4.4 BASIC SOIL CONCEPTS

Approximately half of all North Carolinians use onsite systems to treat and dispearse of their household wastewater. These systems generally rely on a wastewater receiving tank or septic tank, along with a treatment and dispersal field for proper sewage treatment and dispersal. Most wastewater purification occurs in soil beneath the drainfield.

A soil absorption system for wastewater dispersal and treatment utilizes physical, chemical and biological soil processes that absorb and treat wastewater and its constituents.

Not all soils and sites will adequately treat and dispose of wastewater. Soil and site evaluations are necessary in order to locate appropriate sites. This section presents soil concepts that are required to conduct a soil and site evaluation.

The Use of Soil for Onsite Systems

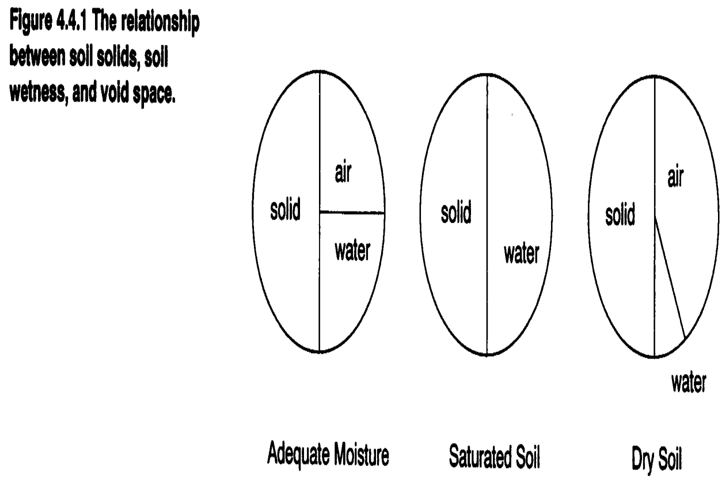
There are many methods to treat and disperse of wastewater. Onsite systems usually rely on soil treatment since this is an inexpensive and reliable medium for wastewater treatment and dispersal. The porous nature and biological activity of soil are key characteristics in absorbing and treating wastewater.

Since there are many variations in soil characteristics, not all soils can suitably treat and dispose of wastewater. The challenge for those involved with onsite systems is to design and install wastewater systems that optimize a soil's treatment potential.

Note the following characteristics when selecting sites for onsite systems:

- Purified wastewater processes, physical filtration by soil particles, chemical treatment through ion exchange, transformation in chemical reactions, biological oxidation, decomposition by micro-organisms, and uptake of nutrients by plants;
- Soils can vary greatly over short distances. Because of their spatial variability, soil knowledge becomes critical in the selection and evaluation of the sites where onsite systems will be located;
- All soils are composed of mineral matter, organic matter, and voids or spaces that can be filled with either water or air. Soil water and soil air are inversely related to each other because soil water and soil air compete for the same void space in the soils (see Figure 4.4.1); and
- A winding flow path through soil voids that is neither too rapid nor too slow provides maximum treatment of wastes through natural soil processes.

Figure 4.4.1 The relationship between soil solids, soil wetness, and void space.



Definition of Soils

Soil is defined differently by groups that use soils for varying processes.

For the purposes of site and soil investigations for onsite systems in North Carolina, the most important definition is that contained in the Rules for Sewage Treatment and Disposal Systems:

> **"the naturally occurring body of porous mineral and organic materials on the land surface. Soil is composed of sand-, silt-, and clay-sized particles that are mixed with varying amounts of larger fragments and some organic material. Soil contains less that 50 percent of its volume as rock, saprolite, or coarse-earth fraction (mineral particles greater than 2.0 millimeters). The upper limit of the soil is the land surface, and its lower limit is 'rock,' 'saprolite,' or other parent materials."**

Reference
15 NCAC 18A.1935(41)

Engineers define soil as "any unconsolidated material composed of discrete solid particles with gases and liquids between" (Sowers, 1979).

Soil, as defined by geologists, is "that material which has been so modified and acted upon by physical, chemical, and biological agents that it will support rooted plants" (AGI, 1976).

Soil, as defined by soil scientists, is a naturally occurring, three-dimensional body that has developed at the earth's surface as a result of soil-forming processes: additions, losses, translocations, accumulation, and transformations, as influenced by the five soil-forming factors: parent material; relief; organisms; climate; and time.

Many of the criteria that are used to determine soil suitability for onsite systems come directly from soil characteristics defined by Soil Conservation Service (SCS) in *Soil Taxonomy Handbook* (1993) and in the *Soil Survey Manual* (1994).

The Field Book for Describing and Sampling Soils, Version 2.0 (2002) describes in greater detail the methods used for soil evaluation discussed in this section of the manual. Copies are available from the National Survey Center.

Soil Forming Processes and Factors

Soil forming processes include additions to soil bodies, such as sand blown up onto a sand dune; losses from soil bodies, such as soil erosion; translocations within a soil body, such as downward movement and accumulation of clay-sized particles in the subsoil; and transformations of material within a soil body, such as weathering of sand-sized mica particles into clay-sized kaolinite minerals.

The five soil-forming factors are parent material; relief; organisms; climate; and time:

1) Parent material is the rock or other matter which degrades into soil. Soils are very reflective of their parent material. For example, a soil developed from granite rock will always have a coarse texture and a relatively low pH.

2) Relief refers to both the slope of land and the aspect (the direction in relation to the sun) of the surface. The most obvious influence of relief is through slope. Slope affects losses and additions and thus causes changes in soil depth.

3) Organisms refer to the biological agents such as plants, fungi, and microorganisms that break down parent material into soil particles and also contribute organic matter to the soil. For example, the distribution, quantity, and type of organic matter in a soil developed under prairie vegetation is very different from a soil developed under forest vegetation.

4) Climate encompasses rainfall and snowfall, evaporation, and temperature. Climate controls some chemical and physical reactions and it can also affect the type of organisms in and on a given soil. Weathering of a soil is either hastened by a hot, moist climate, or retarded by a cold, dry climate.

5) Time is an important soil-forming factor because it modulates the other four factors. For example, a younger soil has had less time for its parent material to be changed, and for climate, relief, and organisms to affect the soil forming processes.

Soil Horizons, Profiles and Series

Soils are characterized by the minerals and organic matter from which they are made and by the sequence of these mineral and organic layers. The type of soil layer and the order in which the soil is layered are extremely important in onsite systems because soil layers control the movement of wastewater through the soil into the groundwater and treatment of the wastewater.

Soil Horizons

A soil consists of a number of layers roughly parallel to the earth surface. These layers are called soil horizons.

Reference
15 NCAC 18A.1935(13)

A soil horizon, as defined by the rules,

> **"means a layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil forming processes."**

Soil horizons are identified by different morphological characteristics: texture; structure; color or consistence. (These are discussed in greater detail on page 39.)

Soil scientists use a technical language in which each horizon is separated into one of six master horizons or layers. Master horizons are designated by the capital letters O, A, E, B, C and R where each master horizon indicates a certain set of properties in the soil. The sequence of horizons and horizon differentiation, for any given soil, is dependent on the soil forming factors. Figure 4.4.2 describes and demonstrates the six master layers and their properties.

Every soil contains at least one master horizon, and some soils contain all six master horizons or layers. Generally, a soil contains two or three master horizons.

The arrangement of horizons in the profile affects the rate of wastewater flow through the soil, the direction of flow (vertical or horizontal movement), and the amount of wastewater purification. Thus, the environmental health specialist must be able to identify the horizons present in the profile.

Master horizon designations can be modified by lower case letters that indicate subtle differences within a master horizon. Those symbols relevant to North Carolina soils are included in Table 4.4.1.

Figure 4.4.2
The six master horizons.

Figure 4.4.2 The six master horizons.

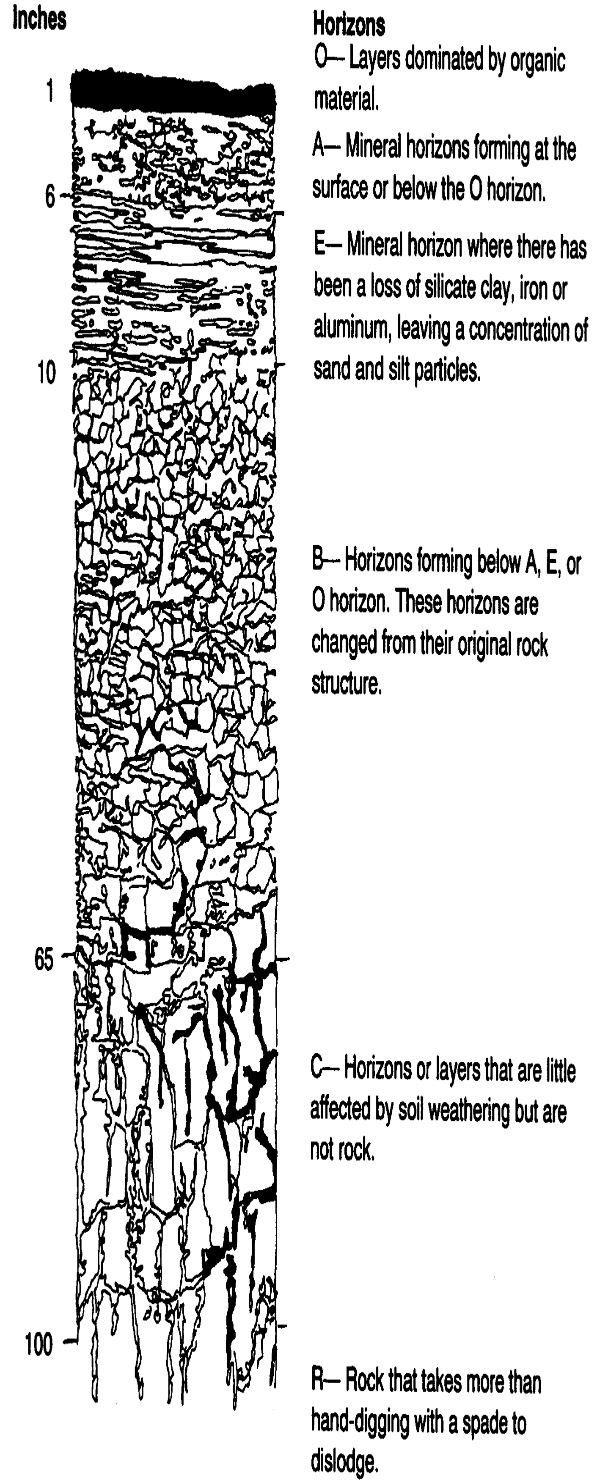


Table 4.4.1
Subordinate Distinctions within Master Horizons (from Soil Survey Staff, 1992).

Reference
15A NCAC 18A.1935(33)

Table 4.4.1 Subordinate Distinctions within Master Horizons (from Soil Survey Staff, 1992).

