquifer, and where the hydraulic head pressure is adequate to raise the water past the upper confining boundary and to the surface is commonly referred to as an ***artesian or flowing well***. An ***unconfined aquifer*** is one where the upper boundary consists of a relatively porous natural material that transmits water readily, and thus it does not confine the stored water, and the water table is free to rise and fall with recharge or withdrawal of water. When water is withdrawn (pumped) from an unconfined aquifer, the water table is drawn down and the water (specific) yield comes from the drainable porosity of the soil or rock material.

The water yield from wells depends on the intrinsic permeability or hydraulic conductivity of the saturated soil or rock material. For soil type aquifer materials consisting of well-sorted gravels, well yields will range from 500 to 1500 gallons per minute (gpm). Well-sorted sands and glacial outwash yield 100 to 500 gpm. Fine sands and mixed silty sand materials generally yield 10 to 100 gpm. For rock materials, well yields are also highly correlated to the extent of rock fractures and consolidation. Wells tapping the large solution channels in the Onondaga limestone formation can yield several thousand gallons per minute. Carbonate formations yield considerably less, more typical of around 200 to 500 gpm. Sandstone formations are still less (around 50 to 200 gpm), and shale formations range from 2 to 50 gpm. Wells yielding only 2 to 10 gpm may be suitable for supplying homes, but are generally not sufficient to support livestock operations. Well yields of 100 gpm or more are generally needed for irrigation.

63. Understand the concepts of pumping and drawdown in wells, the cone of depression, and well capture zones.

When wells are pumped, the water level in the casing is lowered (drawn down) relative to the water level in the aquifer. This ***drawdown*** causes stored water in the aquifer to flow towards the well. The ***cone of depression*** refers to this drawdown, since the water level surface in the aquifer material exhibits a conical shape with increasing distance in all directions away from the well. The bottom of the cone is the drawdown water level in the well. The size of the cone of depression, or the distance away the water level is affected by a pumping well depends on the pumping rate, the specific yield and conductivity of the aquifer material, and the length of time the well is pumped. High pumping rates for long periods of time will lower water levels a long distance away. In unconfined aquifers, the water level is typically affected less than 100 feet away, but can extend for several hundred feet. However, in confined aquifers, the water level can be affected for several hundred to several thousand feet away.

The ***capture zone*** of a well refers to the area on the surface under which water drains towards a pumping well. Essentially this area extends up-gradient from the well to the boundary of the groundwater divide (where the groundwater would slope to another direction). The importance of defining the extent of the capture zone is that activities on the land surface that overlie the capture zone may eventually pollute the well. Pollutants that readily leach, and which are transported to the aquifer, will affect the well water quality. Shallow unconfined aquifers are particularly vulnerable to contamination because there is no restricting soil layer above these aquifers to divert leached pollutants.

64. Understand the relationship between geologic conditions and the potential for groundwater and surface water contamination.

Soil layering and varying subsoil geologic conditions will significantly affect water movement. Layers that are permeable allow water to flow in any direction. However, layers that are impermeable impede water movement, and the flow of water is then redirected through more permeable layers. The depths, separation distance between layers of differing permeability, and the slope of impermeable layers all affect water movement and the direction in which it moves. Different combinations of depths and separation between layers also affect water movement in different ways, and whether water flows primarily to surface or groundwater.

Groundwater is most easily contaminated when the soil is permeable to great depths. The deep unconsolidated permeable materials of alluvial valley-fill common to Central NY and NY's Southern Tier valleys or in the Coastal Plain area of Long Island, NY are examples where leaching of nitrates and soluble pesticides can contaminate the groundwater. In contrast, an impermeable layer that lies just below the surface, such as in soils with fragipans, impedes downward water movement, and excess water is forced to move laterally (interflow). If the soil is sloping and the fragipan is not, the water is forced back to the surface. This will show up as a seep in the landscape, and the runoff from this may cause surface water contamination. These types of soils are common in the Catskills region of New York, where surface runoff contaminated with phosphorus facilitates the eutrophication of reservoirs.

65. Understand recharge areas for groundwater and surface water.

The deep permeable soil deposits facilitate deep percolation and provide areas for groundwater recharge. In contrast, soils with shallow impermeable layers or drainage restrictions recharge surface water.

66. Understand and apply the concepts of hydrologically sensitive areas and critical management zones at the field, farm and watershed levels. Be able to give examples.

Hydrologically sensitive areas (HSA's) are areas in the landscape where there is a high hydrologic risk for water movement off-site. Thus, HSA's have a high potential for transporting pollutants off-site. Examples of HSA's include:

- Impervious surfaces (barnyards, bunker pads).
- Relatively impermeable (crusted or frozen soil, soil with shallow hardpans or fragipans) and erosion prone (low permeability, sloping) soils.
- Saturated soils (poorly drained soils, variable source saturating areas, seeps).
- Flood plains (especially those that flood frequently).
- Flowing surface water areas (perennial and intermittent streams, concentrated flow paths).
- Groundwater recharge areas (highly permeable soils, sinkholes, shallow soil over Karst – a special type of landscape that is formed by the dissolution of soluble rocks, including limestone and dolomite).

The first two examples of HSA's occur as a result of rainfall and processes of infiltration-excess. For nutrient management planning and CAFO permitting purposes, various NRCS standards are available to address these areas, and RUSLE is used to address the erosion prone soil areas. The latter four examples are induced by saturation-excess hydrologic processes, and these areas are addressed with the NRCS nutrient management standard, in conjunction with the P and N Leaching Index risk tools. Critical management zones are where the application or loading of potential pollutants, and their availability, overlap with the HSA, resulting in the mixing and transport of the pollutants. A common example of a critical management area is when manure is applied in a low lying area of the field that saturates quickly during a rain event, producing runoff that transports the manure off-site.

67. Understand key processes that occur in wetlands and riparian buffer zones and their role in a watershed.

Wetlands are areas of wet soil (hydric soil) that is inundated or saturated under normal circumstances, and would support a prevalence of hydrophytic vegetation (plants adapted to survive in low soil oxygen environments). Key processes that occur in wetlands, in addition to providing diverse biota and wildlife habitat, are to slow the transport of water and provide surface water storage (unless already filled), resulting in the retention and removal of suspended and many dissolved pollutants. For example, denitrification and reduction of other chemical compounds (pesticides) are a key function. Wetlands are quite effective at removing suspended and particulate materials, such as phosphorus bound to soil particles, but are less effective at retaining dissolved phosphorus. ***Riparian buffer zones*** (an area of land immediately adjacent to water bodies) share many of the same characteristics and functional processes of wetlands, but depending on their position in the landscape are generally less saturated. Thus, riparian buffers may also serve to infiltrate incoming surface runoff, facilitating the removal of suspended and some dissolved pollutants that readily absorb to soil. When streams flood, water flowing out into the riparian buffer may also be cleansed as sediments, nutrients, and other pollutants are attenuated (reduced and retained) in the buffer zone.

68. Understand the multiple-barrier concept in watershed protection.

The multiple barriers concept is a strategy applied to minimize the occurrence, availability, and transport of pathogens to surface and groundwater supplies. It consists of four major barriers:

- Imports and bio-security to reduce occurrence of unwanted pathogens
- Animal health and hygiene to minimize the spread and availability of pathogens
- Waste management to contain and further reduce availability
- Land application BMP practices to reduce transport and off-site exports

More information and implementation of the multiple barrier concept is addressed in New York's USDA-NRCS Conservation Practice Standard NY-783.

