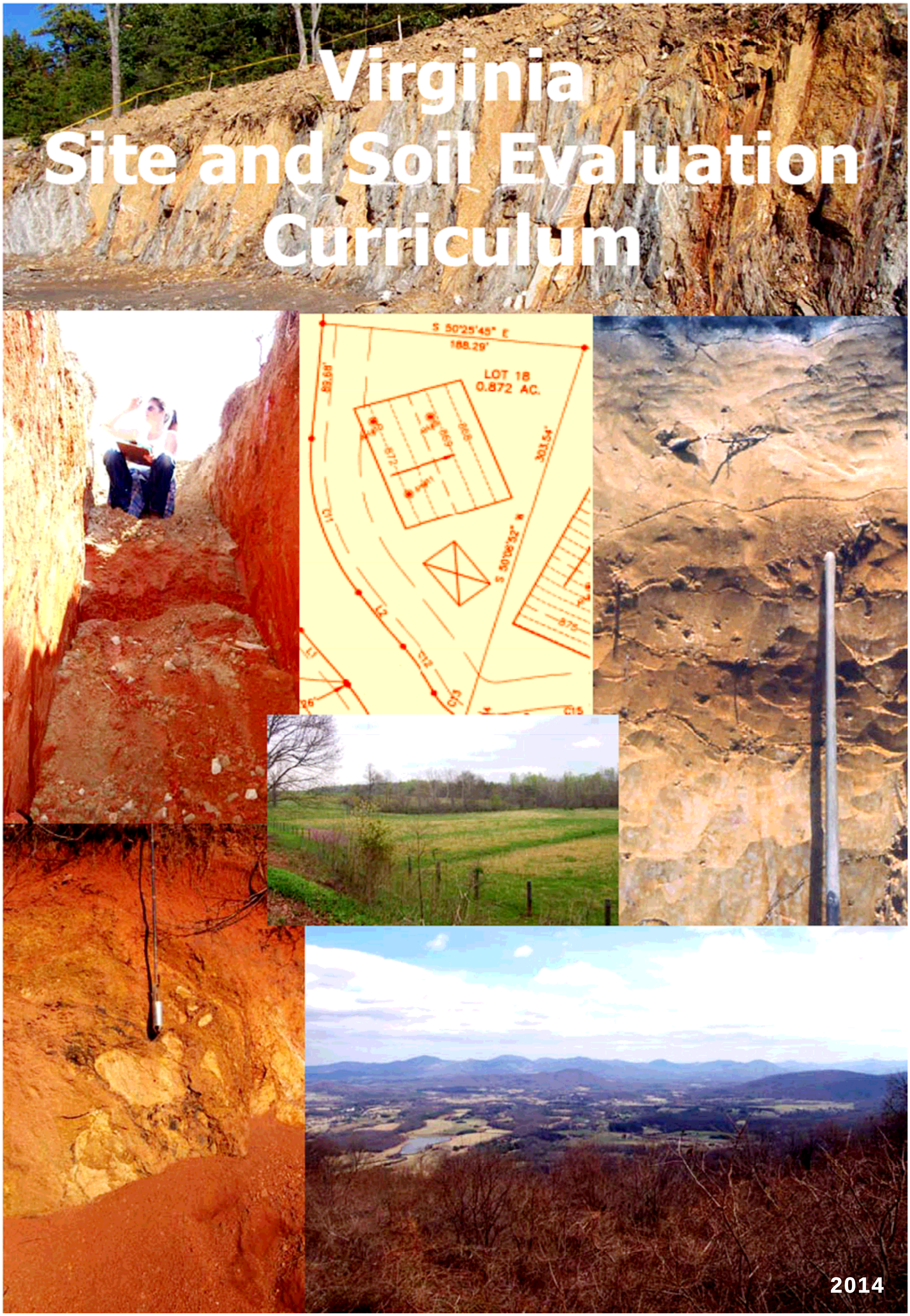
Virginia Site and Soil Evaluation Curriculum



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Acknowledgements

The mention of trade names or commercial products does not constitute an endorsement or recommendation for use from these individuals or entities, nor does it constitute criticism for similar ones not mentioned.

This document was adapted for Virginia from the following:

Lindbo, D.L., M. Stolt, R. Miles, D. Mokma, S. Greene, and M. Hoover. (2005). Soil Module Text. (D.L. Lindbo and N. E. Deal eds.). Model Decentralized Wastewater Practitioner Curriculum. National Decentralized Water Resources Capacity Development Project. North Carolina State University, Raleigh, North Carolina.

And:

The Virginia Department of Health Quality Assurance Committee Best Management Practices (BMP) for Soil and Site Evaluations August 1, 2006. Committee members: Phillip Cobb, Jay Duell, and Beth Manghi

Chapter 3 was adapted primarily from the following:

U.S. Environmental Protection Agency National Health and Environmental Effects Research Laboratory. Alan J. Woods (Dynamac Corp.), James M. Omernik (USEPA), Douglas D. Brown (US Forest Service), Jeffrey A. Comstock, Sandra H. Azevedo, M. Frances Faure, and Suzanne M. Pierson (OAO Corp.). (2003). *Level III and IV Ecoregions of EPA Region 3*. EPA.

U.S. Environmental Protection Agency. Glenn E. Griffith, James M. Omernik, Alan J. Woods (Dynamac Corp.), James M. Omernik (USEPA), Douglas D. Brown (US Forest Service), Jeffrey A. Comstock, Sandra H. Azevedo, M. Frances Faure, and Suzanne M. Pierson (OAO Corp.). (November 20, 2008). *Ecoregions of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia.* EPA.

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Appreciation to the following for editing and content suggestions:

F. Ashley Allen, Jesse Kurylo, Ruby Shipman, Gary Gilliam, and Steve Simpson

Special appreciation to:

Dr. David L. Lindbo (NCSU) and Callan Bentley (NVCC) for their graphics, information and metaphors made so readily available.

Appreciation to:

Danna Revis, Virginia Department of Health Training Coordinator, for making this document available online and many photo contributors listed with their photographs.

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Jay is Virginia Tech's Interpretive Soil Scientist for Eastern/Central Virginia. He earned his B.S. from the University of Wisconsin-Madison in Botany & Soils in 1975 and M.S. from North Dakota State University (Fargo) in Soils in 1983. Jay mapped soils for the USDA-Soil Conservation Service (now NRCS) in North Dakota from 1976 to 1983. Since 1983, he has been working with Health Departments across Virginia to train their new employees in site and soil evaluation. He works with soils in the on-site wastewater disposal program and visits field sites where there are questions about soil suitability for on-site sewage disposal. Jay is a Virginia Licensed Professional Soil Scientist (LPSS) and an Alternative Onsite Soil Evaluator (OSE).

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Erik is Virginia Tech's Interpretive Soil Scientist for Western Virginia. He earned his B.S. in Environmental Science with a concentration in Soil Science from Virginia Tech in 2000 and his M.S. degree in Soil Science from NC State University in 2005. Erik mapped soils in southwestern Virginia with NRCS from 2005 until 2007. Since 2007, he has been working with Health Departments across Virginia to train their new employees in site and soil evaluation. He works with soils in the on-site wastewater disposal program and visits field sites where there are questions about soil suitability for on-site sewage disposal. Erik is currently working on his Ph.D. at Virginia Tech. He has over 10 years of experience in evaluating soils in Virginia and North Carolina. He has mapped soils in Maryland, South Carolina, West Virginia, and Virginia with NRCS. He is a Virginia Licensed Professional Soil Scientist (LPSS) and a North Carolina Board Licensed Soil Scientist (NCBLSS).

Steve Thomas

Steve has been Virginia Tech's Interpretive Soil Scientist for Northern/Central Virginia since 2011. He earned his B.S. in Agronomy from Virginia Tech in 1976. He has more than 35 years of experience in soil mapping, classification, interpretation, and drainfield investigation and design. Prior to joining Virginia Tech as an Interpretive Soil Scientist, Steve was owner of Thomas EnviroSoil, Inc., a private soil-consulting firm. He also mapped soils from 1976 until 1999 for Virginia Tech and was party leader for 20 years. Steve was appointed by Governor Allen in 1994 to the Sewage Handling and Disposal Regulations Appeals and Review Board. He served for 16 years and was chairman for 6 of those years. Steve is a Virginia Licensed Professional Soil Scientist (LPSS) and Alternative Onsite Soil Evaluator (OSE).

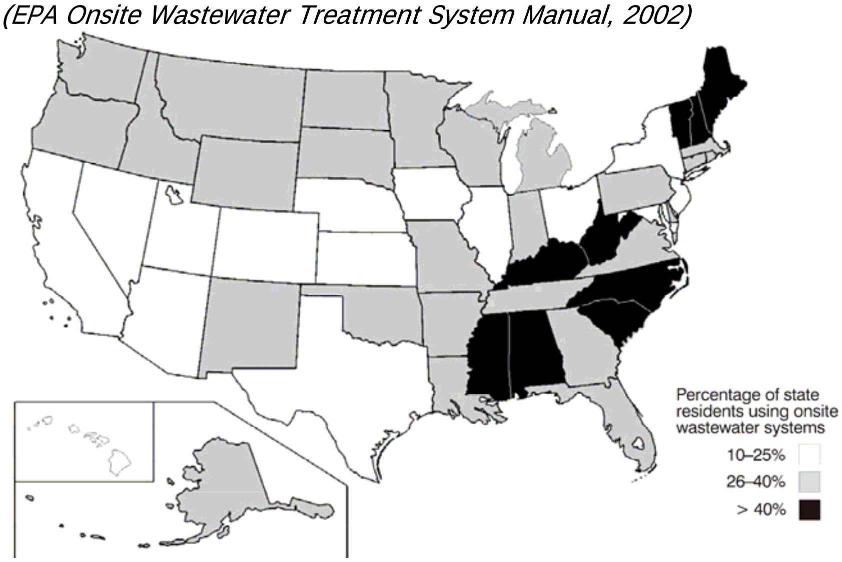
Soil and Site Evaluation for Onsite Wastewater Treatment and Dispersal

Preface

The Virginia Site and Soil Evaluation Curriculum will address the use of soil morphology, landscape description, interpretation of data, and non-soil data for onsite wastewater (OSWW) applications. The curriculum begins with (chapters 1,2 and 4) the basics of soil science. Chapter 3 is an abbreviated discussion of the Physiography, Geology and Soil Systems in Virginia. It is intended to familiarize soil evaluators with soil characteristics in specific areas of the state. Chapter 5 involves site evaluation and Chapter 6 is about design considerations and how they relate to soils. Chapter 7 is intended to offer possible causes and solutions to assist the designer with failed sewerage systems.

This document is designed as a supplement for both lecturers and students. It is written in context with the *2000 Virginia Sewage Disposal and Handling Regulations* and *the 2011 Alternative Onsite Sewage System Regulations*. Soil evaluation methodology is described to a degree necessary to properly evaluate a site for onsite wastewater disposal. It is not intended to be a comprehensive discussion of soil morphology, genesis, etc. These subjects are covered in great detail in reference texts such as *The Nature and Properties of Soils* (Brady and Weil), *Soil Science Made Simple*, (Kohnke and Franzmeier), *Environmental Soil Physics* (Hillel), *Soil Classification and Genesis* (Buol, Hole, McCracken, and Southard), *Soil Taxonomy* (NRCS), *Field Book for Describing and Sampling Soils* (NRCS), *Glossary of Soil Science Terms* (Soil Science Society of America), and *Soil Survey Hand Book* Chapter 3 (NRCS).

Figure: 1-1. Onsite Wastewater Systems in the United States
(EPA Onsite Wastewater Treatment System Manual, 2002)



The authors fully intend that there be more material in this document than a practitioner could learn in a single training sequence. This curriculum is intended to be used throughout an evaluator's career.

First Sanitation Law in Virginia

Articles, Lawes, and orders, politique and martiall established May 24, 1610 for the colony in Virginia (by Sir Thomas Dale, deputy governor.)

"No man, woman, launderer, or launderesse dare to wash any unclean linnen, driue bucks, or throw out the water or suds of fowle cloathes, in open streets, within the Pallizadoes, or within forty foote of the same, nor rench, and make clean, any kettle, pot, or pan, or such like vessel within twenty foote of the olde well, or new pumps, nor shall anyone aforesaid, within lesse than a quarter of one mile from the Pallizadoes, dare to doe the necessities of nature, since by these unmanly, slothfull, and loathsome immodesties, the whole fort may bee choaked, and poisoned with ill aires, and so corrupt (as in all reason cannot but much infect the same) and this shall they take notice of, and auoide, upon paine of whipping and further punishment, as shall be thought meete, by the censure of a martiall court." (Sec. 22, pg. 15)

"Euery man shall haue an especiall and due care, to keepe his house sweete and cleane, as also so much of the streete, as lieth before his door, and especially he shall prouide, and set his bedstead whereon he lieth, that it may stand three foote at least from the ground, as he will answer the contrarie at martiall court." (Sec. 25, pg. 16)

(Historical Tracts - Vol. III By Force)

History of Regulations and Onsite Evaluation in Virginia *(adapted from W.J. Meyer[1] papers)*

Prior to 1962, regulations were based on county ordinances "and most counties had no ordinance and those that did, had poorly defined criteria for establishing site and soil suitability" [2]. Grey water was not included as sewage. "Weekend and vacation properties received particularly poor site considerations and designs. This would later present major problems for VDH and owners who took up full time residence in these homes" [2].

Early soil/onsite relationships began in Fairfax County with the help of VA Tech Soil Surveyors. The first VA Tech contract Soil Scientist was assigned to the Health Department in 1961. "Over the next 15 years contract soil scientists were employed in other Northern Virginia counties" [2].

In 1962, the State Board of Health granted power to counties to adopt state rules and regulations. The Board only had jurisdiction 5 miles of a city or town. In the early to mid-1960's, the Housing Board required all home sites to have indoor plumbing, which in turn, required wastewater disposal. These regulations were revised in 1963.

In 1964, the State Board of Health was granted jurisdiction over the entire Commonwealth. Septic System regulations were very general due to variability of soil across the state. In the mid-1960's, the Board of Health declared grey water as sewage.

In 1971, the *Rules and Regulations of the Board of Health* made first mention of physiographic provinces, slope, depth of soil, water tables and rates. However, there were no minimums or standards other than a 60-minute per inch maximum acceptable percolation rate.

In 1972, state law married building permits to health department permits with regard to wastewater disposal. These new septic permits requirements were needed due to an increasing number of subdivisions being built on soils poorly suited for onsite waste disposal systems.

In 1974, there was a re-issuance of the 1971 *Rules and Regulations of the Board of Health* with minor changes.

In 1977, the State Board of Health and the Water Control Board adopted *Sewerage Regulations*.

In 1982, the *Sewage Handling and Disposal Regulations* were adopted, the first to require minimum soil depths and standards. "They were strongly opposed by the development community and were modified by legislature. Instead of a 24 inch stand-off for the installation above the water table as proposed by VDH, the General Assembly revised the stand-off distances to 2 inch for sandy soils to 20 inches for clayey soils and used a sliding scale for intermediate texture soils" [2].

In 1989, the *Sewage Handling and Disposal Regulations* were revised.

In 2000, the *Sewage Handling and Disposal Regulations* were revised and allowed private sector permits to be issued via the AOSE (Authorized Onsite Evaluators approved by VDH) program.

In 2005, private onsite work could only be performed by Authorized Onsite Evaluators in Virginia. Soil Scientists and other previous evaluators were required to have this designation.

In 2009, all persons performing onsite work in Virginia were required to be licensed through the Department of Professional and Occupational Regulation (DPOR), including VDH staff.

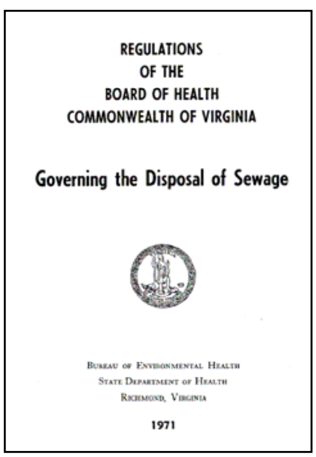
On April 7, 2010, the *Emergency Regulations for Alternative Onsite Sewage Systems* were issued.

On October 7, 2011, the *Emergency Regulations for Alternative Onsite Sewage Systems* expired.

On December 7, 2011, the final *Regulations for Alternative Onsite Sewage Systems* took effect.

[1] William J. Meyers was the first and only VDH VA Tech Contract Soil Scientist until he was joined in 1983 by Jay Conta.

[2] Donald J. Alexander was the previous Director of the Division of Onsite Sewage and Water Services at the Health Department . Currently he is the director of the Virginia Center for Onsite Wastewater Training.

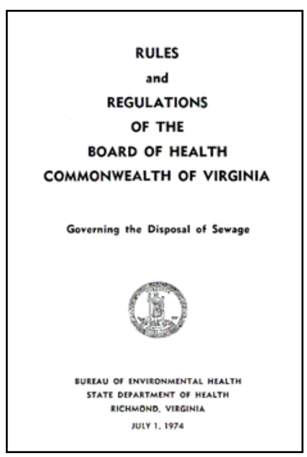


REGULATIONS
OF THE
BOARD OF HEALTH
COMMONWEALTH OF VIRGINIA

Governing the Disposal of Sewage

BUREAU OF ENVIRONMENTAL HEALTH
STATE DEPARTMENT OF HEALTH
RICHMOND, VIRGINIA

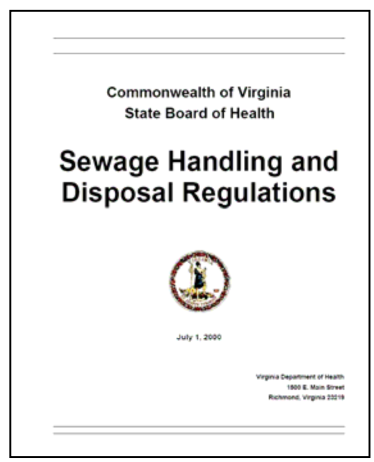
1971



RULES
and
REGULATIONS
OF THE
BOARD OF HEALTH
COMMONWEALTH OF VIRGINIA

Governing the Disposal of Sewage

BUREAU OF ENVIRONMENTAL HEALTH
STATE DEPARTMENT OF HEALTH
RICHMOND, VIRGINIA
JULY 1, 1974



Commonwealth of Virginia
State Board of Health

Sewage Handling and Disposal Regulations

July 1, 2000

Virginia Department of Health
1500 E. Main Street
Richmond, Virginia 23219

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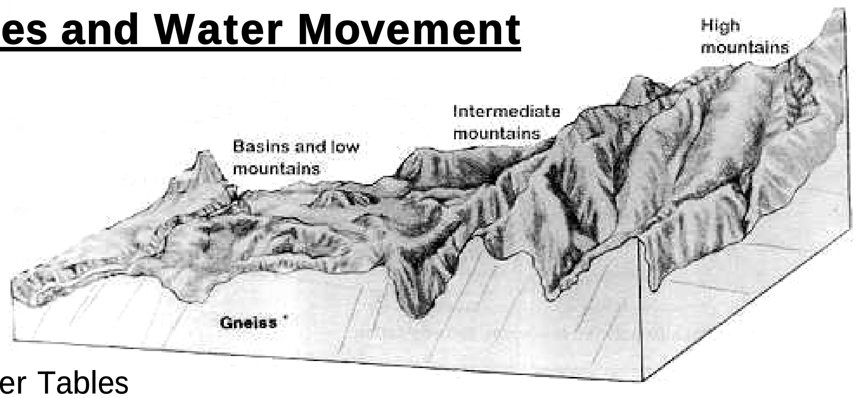
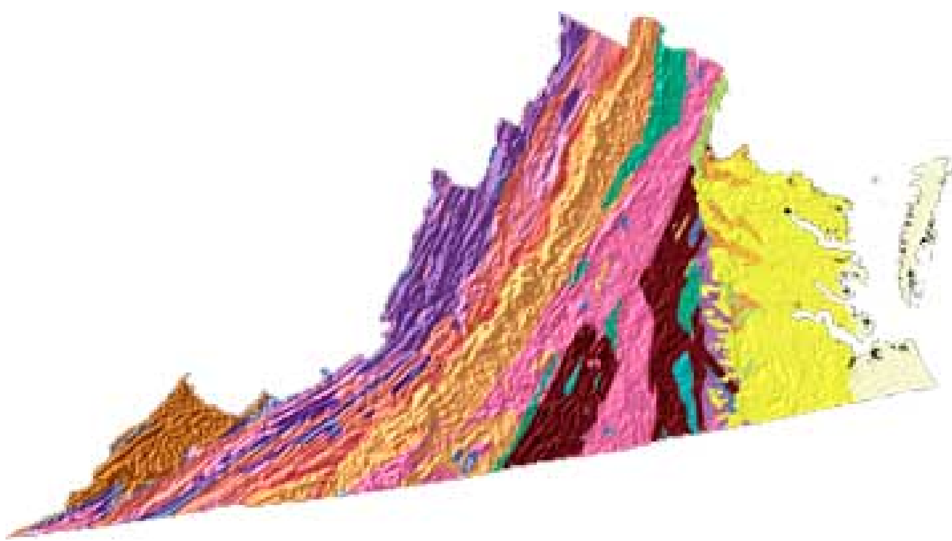


Chapter 3

Virginia Physiography, Geology and Soil Systems



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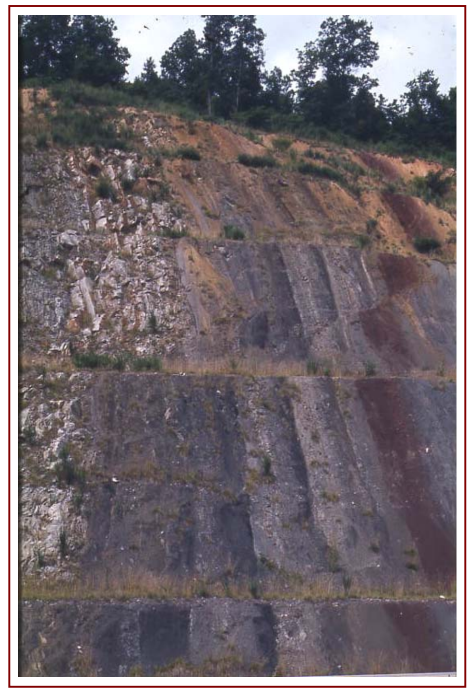
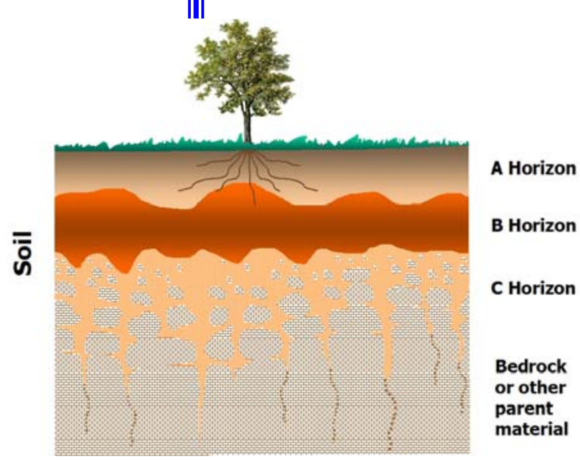
Field Description of Soils





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Chapter 1
Introduction

Onsite wastewater systems collect, treat, and release about 4 billion gallons of treated effluent per day from an estimated 26 million homes, businesses, and recreational facilities nationwide *(EPA Onsite Wastewater Treatment Systems Manual, 2002)*. Where is this 4 billion gallons of water released? Into the soil. How do we know the soil can accommodate this huge volume of wastewater? The purpose of this document is to provide the reader with the basic skills and knowledge necessary to evaluate soil for onsite wastewater treatment in Virginia.

Sections

Figure: 1-1. Not all countries have sewage disposal requirements. *(Photo by Tom Saxton)*

Soils, as a resource, have a vast capacity to treat wastewater, but can be overwhelmed with sometimes tragic results if their specific properties are not properly factored into land use planning.

Proper planning and understanding of the soil will promote controlled impacts and potentially result in improvements to the soil and the environment.

Soil science *(Pedology)* is a branch of science that studies soil formation and soil-related land use. Soil scientists *(pedologists)* view the world in the context of soils and their relationship with the environment. A soil scientist considers multiple factors when investigating soils and considers how soils change across wide geographical areas, such as a state, or smaller areas, such as a single agricultural field. They observe topography, vegetation, soil colors, etc. in order to piece together a conceptual model of how the landscape/soils were developed and may be utilized. A soil scientist must look far beyond the soil just below his feet when a site is visited. An onsite soil evaluator in Virginia must also consider all aspects of the site, not merely the soil.

Soil contains a record of its natural history. The length of time a soil has been in place, the impact of climate, topography, parent materials, biological and human activities are recorded in the soil as properties of horizontal layers *(horizons)* in a *soil profile*, which can be interpreted by a skilled evaluator. Soil drainage conditions also exert a major influence on the morphology (physical appearance and characteristics of a soil) of the soil profile. An experienced evaluator can uncover important information on soil water and air movement by careful observation of soil material, soil color and the properties and sequences of soil horizons at a site. These observations can form a reliable basis for designing appropriate onsite wastewater systems.

What is a soil?

Professions that use soil for varying purposes define soil differently.

- Regulators "'*Soil' means the weathered mineral and organic fraction of the earth's regolith, which is less than or equal to 2.0 mm in size as observed in place. Soil comprises sands, silts or clays or combinations of these textured components and may contain larger aggregate materials such as gravel, cobbles, stones or channers or precipitates from aqueous solution. Soil includes the O, A, B, C, and E horizons*." (VA Sewage Regulations, 2000). "'*Soil' means the groups of natural bodies occupying the unconsolidated portion of the earth's surface which are capable of supporting plant life and have properties caused by the combined effects, as modified by topography and time, of climate and living organisms upon parent materials"* (54.1-2200 of the Code of Virginia).

- Engineers "*Any unconsolidated material composed of discrete solid particles with gases and liquids between"* (Sowers, 1979).

- Geologists *"That material which has been so modified and acted upon by physical, chemical, and biological agents that it will support rooted plants"* (AGI, 1976).

- Academics *"A soil is a porous natural body of mineral, air, water and organic matter that changes, or has changed, in response to climate, topography, time, and organisms."*

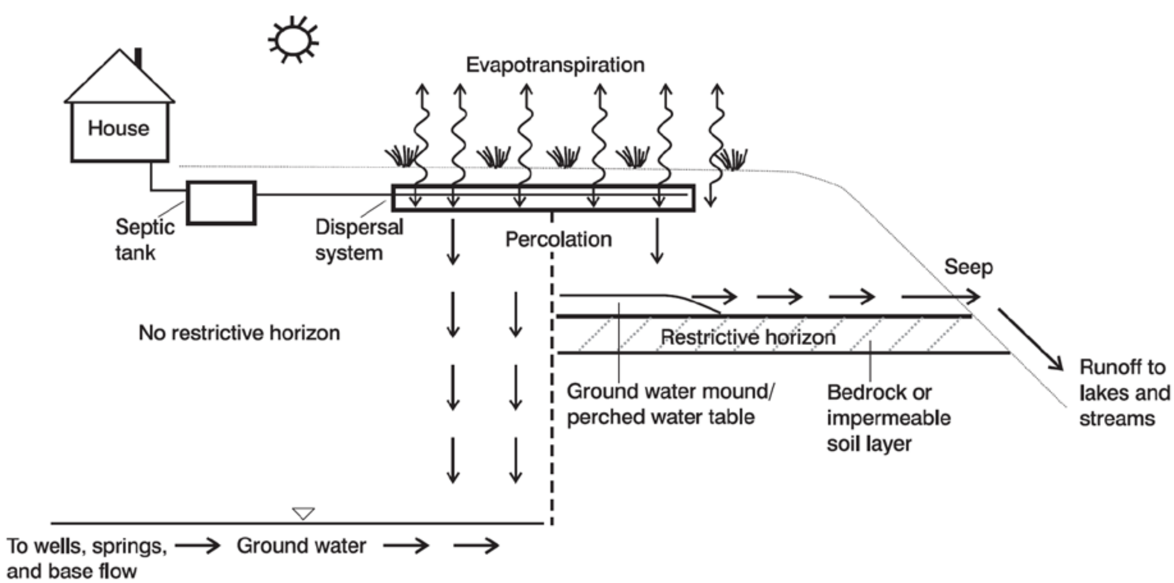


Figure: 1-2. Fate of water discharged from onsite wastewater treatment systems.
(EPA Onsite Wastewater Treatment System Manual, 2002)

Soils are dynamic and reflect the conditions from which they formed. Because they reflect the environment in which they formed, we can use their morphology to understand more about the environment. This and subsequent chapters on soils will present the basic knowledge needed to understand the rudiments of soil and site evaluation for onsite wastewater systems.

Before considering how soil treats wastewater, consider the processes that occur at a wastewater treatment plant. In a treatment plant wastewater is treated in several ways. Biological treatment reduces or removes pathogenic organisms. Chemically, the wastewater is *aerobically* (with oxygen) treated to help convert NH_4 to NO_3. Physical treatment involves settling and filtration of suspended materials. Finally, the treated water is dispersed back into the environment, or reused elsewhere. Many large cities, such as Richmond, have treatment plants. Where is the largest treatment plant? The answer may surprise you; soil is the largest treatment plant or media. In the US, soil accounts for 25%+ of all sewage treatment.

Soils treat wastewater in ways similar to treatment plants. Proper soil treatment requires that there be an aerobic zone with more air than water (unsaturated soil conditions) beneath the trench bottom. As such, Virginia's *Sewage Handling and Disposal Regulations* (henceforth, the regulations) require an aerobic zone below the trench bottom or dispersal zone. In a saturated soil (often anaerobic), all the pores are filled with water. Bacteria and other pathogens move quickly through these pores and are not removed by the soil. They may proceed directly to ground water. Conversely, aerobic conditions create a hostile environment to harmful pathogens by promoting the removal of these microorganisms as the effluent percolates through the soil, hence helping to protect groundwater and the public health. This is the primary purpose of your job when you design onsite wastewater treatment systems (drainfields). Your *charge* is to ensure the protection of the environment and people from dangerous pathogens through proper design and science.

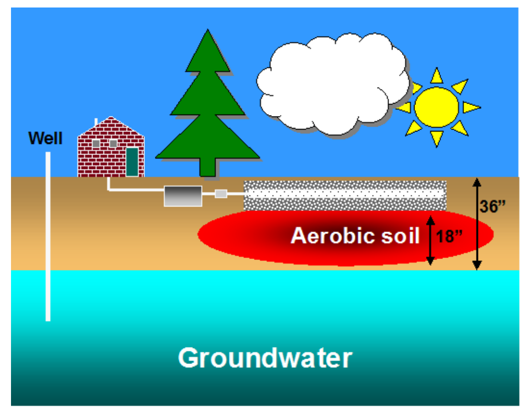


Figure: 1-3. The *Aerobic Zone* in soil is needed to treat effluent. In Virginia, 36" is required for a conventional system. *(NCSU-D. Lindbo)*

What is in soil?

Soil has two major components, solids and pore space, which can be subdivided into five parts overall. Their relative amounts will alter the properties of the soil but no one part is more important than another. The solid component can be subdivided into mineral material, living organic material, and dead organic material, while the pore space can be further subdivided into air-filled and water-filled.

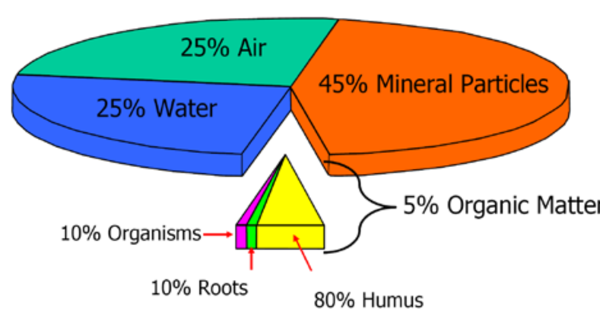


Figure: 1-4. Components of Soil *(TS)*

How does soil form?

Since soil is dynamic, it is important to understand how it forms. This will help us in interpreting the soil once we have described it. In general, soils formed under similar conditions will have similar properties. By altering one of the conditions under which the soil formed, the properties will change. This can account for why, on a given parcel, there are areas of soil suitable for OSWW systems and areas that are unsuitable for OSWW systems. By understanding soil formation one may better predict suitable areas of soil for sewage disposal. This knowledge can save time and money during a field evaluation. When assessing suitability, one must also take the system or system type into consideration. Therefore, an area unsuitable for a conventional OSWW system may be suitable for an alternative treatment system. Furthermore, as technology advances and regulations change, the regulatory requirement for suitability will change.

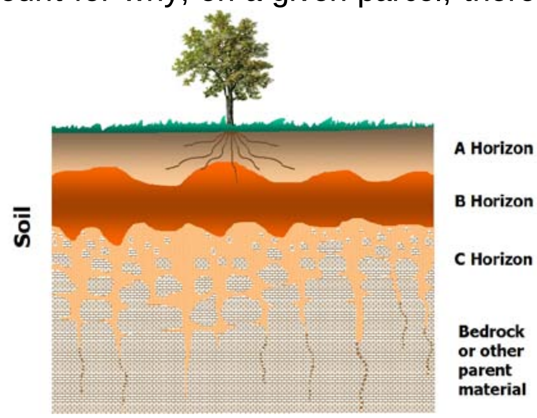


Figure: 1-6. A soil profile develops from the weathering of parent material; which may be bedrock or material that was deposited. *(TS)*

Factors of Soil Formation

Soil genesis or formation is the result of the 5 soil forming factors working together to produce a material specific to that location (Jenny 1942).

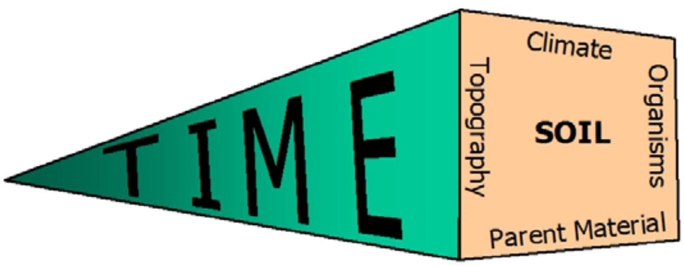


Figure: 1-5. Five Factors of soil formation *(TS)*

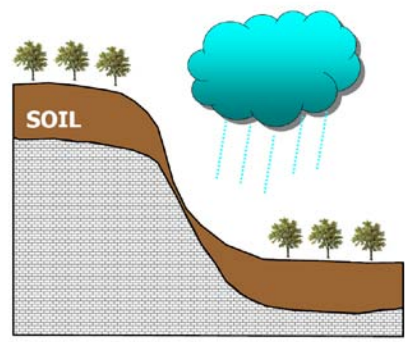


Figure: 1-7. Slope affects soil depth. *(TS)*

Jenny described five factors of soil formation:

1) Parent material is the rock or other matter, which degrades into soil. Soils are reflective of their parent material. For example, a soil developed from rock like sandstone will yield a sandy soil.

2) Topography 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 slope. Slope affects losses and additions to the soil, therefore, causing changes to the thickness of the soil.

Figure: 1-8. Lichens and moss *(organisms)*, freeze-thaw cycles *(climate)* and water weather the granite into smaller pieces *(parent material)*, which will eventually *(time)* become soil. *(Photo by Tom Saxton)*

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 precipitation, 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. A younger soil is less developed, its parent material has not been acted upon by climate, organisms, and topography for as long as an older, and typically more developed, soil.

Some soil scientists add *Anthropogenic* (human activity) as a sixth factor due to the extreme and widespread influence man can have on soils. Others consider man as part of the organism factor.

Soil forms through the interaction of these factors. Generally, no one factor is more important to the formation of a soil than another. However, for the purposes of site evaluation for OWSS systems in Virginia, the influence of parent material and topography are paramount.

1. Parent Material

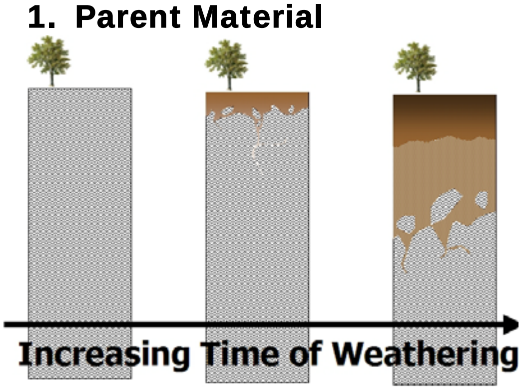


Figure: 1-9. Weathering of Parent material to form soil. *(TS)*

Just as you and I have parents, so do soils. Many of the soils' properties are directly inherited from its parent material. Often these inherited properties can be the difference between a suitable vs. unsuitable soil for an OSWW system. Parent materials can be broken into three basic groups: transported, residual, and organic. The group consisting of transported material is further subdivided based upon the media that transported the sediment (or where the sediment was deposited): water (marine, fluvial/alluvial, and lacustrine), ice (glacial), wind (aeolian), gravity (colluvial).

<u>Transported Parent Material</u>

The most extensive group of parent materials is the group that has been moved from the place of origin and deposited elsewhere. The principal groups of transported materials are usually named according to the main agency responsible for their transport and deposition. In most places, sufficient evidence is available to make a clear determination; elsewhere, the precise origin is uncertain.

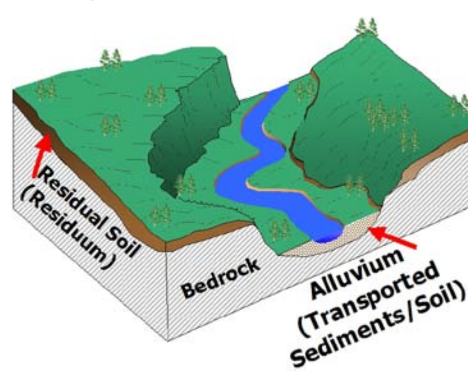


Figure: 1-10. Eroded soil materials that are moved by water and deposited along streams and rivers are a type of Alluvium called Fluvial Deposits. *(TS)*

Water

Fluvial/Alluvial

Alluvial deposits are those moved and deposited by water in a non-marine environment.

Fluvial deposits are alluvial sediments deposited by streams or rivers either in the active stream channel or on the floodplain associated with the channel.

The sediments are coarser near the channel where the water is moving the fastest. Active deposition occurs in the channel and the adjacent active floodplain. The channel is not static and meanders across the plain depositing and eroding material as it moves. Because of this, the fluvial landscape has variably textured sediments across it. Sediments deposited in fluvial environments are often layered or stratified.

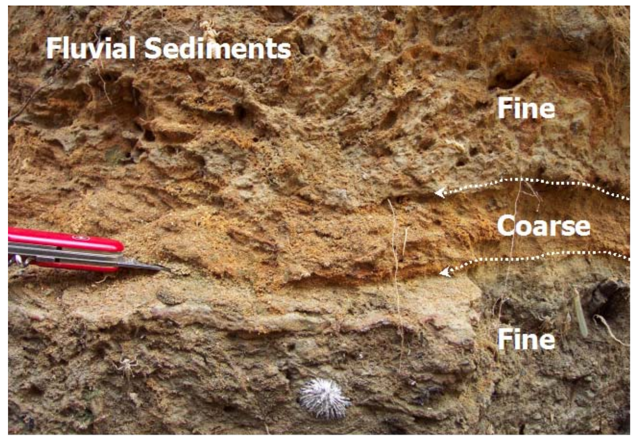


Figure: 1-11. Variably textured sediments in a fluvial deposit (alluvium). What do these differences tell us? They reflect the velocity of the stream at this point at the time of deposition. *(Photo by Tom Saxton)*

Terrace deposits are alluvial sediments deposited by streams or rivers either in the active stream channel or on the floodplain associated with the channel. They have been stranded and are located at higher elevations than the current floodplain due to downward cutting and dissection by the stream or river.

Alluvium is sediment deposited by running water. It may occur on terraces well above present streams or in the normally flooded bottomland of existing streams. These rock fragments are stratified or horizontally oriented.

Local alluvium consist of materials that have washed down slope (slope wash), rock fragments are absent.

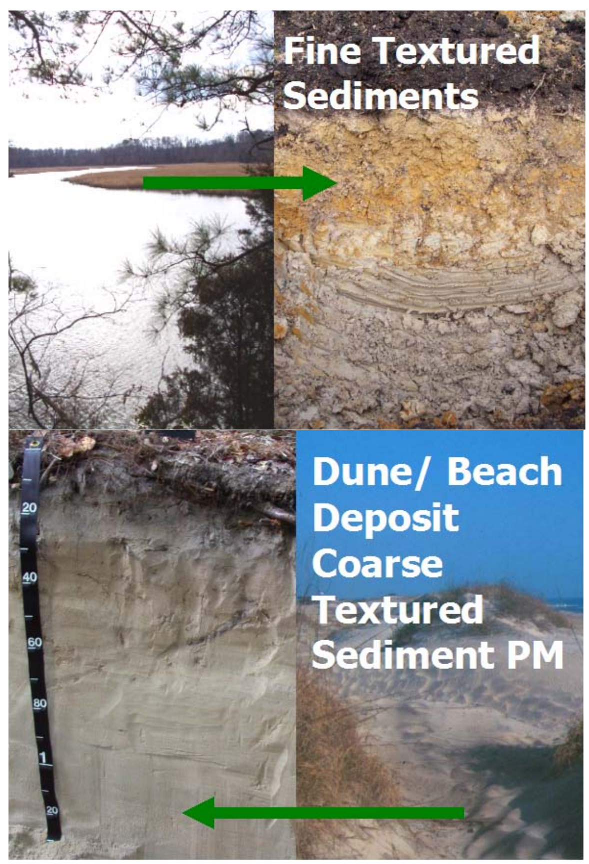


Figure: 1-12. Marine Parent Materials (PM).

Marine

These sediments may be influenced by fluvial processes (fluvial-marine). Along the continental coastline, these soil parent materials are often referred to as coastal plain sediments. The areas adjacent to the coast contain multiple environments for sediment deposition. Sediments deposited in this area are termed Marine sediments and are deposited in water ranging from brackish to salty. *Beaches* are high-energy zones and therefore have sandy (coarse-textured) sediments. Long shore currents and wind may rework these sediments. Low energy environments result in fine-textured sediments with high silt and clay contents. The landscape in these zones is often flat and wet. Shell beds are also typical of a marine environment and may be fine textured as well as containing shells. The depositional environments in a marine setting are constantly shifting, with the beaches over-washing onto the marshes or mud flats, etc. As sea level rises or falls, these zones shift back and forth resulting in an unpredictable assemblage of sediments and textures with depth.

Marine sediments settled out of the sea and commonly were reworked by currents and tides.

Beach deposits mark the present or former shorelines of the sea or lakes. These deposits are low ridges of sorted material and are commonly sandy, gravelly, cobbly, or stony.

Lacustrine (*of small extent in Virginia*)

This topic is reviewed so that you may know the terms should you need to communicate with persons from areas in which this is a consideration. Lake deposited material is referred to as Lacustrine. At the margins of the lake coarser textures may abound but the majority of the sediments will be fine textured. In areas where the lake freezes over in the winter, a distinct layering may occur. This layer is referred to a varve. The winter layer is composed of a finer textured material than the summer material. Varves occur as the result of seasonal cycles of deposition. In Virginia, lagoonal deposits in the Coastal Plain may have similar characteristics. Triassic Basin sedimentary rock in the Piedmont was also formed from lacustrine deposits.

Ice

Glacial *(not found in Virginia)*

This topic is reviewed so that you may know the terms should you need to communicate with persons from areas in which this is a consideration. Several terms are used for material that has been moved and deposited by glacial processes. Glacial drift consists of all of the material picked up, mixed, disintegrated, transported, and deposited by glacial ice or by water from melting glaciers. Glacial till is glacial drift deposited directly by the ice with little or no transportation by water. It is generally an unstratified, heterogeneous mixture of clay, silt, sand, gravel, and sometimes boulders. Two types of tills are often described; basal or lodgement till: dense (compacted) till formed at the base of the glacier, and ablation till: loose (friable) till generally overlying the basal till. Glaciological deposits are material produced by glaciers and carried, sorted, and deposited by water that originated mainly from melting glacial ice. Glacial outwash is a term used for material swept out, sorted, and deposited beyond the glacial ice front by streams of melt water (sometimes referred to as proglacial outwash). Glacial beach deposits are rock fragments and sand that mark the beach lines of former glacial lakes. Depending on the character of the original drift, beach deposits may be sandy, gravelly, cobbly, or stony.

Glaciolacustrine deposits are derived from glaciers but were reworked and laid down in glacial lakes. They range from fine clay to sand. Many of them are stratified or laminated.

A varve consists of annual lacustrine deposit. The finer, clayey portion (darker in color) represents deposition during the winter when the lake was iced-over. This creates a still-water environment. The lighter-colored material consists of coarser, sandier (lighter in color) material that is deposited during warmer periods when the velocity of water entering the lake is higher.

Wind

Aeolian

Aeolian or eolian materials are deposited by the wind. They range in size from sand to clay.

Figure: 1-13. Aeolian deposits on Mars *(NASA)* and at Virginia Beach

Sand dunes in coastal regions, characteristically consist of fine or medium sand. It is high in quartz and low in clay-forming materials. The size of the particles becomes smaller with increasing distance from the source of the sediment.

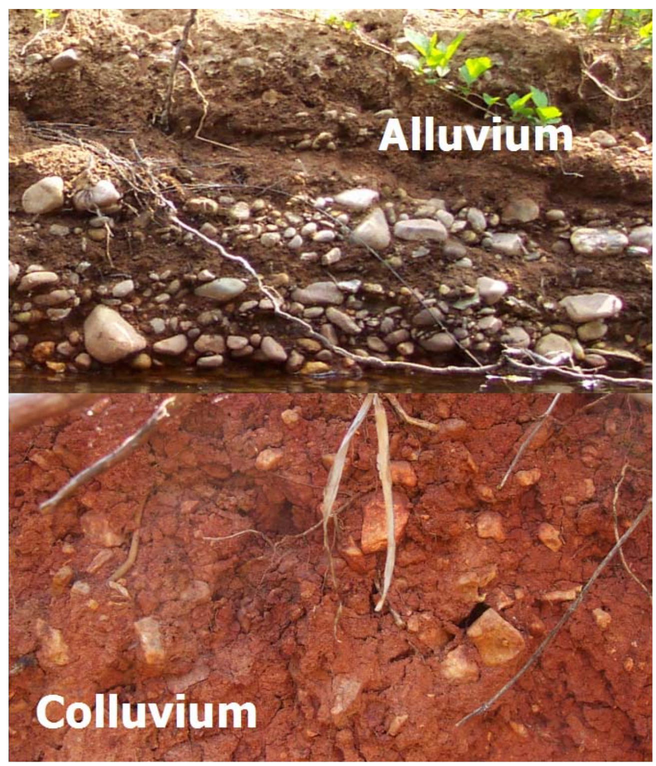


Figure: 1-14. Orientation of transported material; Water-worn cobbles in the alluvium above are oriented horizontally. Smoothed-angular and subrounded rocks in the colluvium below are randomly oriented. *(Photo by Tom Saxton)*

Gravity

Colluvial

Sediments transported down slope by gravity are deposited as *Colluvial* materials. If the movement is slow, it is often difficult if not impossible to see any effect on the soil. However, when movement is rapid, the existing soil may be mixed, reoriented, etc. Colluvial material may look as if it was just dumped from the back of a dump truck. In time it may appear a bit more organized as soil processes act upon it. Often, within a soil developed in colluvium, several events or depositions may be visible. Therefore, it is possible to have more than one parent material represented in a single soil. Water movement through the soil may be impeded as it approaches the contacts between the different parent materials. Colluvial parent materials are found throughout all physiographic provinces in Virginia. It is extremely important they be recognized for onsite wastewater design.

Colluvium: poorly sorted debris that has accumulated at the base of slopes through gravity and soil creep. It consists largely of material that has rolled, slid, or fallen down the slope under the influence of gravity. Accumulations of rock fragments are called talus. Rock fragments in colluvium are usually angular and smoothed to subrounded. This is in contrast to the rounded, water-worn cobbles and stones in alluvium. Colluvial rock fragments are randomly oriented (Figure: 1-14).

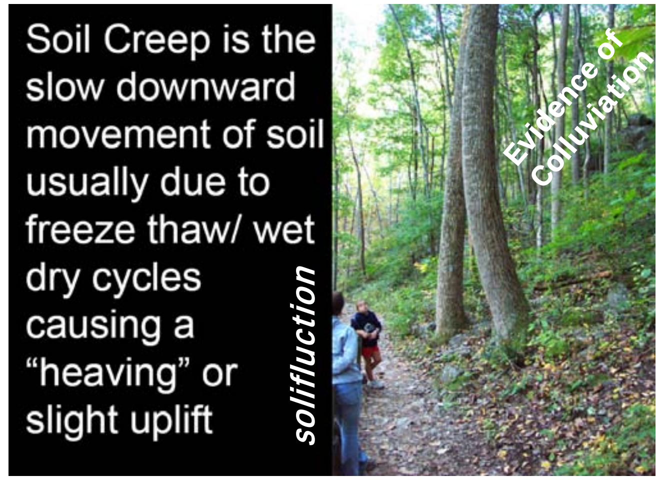


Figure: 1-15. Soil Creep *(colluviation) is caused by solifluction, which is the slow viscous down slope flow of water-saturated soil.* *(Photo by Tom Saxton)*

Residual Parent Material

Soils can also be developed in place from the underlying bedrock. These are referred to as residual materials. The soil developed from these materials inherits properties from the rock and the manner in which the rock weathers both physically and chemically. Residual soils developed from felsic materials weather to low activity clays (kaolinitic). These clays do not expand upon wetting and are generally suitable for onsite wastewater systems. Residual soils developed from sedimentary or mafic materials may weather to high activity clays (smectites). These clays expand upon wetting, and are poorly suited or unsuitable for onsite wastewater systems. This material will be covered in depth in a later chapter.