Symbol	Symbol Name	Symbol Meaning
a	Highly Decomposed Organic Matter	"a" is used with "O" to indicate the most highly decomposed organic materials in organic soils.
b	Buried Genetic Horizon	"b" designates identifiable buried genetic horizons in mineral soils. These genetic horizons had to form prior to being buried.
c	Concretions or Nodules	"c" indicates a significant accumulation of concretions and nonconcretions, if the nonconcretions are cemented with material other than silica (i.e., iron, aluminum, or manganese).
d	Physical Root Restriction	"d" is for root-restricting layers in naturally occurring or man-made unconsolidated sediments or materials.
e	Organic Material of Intermediate Decomposition	"e" is used to identify organic materials of intermediate decomposition in organic soils.
g	Strong Gleying	"g" means that the predominant color of the horizon has a chroma of 2 or less and because of iron being reduced and removed due to wetness or saturation with water.
h	Illuvial Accumulation of [*sic*?] Organic Material	"h" is used only with B master horizons. It indicates the accumulation of illuvial humus.
i	Slightly Decomposed Organic Material	"I" indicates the least decomposed of the organic materials in organic soils.
m	Cementation or Induration	"m" is used for continuous or nearly continuous cementation (>90% cemented). Root penetration is only through cracks.
p	Tillage or Other Disturbances	"p" denotes surface layer disturbances by cultivation, pasturing, or similar uses.
r	Weathered or Soft Bedrock	"r" is used with "C" to indicate layers of soft bedrock.
s	Illuvial Accumulation of Sesquioxides and Organic Matter	"s" is used in conjunction with "b" to indicate an accumulation of illuvial, amorphous, dispersible organic-matter-sesquioxide complexes if both organic matter and sesquioxide portion are significant. Also, the moist color value and chroma value must be 4 or greater. "s" is used in conjunction with "h" if the organic matter and sesquioxide components are significant. In this case, the moist color value and chroma are 3 or less.
t	Accumulation of Silicate	"t" means the accumulation of silicate clay that has either formed in the horizon or has been moved into it by illuviation.
v	Plinthite	"v" is used to indicate the presence of iron-rich, humus-poor, reddish material that is firm or very firm when moist and that
w	Development of Color or Structure	"w" denotes color or structure development in B horizons where there is not a substantial accumulation of illuvial clay.
x	Fragipan Character	"x" indicates genetically developed firmness, brittleness, or high bulk density.

Some horizons allow water to flow through easily; other horizons obstruct water flow. Horizons capable of perching groundwater are brittle and strongly compacted or strongly cemented are referred to as restrictive horizons. If a soil contains a restrictive horizon, the depth at which this horizon is located determines whether this soil is SUITABLE for an onsite system.

As defined by the rules,

> **"a restrictive horizon means a soil horizon that is capable of perching groundwater or sewage effluent and that is brittle and strongly compacted or strongly cemented with iron, aluminum, silica, organic matter, or other compounds. Restrictive horizons may occur as fragipans, iron pans or organic pans, and are recognized by their resistance in excavation or in using a soil auger."**

Other Morphological Properties of Horizons

Table 4.4.2 Description of Horizons and Symbols, Except for the Surface of Peat or Muck

Soil horizons can also be described by depth, thickness, and boundary conditions, as shown in Table 4.4.2.

Table 4.4.2 Description of Horizons and Symbols Except for the Surface of Peat or Muck.

HORIZON:	Use the standard horizon nomenclature
DEPTH:	In inches from the top of A, or surface mineral horizon, except for the surface of peat or muck
THICKNESS:	Average thickness and range
BOUNDARY:	Horizon lower boundaries are described as:

1) Distinctness of boundary:
   abrupt (<1" thick) ……..…………………. a
   clear (1" - 2.5") ………..………………. c
   gradual (2.5" - 5") ……..………………. g
   diffuse (>5") ……………..……………. d

2) Topography of boundary:
   smooth (nearly a plane) ………………………………………s
   wavy (pockets with width > depth) …………………………..w
   irregular (pockets with depth > width) ………………………..i
   broken (discontinuous) ……………………………………b

   Example: an abrupt, irregular boundary is noted as *ai*

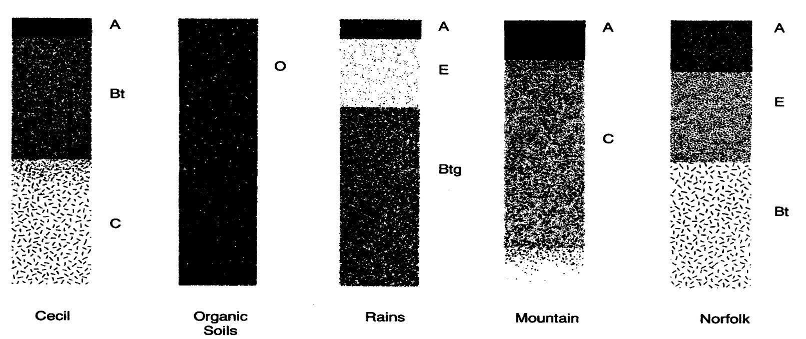
Soil Profiles

Generally, a soil is composed of more than one horizon. If a hole or pit is dug in a soil, the horizons are uncovered for viewing. This vertical cross section of soil, where all horizons are revealed, is called a soil profile.

Soil Series

Soil profiles, showing typical arrangements of horizons for five representative soils in North Carolina, are presented below (Figure 4.4.3). These five soil profiles are but a few examples of over 200 hundred types of soil profiles recognized throughout the state.

Figure 4.4.3
Five typical North Carolina Soil profiles.



Soils can be grouped and classified based on the arrangement of soil properties within each layer of the soil profile. These properties include texture, temperature, wetness, mineralogical classes, organic matter content, and other characteristics.

Soil profiles with specific arrangement of horizons and specific characteristics in each horizon belong to a soil series. All soils in a soil series have similar profile characteristics. Each soil series develops from the same parent material with the same combination of weathering processes.

The following factors are helpful in understanding the soil series concept:

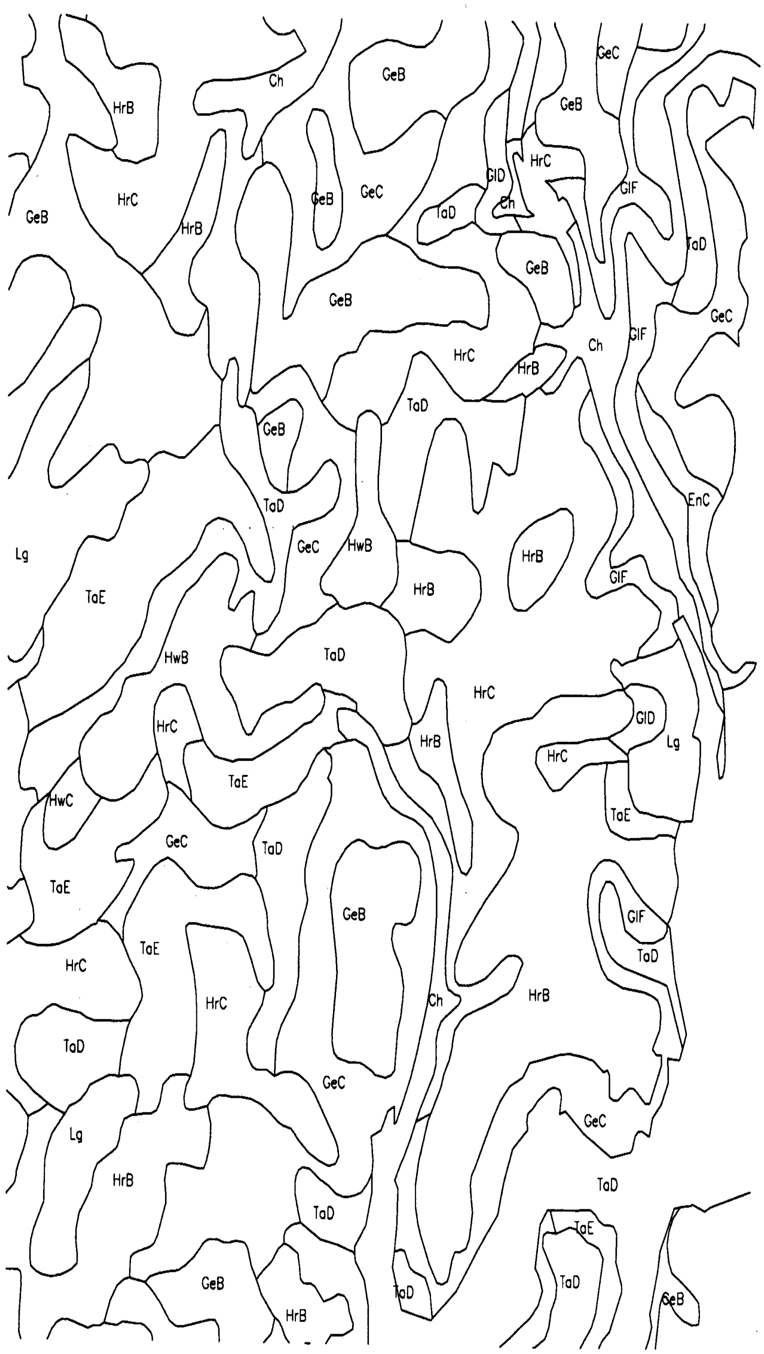
- Soils within the same soil series should be more alike and behave more similarly than soils in different soil series;
- Soil series are generally named for a town or region near the location where the soil series is first described;
- Soil series are strongly associated with relief or topographic location. This is because the soil-forming processes and the other soil-forming factors (parent material, time, climate, and organisms) in a region are the same for one type of topographical location, and tend to form one or a few soil series from the same parent material. Catenas are a good example of the effects of topographic location on the landscape. A catena is a group of related soils in a topo-drainage sequence. A representative North Carolina Coastal Plain catena consists of five soil series: Norfolk, Goldsboro, Lynchburg, Rains, and Pantego. These soils are related by their topographic positions or relief. Relief affects drainage and thus the accumulation of organic matter. Norfolk soils are well-drained, whereas Pantego soils are very poorly-drained;
- Soils are mapped as soil series. Because a soil series tells us about the properties of soil, soil maps reveal a great deal of information about the soil and, consequently, they give a good idea of how an onsite system will function in a location with a given soil series. There are over 250 mapped soil series in North Carolina. (Figure 4.4.4 is a representative soil map from the Piedmont area of North Carolina); and
- Because the scale of soil maps is generally greater than the area of an onsite system, soil maps should be used only in the initial survey of the area. The only reliable method for siting an onsite system in North Carolina is a thorough site and soil evaluation done by qualified specialists at the actual site. The site and soil evaluation must include a thorough evaluation of the soil morphological properties in the soil horizons at that location.

Reference
G.S. 130(A) – 336(b)

NORTH CAROLINA, EACH POTENTIAL LOCATION FOR AN ONSITE SYSTEM IS REQUIRED, BY LAW, TO HAVE A SITE AND SOIL EVALUATION.

Figure 4.4.4 Representative soil map from the piedmont area of North Carolina.

Figure 4.4.4
Representative soil map
From the piedmont area
of North Carolina.



Soil Morphological Characteristics

There are four major morphological characteristics that are used to differentiate soil horizons: soil texture; soil structure; color and consistence. Information on the four major soil morphological characteristics is presented below.

Soil Texture

Soil texture refers to the solid mineral part of soils. The mineral component of the soil is separated into three sizes of inorganic particles—sand, silt, and clay—which are referred to as soil separates.

Reference
15A NCAC 18A.1935(43)(a-1)

Soil particle sizes.

Each soil separate can be categorized into a particular size class. Particle size classification is based entirely upon particle size and does not consider the mineralogy. The onsite sewage disposal rules of North Carolina use the U.S. Department of Agriculture (USDA) particle-size classification system. The USDA particle size classification only considers the fine-earth fraction of the inorganic particles. The maximum particle size for the fine-earth fraction is 2 millimeters.

In the USDA system, sand separates, which are the coarsest material, range in size from 2 to 0.05 millimeters diameter. Silt particles have a size range from 0.05 to 0.002 millimeters in diameter. Clay-sized particles are the smallest particles, fewer than 0.002 millimeters in diameter. The relative size of these three particles is shown in Figure 4.4.5. See Table 4.4.3 for more details.

Figure 4.4.5
Relative particle sizes
(25.4 mm = 1 inch).