69. Be able to identify impaired water bodies and the causes listed for the impairment, and understand the implications for agriculture.

As part of the Federal Clean Water Act Section 303(d), EPA requires state environmental agencies to periodically assess and report on the quality of waters in their state, and to identify and develop a list of impaired waters (water not potentially able to meet quality standards of TMDL criteria). In New York, the Department of Environmental Conservation (NYS-DEC) carries out this task, and has developed the New York State Section 303(d) List of Impaired/TMDL waters. The NYS-DEC has developed and recently updated this list with input from the public, which was approved by the EPA in September 2008. See http://www.dec.ny.gov/docs/water_pdf/303dlist08.pdf. The list identifies the impaired water bodies in New York, lists the type of pollutant impairment and probable causes, and the most likely source of the impairment. The list also prioritizes the impaired water bodies which are in further need of TMDL review and development. Other states in the Northeast would also have similar lists for their states. Where agriculture is listed as the cause of the impairment, Federal and State agency programs working with agriculture will give priority in directing resources to participants (Soil and Water Conservation Districts and producers) in those watersheds.

Competency Area 7: Non-Point Source Pollution

---

70. Distinguish between agricultural and non-agricultural non-point source (NPS) pollution and point source pollution and the extent and importance of each.

Non-point source pollution is pollution having no well defined source, such as that originating from diffuse land surface areas or the atmosphere. Agricultural non-point sources include things like:

- soil erosion (sediment) and runoff and leaching losses of fertilizer nutrients (P, N) and pesticides from intensively cropped land
- nutrients, pathogens, and BOD (Biological Oxygen Demand) loss from land receiving manure applications or when livestock have access to streams
- spray drift from manure and pesticide applications (e.g., causing odor issues or damage to non-targeted plant foliage).

Non-agricultural sources of NPS pollution result from urban and suburban residential and commercial activities and would include:

- sediments, nutrients, pesticides, and petrochemical losses in storm water runoff from impervious surfaces (streets, roads, parking lots)
- nutrient and pesticide losses from lawns, gardens, golf courses
- nutrient and pathogen losses from on-site sewage disposal systems
- sediment losses from active logging areas and construction activities
- various chemical and drift losses from traffic and other diffuse commercial activities and dump areas

Sediment from soil erosion and other non-agricultural source losses constitutes the largest non-point pollutant loading on a mass basis and is the most frequently cited cause of surface water quality impairment. Phosphorus and pathogens (Fecal-type coliforms, Cryptosporidium, Giardia) are also frequently the cause of surface water impairments. Although many pesticides are detected at more than 10% frequency in surface water (atrazine, simazine, metalochlor), the concentrations rarely exceed drinking water maximum contaminant level (MCL) limits. Simazine and diazinon are frequently detected in urban areas.

Elevated levels of nitrates (above the MCL of 10 ppm) are frequently found in groundwater, with some vulnerable areas reporting 10 to 20% of wells exceeding the MCL. The percentage of wells exceeding the MCL for nitrate is generally higher in intensively farmed agricultural areas, but can also be high in densely populated urban areas where on-site systems are used on permeable soils. Pathogens are reported more frequently than pesticides in groundwater. Atrazine is the most commonly detected pesticide in groundwater in agricultural areas, whereas simazine occurs more frequently in urban areas.

Point source pollution is the pollution of surface or groundwater supplies at well defined locations. Agricultural point sources of pollution would include:

- nutrients, pathogens, and BOD losses from barnyards, lagoons, and other livestock facility storage and processing operations (silage leachate and bunker runoff, milkhouse wastewater discharges)
- nutrient and pesticide losses from fertilizer and pesticide storage and rinsing areas
- petrochemical losses from fuel storage areas and machine shop facilities
- nutrient and BOD losses from food processing facilities

Non-agricultural point sources of pollution would be nutrient and BOD discharges from wastewater treatment plants and a variety of volatile and organic and inorganic chemicals from commercial operations and industrial manufacturing and processing facilities.

The most important point sources of pollution from agriculture occur with livestock operations, and barnyard and feeding area runoff would be the most widespread source. However, silage leachate represents a more concentrated pollutant source, although by volume it's not as much. Industrial chemicals from manufacturing are the most widespread and serious point source(s) of pollution, and many are found in groundwater.

71. Describe the main sources of agricultural non-point source (NPS) pollution and their origins.

A. **Nitrogen** – sources are from runoff, tile discharge and leaching losses originating from fertilizer and manure applications in excess of crop needs and requirements. The timing and the amount of application relative to crop growth is critical. For example, a single large application of nitrogen fertilizer to corn in the spring and while plants are still small often results in substantial losses during spring rains and thunderstorms. Using split applications and timing it to crop growth needs results in more efficient use of the applied N. Fertilizer N applied in the fall will generally be denitrified or leached away before it can be used by the following years crop. The fate of manure losses differ from those of fertilizer, with volatilization, nitrification, and denitrification occurring at different times and at different rates depending on surface or incorporation application techniques.

B. **Phosphorus** – sources are from eroded soil (as particulate P), soluble P in runoff and in some tile discharges from soils testing high in P; and from suspended and dissolved organic P in manure runoff and in some tile discharge. High P concentrations can be found in runoff, and in some cases tile drain discharge, especially when rain follows shortly after surface manure applications.

C. **BOD (Biological Oxygen Demand)** – sources are from the application of fresh manure and agricultural process wastewaters, especially if rain immediately follows surface applications. [The BOD arises from the need for oxygen to complete decomposition processes of the organic materials, and thus it lowers the oxygen in receiving waters which may cause fish kills.]

D. **Sediment** – sources are primarily erosion from cropland, especially when there is no vegetative cover on the fields. Sediments may also originate from laneways, field roads, and non-vegetated surface drainage ditches.

E. **Pesticides** – sources are pesticide runoff and leaching, especially when rain occurs shortly after pesticide application. Pesticide drift may also find its way back into surface waters.

F. **Pathogens** – sources are calf housing areas and manure applications, especially when the manure is surface applied and rain causes runoff prior to the manure having time to dry. Surface water and tile drain discharges are usually more impacted than groundwater, but groundwater may also be affected when manure is applied to coarse textured soils, or to shallow soils overlying fractured bedrock.

G. **Silage leachate** – sources are from uncontrolled loss and runoff from silage storage facilities (uncovered bunkers).

H. **Chemicals and toxins** – see Pesticides.

l. **Processing waste water** – sources are the uncontrolled loss or inadequate treatment and disposal of these wastewaters from livestock facilities (i.e., milkhouse drains).

72. Understand the environmental impacts of various agricultural contaminants on the quality of surface water and groundwater as it relates to their various uses.