2. Topography

Topography, or slope position, can greatly influence soil development. Soils developed on different parts of the landscape reflect the influence of drainage. The following should be considered during the evaluation of a site: First, how water moves on a slope as well as through a soil. Secondly, how to describe the slope type and position in two and three dimensions. Finally, how landscapes vary and how that variation affects soil properties.

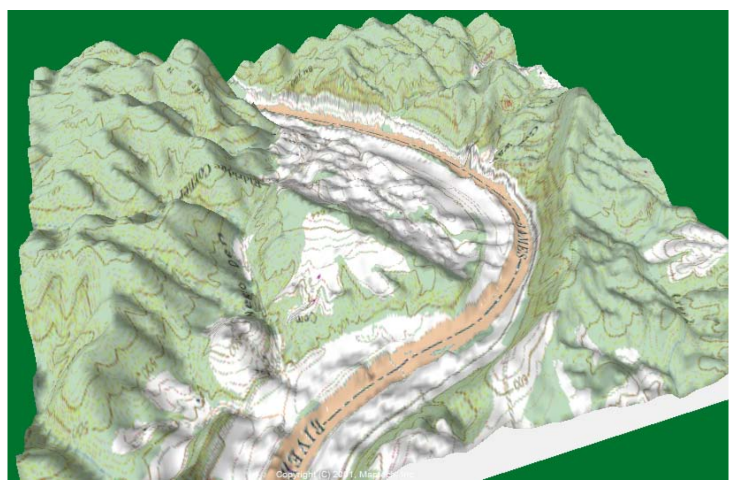


Figure: 1-16. Soil variability is contingent upon topography.

The upslope areas generally, have good external drainage as water flow away from these zones. The lower portions of the landscape have poor external drainage as water flows into these zones.

On a given landscape, each part of the slope has a different name: summit, shoulder, side slope, foot slope, and toe slope. Dissected or rolling topography will have the well drained soils at the summit and the poorly drained soils at the low or toe slope areas. In contrast to rolling topographic areas, the flat regions in the Coastal Plain have the poorly drained soils at the high points away from the drainage ways. The well drained soils occur adjacent to the drainage ways. This factor is extremely important in the onsite world. One must closely examine the topography during the design process. Topography will yield clues that may save time and physical effort if the evaluator considers this factor when selecting a site to evaluate for drainfield use.

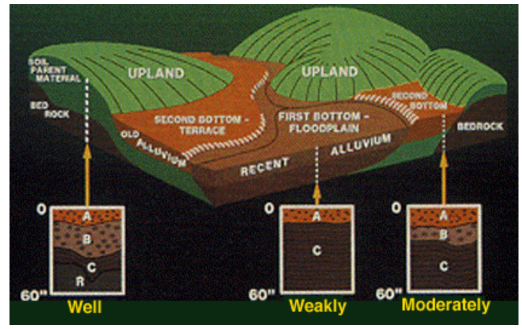


Figure: 1-17. Differences in soil forming factors from one topographic location to another. *(NRCS)*

3. Organisms

Asuming the same parent material, differences in vegetation can produce or reflect profoundly different soils. However, on a given 1-acre site, the effects of vegetation/biology will generally be the same across it. Vegetation can be used to tell us several things about a site before looking at the soil. For example, soil under coniferous vegetation will be acidic. The species of trees and shrubs growing on a site will be related to the wetness of that site and may be good indicators of site suitability. Vegetation may aide in the identification of soil types or the boundaries between different soils. For instance, lichens on the soil surface may indicate shallow depth to bedrock. Eastern red cedar trees favor soils with high base saturation, which are often shrink-swell soils. Chestnut oaks grow on upland drier soils. Needle rush may indicate wet soils. Each physiographic region has soil-vegetation relationships specific to that area. Learning to recognize these relationships will be helpful when choosing a site for investigation.

Figure: 1-18. Organisms affect the development of soil. *(Photos by Tom Saxton)*

Figure: 1-19. Vegetation may reflect soil conditions. Giant cane (*Arundinaria gigantea* ssp. *tecta*) indicates high water tables in the coastal plain (Sussex County). *(Photo by Tom Saxton)*

Plants differ in their root systems, size, aboveground vegetative volume, nutrient content and life cycle. Soils formed under trees are different from soils formed under grass even though other soil-forming factors are similar. Trees and grass vary considerably in their search for food and water and in the amount of various chemicals taken up by roots and deposited in or on top of the soil when tree leaves and grass blades die. Soils formed under grass are much higher in organic matter than soils formed under forests because of their massive fibrous root structure and annual senescence of aboveground vegetation.

There are a multitude of organisms living in the soil. Included among them are mites, ants, snails, beetles, millipedes, springtails, worms, ground hogs, grubs, nematodes, and microorganisms (e.g., bacteria, fungi, actinomycetes and algae). Microorganisms are the most abundant organisms in the soil. The activity of soil organisms is strongly influenced by soil temperature, acidity and soil-water relations. Their major contributions to soil are improved soil structure, nutrient transformations and fertility, aeration and enhanced productivity. Under forests, soil microorganisms are more diverse than under grasslands; however, microorganisms under grasslands are more active and have greater mass than under forest conditions. In general, cultivated fields have fewer organisms than virgin areas. As much as 4,000 pounds of bacteria can be present per acre-furrow slice (furrow slice = a 6-inch depth of soil). This is more than four times the mass of earthworms that can be present. Because of the quantity of organisms present in the soil and their ability to accelerate the decay of organic material, they play a major role in soil formation *(Plant and Soil Sciences eLibrary. 2013.)*.

4. Climate

Climate, in particular rainfall and temperature, can have profound effects on regional differences between soils. Few states have a more diverse climate than that of Virginia. The state has five different climate regions: the Tidewater, Piedmont, Northern Virginia, Western Mountain, and Southwestern Mountain regions. Some localities--Charlottesville, Lynchburg, and Warrenton, for example, have climate amenities such as long growing seasons and infrequent subzero temperature minimums, while winters on the northern Blue Ridge frequently produce bitterly cold temperatures like those of Chicago. Similarly, annual rainfall totals can vary from a sparse 33 inches typical of the Shenandoah Valley to more than 60 inches in the mountains of southwestern Virginia *(Hayden, Bruce P. and Michaels, Patrick J. 2011)*.

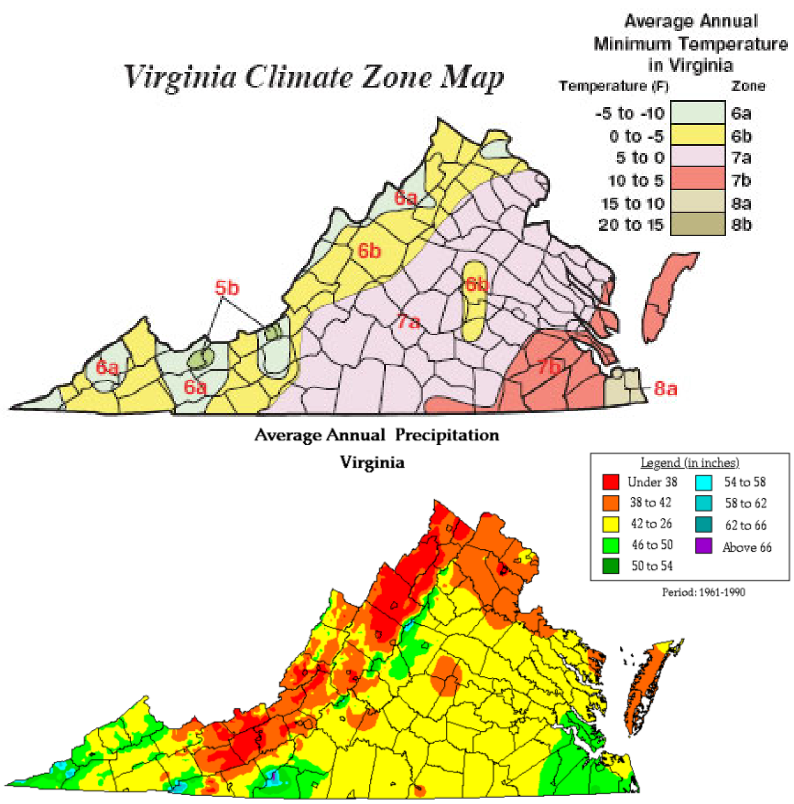


Figure: 1-20. Virginia Climate *(UVA Climate Center)*

Climatic conditions on a given 1-acre site will generally be the same across it. The most noticeable effects of climate are therefore, regional. Soils developed in humid climates like Virginia, typically show multiple horizons, have clay, iron (Fe) accumulation in the subsoil and organic accumulation at the surface. Soils in arid climates lack the organic accumulation and generally have fewer distinct horizons. They may also have shallow accumulations of salts or carbonates because there is insufficient precipitation to leach these constituents. In the southwestern mountains of Virginia, where rainfall is high and temperatures are low, organic matter commonly accumulates to a greater depth than in other areas of the state. This is due to the slow oxidation of the organic matter by microbes as a result of this climate.

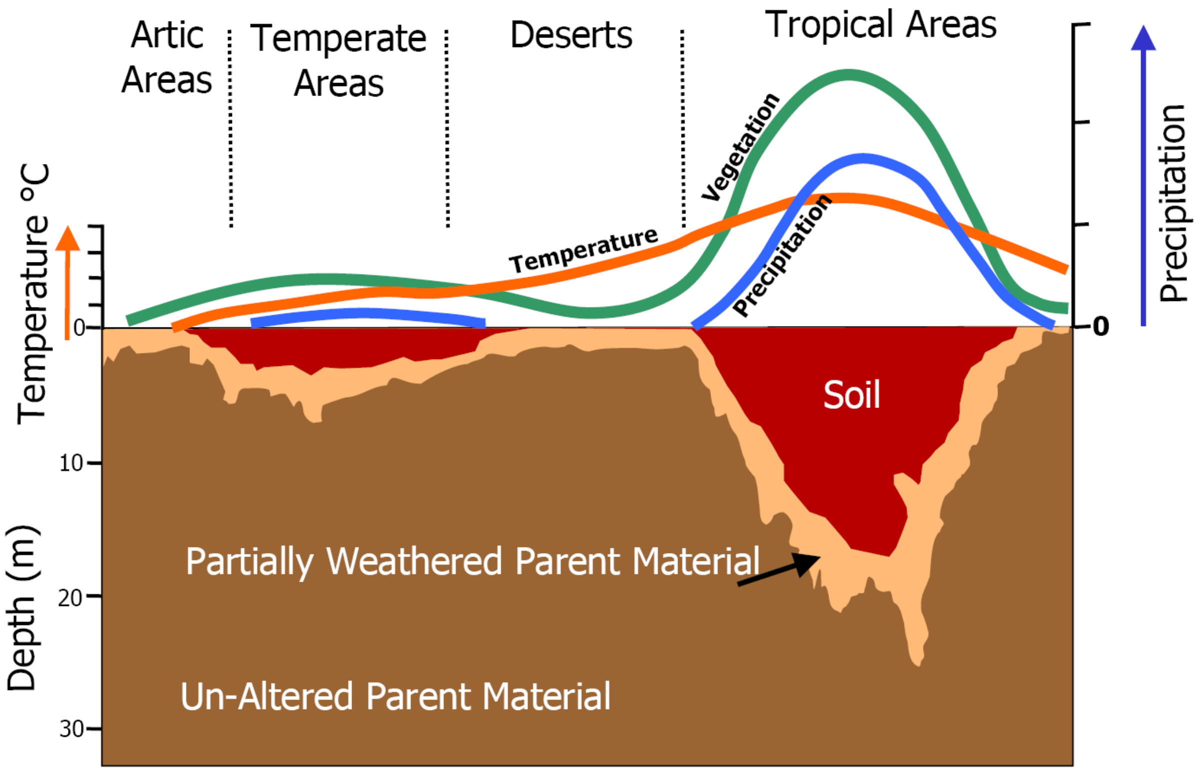


Figure: 1-21. The five factors of soil formation are especially active in warm humid climates with abundant vegetation. *(TS)*

5. Time

Time should be considered not only for how old a soil is, but, also in terms of how long will it take for certain soil properties to develop or redevelop after a soil is disturbed. Freshly deposited materials, such as sand dunes, show little, if any, evidence of soil formation. How long does it take for features to form in a soil? For example, how long does it take for signs of soil wetness to appear or disappear from a soil? How long does it take for soil structure to redevelop in a disturbed area? How will the rate of soil formation affect interpretation and various land uses? Soil development is generally considered in terms of tens of thousands to millions of years.

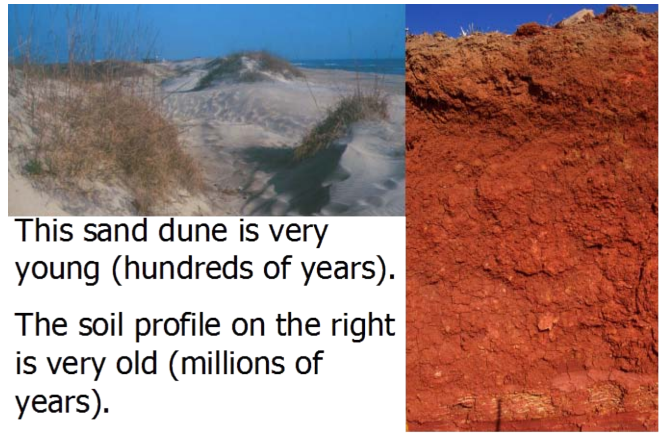


Figure: 1-22. The time it takes for soil development.

Anthropogenic

Anthropogenic, or human induced, changes are often discussed in the same section as biology or vegetation. In the context of land use (onsite wastewater, in particular), man induced changes may have a dramatic effect on the soil properties. These effects are often exhibited to a greater degree or with greater consequences than other biological processes. The effects of tillage may be very dynamic. For example, years of farming may remove many feet of topsoil. Erosion caused by man's activity will remove material, while dredging and filling may create new land. The new land created may not be suitable for onsite wastewater systems, depending on the properties of the material being deposited.

Processes

Ever dug into in the soil and noticed how it seems to change color the deeper you go? Some soils are dark brown near the surface and get lighter in color as you go deeper. Others display a sandy, light-gray layer near the surface with a reddish layer beneath. These different colored layers are known as *horizons*. All the horizons taken together comprise the *soil profile*. Soil horizons form as a result of the four horizon development processes: additions, translocation, removal, and transformation.

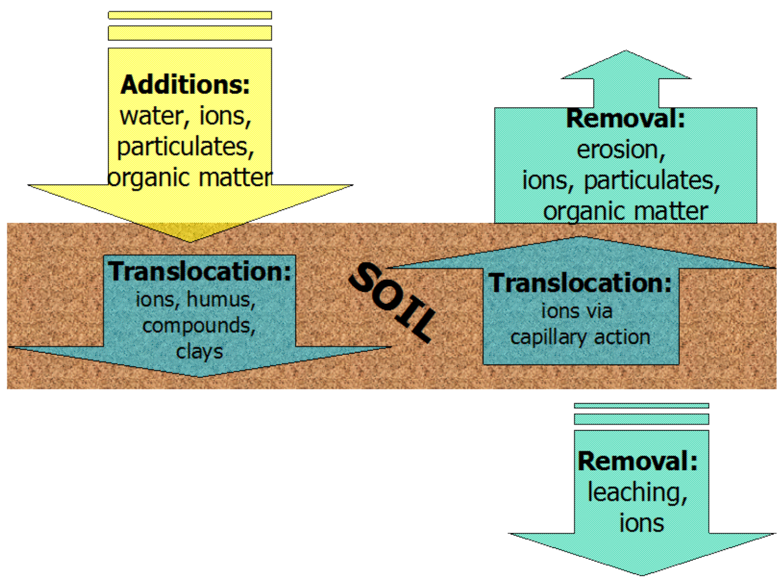


Figure: 1-23. Movement of materials in the soil. *(TS)*

Additions can be materials that are transported into the location where a soil is forming. For instance, dust with a high calcium carbonate content could be blown on to the developing soil, thereby, adding calcium to the evolving profile. Organic matter is added to the soil when dead plants or fallen leaves decompose. Precipitation supplies water to move these materials down into the soil.

Translocation involves the movement of soil-forming materials through the developing soil profile. This is also referred to as *eluviation*. Translocation takes place when water moves through the soil transferring (*eluviating*) materials from upper to lower portions of the soil profile or, causing them to "exit". The layer or horizon that has been depleted of these materials is termed an *eluvial* horizon. Burrowing animals like earthworms, ants, etc., move soil materials within the profile. Burrowing animals create passageways through which air and water can travel, both of which promotes soil development. Water may move upwards in the soil column by capillary action. During this process, ions that have translocated downward may move back up. The process of these materials collecting and concentrating is called *illuviation*. A horizon into which eluviated or translocated materials have moved is termed an *illuvial* horizon.

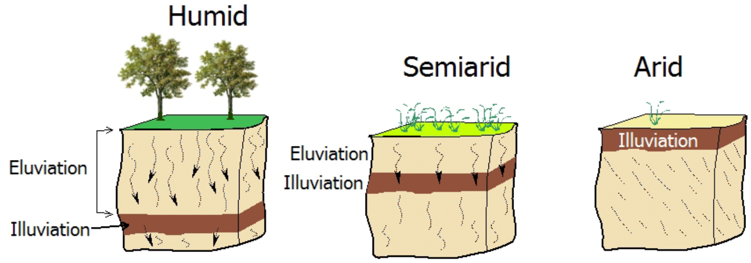


Figure: 1-24. Climate, especially precipitation, affects eluviation and illuviation. *(TS)*

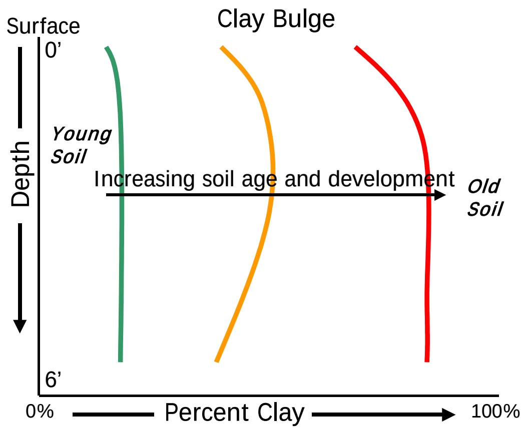


Figure: 1-25. The older and more developed the soil, the more clay that will be present to a greater depth due to eluvial processes. *(TS)*

Removal of soil forming materials means that they are completely removed from the soil profile. Easily dissolved materials like calcium carbonate can be removed from the soil profile in rainy climates. Forms of nitrogen may be removed from the soil and enter the groundwater. This is of concern with onsite wastewater disposal. Other nutrients may also be removed. These nutrients may ultimately appear in environments in which they are not welcome, such as the Chesapeake Bay.

Transformation

Transformations of the materials added to the developing soil occur by chemical and biological processes acting upon them. For instance, leaves falling on the surface and plant roots dying beneath may decompose into a dark brown (organic matter), nutrient-rich material called *humus*. Humus is responsible for the dark brown to black color of many soils, especially near the top of the soil profile. Iron and aluminum can be oxidized under warm, moist climates. Iron may be reduced and become soluble under wet anaerobic conditions. During dry aerobic conditions this iron may become oxidized and precipitate from solution. Soil material is constantly being transformed in one way or another.

Soil horizons develop in response to the relative importance of each of the above processes. All soils are impacted and their character determined by these processes *(Adapted from: Michael Ritter, Earth Online, 2011).*

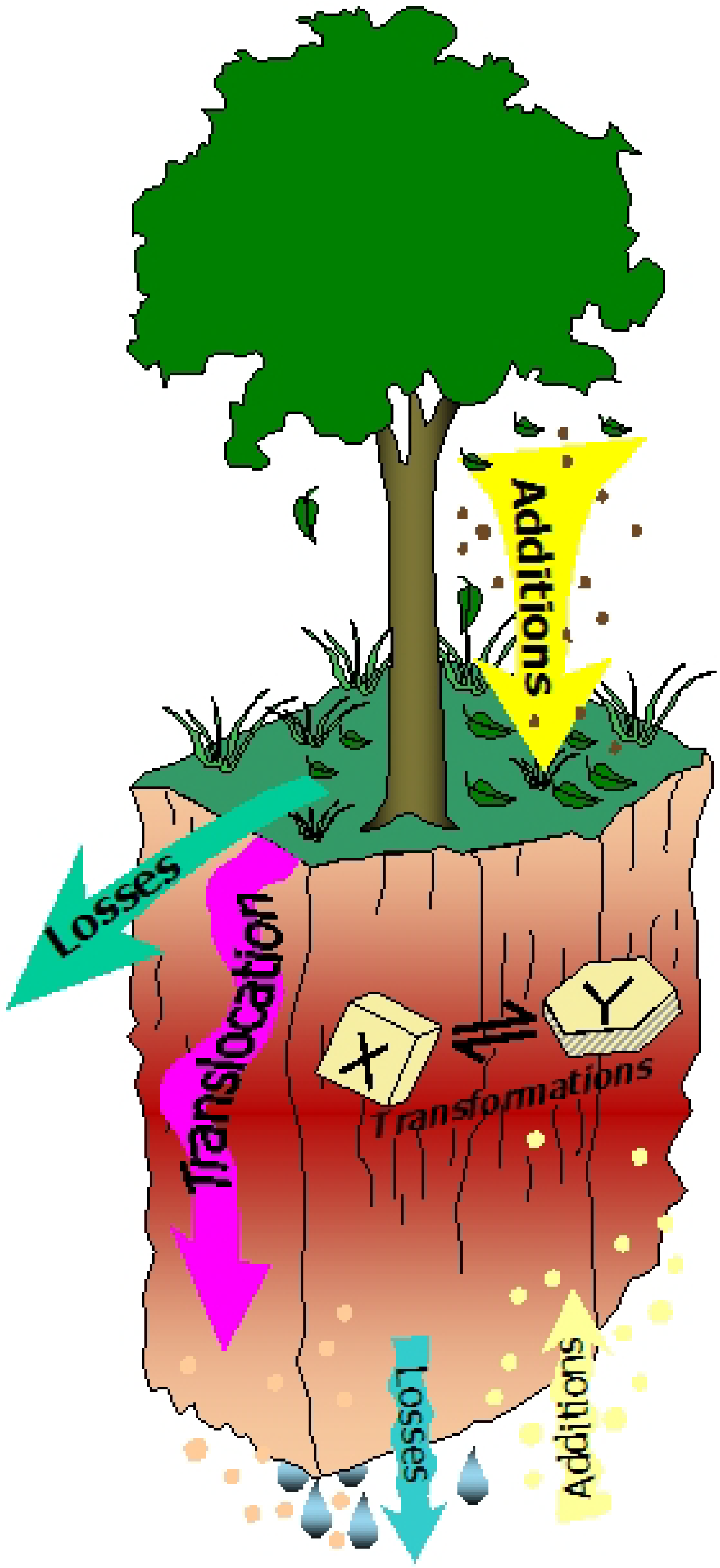


Figure: 1-26. Soil Transformations *(TS)*

Chapter Review

Understanding Concepts

1) What is the meaning of pedology and pedologist?

2) Create your own definition of soil in context with your job and its responsibilities.

3) True / False Wastewater is best treated under anaerobic conditions.

4) What are the two major components of soil?

5) Soil depth on steep slopes tends to be __________________.

6) What moves transported soil?

7) How many climate regions are there in Virginia?

8) What is the most extensive group of parent materials?

9) Do soils weather from the bottom up or the top *(surface)* down?

10) What does *fluvial* mean?

Critical Thinking and Problem Solving

1) How can you determine if a soil is old versus young?

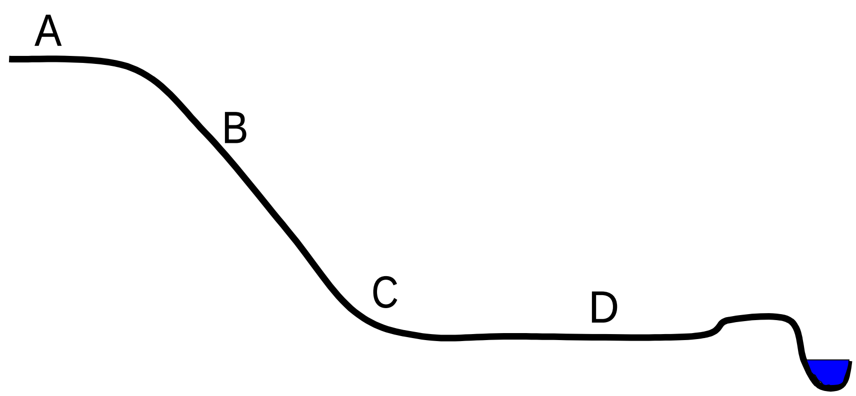
2) How might climate affect the development of a soil?

3) What are some soil characteristics that might be estimated based upon vegetation?

4) Where in Virginia might one find more organic matter in the soil and why?

5) Explain the difference between *illuviation* and *eluviation*.

6) How might one determine the difference in a *colluvial* soil and an *alluvial* soil?



On this given landscape please answer the following questions:

7) At which letter would you expect to find shallow soils?

8) Where would you expect to find the oldest soils?

9) Where would you find *colluvium*?

10) Where would you find *alluvium*?

11) Label the velocity in which the stream was flowing when the sediment was deposited; slow, moderate, fast.

Chapter 2
Slopes, Landscapes and Water Movement

Sections

Slopes and landscapes affect water movement on a broad scale as well as movement in the mesoscale (smaller scale). Water movement through the soil varies with landscape. When this water movement is impeded, a water table may form.

Slope, also called slope gradient or gradient, is the inclination of the land surface from the horizontal. Percent slope is the vertical distance divided by the horizontal distance, and then multiplied by 100 (NSSH). The main components of slope are gradient, complexity, length, and aspect.

> **12 VAC 5-610-593. Physical features.**
>
> Physical features, **landscape** position and soil characteristics affect the ability of soil-based systems to treat and disperse effluent. In order to correctly select and place a sewage system in the environment such that public health and the environment are protected, it is necessary to understand and consider the local hydrologic conditions, the regional geology, and the nature of the soils occurring on the site being evaluated.

Soil slope has an important influence on the amount and rate of surface water runoff as well as the rate and direction of subsurface water movement in the soil. Wastewater is always presumed to move vertically and horizontally on sloping landforms, unless there are confining layers in the soil that limit or prevent such movement.

Slope gradient is a primary factor in determining drainfield trench bottom depth in the Regulations. Simply stated, the steeper the slope the deeper the minimum drainfield installation depth. Best Management Practice in the field is to measure the slope gradient before any soil evaluations are conducted and then determine what the minimum drainfield trench bottom depth should be.

> **12 VAC 5-610-593. Physical features.**
>
> 3. **Slope**. Subsurface soil absorption trench systems shall not be placed on slopes greater than 50% unless terraced. Criteria for other types of onsite systems are contained in Tables 4.3 and 4.4. or impervious strata (See Tables 4.3 and 4.4 of this chapter).

Slope is measured in the field using a hand level, clinometer, or engineering transit. The general procedure is to measure “rise over run” and then multiply by 100 to determine percent slope (see Chapter 5). For example, if the elevation difference on a sloping landform is 8 feet (Rise) over the horizontal distance of 75 feet (Run), then the slope in percent would be: (8 ÷ 75)100 equals 10.6% slope (See fig. 2-1).

Slope complexity refers to the variable land surface shape and steepness over a short distance. This usually means the land surface has two or more sloping segments within a short distance. For example, a drainfield site that is 100 feet long by 75 feet wide may include a gently sloping shoulder (2 to 7% gradients) and a strongly sloping backslope (7 to 15% gradients). Best Management Practice in the field requires that each slope or landform segment be measured separately and drainfield trench depth adjusted accordingly. Or, the designer may design to the most limiting portion of the footprint.

% Slope = Rise/Run x 100

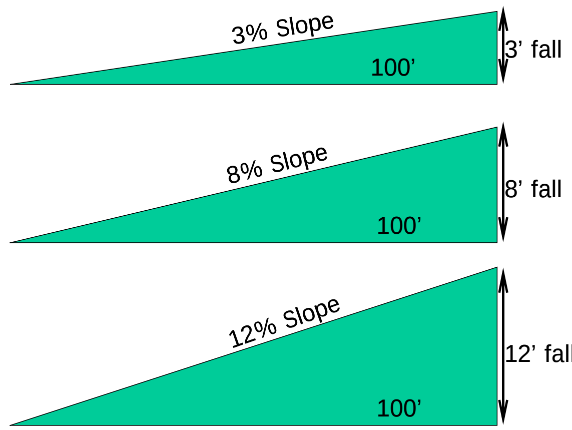


Figure: 2-1. Slope *(TS)*

Slope length exerts control over surface water runoff and potential accelerated water erosion and accompanying sediment deposition. The rate and direction of wastewater movement will also be affected by slope length. The configuration and dimension of a drainfield is determined by an analysis of slope properties at a specific site.

> **12 VAC 5-610-470. Physical features.**
>
> A. Physical features including soil features, **slope**, depth of rock, the location of rock outcrops, drainage ways, marshes, swamps, sink holes, flood plains, artificial drainage systems, and various structures and topographic features found in Tables 4.1 through 4.4 shall be fully and accurately documented in writing as part of the site and soil evaluation.

Landscapes

Generally, when one considers soils one automatically starts to think about what is below their feet, but in order to better understand soils one needs to consider the bigger picture and be able to comprehend how landscape/landforms and soils are related.

Soil geomorphology combines the study of landscape with the study of soil genesis and strives to understand soils based on their place in and on the landscape *(see landform definitions at the end of the chapter)*. In discussing soil geomorphology, the following section will concentrate on slopes (names, types etc) and relating how slope influences water movement. The hydrology of a site (slope and drainage) **must** be considered for onsite sewerage system design.

On a given landscape each part of the slope has a different landform name. Consider comparing the names to parts on your body: head = summit, ridgetop, top, etc.; shoulder = shoulder slope; back or side = back or side slope; foot = foot slope, toe = toe slope (See fig. 2-2). The upslope areas have good external drainage because water flows away from these areas. Whereas, the lower portions of the landscape have poor external drainage because water flows into these zones (areas).

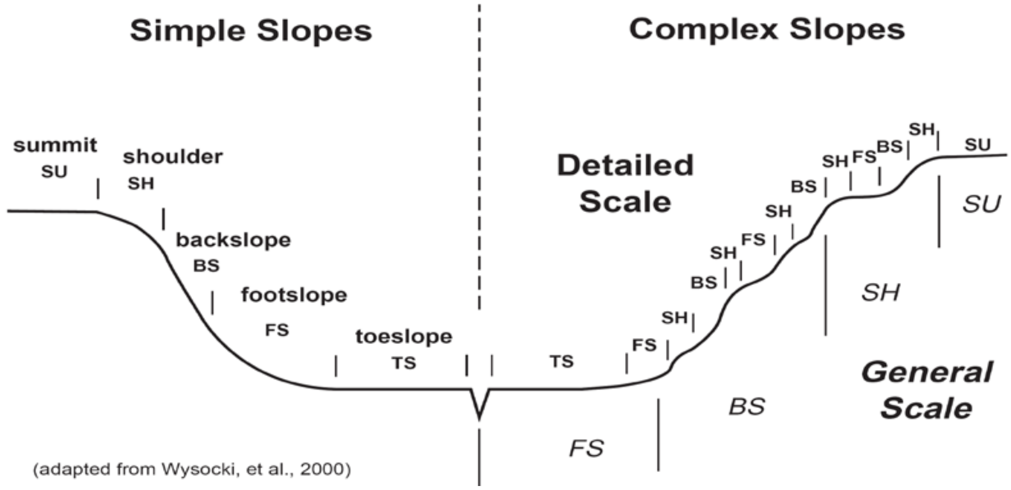


Figure: 2-2. Slope names: Su = summit, Sh = shoulder, Bs = backslope or sideslope, Fs = footslope, and Ts = toeslope *(NRCS)*

Slope shape also affects the amount of water that moves through the soil. Divergent drainage (convex) makes the water disperse and therefore, less goes through the soil at a given spot on the landscape. Convergent drainage (concave) makes surface water accumulate and therefore more water moves into and through the soil (See fig. 2-3). Imagine if it were raining M&Ms. Would you catch more in a bowl if you had it right side up, or upside down? Linear slopes are neither concave nor convex. Water generally moves off these slopes in a sheet flow fashion.

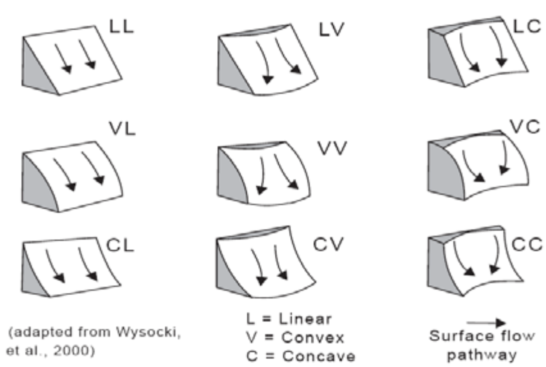


Figure: 2-3. Slope shape is described in two directions: up-and-down slope (perpendicular to the contour), and across slope (along the horizontal contour); e.g., Linear, Convex or LV. *(NRCS)*

When considering a sloping area for a drainfield site, it is important to investigate upslope from the site and the adjacent sides of the site to observe how water will flow on a larger scale. *The landscape position is equal to, if not more important than, soil features in determining the suitability of a site for onsite wastewater disposal.* For example, a head slope "cc" (concave in both directions) may cause water to accumulate over a small (5-10 acre) watershed.

An installed system may be flooded during periods of precipitation resulting in premature failure. Conversely, a nose slope "vv" (convex in both directions) promotes favorable drainage and is a good landform for drainfield locations.

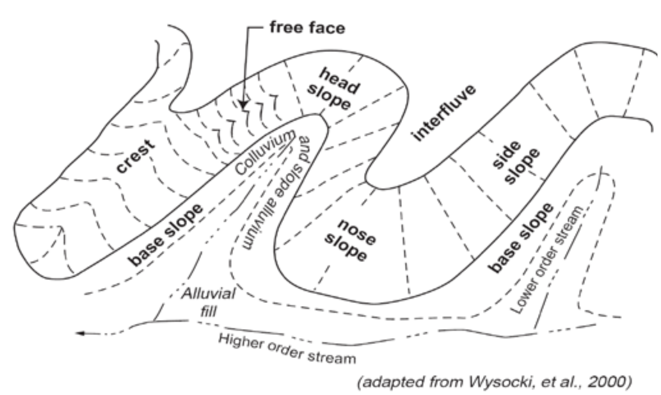


Figure: 2-4 . Geomorphic component in plan view. *(NRCS)*

Surface and subsurface water moving from higher elevations (interfluves and sideslopes) tends to accumulate at lower elevations (base slopes, fig. 2-4). This results in landforms that are less suitable for drainfields.

Aspect is the direction the slope (soil) faces in relationship to the sun's rays (See fig. 2-5). A south-facing slope would usually be warm and dry. A north-facing slope is usually moist and cool. Soil development is different depending upon aspect. Consider the factors of soil formation. What factors are at play with regards to aspect? Climate and organisms vary with the aspect. Aspect in Virginia is most important in the mountainous parts of the state. North/East slopes may require larger and or shallower systems to account for naturally wetter conditions.

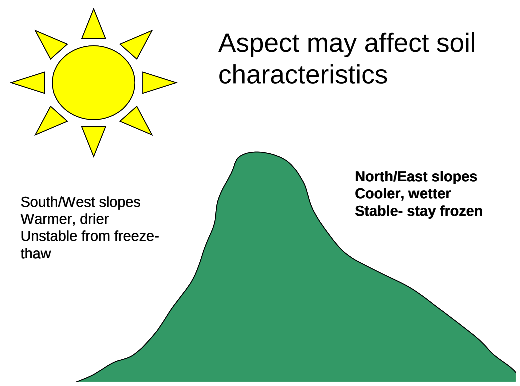


Figure: 2-5. Aspect may affect sewage system design. *(NCSU; David Lindbo)*

Water Movement

Water movement relates to rates of flow into and within the soil and the amount of water that runs off and does not enter the soil. Saturated hydraulic conductivity (measure of the ability of soil to transmit water), infiltration rate, and surface runoff are part of the evaluation.

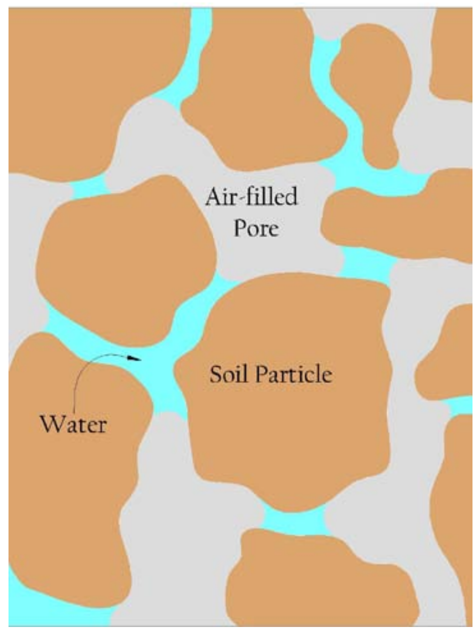


Figure: 2-6. Water in soil *(SKT)*

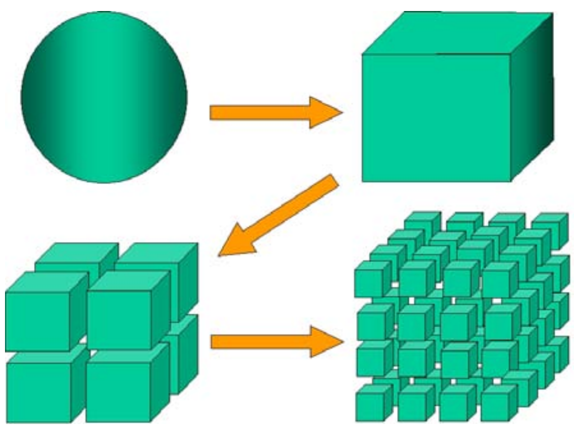


Figure: 2-7. As soil particles become smaller, the surface area increases. More soil water will be held with decreasing particle sizes. Pore size decreases with decreasing particle size. *(TS)*

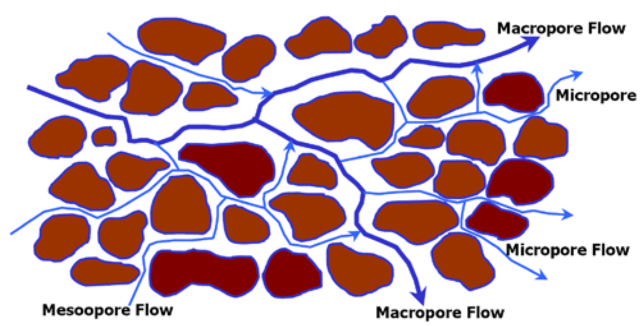


Figure: 2-8. Large (macro) pores offer less resistance to water flow than smaller (micro) pores. *(TS)*

The soil beneath and onsite soil absorption system must aerobic in order for proper treatment to occur. However, water moves out from the trench into the soil primarily by saturated flow. This means that flow out of the trench bottom is controlled by the structural macropores at first (See fig. 2-8). Flow from the trench is not a simple one-dimensional flow. Sidewalls only play a role to the depth at which the trenches are ponded. In a conventional system, this should be minimal. It will be more important in pressure-dosed systems. Once flow leaves the zone of saturation it will become unsaturated flow.

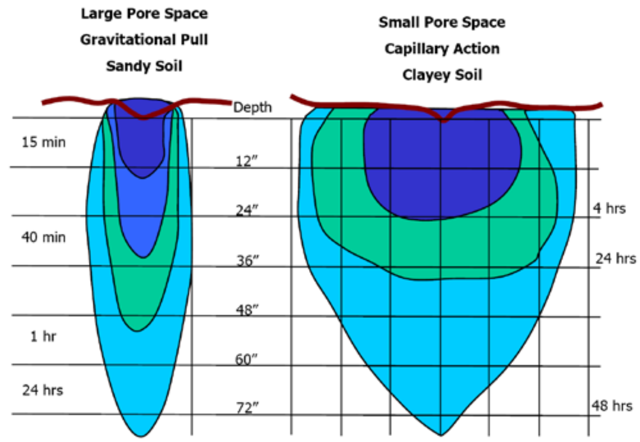


Figure: 2-9. Movement of water through coarse and fine textured material. (*TS)*

Although matrix potential can draw the flow in any direction (highest potential to lowest potential) the majority of the flow is vertical. The highest potential is in the driest soil and will attract and subsequently draw soil moisture into this portion of the soil. Once the water/effluent reaches the groundwater (or restriction) the flow will become gradient driven; generally lateral. A sandier or well-structured soil will conduct water away faster because the larger voids will have a greater conductivity and may allow for deeper flow (See fig. 2-9). The flow or diffusion of air (oxygen) will also be enhanced by the better structure and will therefore, improve treatment. Resistance to water movement in saturated soil is primarily a function of the arrangement and size distribution of pores. Large, continuous pores have a lower resistance to flow (and thus a higher conductivity) than small or discontinuous pores (See fig. 2-8). Soils with high clay content generally have lower hydraulic conductivities than sandy soils because the pore size distribution in sandy soil favors large pores even though sandy soils usually have higher bulk densities (soil's mass per unit volume) and lower total porosities (total pore space) than clayey soils. As a soil pore or channel doubles in size, its resistance to flow is reduced by a factor of 4; in other words its hydraulic conductivity increases 4-fold (water flows more easily).

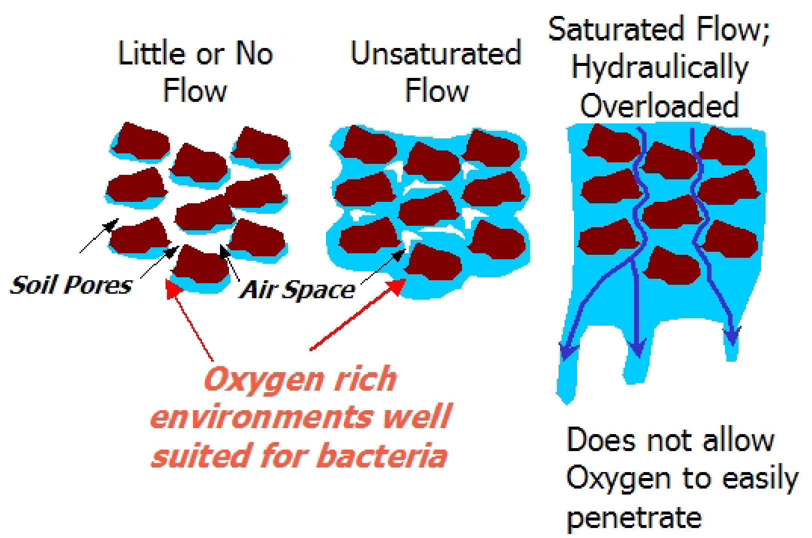


Figure: 2-10. Saturated flow occurs when approximately 95% of pore space is full of water. *(TS)*

The infiltration zone, which is only a few centimeters thick, is the most biologically active zone and is often referred to as the "biomat." After treatment and percolation of the wastewater through this infiltrative surface or biomat and passage through the first few inches of soil, the *wastewater plume* begins to migrate downward until nearly saturated conditions exist (figure 2-12). The worst-case scenario occurs when the plume is mixing with an elevated water table. Moisture potential, soil hydraulic conductivity, and other soil and geological characteristics determine the direction of flow.

Soil Drainage

Water Table

The water table is that portion of the soil-geologic continuum where redoximorphic features have formed by reduction, oxidation, and translocation of iron and manganese compounds. Or, that portion of the soil-geologic continuum that is saturated with groundwater year-after-year in the wettest seasons that may or may not exhibit redoximorphic features, and the saturation can be observed and measured over defined space and time. Virginia requires a vertical standoff from the seasonal high water table (SHWT) to ensure proper treatment of wastewater before it enters groundwater.

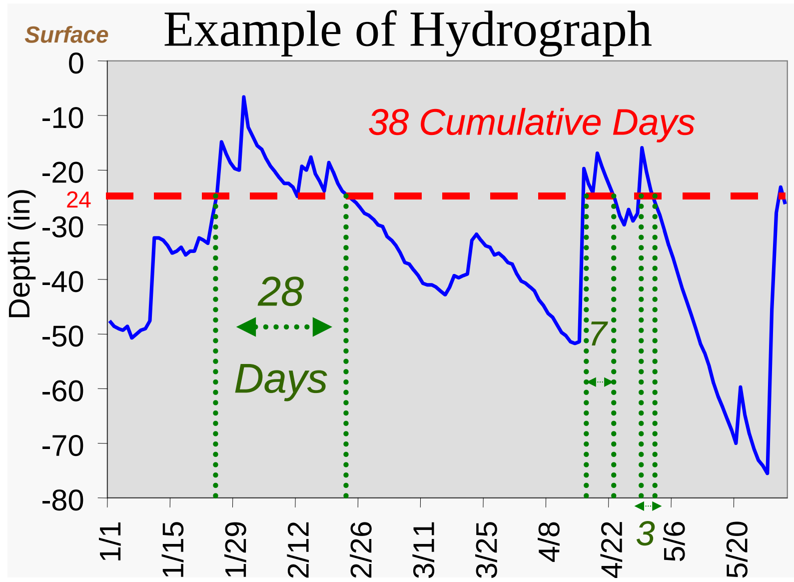


Figure: 2-11. What is a water table? It is not a static characteristic. At 24", this soil is under water for 38 days during the study period. Is that the water table? *(TS)*

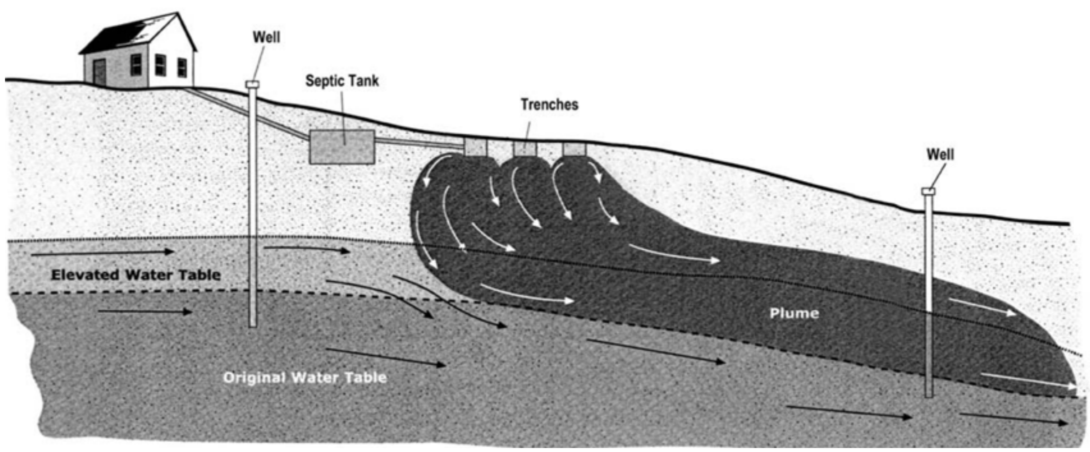


Figure: 2-12. Movement of effluent plume to and along with the saturated zone (water table). *(EPA Onsite Wastewater Treatment Systems Manual, 2002)*

12 VAC 5-610-593. Physical features.

2. **Seasonal water table**. A vertical separation distance between the point of effluent application and a seasonal water table shall be maintained which reflects the quality of the effluent and the receiving environment. Minimum vertical separation distances may be found in Articles 2 (12 VAC 5-610-594 et seq.) and 3 (12 VAC 5-610-597 et seq.) of this part and Tables 4.3 and 4.4.

Types of Water Tables

Two basic kinds of water tables are found in Virginia (Soil Survey Staff, 2006). They are:

(i) *apparent* water table is the level of stabilized water in a fresh, unlined borehole

(ii) *perched* water table is water that lies above an unsaturated zone for at least 3 days and will fall if the borehole is extended. Sources of these water tables include but are not limited to seasonal high-water table, perched water table, tidal water, and seasonally saturated soil by lateral water movement.

Perched water tables are the most common types of water tables found in upland landscape positions in Virginia. More persistent or permanent water tables are found in depressional landforms, modern depositional landforms, flooded landforms, and in the lower Coastal Plain.