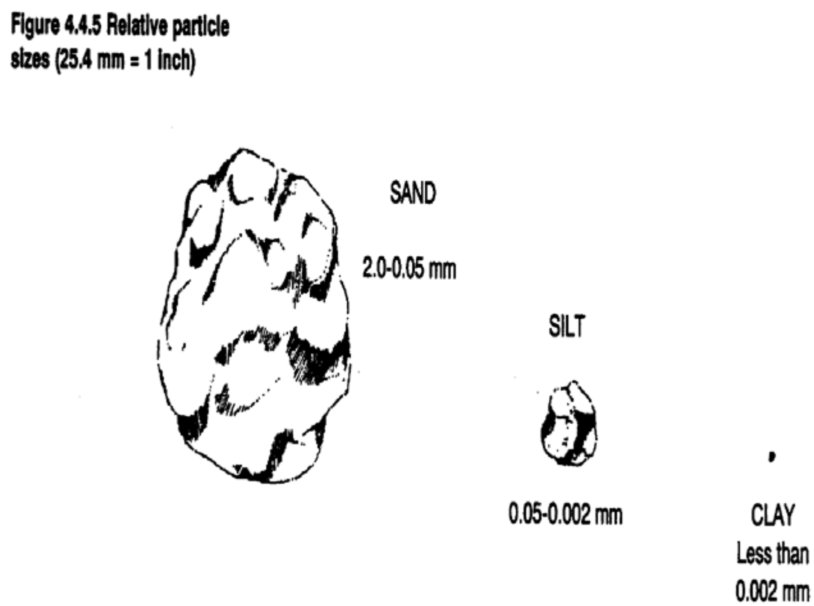


Table 4.4.3 Diameters and Characteristics of Soil Separates (from ASA, 1973.)

Table 4.4.3 Diameters and Characteristics of Soil Separates (from ASA, 1973.)

Soil Separate	Diameter of Particles	General Characteristics
Sand	2-0.05 mm	Individual particles feel gritty when the soil is rubbed between the fingers. Not plastic or sticky when moist.
Silt	.05-.002	Feels smooth and powdery when rubbed between the fingers. Not plastic or sticky when moist.
Clay	less than .002 mm	Feels smooth, sticky, and plastic when moist. Forms very hard clods when dry. Particles may remain suspended in water for a very long time.

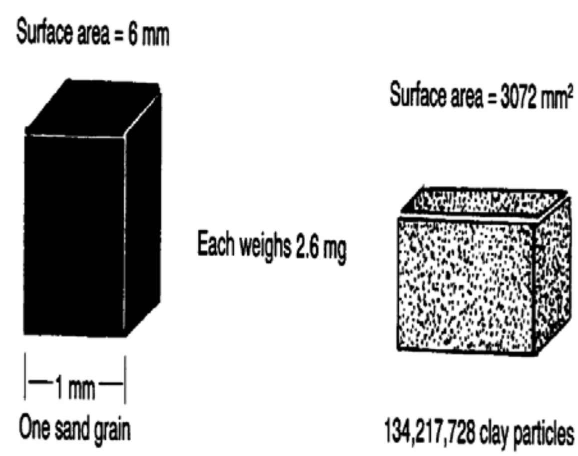
(25.4 mm = 1 inch)

Since sand has a wide range of sizes, the particle-size class of sandy-textured horizons can be further subdivided into subclasses that range from very coarse sands to very fine sands. See Table 4.4.4 for more information. It is important to realize that wastewater will flow through coarse and medium sand horizons much faster than a horizon with a fine or very fine sand texture.

Clay particles (because of their small size) have a much greater surface area for an equivalent weight compared to either silt or sand. The figure below shows the difference in surface area between a sand grain weighing 2.6 milligrams and a clay mass weighing the same (Figure 4.4.6). This increased surface area means that soils with clay have more potential sites for chemical and biological activity. Because of the increased surface area, soils with the right type and quantity of clay provide excellent sites for onsite systems (see sections on Soil Structure and Soil Consistence).

Figure 4.4.6 Size comparison between One grain of sand And a mass of clay.

Figure 4.4.6 Size comparison between one grain of sand and a mass of clay.



Soil Textural Class.

Most soils are a mixture of different soil separates. The texture of the soil in each soil horizon depends on the mixture of the soil separates. Every soil can be placed into one of 12 textural classes. To find the soil textural class, the percentages of sand, silt and clay are plotted on a textural triangle. Figure 4.4.7 shows a soil textural triangle.

Figure 4.4.7
Soil textural triangle.

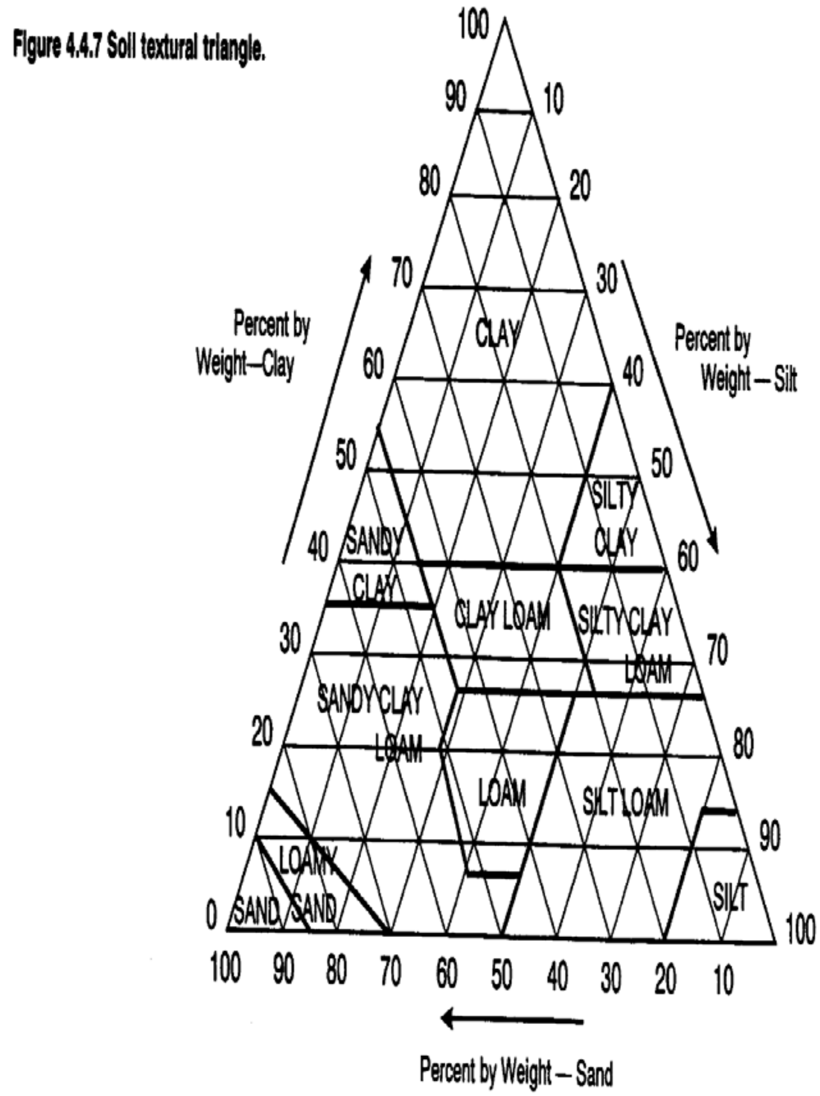


Table 4.4.4
Percentage of Sand Sizes In Subclasses of Sand, Loamy Sand, and Sandy Loam Basic Texture Classes
(Source: Portland Cement Association, 1973)

Table 4.4.4 Percentage of Sand Sizes in Subclasses of Sand, Loamy Sand, And Sandy Loam Basic Texture Classes (Source: Portland Cement Association, 1973)

				SOIL SEPARATES			
Basic soil class	Subclass	Very coarse sand, 2.0-1.0 mm	Coarse sand, 1.0-.05 mm	Medium sand, 0.5-0.25 mm		Fine sand, 0.25-0.1 mm	Very fine sand, 0.1, 0.05 mm
Sands	Coarse sand		25% or more			Less than 50%	Less than 50%
	Sand			25% or more		Less than 50%	Less than 50%
	Fine sand		Less than 25%		**OR**	50% or more	Less than 50%
	Very fine sand						50% or more
Loamy Sands	Loamy coarse sand	25 % or more		Less than 50%		Less than 50%	Less than 50%
	Loamy sand		25% or more			Less than 50%	Less than 50%
	Loamy fine sand		Less than 25%		**OR**	50% or more	Less than 50%
	Loamy very fine sand						50% or more
Sandy Loams	Coarse sandy loam	25% or more		Less than 50%		Less than 50%	Less than 50%
	Sandy loam	Less than 25%	30% or more		**AND**	Less than 30%	Less than 30%
	Fine sandy loam		**OR** Between 15% & 30%			30% or more	Less than 30%
	Very fine sandy loam		Less than 15%		**OR**	More than 40%	30% or more

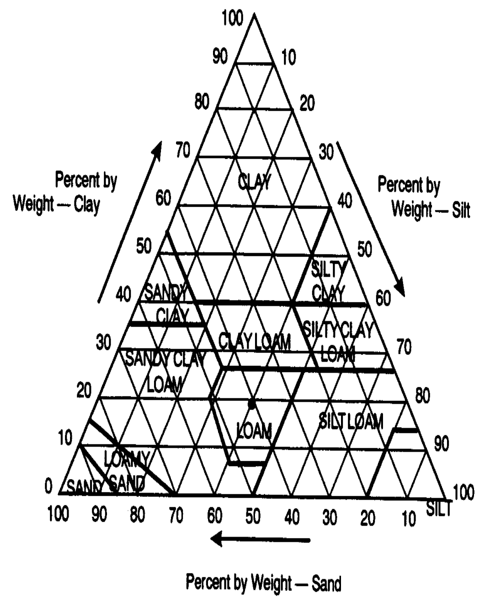
(25.4mm = 1 inch)

Half of the content of fine sand and very fine sand must be composed of very fine sand.

The idea of grouping soils into textural classes was originally developed by the USDA to assist farmers with agronomic decisions. This textural classification system has been adapted for siting and sizing onsite systems utilizing texture influences, soil permeability, and water movement through the soil. Below are several examples of texture determination.

Figure 4.4.8
Percent by Weight - Loams

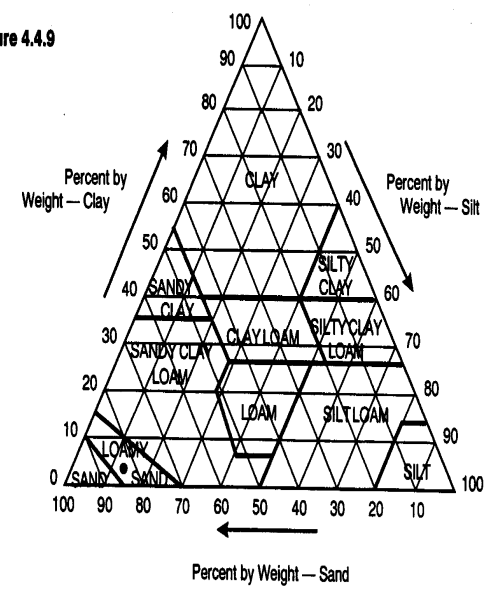
Figure 4.4.8



For example, soil with 40% sand, 40% silt, and 20% clay would be a loam. Look for the area in the soil textural triangle where the 40% line for sand (diagonal line that goes from right to left) intersects the 20% line for clay (horizontal line) and the 40% line for silt (diagonal line that goes from left to right) (Figure 4.4.8). This area of the triangle is where soils are classified as loams.