- Nitrogen - causes eutrophication and hypoxia (low dissolved oxygen and dead zones primarily in bays and estuaries) in surface waters, and nitrate enrichment in groundwater. Elevated concentrations of nitrate or ammonia in surface water also affect aquatic organisms. High nitrate concentrations in drinking water can affect both humans and animals, causing oxygen deficiencies in the blood (methemoglobinemia).
- Phosphorus – causes eutrophication (mainly in ponds, lakes and reservoirs) and hypoxia in coastal waters.
- BOD - causes depletion of dissolved oxygen in surface water which may kill fish and other aquatic organisms, and can deplete oxygen in soil-water affecting plant growth.
- Sediment - causes turbidity of surface waters which affect aquatic habitat, results in sedimentation in ponds, lakes and reservoirs, and increases treatment costs of drinking water supplies.
- Pesticides - cause loss of aquatic life and exceedance of drinking water standards. Atrazine, simazine, metolachlor, and alachlor are often present in surface runoff, tile drain discharge, and groundwater.
- Pathogens - cause impairment of recreational and drinking water, leading to problems with animal and human health when coming into contact or consuming the contaminated water.
- Silage leachate - causes depletion of dissolved oxygen because of high BOD, and ammonia-nitrogen and phosphorus enrichment of water. The high BOD and ammonia-nitrogen may kill fish and other aquatic organisms. Suspended organics make it difficult to treat for drinking water.
- Process wastewaters - cause turbidity, depletion of oxygen and nutrient enrichment of receiving waters. Milkhouse wastewater contains suspended milk solids and is mostly enriched with dissolved phosphorus. Barnyard runoff is similar to silage leachate, but generally has slightly lower concentrations.

73. Identify basic water quality indicators and explain their significance.

Water quality indicators consist of physical, chemical, and biological parameters. People traditionally have used their basic senses of sight, smell, and taste to evaluate water quality suitability, and water that looks ***turbid*** and colored (containing ***total suspended and/or dissolved solids*** materials) is deemed unfit for drinking. These basic physical indicators are still currently used to determine water quality violations because of the implications for inclusion of other chemical and biological indicators. Turbid water intercepts light transmission, reducing photosynthesis of aquatic species and interrupting food chain production. Sediments get into fish gills and cover nesting areas. Turbidity may indicate inputs of ***BOD (Biological Oxygen Demand*** – a characteristic of many wastewaters***)*** that consume oxygen (measured as ***dissolved oxygen – DO***) vital to benthic (aquatic dwelling) organisms. Suspended materials are also frequently indicators of ***P*** (causing eutrophication – a process where water bodies (like ponds) receive excess nutrients that stimulate excessive plant (weed) growth). Suspended materials may also be indicators for the presence of ***total (or fecal and E. coli) coliform*** inputs (potentially pathogenic organisms to humans). Phosphorus concentrations in pristine natural waters are generally less than 0.05 ppm, so a little P enrichment goes a long way in producing algal blooms. The presence of fecal coliforms or E. coli indicates fecal waste inputs, and their presence in very low numbers restricts water use for swimming and drinking. The ingestion of as few as 10 E. coli organisms of the 0157:H7 strain can result in serious health effects. Off-color (or shininess) of water is an indication of ***dissolved organic carbon (DOC)***, which may be produced naturally from decaying plant material, but is also often indicative of wastewater, pesticide, or solvents (oil, grease) inputs. ***Ammonium-N*** is an indicator of wastewater pollution, and concentrations greater than 2 ppm affect fish and other aquatics. Since ***nitrate-N*** disrupts oxygen transfer in the blood (Methemoglobinemia), the standard drinking water concentration is 10 ppm, but concentrations above 2 to 3 ppm are indicative of nutrient enrichment, and can have adverse effects on many aquatic species. Nitrate-N concentrations above 25 ppm can impact livestock health. The absence of certain aquatic macroinvertebrate (biological) organisms (i.e., mayflies, caddisflies, riffle beetles), or the presence of midges, horsefly, and tubificid worms instead, is often an indication of nutrient enrichment in streams.

74. Understand the concept of best management practices for NPS pollution control.

Best management practices (BMP's) are structural, nonstructural, and managerial techniques recognized to be the most effective and practical means to reduce surface and groundwater contamination while still allowing the productive use of resources. It's important to note that a BMP may not always be the ***best available technology (BAT)*** for containing, treating, or reducing a pollutant from water, because the BAT may be impractical and prohibitively expensive. For example, boiling water may be the BAT for reducing pathogens in water, but it's not likely to be a BMP for addressing pathogens in surface runoff from agricultural lands. By definition, a BMP also would not be one that restricts or prohibits the productive use of resources.

75. Know some appropriate best management practices for agricultural NPS and Point Source pollution control in a given farming system.

Examples of structural BMP's (terraces) for addressing NPS soil erosion were listed in Item 47. Some examples of nonstructural (cover crop) and management measures (crop rotations) to address NPS soil erosion are listed in Item 46. With regards to point sources, some structural BMP's would be diversions for diverting uncontaminated water away from barnyards or vegetated filter strips for treating the contaminated runoff from the barnyard. Nonstructural and management measures would include recycling flush water and feed management to reduce the volume of contaminated water released or the concentration of contaminants in barnyard runoff. See http://www.nrcs.usda.gov/technical/Standards/ for a suite of BMP's commonly applied to farming systems.

76. Understand federal, state and local laws and regulations related to NPS and point source pollution control.

A. **Clean Water Act** – the Clean Water Act (CWA), first promulgated in 1972, is the primary federal law in the United States governing water pollution. The Act is the cornerstone of surface water quality protection and addresses aspects of both point and NPS pollution. For a summary of what the Act contains and for more information see http://www.epa.gov/lawsregs/laws/cwa.html.

B. **Safe Drinking Water Act** – the Safe Drinking Water Act (SDWA), originally passed by Congress in 1974, is the principal federal law in the United States that ensures safe drinking water for the public.

The Act sets forth primary and secondary drinking water quality standards and oversees states, localities, and water suppliers who provide public drinking water. A public water supply is an entity that provides at least 25 people. The primary drinking water standards include maximum contaminant level (MCL) or concentration thresholds set to protect human health. Secondary standards are generally related to drinking water aesthetics or are ones where MCL's have yet to be established regarding impact to human health. More information on the Act can be found at http://www.epa.gov/OGWDW/sdwa/basicinformation.html.

C. **Coastal Zone Management Act** – the Coastal Zone Management Act (CZMA), adopted in 1972, has the objective of controlling nonpoint sources of pollution that affect coastal water quality. In this regard it serves to protect bays and estuaries, including those in the Great Lakes. The nonpoint source measures of control are inextricably linked to agricultural operations in watersheds which discharge to coastal waters (Susquehanna River - Chesapeake, Hudson River - Long Island Sound). More information on the CZMA impacting agriculture can be found at http://www.epa.gov/oecaagct/lzma.html#Summary%20of%20Coastal%20Zone%20Management%20Act%20and%20Amendments.

D. **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** – the Federal Insecticide, Fungicide, and Rodenticide Act, first enacted in 1947, established the federal governments control on pesticides. The Act establishes a system of pesticide regulation, sales, distribution and uses to protect applicators, consumers, and the environment. The Act established the registration of pesticides and pesticide applicators, and provides for oversight on intended uses, appropriate dosage, and material hazards specifications. More information can be found at http://www.epa.gov/pesticides/regulating/laws.htm.

E. **Local regulations** – state and local laws have evolved to promulgate the federal laws, and in most cases follow the rules and recommendations established by federal law. Specific details regarding state and local laws are best determined by contacting state and local agencies.

Competency Area 8: Concentrated Source Pollution

---

77. Understand the advantages, disadvantages, and situational appropriateness of various options for handling milking center waste and/or other process waste waters.

A. **Septic systems/leach fields** – Septic systems and leach fields are typically low in cost but are not generally suitable for treating large volumes of milking center or other process waste waters. Leach fields are easily clogged with overflow of suspended milk solids.