Water tables develop during the wet season (late fall through early spring) when transpiring trees and other vegetation are dormant and cold temperatures hinder evaporation. Fluctuations in water table depths respond directly to precipitation events. When it rains, the water levels will spike. How fast they drain depends on landscape gradient and permeability of the soil. Water tables can also follow yearly precipitation trends. During drought years, water tables may not develop during that wet season. Long-term drought may delay or preclude water tables from reaching their usual levels even after normal rainfall for several years.

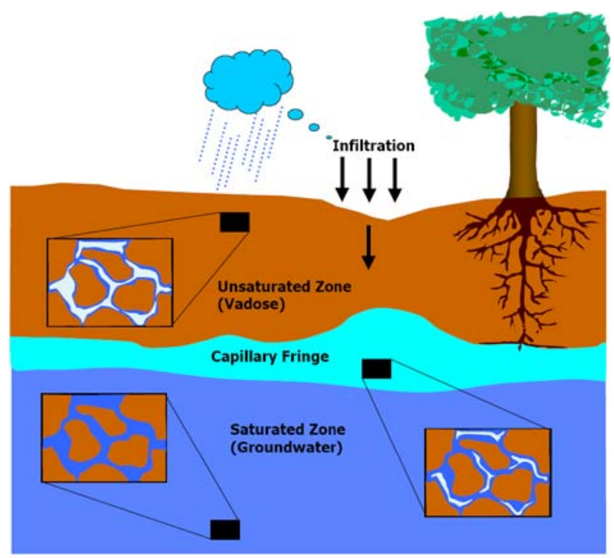


Figure: 2-13. The capillary fringe may *"make or break"* a subsurface soils absorption system. *(Adapted from Michigan State University)*

Underground water occurs in two different zones. One zone, which occurs immediately below the land surface in most areas, contains both water and air and is referred to as the *unsaturated or vadose zone* (See fig. 2-13). The unsaturated zone is the portion of the soil used for wastewater disposal. The *saturated zone* is one in which all interconnected openings are full of water and may underlie the unsaturated zone. Recharge of the saturated zone occurs by movement of water from the land

12 VAC 5-610-470. Physical features.

D. Minimum depth to seasonal water table. As used herein, **"seasonal water table"** means that portion of the soil profile where a color change has occurred in the soil as a result of saturated soil conditions or where soil concretions have formed.
Typical colors are gray mottlings, solid gray or black. The depth in the soil at which these conditions first occur is termed "seasonal water table."

surface through the unsaturated zone. Saturated flow occurs when the soil water pressure is positive; that is, when the soil matrix potential is zero (saturated wet condition). In most soils, this situation takes place for example, when about 95 percent of the total pore space is filled with water. The remaining 5 percent is filled with entrapped air. If the soil remains saturated for a long time (several months or longer) the percent of the total pore space filled with water may approach 100.

The *capillary fringe*, the subzone between the unsaturated and saturated zones, occupies the lowest part of the unsaturated zone. The capillary fringe results from the attraction between water and soil. As a result of this attraction, water clings as a film on the surface of soil particles and rises in small-diameter pores against the pull of gravity. The thickness of the capillary fringe (or, how high water is drawn above the saturated zone) varies, but is greatest for clayey soils and minimal for sandy soils. Imagine a paper towel held in a pan of water. The water will flow up against the pull of gravity far onto the towel. This area of the wetted towel is the capillary fringe. There is no free water here, but the towel is very moist. The capillary fringe is immediately above the seasonal high water table (SHWT). While not recognized in a regulatory sense, this zone has a large influence on the efficient functioning of an onsite wastewater disposal system. This is true because the capillary fringe is nearly saturated, has little oxygen and so provides little treatment for wastewater. Best Management Practices would suggest consideration be given to this zone during a site evaluation, especially in clayey soils.

Soil Drainage Classes

Table: 2-1. Soil Drainage classes *(NRCS)*

Drainage Class	H_2O Removal	Depth to Water Table (inches) *	Free Water
Excessively to Somewhat excessively	Very rapid to rapid	60"+	Very rare or very deep
Well	Readily	40-60"	Deep or very deep
Moderately well	Somewhat slowly	20-40"	Moderately deep
Somewhat poorly	Slowly	10-20"	Shallow to moderately deep
Poorly	Slowly *(variable)*	0-10"	Shallow to very shallow
Very poorly	Slowly	0-6"	Very shallow
* *Based upon soil features*			

Soil drainage classes were originally established to aid agricultural land use practices in relation to crop growth. Soil drainage can be expressed as a function of the frequency and duration a soil is saturated. It is also a measure of how rapidly free water is removed from a soil. Free water is water not held by tension or suction and is "free" to move with the slope gradient. Soil water tables develop if free water is unable to be readily removed from a site. This may be due to soil (internal drainage) or landscape properties (external drainage). If little or no gradient exists, free water tends to move in the vertical direction. Slowly permeable soil materials or a soil layer that restricts or retards the downward movement of water could also cause saturation.

Soils are categorized by their drainage and are assigned to drainage classes (See table 2-1) based upon the depth to wetness indicators (See redox discussion in Chapter 4). Well drained (and better) soils are identified by bright uniform colors that indicate oxidized conditions for most of the year. Well drained soils that are permeable usually absorb and transmit natural precipitation readily and will most likely have few problems handling the additional hydrologic load of an onsite wastewater system. Less well drained soils (MWD/SWP) are limited in their ability to remove water. They are identified by duller yellower matrix colors such as pale brown and gray splotches throughout the profile (See fig. 2-15). A mixture of gray and red or brown colors usually indicates a fluctuation between saturated and unsaturated conditions during the growing season. These soils are not as well suited for onsite use and may require the use of a treatment system. Poorly and very poorly drained soils have progressively persistent water tables that are closer to the ground surface. They often contain thick black surface layers followed by gray matrix colors. These soils are unsuitable for any onsite system because of shallow frequent occurrence of free water or ponded water on the soil surface.

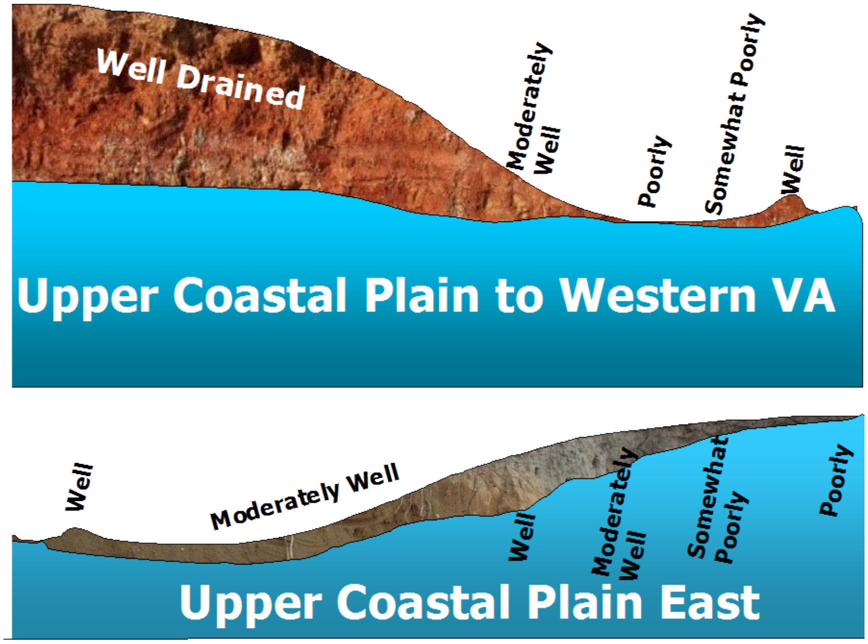


Figure: 2-14. Potential topographic affects upon drainage. Top landscape represents dissected, rolling and bottom represents broad, flat regions. The blue color represents the seasonal high water table. *(TS)*

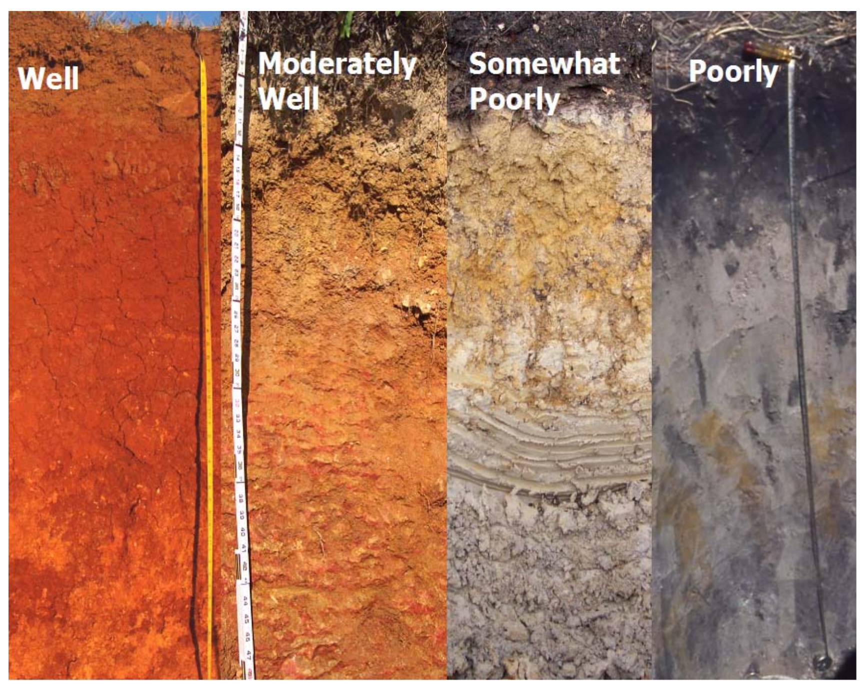


Figure: 2-15. Color is an indicator of soil drainage. *(Photos by Tom Saxton)*

Soil Drainage and Topographic Relationships

Since topography plays a role in designing and evaluating a site for its drainage potential, we must consider aspects of topography that influence soil drainage. Steeper slopes have rapid runoff and little infiltration. This yields better-drained soil. Gentle slopes have slower runoff and more infiltration, which may yield more poorly drained soils. Topographic relationships can be broken into 2 distinct groups; dissected regions and broad, flat regions.

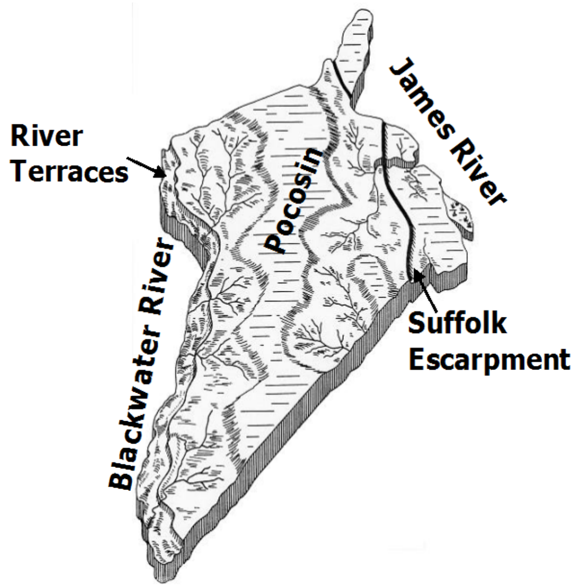


Figure: 2-16. Pocosins in Isle of Wight County are poorly drained. They occur on broad flat regions. These areas are common in the coastal plain. *(SKT)*

Dissected or rolling topography will have the well drained soils at the summit (interfluve) and the less well drained (poorly drained) soils at the low toe slope and footslope areas. Drier soil on summits appears reddish to strong brown. Poorly drained soils are pale yellow to gray in color. In contrast to rolling topographic areas, the flat regions have the poorly drained soils at the high points away from the drainage ways (Pocosins in the Coastal Plain). The well-drained soils occur adjacent to the drainageways and steep slopes.

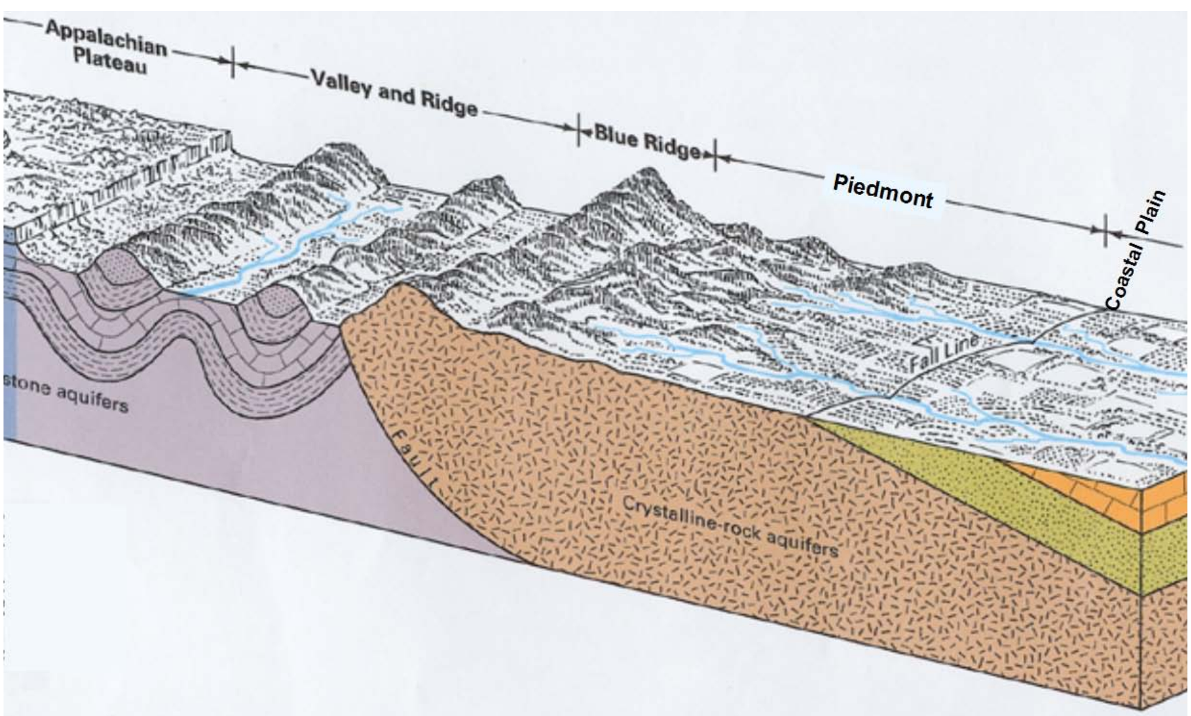


Figure: 2-17. Dissected rolling topography occurs in the upper coastal plain to the western portion of Virginia. *(USGS Groundwater Atlas)*

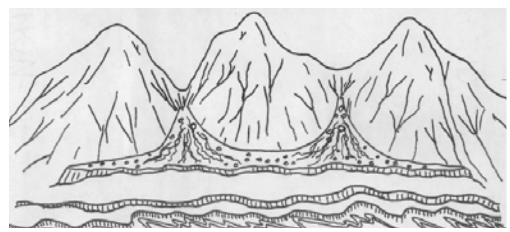
Landscapes and Landforms

A *landscape* is a collection of related landforms. *Landforms* are any physical, recognizable form or feature on the earth's surface, having a characteristic shape, and produced by natural causes *(SSSA).* For instance, a mountain is a landscape, which may encompass a cliff; a landform. A river valley landscape may encompass a floodplain, levee, or terrace landform.

The Virginia Sewage and Handling and Disposal Regulations (2000) require that any onsite wastewater system be installed in a suitable landscape position. The Yes or No determination relies upon the evaluator to make a decision on whether any onsite system will be negatively impacted by placing the system in or on a landform that is considered unsuitable. According to the Regulations, unsuitable landforms may include: Marshes and Swamps, Steep Slopes, Drainage Ways, Fill Material, Sink Holes, Flood Plains, and Alluvial and Colluvial deposits.

Guidance and Best Management Practices provide the following terms, definitions, and concepts that can be used in describing and documenting the physical earth setting that an onsite wastewater system will be placed on or in.

Alluvial Fan—a low, outspread mass of loose materials and/or rock material; commonly with gentle slopes, shaped like an open fan, deposited by a stream at the place where it issues from a narrow mountain or upland valley. It is steepest near its apex which points upstream and slopes gently and convexly outward with a gradual decrease in gradient.



Fan *(VA Tech; Jeffrey Howard, 1978)*

Backslope—the hillslope profile position that forms the steepest and generally linear, middle portion of the slope. In profile, backslopes are commonly bounded by a convex shoulder above and a concave footslope below. Backslopes are commonly erosional surfaces. (National Soil Survey Handbook (NSSH)).

Backswamp—a floodplain landform that consists of extensive, marshy or swampy depressed areas of flood plains between natural levees and valley sides or terraces. (NSSH).

Channel—the hollow bed where a natural body of surface water flows or may flow. (NSSH).

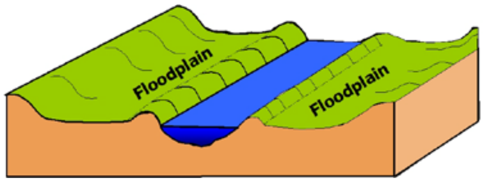
Drainageway—a depressional, roughly linear course or channel along which water moves on the surface and/or the subsurface in draining an area. The drainageway may be very shallow and lack a defined channel or may be incised with a defined channel.

12 VAC 5-610-470. Physical features.
B. **Drainageway**. A drainage way is a concave portion of the landscape in which surface water or rain water run-off gathers intermittently to flow to a lower elevation.

12 VAC 5-610-593. Physical features.
4. **Drainageways**. Subsurface soil absorption systems shall not be placed at a position in a drainage way subject to intermittent flooding.

Floodplain—the nearly level plain that borders a stream or river and is subject to inundation under floodstage conditions. It is usually a constructional landform built of sediment deposited during overflow and lateral migration of the streams. (NSSH)

12 VAC 5-610-593. Physical features.
7. **Floodplains**. Subsurface soil absorption systems shall not be placed in flood plains subject to annual or more frequent sustained (24 hours) flooding.
Table 4.2. Minimum Distance (Ft) from Bottom or Sidewall of Subsurface Soil Absorption System Trench Streams I, II, III, IV (Soil Texture Group) --- 50 feet--The set back distance may be reduced to 10 feet in Group III and IV soils and 20 feet in Group I and II soils if the subsurface soil absorption system is designed to produce unsaturated flow condition in the soil.



Floodplain *(TS)*

Footslope—the hillslope profile position that forms the concave surface at the base of a hillslope. It is a transition zone between upslope sites of erosion and downslope sites of deposition. (NSSH)

Geomorphic Component—a fundamental, three dimensional piece or area of a geomorphic setting (i.e. hills, mountains, terraces, flat plains, etc.) that has unique and prevailing kinetic energy dynamics and sediment transport conditions which result in their characteristic form, patterns of sedimentation and soil development. (NSSH).

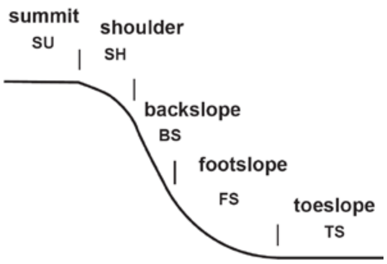
Gully—a small channel with steep sides caused by erosion and concentrated but intermittent flow of water usually during heavy rains. Gullies are common in the Virginia Piedmont and mostly caused by past farming activities.


Gully (Erosional)

Head Slope—a geomorphic component of hills consisting of a laterally concave area of a hillside, especially at the head of a drainageway, resulting in converging overland flow; head slopes are dominated by colluvium and slope wash sediments; contour lines form concave curves. (NSSH).

Hill—a generic term for an elevated area of land surface, rising at least 30m (100 feet) to as much as 300 meters (approx. 1000 feet) above surrounding lowlands, usually with a nominal summit area relative to bounding slopes, a well-defined rounded outline and slopes that generally exceed 15 percent.

Hillslope Profile—the sequential, sloping components of an elevated or topographic high, from the highest point to lowest point. The components may include the ridgetop, shoulder, backslope, footslope, and toeslope, though all may not be present.



Hillslope Profile *(NRCS)*

Intermittent Stream—a stream or reach of a stream, that does not flow year-around and whose channel is generally below the local water table; it flows only when it receives significant rainfall or snow melt, or during periods of prolonged wetness.

Knickpoint—any interruption or break in slope. (NSSH).

Knoll—a small, low, rounded hill rising above adjacent landforms. (NSSH).

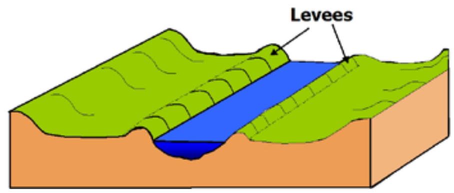
Landform—any physical, recognizable form or feature on the earth's surface, having a characteristic shape and range in composition, and produced by natural causes. Landforms provide an empirical description of similar portions of the earth's surface. (NSSH).

Landscape—an assemblage, group, or family of spatially related, natural landforms over a relatively large area; the land surface, which the eye can comprehend in a single view. (NSSH).

Marine Terrace—a constructional coastal strip, sloping gently seaward, veneered by marine deposits. (NSSH).

Mountain—a generic term for an elevated area of the land surface, rising more than 300 meters above surrounding lowlands, usually with nominal summit area relative to bounding slopes and generally with steep sides (greater than 25 percent slope). (NSSH).

Natural Levee—a long, narrow low ridge or embankment of sand and coarse silt, built by a stream on its flood plain and along its channel, especially in time of flood when water overflowing the normal backs is forced to deposit the coarsest part of its stream load. It has a gentle slope away from the river and toward the surrounding floodplain, and its highest elevation is closest to the riverbank. (NSSH).



Levee *(TS)*

Noseslope—a geomorphic component of hills consisting of the projecting end (laterally convex area) of a hillside, resulting in predominantly divergent overland water flow; contour lines generally form convex curves (NSSH).

Physiographic Province—a region of which all parts are similar in geologic structure and climate and which has consequently had a unified geomorphic history. (NSSH).

> **12 VAC 5-610-450. General.**
> Soil evaluation for a subsurface soil absorption system shall follow a systematic approach including consideration of **physiographic province**, topography, available area, degree of slope, and soil profile (thickness of each horizon, color, permeability, and texture).

Pocosin—a coastal plain landform that consists of an un-dissected upland flat landscape. Derived from Native American for S*wamp on a hill*. The soils have high water tables at or near the surface during the winter and spring.

Relief—the relative difference in elevation between the upland summits and the lowlands or valleys of a given region. (NSSH).

Pocosin

Rise—a slightly elevated area with very gentle slopes and very low relief. Elevation differences range from a few inches to 3 feet. This is common in the Virginia Coastal Plain and often in broad, upland drainageways that have a delta-like landform.

Ridgetop—a long, narrow elevation of the land surface that is bounded by gentle to steep slopes. A ridgetop has the highest, relative topographic position, and the relief may be slight to pronounced. Used interchangeably with summit.

Saddle *(same site above & below)*

Saddle—a low, dipping point on a ridge or summit; on opposite sides of the saddle are upland drainageways that drain in opposite directions.

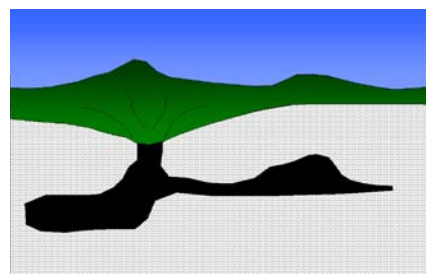
Salt Marsh—a flat, poorly drained area that is commonly subject to daily flooding by tidal brackish to saline water. Salt marshes support only salt tolerant vegetation.

> **12 VAC 5-610-593. Physical features.**
> 1. **Marshes** and swamps. Placement of subsurface soil absorption systems on or in swamps and marshes is prohibited.

Shoulder—the hillslope profile position that forms the convex, erosional surface near the top of a hillslope. If present, it comprises the transition zone from summit to backslope. (NSSH).

Side Slope—a geomorphic component of a hill slope profile consisting of a laterally planar area of a hillside, resulting in predominantly parallel overland water flow; contour lines generally form straight lines. (NSSH).

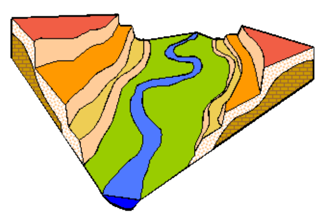
Sinkhole—a closed, circular or elliptical depression, commonly funnel-shaped, characterized by subsurface drainage and formed either by dissolution of the surface of underlying limestone bedrock, or by collapse of underlying caves within bedrock. Complexes of sinkholes in carbonate-rock terrain are the main components of karst topography. (NSSH).



Sinkhole *(TS)*

> **12 VAC 5-610-593. Physical features.**
> 6. **Sinkholes**. Placement of a subsurface soil absorption system at the low point of a sinkhole is prohibited. For set back distance see Table 4.2.

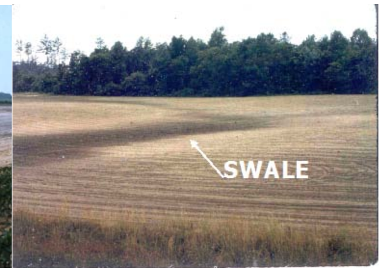
Stream Terrace—one or a series of platforms in a stream valley, flanking and more or less parallel to the stream channel, originally formed near the level of the stream, and representing the remnants of an abandoned flood plain, stream bed, or valley floor produced during a former state of fluvial erosion or deposition. (NSSH) Much like a series of step-like treads and risers (see Terrace on following page). There may be multiple terraces or a single terrace.



"Stair-stepping" Stream Terraces *(TS)*

Summit—the topographically highest position of a hillslope profile with a nearly level or gently sloping (planar or only slightly convex) surface. (NSSH). Used interchangeably with ridgetop.

Swale—a shallow, open depression, which lacks a defined channel but can funnel overland or subsurface flow into a drainageway. Soils in swales tend to be moister and have thicker surface horizons compared to the nearby upland landforms. (NSSH).



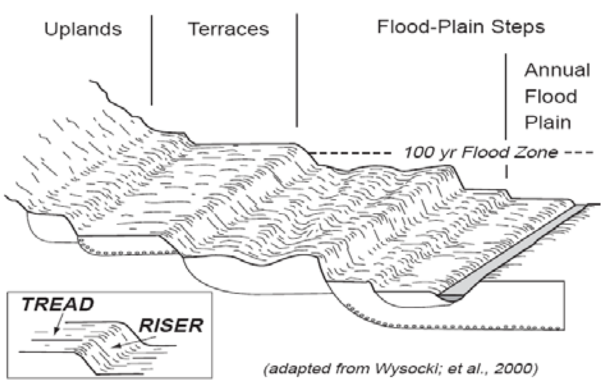
Swamp—an area of low, saturated ground intermittently or permanently covered with water, and predominantly vegetated by shrubs and trees. (NSSH)


Swamp

> 12 VAC 5-610-593. Physical features.
> *Chapter 2* Marshes and ***swamps***. Placement of subsurface soil absorption systems on or in swamps and marshes is prohibited.

Toeslope—the hillslope position that forms the gently inclined surface at the base of a hillslope. Toeslopes in profile are commonly gentle and linear, and are constructional surfaces forming the lower part of a hill-slope continuum that grades to a drainageway or floodplain. (NSSH)

Terrace—a step-like surface, bordering a valley floor or shoreline, which represents the former position of a floodplain, lake or seashore. (NSSH)



Upland—the land and landforms at a higher elevation than the drainageway, flood plain or low stream terrace.

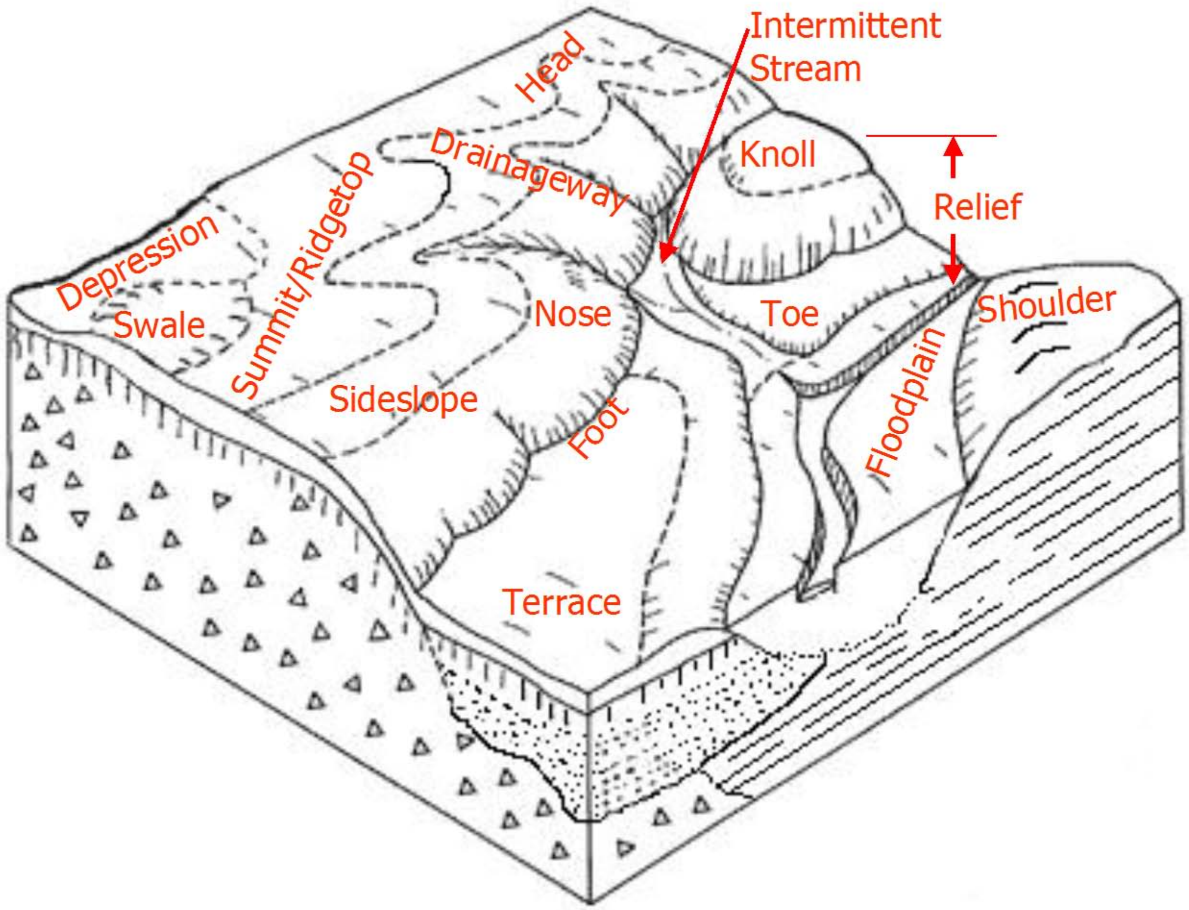


Figure: 2-18. Landforms and Landscapes

Chapter 2 Review

Understanding Concepts

1) What is the percent slope of a gradient that has 5 feet of fall in 50 feet of linear distance?

2) Which slope shape is better suited for onsite wastewater disposal systems and why?

3) True / False Water moves more easily through micropores.

4) If you had a choice during a site evaluation, which slope aspect would be best suited for subsurface soil absorption systems?

5) What is the *biomat* and why it is important?

6) True / False A collection of large particles has more surface area than the same volume of smaller particles.

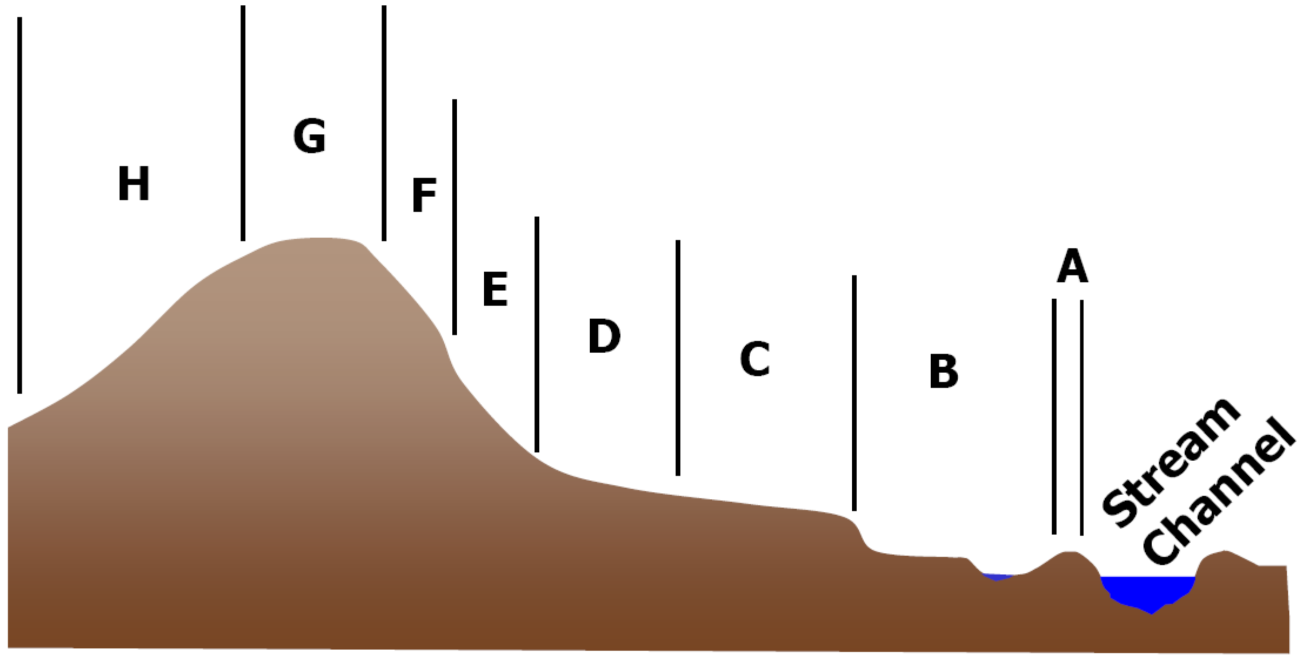
7) Consider slope shape. How does water move across a linear slope?

8) Consider slope shape. How does water move across a convex slope?

9) Consider slope shape. How does water move across a concave slope?

10) Which geomorphic component would you choose for your drainfield and why?

Critical Thinking and Problem Solving



1) What are the slope names?

A. ____________________ B. ____________________ C. ____________________

D. ____________________ E. ____________________ F. ____________________

G. ____________________

2) Show the best and worst areas for drainfields (in regards to water movement and soil drainage) by shading or coloring the diagram.

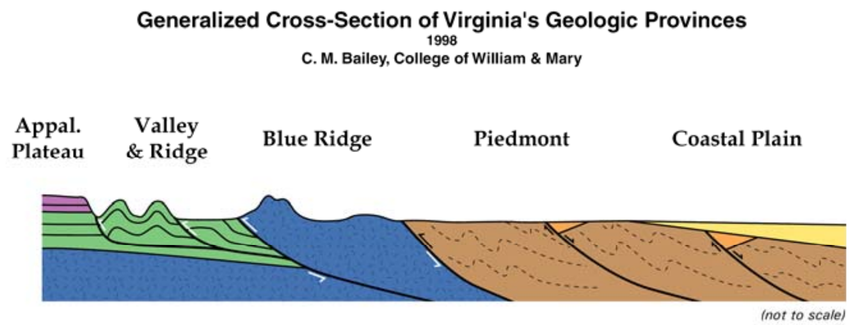
3) How might this be different in the Coastal Plain on broad, flat areas?

4) Do our sewage regulations allow the installation of a drainfield at letter A? If so, under what conditions?

Chapter 3
Virginia Physiography, Geology and Soil Systems

Generally, when one considers soils, they automatically start to think about what is below their feet. But, in order to better understand soils, one needs to consider the larger picture and be able to comprehend how landscape/landforms and soils are related. There are more than 600 soil series mapped in Virginia. These soils show great ranges in properties and subsequent suitabilities for different uses. Much of the difference in soils relates to the geologic parent materials from which they have formed as well as the local topography *(Baker, 2000).* This section discusses the physiography, geology, typical landforms and soil systems of Virginia.

Sections



The geology, geomorphology and climate of Virginia divide the state into five major soil regions (Physiographic Provinces), the Coastal Plain, Piedmont, Blue Ridge Mountains, Valley and Ridge and the Appalachian Plateau. This plateau is also often referred to as the Allegheny or Cumberland Plateau. In this document, it will generally be referred to as the Appalachian Plateau. Within each region distinct associations of soils exist. These soil associations will be referred to as soil systems. A soil system is a recurring

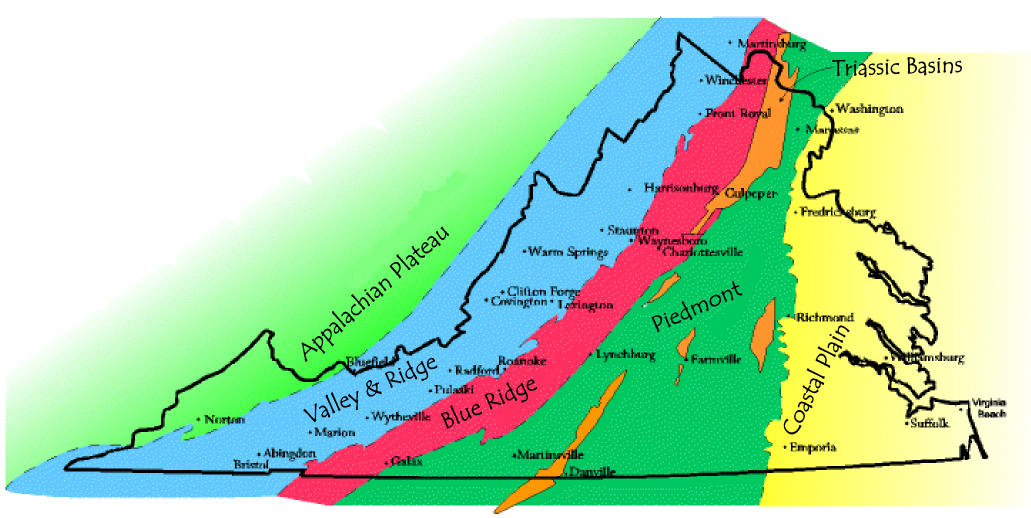


Figure: 3-1. Virginia's Physiographic Provinces. *(Department of Geology, James Madison University)* group of soils that occupies the landscape from the interstream divide to the stream. The soils that make up these systems usually occupy specific landscape positions as a result of the internal soil environment produced by the interaction of stratigraphy, hydrology, geomorphology and climate. Soil systems change when one or more of the factors controlling soil properties change. Soils with similar soil forming factors, on a hillslope, linked by topography, and that vary only by drainage are called a *catena*.

The next map, figure 3-2 and corresponding descriptions are the most comprehensive broad discussion of the soils and physiography of Virginia that could be located by the authors. The following narrative is intended to give the user a general idea of the landscapes, soils and geologic characteristics of Virginia. There are 28 mapping units used to delineate ecoregions across the state. Each delineation is based upon a combination of physiographic, geologic, soil and ecological characteristics. This map is only one of many and there are numerous criteria that may be used to differentiate soils in different areas of the state.

Soil mapping is a man-made concept intended to identify, quantify and separate soils based upon their characteristics. However, nature is a continuum and cannot be totally quantified into distinct, unique units. Yet, this is what man has tried to do. For soil mapping to be of the most benefit, it should be done with the specific use intended in mind. A soil map for agricultural purposes will not be the same as a map for urban development or engineering purposes. There may be some similarities, but the criteria for separating the different soils are different for each use. The scale of the map also dictates what is mapped. The figure 3-2 map is a large-scale map in which many soils (hundreds in some cases) were combined for each mapping unit. These are broad generalities and are intended to give a widespread understanding of soils in a physiographic area. Please feel free to enjoy the following narrative because *soils are exciting!*

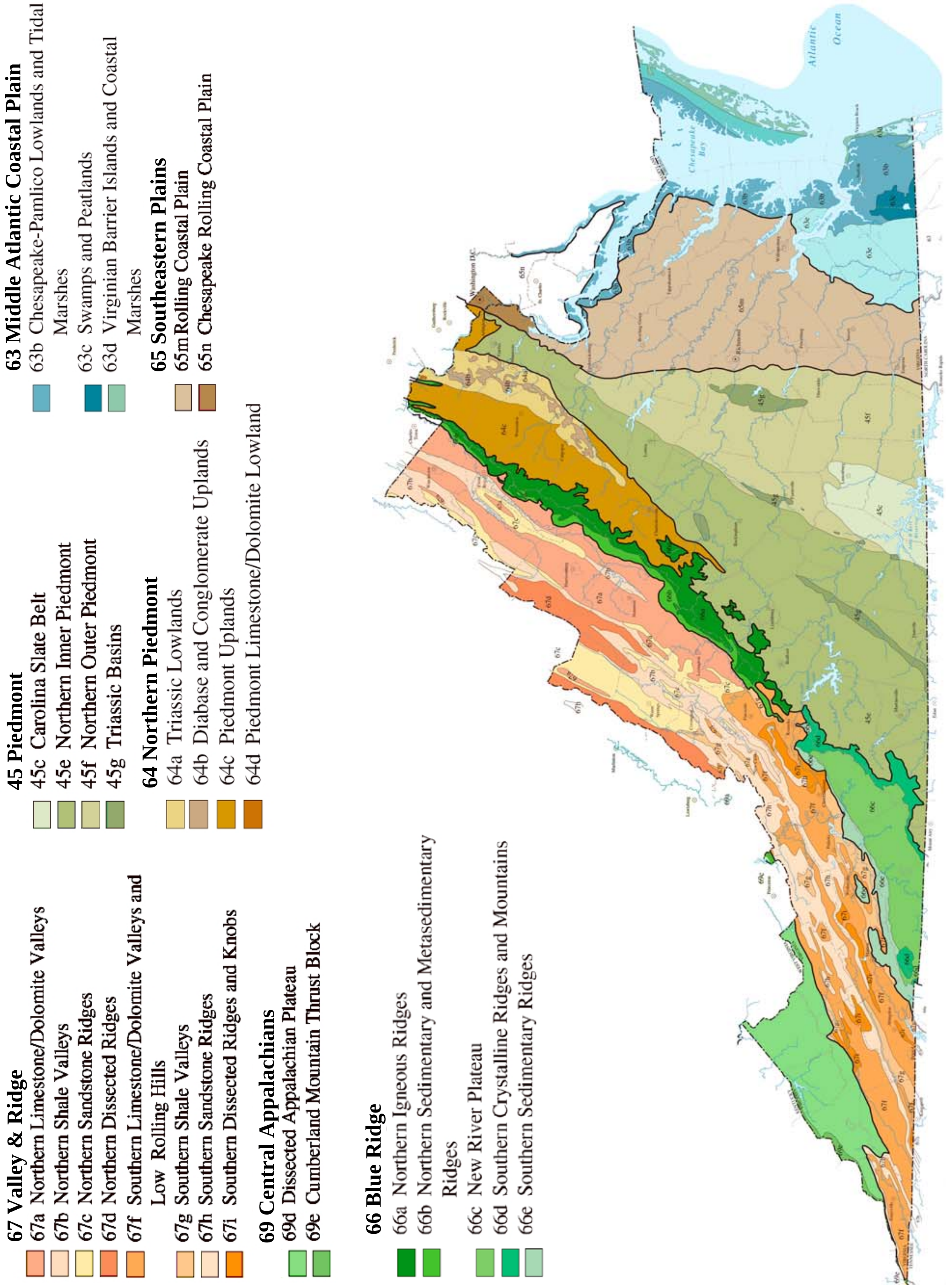
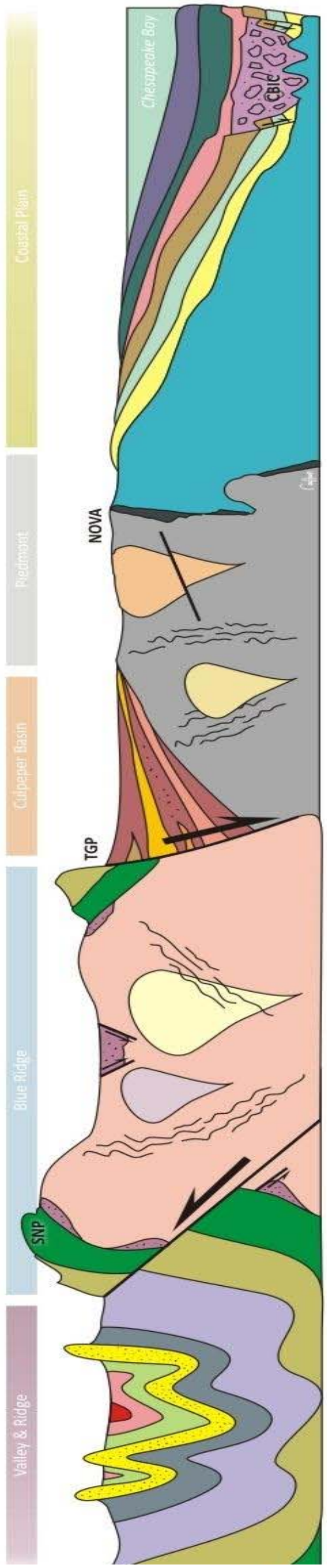
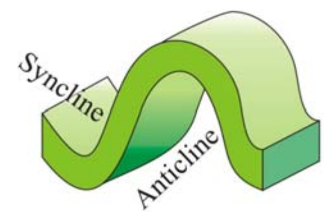


Figure: 3-2. Level III Ecoregions of Virginia mapping unit descriptions have been edited and used for this chapter. *(EPA)*

Figure: 3-3. Cross-section of northern Virginia Physiography as conceived by Callan Bentley *(NVCC)*.



Imagine traveling from the small valley at the bottom of this diagram (figure 3-3) in the area colored red. This is in the northern Shenandoah Valley. The destination is the Chesapeake Bay. The first 20 minutes of the trip are spent in the folded Paleozoic strata of the Valley and Ridge Province. The drive is along strike *(the compass direction or trend taken by a structural surface (e.g. a bed or fault plane) as it intersects the horizontal)* for about ten minutes, following the axis of the Massanutten Synclinorium *(series of synclines and anticlines so grouped that taken together they have the general outline of a concave dip or bowl)*, going across limestone sandstone and shale. Turning right at Waterlick (67b), the drive crosses strike to the east for another ten miles crossing shale, limestone and sandstone. Collectively, all these strata were deposited in sedimentary conditions during the Cambrian, Ordovician, Silurian, and Devonian periods of geologic time (see figure 3-36). The carbonates record Bahamas-like conditions, while the clastic sediments *(rock or sediment composed mainly of fragments derived from preexisting rocks or minerals and moved from their place of origin)* occur in pulses correlated to episodes of mountain building further east.



(Callan Bentley, NVCC)

They were all folded up during late Paleozoic mountain building accompanying the assembly of Pangaea *(supercontinent that included all the landmasses of the Earth before the Triassic period)*. North of Front Royal, the direction turns north on route 522 and cross the North Fork of the Shenandoah River. Once on Interstate 66, it's a short drive to cross the trace of the Blue Ridge Thrust Fault and enter the Blue Ridge Province. To the south is Shenandoah National Park (SNP), astride the Blue Ridge itself.

The car cuts down section through layers of metasediments (66b) *(sedimentary rock that has been metamorphosed)*, which were deposited on the rifted margin of ancestral North America

Laurentia; *(core of North America in the time from the breakup of the precambrian supercontinent Rodinia to the formation of Pangaea*) after Rodinia split apart and opened up the Iapetus Ocean *(ocean that existed in the Neoproterozoic and Paleozoic eras of the geologic timescale between 600 and 400 million years ago)*. As paleo-Virginia cooled down and subsided, a series of sands and muds tracked their way west towards the interior of the continent, with limy precipitates following behind. These metasediments overlie the Catoctin Greenstone (66a), a now-metamorphosed series of basalt flows that date to the Neoproterozoic. Beneath all of these rocks is the Blue Ridge basement complex: various plutons *(igneous rocks formed at great depth)* and their metamorphosed descendents, criss-crossed by shear zones *(linear zone of fractured and smeared-out rocks)* and dikes *(igneous intrusions that cut across the existing rock)*.

Half an hour later, Bull Run Mountain is crossed via Thoroughfare Gap (TGP), a water gap cut by Broad Run. Structurally, Bull Run Mountain is a mirror image of the Blue Ridge, at least in the broadest of strokes (64c). It's the eastern limb of the Blue Ridge Anticlinorium *(series of anticlines and synclines so grouped that taken together they have the general outline of an arch; see figure 3-51)*. Quartz sandstones hold up the mountain. On the far (eastern) side of Thoroughfare Gap, the car leaves the Blue Ridge and enters the Culpeper Basin (64a), a failed rift *(a place where the Earth's crust and lithosphere were being pulled apart)* that opened up during the Triassic and Jurassic.