Figure 4.4.9
Percent by Weight – Loamy Sand

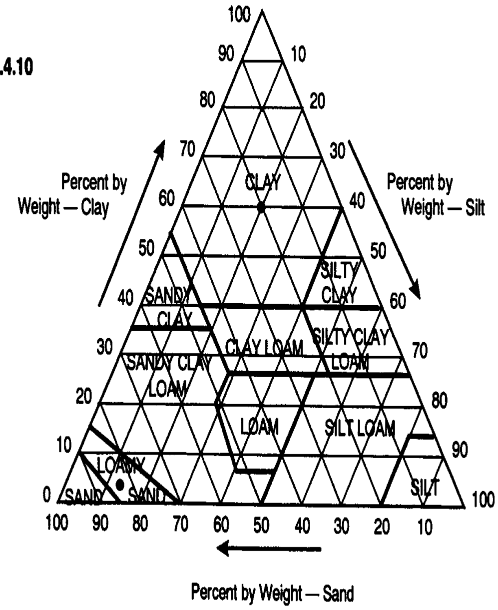
Figure 4.4.9



A soil with 80% sand, 15% silt, and 5% clay would be a loamy sand. Look for the area in the soil textural triangle where the 80% line for sand intersects the 5% line for clay and the 15% silt (Figure 4.4.9). This area of the triangle is where soils are classified as loamy sand.

Figure 4.4.10
Percent by Weight - Clay

Figure 4.4.10



A soil with 20% sand, 20% silt, and 60% clay would be a clay. Look for the area in the soil textural triangle where the 20% line for sand intersects the 60% line for clay and the 20% silt (Figure 4.4.10). This area of the triangle is where soils are classified as clay.

Soil Voids.

Voids are the spaces in between particles of sand, silt, and clay. Every soil contains a certain percentage, normally between 35 percent and 50 percent of its volume in voids. Soil voids determine water and air movement within a soil.

Water and air flow by moving through the void spaces of soils. The ease with which water and air can flow through a soil is determined by the size of the voids, the number of voids in the soil, and how well the voids are connected to each other.

The amount, size, and connectivity of soil voids are determined, in large part, by soil texture. Therefore, soil texture becomes a critical factor in determining the rate of wastewater flow through a soil horizon.

The size of individual void spaces effects water movement through a soil horizon. For example, even though a clay-textured horizon will generally have more void space than a sandy-textured horizon, the movement of wastewater through a clay-textured horizon will be slower. Water flows more quickly through the few large voids in the sand than through the many tiny voids in the clay-textured horizon. In order to account for these differences in wastewater flow, onsite systems installed in clay soil would require a much larger drainfield than a similar system located in sandy soil.

Organic Matter.

In addition to the soil mineral solids, soils also contain organic matter. Organic matter consists of decomposed leaves, twigs, animal droppings, air and water. Most soils have organic matter contents that range between one and five percent of the total soil weight. When the majority of the solids are mineral, soils are referred to as mineral soils.

Although organic matter makes up only a small portion of the soil, it is very important in determining several soil properties. Organic matter partially determines how much water can be held by the soil. Organic matter increases the surface area of a soil. Increased surface area is important in the retention of some of the wastewater constituents such as viruses, phosphorus, and ammonium.

Some soils, called organic soils, are primarily composed of organic matter with only a small amount of mineral solids. Organically stained soils (soils stained by decomposing organic matter) should not be confused with organic soils. Organic soils must have more than 20 percent organic matter by weight to be classified as an organic soil.

Reference
15A NCAC 18A.1935(21)

As defined by the rules, organic soils are

> **"those organic mucks and peats consisting of more than 20 percent organic matter (by dry weight) and 18 inches or greater in thickness."**

Organic soils are always UNSUITABLE for onsite systems because they do not drain properly. Treatment and disposal fields cannot function in organic soils. Further, organic soils may burn, leaving the septic system exposed.

Soil Color

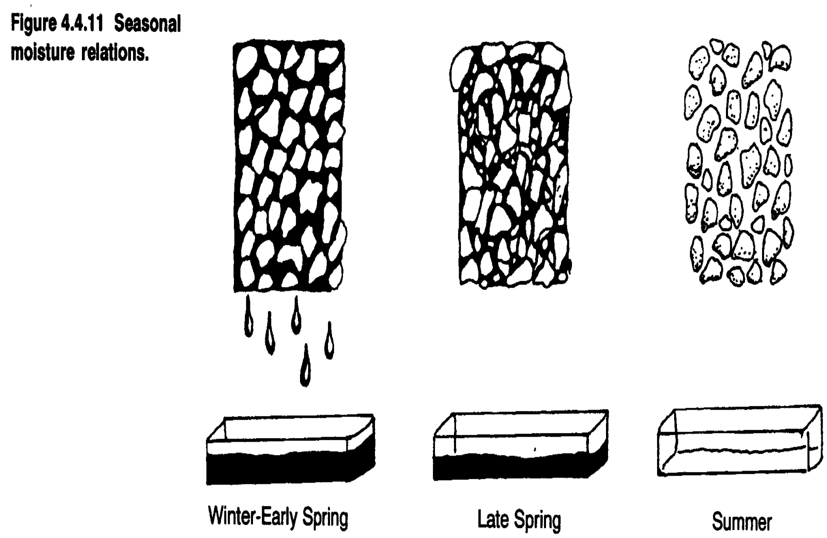
The initial soil color formation is naturally gray to white. Over time, soil develops other colors. Soil particles become coated with inorganic substances or organic matter that is translocated or moved through the soil profile. For example, organic matter, such as decaying leaves and twigs, can be translocated from the soil surface downward to the A, B, and C soil horizons by rainwater moving downward through the soil. The decaying organic matter forms a brown or black coating on soil particles, causing the soil to appear brown or black. A coating of iron oxide on soil particles creates a red soil.

Soil Color and Soil Wetness.

Soil color is a very useful tool for investigations of soils for onsite wastewater disposal since color can indicate the wetness of a soil. Soils that are too wet are inappropriate for siting an onsite system.

Because of rainfall patterns and evapotranspiration, soils in North Carolina are drier during summer and fall and wetter during winter and spring. Wet soils reduce the amount of air available for bacteria to treat the wastewater. The high water table causes direct wastewater flow in groundwater without sufficient treatment. Figure 4.4.11 demonstrates the difference in water content between seasons.

Figure 4.4.11
Seasonal moisture relations.



Well aerated soils (air moving freely through void spaces), contains enough oxygen to oxidize iron to its highest state (Fe^{+3}) causing soils to have a uniform bright color. This bright orange or red color is the same color that occurs when metal rusts. In this state, the soil is aerobic and soil organisms use oxygen for their metabolism. These aerobic organisms are able to rapidly treat wastewater when applied to the soil.

Saturated soils differ in color. With saturated soil, water replaces the air in void spaces causing oxygen immobility within the soil, anaerobic, or without oxygen. Many anaerobic bacteria use iron, aluminum or sulfate substitutes for oxygen in their metabolism. Therefore, when a soil is saturated, iron is reduced by bacteria to Fe^{+2} and it becomes soluble in water and can be moved or translocated out of or through the soil. Organisms are able to treat wastewater slowly and the system is likely to malfunction in an anaerobic state.

Saturated soil is gray color since iron is absent or reduced to its non-color state (Fe^{+2}). Soils with fluctuating wetness conditions—when soil is saturated in winter and spring, well aerated in summer and fall— develop a distinctive splotchy color pattern of mixed rust-orange and gray called soil mottling. Thus, soil color becomes a good indicator of moisture status.

Soil scientists use a very specific system—*The Munsell Color System*—to standardize soil color descriptions. In the Munsell color system, each color is broken into three components: hue; value; and chroma.

1.) Hue is the basic color. Hue ranges from a value of 10R, which is a red soil, to 7.5YR or 10YR, which are brown soils, to 5Y, which is a yellow soil.
2.) Value is the lightness or darkness of the color.
3.) Chroma is the purity or strength of the color. A chroma of 0 is relatively colorless and a chroma of 8 is relatively colorful.

The Munsell color book is composed of color chips with various components of hue, value, and chroma. A soil sample is compared with color chips and the appropriate color designation that matches the soil is noted and recorded.

Munsell Color System.

The matrix color is the dominant soil color of the horizon. Each matrix color can have a range of value, hue and chroma.

Two Munsell charts are displayed in Figure 4.4.12. The left color chart displays various combinations of value and chroma for a soil with a 7.5YR hue. The right color chart shows value and chroma combinations for a soil with a 10YR hue. Value and chroma designations are added to the hue. For example, the soil in Figure 4.4.12 could be described as a 7.5YR 3/2 if it has a brown matrix color and a dark gray tinge. A soil designated as 10YR 5/1 is a gray soil.

Soil Mottling.

If water cannot drain freely through the soil, then a color pattern called soil mottling usually develops. When a soil is repeatedly saturated for an extended period and drained, the iron compounds are biochemically reduced during saturation and then chemically oxidized when the soil drains. These conditions lead to a mottling pattern of bright rust or orange-colored spots and dull gray-colored spots on the background color of the soil. Soil scientists call bright spots high chroma mottles and dull spots low chroma mottles.

Mottles are described in terms of their abundance or number, size and contrast compared to the background soil color. If greater than 2 percent of the soil contains mottles in chroma of two or less, then the soil is generally considered wet (see Table 4.4.5). The abundance of mottles can be easily estimated using charts such as Figure 4.4.13.

Table 4.4.5 Mottle Abundance, Size, and Contrast.

Table 4.4.5 Mottle Abundance, Size, and Contrast.

MOTTLING: A description of mottling requires a notation of the colors and of the pattern. Colors may be noted by Munsell symbols for the matrix and color names for the mottles. Patterns may be noted in terms of:

(1) Abundance:

few	(mottles<2% of surface)	f
common	(mottles 2-20% of surface)	c
many	(mottles>20% of surface)	m

(2) Size:

fine	(<5 mm.)	1
medium	(5-15 mm.)	2
coarse	(>15 mm.)	3

(3) Contrast:

faint	(Hue and chroma of matrix and mottles closely related)	f
distinct	(Matrix and mottles vary several units in hue, value, and chroma)	d
prominent	(Matrix and mottles vary several units in hue, value, and chroma)	p

Thus a gray horizon with yellow and reddish brown mottles that are common (c), coarse (3), and distinct (d) is noted as: 10YR 5/1,c3d, yellow an reddish brown mottles.

(25.4mm. = 1 inch)

Figure 4.4.12 Munsell charts.

In North Carolina, the only combination of abundance and contrast of mottles that designates a well-drained soil is few and faint. Any other combination of the mottling categories of abundance and contrast, for example common and distinct, indicate potentially wet conditions.

The presence of low-chroma colors, such as Chroma 2 or lower, usually means that the soil is saturated for part of the year. This often occurs when the water table rises during a wet season and saturates the soil.

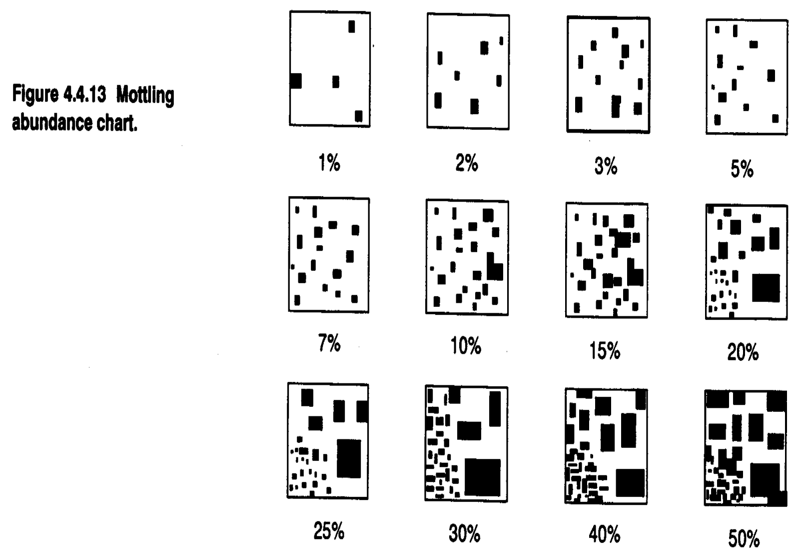
The depth to low-chroma colors in a soil can help determine the depth to the seasonal wetness and soil drainage class. This knowledge of soil wetness can be used in assessing the suitability of a soil for siting onsite systems.