B. **Vegetative filter areas** – Vegetative filter areas are more costly but are reasonably effective in treating process wastewaters, providing certain design and maintenance criteria are met. Some examples of these criteria include settling and screening out solids and large organic debris, using effluent distribution methods that provide sheet flow across the entire filter area, sizing the filter area appropriately based on hydraulic loading and nutrient loading and removal criteria, and locating the filter area on suitable soils that can absorb, adsorb, and process the nutrient loads. For milking center waste water, it's important to settle out the suspended solids first, and provide good effluent distribution on soils that adsorb phosphorus. For silage leachate collection and treatment systems, the highly concentrated effluent should be diverted or diluted to avoid vegetation kill zones in the filter area.

C. Aerobic lagoon – The advantages of an aerobic lagoon are to provide storage and disposal flexibility, they may use less land around the facility for treatment, there may be opportunities for liquid recycling, wastewater treatment becomes a part of the nutrient management plan when the effluent is removed, and they often entail lower labor needs and operating costs. Disadvantages of an aerobic lagoon are offensive odors may occur, aeration may be necessary, overtopping may occur (or effluent and sludge removal may need to be more frequent, especially if undersized), and the potentially high volumes of storm water runoff from barnyards and feed storage areas often necessitate an increase in size and cost.

D. Organic filter beds – Organic filter beds are suitable for small wastewater volumes and are quite effective at removing ammonia-N. However, they may actually release P as the organic filter media decomposes. The main disadvantages of an organic filter bed is the cost is generally prohibitive to treat large runoff volumes and the organic media beds need to periodically be replaced as they decompose. In New York, organic media beds are no longer being recommended because of their unpredictable performance and high maintenance requirements.

E. Constructed wetlands – The advantages of constructed wetlands are they are capable of providing a high level of treatment, inexpensive to operate and largely self-maintaining, can handle variable loadings, and they may reduce the amount of land needed for land application. The disadvantages are the direct inflow of concentrated process wastewaters may kill vegetation (hydrophytic plants are quite sensitive to high ammonia levels), large influxes of runoff induce large changes in water levels, thus reducing treatment reliability, and they may require water inputs during non storm events. Furthermore, constructed wetlands require a single dedicated land use, can potentially harbor mosquitoes and generate offensive odors, and are often more expensive to construct than other treatment options. Because of these disadvantages, other pre-treatment facilities (e.g., low flow collection, surcharge storage) are usually still needed.

F. Stone filled trench – The advantage of using stone filled (infiltration) trenches is simplicity, but they are not generally suitable to accepting large volumes of process wastewater without being prohibitively large or being constructed in highly permeable, well drained soils, in which case there is potential for groundwater contamination. Stones are not particularly effective at P adsorption. When saturated conditions occur in the trench, septic and odorous conditions arise, and high inputs of organic materials may quickly clog areas of the trench.

G. Spray irrigation – The advantages of spray irrigation are large wastewater volumes are easily handled, it's the best method of distributing wastewater over large areas for effective nutrient removal and retention, and it can provide needed crop nutrients as part of a nutrient management plan. The disadvantages to spray irrigation, especially in the Northeast, are the wastewater likely needs to be stored for application during dry periods and it may be difficult and not acceptable to use during winter periods. With spray irrigation, any concentrated effluents may burn or contaminate vegetation, and these systems require pumps, a network of pipes, and pumping energy inputs.

H. **Aerobic septic system** – The aerobic septic system is similar to a regular septic system except that the effluent is decomposed and treated aerobically rather than anaerobically. An advantage of an aerobic septic system is the treated effluent is of better quality for land application or disposal to the leach field, so a leach field is less likely to plug. Thus, the aerobic septic system may be better suited to sites where an ordinary septic system and leach field would fail. Some disadvantages of the aerobic septic system are that it is more expensive to construct than a traditional septic system, and it's not generally practical for large wastewater volumes.

I. **Inclusion in liquid manure handling system** – When process wastewaters are added to the liquid manure handling system, which most often uses the aerobic lagoon approach discussed in C above, the lagoon needs to be increased in size to handle the additional wastewater volumes.

78. Describe the potential pollution impacts of silage leachate.

Silage leachate is acidic (pH around 4), and contains high concentrations of BOD, ammonia-N, phosphorus, potassium, and organic carbons. Silage leachate is one of the most environmentally contaminating wastes produced on a livestock farm if it's not contained, treated, and disposed of properly. Any direct discharges of concentrated silage leachate to streams leads to rapid deoxygenation and a decrease in pH, potentially killing fish and other benthic organisms. The direct discharge to vegetated areas kills the vegetation and causes septic odors. Silage leachate is corrosive to steel and concrete, which further complicates managing this waste.

79. Explain management factors that reduce or prevent the potential of stored silage to leach.

Humid climatic conditions exasperate the production of silage leachate. On an equal mass basis, grass ensilage produces more fermentable leachate than corn because of the finer chop size and higher moisture content at harvest. However, compared to corn, grass ensilage is usually put into storage at a denser pack during summer months, so less total leachate runoff tends to escape during rain events. Management factors to reduce leachate volume and runoff from silage bunkers are to harvest crops at maturity and drier moisture content, avoid filling during rainy periods, and to cover the bunkers as quickly as possible.

80. Understand the various methods to manage and treat high and low flow silage leachate.

Low volumes of highly concentrated leachate (low flow) should be collected and diluted prior to land application. Low flow leachate is generally leachate that is discharged undiluted from the pressure of the weight of silage piled. Dilution by adding small amounts of leachate to dry manure prior to disposal with a spreader, or to transfer the low flow to the manure lagoon for later spreading is recommended. Silage leachate that has been diluted with storm water runoff (high flow) can be either added to the manure storage lagoon, or when concentrations are acceptable, the wastewater can be diverted to appropriately designed vegetated filter or treatment areas or perhaps be applied directly to crop fields through irrigation.

81. List management and environmental objectives for improving a barnyard.

The primary management objectives for improving a barnyard are to enhance livestock health and to make the care and feeding operations more efficient. Environmental objectives are to reduce offensive odors, improve facility aesthetics, and to minimize any off-site loss of contaminants that may impair water quality.

82. Discuss why excluding clean water is important and describe methods of excluding outside (clean) water from barnyards and other livestock areas.

Excluding clean water from barnyards and livestock areas reduces the potential and the volume of water that may become contaminated and flow off-site from the livestock production operations. Typical approaches to excluding clean water include the collection and diversion of rainwater from roof areas and the diversion of adjacent (upslope) in-coming runoff water around the barnyard, feedlot, and other feed and manure storage areas.

83. Discuss advantages and disadvantages of various barnyard surfaces.

An advantage of an earthen, permeable barnyard surface is that it may infiltrate and retain contaminants in place. However, if the area is permeable, groundwater may become contaminated. Generally, livestock traffic quickly turns earthen surfaces into seas of mud or compacted soil, from which animal health and runoff water quality soon deteriorate. Smooth concrete surfaces are easily to clean, but will quickly result in surface runoff and contaminated surface runoff if not kept absolutely clean. Slightly roughened minimally sloping concrete is best for animal footing. The roughened surface is more difficult to keep clean but has the ability to retain small amounts of precipitation without generating runoff.