During the Mesozoic, the Culpeper Basin was trying its hardest to become a proper ocean basin. However, its cousin to the east, the Atlantic Basin, kept opening wider and wider, and eventually split down the middle to initiate seafloor spreading, and the Mid-Atlantic Ridge. The Culpeper Basin (see figure 3-47) stopped subsiding, and filled in with sediment and mafic volcanics *(lava high in iron and magnesium)* (64b). You can find dinosaur footprints in some of its layers. It's one of many "Newark Supergroup" basins that stretch up and down the east coast. These rocks weather out in low relief, and the Culpeper Basin is sometimes called the "Triassic Lowland."

At Centreville, the car climbs up a short rise and emerges onto the crystalline rocks of the Piedmont (45e) "plateau." This is the crushed-up, mangled, tortured remains of the Iapetus Ocean basin. They are metamorphosed oceanic sediments and volcanic island arc rocks; various terranes that "wrecked" against the edge of the ancestral North American continent. These rocks have lost most of their original stratification, and are folded, foliated, and faulted as well as being recrystallized. In other words, they have been *metamorphosed*. Granites and other plutonic rocks intruded them in many places. Ophiolite slices *(metamorphosed slabs and slivers of oceanic crustal rocks)* may be found in the Piedmont too. One set lies in Annandale, Virginia (NOVA), exposed in the gully cut by Indian Run, behind the Annandale branch of the Fairfax County Public Library.

Continuing east, through DC and across the Fall Zone *(see Fall Zone section later in this chapter)*, the trip enters the Coastal Plain Province (65m), a relatively subdued landscape with Tidewater Rivers. The geology in the Coastal Plain is dominated by sedimentary strata that dip *(maximum angle that a structural surface, (e.g. a bedding or fault plane) makes with the horizontal, measured perpendicular to the strike of the structure and in the vertical plane (430-VI-NSSH, 2008))* gently east (63b), under Chesapeake Bay and the Delmarva Peninsula, and out onto the Atlantic continental shelf. There are Cretaceous layers at the base, and lots of Miocene strata in the stack. One feature that mars this otherwise sedate pile of blanket-like layers is the Chesapeake Bay Impact Crater (CBIC), a late Eocene astrobleme *(an erosional scar on the earth's surface, produced by the impact of a cosmic body)* that punctured through the older Coastal Plain strata, but is now buried beneath younger Coastal Plain strata. A cylinder of impact breccia *(cemented rubble)* overlies the sombrero-shaped crater itself, which is excavated into the underlying crystalline rocks (we would call them “Piedmont” rocks if they were exposed on the surface).

This trip has traversed about 1.1 billion years of geologic history, and two complete Wilson Cycles of supercontinent formation and breakup. The route features sedimentation, compressional structures associated with mountain building, and extensional structures associated with the opening of ocean basins. It’s diverse, and epic, and it makes for an exciting drive. *(Edited and adapted courtesy of Callan Bentley; http://www.nvcc.edu/home/cbentley/)*

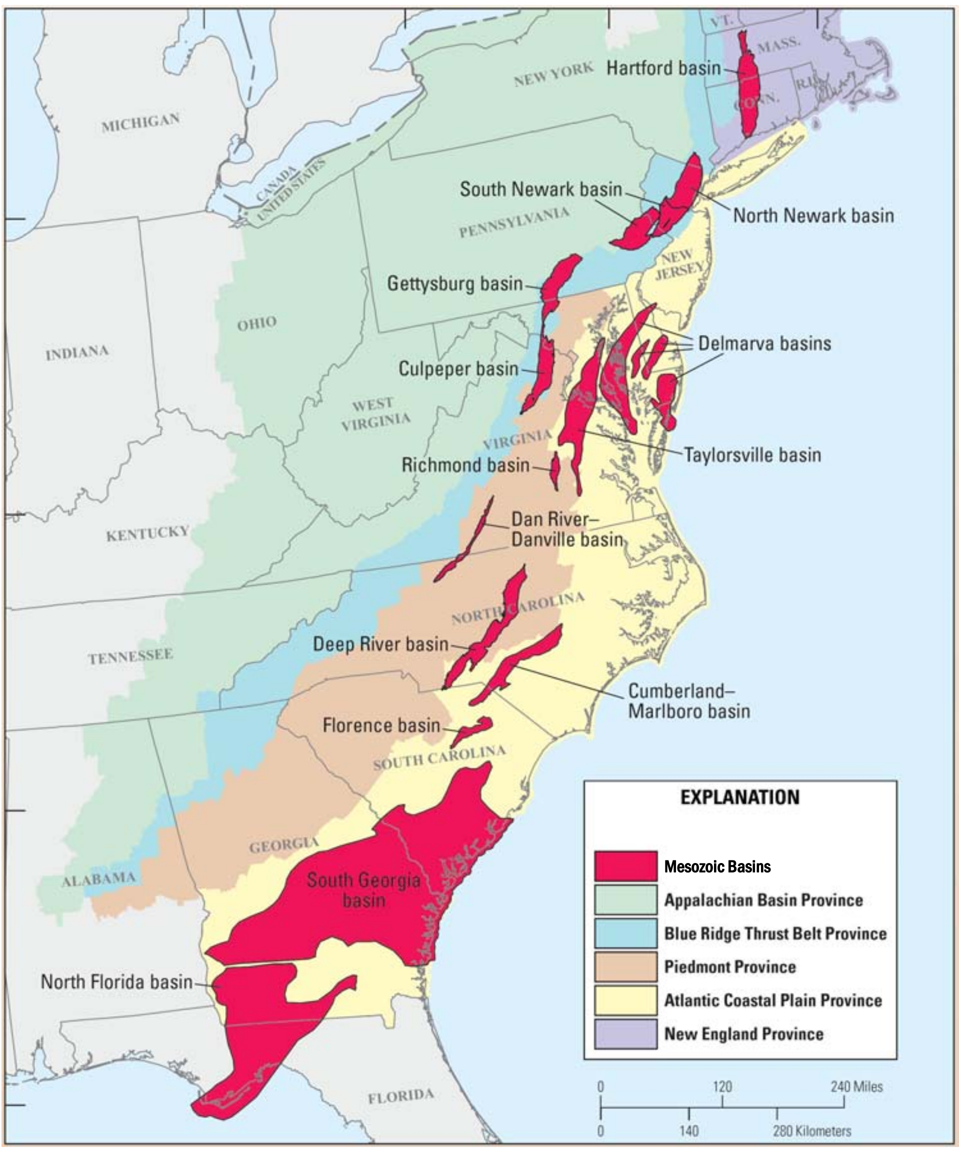


Figure: 3-4. Mesozoic basins along the east coast; many are buried by Coastal Plain deposits. *(Adapted from USGS Fact Sheet 2012–3075 June 2012)*

Soil Taxonomy is the system of soil classification used by the National Cooperative Soil Survey and has six categories (Soil Survey Staff, 1999 and 2006). Beginning with the broadest, these categories are the order, suborder, great group, subgroup, family, and series. Classification is based on soil properties observed in the field or inferred from those observations or from laboratory measurements. The categories are defined in the following paragraphs. You will not need to fully know or understand soil taxonomy as an onsite soil evaluator. However, a basic understanding of the concepts and knowledge of the soil series in your work area will help you immensely throughout your career.

ORDER. Twelve soil orders are recognized. The differences among orders reflect the dominant soil-forming processes and the degree of soil formation. Each order is identified by a word ending in *sol*. An example is Alfisol.

SUBORDER. Each order is divided into suborders primarily on the basis of properties that influence soil genesis and are important to plant growth or properties that reflect the most important variables within the orders. The last syllable in the name of a suborder indicates the order. An example is Udalf (*Ud*, meaning humid, plus *alf*, from Alfisol).

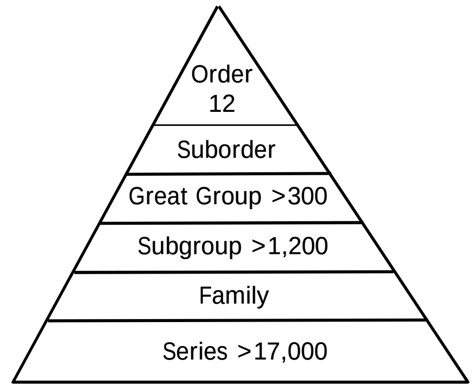


Figure: 3-5. Hierarchy of Soil Taxonomy.

GREAT GROUP. Each suborder is divided into great groups on the basis of close similarities in kind, arrangement, and degree of development of pedogenic horizons; soil moisture and temperature regimes; type of saturation; and base status. Each great group is identified by the name of a suborder and by a prefix that indicates a property of the soil. An example is Hapludalfs (*Hapl*, meaning minimal horizonation, plus *udalf*, the suborder of the Alfisols that has a udic moisture regime).

SUBGROUP. Each great group has a typic subgroup. Other subgroups are intergrades or extragrades. The typic subgroup is the central concept of the great group; it is not necessarily the most extensive. Intergrades are transitions to other orders, suborders, or great groups. Extragrades have some properties that are not representative of the great group but do not indicate transitions to any other taxonomic class. Each subgroup is identified by one or more adjectives preceding the name of the great group. The adjective *Typic* identifies the subgroup that typifies the great group. An example is Typic Hapludalfs.

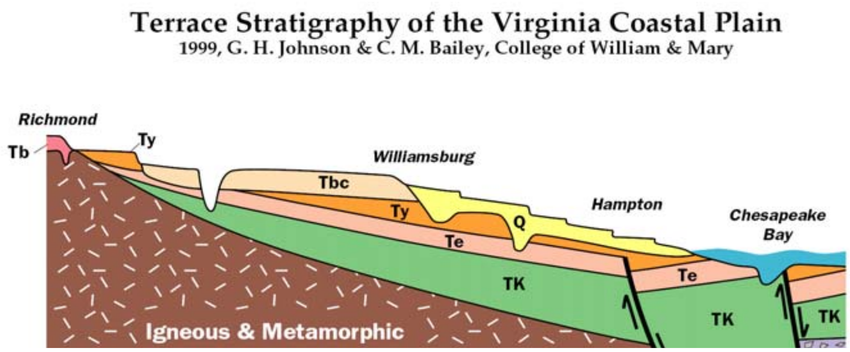
FAMILY. Families are established within a subgroup on the basis of physical and chemical properties and other characteristics that affect management. Generally, the properties are those of horizons below plow depth where there is much biological activity. Among the properties and characteristics considered are particle-size class, mineralogy class, cation-exchange activity class, soil temperature regime, soil depth, and reaction class. A family name consists of the name of a subgroup preceded by terms that indicate soil properties. An example is fine, smectitic, mesic Typic Hapludalfs.

SERIES. The series consists of soils within a family that have horizons similar in color, texture, structure, reaction, consistence, mineral and chemical composition, and arrangement in the profile. Soil Series names will be used throughout this chapter.

Table: 3-1. Twelve orders of Soil Taxonomy and the characteristics of these orders.

Soil Order	Formative Terms	Characteristics
Common to Virginia	**Less Frequent in Virginia**	**Not found in Virginia**
Alfisols	Alf, meaningless syllable	Moderately leached soils with a subsurface zone of clay accumulation and >35% base saturation (high fertility). In Virginia, these soils commonly occur in material weathered from carbonates or mafic rock.
Andisols	Modified from ando	Soils whose parent materials are of recent volcanic origin. They contain much fine volcanic ash (glass). The name comes from andesite, a rock of volcanic origin.
Aridisols	Latin, aridies, dry	$CaCO_3$-containing soils of arid environments with subsurface horizon development.
Entisols	Ent, meaningless	Soils with little or no morphological development (derived from rec*ent*). In Virginia, normally encountered on steep slopes and young soils formed from alluvium.
Gelisols	Latin gelare, to freeze	Soils with permafrost within 2 m of the surface during the warm months of the year and subject to *cryoturbation.*
Histosols	Greek, histos, tissue	Organic soils, that in Virginia, are found primarily in the Coastal Plain.
Inceptisols	Latin, incepum, beginning	Soils with weakly developed subsurface horizons (in the early stages of development), with little subsurface accumulation of any materials. In Virginia, normally encountered on steep slopes and young soils formed from alluvium.
Mollisols	Latin, mollis, soft	Grassland soils with high base status; in Virginia, typically located on floodplains and terraces of rivers whose watersheds encompass areas of carbonates.
Oxisols	French oxide	Intensely weathered soils of tropical and subtropical environments.
Spodosols	Greek spodos, wood ash	Acid forest soils with a subsurface accumulation of metal-humus complexes. These soils have subsoil horizons that are darkened by an accumulation of humic materials and also enriched with iron and/or aluminum (a spodic horizon). These soils only form in sands. In Virginia, these soils occur in mountain soils weathered from sandstone and quartzite and Coastal Plain deposits that are mostly silica sand (sand dunes and stream terraces).
Ultisols	Latin ultimus, last	Strongly leached soils with a subsurface zone of clay accumulation and <35% base saturation. They are similar to Alfisols, except that they are low in "bases" (low fertility). These soils are the dominant soil order in the Southeastern United States. In Virginia, they are weathered from rocks and deposits that have an acidic nature.
Vertisols	Latin verto, turn	Clayey soils with high shrink/swell capacity that during the dry season, form huge cracks, 10-12 cm (4–5 inches) wide. The dry surface crumbles or is blown into these cracks, gradually turning the soil over or *invert*. In Virginia, these soils may be found in Mesozoic Basins and in soils weathered from mafic rock.

The Coastal Plain Province extends from the Fall Zone eastward to the Atlantic Ocean. Through the Fall Zone, the larger streams cascade off the resistant igneous and metamorphic rocks of the Piedmont to sea level. Large tidal rivers, the Potomac, Rappahannock, York, and James, flow southeastward across the Coastal Plain to the Chesapeake Bay. The Bay, in turn, empties into the Atlantic Ocean. The topography of the Coastal Plain is a terraced landscape that stair-steps down to the coast and to the major rivers. The risers (figure 3-8) are former shorelines and the treads are emergent bay and river bottoms. The higher, older plains in the western part of the Coastal Plain are more dissected by stream erosion than the lower, younger terrace treads. This landscape was formed over the last few million years as sea level rose and fell in response to the repeated melting and growth of large continental glaciers and as the Coastal Plain slowly uplifted. During the glacial maxima, much of the continental shelf was emergent and the Susquehanna flowed through the Chesapeake lowland and across the exposed shelf to the sea 80 km or more to the east.



Coastal Plain Geologic Time Scale

Courtesy of William and Mary Department of Geology

Time (Ma)	Eon	Era	Period	Epoch	Events
0.011	Phanerozoic	Cenozoic	Quaternary	Holocene	Chesapeake Bay forms
1.8				Pleistocene	Dramatic climate oscillations, rise & fall of sea-level cutting scarps along major rivers
5.0			Tertiary	Pliocene	Marine sedimentation in Yorktown Formation
23				Miocene	Chesapeake group, erosional interval
38				Oligocene	Chesapeake Bay Impact Structure
54				Eocene	Erosional interval
65				Paleocene	Shallow sea covers eastern Virginia
146		Mesozoic	Cretaceous		Atlantic ocean opens, east flowing rivers (Roanoke, James, Rappahannock, etc.)
208			Jurassic		Atlantic rifting begins; deposition of sediments in rift-basins
245			Triassic		

Figure: 3-6. Geologic Time Scale in the Virginia Coastal Plain.

The Chesapeake Bay was created about 5000 to 6000 years ago when the lower course of the Susquehanna River through the Chesapeake lowland was flooded as melt water from the large Pleistocene continental glaciers raised sea level. Continuing sea level rise and shoreline erosion caused the bay to expand its aerial extent.

The Virginia Coastal Plain is underlain by a thick wedge of sediments that increases in thickness from a featheredge near the Fall Zone to more than 4,000 meters under the continental shelf. These sediments rest on an eroded surface of Precambrian to early Mesozoic rock. Two-thirds of this wedge is comprised of late Jurassic and Cretaceous clay, sand, and gravel; they were stripped from the Appalachian mountains, carried eastward by rivers and deposited in deltas in the newly formed Atlantic Ocean basin. A sequence of thin, fossiliferous marine sands of Tertiary age overlies the older strata. They were deposited in warm, shallow seas during repeated marine *transgressions* across the Coastal Plain.

This pattern of deposition was interrupted about 35 million years ago by a large meteorite that plummeted into a shallow sea, and created a crater more than 90 km in diameter, termed the Chesapeake Bay Impact Structure. It was subsequently buried under about 1.2 km of younger sediment. Latest Tertiary and Quaternary sand, silt, and clay, which cover much of the Coastal Plain, were deposited during interglacial high stands of the sea under conditions similar to those that exist in the modern Chesapeake Bay and its tidal tributaries. *(William & Mary Dept of Geology Coastal Plain Province The Geology of Virginia.htm)*

Soils of this region are formed from unconsolidated sediments deposited when the ocean level was much higher than at present. As sea levels lowered, meandering rivers and streams that originated in the western part of the state and flowed to the east reworked many of these deposits. In general, the closer to the coast, the nearer the water table to the soil surface. Soils in the coastal plain are acidic, infertile, highly weathered, and vary from sandy textures to very clayey textures. There are significant acres of poorly drained soils with high water tables in the Coastal Plain region. Many of these areas are in woodland or exist as jurisdictional wetlands, which are protected from drainage by current law. These wetland areas provide the essential mechanisms necessary to slow water movement from uplands to estuaries and bays of eastern Virginia, thus serving to maintain high water quality and a sustainable biodiversity for the region. *(Baker, 2000)*

The Virginia Coastal Plain is often divided into eastern (outer) and western (inner) sections based on topographic features. The ***outer Coastal Plain*** also know as the ***middle atlantic Coastal Plain*** or ***lower Coastal Plain*** *(in Virginia)* (figure 3-8) is an undulating to nearly flat landscape marked by several ancient marine terraces bounded by scarps that mark former Pleistocene shorelines. South of the James River, the outer Coastal Plain lies within the Mid-Atlantic Embayed Region, a region of sounds, embayments, and flatwoods stretching from Back Bay, Virginia to the Neuse River in North Carolina. In Virginia, this includes 63b, 63c and 63d on the ecoregions (figure 3-7). The ***Embayed Region*** includes the Great Dismal Swamp and the North Landing and Northwest Rivers, northern extensions of Currituck Sound. A line through the towns of Suffolk, north to Gloucester and Westmoreland on the Potomac, roughly marks the boundary between the inner and outer coastal plain. East of this line, the outer Coastal Plain does not exceed 18 m (60 ft) elevation and includes the Embayed Region, the western shore of the Chesapeake Bay, and the Eastern Shore**,** representing the southern end of the Delmarva Peninsula. Lying on the eastern edge of the Eastern Shore, and continuing south of the Chesapeake Bay, is a chain of large bay and marsh complexes and barrier islands with both active and stabilized dunes. These islands are dynamic landscapes that are constantly buffeted by powerful wind and waves, eroding on the

ocean side and accreting on the sound side.
(http://www.dcr.virginia.gov/natural_heritage/ncoverview.shtml)

The ***inner Coastal Plain*** is a broad upland, gently dissected by streams, and locally quite rugged where short, high gradient streams have incised steep ravine systems. Four large tidal rivers; the Potomac, Rappahannock, York, and James drain the northern part of the inner Coastal Plain, flowing southeastward into the Chesapeake Bay and dissecting the area into three prominent peninsulas. The Northern Neck is the peninsula between the Potomac and Rappahannock Rivers, while the Middle Peninsula lies between the Rappahannock and York Rivers. The area between the York and James Rivers is simply referred to as The Peninsula. *(http://www.dcr.virginia.gov/natural_heritage/ncoverview.shtml)*

Some authors subdivide this section into the middle and upper coastal plain. These separations are normally made along old scarp lines (shoreline beaches). The Ecoregion map (figure 3-7) combines these two into map unit 65. This portion of the coastal plain is older and more dissected than map unit 63.

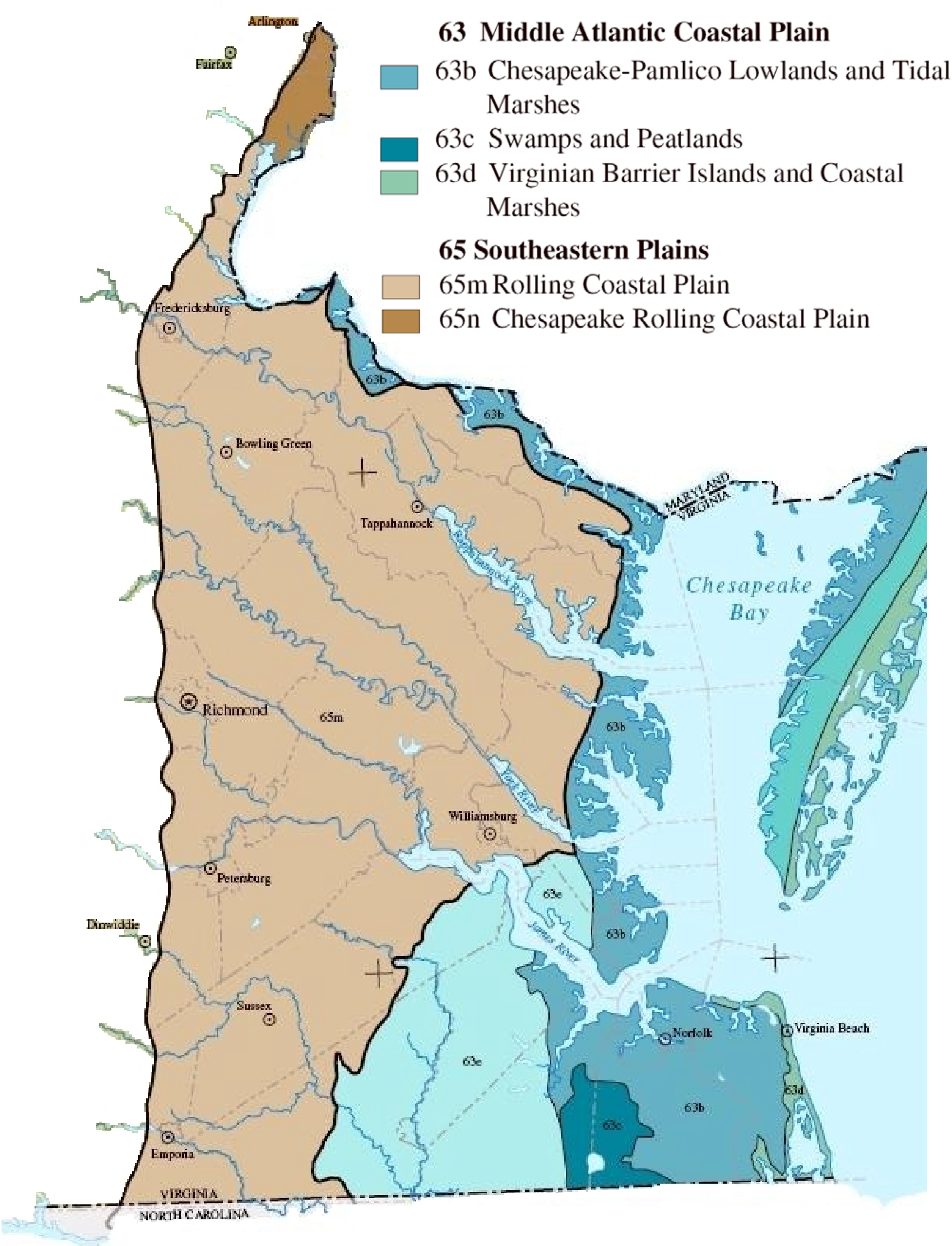


Figure: 3- 7. Virginia Coastal Plain Ecoregions. Note that the ecoregions follow very closely to the scarps shown in figure 3-8. *(EPA Level III Ecoregions of Virginia)*

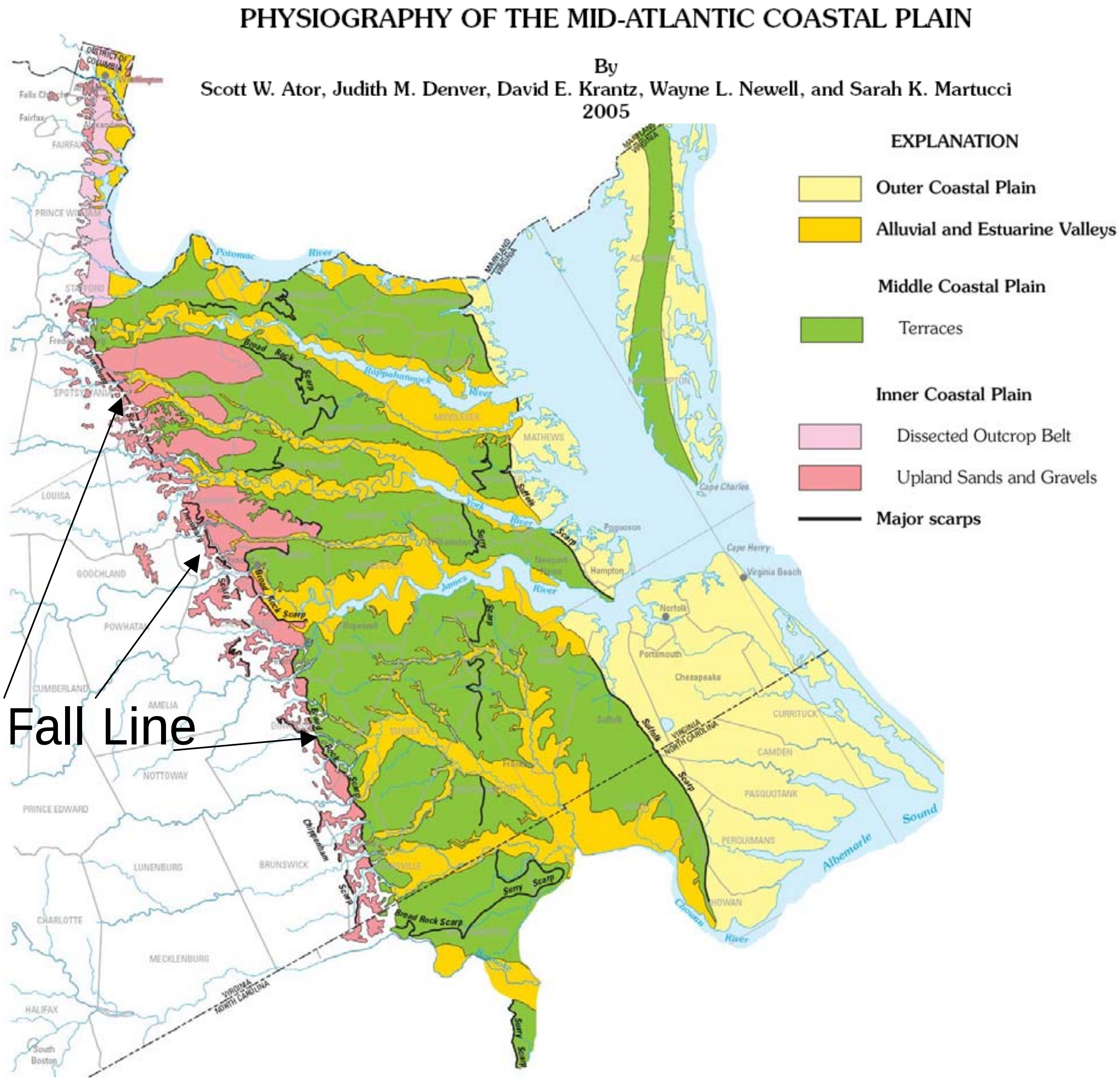


Figure: 3-8. These major scarps are remnants of old shorelines (beaches) when sea level was higher than today. Rivers in ancient alluvial fans deposited these sediments. The rivers carried material from the Valley and Ridge, Blue Ridge Mountains and the Piedmont to be deposited in the Coastal Plain. The soils and landscapes decrease in age eastward. Remnants of fans may be found on undissected uplands many miles to the west of the Fall Zone. *(USGS)*

63b. Chesapeake – Albemarle Silty Lowlands and Tidal Marshes

Ecoregion 63b is universally low in elevation and is characterized by nearly flat terrain, terraces, tidal marshes, ponds, and swampy streams. Brackish wetlands are common. Elevations range from 0 to 50 feet (0-15 m) and relief is less than 35 feet (11 m); surrounding ecoregions are both higher and better drained. Ecoregion 63b is underlain by unconsolidated lower terrace sediments of Quaternary age (see figure 3-6). Alluvial sand and silt, estuarine sand and silt, saline marsh deposits, and marine sand, silt, and clay are also common. Ultisols (old soils), which are an order in the US system of soil taxonomy and Histosols (organic soil order), are common. Streams are usually low in gradient, sluggish, tidally influenced, poorly incised, and have undefined channels; they are fed by shallow groundwater aquifers and become brackish as they begin to mix with the Chesapeake Bay.

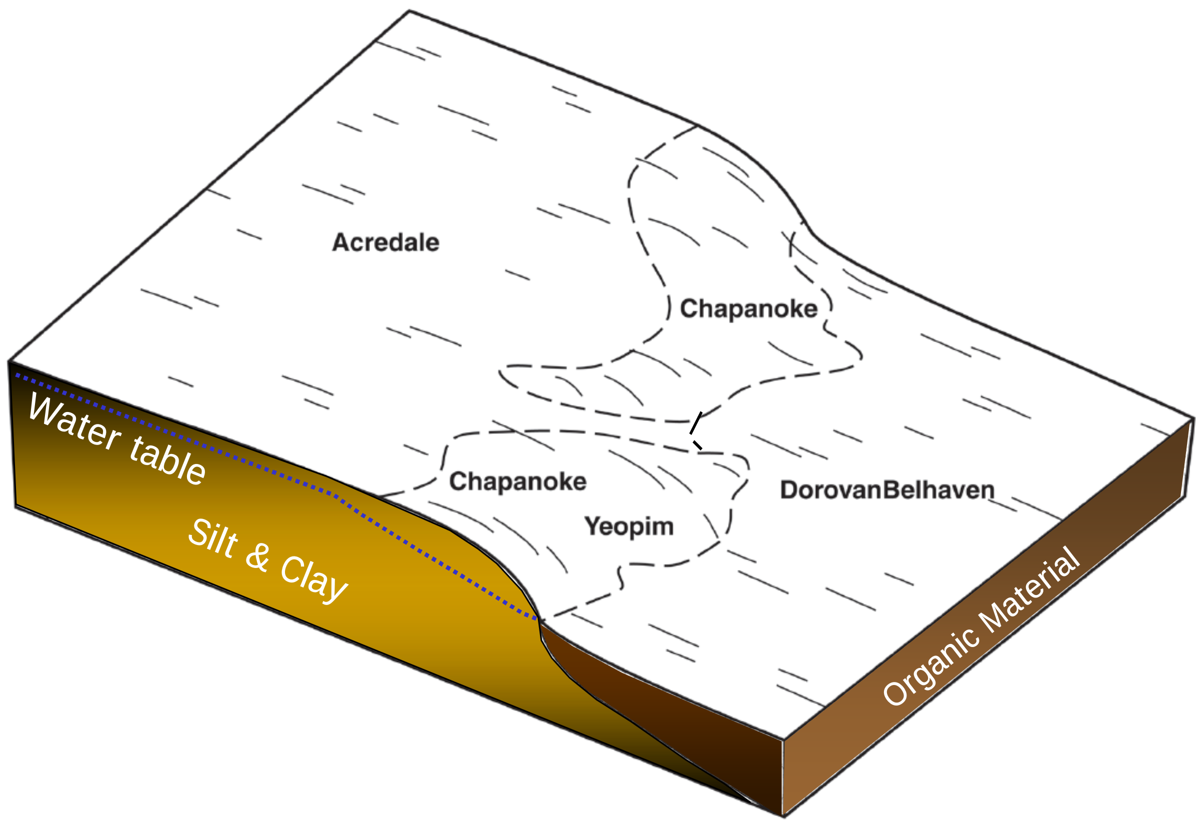


Figure: 3-9. Idealized landscape in Chesapeake and Virginia Beach, which shows the relationship between soils formed from marine sediments and those formed from organic material. Acredale soils are poorly drained whereas Chapanoke Soils are somewhat poorly and Yeopim Soils are moderately well drained. The better drainage occurs at the slope break where natural drainage occurs. Dorovan Soils are very poorly drained and have greater than 51” of organic material overlying mineral soils. Belhaven Soils are also very poorly drained. Thickness of the organic layer, however, is less than 51”. Both Dorovan and Belhaven are Histosols. None of these soils are suitable for drainfields. *(NRCS Chesapeake Soil Survey)*

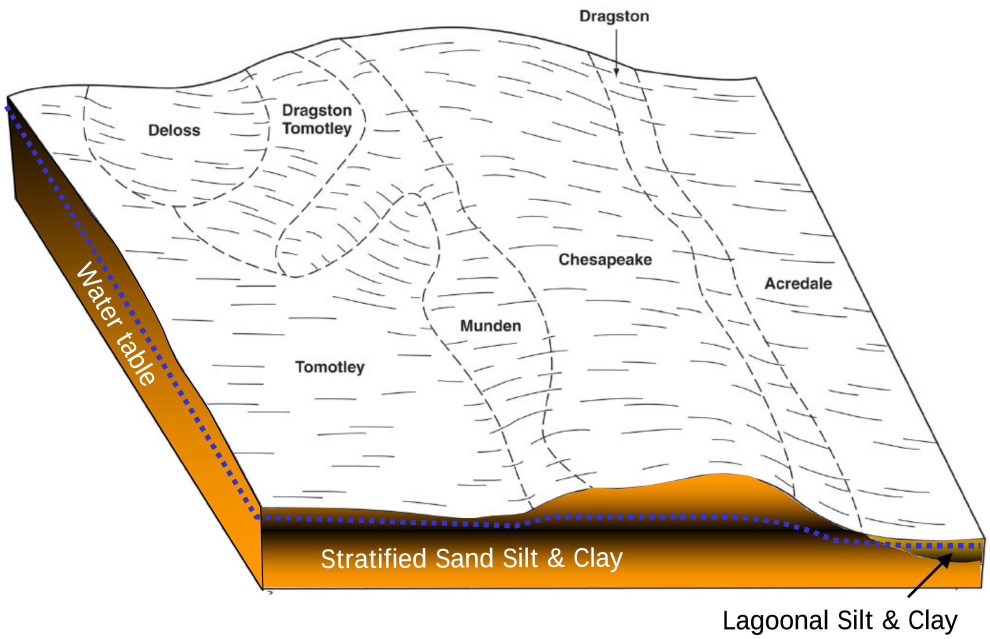


Figure: 3-10. Idealized landscape and drainage relationships in Chesapeake and Virginia Beach. Chesapeake Soils, which are well drained, are not as wet as those on either side. They are fine loamy textured and are suitable for drainfields. Acredale soils formed from fine-textured lagoon deposits and are fine silty (unsuitable for drainfields); they are poorly drained. Tomotley soils are also poorly drained, but are fine loamy (unsuitable). Deloss is a very poorly drained fine loamy soil (unsuitable). Munden is moderately well drained and is coarse loamy. Munden soils may be suitable for alternative treatment systems. Dragston is also coarse loamy, but is somewhat poorly drained and is not normally suitable for drainfields. *(NRCS Chesapeake Soil Survey)*

Seasonal Water Table Relationships Between Selected Soil Series

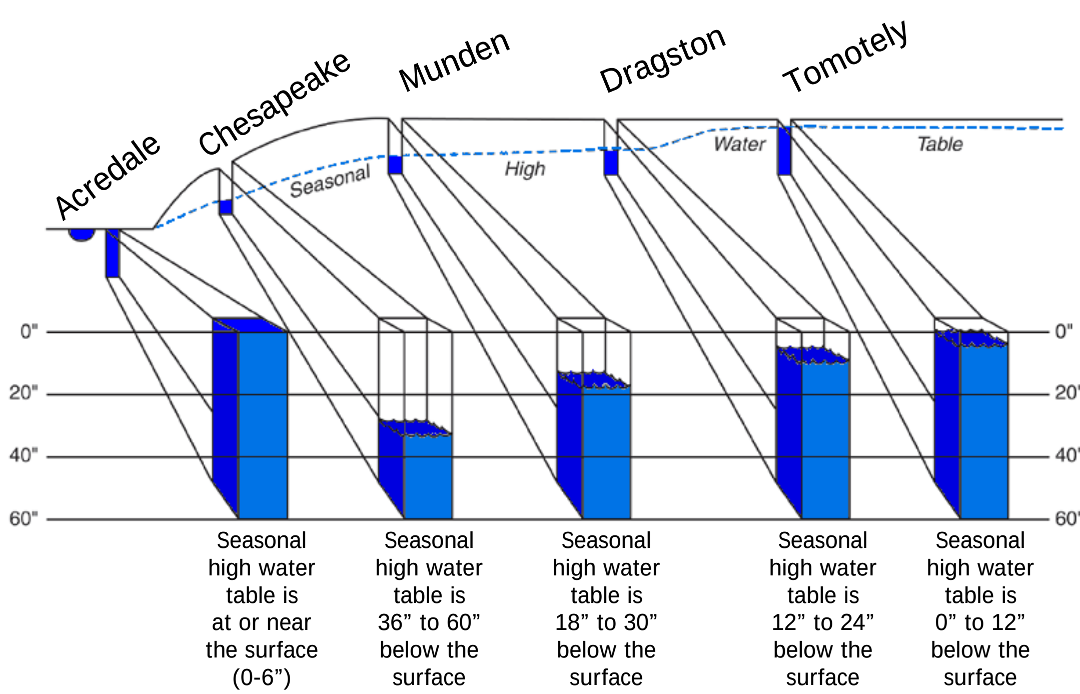


Figure: 3-11. Relative seasonal high water table for selected soil series located on figure 3-10 block diagram. *(NRCS Chesapeake Soil Survey)*

Figure: 3-12. Ditch maintenance in an area of poorly drained Acredale Soil. *(NRCS Chesapeake Soil Survey)*

Extensive tidal marshes and salt estuarine bay marshes are found on the poorly drained soils of the silty low terraces of Ecoregion 63b. The tidal marshes are most extensive on the lower Eastern Shore of the Chesapeake Bay; here, the terrain is low and tidal marshes extend farther inland than in other coastal areas.

In Chesapeake and Virginia Beach, drainage ditches are often used to lower the water table in order to install onsite sewage disposal systems in these soils. Limitations for drainfields are seasonal high water table and in the case of the fine silty soils, slow rates of absorption.

63c. Dismal Swamp

The Dismal Swamp (63c) is a large, forested wetland with extensive organic deposits (Histosols). Ecoregion 63c is nearly flat, very poorly and poorly drained, and is underlain by lagoonal strata and impermeable clays. Thick peat (Histosols) deposits are characteristic and extensive. These Histosols formed under

Figure: 3-13. Representative profile of the very poorly drained Deloss Soil Series. *(NRCS Chesapeake Soil Survey)* saturated or very poorly drained conditions; they are derived from organic material and are very acidic. The largest natural lake in Virginia, Lake Drummond, is located in Ecoregion 63c. Elevations range from about 15 to 20 feet. These soils are not suitable for onsite sewage disposal systems.

63d. Barrier Islands-Coastal Marshes

Ecoregion 63d is composed of beaches, dunes, low terraces, beach ridges, and barrier islands that are fringed by lagoons, bays, tidal salt marshes, mudflats, networks of tidal channels, or ocean. An extensive barrier – back barrier system parallels much of the Atlantic shore. Elevations range from only 35 feet (11 m) to sea level. The Barrier Islands and Coastal Marshes (63d) ecoregion is more exposed to the open ocean than other nearby regions and, resultantly, its landforms are more dynamic. Significant wave and wind action occurs and has affected both landforms and the position of the shoreline itself. In the last 10,000 years, the overall trend for the sandy coastline has been westward retreat; from the mid-1950s or mid-1960s to the early-1980s, net erosion averaged five feet (1.5m) per year. The barrier islands, in particular, have been heavily affected by hurricanes while protecting the mainland from erosion.

Ecoregion 63d is underlain by Quaternary unconsolidated sand, silt, and clay that were laid down as beach, dune, barrier beach, saline marsh, terrace, and near shore marine deposits. Soils are mostly Entisols (young soils), Ultisols (old soils), and Inceptisols (middle-aged soils). Limitations for drainfields are excessive rates of absorption, which may lead to groundwater contamination, slow rates of absorption in fine textured sediments, and seasonal high water tables.

63e. Mid-Atlantic Flatwoods

Ecoregion 63e is a broad plain composed of middle-elevation terraces, sandy ridges, and broad, shallow valleys. Evergreen shrub bogs or "pocosins" are characteristic and are found on flat, poorly drained undissected uplands between major streams. Entisols (young soil order) occur on floodplains and terraces of the small streams and rivers whose watersheds are entirely within the coastal plain. Elevations range from 0 to 100 feet (0-30 m) and local relief is less than 30 feet (9 m). Dissection and elevation are generally less than ecoregions to the west and many streams meander widely. Drainage is often restricted and Aquults (wet Ultisols) are the most extensive soils; they are a contrast to the better-drained Udults (dry Ultisols) that are common on the Rolling Coastal Plain (65m).

Aquults are Ultisols that are saturated with water for periods long enough to limit their use for most crops other than pasture or woodland unless they are artificially drained. Aquults have redoximorphic features, iron-manganese concretions or gray colors immediately below the topsoil, and gray colors in the subsoil. Udults are Ultisols that have low or moderate amounts of organic carbon and reddish or yellowish subsoils. Udults are not saturated with water for periods long enough to limit their use for most crops. Aquults and Udults are suborders in the U.S. system of soil taxonomy. *(Glossary of Soil Science Terms)*

Limitations of the soils for onsite sewage disposal systems in this mapping unit are primarily seasonal high water tables. In areas where soils weathered from fine textured sediments occur, slow rates of absorption are also a limitation.

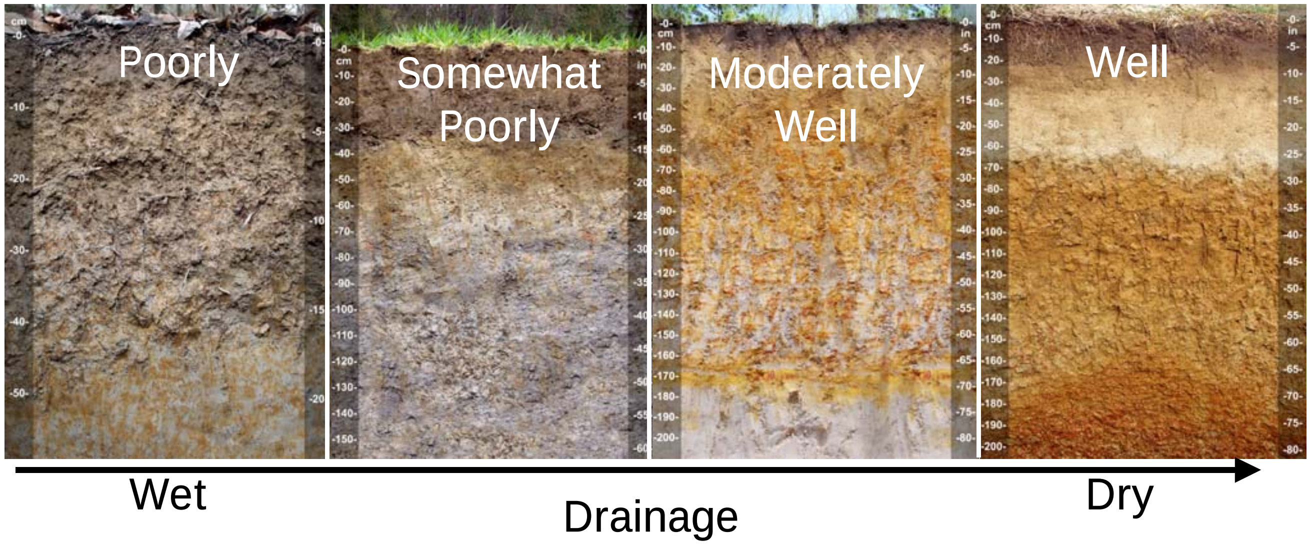
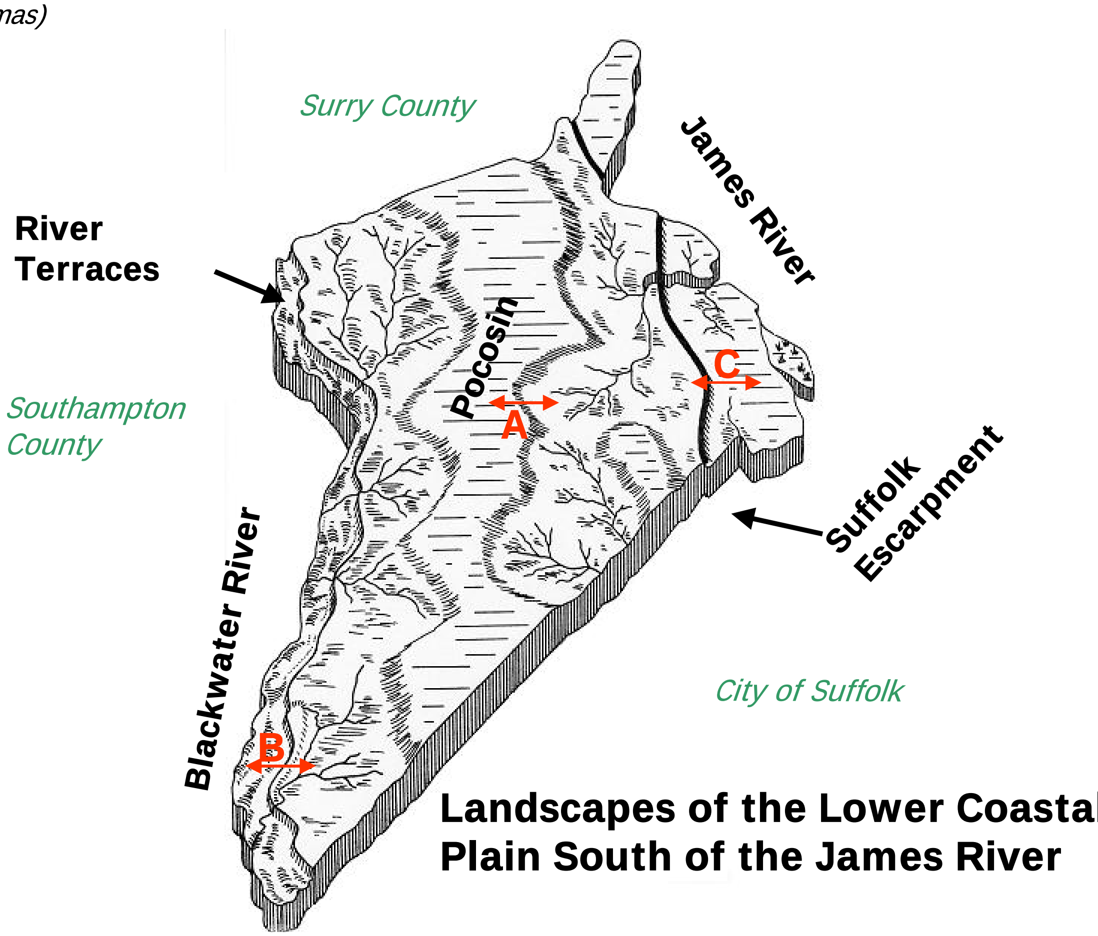


Figure: 3-14. Drainage classes across landscape "A". All these soils are fine loamy. Their drainage is determined by landscape position. Poorly drained soils are unsuitable for drainfields and well-drained soils are suitable. The two in between may be suitable for certain alternative treatment systems. *(Photos by John Kelly)*

Figure: 3-15. Isle of Wight County block diagram of selected landscapes. See Landscape A, B and C figures. The Suffolk Escarpment is the boundary between mapping unit 63e to the west and 63b to the east. Spodosols & psamments occur on the Blackwater River terraces, which are primarily sandy deposits. *(Drawing by Steve Thomas)*



Landscape "A"

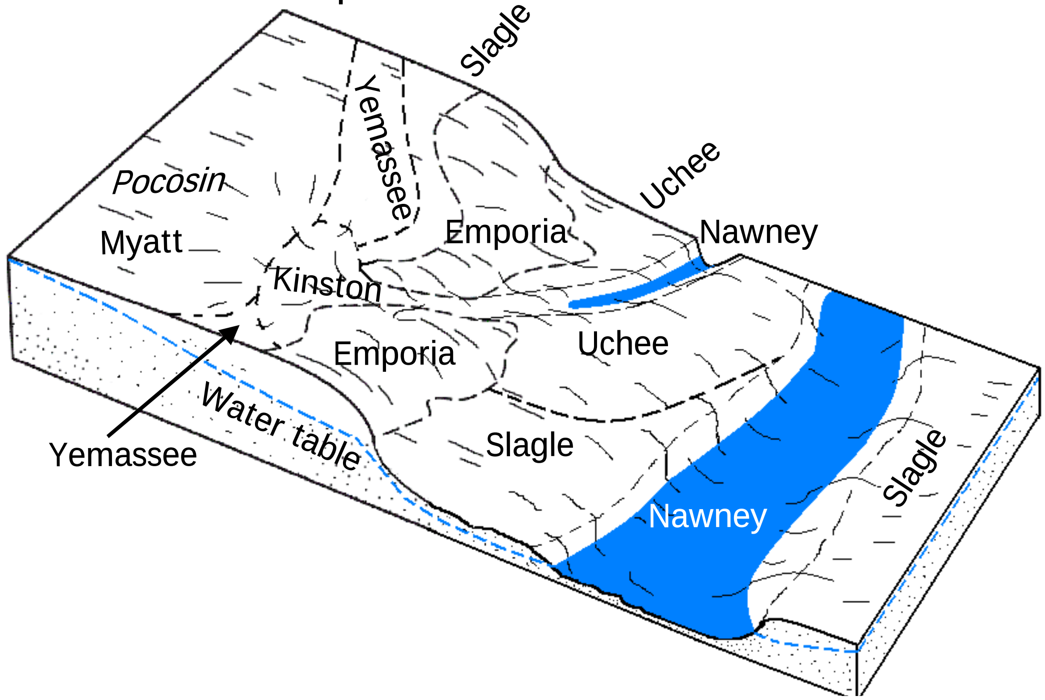


Figure: 3-16. Lower Coastal Plain South of the James River; representative landscapes and soil series. The soils on the Pocosin are Aquults (Myatt, Yemassee Soil Series) and are poorly and somewhat poorly drained (respectively). Soils formed from alluvium (Nawney and Kinston Soil Series) are Entisols and are poorly drained. The other soils are Udults. Slagle soils are moderately well drained. Emporia and Uchee soils are well drained. The Pocosins are wet due to lack of dissection into this landscape. The soils on the slopes are better drained and are more likely to be suitable for onsite sewage disposal systems.