As defined by the rules

Reference
15A NCAC 18A.1942

> **"soil wetness conditions caused by a seasonal high-water table, perched water table, tidal water, seasonally saturated soils or by lateral water movement shall be determined by observation of colors of Chroma 2 or less (Munsell color chart) in mottles or a solid mass."**

Figure 4.4.13
Mottling abundance chart.



Cautionary Note: Mottling may be caused by natural variations in the parent material and not by soil wetness.

Other site characteristics such as vegetation and landscape position can indicate where wet soil conditions are likely to occur. Trees such as cedar growing in concave landscape positions often indicate the presence of wet soils on a lot.

Soil Drainage Class

The SCS has established criteria for seven soil drainage classes. The soil drainage class is a measure of how wet the soil is during the year. Each drainage class is based on how frequently and how long the soil stays wet during a yearly cycle. See Table 4.4.6 for details on soil drainage classes.

Table 4.4.6
Criteria for
Soil Drainage Classes

Table 4.4.6 Criteria for Soil Drainage Classes	
Excessively drained. Water is removed very rapidly. Internal free water occurrence commonly is very deep; annual duration is not specified. The soils are commonly very coarse-textured, rocky, or shallow. Some are steep. All are free of mottling related to wetness. **Somewhat excessively drained.** Water is removed from the soil rapidly. Internal free water occurrence commonly is very deep; annual duration is not specified. The soils are usually sandy and rapidly pervious. Some are shallow. A portion of the soils are so steep that a considerable part of the precipitation received is lost as runoff. All are free of the mottling related to wetness. **Well-drained**. Water is removed from the soil readily but not rapidly. Internal free water occurrence commonly is deep or very deep; annual duration is not specified. Water is available to plants throughout most of the growing season in humid regions. Wetness does not inhibit growth of roots for significant periods during most growing seasons. Well-drained soils are commonly medium textured. They are mainly free of the mottling related to wetness. **Moderately well-drained.** Water is removed from the soil somewhat slowly during some periods of the year. Internal free water occurrence commonly is moderately deep and transitory through permanent. The soils are wet for only a short time during the growing season, but long enough that most mesophytic crops are affected. They commonly have a slowly pervious layer within the upper 1m, periodically receive high rainfall, or both.	**Somewhat poorly- drained.** Water is removed slowly enough that the soil is wet at shallow depth for significant periods during the growing season. Internal free water occurrence commonly is shallow and transitory. Wetness markedly restricts the growth of mesophytic crops unless artificial drainage is provided. The soils commonly have one or more of the following characteristics: they contain a slowly previous layer, have a high water table, receive additional water from seepage, occur under nearly continuous rainfall, or on a flat landscape. **Poorly-drained.** Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season, or remains wet for long periods. Internal free water occurrence is shallow or very shallow and common or persistent. Free water is commonly at or near the surface for long enough during the growing season that most mesophytic crops cannot be grown unless the soil is artificially drained. The soil, however, is not continuously wet directly below plow-depth. Free water at shallow depth is usually present. This water table is commonly the result of a shallow, slowly pervious layer within the soil seepage of nearly continuous rainfall, or a flat landscape position far removed from streams. **Very poorly-drained**. Water is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season. Internal free water occurrence is very shallow and persistent or permanent. Unless the soil is artificially drained, most mesophytic crops cannot be grown. The soils are commonly level or depressed and frequently ponded. If rainfall is high or nearly continuous, slope gradients can be moderate or high. Often these soils are located in the center of the interfluves on flat landscapes far removed from streams.

Redoximorphic Features

Until 1992, soil scientists used fewer than two chromas to signify wet soils. In 1992, the definition of a wet soil was broadened to include saturation, reduction, and morphological indicators because it was believed that color alone was not a specific enough indicator of soil wetness (Vepraskas, 1992.). Under the new classification, wet soils must meet specified criteria for the following characteristics: depth of saturation; occurrence of reduction; and presence of redoximorphic features. Redoximorphic features are iron nodules and mottles created by the process of reduction, translocation, or movement, and finally by oxidation of iron and manganese (Figure 4.4.14).

Figure 4.4.14 Redoximorphic features (from Vepraskas, 1992).

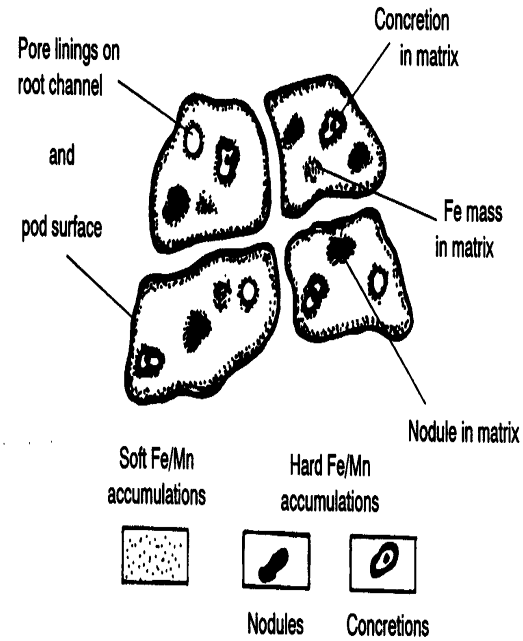


Figure 4.4.14 Redoximorphic features (from Vepraskas, 1992).

Redoximorphic features could have formed in the past and may not represent current soil wetness. For this reason, all three characteristics—saturation, reduction, and redoximorphic features—must be considered:

1.) Saturation means that a soil is periodically saturated within the first 2 meters. This saturation may occur in the entire 2 meter layer or in a portion of that layer.

2.) Reduction no longer refers only to the absence of oxygen, but now also includes the presence of reduced iron.

3.) Redoximorphic features include only mottles and iron nodules formed by the reduction, translocation, and oxidation of iron and manganese due to wetness. Mottles are a broader category of features which includes redoximorphic features, carbonate accumulations, organic stains, and parent material color variation.

Redoximorphic features are not currently used to determine soil wetness in the North Carolina onsite wastewater rules, since the observation of soil saturation with monitoring wells is required to confirm the presence of a soil wetness condition when using redoximorphic features. Direct monitoring of soil saturation is an option within the rules, but is not required for each and every lot.

Soil Structure

Soil structure is a measure of how the tiny particles in the soil group together to form aggregates. Soil structure has a pronounced effect on internal drainage and wastewater treatment.

Soil structure, as defined by the rules, is

> **"the arrangement of primary soil particles into compound particles, peds, or clusters that are separated by natural places of weakness from adjoining aggregates."**

Reference
15A NCAC 18A.1935(42)

The soil aggregates, known as peds form when soil components such as sand, silt, clay, and organic matter adhere to one another.

A ped is defined in the rules as

> **"a unit of soil structure, such as an aggregate, crumb, prism, block, or granule formed by natural processes."**

Ped dimensions range from fingernail to softball size.

Reference
15A NCAC 18A.1935(23)

Grades, Size, and Types of Structure.

Soils have different grades, sizes, and types of structure. See Table 4.4.7 for more details:

1) The grade of a soil structure refers to the stability of the ped, a measure of how easily the ped breaks into smaller units or forms larger units. The structural grade is described when the soil is in a moist state. Stable peds preserve soil permeability and aerations, which promotes sewage treatment.

2) The size of a soil structure refers to the size of individual peds in a horizon. The sizes range from very fine to very coarse. Most horizons have a mixture of ped sizes; therefore, the predominant ped size in a horizon is described. Soil with only large peds may have poor internal drainage and poor aearation, which inhibits sewage treatment.

3) The type or form of a ped (structure) refers to a ped's shape. Table 4.4.8 lists the various characteristics of soil structures. Parent material and organic matter can affect the shape of peds. Soils with a type of clay mineralogy, known as 1:1 mineralogy, produce sub-angular blocky peds. Soils with blocky or granular structure have well connected soil pores, which promote soil aeration and treatment of wastewater. Soils with 2:1 mineralogy produce angular blocky peds in the summer and massive in the winter due to drying (shrinking) and wetting (swelling). Since massive soils have poorly connected pores, the soil has low internal permeability, which inhibits soil aeration wastewater treatment.

Table 4.4.7
Soil Structure Grades, Sizes, and Shapes.

Table 4.4.7 Soil Structure Grades, Sizes, and Shapes.

Grade	
0 – structureless	No aggregation or orderly arrangement (massive or single grain).
1 – weak	Poorly formed, nondurable, indistinct peds that break into a mixture of a few entire and many broken peds and much unaggregated material.
2 – moderate	Well-formed, moderately durable peds, indistinct in undisturbed soil, that break into many entire and some broken peds but little unaggregated material.
3 – strong	Well-formed, durable, distinct peds, weakly attached to each other, that break almost completely into entire peds.

		Shape	
Size (Ped Diameter)	pl-platy gr-granular cr-crumb	abk-angular blocky sbk-subangular blocky	cl-columnar pr-prismatic
vf – very fine	<1 mm	>5 mm	<10 mm
f – fine	1-2 mm	5-10 mm	10-20 mm
m – medium	2-5 mm	10-20 mm	20-50 mm
c – coarse	5-10 mm	20-50 mm	50-100 mm
vc – very coarse	>10 mm	>50 mm	>100 mm

(25.4 mm = 1 inch)

Table 4.4.8
Types of Structure,
Structure Description,
and Site Suitability.

Table 4.4.8 Types of Structure, Structure Description, and Site Suitability.