84. Explain establishment and/or maintenance requirements of barnyards and barnyard runoff treatment options.

Barnyards should be constructed and established so that cleaning can be easily and efficiently accomplished without leaving residual deposits, especially in areas where the residuals would impede rainfall runoff or runoff collection devices. Barnyards that are cleaned frequently improve animal health, are easier to clean, and reduce concentrations of contaminants in any runoff. Barnyards are sloped to runoff collection chambers, and concrete curbs are usually installed to which cleaning equipment can push against. Barnyard runoff treatment options are to collect and transfer the effluent to a manure storage lagoon, or to utilize a series of screens and settling tanks to remove suspended materials and digestable solids, and then to transfer the runoff effluent to a vegetated filter or other treatment area. Considerations should be given to limiting the size of barnyards, eliminating them altogether, or placing a roof over them to minimize or prevent the amount of contaminated runoff water that is generated. The real need and purpose for a barnyard should be addressed, as barnyards may not be necessary. Smaller travel ways can perhaps be used to move livestock between the milking parlor and the pasture, or other feeding and holding areas. Wastewater treatment strips may be very difficult to build for barnyards in some areas because of limiting site conditions and current standard (regulatory) requirements.

Competency Area 9: Conservation Planning

---

85. Explain how policies, procedures, technical guidance, and programs at the federal, state and local level fit together in the planning process. Understand the key elements of the planning process.

The National Environmental Policy Act (NEPA. Pub. L. 91-190, 42 U.S.C. 4321-4347, January 1, 1970, as amended by Pub. L. 94-52, July 3, 1975, Pub. L. 94-83, August 9, 1975, and Pub. L. 97-258, § 4(b), Sept. 13, 1982) requires agencies of the Federal Government to " . . utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment . . .". The United States Department of Agriculture - Natural Resources Conservation Service (NRCS) developed the 9-Step Conservation Planning Process that enables the agency to meet this NEPA regulation while assisting Tribal governments, farmers, ranchers, and other landowner in the decision making process. The planning process thus establishes a framework in the spirit of NEPA for planning and applying conservation practices/systems which will "…encourage productive and enjoyable harmony between [people and their environment]…" (NEPA 1969). As presented in NRCS policy, the objective of conservation planning is to help each client attain sustainable use and sound management (prevent degradation) of soil, water, air, plant, and animal, plus energy (SWAPA+E) resources while also including consideration and strategies in meeting human, social, and economic needs (SWAPA+H). The NRCS-National Planning Procedures Handbook (NPPH) provides procedures and guidance on implementing the conservation planning policy. The NRCS-Field Office Technical Guide (FOTG) is the primary technical reference for the agency. It is composed of five sections which contain either directly or by reference technical information about the SWAPA resources as discussed above.

In New York, the Soil and Water Conservation Committee developed the "Agriculture Environmental Management System" (AEM). AEM is a voluntary, incentive-based program that helps farmers make common-sense, cost-effective and science-based decisions to help meet business objectives while protecting and conserving the State's natural resources. Farmers work with local AEM resource professionals to develop comprehensive farm plans using a tiered process. The tiered process provides a complimentary series of actions to the NRCS planning process, providing mission critical information to planners and landowners regarding existing farm and natural resource conditions. This combined NRCS-AEM process in New York provides a synergistic approach to ascertain federal and state programs appropriate to address on-farm concerns, and to leverage federal and state programs to provide technical and financial assistance to farmers developing and implementing conservation plans. (AEM, 2008). Thus, the NRCS-AEM strategy is designed to facilitate the development of comprehensive tactical plans based upon the inputs and outputs of the planning process, helping to identify and systematically treat the resource concerns and opportunities on the farm.

86. Explain how federal, state, and local programs support implementation of conservation plans.

Technical and financial assistance is offered to farmers in a voluntary, cost-share driven incentive environment through conservation programs offered from federal, state, and/or local governments. Such programs reflect the public's concern over a broad range of environmental conditions and their desire to address these problems. The non-farming public wishes for a clean, stable natural resource base which provides an adequate, affordable food supply. In addition, the natural and social amenities (green space, viewsheds, quality of the soil, water, and air resources, and wildlife health and habitat) brought about by the conservation and wise use of our natural resources are also highly desired public goods. When farmers implement conservation plans through participation in conservation programs they underscore their concern for these same issues and bolster their environmental stewardship. This environmental and socially responsible behavior also results in social and community benefits reflected in the quality of life for all.

Federal, state and local programs provide technical and financial assistance to farmers and other landowners interested in developing and implementing a conservation plan. Technical assistance is brought to bear by NRCS and Soil and Water Conservation District (SWCD) employees, as well as certified Technical Service Providers (TSP) from the private sector. These individuals provide expertise from discipline areas such as agronomy, sediment and erosion control, animal science, engineering, water quality, nutrient and pest management, forestry, and wildlife. Thus, these individuals are subject matter experts tasked to providing guidance and decision making assistance to farmers and other landowners. A significant portion of the technical assistance cost is covered through the salaries of the public sector employees. TSP fees are offset through cost sharing available through federal and state conservation programs. A varying percentage of the cost of the materials and services for the installation of a conservation practice or system composed of practices (conservation management systems) is addressed through the financial assistance provisions of a variety of federal and state conservation programs. Leveraging of these programs at the local level is a very effective strategy to provide a significant amount of the financial assistance that a farmer needs.

87. Understand the NRCS 9-Step Planning Process, including identifying resource concerns, planning criteria, and client objectives, and other State planning tools.

The United States Department of Agriculture - Natural Resources Conservation Service (NRCS) developed and uses a three phased - nine-step conservation planning process (Figure 1). It is a systematic, interdisciplinary approach which ensures the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making (See NEPA). The planning process establishes a framework in the spirit of NEPA for planning and applying conservation practices/systems which will "…encourage productive and enjoyable harmony between [people and their environment]…" (NEPA 1969). The planning process is presented in the NRCS "National Planning Procedures Handbook (NPPH) available at http://directives.sc.egov.usda.gov/17088.wba. The NPPH provides the following overview of conservation planning:

> *"Conservation planning is a natural resource problem solving and management process. The process integrates economic, social (cultural resources are included with social), and ecological considerations to meet private and public needs. This approach, which emphasizes desired future conditions, helps improve natural resource management, minimize conflict, and address problems and opportunities. The success of conservation planning and implementation depends on the voluntary participation of clients. While participation is voluntary, NRCS personnel must carry out outreach activities to reach underserved customers, such as minority, and small producers with limited resources, to ensure that services are offered to them on an equal basis with traditional customers. It is imperative that all customers be treated fairly and equitably, with dignity and respect. The planning process used by NRCS is based on the premise that clients will make and implement sound decisions if they understand their resources, natural resource problems and opportunities, and the effects of their decisions. Conservation planning helps clients, conservationists, and others view the environment as a living system of which humans are an integral part. Conservation planning enables clients and planners to analyze and work with complex natural processes in definable and measurable terms." (NPPH 2003).*

In New York, the AEM System utilizes a tiered process, consisting of the following five tier distinctions:

Tier 1 – Inventory current activities, future plans, and potential environmental concerns.

Tier 2 – Document current land stewardship; assess and prioritize areas of concern.

Tier 3 – Develop conservation plans addressing concerns and opportunities tailored to farm goals.

Tier 4 – Implement plans utilizing available financial, educational and technical assistance.

Tier 5 – Evaluate to ensure the protection of the environment and farm viability. (http://www.agmkt.state.ny.us/SoilWater/aem/index.html)

Tiers 1 and 2 provide a complimentary series of actions to the NRCS planning process, providing the information to planners in consultation with the landowners, and documenting and prioritizing landowners concerns, needs, and future plans. Tiers 3 through 5 provide a venue for tailoring the plan and for implementation. The interaction of the Nine Step Process and AEM is summarized in Table 1.