Landscape "B"

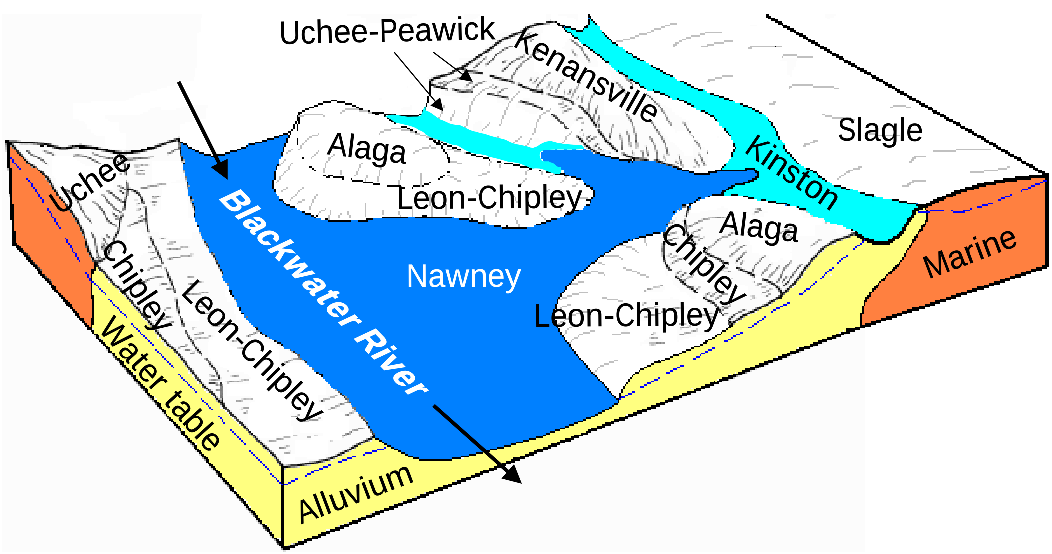


Figure: 3-17. Lower Coastal Plain South of the James River; representative landscapes and soil series. The stream terraces and floodplains are Entisols (Alaga, Chipley, Nawney, and Kinston Soil Series) and formed from alluvium (yellow). Leon is a Spodosol. The Upland soils are Ultisols and formed from marine deposits (orange). The soils on the slopes are better drained and are more likely to be suitable for onsite sewage disposal systems.

Figure: 3-18. The texture of both these soils is sand or loamy sand. The soil on the left is a Spodosol the one on the right is an Entisol and is well drained. *(Photos by John Kelly)*

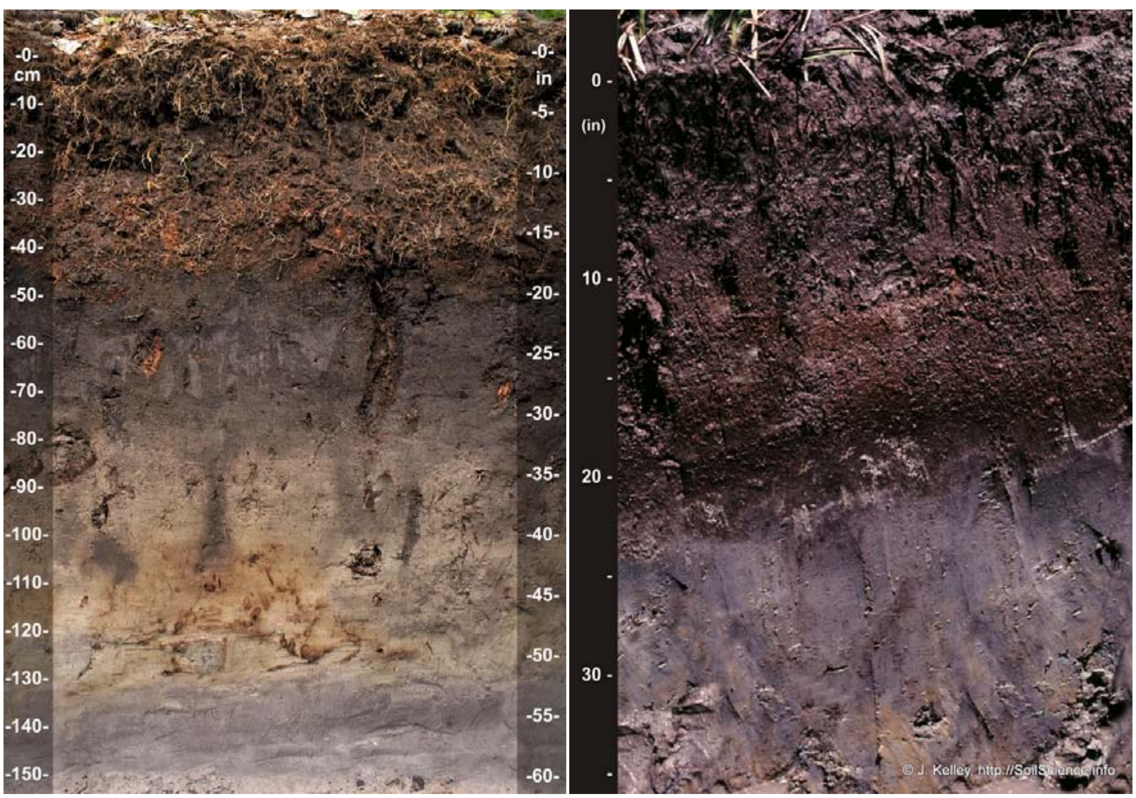


Figure: 3-19. Two organic soils over marine sediments (mineral soils). These soils are very poorly to poorly drained. They are not suitable for any kind of onsite sewage disposal system and are normally found in wetlands. *(Photos by John Kelly)*

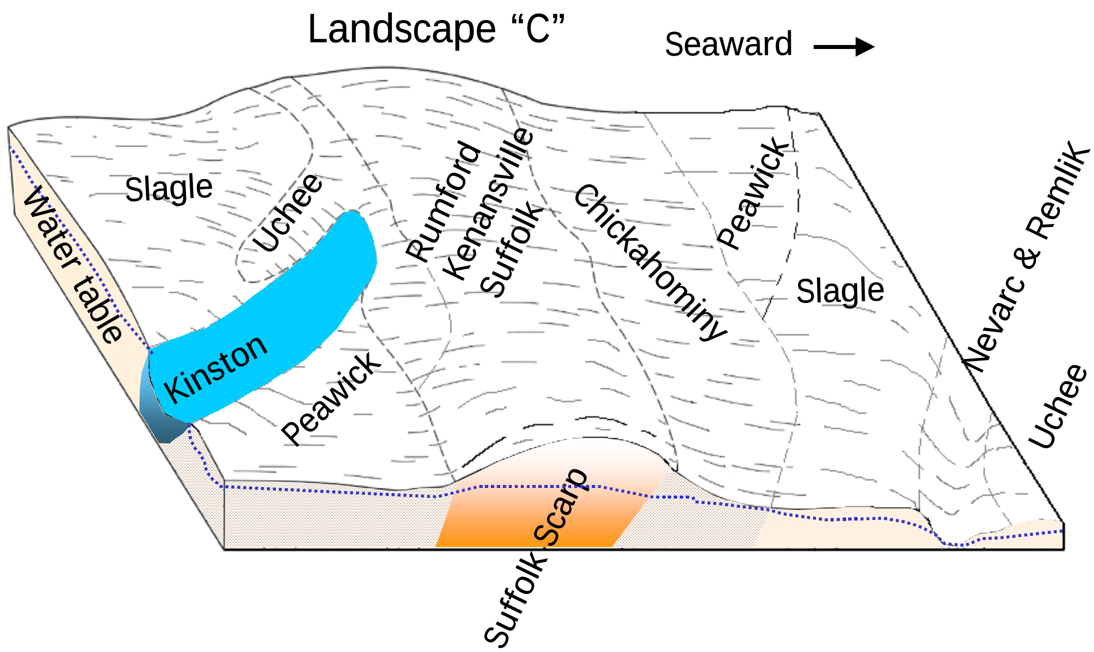


Figure: 3-20. Lower Coastal Plain South of the James River; representative landscapes and soil series. The soils on the Suffolk Escarpment (scarp) are sandier than the surrounding soils because this was once a shoreline beach. Peawick and Chickahominy soils formed from marine clays that were deposited in a lagoonal or marsh environment. They have high shrink-swell potential. Soils on the escarpment are well suited for onsite sewage disposal systems. Soils below the escarpment are not.

Figure: 3-21. Representative Profile of the Slagle Soil Series, which is fine-loamy and moderately well drained. Slagle is generally suitable for an alternative treatment system. *(NRCS Southampton County Soil Survey)*

Figure: 3-22. Representative Profile of the Uchee Soil Series, which is fine-loamy and well drained. Uchee is generally suitable for drainfields. *(NRCS Charles City County Soil Survey)*

Ecoregion 65 is composed of irregular plains with the western boundary occurring at the Fall Zone where the metamorphic rocks of the Piedmont and the sedimentary material of the Coastal Plain interfinger. The Cretaceous, Miocene and pliocene or Cenozoic-age sands, silts, and clays of the region contrast geologically with the older igneous and metamorphic rocks of the Piedmont. Elevations range from sea level to about 300 feet (91 m); relief and maximum elevations are less than in the neighboring Piedmont. The most common soils are Ultisols.

Ecoregion 65's border with the Middle Atlantic Coastal Plain (63) is based on elevation, topography, and drainage. Ecoregion 65 is typically higher, not as level, better drained, and less marshy than Ecoregion 63. Both ecoregions 63 and 65 are underlain by unconsolidated (loosely arranged and unstratified) sediments. Holocene-age (see figure 3-6) deposits are restricted to the Middle Atlantic Coastal Plain (63).

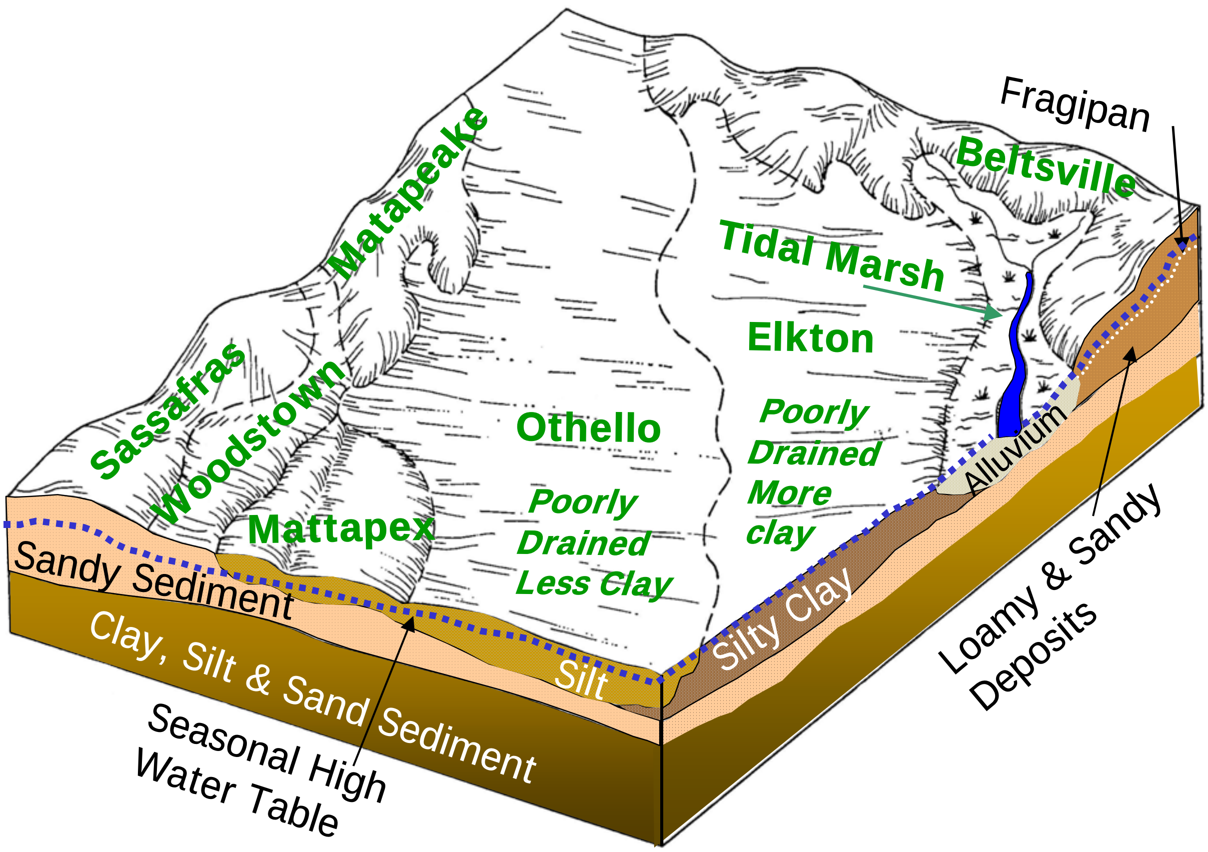


Figure: 3-23. Northern neck area idealized landscapes and soil series (65m).

Sassafras soils are well drained and fine loamy. They are well suited for drainfields. Woodstown soils are also fine loamy, but they are moderately well drained. They may be suitable for alternative treatment systems.

Matapeake soils are fine silty and well drained. Rates of absorption may limit the use of this soil for drainfields. Mattapex soils are also fine silty but they are moderately well drained. Rates of absorption and seasonal high water tables restrict this soil's use for drainfields.

Othello soils are fine silty and poorly drained. Elkton soils are also poorly drained and fine silty, but these soils have a higher percentage of clay than do Othello soils. Beltsville soils are moderately well drained fine loamy soils that have a fragipan 20-40 inches deep. These three soils are not suitable for drainfields.

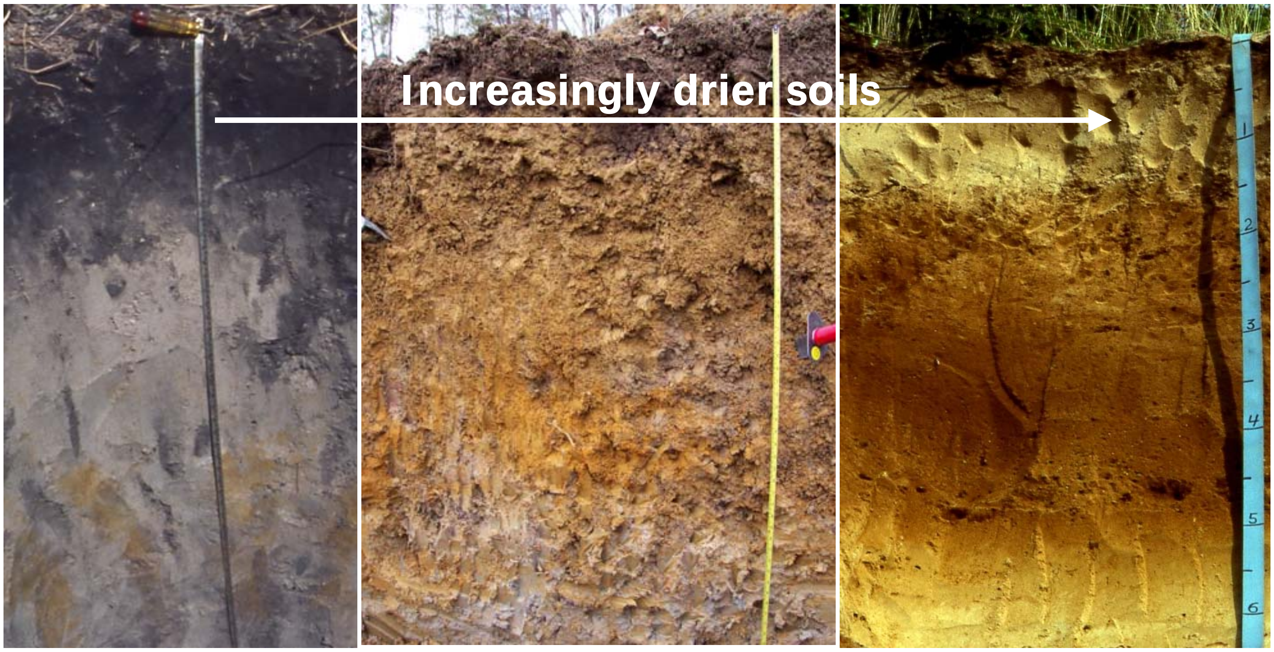


Figure: 3-24. Common soil series found in the 65m mapping unit. Othello (or Acredale, Bethera and Chickahominy (less silty)) Soil Series is on the left. This soil is fine silty and poorly drained. Mattapex (or Ackwater, Peawick (less silty)) Soil Series is in the center and is fine silty and moderately well drained. Sassafras (or Suffolk) Soil Series is on the right. It is fine loamy and well drained. Sassafras is the only suitable soil for a drainfield. *(Photos by Bill Kitchel, Tom Saxton & Carl D. Peacock, Jr.)*

65m. Rolling Coastal Plain

Ecoregion 65m is a rolling, hilly, dissected portion of the Inner Coastal Plain that is made up of sedimentary material. Lithology is distinct from the adjacent Northern Outer Piedmont (45f) that is composed of metamorphic rocks. The terrain is hillier than the Chesapeake-Albemarle Silty Lowlands and Tidal Marshes (63b). Elevations typically range from 30 to 250 feet and local relief is 25 to 175 feet (7.6-53 m). Relief, elevation, and channel gradients are generally greater than in the Middle Atlantic Coastal Plain (63); correspondingly, drainage also tends to be better. Parts of the Fall Zone are included in the westernmost portion of the Rolling Coastal Plain (65m) where outliers of Coastal Plain sediments of varying thickness overly Piedmont rocks and soils.

The Rolling Coastal Plain (65m) is mostly underlain by unconsolidated Tertiary sand, silt, clay, and gravels of the Bacons Castle Formation and the Chesapeake Group *(Virginia Division of Mineral Resources, 1993)*. Holocene-age deposits and metamorphic rocks are typically absent. Ultisols are common. They are better drained than the Aquults of the Middle Atlantic Coastal Plain (63). Limitations for drainfields include seasonal high water tables and slow rates of absorption.

65n. Chesapeake Rolling Coastal Plain

Ecoregion 65n is a hilly upland with narrow stream divides in the northern portion of the state. Streams are incised, and soils are well drained and loamy in texture. It is hillier, more dissected, and better drained than the Middle Atlantic Coastal Plain (63) and its underlying sedimentary materials are distinct from the older, metamorphic rocks of the Piedmont. Elevations are less than 400 feet (122 m) and local relief ranges from 25 to

225 feet (7.6-69 m); maximum elevation and relief are in between those of the higher Piedmont and the lower Middle Atlantic Coastal Plain (63). The soils are predominantly Ultisols. Soils in this area are predominantly weathered from the Potomac Formation. Sediments of the Potomac Formation were deposited during Cretaceous time. Cretaceous clays present many problems for the building industry. Limitations are shrink swell clays, unstable slopes and soils that have rates of absorption too slow for onsite sewage disposal systems. Sandier deposits above these strata are better suited for onsite sewage disposal systems.

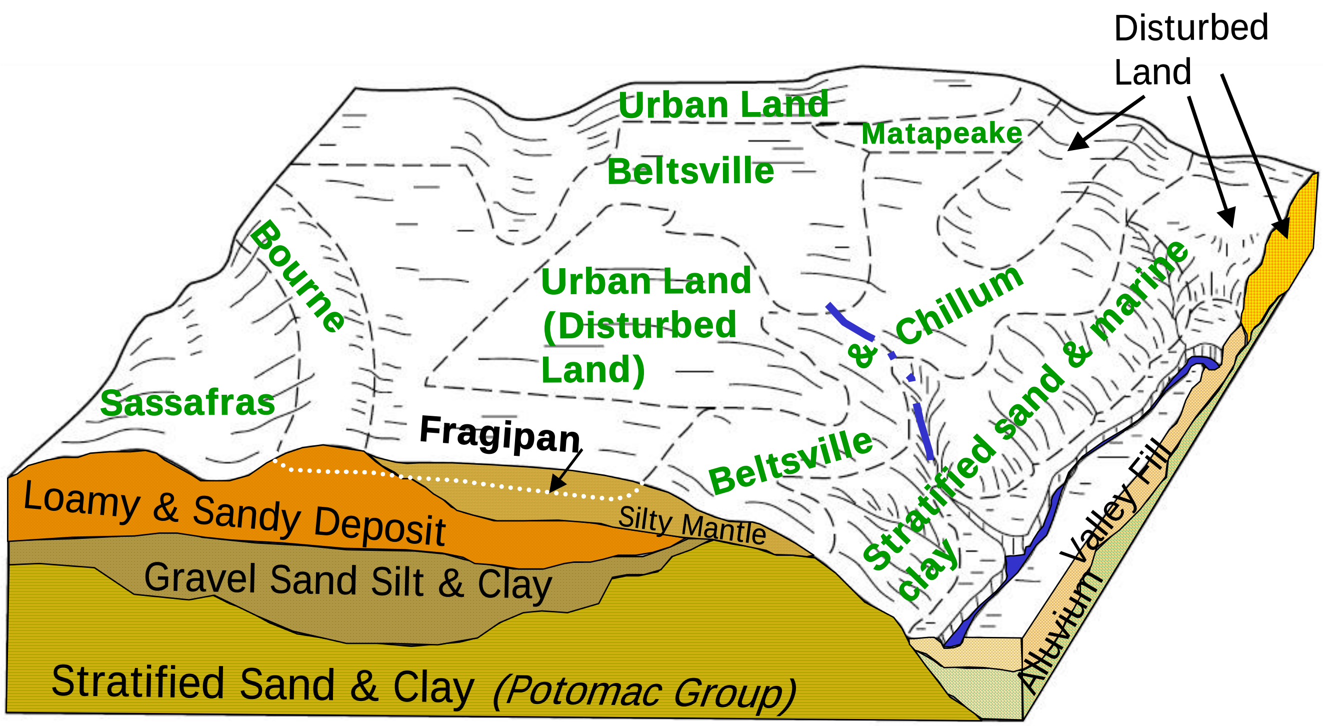


Figure: 3-25. Idealized landscape near Washington DC in the 65n mapping unit. Sassafras soils are well drained and fine loamy in texture. Sassafras soils are well suited for drainfields.

Bourne and Beltsville soils both have fragipans and are moderately well drained. They are not normally suitable for drainfields.

Disturbed Land or Urban Land (Udorthents) are soils that have been altered by man. Basically, they are compacted fill material and are unsuitable for drainfields.

Matapeake soils are fine silty and well drained. Rates of absorption may limit the use of this soil for drainfields.

Chillum is also a fine silty soil. It is well drained and is derived from wind (aeolian) blown silt deposits. It is not normally suitable for drainfields due to slow rates of absorption.

Stratified sand and clay are encountered on steep slopes between the higher elevations of the coastal plain and lower elevations. These cretaceous marine clays have high to very high shrink swell and often cause landslides.

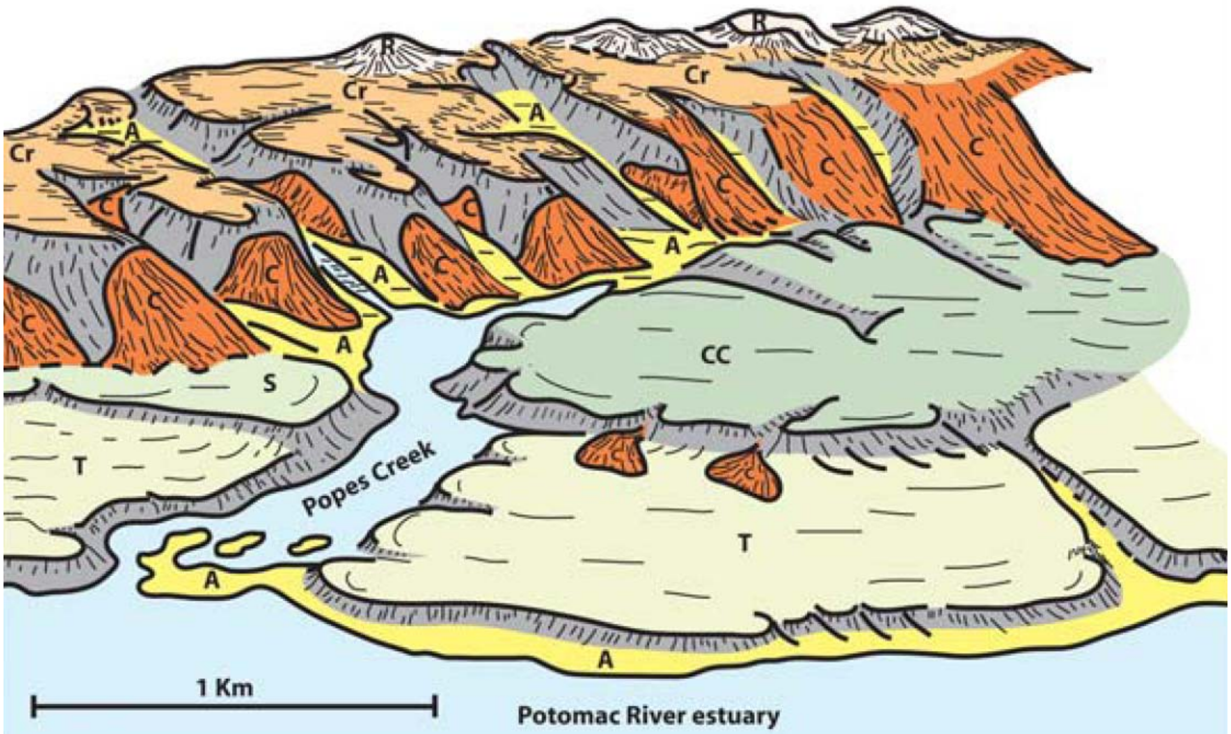


Figure: 3-26. The complexity of soils in mapping unit 65n is demonstrated with this diagram. This is a south view, oblique perspective from the Colonial Beach South 1:24 000 scale quadrangle. Local relief ranges from 0–60 m. 'R' is eroded, deeply weathered regolith (residuum); untagged grey areas are eroded Miocene–Pliocene marine substrate; 'Cr' is colluvial–alluvial deposits eroded from 'R'; 'C' is younger colluvium from mid-Pleistocene to Recent; 'CC' is 25m estuarine terrace deposits (Charles City Formation); S is 12m estuarine terrace deposits (Shirley Formation, MIS 7?); 'T' is 3–4 m estuarine terrace deposits (Tabb Formation-Kent Island Formation); and 'A' is modern alluvium including Potomac River beach and tidal wetlands.

(Newell, W.L and B.D. Dejong; Geological Society, London, Special Publications 2011; v. 354; p. 259-276. Cold-climate slope deposits and landscape modifications of the Mid-Atlantic Coastal Plain, Eastern USA.)

Table: 3-2. Major soils in the Virginia Coastal Plain

Textural Family	Drainage Class				
	Excessively Well to Well	Moderately Well	Somewhat Poorly	Poorly	Very Poorly
Fine *Mixed Mineralogy*	Masada Caroline**	Craven Dogue Peawick	Lenoir Wahee Newflat	Acredale Chastain Chickahominy Roanoke	Cape Fear
Kaolinitic	Faceville**				
Fine Silty *Mixed Mineralogy*	Matapeake	Yeopim Mattapex	Chapanoke	Othello	Levy
Fine Loamy *Mixed Mineralogy*	Pamunkey State Wickham	Altavista Bourne*** Tetotum Woodstown	Augusta Bertie	Fallsington Tomotley	Deloss Portsmouth
Fine Loamy *Siliceous Mineralogy*	Emporia Kempsville Kenansville* Suffolk Sassafras	Slagle Goldsboro**	Yemassee Lynchburg**	Myatt Rains**	
Kaolinitic	Norfolk** Orangeburg** Uchee*				
Coarse Loamy *Mixed Mineralogy*	Bojac Conetoe	Munden	Dragston	Nimmo	Arapahoe
Coarse Loamy *Siliceous Mineralogy*	Rumford	Nansemond			
Sandy *Mixed Mineralogy*	Tarboro	Seabrook			
Sandy *Siliceous Mineralogy*	Alaga Bibb Catpoint	Pactolus	Chipley	Leon *(spodic)*	

*Arenic
**Palic
***Fragipan

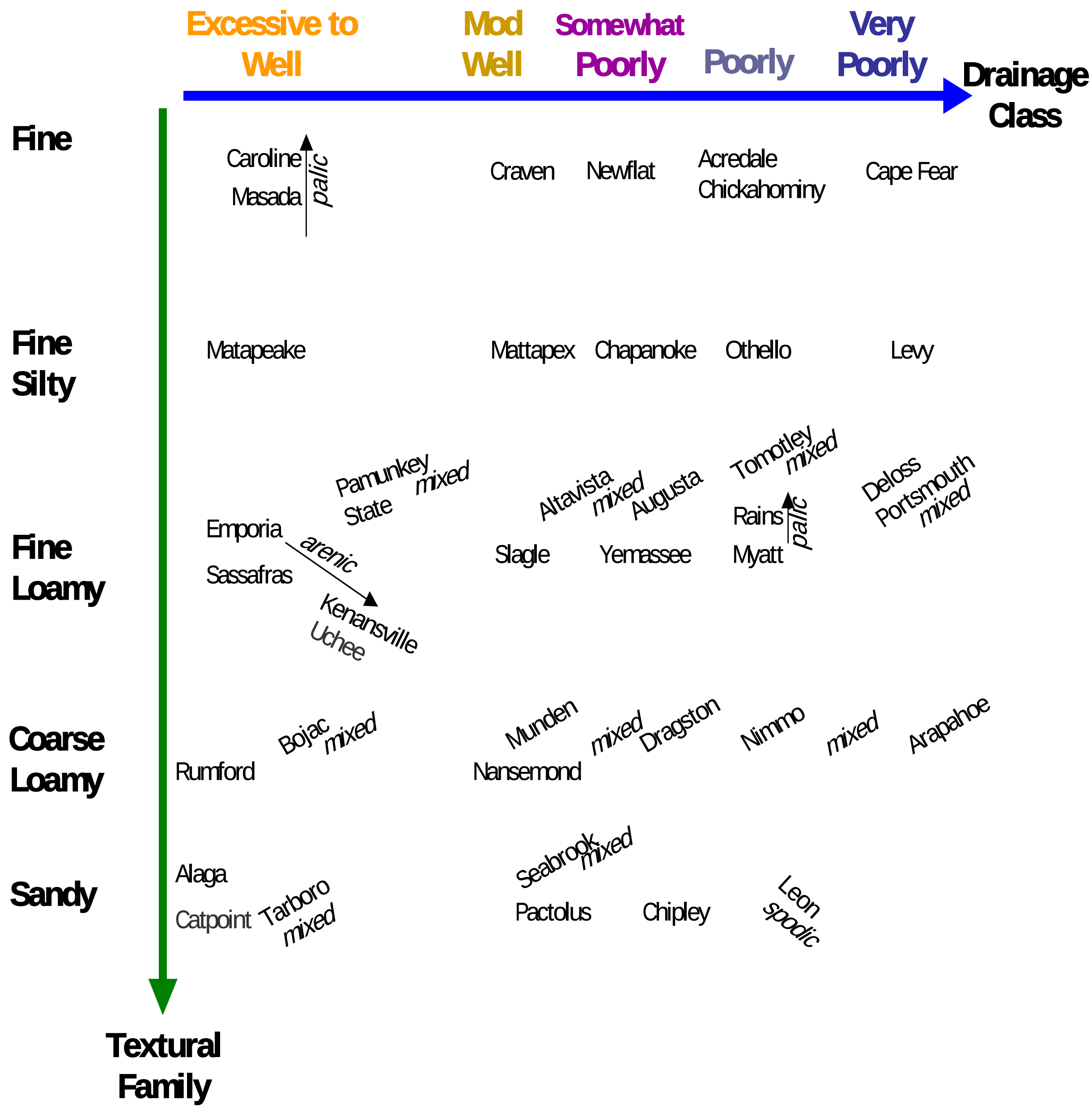


Figure: 3-26b. Selected Coastal Plain Soil Series relationships.

Mineralogy and textural class can imply genesis of the soils. Coarse sediments were deposited in swift water environments such as beachheads and fast moving stream terraces. Fine sediments were deposited in still water environments like swamps, backswamps and marshes. Mixed mineralogy implies that the material originated from the west (piedmont and mountains) and was deposited in a fluvial (river) environment. Siliceous mineralogy suggests the sediment is of marine origin and deposited in an ocean environment. However, these soils have not been consistently mapped across the Coastal Plain to a degree sufficient to draw anymore than local conclusions about their genesis.

Drainage classes are primarily related to current landscapes and to a lesser degree to textural classes.

A palic clay curve *(clay does not decrease 20 percent before 60 inches)* may indicate greater age if it is a result of pedogenesis. If it is a result of deposition, there is no age implication.

The Fall Zone is a 900-mile (1,400 km) escarpment where the Piedmont and Atlantic Coastal Plain meet. The Fall Zone marks the geologic boundary of hard-metamorphosed bedrock terrain and the sandy, relatively flat outwash plain of the Coastal Plain.

Examples of the Fall Zone include the Potomac River's Great Falls and the rapids in Fredericksburg on the Rappahannock River as it passes over the Fall Zone. At Richmond, where the James River falls across a series of rapids down to the tidal estuary of the James River and at Petersburg where the Appomattox River falls over rapids.

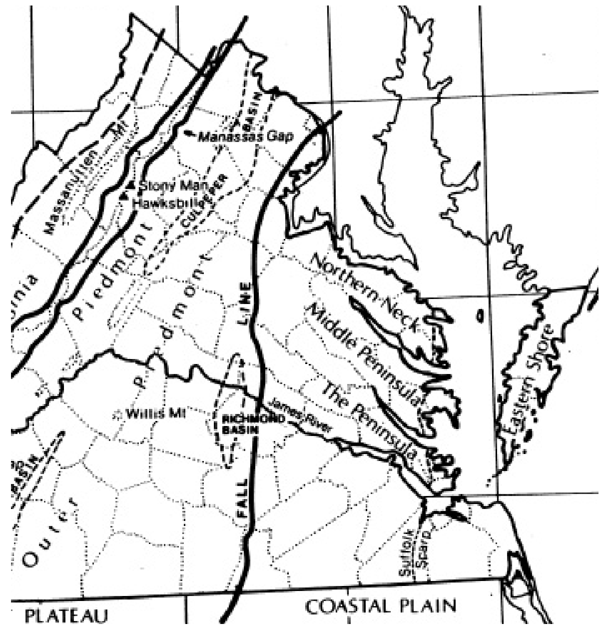


Figure: 3-27. The Fall Zone follows the approximate westward extension of early seas. *(dcr.virginia.gov/natural_heritage/natural_communities)*

Before navigational improvements were made to rivers, the Fall Zone was often the head of navigation due to rapids and waterfalls. Numerous cities were founded at the intersection of rivers and the Fall Zone. U.S. Route 1 and 95 link many of the fall zone cities. Differential erosion along the contact between the soft Coastal Plain strata and the hard Piedmont crystalline rocks commonly causes these falls or rapids to form in streams at or slightly west of the boundary between the two terrains.

There are faults along the Fall Zone that act like a hinge between the uplifting Appalachians to the west and the subsiding Coastal Plain to the east. This fault extends from New Jersey to Texas (*Howard, 1978) (Weems and Edwards, 2007)*.

Figure: 3-28. Marine transgression westward. *(William Mary Department of Geology, C.M. Bailey)*

Along the eastern border at the Fall Zone, the change in geology from crystalline bedrock to unconsolidated sediments of the Coastal Plain accelerates the down-cutting of streams, creating a low escarpment with high-gradient flows along the major water courses. Rivers that cut across the Fall Zone characteristically have dramatic rapids and falls such as those seen along the James River in Richmond, the Rappahannock River west of Fredericksburg, and the Potomac River west of Washington, D.C. (http://www.dcr.virginia.gov/natural_heritage/ncoverview.shtml)

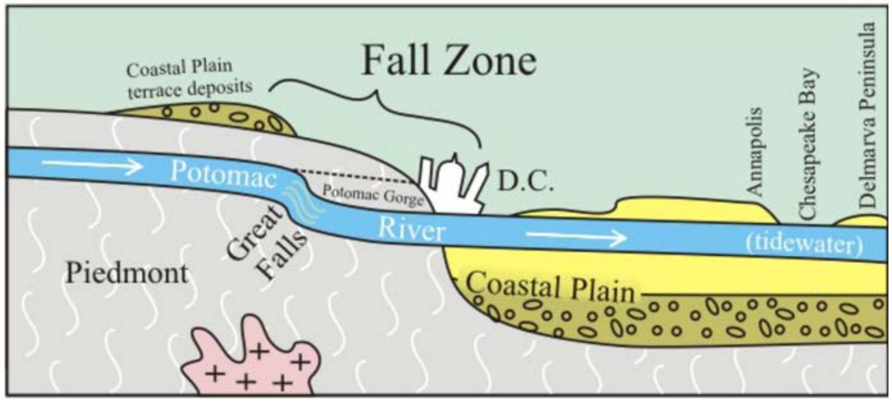


Figure: 3-29. Idealized Fall Zone concept in Northern Virginia. The Potomac is thought to have deposited broad, gently sloping, coalescing alluvial fans adjacent to and on the east of a low fault scarp marking the edge of the Piedmont upland. *(Callan Bentley, NVCC, 2006)* The James River is similar near Richmond and the Rappahannock River near Fredericksburg.

Sediments east of the Fall Zone were deposited by a combination of marine and fluvial environments. The Fall Zone itself is composed of metamorphosed piedmont bedrock irregularly overlain by a veneer of fluviomarine sediments. The seas made numerous transgressions back and forth over the Coastal Plain during Pleistocene, Pliocene, Miocene and Cretaceous (see figure 3-6). They are thought

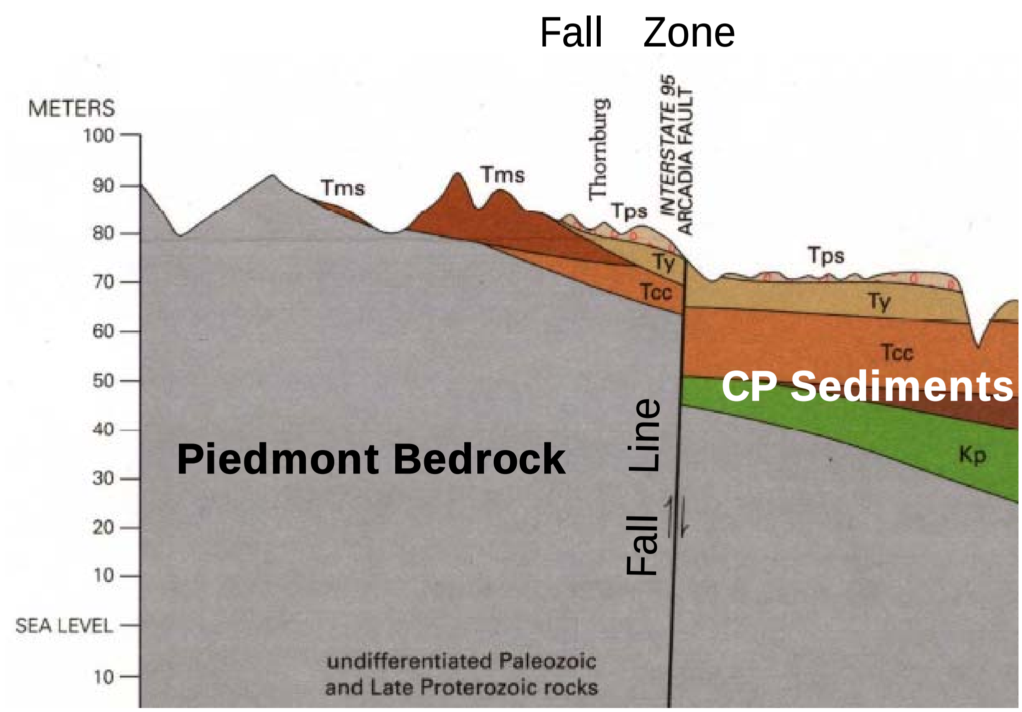


Figure: 3-30. Transect segment south of Fredericksburg showing Coastal Plain sediments "thinning" westward at the Fall Zone. *(USGS; Geologic Map of the Fredericksburg 30' x 60' Quadrangle, Virginia and Maryland By Robert B. Mixon, Louis Pavlides, David S. Po wars, Albert J. Froelich, Robert E. Weems, J. Stephen Schindler, Wayne L. Newell, Lucy E. Edwards, and Lauck W. Ward)*

to have transgressed into the eastern piedmont at least once during Miocene *(Weems and Edwards, 2007)*. Evidence of this may be seen throughout the eastern piedmont in the form of upland soils weathered from transported sediments overlying residuum weathered from bedrock. These thin veneers or "cappings" of transported sediments have weathered to form soils. These soils have important characteristics that affect the functioning of onsite sewage disposal systems and should be carefully evaluated and documented.

The City of Richmond is on the Fall Zone, with the western section on the Piedmont Plateau and the eastern section on the Atlantic Coastal Plain. The oldest formation is the Precambrian Petersburg Granite of the Piedmont Plateau. Below the Fall Zone, the granite is overlain with Coastal Plain sediments. Directly on top of the granite is the Potomac Group, consisting of arkosic sands and clay of Early Cretaceous age (see figure 3-6). Directly above the Potomac Group is the Pamunkey Group of Eocene age consisting of glauconitic sands and marl. During Miocene, Richmond was covered by the Atlantic Ocean, which deposited clay, silt, sand, and marl of the Calvert Formation (Chesapeake Group). The youngest sediments are the Columbia Group of Pleistocene age, consisting of 20 feet of water-bearing sand and gravel overlain with 20 feet of clay. The Piedmont Plateau has thin gravelly, sandy, and clayey sedimentary deposits on the highest ridges, which are thought to be remnants of the Brandywine terrace. *(William & Mary Dept of Geology Piedmont Province for Students & Teachers The Geology of Virginia.htm)*

Figure: 3-31. Bill Kitchel (soil scientist) investigates soils weathered from the Tg_1 mapping unit shown on the western side of the Bon Air Quadrangle cross-section map (figure 3-32.). *(Photo by Tom Saxton)*

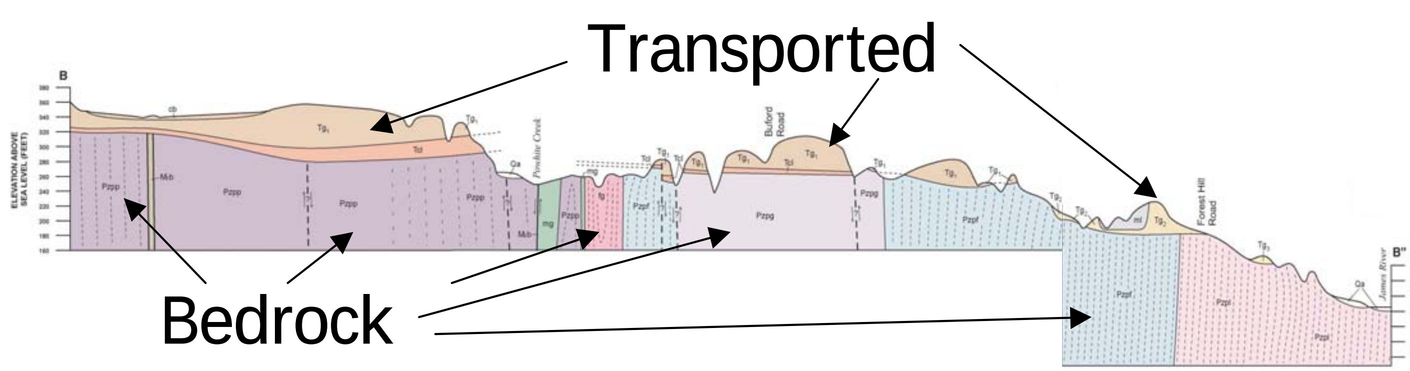


Figure: 3-32. Cross-section from the Geology of the Bon Air Quadrangle (Richmond area) showing a thin veneer of transported material over bedrock residuum at the Fall Zone in Richmond. *(The Virginia Division of Mineral resources; Geology Map of The Bon Air Quadrangle, Virginia, Mark W. Carter, C. R. Berquist, Jr., Amy K. Bondurant and Heather A. Bleick;, 2007)*

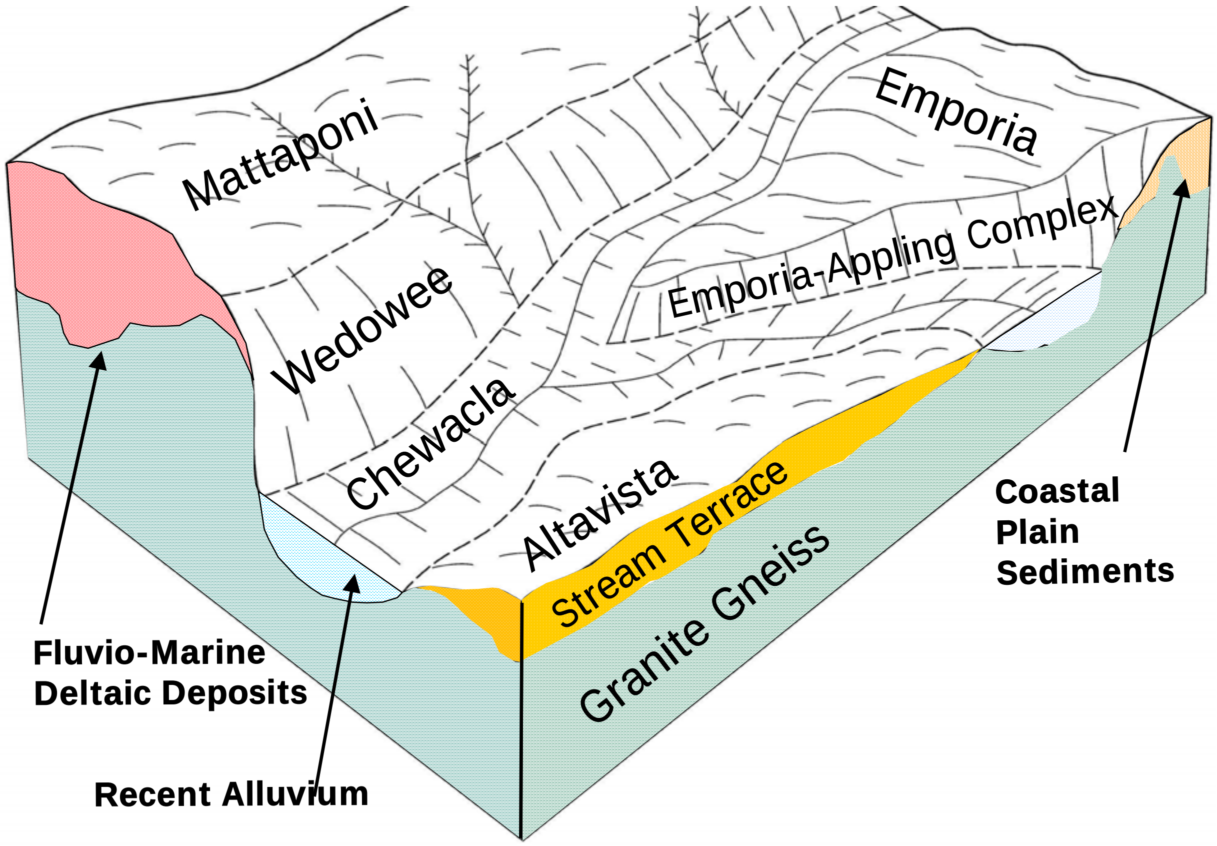


Figure: 3-33. Idealized catena of soils within the Fall Zone. Wedowee and Appling soils have clayey Bt horizons and are weathered from granite and granite gneiss (Piedmont residuum). Emporia soils are fine loamy. Mattaponi soils are clayey. Both Emporia and Mattaponi are weathered from marine and fluvio-marine deposits. Altavista is fine loamy and weathered from old stream deposits. It is found on low stream terraces. Chewacla is a young soil weathered form recent alluvium on floodplains.