Kind of Structure	Description of Aggregate (Peds)		Horizon	Suitability
Crumb	Aggregates are small, porous, and weakly held together.	Nearly spherical, with many irregular surfaces.	Usually found in surface soil or A horizon.	SUITABLE
Granular	Aggregates are small, non-porous, and are strongly held together.			SUITABLE
Platy	Aggregates are flat or plate-like, with horizontal dimensions greater than the vertical; plates overlap, usually causing slow permeability.		Usually found in E horizons or horizons of soils formed from silt.	UNSUITABLE
Angular Blocky	Aggregates have sides that join at sharp angles, tend to overlap.	Nearly block-like, with 6 or more sides. All 3 dimensions about the same.	Usually found in subsoil or in B horizon.	PROVISIONALLY SUITABLE if size is ≤ 2.5 cm. UNSUITABLE if size is >2.5 cm.
Subangular Blocky	Aggregates have sides forming obtuse angles, corners are rounded; usually more permeable than angular blocky type.			PROVISIONALLY SUITABLE if size is ≤ 2.5 cm. UNSUITABLE if size is >2.5 cm.
Prismatic	Without rounded caps on top.			UNSUITABLE
Columnar	With rounded caps on top.			UNSUITABLE
No Structure -- Single Grain	Soil material does not cling together and does not form aggregates.		Usually found in substratum or in C horizon.	SUITABLE
No structure -- Massive	Soil material clings together in large uniform masses, without peds.			UNSUITABLE

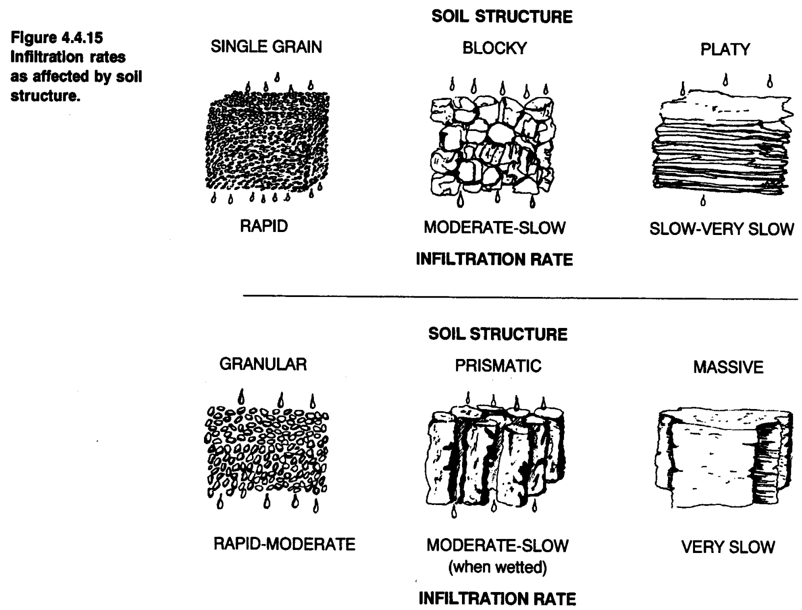
The Effect of Structure on Water Movement Through Soil.

Soil structure is an important characteristic for siting onsite systems since soil structure effects the movement of water and sewage through the soil. Although the porosity is greater inside a ped, the majority of water flows through the voids. Frequently, the only wastewater flow path in a soil that is sufficiently fast for wastewater disposal is between the peds.

Well-developed, fine peds can have an acceptable amount of wastewater flow through voids between peds. Voids between peds and structural pores are large and well connected, and promotes internal drainage and soil aeration. Structural porosity may account for up to 90 percent of soil's permeability and is particularly important in clayey soils.

If peds are too large in size (for example, greater than 1 inch or 2.5 cm) wastewater moves too slowly. Since the total porosity for the entire volume of soil is reduced when compared to a soil with many smaller peds, the soil is unable to absorb the sewage adequately to prevent ponding at the ground surface.

Figure 4.4.15 Infiltration rates As Effected by Soil structure.



Because soil structure affects wastewater flow, soils with certain structures, such as platy, massive, and prismatic structure, cannot be used to treat onsite waste effluent. Soils with platy structure are slowly permeable because the structural voids are oriented horizontal to the ground surface and vertical movement of water is very slow. Massive soils have few if any structural pores. The porosity that does exist in a massive soil is poorly connected and internal permeability is extremely slow. Both platy and massive structure types inhibit soil aeration, which inhibits sewage treatment.

Prismatic structure has pores which are oriented in a vertical direction with respect to the ground surface. If these vertical structural pores intersect the bottom of the absorption trench, they can provide a direct conduit for untreated wastewater to the underlying water table.

The size of the structural aggregates or peds generally increases through the A and B horizons. The soil in the C horizon is more massive and structureless, which means that there are few or no structural aggregates. Since there are no peds present, wastewater flowing through the C horizon can no longer be related to peds.

Changes in Soil Structure.

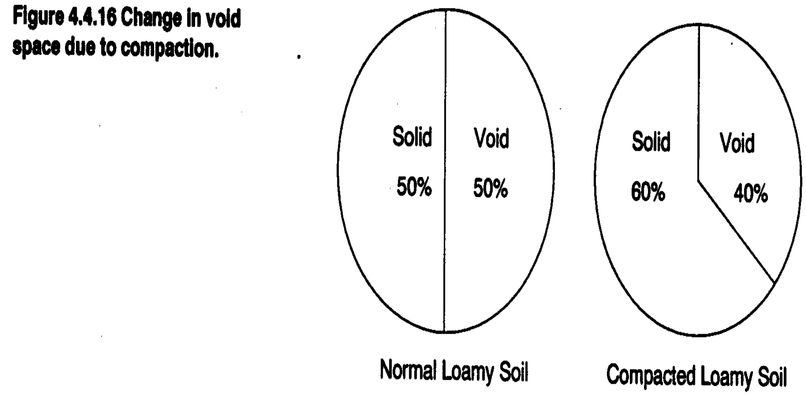
Soil structure is not static. Peds can be changed by natural or man-made conditions such as: wetting and drying; freezing and thawing; physical activity of roots and soil animals; influence of decaying organic matter and of slimes from microorganisms and other life forms; modifying effects of adsorbed cations, clay films, iron oxides, and aluminum oxides; and construction activities. Examples of changed soil structure are presented below:

1.) Wastewater movement of soil can change soil structure. Sodium causes soil particles to disassociate from each other. Wastewater high in sodium (for instance, as a result of brine from a home water softener) can cause soil peds to disperse or break apart, which in turn will decrease void volume between the peds. Wastewater movement will then be restricted because the voids are much smaller and the total volume of voids in the soil is reduced.

2.) Construction of onsite systems in clay soils that depend on the preservation of voids between the peds must occur during dry weather. If construction occurs during wet weather, excavation of trenches can result in clays being smeared across the face of the soil. This smearing blocks voids between peds and impedes wastewater movement. If construction does occur when the soil is wet, rake the sidewalls to remove smeared clay.

3.) Equipment used to construct a house or septic tank system may compact the soil. Compaction, or compressing the soil, changes the amount of the total void space and the distribution of the void sizes. This reduces the space available for air and water in the soil. Soil compaction generally reduces the structural porosity, the spaces between the pods, more than the internal porosity. When structural porosity is reduced, the volume and the continuity of the larger voids that transport water are reduced. Internal soil permeability may be reduced by as much as 90 percent and soil aeration required for sewage treatment will be insufficient for proper treatment of sewage (Figure 4.4.16).

Figure 4.4.16
Change in void space due to compaction.



Soil Consistence

Soil consistence is a measure of how well the soil sticks together and how resistant peds are to damage; it is also used to determine clay mineralogy in the field since soil consistence is dependent on clay mineralogy. The type of clay in the soil affects both the consistence and the permeability of the soil.

Soil consistence is important for onsite system site evaluation since it indicates how much the soil will shrink and swell during wet or dry periods. If the soil swells with moisture from the effluent from a septic tank system, the structural voids will be filled by the expanding clay particles. The rate at which wastewater moves through the soil is greatly reduced by this loss of structural porosity, it can cause a septic tank system to fail.

Soil Consistence and Moisture Content.

The consistence of soil changes with moisture content can be described when the soil is dry, moist or wet. Only two moisture conditions are used to determine consistence when evaluating a site for an onsite system in North Carolina. Soil consistence is listed and the field evaluation procedure is described for these two moisture conditions in Table 4.4.9.

When the soil is wet, its consistence can be described by two characteristics: plasticity and stickiness. Plasticity is a measure of the soil's cohesiveness which determines how easily the soil can be shaped by pressing or molding it. Stickiness is the ability of a substance to adhere to another substance. The more plastic the soil, means it is more likely the soil has clays and will swell when sewage is applied, making it a less suitable an onsite system. Soils that are very plastic and very sticky are classified as having expansive mineralogy which is unsuitable for an onsite system.

Table 4.4.9
Soil Consistency Descriptions and Abbreviations.

Table 4.4.9 Soil Consistency Descriptions and Abbreviations.

I. Wet consistence - moisture content at or slightly more than "field moisture capacity."	
A. Stickiness - quality of adhesion to other objects	
0. Nonsticky (wso)	Almost no natural adhesion of soil material to fingers.
1. Slightly sticky (wss)	Soil material adheres to one finger, but other finger is clean.
2. Sticky (ws)	Soil material adheres to both fingers and thumb; stretches somewhat.
3. Very sticky (wvs)	Soil material strongly adheres to both thumb and finger.
B. Plasticity - capability of being molded by the hands.	
0. Nonplastic (wpo)	No "wire" can be formed by rolling material between the hands.
1. Slightly plastic (wps)	Only short (<1 cm) "wires" are formed by rolling material between the hands.
2. Plastic (wp)	Long wires (>1 cm) can be formed and moderate pressure is needed to deform a block of the molded material.
3. Very plastic (wvp)	Much pressure is needed to deform a block of the molded material.
II. Moist consistence - soil moisture content between dryness and "field moisture capacity."	
0. Loose (ml)	soil material is noncoherent. Used with single grain structureless condition.
1. Very friable (mvfr)	Aggregates crush easily between thumb and finger.
2. Friable (mfr)	Gentle thumb and finger pressure is required to crush aggregates.
3. Firm (mfi)	Moderate thumb and finger pressure is required to crush aggregates.
4. Very firm (mvfi)	Strong thumb and finger pressure is required to crush aggregates.
Extremely firm (mefi)	Aggregates cannot be broken by thumb and finger pressure.

*1 cm ~ 1/2 inch

Clay Mineralogy

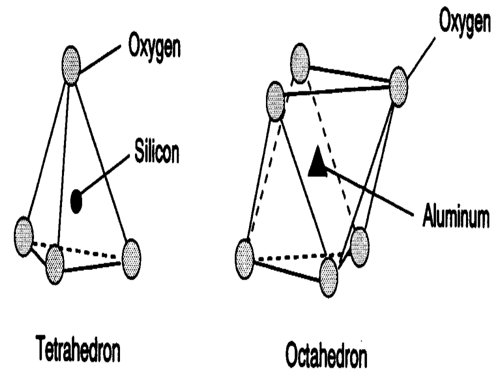
Clay mineralogy describes the type of clay in a soil and how the soil behaves wet or dry. Understanding the behavior of wet soil is important in siting onsite systems.

Clays are particles of soil fewer than 2 microns in diameter. Clays formed from aluminosilicate minerals in the Southeastern part of the country are known as temperate region clays or silicate clays.

Silicate clays are composed of a definite crystalline structure derived from the original rock minerals. Silicate clays have two basic structural units: a tetrahedron of four oxygen atoms surrounding a central cation, which is usually silicon (Si^{4+}); or an octahedron of 6 oxygen atoms surrounding a cation, usually aluminum (Al^{3+}). See Figure 4.4.17.

Figure 4.4.17 Structural units Of silicate clays.

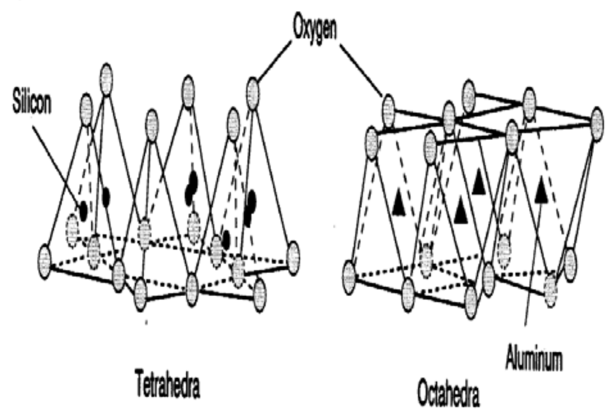
Figure 4.4.17 Structural units of silicate clays.



The tetrahedral or octahedral are linked together to form microscopic silica and alumina sheets, respectively (as shown in Figure 4.4.18). These alumina and silica sheets combine to form lamellae, a two to three layer stack of aluminum and silica sheets. Stacks of lamellae form clay particles.

Figure 4.4.18 Tetrahedra and Octahedral linkages.

Figure 4.4.18 Tetrahedra and octahedra linkages.