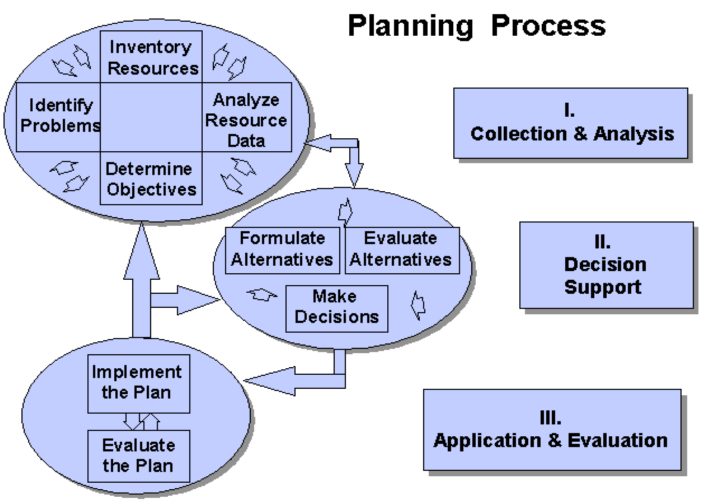


Figure 1: The NRCS Three Phase – Nine Step Conservation Planning Process.

Table 1: AEM and the NRCS Planning Process

AEM Tier	Function	NRCS Step Groups for AEM	Phase	NRCS Steps
Tier I	Questionnaire – Inventory current activities, future plans and potential environmental concerns	Preplanning Tool		
Tier II	Worksheets - Document current land stewardship; assess and prioritize areas of concern.	Preplanning Tool		

AEM Tier	Function	NRCS Step Groups for AEM	Phase	NRCS Steps
Tier III	Plan - Develop conservation plans addressing concerns and opportunities tailored to farm goals	NRCS Steps 1-7	Phase I Collection and Analysis Phase II Decision Support	1. Identify Problems 2. Determine Objectives 3. Inventory Resources 4. Analyze Resource Data 5. Formulate Alternatives 6. Evaluate natives 7. Make Decisions
Tier IV	Implementation - Implement plans utilizing available financial, educational and technical assistance	NRCS Step 8	Phase III Application and Evaluation	8. Implement the Plan
Tier V	Evaluation - Evaluate to ensure the protection of the environment and farm viability	NRCS Step 9		9. Evaluate the Plan

88. Explain the uses of the following USDA NRCS references:

A. Field Office Technical Guide (FOTG)

The Field Office Technical Guide (FOTG) is the primary technical reference for the Natural Resources Conservation Service (NRCS). It is also the umbrella document for NRCS Technical Releases and References. The FOTG is available on-line and is known there as the electronic FOTG or eFOTG. It is divided into five sections:

Section I – General Resource References

Section I contains general state maps, descriptions of Major Land Resource Areas, watershed information, and links to NRCS reference manuals and handbooks. Section I contains links to researchers, universities, and cooperating agencies. Section I also contains conservation practice costs, natural resource related laws and regulations, cultural resources, and information about protected plant and animal species.

Section II – Natural Resources Information

Section II contains detailed information about soil, water, air, plant, and animal resources. NRCS Soil Surveys, Hydric Soils Interpretations, Ecological Site Descriptions, Forage Suitability Groups, Cropland Production Tables, Wildlife Habitat Evaluation Guides, Water Quality Guides, and other related information can be found in this section as it becomes available.

Section III – Resource Management Systems and Planning Criteria

Section III contains detailed information about NRCS Planning Criteria, which establish standards for resource conditions that help provide sustained use. It also provides guidance for the development of conservation management systems (CMS).

Section IV – Practice Standards and Specifications

Section IV contains the NRCS Conservation Practice standards, specifications, guidelines, statements of work, and job sheets. Practice standards define the practice and where it applies. Practice specifications are detailed requirements for installing the practice in the state.

Section V – Conservation Effects

Section V provides background information on how conservation practices affect each identified resource concerns in the state. http://www.nrcs.usda.gov/technical/efotg/index.html.

B. National Handbook of Conservation Practices (NHCP)

The Natural Resources Conservation Service (NRCS) is the lead USDA agency for providing conservation technical assistance and planning on privately owned lands. The National Handbook of Conservation Practices (NHCP) establishes national standards for conservation practices commonly used to address natural resource concerns and opportunities. Each NRCS State office localizes the Field Office Technical Guide (FOTG) to its geographic area and establishes quality requirements for applying conservation practices within its area of responsibility. Revised local practice standards are to be equal to or more rigorous than the national standard. Conservation practice standards are in section IV of the FOTG. The NHCP not only houses the current national conservation practice standards but also provides guidance and direction on maintaining conservation practice standards, offers several ways for obtaining the standards, and encourages involvement in the process of developing new or revising current standards.

National conservation practice standards should NOT be used to plan, design, or install a conservation practice or system of practices. The national practice standards are reviewed and adapted for each state to meet local conditions. Use the standard developed by the state in which you are working to ensure that you meet all state and local criteria which may be more restrictive than the criteria found in the national version of the practice standard. In addition, each state determines which National conservation practice standards are applicable in their state. States add the technical detail needed to effectively use the standards at the field office level, and issue them as state conservation practice standards. New or revised state practice standards are posted to the Federal Register for review and comment by the public for a minimum of 30 days. State conservation practice standards may be found in Section IV of the Field Office Technical Guide (FOTG). The national NHCP web site also contains the National NHCP Notices; conservation practice job sheets, statements of work, information sheets, and other references.

Conservation practice standards in the NHCP evolved in accordance with advancement in farming and ranching techniques used throughout the world and with changes in technology as documented by research, conservation field trials, and accumulated experience. Practice standards need to be reviewed and maintained continuously to stay current with rapid changes in technology and to ensure that they address multiple resources. Reviews ensure that standards:

- Provide timely incorporation of new technologies.
- Address multiple resource concerns.
- Are consistent in format and content.
- Enhance interagency cooperation with regard to development of standards.
- Account for the varied conservation activities expected of NRCS in the future.

National policy and the practice standards are developed for the protection of the landowner, conservation contractors, Soil and Water Conservation District (SWCD) employees, and NRCS employees. When a practice is installed according to criteria specified in the practice standard and the plans and specifications:

- The landowner receives a conservation product that solves the apparent resource problem.
- The contractor understands his/her responsibility in providing a quality job on the ground and is not required to warranty a product beyond the requirements of the standard.
- The NRCS is protected by being assured that its employees are working within the scope of their employment.

The following definitions help to clarify the different documents that are found in the NHCP or Section IV of the FOTG.