The Piedmont is the largest province in Virginia. To its east is the Fall Zone, which separates the province from the Coastal Plain, and to its west are the mountains of the Blue Ridge province. The land surface of the province slopes gradually from a general elevation of about 300 m (1,000 ft) near the Blue Ridge to roughly 50 m (160 ft) at the Fall Zone. In the southern part of the state, the Piedmont is nearly 300 km (190 mi) wide, gradually narrowing to approximately 75 km (45 mi) wide in northern Virginia. The Piedmont has gently rolling hills, deeply weathered bedrock, and very little solid rock at the surface. Most rocks at the surface become weathered in the humid climate and buried under a blanket of "rotten rock", called saprolite several meters thick. Most places where you can find outcrops of solid rock are usually in stream valleys where the saprolite has been removed by erosion. The land becomes hillier as the Blue Ridge is approached. Many igneous and metamorphic rocks make up the bedrock of the Piedmont. Most of these rocks range in age from the late Precambrian to

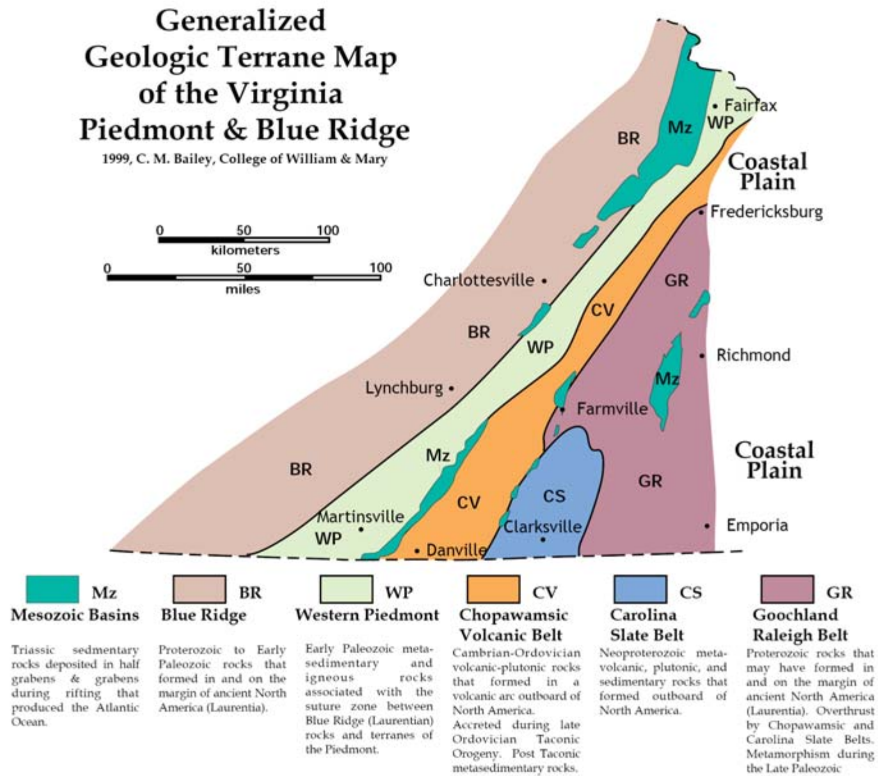


Figure: 3-34. Geologic terranes are different landmasses that have been “crunched” together during different continental collisions. *(William & Mary Dept of Geology Piedmont Province for Students & Teachers The Geology of Virginia.htm)*

Paleozoic (see figure 3-36) and further west make-up the insides of the ancient Appalachian Mountains. Triassic sedimentary and igneous rocks can be found in many basins (Mz) that formed when the supercontinent Pangaea (Africa and North America today) ripped apart to create the Atlantic Ocean 245 million years ago. These areas are where continental crust failed to pull apart enough to produce a full-fledged ocean basin. Instead these rift valleys were intruded by magma (now diabase and basalts) and filled with sediments (now siltstones, sandstones and conglomerates) eroded off the Appalachians (see figure 3-46).

Many of the rocks in the Piedmont have a complex geologic history, and some may have formed in areas outside of North America. Geologic terranes are groups of rock with very different pasts and are separated from one another by faults. The oldest rocks are approximately 1100 million years old, and can be found just west of Richmond in a place called the Goochland terrane. Rocks of the Goochland terrane are similar in composition to Precambrian-age rocks in the Blue Ridge province. Other terranes include Cambrian-

Ordovician igneous rocks that are thought to be what is left of an ancient volcanic arc (like the present-day Aleutian Islands in Alaska, or islands of the Caribbean) that collided with and stuck to the eastern edge of North America. Granitic rocks of Paleozoic age are common, and also formed during this time due to partial melting of older source rocks that were heated during mountain building. Many of the terranes were altered when the volcanic arc smashed into Virginia. Valuable economic resources in the Piedmont province include high quality slate in the late Ordovician Arvonia Formation. *(William & Mary Dept of Geology Piedmont Province for Students & Teachers The Geology of Virginia.htm)*

Like the Coastal Plain, the Piedmont can be divided into eastern ("outer") and western ("inner") zones by topographic features, and into northern and southern sections by the James River. The ***outer Piedmont*** comprises the eastern two-thirds of the province, including several low, nearly level ***Mesozoic basins*** (*e.g.*, the Culpeper, Richmond, Farmville, and Danville Basins). Willis Mountain is a pronounced monadnock (a mountain or rocky mass that has resisted erosion and stands isolated, also known as an inselberg) located in eastern Buckingham County. It is held up by resistant kyanite quartzite. The kyanite is mined and used in high-temperature ceramics like spark plugs. *(http://www.dcr.virginia.gov/natural_heritage/ncoverview.shtml)*

Figure: 3-35. Willis Mountain in Buckingham County is a monadnock. Mining operations for kyanite are visible. *(Photo by Tom Saxton)*

The ***inner Piedmont*** contains the steeply rolling to hilly belt lying just east of the Blue Ridge, including a number of more or less isolated monadnocks or foothill ranges such as the Bull Run Mountains in northern Virginia, the Southwest Mountains near Charlottesville, Candler's Mounatain at Lynchburg and Smith Mountain southwest of Lynchburg. These monadnocks reach elevations of about 300 m (1,000 ft) to more than 600 m (2,000 ft). The Culpeper Mesozoic Basin spans the inner and outer Piedmont. Except in dissected or foothill areas, most of the province is covered by a thick mantle of soil and saprolite that has weathered in place and obscured much of the geologic parent material. *(http://www.dcr.virginia.gov/natural_heritage/ncoverview.shtml)*

Igneous and metamorphic rocks dominate the Piedmont region. The predominant soil parent material rocks are gneiss, schist, and granite, of which quartz, feldspar, and mica are the dominant primary minerals. Soils developed from these rocks and minerals form acid, infertile soils, with sandy loam, loam or silt loam surfaces and clayey subsoils. Many of the clayey subsoils are red or yellowish red due to the oxidized iron weathered from the primary minerals. Depth to bedrock is shallower in steep areas and deeper, usually greater than six feet in broad rolling landscapes. Acidic soils in the Piedmont are generally well suited for onsite sewage disposal systems.

Other soils in the region were formed from igneous and metamorphic rocks with a high base content of calcium and magnesium. Soils formed from such minerals tend to be more fertile, but in some instances, they form clayey subsoils with a very high capacity to shrink and swell on wetting and drying. The depth to bedrock is generally two to six feet.

Basic or mafic soils are commonly less permeable than soils weathered from acidic rocks. They often present problems for onsite sewage disposal systems.

Scattered throughout the Piedmont are other soil areas formed from sandstone, shale and conglomerate, which were geologic sediments, deposited in Triassic-Jurassic age (Mesozoic) Basins. These ancient basins are oriented in a northeast to southwest direction, roughly paralleling the Appalachian Mountain belt. Soils weathered from these rocks may have high clay content and high water tables. Depth to bedrock varies from two to ten feet. Shrink-swell soils are common. The soils in these basins present difficulties for onsite sewage disposal systems.

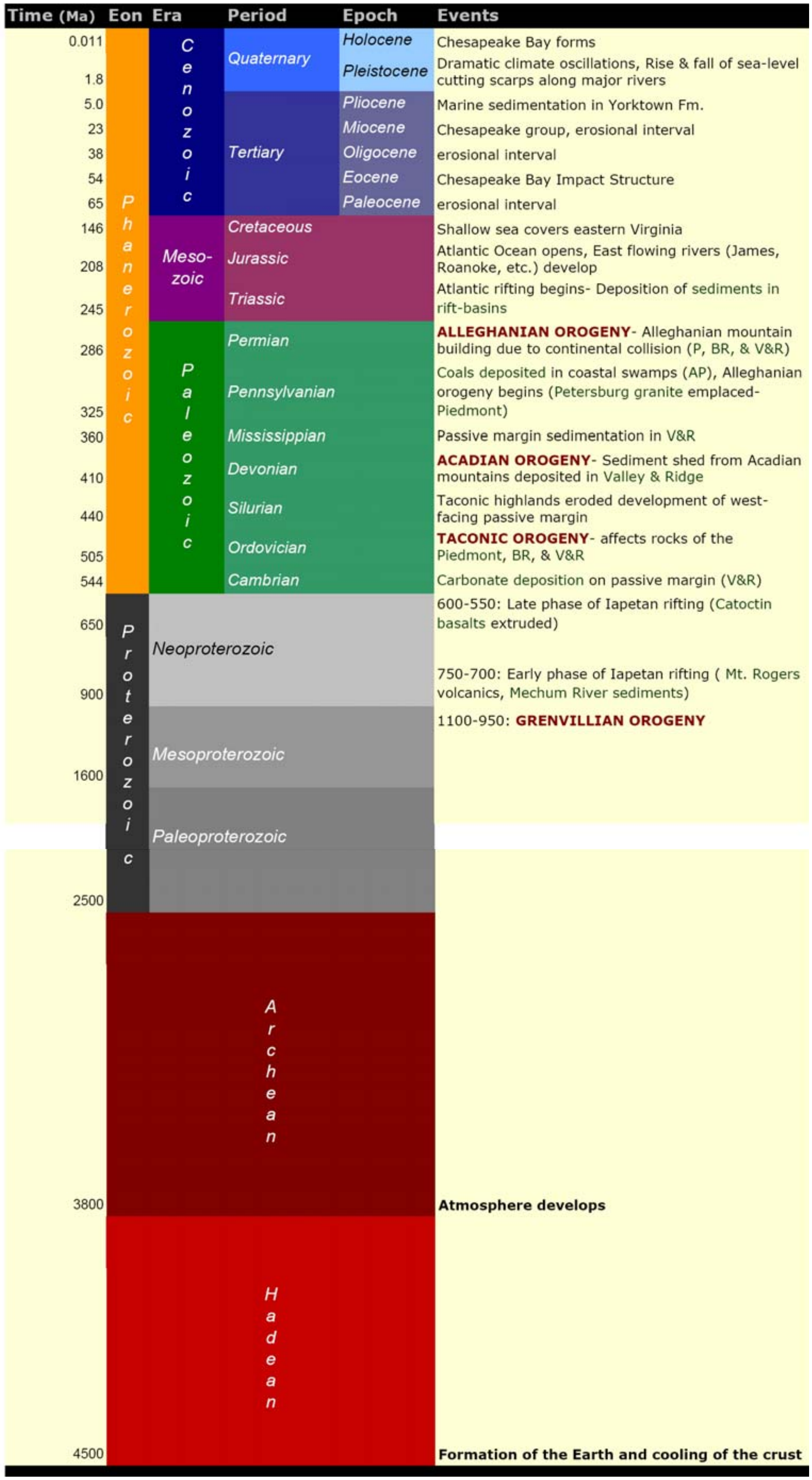


Figure: 3-36. Geologic Time Scale. *(William and Mary Department of Geology)*

Rifting and Creation of a Divergent Continental Margin

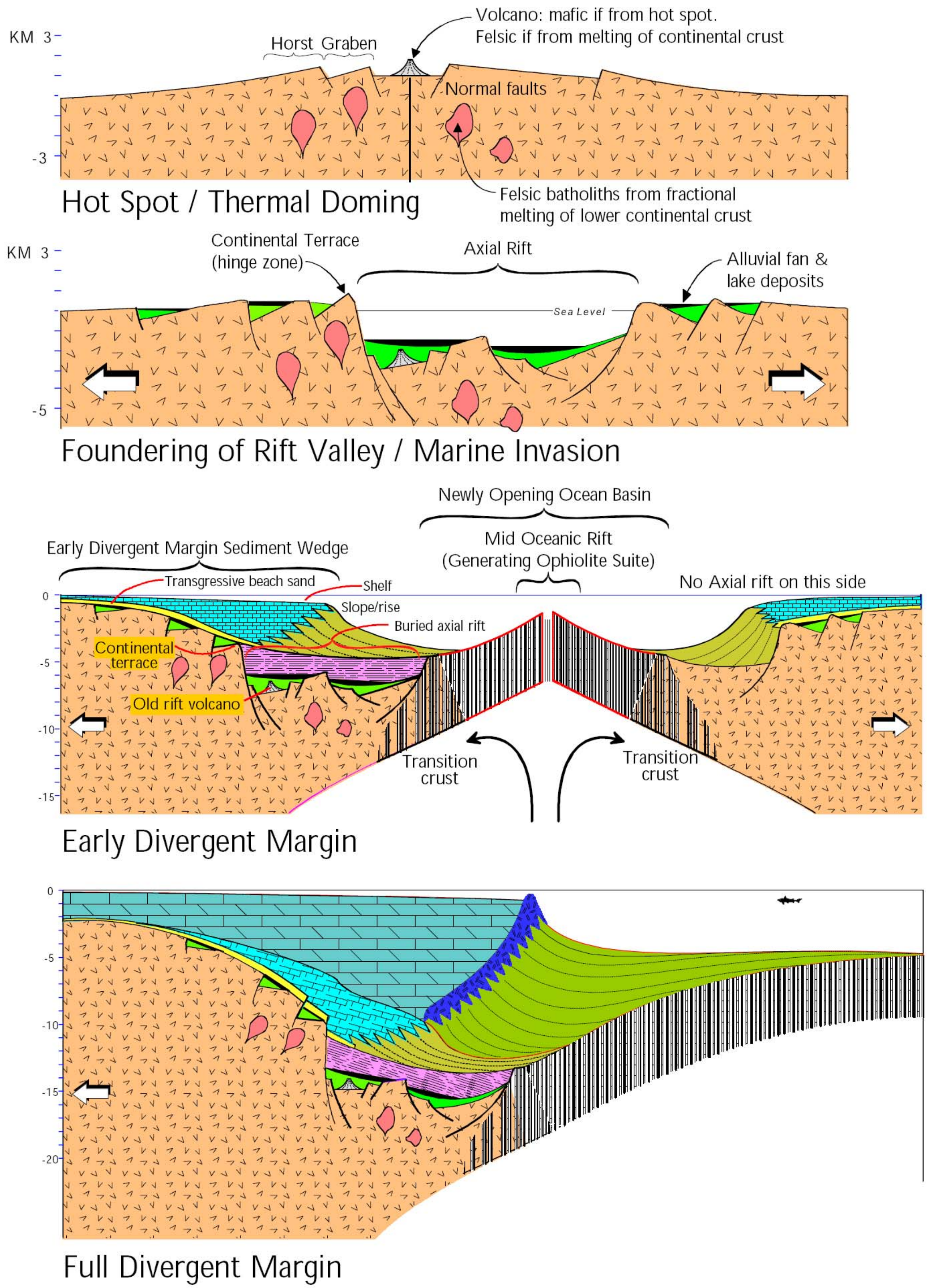


Figure: 3-37. Rift Basin Formation. *(James Madison University, Department of Geology)*

The most common soil order in the Piedmont is the Ultisol *(Buol, 1973)*, which have highly weathered soils with low base saturation. Base saturation is a measurement of the percentage of a soil's cation exchange capacity (negatively charged edges) that is occupied by the base cations $Ca2^{+}$, $Mg2^{+}$, Na^{+}, and K^{+}. Ultisols predominate over metasedimentary rocks and felsic intrusions. A second well-developed soil order, the Alfisols, consists of intermediately weathered soils with high base saturation. Alfisols are typically mapped over mafic and ultra-mafic parent materials, such as gabbro and diabase *(Genthner, 1990)*. Other common orders mapped in the Piedmont are Inceptisols and Entisols. These soils are both relatively unweathered soils showing little or no morphologic profile differentiation, and are commonly mapped on steep slopes, highly dissected uplands, or floodplains. *(The Geological Society of America Field Guide 16 2010)*

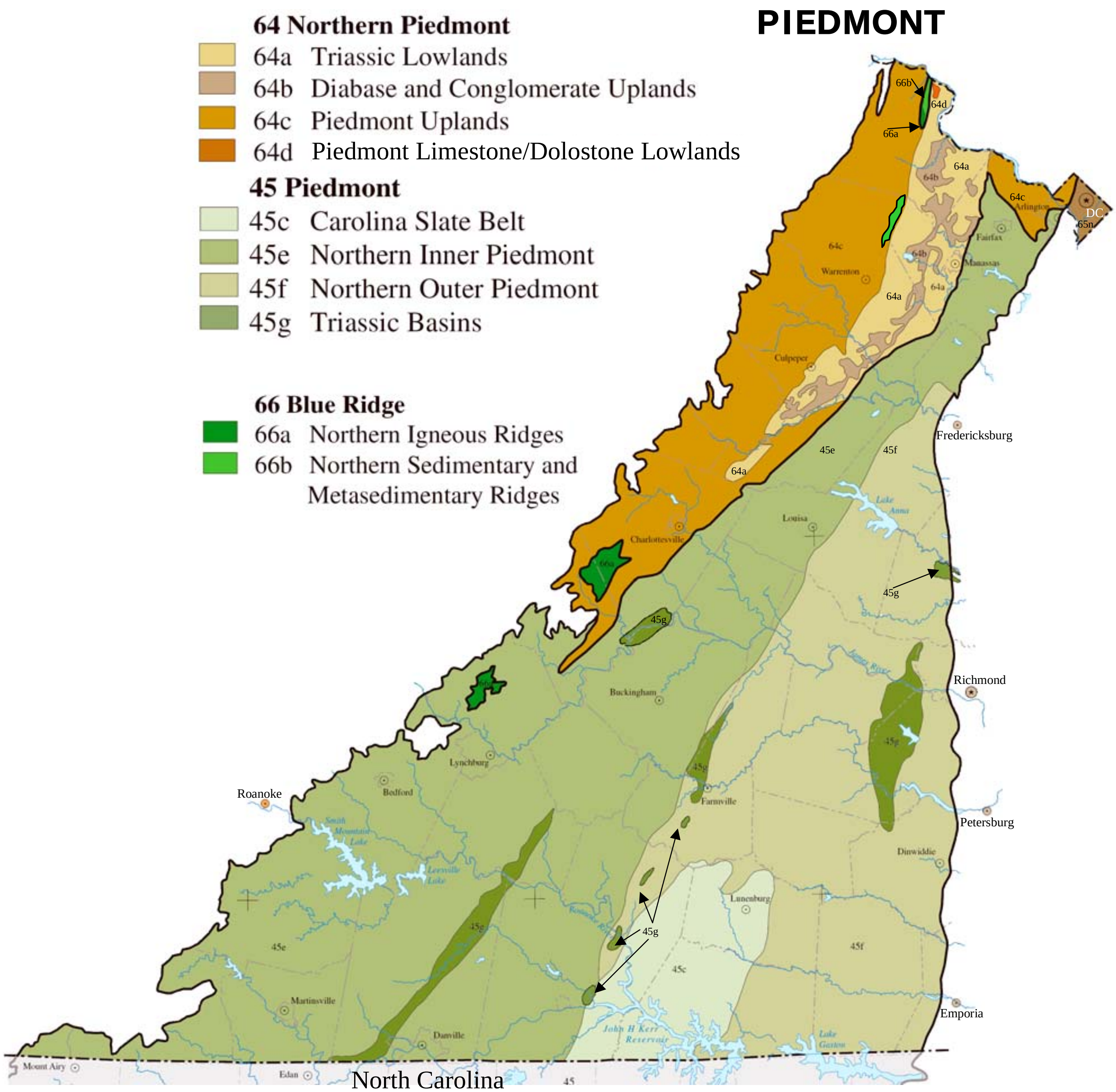


Figure: 3-38. Piedmont Ecoregions. *(EPA Level III Ecoregions of Virginia)*

45. Piedmont

The Piedmont (mapping unit 45) is largely wooded and consists of irregular plains, low rounded hills and ridges, shallow valleys, and scattered monadnocks. It is a transitional area between the mostly mountainous ecoregions of the Appalachians to the west and the lower, more level ecoregions of the coastal plain to the east. Crestal elevations typically range from about 200 to 1,000 feet (61 - 305 m) but higher monadnocks occur and reach 2,000 feet (610m). Following settlement, much of the area was cultivated causing significant soil loss.

The Piedmont (45) is underlain primarily by deeply weathered, deformed metamorphic rocks that have been intruded by igneous material. Sedimentary rocks also occur locally but are much less dominant than in the Middle Atlantic Coastal Plain (63) or the Southeastern Plains (65). Ultisols occur widely and have developed from residuum; they are commonly clay-rich, acid, and relatively low in base saturation. Thin veneers of soils weathered from transported material are also common throughout the piedmont. These commonly occur as terraces adjacent to streams and rivers and on upland divides. They also occur on colluvial landscapes.

The boundaries of the Piedmont (45) are shown on figure 3-38. The Fall Zone forms the border between the Piedmont and the lower Southeastern Plains (65) that are to the east of the Fall Zone. Ecoregion 65 is composed of fluvio-marine sediments that are lithologically distinct from those of Ecoregion 45. The boundary of the Piedmont (45) with the Blue Ridge Mountains (66) is based on elevation and topography. Ecoregion 66 is higher and far more rugged than Ecoregion 45. The boundary between the Piedmont (45) and the cooler Northern Piedmont (64) was determined by forest type and soil temperature. An oak – pine forest region encompasses Ecoregion 45 and an oak – chestnut forest region includes Ecoregion 64. On the ecoregion map (figure 3-38) the Piedmont (45) contains four subdivisions: the Carolina Slate Belt (45c), Northern Inner Piedmont (45e), Northern Outer Piedmont (45f), Triassic Uplands (45g).

45c. Carolina Slate Belt

The Carolina Slate Belt (45c) is an irregular plain with low rounded ridges and shallow ravines. Deeply weathered, fine-grained metavolcanic (metamorphosed igneous rock) and metasedimentary rocks (sedimentary rocks that have been metamorphosed) of the Carolina Slate Belt that have been intruded by igneous rock characteristically underlie this area. Within the Piedmont (45), only the sedimentary rocks of the Triassic Basins are finer-grained and less metamorphosed. Slate, phyllite, metasiltstone, metatuff, felsic volcanic rocks, and Virgilina Greenstone (metavolcanic) underlie Ecoregion 45c in Virginia. These rocks are somewhat less resistant to erosion than those of the adjoining Northern Outer Piedmont (45f) and physiography reflects these differences. Ecoregion 45c has lower crestal elevations and greater valley widths than adjoining ecoregions. Clay-rich weathering products (i.e. saprolite) have developed on bedrock but are typically thinner than in neighboring parts of the Piedmont. As a result, bedrock is close enough to the surface to impede both valley incision and erosion. Shallow depths to weathered bedrock and heavy textured soils may affect drainfield design. Local relief is 50 to 250 feet (15-76 m) and elevations range from 350 to 625 feet (107-191 m). The soils of the Carolina Slate Belt (45c) were derived from residuum and have high silt content. They are primarily fine-textured Ultisols. Soil series commonly identified in this mapping unit are: Goldston, Badin, Tatum, Tarrus, Nanford, Herndon, Georgeville, Cid and, Lignum. Veneers of transported sediments or *cappings* overlying these residual

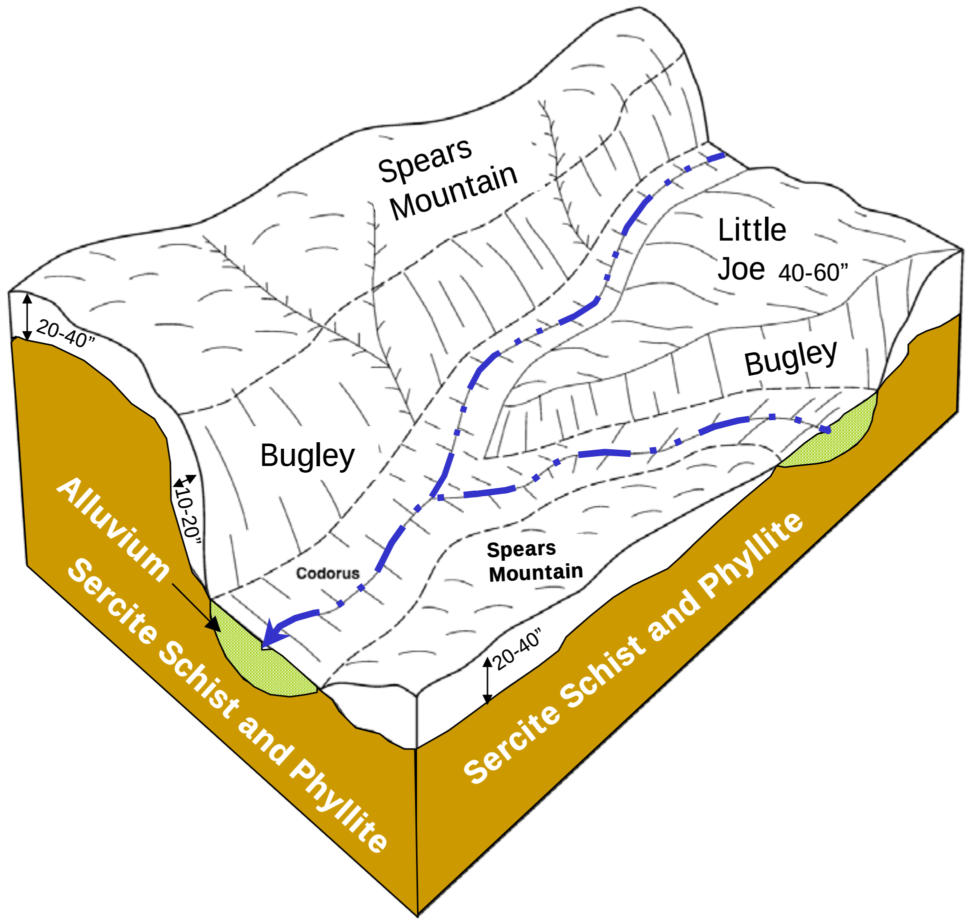


Figure: 3-39. Idealized soil catena in the Candler Formation (mesic) ecoregion 45e. These soils are typical of western Buckingham, Appomattox, Campbell, and eastern Bedford, Amherst, and Nelson Counties. These soils extend northward to Orange County. Little Joe is also known as Tatum (thermic) and Bugley is known as Manteo (thermic). Spears Mountain (mesic) is shallower than Tatum/Little Joe. Depth to bedrock is shown. The Candler Formation is thought to be a remnant of the eastern slope of the Blue Ridge Mountains and a mirror image of the Chilhowie Group *(personal communication William Henika, 2013)*.

soils are common and may have perched water tables above the contact between the capping and the residuum. Drainfield designs must accommodate these soil properties when encountered.

45e. Northern Inner Piedmont

Ecoregion 45e is a dissected upland composed of hills, irregular plains, and isolated ridges and mountains; monadnocks are far more common in Ecoregion 45e than in the Northern Outer Piedmont (45f). General elevations become higher towards the western boundary and to the south at the Roanoke River, where the land rises to become a broad, hilly upland. Elevations typically range from 200 to 1,000 feet (61-304 m) but higher elevations of up to 2,000 feet occur on scattered monadnocks. Local relief is typically 100 to 400 feet (30-121 m) but, on monadnocks, can be as much as 1,100 feet; in general, relief is markedly greater than in the Northern Outer Piedmont (45f) but less than in the Blue Ridge Mountains (66) to the west.

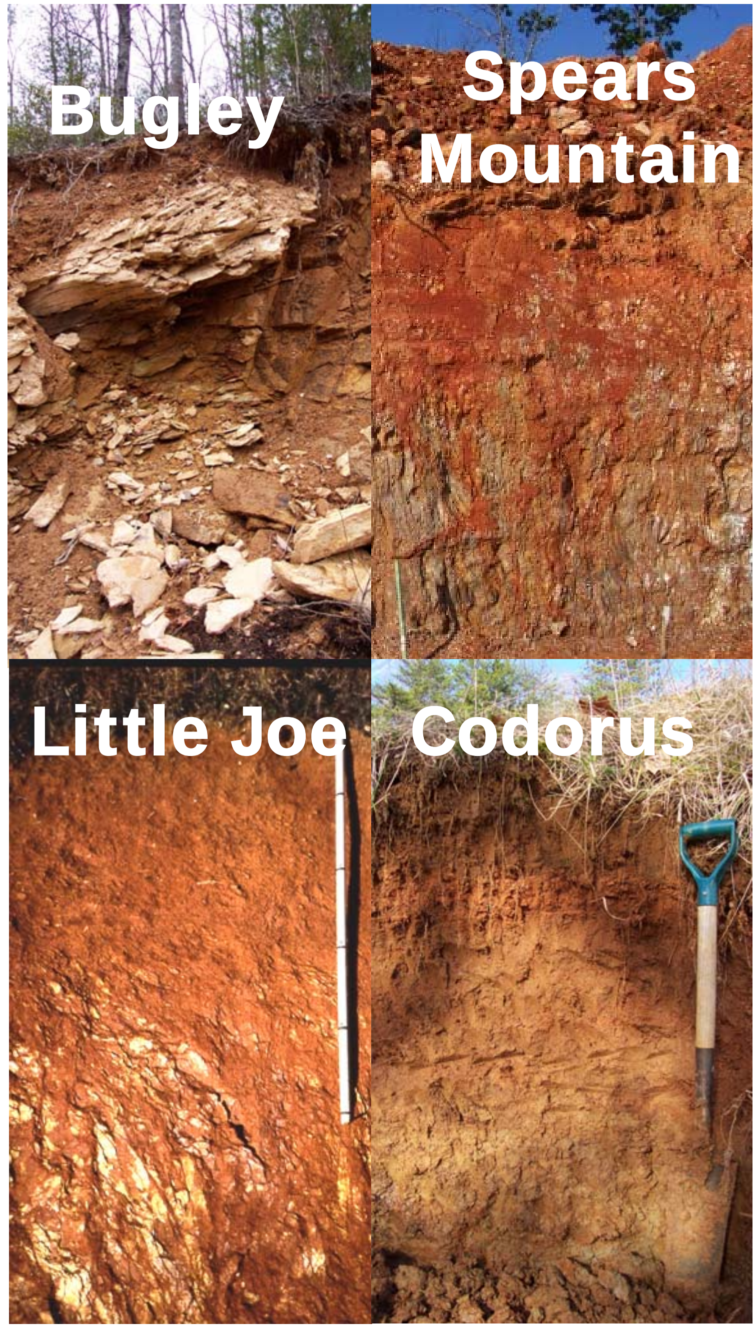


Figure: 3-40. Soil profiles form the catena found in ecoregion 45e on the previous page (figure 3-48). Note the increasing depth of the soils from top left to bottom right. Codorus Soils (Chewacla), found on floodplains, are alluvial soils and have a water table. Bugley Soils (Manteo) are 10-20 inches deep to bedrock. Spears Mountain (Badin) Soils are 20-40 inches to weathered rock. Little Joe Soils (Tatum) are 40-60 inches to weathered rock. These three (residual) soils are weathered from the same parent material. Landscape position has affected the depth to bedrock or paralithic (soft bedrock) material. *(Photos by Tom Saxton)*

The Northern Inner Piedmont (45e) is characteristically underlain by highly deformed and deeply weathered Cambrian and Proterozoic feldspathic gneiss, schist, and melange. It is intruded by plutons and is veneered by clay-rich weathering products (i.e. saprolite). Ultisols occur widely and have developed from residuum; they are typically clay-rich, acidic, and relatively low in base saturation. Commonly encountered soil series are: Cecil (Clifford), Madison, Pacolet (Fairview), Louisburg, Appling (Toast), Wedowee, Georgeville (Penhook), Tatum (Little Joe), Nason, Spears Mountain, and Manteo. Soils vary greatly in depth and character, but often provide some of the best properties for onsite sewage disposal systems in Virginia. Veneers of transported sediments or *cappings* overlying these residual soils are common and may have perched water tables above the contact between the capping and the residuum. Drainfield designs must accommodate these soil properties when encountered.

In areas where the bedrock has high base content with minerals such as hornblende, amphibole and chlorite, the soils may present difficulties for onsite sewage disposal systems. Some these soils may have shrink-swell properties and or high water tables with restricted permeability that preclude their use for drainfields. Soil series commonly found in these areas are: Iredell, (Jackland), Mecklenburg (Oak Level), Poindexter (Spriggs), Enon, and Wilkes (Siloam). Cullen (Minnieville) soils are commonly encountered on the borders where the mineralogy is mixed acid and basic in nature.

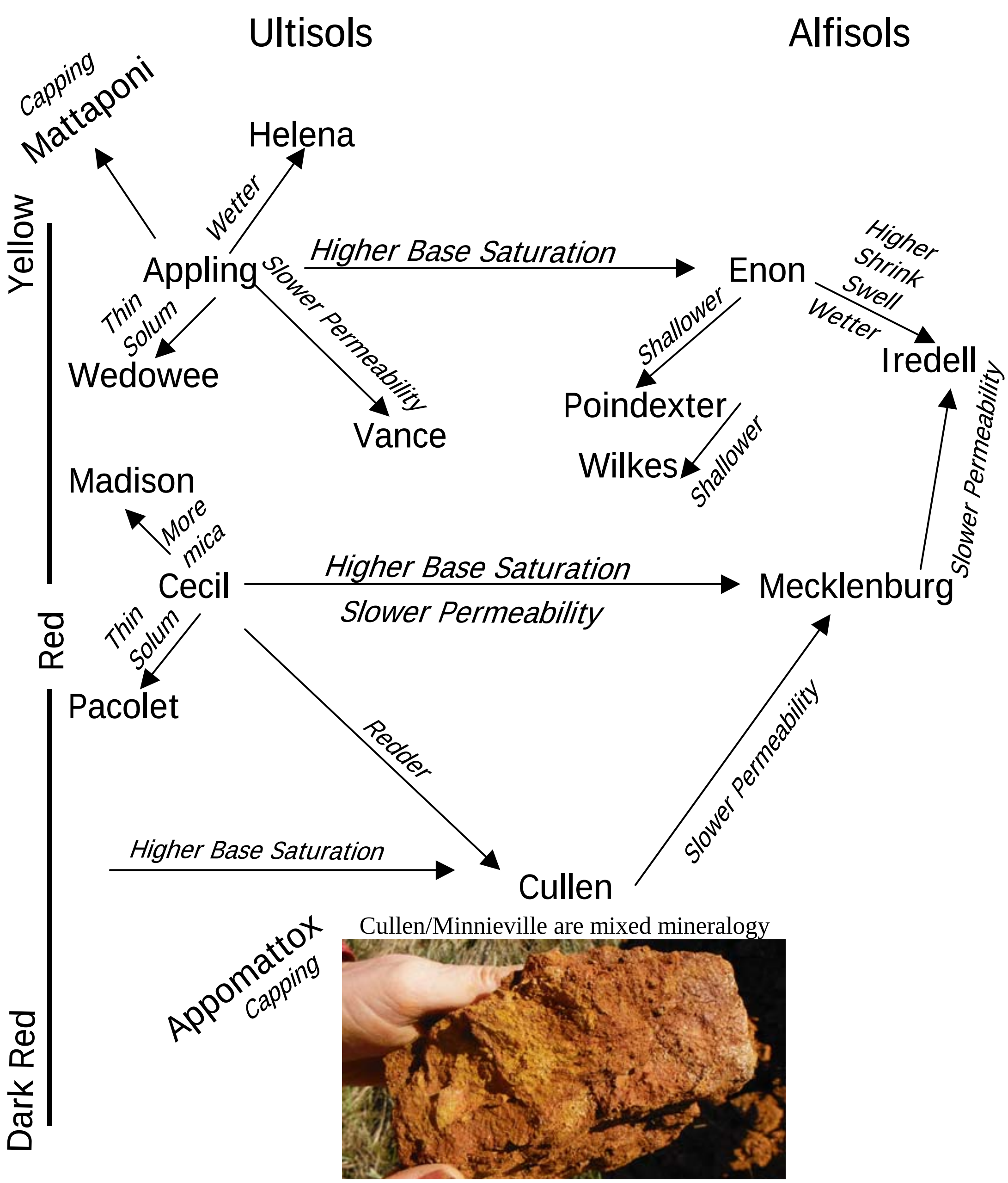


Figure: 3-41. Relationship between selected soils series found in the thermic portions of 45e and 45f.

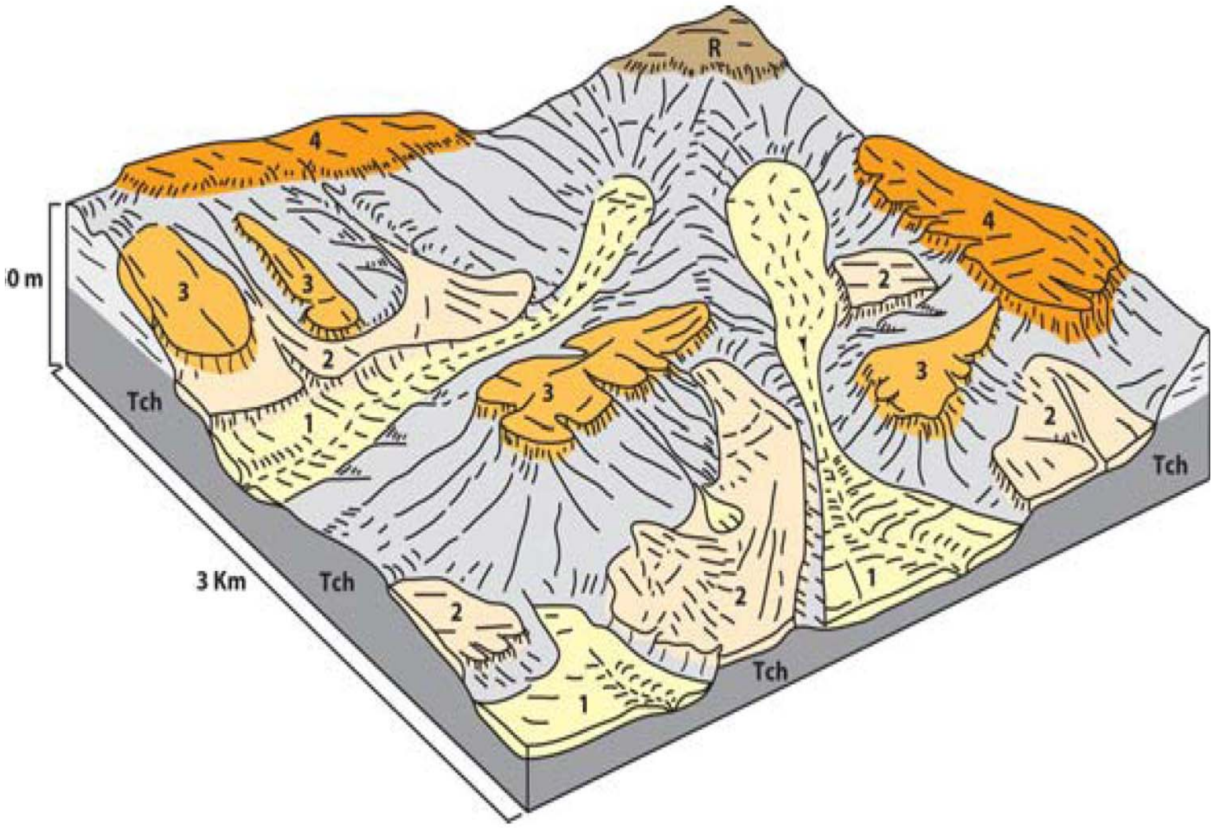


Figure: 3-42. Veneers of transported soils are located on various landscapes overlying Piedmont residuum. Tch represents Piedmont bedrock (country rock). Soil R is an old capping (Ultisol) that may have been deposited during Miocene time. This soil is red and clayey. Soil 4 is a capping that may have been deposited during Pliocene time and is yellowish red to strong brown and clayey (Ultisol). Soil 3 is weathered from Piedmont residuum (Ultisol). Soil 2 represents Pleistocene aged mass wasting deposits (colluvium) from higher elevations and resembles Piedmont residuum (Ultisol) and or low stream terraces. It may have a perched water table. Soil 1 is representative of recent (young) alluvial (Holocene) deposits that normally have a high water table (Inceptisols and Entisols) and are loamy. *(W.L. Newell and B.D. Dejong, Cold-Climate slope deposits and landscape modifications of the Mid-Atlantic Coastal Plain, Eastern USA Geological Society, London, Special Publications 2011; v. 354; p. 259-276 doi: 10,1144/SP354.17)*

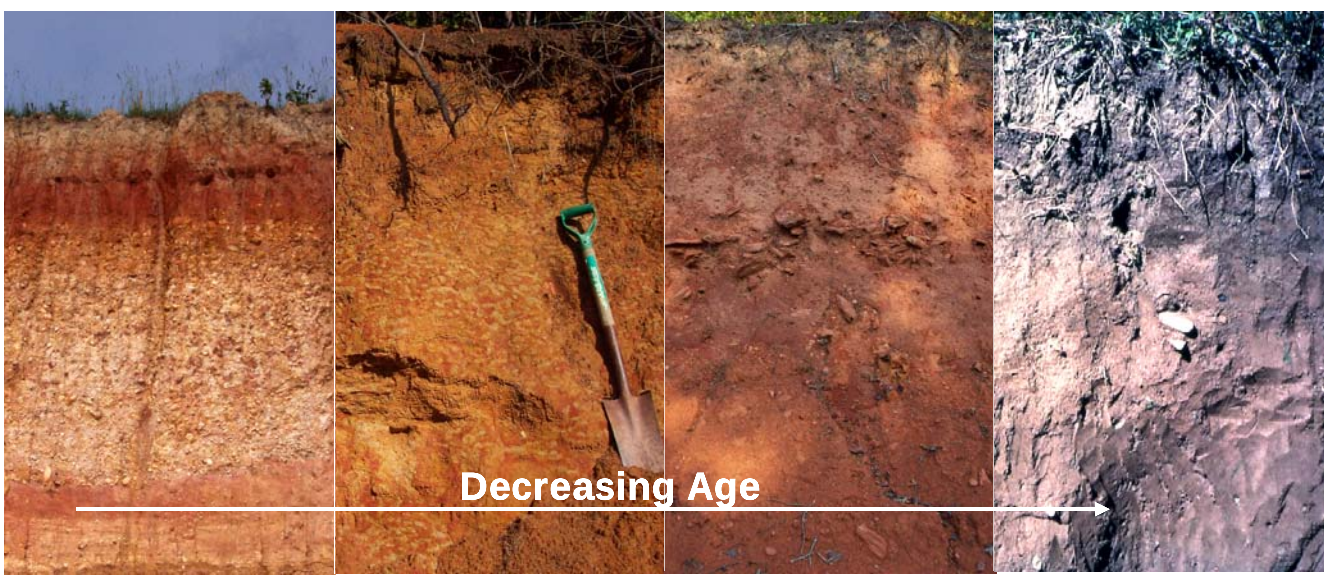


Figure: 3-43. Examples of transported soils. The profile on the left is representative of *Soil R* above (figure 3-42) and is the oldest deposit. The soil with the shovel represents *Soil 4*. Note the schist stone line in *Soil 2*. The right profile is a Holocene floodplain deposit representative of *Soil 1* and is the youngest deposit. *(Photos by Tom Saxton)*

45f. Northern Outer Piedmont

The Northern Outer Piedmont (45f) is an irregular plain with low rounded ridges and shallow ravines; ranges of low hills are scattered across Ecoregion 45f but monadnocks

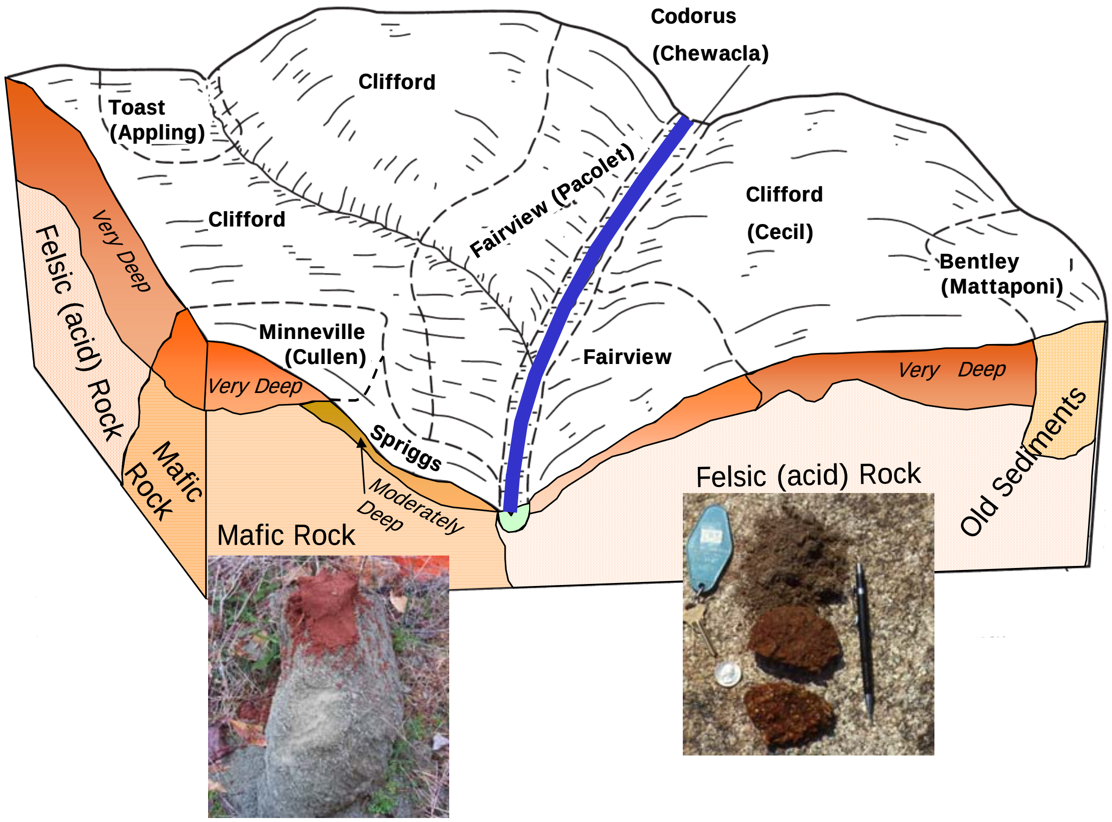


Figure: 3-44. This is a common catena found throughout the Piedmont. Soils in the southeastern piedmont are warmer (thermic) than soils found in the northern and western Piedmont (mesic). The soil names in parentheses were once mapped all over the piedmont. They are thermic. Once the temperature difference was recognized as a part of soil development, soils were given new names and identified in the colder portions (mesic) of the state. The two soils would not be different in the context of onsite sewage disposal. *(Photos by Tom Saxton)*

are more rare than in the Inner Piedmont (45e). An area of rapids, cascades, waterfalls, and islands (the Fall Zone) occurs along the eastern boundary of Ecoregion 45f where it adjoins the Coastal Plain. It contains urban and industrial areas such as Fredericksburg, Richmond and Petersburg. Elevations range from 200 to 675 feet (61-206 m) and relief varies from 100-250 feet (30-76

Figure: 3-54. The boundary between Clifford (Cecil) Soils (felsic) on the left and Minnieville (Cullen) Soils (mafic) on the right is clearly visible in Appomattox County near the eastern border of 45e. *(Photo by Tom Saxton)* m). Maximum relief and elevation are less than in the Northern Inner Piedmont (45e) to the west and greater than in the Middle Atlantic Coastal Plain (63) to the east. The Northern Outer Piedmont (45f) is underlain mostly by deformed, deeply weathered gneissic rock that is intruded by plutons and veneered with saprolite. It is lithologically distinct from the Carolina Slate Belt (45c) and sedimentary rock of the Triassic Uplands (45g). Ultisols predominate and have developed from residuum and deltaic deposit outliers west of the fall zone; they are commonly clay rich, acidic, and relatively low in base saturation. Commonly encountered soil series are: Cecil (Clifford), Madison, Pacolet (Fairview), Louisburg, Appling (Toast), and Wedowee. Soils vary greatly in depth and character, but often provide some of the best properties for onsite sewage disposal systems in Virginia. Veneers of transported sediments or *cappings* overlying these residual soils are common and may have perched water tables above the contact between the capping and the residuum. This becomes increasingly common with decreasing distance from the Fall Zone. Drainfield designs must accommodate these soil properties when encountered.