The arrangement of the alumina and silica sheets determines the clay type. The lamella of a 1:1 clay mineral, such as kaolinite, is a silica sheet attached to an alumina sheet. Shared oxygen atoms link the two sheets. See Figure 4.4.19. These two-layer silica-alumina-lamellae are then stacked together in a repeating fashion. Hydrogen bonds between the lamellae hold the overall crystal lattice together in a rigid fashion as shown in Figure 4.4.20.

Figure 4.4.19
Arrangements
Of two-layer lamella.

Figure 4.4.19 Arrangements of two-layer lamella.

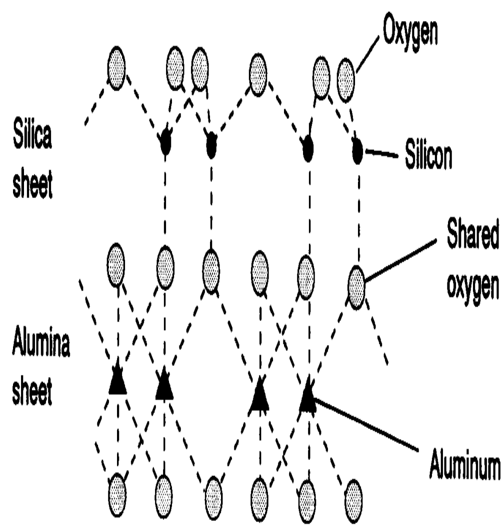
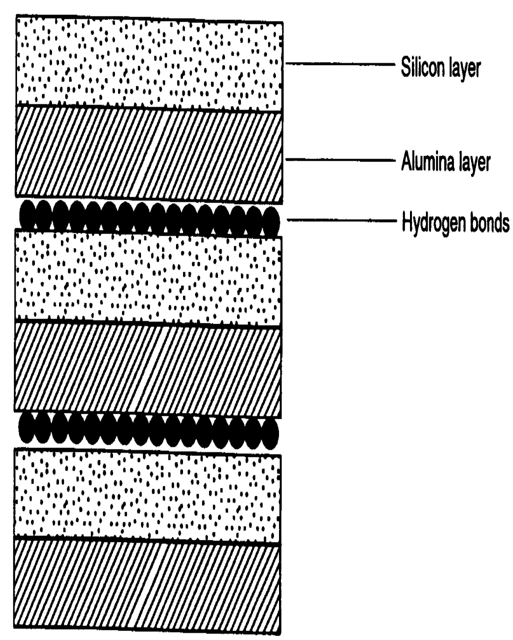


Figure 4.4.20
Repeating two-layer lamella.

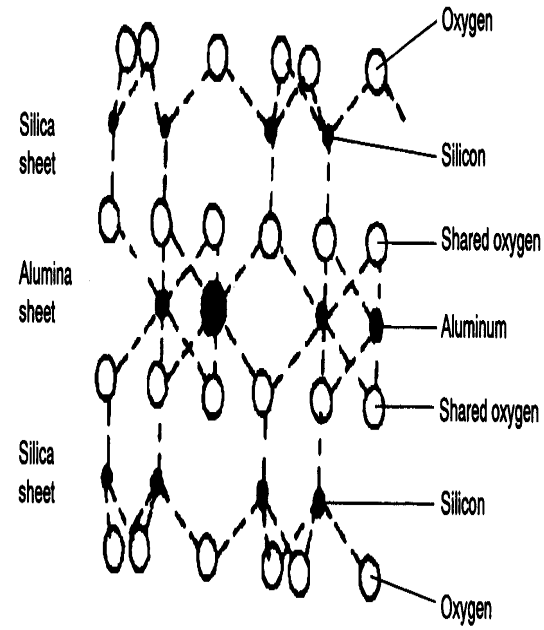
Figure 4.4.20 Repeating two-layer lamella.



The lamella of 2:1 clay minerals, such as montmorillonite and bentonite, is an alumina sheet sandwiched between a silica sheet on either side and held by a shared oxygen atom (as seen in Figure 4.4.21). The three-layer lamellae of montmorillonite are held together loosely. This loose arrangement allows water and cations to move in and out of the clay mineral structure by moving between the lamellae. Figure 4.4.22 shows the loose lamellae of montmorillonite.

Figure 4.4.21 Arrangement of Three-layer lamella.

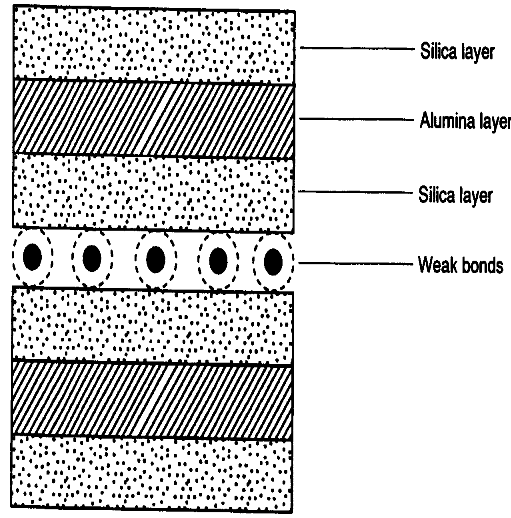
Figure 4.4.21 Arrangement of three-layer lamella.



- Mixed mineralogy clays have a mixture of both 2:1 and 1:1 clays;
- Soils containing the 1:1 clay types swell less with moisture than 2:1 clays and do not impede water flow with moisture as much as the 2:1 or mixed mineralogy clays. If the percentage of clay is not too large, soils that have 1:1 clay mineralogy, such as kaolinite, have excellent potential to absorb and treat wastewater, if the drainfield is large enough. These soils generally have good structure and the increased surface area of the clay particles provides additional sites for wastewater treatment to occur; and
- Because ions and water can move in and out between the lamellae or a layered stack made of alumina and silica, 2:1 clays shrink when dried and swell when wet. This shrinking and swelling makes these soils UNSUITABLE for onsite systems. Because structural porosity and internal permeability of the soil is reduced by the expanding clay, the soil will not be able to absorb the daily wastewater flow to the system and untreated sewage will come to the ground surface.

Figure 4.4.22
Repeating three-layer lamellae.

Figure 4.4.22 Repeating three-layer lamellae.



When these clays are wet and swollen, little wastewater can flow through the soil. When the clay is dry, shrinkage cracks form and the effluent receives no treatment since it moves through the open cracks too quickly.

- Formation of 1:1 and 2:1 clays is primarily determined by the parent material. For example, 1:1 clays form from felsic parent material, such as granite, whereas 2:1 clays form from mafic parent material, such as diabase;
- Soil particles, particularly clay, have negative charges. These negative charges attract and hold nutrients and other positively charged ions or molecules; and
- Surface area, and thus total negative charges, differs between clay types. The surface area of 2:1 clay is 40 times greater than 1:1 clay.

Table 4.4.10
The Influence of Clay Type On the Siting Of Onsite Systems

Table 4.4.10 summarizes the suitability of various clays for onsite wastewater systems.

Table 4.4.10 The Influence of Clay Type on the Siting of On-Site Systems

Clay Type	Acceptable for On-Site Wastewater System Installation
1 to 1	Yes
Mixed Mineralogy	Maybe*
2 to 1	No

*See Section 4.5 (Clay Mineralogy) for more details.

Soil Hydraulic Parameters

Saturated Hydraulic Activity

Hydrologic parameters describe the way water moves through soil and are critical components in siting onsite systems.

Saturated hydraulic conductivity is the rate at which water moves through a saturated soil. All pore voids are filled with and transmit water in a saturated soil. The rate of flow through a soil is dependent on the sizes, number, and interconnectedness of the voids in the soil. The number of voids, their size, and spacing depend on numerous soil characteristics such as texture, mineral content, structure, biological activity, and horizon placement. Saturated hydraulic conductivity will vary between soil horizons within the same profile and from location to location.

Saturated hydraulic conductivity is important in onsite systems. The hydraulic parameter can help the designer determine the volume of wastewater that the site can transmit in a given time when the soil is saturated. The measure of water movement through a saturated soil has the units of distance/time and is given the symbol Ksat. Each soil horizon has its own individual Ksat, which normally varies greatly from the Ksat of other horizons in the same profile. Based on measurements of saturated hydraulic conductivity, soils are grouped into six classes, from very low to very high hydraulic conductivity. See Table 4.4.11 for a complete listing of saturated hydraulic conductivity classes.

Saturated hydraulic conductivity is not typically used in North Carolina as an evaluation tool for determining wastewater flow through a soil for onsite systems with flows less than 1,500 gallons per day. To accurately measure Ksat, each horizon in a profile must be tested. Three or more measurements must be taken for each soil horizon. Different techniques may be required for the measurement, depending on the season of the year when the testing is performed. This requires more time, money and effort than most people want to expend. Additionally, Ksat tests are conducted using clean water.

Wastewater, with its particulate matter, causes water to move more slowly through a soil and thus Ksat measurements for wastewater differ. Because of these difficulties, determining saturated flow, North Carolina does not use Ksat to evaluate a site's potential for an onsite treatment and disposal system; a site evaluation is performed instead. (For more information see Section 4.5.)

Water can move through soil even if the soil is not saturated. The unsaturated hydraulic conductivity is a measurement of the rate at which water moves in unsaturated soils.

Unsaturated Hydraulic Conductivity

Unsaturated hydraulic conductivity can help the designer determine the volume of wastewater that the site can transmit in a specific time when the soil is unsaturated. Onsite treatment and disposal fields are supposed to have an unsaturated zone under the trenches to allow the wastewater to be treated aerobically.

Table 4.4.11
Estimates of Saturated Hydraulic Conductivity from Soil Properties

Table 4.4.11 Estimates of Saturated Hydraulic Conductivity from Soil Properties

Class	Rate*	Soil Properties
Very High	>14.2	Rocky
		Sandy with coarse sand or sand texture, and loose consistency
		More than 0.5 percent medium or coarser vertical pores with high continuity
High	14.2-1.4	Other sandy, sandy-skeletal, or coarse-loamy soil materials that are very friable, friable, soft, or loose
Moderate	1.4-0.14	Sandy in other consistence classes except extremely firm or cemented
		10 to 35 percent clay with moderate structure, except platy, or strong very coarse prismatic structure; and with common surface features except stress surfaces or slickensides on vertical surfaces of structural units
		0.1 to 0.2 percent medium or coarser vertical pores with high continuity
Mod. Low	.14-0.01	Other sandy classes that are extremely firm or cemented
		18 to 35 percent clay with other structures and surface conditions except pressure or stress surfaces
		Greater than 35 percent clay and moderate structure except if platy or very coarse prismatic; and with common vertical surface features except stress surfaces or slickensides
		Medium or coarser vertical pores with high continuity, but <0.01 percent
Low	0.01-0.001	Continuous moderate or weak cementation
		Greater than 35 percent clay and meets one of the following: weak structure, weak structure with few or no vertical surface features, platy structure, common or many stress surfaces or slickensides
Very Low	<0.001	Continuously indurated or strongly cemented and with less than common roots
		Greater than 35 percent clay and massive or exhibits horizontal depositional strata and less than common roots

*Inches/hour

Source: Adapted from SCS (1983)

With unsaturated soil conditions, voids are not completely filled with water. Unsaturated hydraulic conductivity depends on the water content of the soils as well as soil characteristics such as texture, mineral content, structure, biological activity, and horizon placement. At the same moisture status, unsaturated hydraulic conductivity, like saturated hydraulic conductivity, will vary between soil horizons within the same profile and from location to location.