- Conservation Practice Standards
  A statement of acceptable quality or technical excellence in terms of both form and function (performance), usually expressed in terms of limits; i.e., minimum or maximum. The conservation practice standard contains information on why and where the practice is applied, and sets forth the minimum quality criteria that must be met during the application of that practice in order for it to achieve its intended purpose(s).
- Conservation Practice Specification
  An explicit set of requirements to be satisfied by a material, product, system, or service, such as construction. It also identifies the methods for determining whether each of the requirements is satisfied.
- Conservation Practice Information Sheets
  The conservation practice information sheet contains a photograph of the installed practice, plus a definition or description of the practice, where it is commonly used and a brief description of the conservation effects of this practice when it is properly applied.
- Conservation Implementation Requirements
  The conservation practice Implementation Requirements provide detailed requirements for the design, installation, and checkout for the conservation practice,
- Statements of Work
  The Statements of Work outline deliverables required to document the design, installation, and checkout for all conservation practices in the National Handbook of Conservation Practices (NHCP),
  ftp://ftp-fc.sc.egov.usda.gov/NHQ/practice-standards/notices/nhcp-chapter1.pdf
  http://www.nrcs.usda.gov/technical/Standards/nhcp.html
  http://www.nrcs.usda.gov/technical/Standards/

C. National Planning Procedures Handbook (NPPH)

(see item 87 – Understand the NRCS 9-Step Planning Process and other State planning tools)

The purpose of this handbook is to provide guidance on the planning process the Natural Resources Conservation Service (NRCS) uses to help develop, implement, and evaluate conservation plans for individuals, and area wide conservation plans or assessments for groups. NRCS provides conservation planning and technical assistance to clients (individuals, groups, and units of government). These clients develop and implement plans to protect, conserve, and enhance natural resources (soil, water, air, plants, and animals) within their social and economic interests.

In 1947, Hugh Hammond Bennett, the father of soil conservation and first Chief of the Soil Conservation Service (now the NRCS) identified the principles of conservation planning in his text, “Elements of Soil Conservation”. According to Bennett, an effective conservation planner must adhere to the following principles:

- Consider the needs and capabilities of each acre within the plan
- Consider the farmer’s facilities, machinery, and economic situation
- Incorporate the farmer’s willingness to try new practices
- Consider the land’s relationship to the entire farm, ranch, or watershed
- Ensure the conservationist’s presence out on the land

The NPPH reaffirms these principles throughout the planning process for all types of land uses.

Planning involves more than considering individual resources. It focuses on the natural systems and ecological processes that sustain the resources. The planner strives to balance natural resource issues with economic and social needs through the development of conservation management systems (CMS). The conservation planning process helps the planner and client accomplish the following:

- Help protect, conserve, and enhance natural resources.
- Design alternatives that meet local resource quality criteria for identified resource issues.
- Include the consideration of human concerns toward achieving sustainable agriculture.
- Consider the effects of planned actions on interrelated geographical areas (i.e., looking off-site, beyond the planning unit boundary).
- Consider and explain the interaction between biological communities and society.
- Focus on ecological principles.
- Consider the effects and interactions of planned systems and practices on the natural resources, as well as economic and social considerations.
- Assist with development of plans, regardless of scale, which will help achieve the client’s and society’s objectives.
- Identify where knowledge, science, and technology need to be advanced.

The planning process is used to assist clients in developing conservation plans for individuals, or area wide conservation plans or assessments for groups within watersheds or other defined areas. The process thus establishes a framework for planning and applying conservation systems on individual land units, as well as multiple ownerships. It also provides opportunities for input by stakeholders during development of area wide conservation plans or assessments.

Planning is complex and dynamic. Successful planning requires not only a high level of knowledge, skills, and abilities on the part of the planner, but also the exercise of professional judgment. To gain or maintain the knowledge, skills, and abilities, this handbook can be used as a training tool by less experienced planners and as a reference tool by experienced planners.

The United States Department of Agriculture - Natural Resources Conservation Service (NRCS) developed the 9-Step Conservation Planning Process that enables the agency assist Tribal governments, farmers, ranchers, and other landowners in the conservation planning decision making process. The process establishes a framework for planning and applying conservation practices/systems which will facilitate and encourage productive and enjoyable harmony between people and their environment (see NEPA).

As presented in NRCS policy, the objective of conservation planning is to help each client attain sustainable use and sound management (prevent degradation) of soil, water, air, plant, and animal (SWAPA) resources while also including consideration and strategies in meeting human, social, and economic needs (SWAPA+H).

The NRCS-National Planning Procedures Handbook (NPPH) provides procedures and guidance on implementing the conservation planning policy. In New York State, the State Soil and Water Conservation Committee developed the "Agriculture Environmental Management System" (AEM). AEM is a voluntary, incentive-based program that helps farmers make common-sense, cost-effective and science-based decisions to help meet business objectives while protecting and conserving the State's natural resources. Farmers work with local AEM resource professionals to develop comprehensive farm plans using a tiered process.

D. Guide to Agricultural Environmental Management (AEM)
(see Item 87 – AEM Tier planning process)

In New York State, the State Soil and Water Conservation Committee developed the "Agriculture Environmental Management System" (AEM). AEM is a voluntary, incentive-based program that helps farmers make common-sense, cost-effective and science-based decisions to help meet business objectives while protecting and conserving the State's natural resources.

The NRCS-AEM strategy is designed to facilitate the development of comprehensive tactical plans based upon the inputs and outputs of the planning process in helping to identify and systematically treat the resource concerns and opportunities on the farm.

89. Define "Concentrated Animal Feeding Operation" (CAFO) and "Animal Feeding Operations" (AFO) and explain how these relate to local regulations and national Clean Water strategies.

- **Concentrated Animal Feeding Operation (CAFO)**

  An AFO that is defined as a Large CAFO or as a Medium CAFO…, or that is designated as a CAFO… Two or more AFOs under common ownership are considered to be a single AFO for the purposes of determining the number of animals at an operation, if they adjoin each other or if they use a common area or system for the disposal of wastes. [40 CFR 122.23(b)(2)]

- **Large Concentrated Animal Feeding Operation (Large CAFO)** [40 CFR 122.23(b)(4)] An AFO is defined as a Large CAFO if it stables or confines as many or more than the numbers of animals specified in any of the following categories:
  - 700 mature dairy cows, whether milked or dry;
  - 1,000 veal calves;

- 1,000 cattle other than mature dairy cows or veal calves. Cattle includes but is not limited to heifers, steers, bulls and cow/calf pairs;
- 2,500 swine, each weighing 55 pounds or more;
- 10,000 swine, each weighing less than 55 pounds;
- 500 horses;
- 10,000 sheep or lambs;
- 55,000 turkeys;
- 30,000 laying hens or broilers, if the AFO uses a liquid manure handling system;
- 125,000 chickens (other than laying hens), if the AFO uses other than a liquid manure handling system;
- 82,000 laying hens, if the AFO uses other than a liquid manure handling system;
- 30,000 ducks (if the AFO uses other than a liquid manure handling system); or
- 5,000 ducks (if the AFO uses a liquid manure handling system)

- **Medium Concentrated Animal Feeding Operation (Medium CAFO)** [40 CFR 122.23(b)(6)]
  The term Medium CAFO includes any AFO with the type and number of animals that fall within any of the ranges listed below and which has been defined or designated as a CAFO. An AFO is defined as a Medium CAFO if the type and number of animals that it stables or confines falls within any of the following ranges:

  - 200 to 699 mature dairy cows, whether milked or dry;
  - 300 to 999 veal calves;
  - 300 to 999 cattle other than mature dairy cows or veal calves. Cattle includes but is not limited to heifers, steers, bulls and cow/calf pairs;
  - 750 to 2,499 swine each weighing 55 pounds or more;
  - 3,000 to 9,999 swine each weighing less than 55 pounds;
  - 150 to 499 horses;
  - 3,000 to 9,999 sheep or lambs;
  - 16,500 to 54,999 turkeys;
  - 9,000 to 29,999 laying hens or broilers, if the AFO uses a liquid manure handling system;
  - 37,500 to 124,999 chickens (other than laying hens), if the AFO uses other than a liquid manure handling system;
  - 25,000 to 81,999 laying hens, if the AFO uses other than a liquid manure handling system;
  - 10,000 to 29,999 ducks (if the AFO uses other than a liquid manure handling system); or
  - 1,500 to 4,999 ducks (if the AFO uses a liquid manure handling system); and

  Either one of the following conditions is/are met: http://cfpub.epa.gov/npdes/glossary.cfm#L

90. Understand the roles and responsibilities of the local, state, and federal conservation agencies (i.e. CES, SWCD, FSA, NRCS, DEC, RD, EPA, DOH, and RC&D).