In areas where the bedrock has high base content with minerals such as hornblende, amphibole and chlorite, the soils may present difficulties for onsite sewage disposal systems. Some these soils may have shrink-swell properties and or high water tables with restricted permeability that preclude their use for drainfields. Soil series commonly found in these areas are: Iredell, (Jackland), Mecklenburg (Oak Level), Poindexter (Spriggs), Enon, and Wilkes (Siloam). Cullen (Minnieville) soils are commonly encountered on the borders where the mineralology is mixed acid and basic in nature.

45g. Triassic Basins The Triassic Basins (45g) ecoregion is an irregular plain with low rounded hills, gentle ridges, and shallow valleys. These basins occupy topographically lower terrains than surrounding ecoregions. They formed as rift basins much like today's African Rift Valley and Death Valley in California, during continental separation. The underlying sedimentary stratum is characteristic and is distinct from the metamorphic rocks of the surrounding portions of the Piedmont. Ecoregion 45g includes multiple discrete areas in Virginia. The Danville, Farmville, and Richmond Basins are the largest. Mesozoic rocks that were formed from sediments that washed into these rift valleys during Triassic and Jurassic time (see figure 3-36). Red Triassic sandstone, conglomerate,

Figure: 3-45. Triassic boundary conglomerate (breccia) located on the western edge of the Farmville Triassic Basin in Buckingham County. The western edge of the basin was once an escarpment (fault scarp). Piedmont country rock of various kinds rolled and tumbled down into the basin and were subsequently cemented together by the mud in the basin. This photo shows these pieces of country rock cemented in a sandy (purple) matrix. *(Photo by Tom Saxton)* siltstone, shale, and breccia (figure 3-45) of the Newark Supergroup dominate and dikes and sills composed of the igneous rock diabase also occur. Non-marine aquatic fossils and/or dinosaur tracks are found embedded in the sedimentary rock (Dietrich, 1990). Elevations range from 200-875 feet (61-267 m) and local relief is 75 to 450 feet (23-137 m). In the Farmville and Richmond basins, physiography is generally similar to surrounding crystalline rock areas but there is slightly less relief. Parts of the Danville Basin, in Pittsylvania County, on the other hand, are higher and have more relief than adjacent portions of the Piedmont because relatively resistant rocks, including conglomerate and graywacke, underlie them. In the Culpeper basin, topographic "highs" are normally underlain by diabase. Soils developed in these basins are often shallow to bedrock, have high water tables or have impermeable clays with high potential for shrinking and swelling. These characteristics have lead to less urban development due to lack of suitability for onsite sewage disposal systems. Shrink-swell soils have been a major problem in urban areas where sewer is provided because houses have been constructed despite the characteristics of the soils. In Chesterfield County, alternating shrinking and swelling of the soils has damaged many homes. Foundations have cracked and chimneys have collapsed as a result of this soil property.

Soil may spur more loan problems

Continued from first page

pointed by the buyer.

"You're dealing with a situation no one has really gotten a handle on," he said. "I don't think it's an area where the mortgage lender can be the judge and the jury at this point in time."

The mortgage lender's action also adds an exclamation point to a concern of homeowners with troubled foundations: that prospective buyers of their homes may not be able to obtain mortgages for current values.

A sketch of the details:

Last August, the Johnsons and their two children moved from Asheville, N.C., to Richmond when Stan Johnson became the associate director of the Hunter Holmes McGuire Veterans Affairs Medical Center in South Richmond.

In August, the Johnsons signed a contract on the Woodlake home being built by C. Richard Dobson Builders, a large home building outfit based in Newport News. The loan was approved by New Jersey-based PHH US Mortgage Corp., which sold the family's Asheville home.

The Johnsons made a $2,000 down payment to the builder and also paid for the upgrades to the approximately $139,000 home.

"We were to close on October 31st, but everything wasn't finished," Mrs. Johnson said. "We delayed it about a week. During that

1992 Richmond Times Dispatch Shrink-swell soil problems

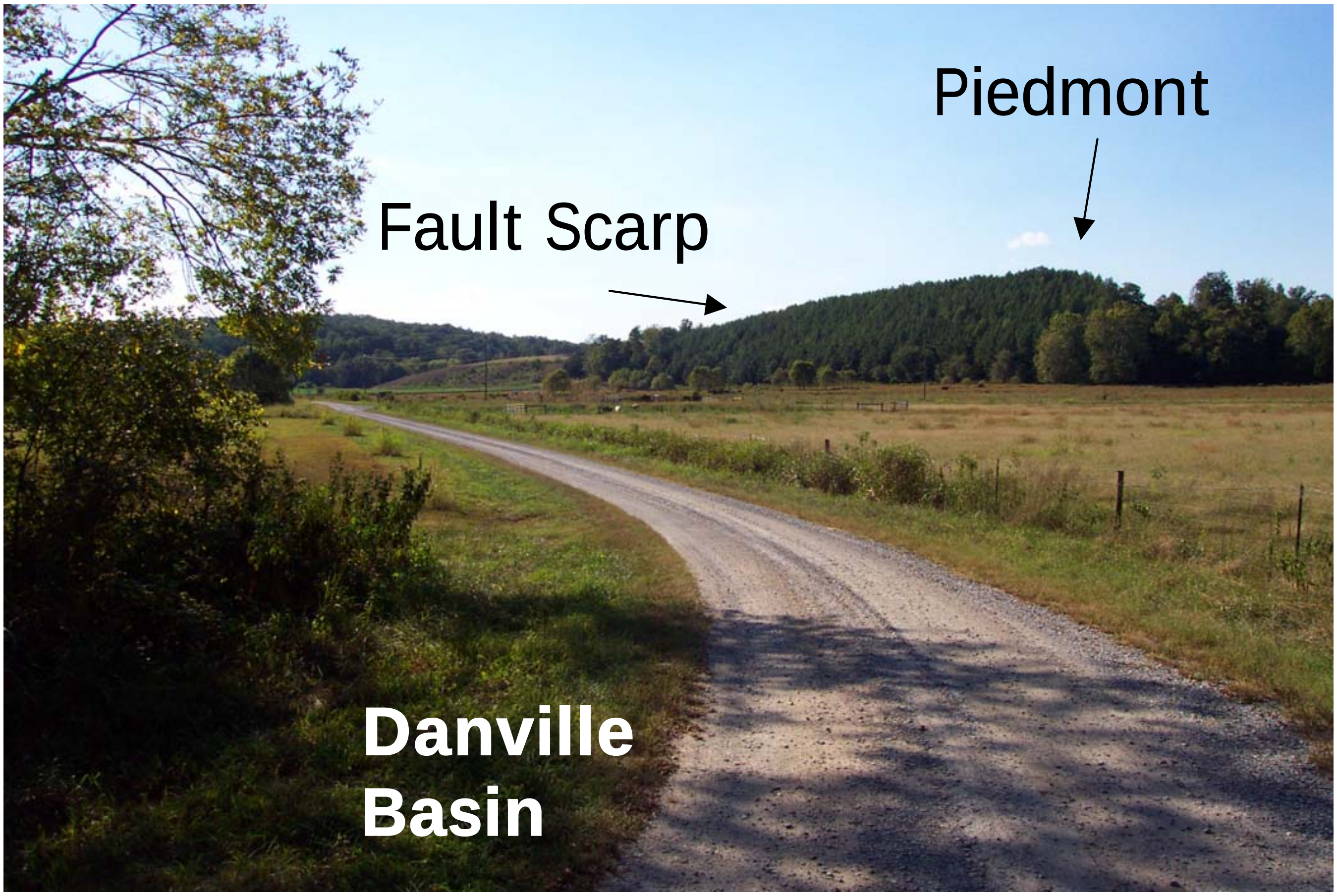


Figure: 3-46. An old eroded fault scarp is clearly visible in the northern portion of the Danville Basin. This escarpment was once much higher in elevation relative to the basin. Piedmont on the photo refers to Piedmont country rock or rock that is older than the rock found in the basin. *(Photo by Tom Saxton)*

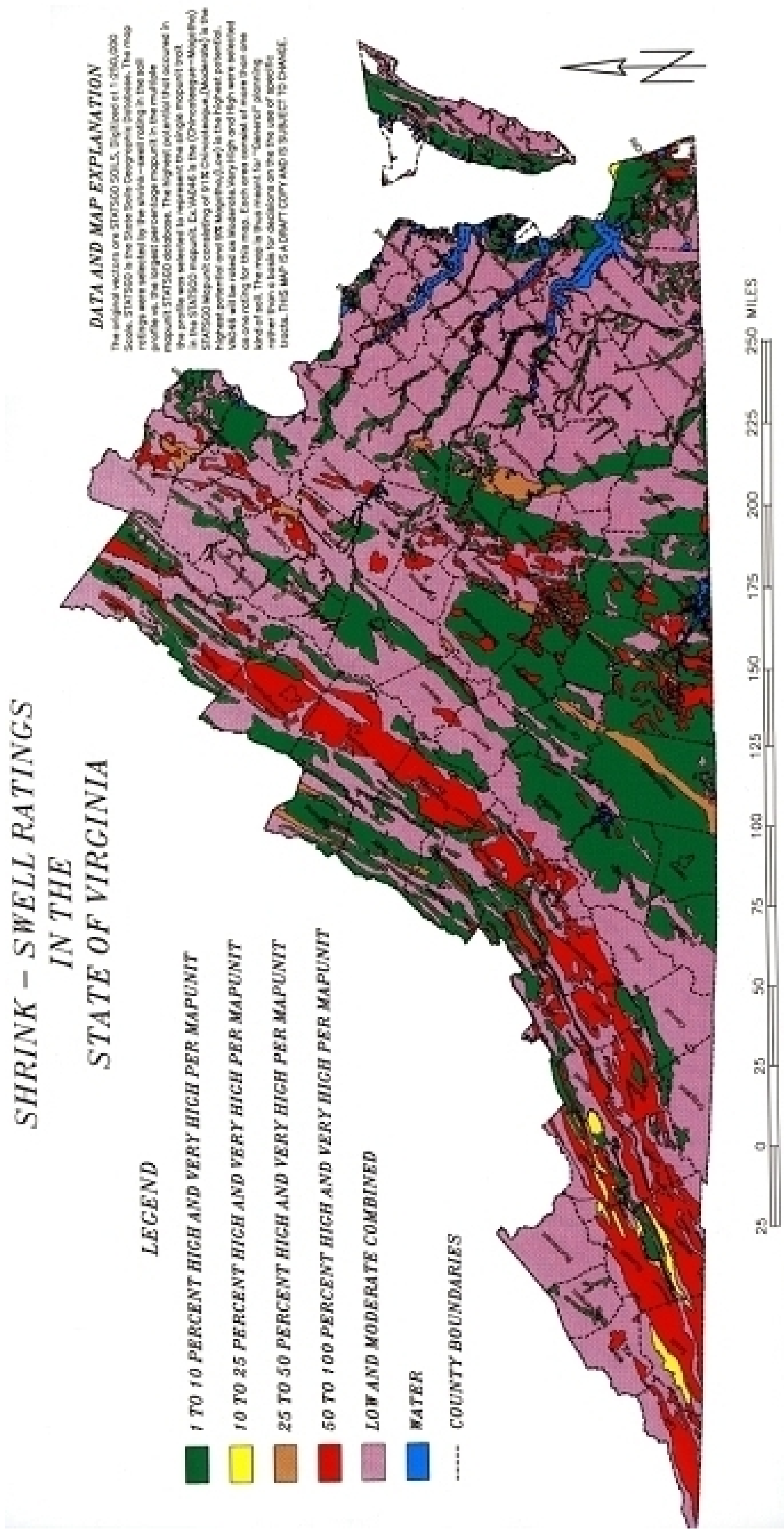


Figure: 3-46B .Shrink-swell soils in Virginia Counties. *(NRCS)*

64. Northern Piedmont

Ecoregion 64 consists of low rounded hills, irregular plains, and open valleys and is underlain by metamorphic, igneous, and sedimentary rocks. Crestal elevations typically range from about 325 feet (99 m) on limestone to 1,300 feet (396 m) on more resistant metamorphic rock. Isolated, higher, rocky hills and ridges occur and were formed by diabase intrusions. Soils within the Northern Piedmont (64) are generally deep, well-developed Alfisols and Ultisols. The border with the Valley and Ridge (67) is based on topography, lithology, and geological structure. The boundary with the Piedmont (45) is based on potential natural vegetation and soil temperature; the dominantly Appalachian Oak Forest of the Northern Piedmont (64) contrasts with the Oak-Hickory-Pine Forest of Ecoregion 45 to the south.

On the ecoregion map (Figure 3-38), the Northern Piedmont (64) is composed of four subdivisions: the Triassic Lowlands (64a), the Diabase and Conglomerate Uplands (64b), the Piedmont Uplands (64c), and the Piedmont Limestone/Dolostone Lowlands (64d) located in a small area of Loudon County. Descriptions of the individual characteristics of these four ecoregions follow.

64a. Triassic Lowlands

Ecoregion 64a is a plain underlain and delineated by sedimentary rock and characterized by wide undulating ridges, broad nearly level valleys, limited local relief. Typical hilltop elevations generally rise westward from 175 to 600 feet (53-183 m) and local relief is only 30-200 feet (9-61 m). Ecoregion 64a is higher than the Piedmont Limestone/Dolostone Lowlands (64d), but lower than either the Piedmont Uplands (64c) or the Diabase and Conglomerate Uplands (64b); it is not as deeply dissected as Ecoregion 64c. The boundaries of Ecoregion 64a generally occur at the limit of nonresistant Triassic deposits. Changes in topography and soils often coincide with these boundaries.

Soils of Ecoregion 64a were derived from Triassic-Jurassic sandstone, shale, siltstone, and basalt (that occurs only in the Culpeper basin as three principle basalt flows separated by sedimentary rocks *(Virginia Division of Mineral Resources 1993)*). These rock types are all members of the Newark Supergroup and include two basins: the Barboursville and Culpeper Triassic Basins. Mostly deposited as a shallow-water mud in lakes and slow streams, this rock recorded footprints of several species of dinosaurs and other reptiles, best known from exposures in a large quarry near Culpeper. Roads paved with rock from this quarry appear purple in color. The lithology is distinct from the metamorphic rocks of the surrounding portions of the Piedmont. The soils were derived from residuum and are mostly Alfisols containing a moderate to high level of subsoil base saturation. They are less fertile than the Alfisols of Ecoregion 64d, which were derived from carbonates, but are slightly more fertile than the Ultisols and Inceptisols of Ecoregion 64c, which were derived from metamorphic rock. Soils weathered from these rocks are often shallow to bedrock and have a distinct dusky red or purple-brick color. Common soil series recognized in this mapping unit are: Clover, Nestoria, Oatlands, Panorama, Dulles, Bucks, and Penn. Present day flora and vegetation on basic soils in the Culpeper Basin are distinct from that occurring on more acid, less fertile soils of the neighboring Piedmont Uplands (64c) that are underlain by Paleozoic and Precambrian metamorphic rock. High water tables are more common than in surrounding piedmont soils. Many of the soils have distinctively heavy plastic clay that is subject to shrink-swell characteristics. These factors limit the use of the soils in this mapping unit for drainfields.

The following is a description of how soil classification is employed to identify and separate different soils in the United States. The U.S. Department of Agriculture's soil taxonomic classifications are read from right to left, and the formative elements of the *subgroup* are in italics. An example for a soil commonly found in 64a is the Penn Soil Series. These soils are fine-loamy, mixed, superactive, mesic *Ultic Hapludalfs*.

Order → *Alfisol* (clay-rich, high base saturation)

Suborder → *Udalf* (udic soil moisture regime)

Great Group → *Hapludalf* (insufficiently distinguished [morphologically or chemically] to merit classify cation as another great group)

Subgroup → *Ultic* Hapludalf (sufficiently leached that base saturation is lower than for a Typic Hapludalf).

Penn surface horizons are dark reddish brown (5YR 3/3), silt loams, and have relatively low base saturation. Subsurface horizons show increases in gravels (>2 mm) or channers, as well as a pronounced color shift to redder hues (2.5YR 4/4) that reflect the underlying parent material, often reddish shale, siltstone, or fine-grained sandstone of Triassic–Jurassic age (145–250 m.y. B.P.). *(Sherwood et al., 2010)* Depth to weathered bedrock ranges from 20-40 inches. The subsoil is silt loam, silty clay loam or clay loam.

64b. Diabase and Conglomerate Uplands

Ecoregion 64b is characterized by wooded, stony, hills and steep ridges that are composed of highly resistant igneous (diabase), heat-altered sedimentary rock, or sedimentary rock. Crestal elevations are typically 300-1,150 feet (91-351 m). Local relief varies substantially from a minimum of about 50 feet to a maximum of 650 feet (15-198 m). Ecoregion 64b is underlain mostly by Triassic conglomerates and reddish sandstones that were intruded by Triassic and Jurassic diabase along a series of linear sills and dikes. The

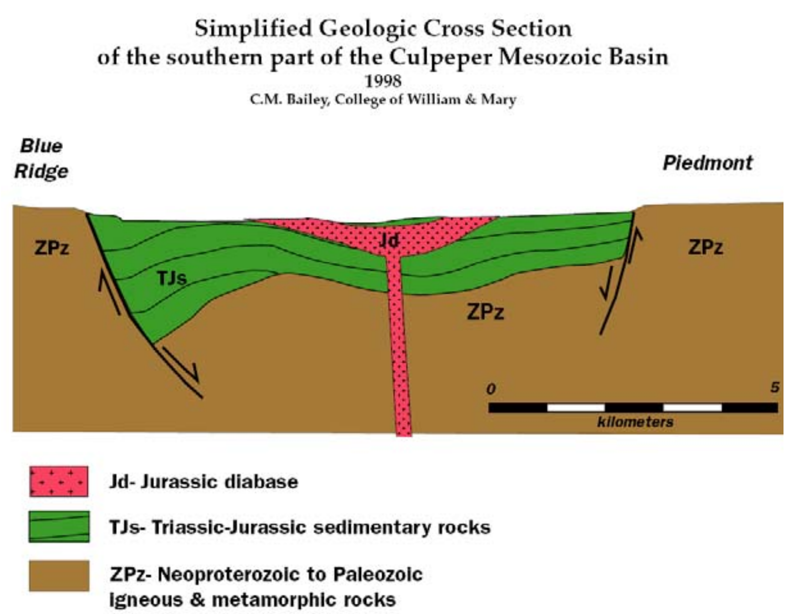


Figure: 3-47. 64a and 64b geological cross-section. *(William and Mary Department of Geology)* igneous rocks include flows of basalt that erupted on the surface and subsurface intrusions of basaltic magma known as diabase. These intrusions, in turn heated, nearby sediments and altered them into harder, denser, and less porous material such as hornfels (baked shales). Examples of soils weathered from hornfels are: Sycoline, Kelly and Catlett. The primary ridge formers are conglomerates and, most commonly, diabase (trap rock). Diabase is quarried extensively in Northern Virginia to produce the familiar gray crushed stone found on roadways. Common soil series are: Hattontown, Haymarket, Jackland, and Waxpool. Soils weathered from these rocks often contain shrink-swell clays, shallow depth to bedrock and high water tables and commonly are not suitable for onsite sewage disposal systems.

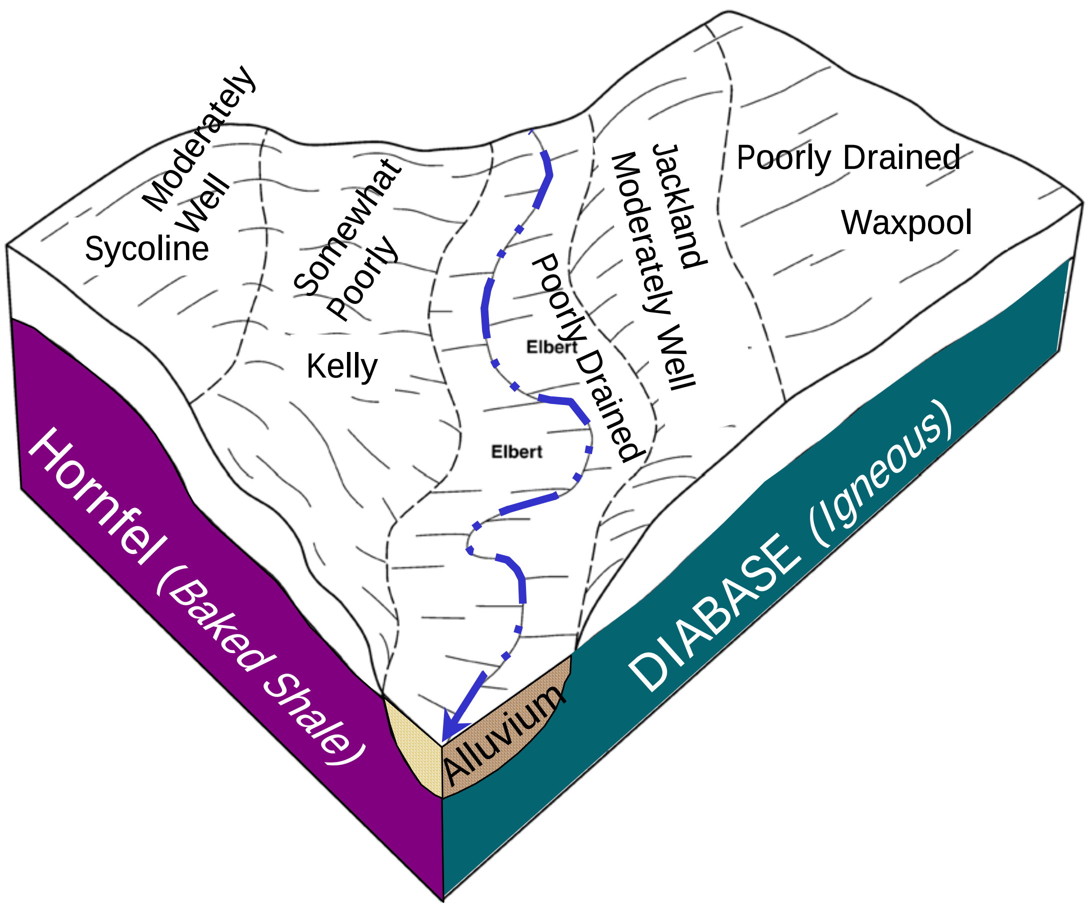


Figure: 3-48. Idealized landscape in ecoregion 64b. These soils are all composed of heavy plastic clays with shrink-swell properties. Please refer to Chapter 2 for soil drainage. *(NRCS Soil Survey of Culpeper County)*

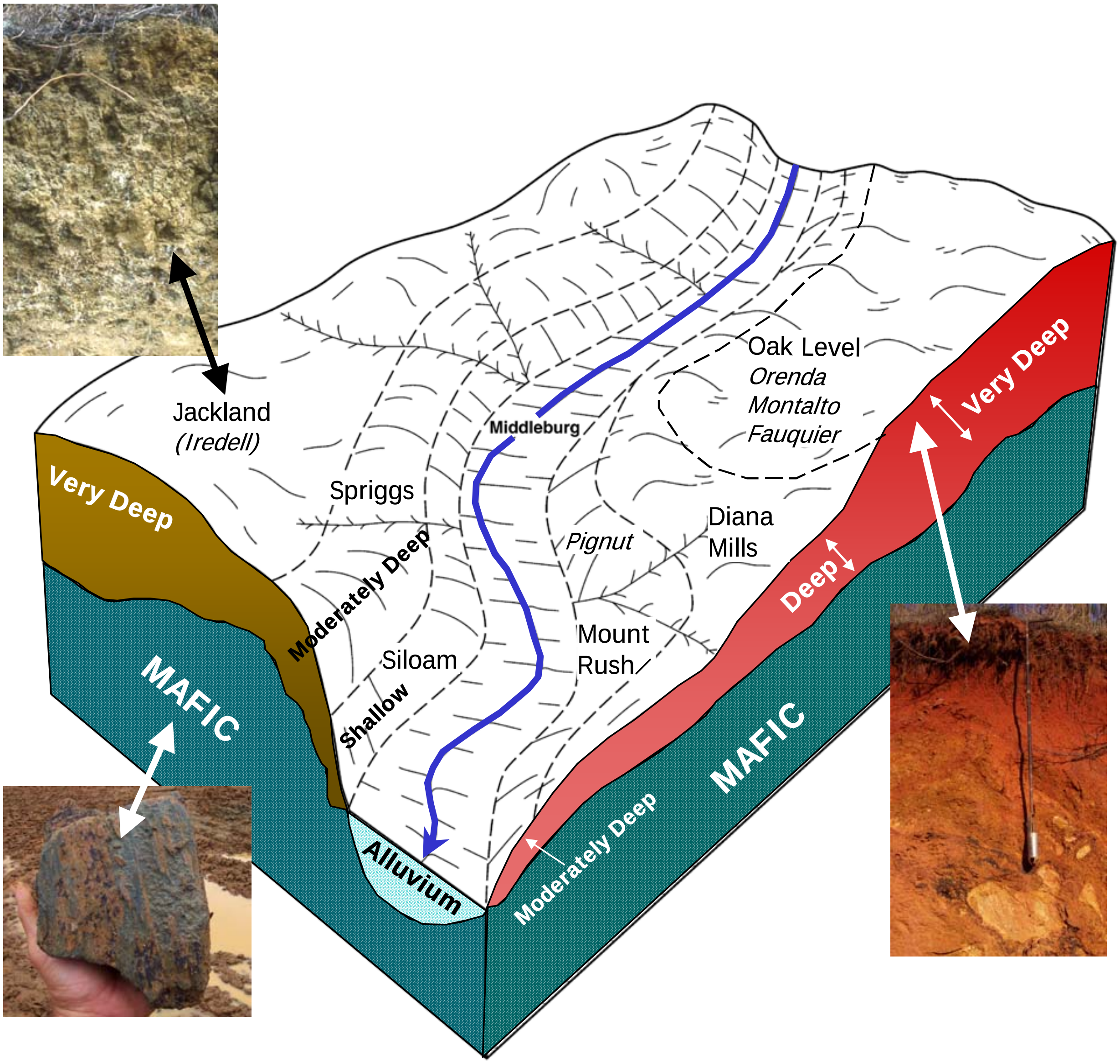


Figure: 3-49. Two idealized catenas of soils, that commonly weather from mafic bedrock. Catena's similar to this are common throughout much of the Piedmont of Virginia. Similar landscapes may be found in the 64c, 45e and 45f mapping units. The soil names may be changed in different parts of the state due to soil temperature or mineralogy, but generally, the properties are similar. There are other soil names shown in italics that may be used in different parts of the state.

The clays in the *Jackland* landscape normally have high to very high shrink-swell potential and have moderately slow to very slow permeability. The clays in the *Oak Level* landscape have moderate to high shrink-swell potential and moderate to slow permeability. Depth classes are as follows: very shallow less than 10 inches, shallow 10 to 20 inches, moderately deep 20-40 inches, deep 50- to 60 inches, and very deep is greater than 60 inches. The soils on the *Oak Level* landscape are redder than the soils on the *Jackland* landscape. In this case, depth refers to depth to weathered bedrock. Generally, the steeper the slope the shallower the soil. *(Photos by Tom Saxton)*

64c. Piedmont Uplands

Ecoregion 64c is characterized by rounded hills, low ridges, relative high relief, and narrow valleys and is underlain by metamorphic rock. Irregular plains and narrow valleys typically have elevations that often range from about 450 feet to 1,000 feet (137-304 m) and a local relief that is often 130 feet to 330 feet (40 to 101 m). The Piedmont Uplands (64c) have substantially higher relief than the Triassic Lowlands (64a), Piedmont Limestone/Dolostone Lowlands (64d), or the Outer Piedmont (45f). Metamorphic rocks of Lower Paleozoic and Precambrian age underlie the ecoregion and are folded and faulted. Precambrian gneisses are common in the east. Deep Ultisols and Inceptisols are common and have developed from residuum. These Ultisols are capable of supporting highly diversified farms, even though they are less fertile than the soils of Ecoregion 64d. Soils derived from quartzite are commonly stony and are often forested. The boundary of Ecoregion 64c follows the limit of the Lower Paleozoic and Precambrian metamorphic rocks; they are distinct from the largely sedimentary rock of the surrounding ecoregions. These soils are generally well suited for onsite sewage disposal systems.

64d. Piedmont Limestone/Dolostone Lowlands (Loudon County)

Ecoregion 64d is a very fertile and intensively farmed area underlain mostly by limestone and dolostone. These carbonates have been weathered to form a nearly level to undulating terrain that contains sinkholes, caverns, and disappearing streams. Ecoregion 64d is lithologically distinct from the metamorphic rock of the neighboring Piedmont Uplands (64c). Elevations are lower than adjacent ecoregions, typically 250-525 feet (76-160 m). Ordovician limestone predominates. It provides a high yielding aquifer riddled with solution channels that reduce water filtration; as a result, groundwater is sometimes contaminated. Other Ordovician and Cambrian formations occur and contain limestone, dolostone, and shale. The soils, unlike those of surrounding ecoregions, are derived largely from carbonate rock and are very fertile. These base-rich Alfisols (Hapludalfs) developed under a humid and mild climate. The Piedmont Limestone/Dolostone Lowlands (64d) have a favorable natural environment for agriculture. The limitations for onsite sewage disposal systems are the potential to contaminate groundwater, rock out-crops and slowly permeable subsoils.

The Geology of the Blue Ridge Province encompasses the oldest rocks in Virginia. Amongst these rocks are different types of granite, which date back over one billion (1,200,000,000) years. Some of the rocks in the Blue Ridge were there before there was even life on Earth. Younger rocks from the Paleozoic era cover the eastern side of the Blue Ridge. The rocks that make up the Blue Ridge (A) have been shoved over the rock layers of its neighbor to the west, the Valley & Ridge province. The rocks were moved to the northwest, when what today is today Africa and North America, were sandwiched together, pushing the Blue Ridge on top of the Valley & Ridge along a fault. Rock deformation of older igneous and metamorphic rocks show that the continents squeezed together during the Paleozoic. The gap that formed when Africa and Virginia spread apart is known as the Iapetus Ocean. A series of sedimentary rocks derived from the weathering of the interior of the ancestral North American Continent ranging from alluvial conglomerates to marine shales were deposited along with volcanic ash into this ocean.

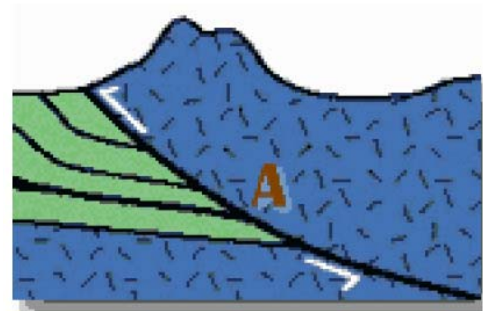


Figure: 3-50. The Blue Ridge (A) was shoved over top of the Ridge and Valley (green) during continental collisions. *(William and Mary Department of Geology, C.M. Bailey)*

In areas of the central and northern Virginia Blue Ridge, basalt flows associated with the opening of the Ipapetus Ocean 570 million years ago, flowed out over the sedimentary units. Later, these basalts were metamorphosed to form the greenstones of the Catoctin Formation (66a).

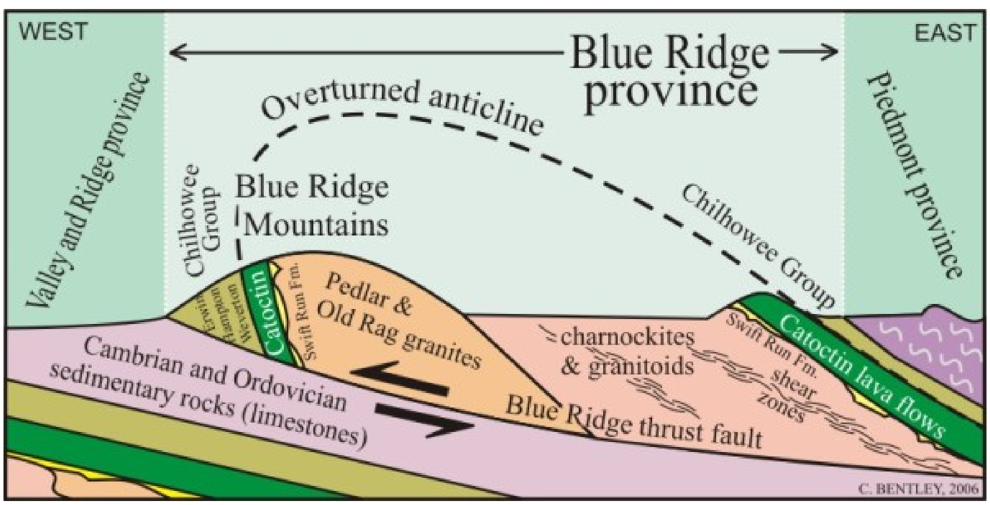


Figure: 3-51. Blue Ridge anticlinorium as conceived by Callan Bentley (NVCC).

When the Iapetus Ocean opened, the sea level rose, moving the beaches inland. Following this rifting and associated basalt flows mentioned above, clastic sediments *(composed of rock fragments)* associated with the Iapetus Ocean margin covered portions of the flows. These make up the Chilhowie Group (66b), which occupy the western flank of the Blue Ridge Mountains and the Candler Formation east of Southwest Mountain. Metamorphism that altered the Catoctin basalts to greenstone affected the siliceous clastic rocks producing mainly quartzites, phyllites, and schists.

Today, the Shenandoah National Park occupies much of the Blue Ridge Mountain crest in northwestern Virginia. Moving eastward from the Blue Ridge Mountains toward the core of the Blue Ridge Province, a number of monadnocks or inselbergs are evident in the western portion of the province. Farther east, the land is gently rolling until it reaches a low ridge composed of Catoctin greenstone that forms the eastern edge of the Blue Ridge Province. Structurally, the Blue Ridge has been described as an anticlinorium (see Figure 3-51) with the flanks held up by the relatively resistant Catoctin greenstone and the oldest rocks in the center.

Figure: 3-52. Blue Ridge Mountains in Nelson County. Photo taken from the top of Crab Tree falls. *(Photo by Tom Saxton)*

Figure: 3-53. Typical New River Plateau (66c) landscape. Christmas Tree Farms are in the Blue Ridge Physiographic Province. *(NRCS Soil Survey of Grayson County)*

In the southern Blue Ridge of Virginia, a broad plateau-like upland rises over 500 m from the Piedmont along a prominent escarpment. Mount Rogers in the southwestern Virginia Blue Ridge, at 1746 meters, is the highest peak in Virginia. An igneous event dating from about 800 mya to 600 mya occurred in this area. It includes the remains of a rhyolitic volcanic pile and a volcano.
(William and Mary Department of Geology Blue Ridge Province for Students & Teachers The Geology of Virginia.htm. And W. Cullen Sherwood, Tony Hartshorn and L. Scott Eaton; Department of Geology and Environmental Science, James Madison University; The Geological Society of America, Field Guide 16 2010)

66. Blue Ridge Mountains

Ecoregion 66 is a narrow strip of mountainous ridges that are forested and well dissected. Crestal elevations range from about 1,000 feet to over 5,700 feet (305-1,737 m) on Mt. Rogers and tend to rise southward. Local relief is high and both the side slopes and the channel gradients are steep.

The Blue Ridge Mountains (66) are underlain by resistant and deformed metavolcanic, igneous, sedimentary, and metasedimentary rock. Inceptisols, Ultisols, and Alfisols have developed on the Cambrian, Paleozoic, and Precambrian rock. Colluvium is more common than residuum. Generally, colluvium is suitable for onsite sewage disposal systems; however, there are often limitations. These include: perched water tables and discontinuities with rates of absorption too slow immediately above and below the discontinuity.

The Blue Ridge Mountains (66) can be divided into northern (ecoregions 66a and 66b) and southern parts (ecoregions 66c, 66d, 66e) at the Roanoke River (Hack, 1982). South of the Roanoke River, the Blue Ridge Mountains become higher and lithologically complex. Climate varies significantly. Generally, both growing season and precipitation increase southward. The frost-free period varies from less than 150 days to more than 175 days, and the precipitation varies from 39 to 49 inches (99-124 cm). Locally, however, relief and topographic position have significant effects on the microclimate.

On the ecoregion map (figure 3-65), the Blue Ridge Mountains ecoregion (66) is composed of five sub-regions: the Northern Igneous Ridges (66a), the Northern Sedimentary and Metasedimentary Ridges (66b), the Interior Plateau (66c), the Southern Igneous Ridges and Mountains (66d), and the Southern Sedimentary Ridges (66e).

Figure: 3-54. Looking southwest from the Blue Ridge Parkway on the Nelson County – Augusta County border. Meta-igneous (Catoctin Greenstone) rocks are in the foreground (66a) and metasediments of the Chilhowie Group (slate, phyllite and quartzite) are in the background (66b). Note that drainage ways often occur at geologic and soil boundaries. *(Photo by Tom Saxton)*

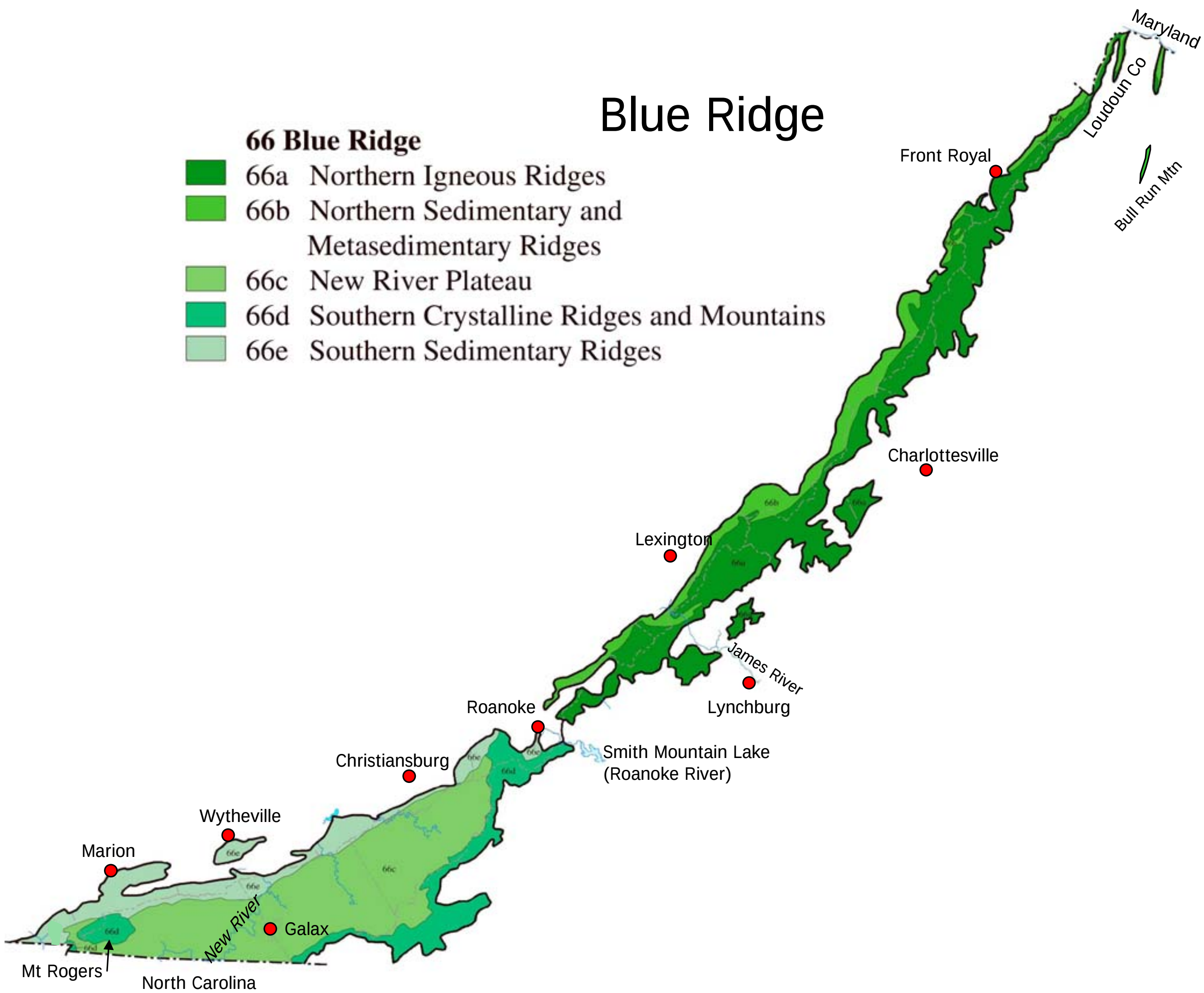


Figure: 3-55. The Blue Ridge Mountains. The northern section is separated from the southern at the Roanoke River (Smith Mountain Lake). *(EPA Level III Ecoregions of Virginia)*

66a. Northern Igneous Ridges
Ecoregion 66a extends southwestward from South Mountain, Pennsylvania, to near the Roanoke River. It consists of pronounced ridges separated by high gaps and coves. Mountain flanks are steep and well dissected.

Precambrian and Paleozoic metavolcanic and igneous rock underlie Ecoregion 66a. Typically occurring in Virginia are basalt and metabasalt (greenstone) of the Catoctin Formation, granite and granodiorite of the Virginia Blue Ridge basement complex, and metasediments interbedded with metaigneous rocks of the Swift Run Formation to the north. Inceptisols, Alfisols, and Ultisols have commonly developed from the

Figure: 3-56. Fauquier soils are common in 66a. Rock occurs from 40 to 60 inches. Drainfields may be larger due to slow rates of absorption. *(Photo by Tom Saxton)* bedrock. Catoctin and Myersville are the primary residual soils. Montalto and Fauquier may be encountered. Lew soils consist of greenstone colluvium and are common in depositional landscapes. Soils in 66a are not well suited for onsite sewage disposal systems due to depth to rock, slow rates of absorption, rocky surfaces and steepness of slope.

The boundary between Ecoregion 66a and the Northern Sedimentary and Metasedimentary Ridges (66b) is shown in figure 3-55; it follows the contact between igneous-metavolcanic rocks and sedimentary-metasedimentary rocks.

Table 3-3. Representative Soil Series in the Northern Igneous Ridges region (66a).

Series	Common Slope Range %	Textural Family	Mineralogy	B Horizon Color	Comments
Residuum					
Catoctin	0 to 80	Loamy-Skeletal	Mixed	Strong brown (7.5YR 5/6)	Well drained, on ridges and side slopes, channery
Myersville	7 to 40	Fine-loamy	Mixed	Yellowish red (5YR 4/6)	Silty Clay Loam Bt, moderate (to slow) permeability, Cr or R @ 40-60 inches
Monalto	7 to 65	Fine	Mixed	Red (2.5YR 4/6)	Very Deep, mn stains, slow to moderate slow permeability
Fauquier	10-25	Fine	Mixed	Red (2.5YR 4/6)	Very Deep, on undulating to steep uplands, moderately slow permeability, mn stains
Colluvium					
Lew	2 to 75	Loamy-Skeletal	Mixed	Strong brown (7.5YR 5/6)	Lower Sideslopes, very channery or stony, discontinuity
Dyke	0 to 35	Fine	Mixed	Dark red (10R 3/6)	On footslopes, fans, and high terraces, Rhodic, discontinuity around 4', cobbly 2C horizon

Northern Igneous Ridges region (66a)

Mesic Soil families

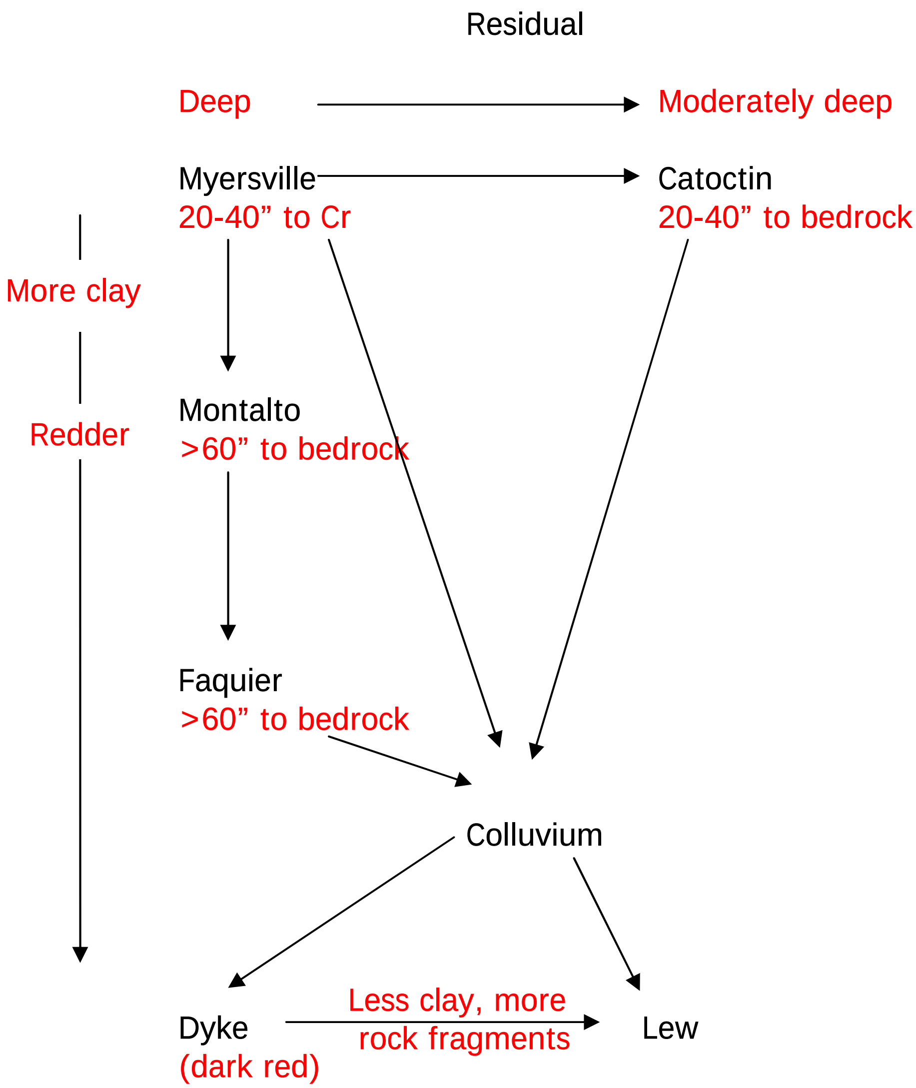


Figure: 3-56b. Soil series relationships in the 66a ecoregion.

66b. Northern Sedimentary and Metasedimentary Ridges

Ecoregion 66b extends from South Mountain, Pennsylvania, to the Roanoke River area. It is composed of high, steeply sloping ridges and deep, narrow valleys.

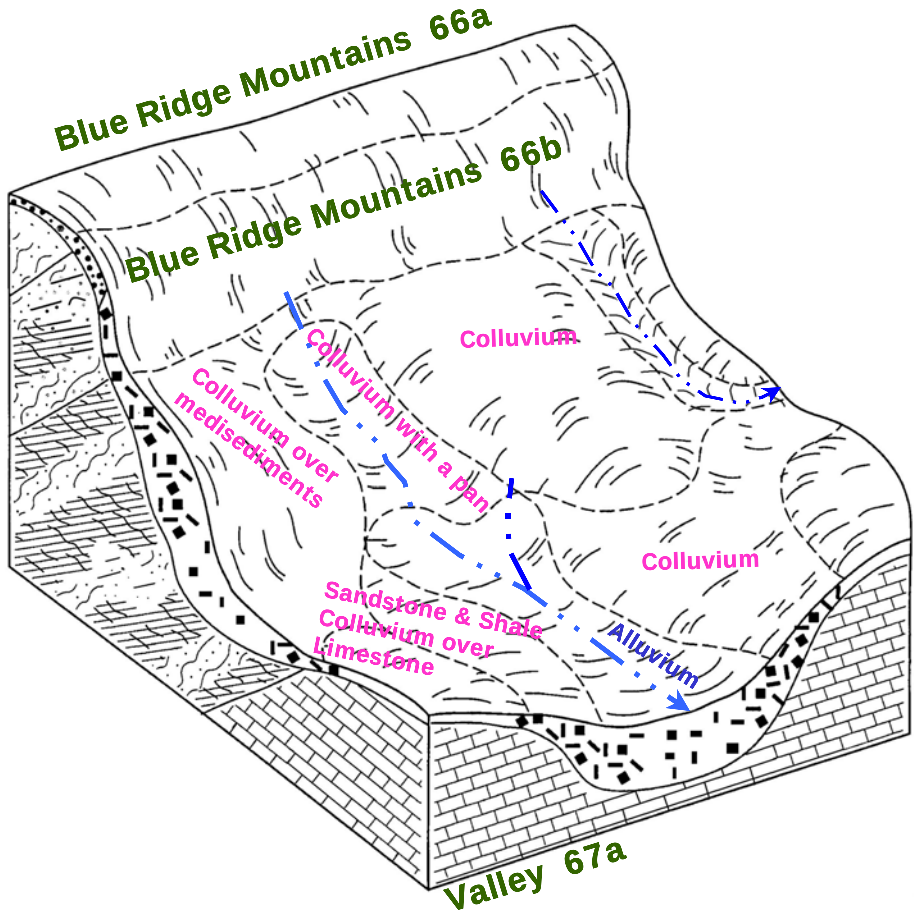


Figure: 3-57. Typical Blue Ride Mountain landscape north of the James River viewed looking eastward. *(NRCS Soil Survey of Frederick County Maryland)*

Erosion resistant sedimentary and metasedimentary rock of Cambrian age underlies Ecoregion 66b. Typically, Inceptisols and Ultisols developed from the bedrock. Cardiff (slate), Cataska (phyllite) Dekalb (sandstone and quartzite), Laidig (fragipan), Sylco (slate and phyllite), Whiteford (slate and phyllite) are common soil series found in this ecoregion. Soils in 66b are not well suited for onsite sewage disposal systems due to slope, shallow depth to rock and content of metasediment fragments.