In an unsaturated soil, the driving force of water movement is a gradient potential that is caused by suction. Matric suction is the affinity of water molecules to other water molecules or to capillary voids. Water moves from higher to lower matric suction potentials. In other words, water moves from voids that are full to voids that are unfilled. The geometric shape and size of the voids can affect the matric potential. For example, the large voids in sandy soils empty quickly. Once the soil is desaturated, water is trapped in capillary wedges that do not contact other capillaries and water movement stops.

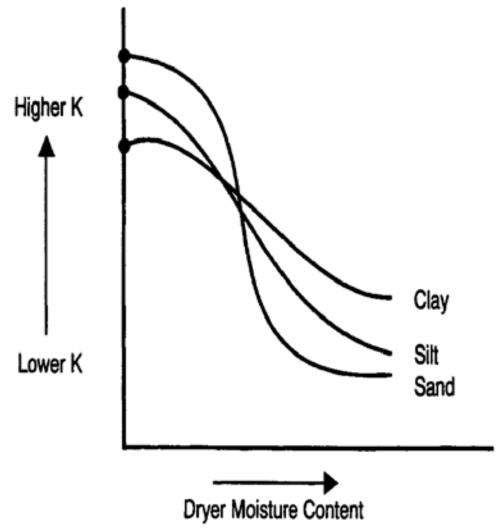
Once the biomat has formed in the treatment and disposal trenches, it often becomes the limiting layer or controlling layer for water flow. In those cases, the biomat is the least conductive layer to water flow. If there is no restrictive soil layer beneath the trenches, then wastewater moves through the soil in unsaturated flow after it passes through the biomat. Since unsaturated flow is slower than saturated flow, the wastewater flows through the soil at a slower flow rate. The slower flow rates give the wastewater more contact time in the soil profile and more time to be cleansed by biochemical and chemical processes before it becomes part of the groundwater. Be aware, however, that there may be soil layers under the trench that have such slow permeability that these soil layers, rather than the biomat, control the rate of wastewater flow through the soil. When this occurs, the soil around the trench will saturate and the system will fail to work properly.

Keep in mind that any site rated SUITABLE or PROVISIONALLY SUITABLE must have at least 12 inches to 18 inches of separation between the trench bottom and soil wetness conditions or other restrictive horizons.

Two specific soil characteristics affecting unsaturated hydraulic conductivity are soil texture and depth. As soils dry from saturated conditions to lower moisture levels, the hydraulic conductivity decreases. This decrease of hydraulic conductivity varies with soil texture. In sandy soils, hydraulic conductivity decreases very quickly as the moisture content drops; in clay soils the decrease is much slower. This decline in hydraulic conductivity is shown in Figure 4.4.23. It is interesting to observe from this graph that the unsaturated hydraulic conductivity is lower for sands than clays at lower soil moisture contents.

Figure 4.4.23 Hydraulic conductivity And soil moisture by soil texture.

Figure 4.4.23 Hydraulic conductivity and soil moisture by soil texture. (Note: above curves are drawn on a log-log scale: The actual hydraulic conductivities of different soils can vary greatly.)



Landscape Position and Slope

Landscape position and slope effect water movement across a site and through the soil. An understanding of slope and landscape position therefore, is critical in predicting water flow and site suitability for onsite system placement. Well-positioned onsite systems ensure that water is drained away from the site and that an adequate depth of aerated soil (12inches -18 inches) is maintained under the treatment and disposal trenches.

The Effects of Topography and Landscape Position on Onsite System Placement

Relief includes slope and landscape position, and is one of five soil-forming factors. Climate, organisms, parent material, and time, affect the soil's characteristics. Relief has a pronounced effect on the soil type and depth, characteristics that are critical in determining the suitability of a site for the placement of an onsite system.

Slope and Topography.

Slope refers to the inclination of the land surface whereas topography refers to the physical features of an area of land, especially the surface configuration.

The topography of an area can be described as hilly, mountainous, flat, or as a coastal plain, foothills, piedmont terrain, plateau, or mountain ridges. Topography can be simple, such as in areas with smooth land surfaces or complex, such as in areas that have abruptly irregular land surfaces. For example, contours of elevation, and the shapes of hills, mountains, valleys, ravines, streams, and rivers are shown on a topographic map.

Conventional onsite systems can be installed on a 0-65 percent slope. When the slope exceeds 65 percent, it becomes unsafe to operate equipment necessary to install a system. The shape of the slope at a specific site is also important. For example, a site on a slope may have an outward or convex curve, which is a good placement site since rainwater flows away from the site. A slope with inward or concave curve is a poor placement site since rainwater runoff collects over the system.

Landscape Position.

Landscape position is the specific position on a topographic feature. For example, an area may have a hilly topography and the landscape position of an onsite system may be at the bottom of one hill in the area. The landscape position of the treatment and disposal field is critical to the performance of an onsite system.

Slope and Landscape Position.

Figure 4.4.24 shows the different landscape positions: interfluve or ridgetop; shoulder slope; side slope; foot slope; and toe slope.

- The interfluve, or ridgetop, is the flat area between streams. If the distance between streams is large then the area is called the interfluve. Conversely, if the distance is small, then the flat area is the ridgetop;
- The shoulder slope is the landscape position adjacent to the interfluve—where the flat areas begin to break into a slope. This slope is convex and water runs off without accumulating in the soil. In the Coastal Plain, such landscape positions give rise to a "dry edge" of soils that are often adjacent to a stream or river;
- Side slopes have nine distinct slope types: linear-linear; linear-convex; linear-concave; convex-linear; convex-convex; convex-concave; concave-linear; concave-convex; and concave-concave (Figure 4.4.25);
- Linear slopes follow a straight line down the slope but may be flat or curve across the slope in the horizontal direction. If the land follows a straight line down and across the slope, then it is called linear/linear. If the linear slope curves outward across the slope it is linear/convex, and if it curves inward, linear/concave.
- More runoff flows away from the site on linear/linear and linear/convex slopes than linear/concave slopes. This means that less water accumulates in the soil on linear/linear and linear/convex slopes than on linear/concave slopes; and
- The foot slope and the flatter toe slope form toward the bottom of the slope. This is where colluvium, soils form from debris moving down the hill, and alluvium, soils form from deposits of sediment from streams, is found. The toe and foot slopes have a concave shape in the vertical direction and are often poorly drained.

Figure 4.4.24
Topographical location
And landscape position.

Figure 4.4.24 Topographical location and landscape position.

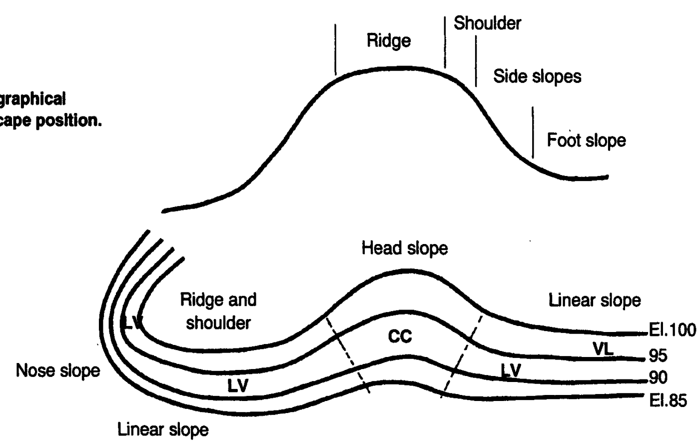
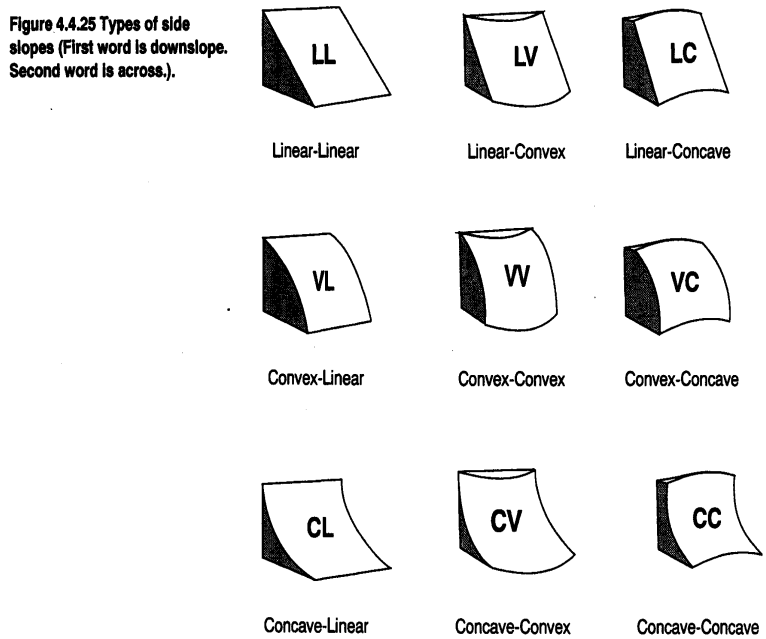


Figure 4.4.25
Types of side slopes



Landscape Position and Slope in Siting Onsite Systems.

Because slope and landscape position have pronounced effects on the soil type, soil depth, and drainage, these factors are extremely important in site evaluations for onsite systems. However, slope and landscape position must always be evaluated at each site because soil conditions and drainage vary in different regions.

The following points indicate how slope and landscape positions should be used for site evaluations:

Reference
15A NCAC 18A.1940

Reference
15A NCAC 18A.1956

- Land with a uniform slope less than 15 percent is considered SUITABLE for onsite systems;
- If the topography is such that the land has a uniform slope between 15 percent and 30 percent, then that land is considered PROVISIONALLY SUITABLE for onsite systems;
- Land with a slope greater than 30 percent is classified as UNSUITABLE unless an investigation shows that a modified conventional onsite system can be installed properly as under rule *15A NCAC 18A.1956*.
- Slopes greater than 65 percent are always classified as USUITABLE;
- Topography with complex shapes to the slopes or many gullies and ravines cutting the slopes is considered UNSUITABLE for onsite systems;
- Depressions, or bowl-shaped indentations in the land surface, are usually inappropriate sites for onsite systems and are classified as UNSUITABLE. Depressions collect water and are generally wetter than the surrounding soils, making them UNSUITABLE. However, if the site complies with other requirements and is approved by the local health department, the site may be considered SUITABLE; and
- Toe slopes, foot slopes, head slopes, and depressional areas are difficult landscape positions for siting septic systems because these locations are frequently too wet for system installation.

Reference
15A NCAC 18A.1940

Occasionally the same landscape position in the three geographic regions in North Carolina (Table 4.4.12) differs in suitability due to varying degrees of drainage. For example, although the interfluve position is an excellent location for onsite systems in the Piedmont and Mountains, it is a poor site in the Coastal Plain. In the Piedmont, the interfluve is a ridge, which is a dry landscape position with substantial local relieve above any nearby streams, while in the Coastal Plain, the inerfluve is a broad flat area between streams, which is a wet landscape position with little local relief above any nearby streams.

Table 4.4.12
Landscape Position and
Onsite System Siting Potential

Table 4.4.12 Landscape Position and On-Site System Siting Potential

	Geographic Regions		
Landscape Position	**Piedmont**	**Mountains**	**Coastal Plain**
Interfluve	excellent	excellent	poor
Shoulder	excellent	excellent	good
Side Slope:			
Linear/Linear	good	good	good
Linear/Convex	good	good	good
Linear/Concave	poor	poor	poor
Convex/Linear	excellent	excellent	excellent
Convex/Convex	excellent	excellent	excellent
Convex/Concave	poor	poor	poor
Concave/Linear	poor	poor	poor
Concave/Convex	poor	poor	poor
Concave/Concave	extremely poor	extremely poor	extremely poor
Foot Slope	poor	poor	poor
Toe Slope	poor	poor	poor

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