- **Cooperative Extension Service (CES)**

  Cornell Cooperative Extension is a key outreach system of Cornell University with a strong public mission and an extensive local presence that is responsive to needs in New York communities. The Cornell Cooperative Extension educational system enables people to improve their lives and communities through partnerships that put experience and research knowledge to work. Cornell

Cooperative Extension operates on the Cornell campus through the leadership of faculty and staff in departments in the College of Agriculture and Life Sciences and the College of Human Ecology, with contributions from the College of Veterinary Medicine. The county-based Cornell Cooperative Extension associations and the New York City office provide 56 portals to Cornell University. Extension educators in these locations form powerful community-university partnerships with the Cornell campus, and involve local constituents to address the issues and concerns of New Yorkers. http://www.cce.cornell.edu/editor/show/About_Extension. Similarly, the New England states have their own Cooperative Extension systems.

- **Soil and Water Conservation Districts (SWCD)**

Soil and Water Conservation Districts are government entities that help control the use of land and water in U.S. states and insular areas. There are more than 3,000 in the United States. Depending on the state, they may also be known as soil and water conservation districts, soil conservation districts, resource conservation districts, or other similar names. Nationally and within each state, the districts are generally coordinated by non-governmental associations. District borders often coincide with county borders. http://en.wikipedia.org/wiki/Soil_and_water_conservation_district

- **Farm Service Agency (USDA-FSA)**

The Farm Service Agency (FSA) administers and manages farm commodity, credit, conservation, disaster and loan programs as laid out by Congress through a network of federal, state, and county offices. These programs are designed to improve the economic stability of the agricultural industry and to help farmers adjust production to meet demand. Economically, the desired result of these programs is a steady price range for agricultural commodities for both farmers and consumers. State and county offices directly administer FSA programs. These offices certify farmers for farm programs and pay out farm subsidies and disaster payments. Currently, there are 2,346 FSA county offices in the continental states. FSA also has offices in Hawaii, and a few American territories.

More than 8,000 farmer county committee members serve in FSA county offices nationwide. Committee members are the local authorities responsible for fairly and equitably resolving local issues while remaining dually and directly accountable to the Secretary of Agriculture and local producers though the elective process. They operate within official regulations designed to carry out Federal laws and provide a necessary and important voice in Federal decisions affecting their counties and communities. Committee members make decisions affecting which FSA programs are implemented county-wide, the establishment of allotment and yields, commodity price support loans and payments, conservation programs, incentive, indemnity, and disaster payments for commodities, and other farm disaster assistance. For more information see: http://www.fsa.usda.gov/FSA/webapp?area=about&subject=landing&topic=landing.

- **Natural Resources Conservation Service (USDA-NRCS)**

Since 1935, the Natural Resources Conservation Service (originally called the Soil Conservation Service; http://www.nrcs.usda.gov/about/) has provided leadership in a partnership effort to help America's private land owners and managers conserve their soil, water, and other natural resources. NRCS employees provide technical assistance based on sound science and suited to a customer's specific needs. The agency provides financial assistance for many conservation activities through Federal conservation programs. Participation in these programs is voluntary.

- Conservation Technical Assistance (CTA) program provides voluntary conservation technical assistance to land-users, communities, units of state and local government, and other Federal agencies in planning and implementing conservation systems.
- NRCS reaches out to all segments of the agricultural community, including underserved and socially disadvantaged farmers and ranchers, to ensure that our programs and services are accessible to everyone.
- NRCS manages Federal natural resource conservation programs that provide environmental, societal, financial, and technical benefits.
- Science and technology activities provide technical expertise in such areas as animal husbandry and clean water, ecological sciences, engineering, resource economics, and social sciences.
- NRCS provides expertise in soil science and leadership for soil surveys and for the National Resources Inventory, which assesses natural resource conditions and trends in the US.
- NRCS provides technical assistance to foreign governments, and participate in international scientific and technical exchanges.

- **Department of Environmental Conservation (NYS-DEC)**

The New York State Department of Environmental Conservation (DEC) was created to bring together in a single agency all state programs directed toward protecting and enhancing the environment.

> *"The quality of our environment is fundamental to our concern for the quality of life. It is hereby declared to be the policy of the State of New York to conserve, improve and protect its natural resources and environment and to prevent, abate and control water, land and air pollution, in order to enhance the health, safety and welfare of the people of the state and their overall economic and social well-being." - Environmental Conservation Law, Article 1*

DEC's goal is to achieve this mission by embracing the elements of sustainability - the simultaneous pursuit of environmental quality, public health, economic prosperity, and social well-being, including environmental justice and the empowerment of individuals to participate in environmental decisions that affect their lives. http://www.dec.ny.gov/about/511.html

- **Rural Development (USDA-RD)**

The USDA Rural Development is committed to helping improve the economy and quality of life in all of rural America. The agency administers programs that touch rural America in many ways.

- Financial programs support essential public facilities and services as water and sewer systems, housing, health clinics, emergency service facilities, and electric and telephone service.
- Promote economic development by supporting loans to businesses through banks and community-managed lending pools.
- Technical assistance and information to help agricultural and other cooperatives get started and improve the effectiveness of their member services; and provide technical assistance to help communities undertake community empowerment programs.

Rural Development achieves its mission by helping rural individuals, communities and businesses obtain the financial and technical assistance needed to address their diverse and unique needs. Rural Development works to make sure that rural citizens can participate fully in the global economy. http://www.rurdev.usda.gov/rd/index.html

- **Environmental Protection Agency (US-EPA)**

  EPA leads the nation's environmental science, research, education, and assessment efforts. The mission of the EPA is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people and:
  - Develops and enforces regulations
  - Gives grants
  - Studies environmental issues
  - Sponsors partnerships
  - Teaches people about the environment
  - Publishes information

  http://www.epa.gov/epahome/aboutepa.htm and http://www.epa.gov/epahome/whatwedo.htm

- **Department of Health (NYS-DOH, County-DOH)**
  The Department of Health works with its federal, state and local partners to help people in the state stay healthier and safer. Our programs and services help prevent illness and injury, promote healthy places to live and work, provide education to help people make good health decisions and ensure our state is prepared for emergencies.

- **Resource Conservation and Development Councils USDA-NRCS-RC&D)**
  The purpose of the Resource Conservation and Development (RC&D) program is to accelerate the conservation, development, and utilization of natural resources, improve the general level of economic activity, and to enhance the environment and standard of living in designated RC&D areas. It improves the capability of State, tribal and local units of government and local nonprofit organizations in rural areas to plan, develop, and carry out programs for resource conservation and development. The program also establishes or improves coordination systems in rural areas. Current program objectives focus on improvement of quality of life achieved through natural resources conservation and community development which leads to sustainable communities, prudent use (development), and the management and conservation of natural resources. RC&D areas are locally sponsored areas designated by the Secretary of Agriculture for RC&D technical and financial assistance program funds. http://www.nrcs.usda.gov/programs/rcd/.