The boundary between Ecoregion 66b and the Northern Igneous Ridges (66a) is shown in Figure 3-55; it follows the contact between igneous-metavolcanic rocks and sedimentary-metasedimentary rocks. Locally, more complex boundaries and other geologic units are common.

Table 3-4. Representative Soil Series in the Northern Sedimentary and Metasedimentary Ridges (66b).

Series	Common Slope Range %	Textural Family	Mineralogy	B Horizon Color	Comments
Residuum					
Cardiff	0 to 50	Loamy-Skeletal	Mixed	Yellowish brown (10YR 5/4)	Weathered from hard quartzitic slate, phyllite, Cr @ 20-40", Hard slate bedrock is below 40 inches.
Cataska	5 to 95	Loamy-Skeletal	Mixed	Strong brown (7.5YR 5/6)	Affected by soil creep in the upper part, weathered from low-grade metasedimentary rocks such as siltstone, slate and phyllite with some bands of thinly-bedded metasandstone, Cr 10-20"
Dekalb	0 to 80	Loamy-Skeletal	Mixed	Yellowish brown (10YR 5/4)	Weathered from gray and brown acid sandstone in places interbedded with shale and greywacke, cobbly, R range from 20-40"
Sylco	35 to 95	Loamy-skeletal	Mixed	Strong brown (7.5YR 5/6)	On mountain summits and side slopes, Elevations generally range from about 1,800 to 4,500 feet, Depth to phyllite slate, or metasandstone bedrock 20-40"
Whiteford	0 to 25	Fine-Loamy	Mixed	Strong brown (7.5YR 5/6)	Very deep, well drained, moderately permeable soils
Colluvium					
Laidig	8 to 55	Fine-Loamy	Siliceous	Yellowish brown (10YR 5/6)	Fragipan, perched water tables, on middle and lower slopes

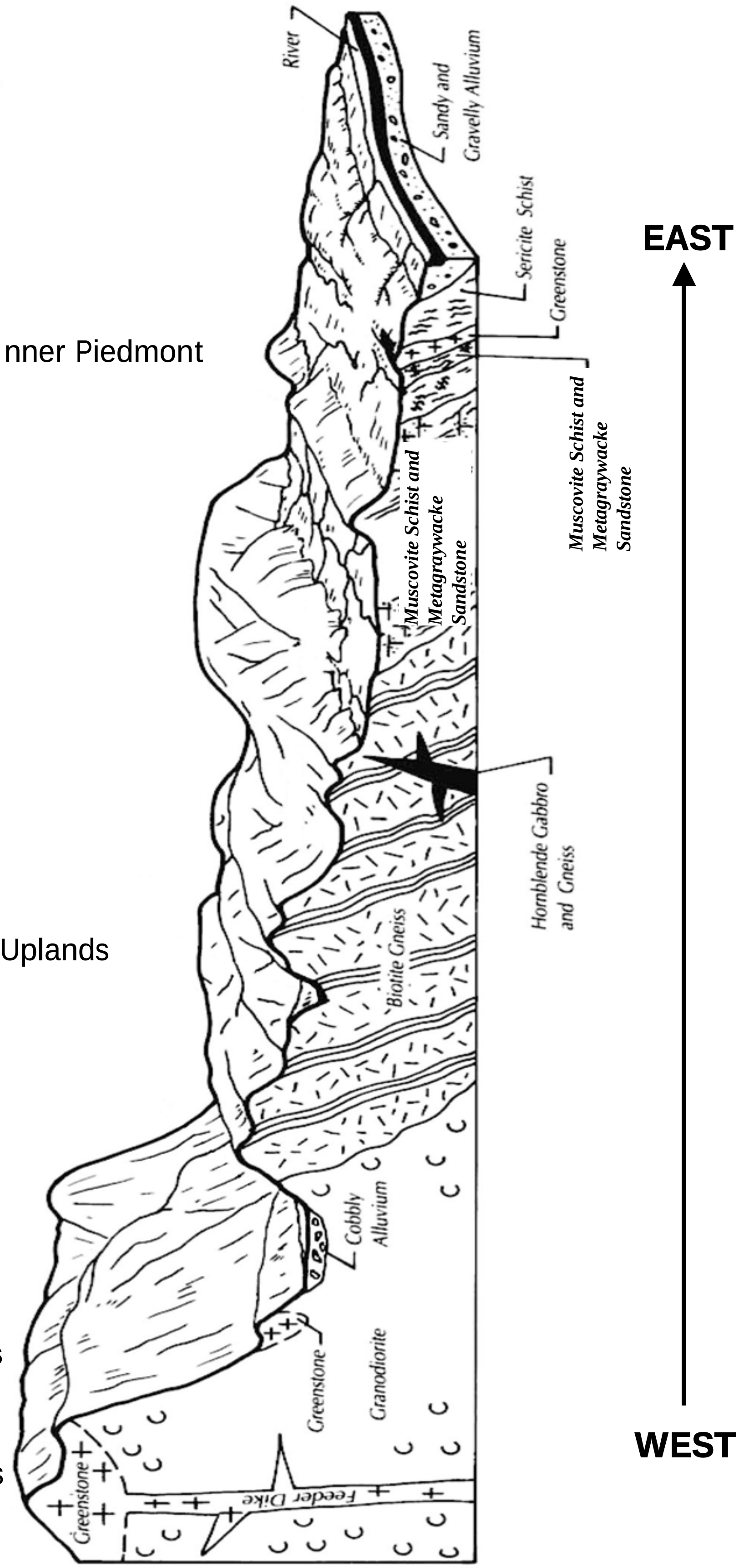


Figure: 3-58. Typical cross section from the crest of the Blue Ridge Mountains east into the Piedmont north of the Roanoke River. *(NRCS Soil Survey of Nelson County)*

66c. New River Plateau
Ecoregion 66c is a high, hilly plateau punctuated by scattered isolated knobs (monadnocks). The plateau (66c) is more than 1,000 feet (304 m) higher than the nearby Piedmont.

Ecoregion 66c is underlain by Precambrian metamorphic rock, including quartzite, graywacke, and metaconglomerate of the Lynchburg Formation. Gneiss and schist also outcrop. Inceptisols, Alfisols, and Ultisols occur and Chester, Hayesville, Glenelg, Edneytown, Edneyville, Chestnut and Myersville soils are common. Ultisols are generally well suited for onsite sewage disposal systems. Alfisols may have less permeability, but with sufficient depth are suitable for drainfields unless shrink swell characteristics are encountered. Depth to rock is generally a limitation for Inceptisols.

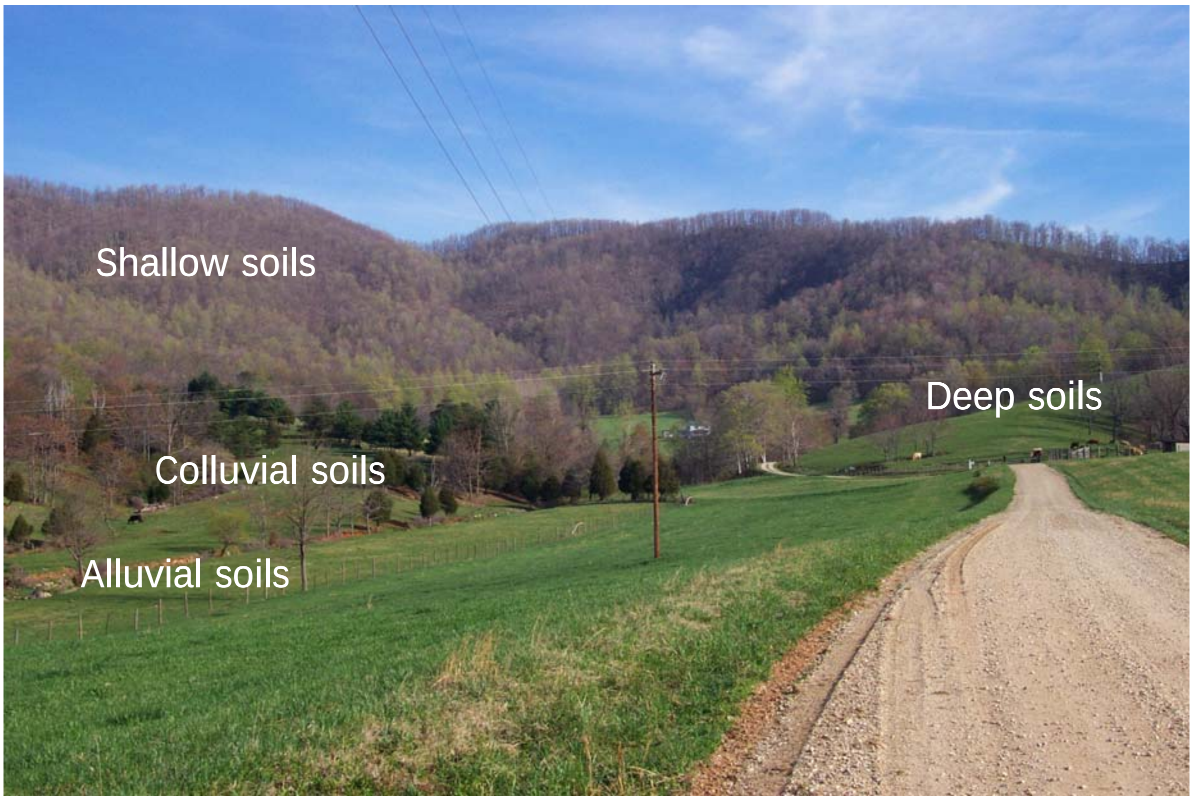


Figure: 3-59. Soils in the 66c mapping unit. *(Photo by Tom Saxton)*

Ecoregion 66c's boundary is shown in figure 3-55; its muted relief, lower elevations, and lower woodland density are a marked contrast to those of the Southern Igneous Ridges and Mountains (66d) and Southern Sedimentary Ridges (66e), which are adjacent.

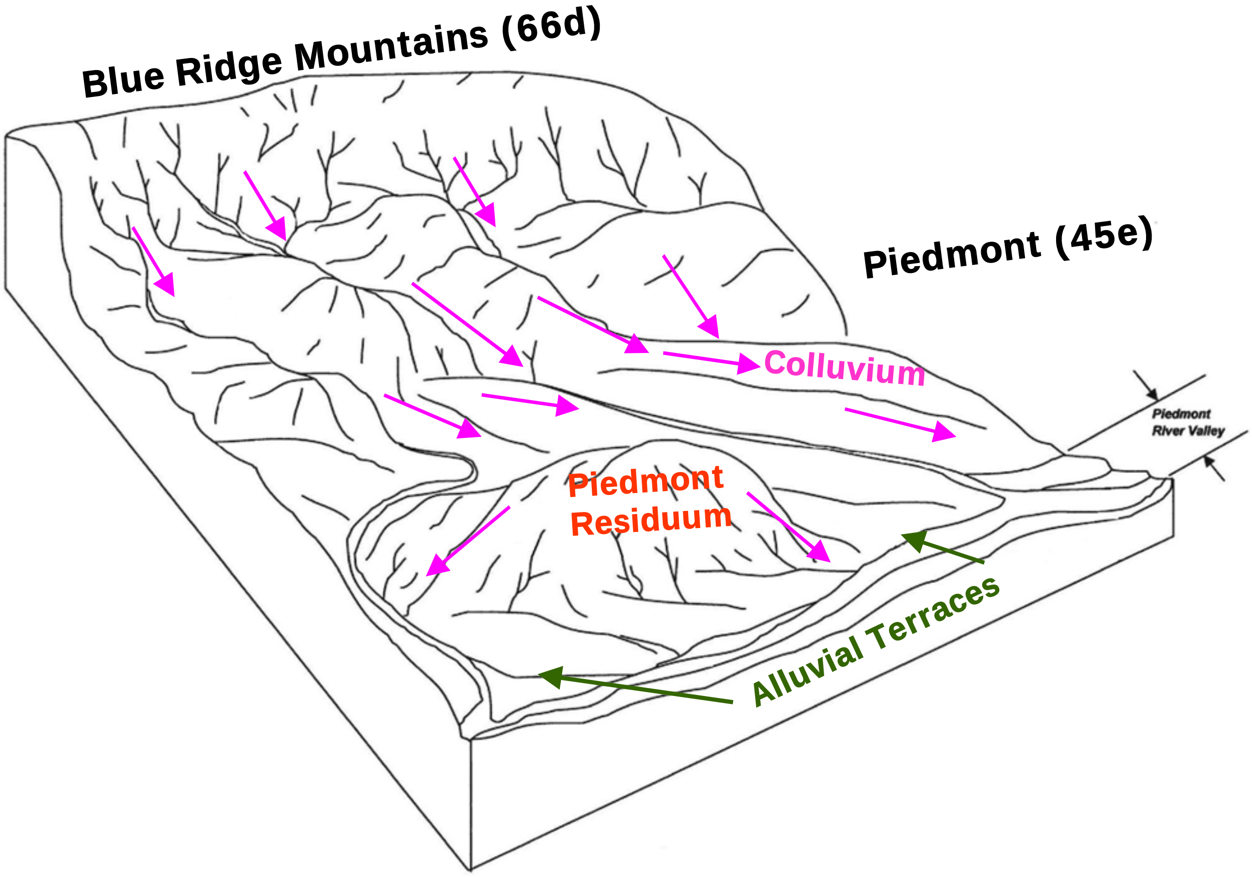
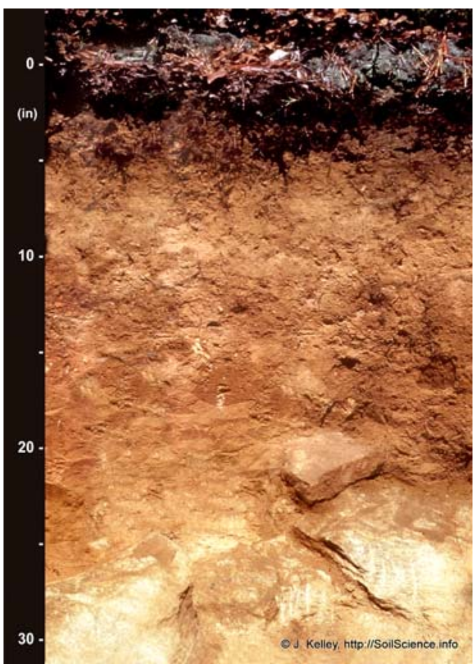


Figure: 3-60. Typical landscapes south of the Roanoke River to the North Carolina state line on the eastern side of the Blue Ridge Mountains, looking westward. *(NRCS Franklin County Soil Survey)*



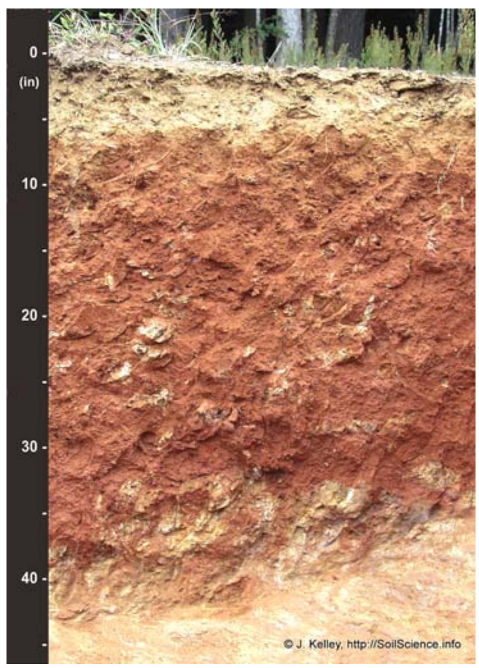


Figure: 3-61. Chestnut Soils on the left may be found on the Blue Ridge portion of the diagram above and Woolwine Soils to the right might be expected in the Piedmont residuum area. They are both moderately deep to rock (20-40 inches). *(Photos by John Kelly, http://SoilScience.info)*

66d. Southern Crystalline Ridges and Mountains

Ecoregion 66d extends from near the Roanoke River into Tennessee and North Carolina border. It consists of pronounced ridges and mountain masses separated by high gaps and coves. Mountain flanks are steep and well dissected.

Precambrian and Paleozoic rock underlies Ecoregion 66d. The Mt. Rogers Volcanic Group, the Virginia Blue Ridge Complex, and the Lynchburg Formation are commonly exposed. Common rocks are gneiss and schist. Typically, Inceptisols (Dystrochrepts) and Ultisols (Hapludults) developed from the bedrock. The Hayesville, Glenelg, Edneytown, Edneyville Chestnut, Tate and, Porters soils are widespread. Generally, the Ultisols in this area are well suited for subsurface soils absorption systems as long as there is sufficient depth above bedrock. Inceptisols are generally limited by the depth to bedrock. The boundary between ecoregion 66d and the Southern Sedimentary Ridges (66e) is shown in figure 3-55; it follows the contact between igneous-metamorphic and sedimentary-metasedimentary rocks.

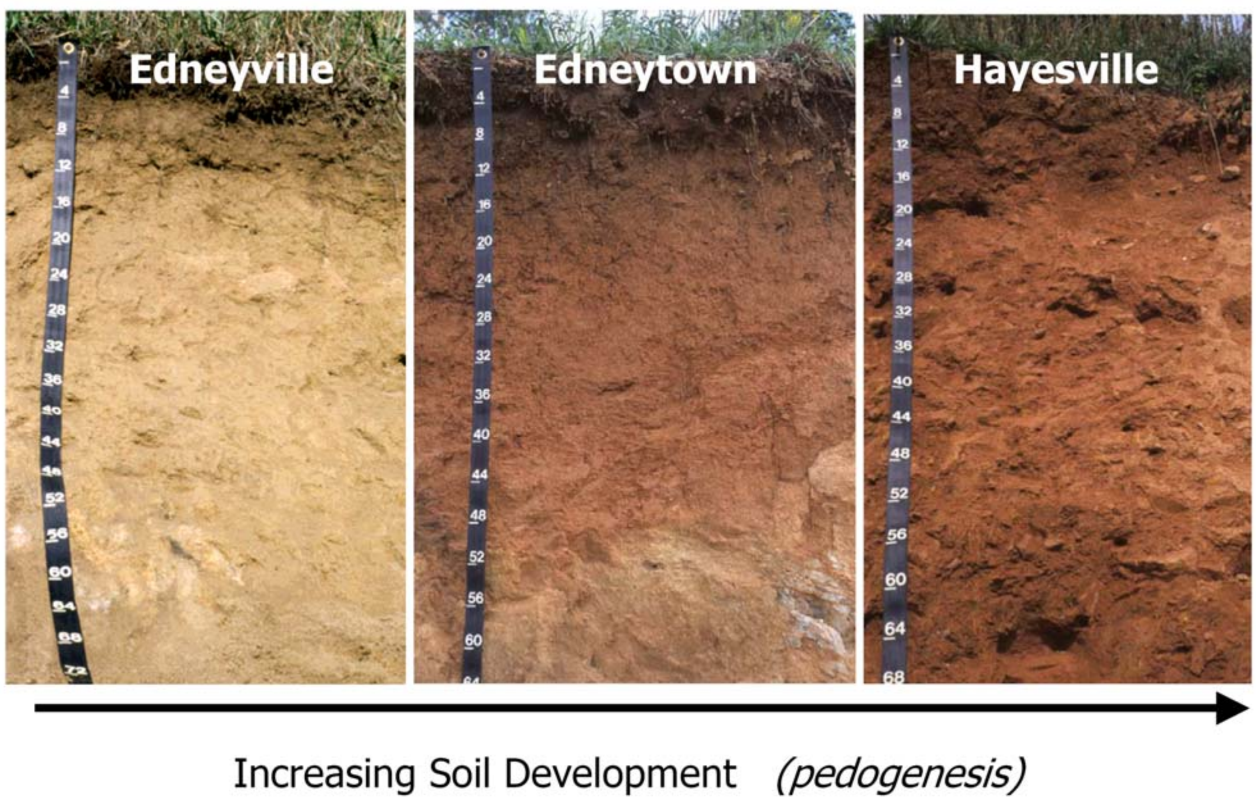


Figure: 3-62. Commonly occurring soils found in the 66c and 66d mapping units. Soils on young landscapes have not had time to develop as much as those on older more stable ones. However, each of these soils is well suited for drainfields. *(NRCS Soil Survey of Grayson County)*

Table 3-5. Representative Soil Series for the Southern Crystalline Ridges and Mountains region (66d).

Series	Common Slope Range %	Textural Family	Mineralogy	B Horizon Color	Comments
Residuum					
Hayesville	2 to 60	Fine	Kaolinitic	Red (2.5YR 5/6)	"Mountain Cecil", very deep, moderate permeability in the subsoil and moderately rapid permeability in the underlying material
Porters	2 to 60	Fine-loamy	Kaolinitic	Brown (7.5YR 4/4)	Deep, well drained, moderately permeable soils on cool, north- to east-facing or shaded ridges and side slopes, umbric epipedon, R @ 40-60".
Glenelg	5 to 95	Fine-loamy	Mixed	Yellowish brown (10YR 5/6)	Mica schist p.m. Saturated hydraulic conductivity is moderately high in the subsoil and moderately high to high in the substratum
Edneytown	15 to 50	Fine-loamy	Mixed	Strong brown (7.5YR 5/8)	Very deep, well drained, permeability is moderate in the subsoil and moderately rapid in the underlying material
Edneyville	2 to 95	Coarse-loamy	Mixed	Yellowish brown (10YR 5/6)	Very Deep, Bw horizons, moderately rapid to rapid permeability
Chesnut	15 to 95	Coarse-loamy	Mixed	Yellowish brown (10YR 5/6)	Well drained soils on gently sloping to very steep ridges and side slopes , Cr @ 20-40, hard granite gneiss at 40+
Colluvium					
Tate	5-15	Fine-loamy	Mixed	Yellowish brown (10YR 5/6)	On colluvial fans, foot slopes, and benches in coves
Tusquittee	15-50	Fine-loamy	Isotic	Brown (7.5YR 4/4)	Very deep, well drained soils on gently sloping to very steep benches, foot slopes, toe slopes, and fans in coves
Parent Material = igneous and high-grade metamorphic rocks such as granite, granodiorite, mica gneiss and schist. Soils found at elevation ranges from 1400 to 4000 feet. Soil formed in residuum may be affected by soil creep in the upper part					

Southern Crystalline Ridges and Mountains region

Mesic Soil Families

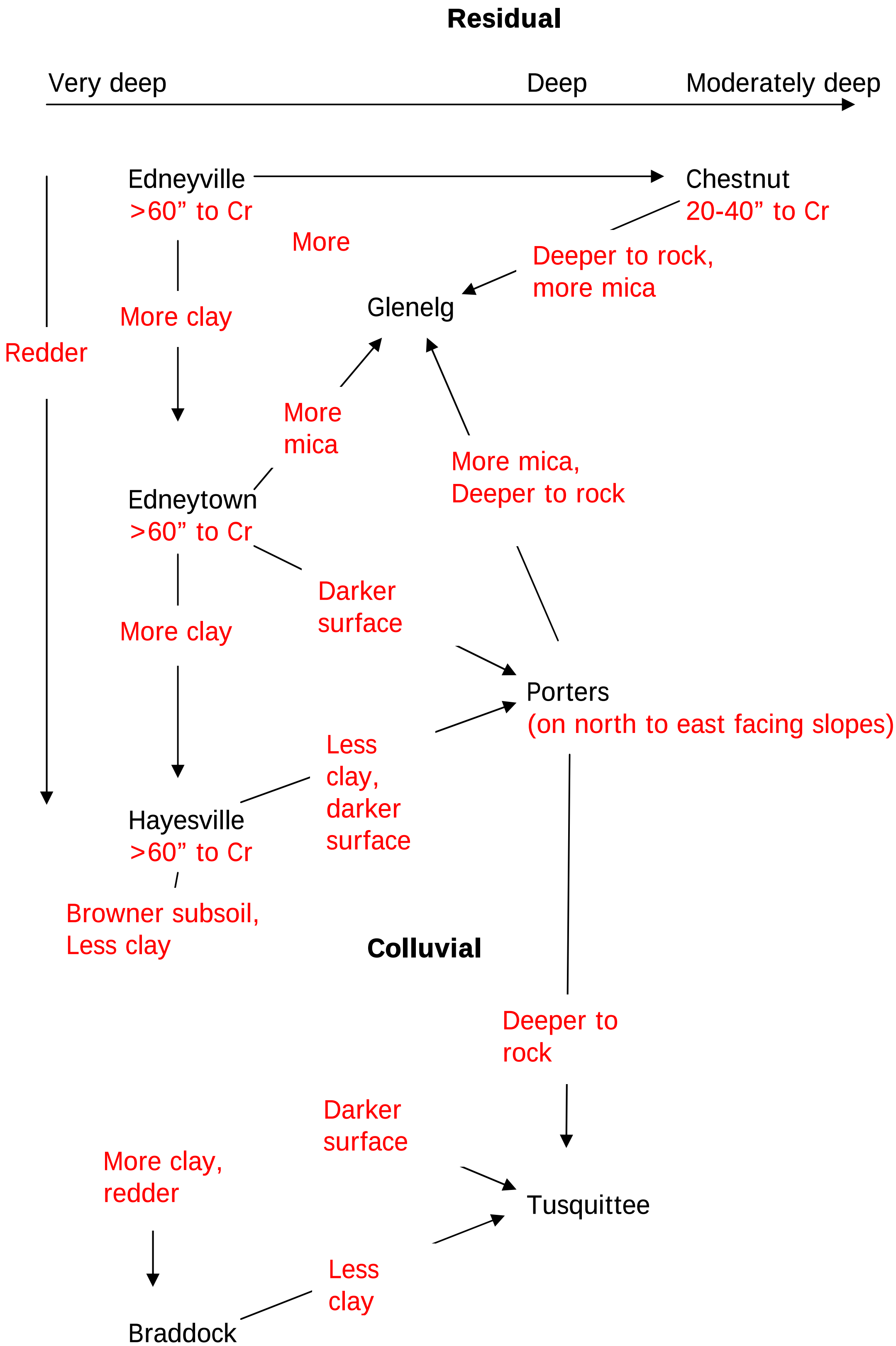


Figure: 3-63. Soil series relationships in the 66d ecoregion.

66e. Southern Sedimentary Ridges

Ecoregion 66e extends from the Roanoke River into Tennessee. It is composed of high, steeply sloping ridges and deep, narrow valleys.

Cambrian sedimentary and metasedimentary rocks, including sandstone, shale and quartzite of the Chilhowee Group, underlie Ecoregion 66e. Ridge crests are underlain by resistant sandstone (or metasandstone) and quartzite, while side slopes are made up of phyllite, shale, siltstone, and sandstone. Typically, Inceptisols (Dystrochrepts) developed from the bedrock. The Berks, Weikert, Dekalb, Sylco, Sylvatus, and Unicoi soils are common. Depth to bedrock and steep slopes are limitations for subsurface soil absorption systems.

The boundary between Ecoregion 66e and the Southern Igneous Ridges and Mountains (66d) is shown in figure 3-55; it follows the contact between igneous-metamorphic and sedimentary metasedimentary rocks.

Colluvium *(soils formed from deposits moved by gravity)* is common throughout Virginia and at times represents challenges to the onsite designer. Whenever there are transported soils, strata's within the deposits may occur that inhibit water movement. It is important for the site evaluator to be aware that these soils are especially common in mountainous regions and to anticipate them prior to performing extensive site work. Figure 3-64 shows four common transported soils that may be anticipated on the Valley and Ridge floor at the foot of the Blue Ride Mountains. Three are colluvial and one is alluvial.

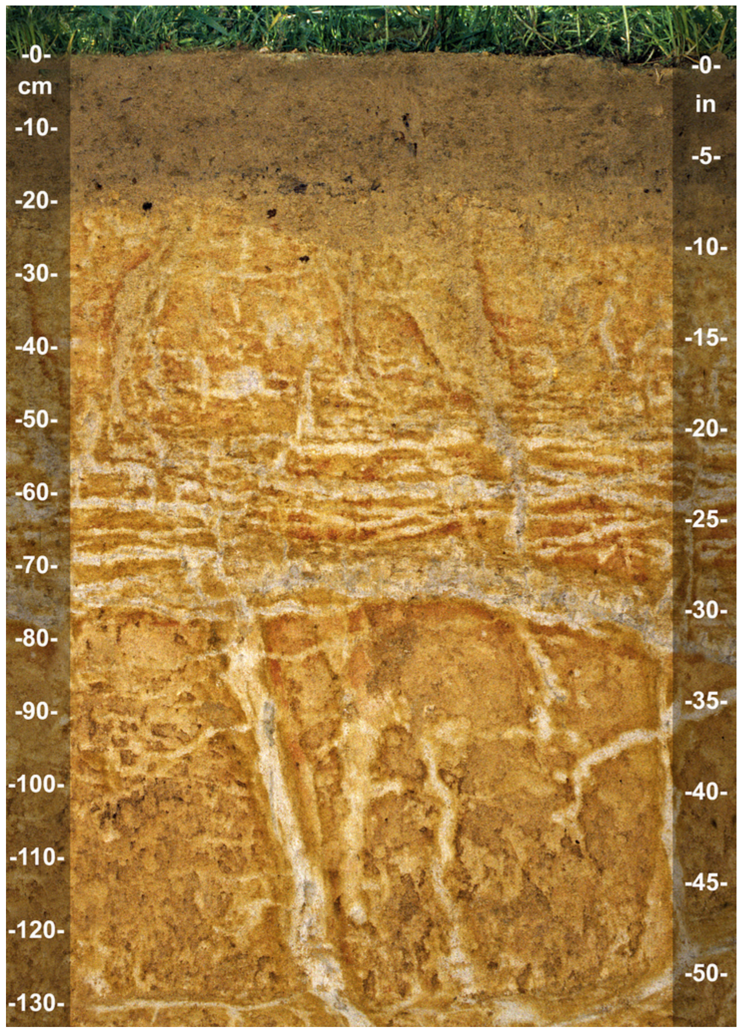


Figure: 3-64. This soil has a fragipan that restricts water movement. It is especially evident from 50 to 80 centimeters. Soils like this commonly occur on colluvial fans on the western foot slopes of the Blue Ridge at the intersection with the Ridge and Valley. They most commonly form in sandy colluvial deposits. Drainfields cannot be installed in these soils. *(Photo by John Kelly)*

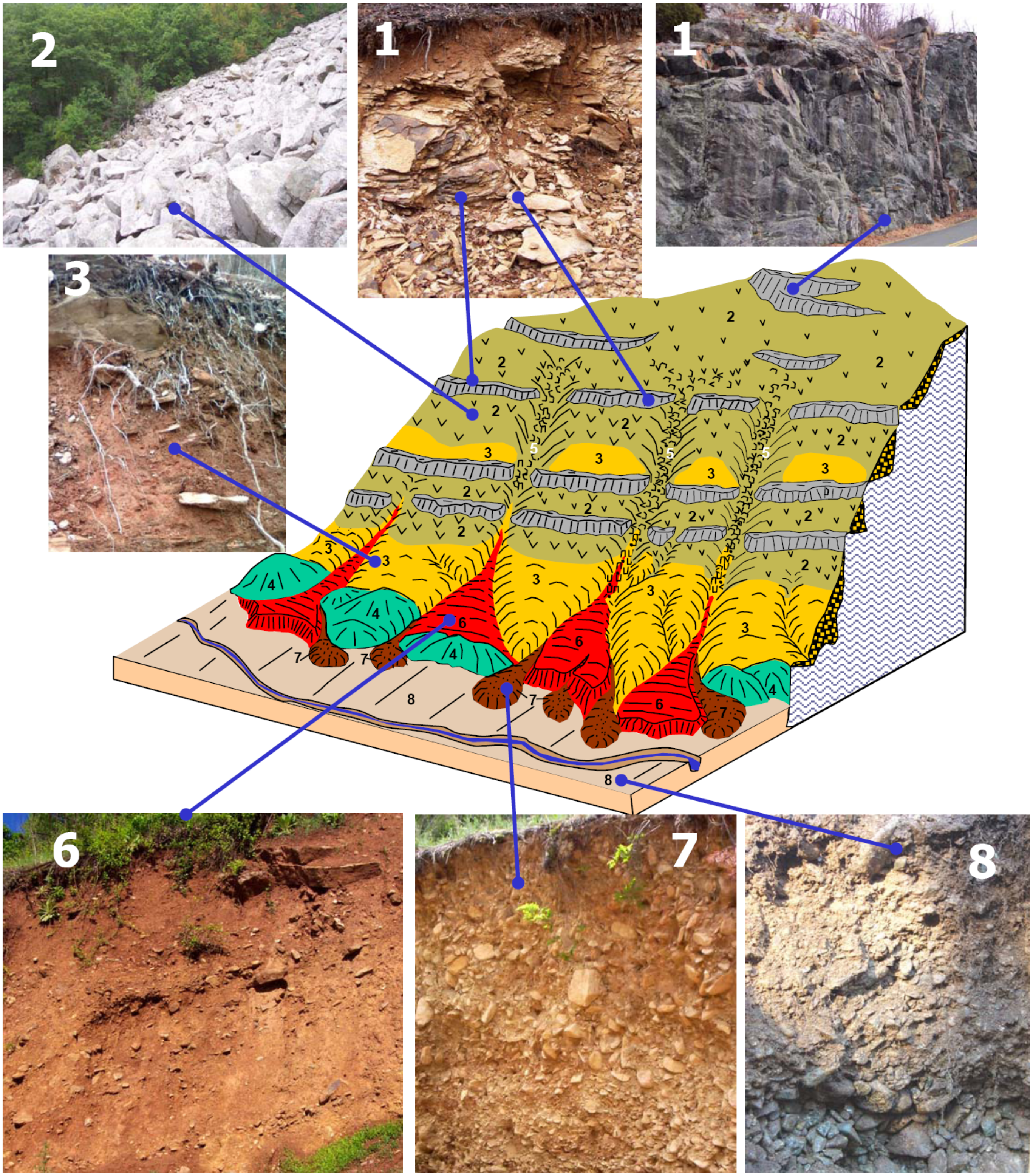


Figure: 3-65. The western slopes of the Blue Ridge have steeper slopes than the eastern side, therefore, resulting in very rugged terrain and various degrees of colluviation. This idealized landscape represents common scenarios along the western slopes from the northern to the southern parts of Virginia. 1= bedrock outcrops (two kinds shown that are common; Catoctin greenstone (top R) and metasediments-phyllite (top L), 2= talus slopes (quartzite), 3= colluvial slopes, 4= residual soils (no photo), 5= boulder streams (no photo), 6= upper debris fans, 7= lower debris fans, 8= floodplain (alluvium). *(Diagram adapted from SE Friends of the Pleistocene Field Guide, 1992) (Photos by Tom Saxton)*

The geology of the Valley & Ridge Province is made up of long parallel ridges and valleys with folded Paleozoic sedimentary rock [A] below and inside them. The valleys and ridges were produced when bands of rocks, which were folded and faulted, eroded differently. Cambrian-aged sandstones (540 million years-old) from the western Blue Ridge are overlain by carbonates that made up a big region of limestone and dolostone called the Great American Carbonate Bank. For at least 70 million years carbonates were deposited in a shallow tropical ocean along the southeast edge of North America. Today these carbonates (up to 3.5 kilometers in thickness) are exposed in the Great Valley (also known as the Shenandoah Valley in central and northern Virginia); the easternmost portion of the Valley & Ridge province. Well-developed caves and sinkholes can be found in the Great Valley. By middle Ordovician time, sand and gravel that washed down from new mountains pushed up to the east of the Valley & Ridge Province in the Piedmont of today. Most of the sediment that sloughed off the Taconian Mountain belt was mud, sand and a small amount of gravel. This sediment is a record the uplift and erosion of the Taconic Mountains. By late Silurian, carbonates were again being deposited in the area. The sediment deposition continued from the Silurian through the Carboniferous (the Mississippian & Pennsylvanian) in the Valley & Ridge and Appalachian Plateau. These deposits record pulses of uplift & mountain building to the east. Continental collision in the late Paleozoic produced a fold and thrust belt, which thrust Blue Ridge rocks to the northwest on top of the Paleozoic rocks [B]. Paleozoic sedimentary rocks of the Valley & Ridge were also folded and moved westward along thrust faults [C].
(William & Mary Dept of Geology Valley & Ridge Province for Students & Teachers The Geology of Virginia.htm)

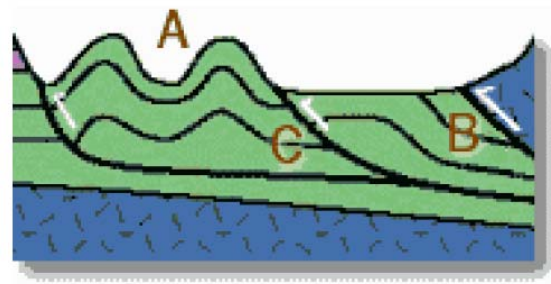


Figure: 3-66. Valley & Ridge *(William & Mary Department of Geology C.M. Bailey)*

67. Valley and Ridge
Ecoregion 67 extends from Pennsylvania, through Virginia along a southwesterly axis. It is characterized by alternating forested ridges and agricultural valleys that are elongated, folded and faulted. The Valley and Ridge (67) narrows toward the south and is generally bordered by the higher Blue Ridge Mountains and the higher and less deformed Appalachian Plateau.

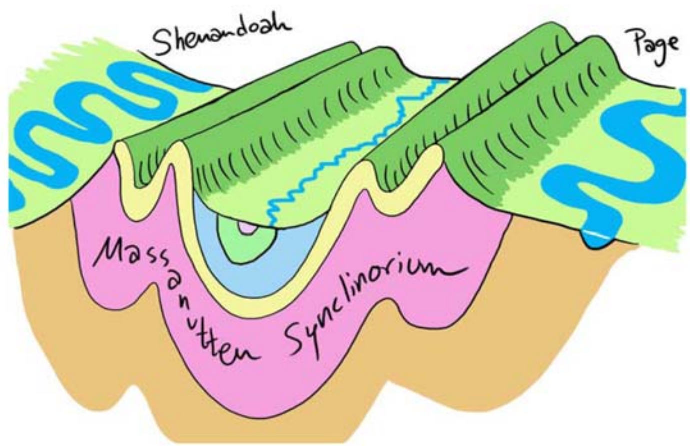


Figure: 3-67. Idealized graphic of the folding of the Great Valley. *(Callan Bentley, NVCC)*

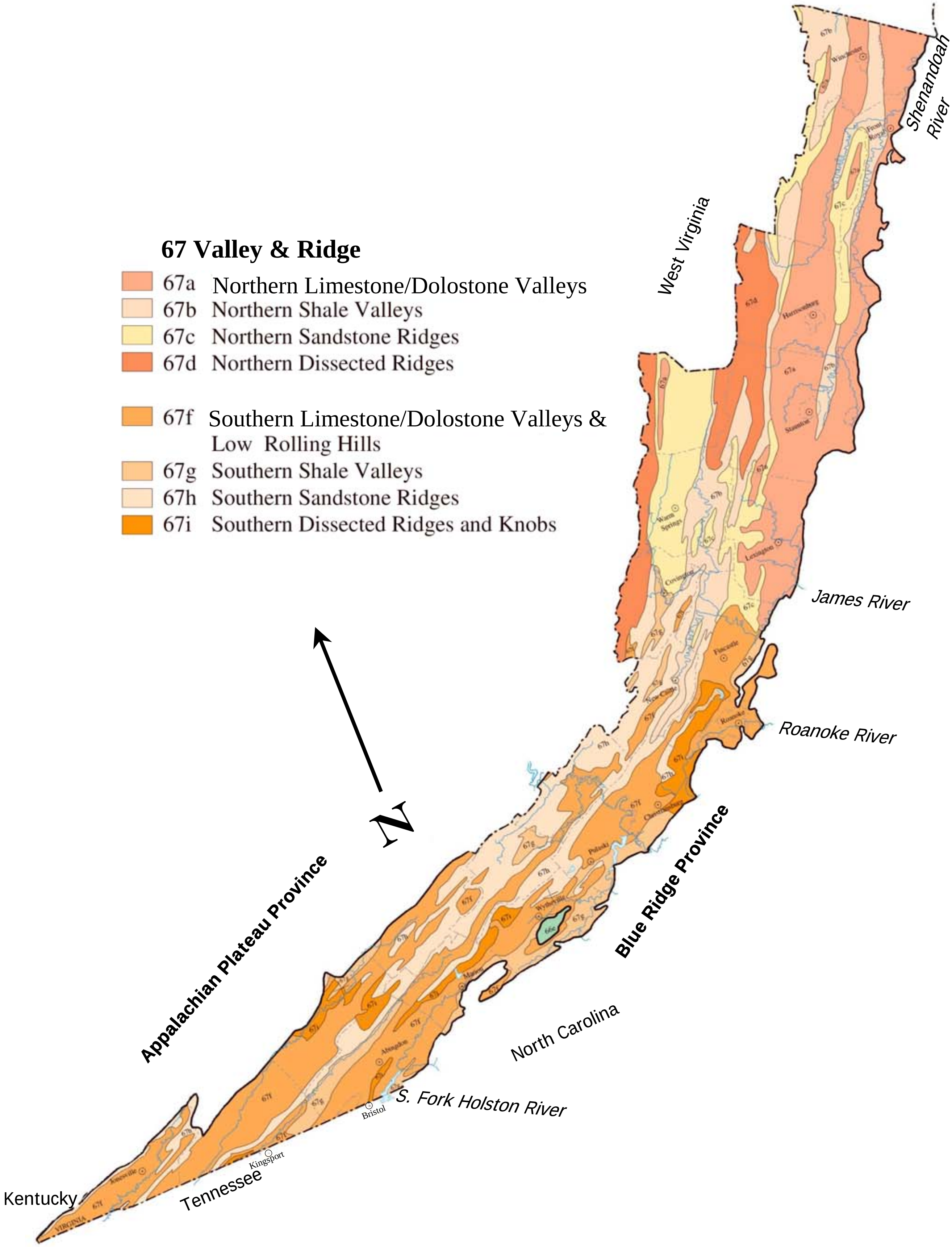


Figure: 3-68. Ridge and Valley Ecoregions. *(EPA Level III Ecoregions of Virginia)*

Underlying Ecoregion 67 are largely Paleozoic sedimentary rocks that have been folded and faulted. Sandstone, shale, limestone, and dolostone are the predominant rock types. Lithological characteristics often determine surface morphology. Many ridges are formed on well-cemented, relatively resistant material such as sandstone or conglomerate. They are often parallel to and alternate with valleys. Valleys tend to be created on weaker strata, including limestone and shale. Inceptisols and Ultisols are common and were developed on non-carbonate rock. Alfisols and Ultisols are found in the limestone valleys. The valleys vary in micro topography and agricultural potential. Valleys derived from limestone and dolostone are smoother in form than those developed in shale. Shale valleys often display a distinctive rolling topography. Soils derived from limestone are often suitable for onsite sewage systems, while those derived from shale are less suitable if not unsuitable. Soils weathered from sandstone while permeable, are often shallow to rock. Colluvium is commonly encountered at the base of slopes. The composition of the colluvium is contingent upon the source material. Transported soils such as colluvium, often have restrictions and restrictive layers that impede water movement. They should be evaluated carefully for onsite sewage disposal systems.

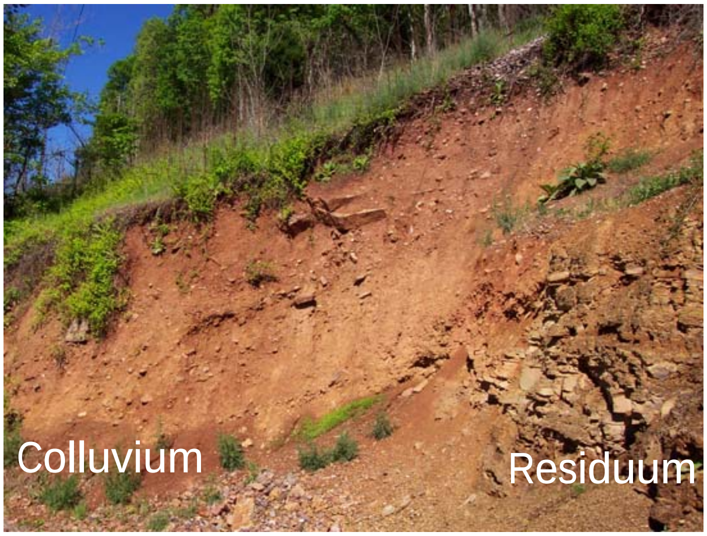


Figure: 3-69. Colluvium over residuum of interbedded limestone and shale in Montgomery County in the 67i mapping unit. *(Photo by Tom Saxton)*

The Valley and Ridge (67) is significantly lower than the Central Appalachians (69). As a result, it has less severe winters, considerably warmer summer temperatures, and lower annual precipitation due to a rain shadow effect.

Figure: 3-70. Looking northeast towards the Blue Ridge Mountains from 67a near the Rockbridge/ Augusta County line. 66b (metasediments) encompasses the closer lower ridges and 66a (greenstone) is in the distance. *(Photo by Tom Saxton)*

On the ecoregion map (figure 3-67), the Valley and Ridge (67) is composed of 9 ecoregions: the Northern Limestone/Dolostone Valleys (67a), the Northern Shale Valleys (67b), the Northern Sandstone Ridges (67c), the Northern Dissected Ridges (67d), the Southern Limestone/Dolostone Valleys and Low Rolling Hills (67f), the Southern Shale Valleys (67g), the Southern Sandstone Ridges (67h), and the Southern Dissected Ridges and Knobs (67i). Each is underlain by folded and faulted sedimentary rock, which is distinctive of the ecoregion. The division between ecoregions 67a, 67b, 67c, and 67d and ecoregions 67f, 67g, 67h, and 67i occurs in a broad zone near the James River.

67a. Northern Limestone/Dolostone Valleys

Ecoregion 67a is a lowland characterized by broad, level to undulating, fertile valleys that are extensively farmed. The Great Valley and the Shenandoah Valley occur in Ecoregion 67a. Sinkholes, underground streams, and other karst features have developed on the underlying limestone/dolostone. Silurian, Ordovician, and Cambrian limestone and dolostone commonly underlie Ecoregion 67a. Interbedded with the carbonates are other rocks, including shale, which give the ecoregion topographic and soil diversity. Alfisols and Ultisols have developed from the rock. Frederick, Lodi, Endcav, Carbo, Chilowie, Edom, and Opequon soils are common. Figure 3-67 shows the boundaries of Northern Limestone/Dolostone Valleys (67a). Base-rich soil, muted terrain and limestone, dolostone, and calcareous shale bedrock are characteristic. Soils weathered from limestone are often the best suited for onsite sewage disposal systems in the Valley and Ridge Physiographic Province. Depth to bedrock, karst topography and slow rates of absorption are common limitations.

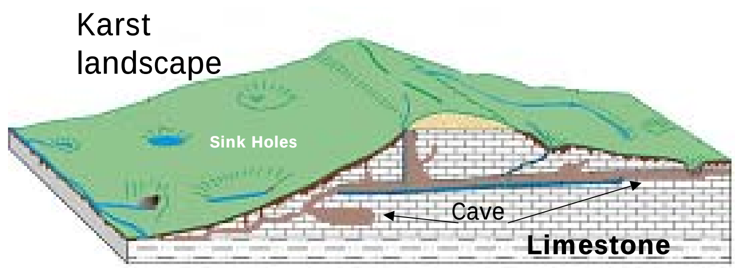


Figure: 3-71. Karst topography presents challenges for the onsite program due to the potential to contaminate groundwater. Construction of private drinking water wells may also be a challenge in this area. *(Adapted from the Kentucky Geological Survey, University of Kentucky).*

67b. Northern Shale Valleys

Ecoregion 67b extends over a large area from northeastern Pennsylvania to near the James River in Virginia. It is characterized by rolling valleys and low hills and is underlain mostly by shale, siltstone, and fine-grained sandstone. The bedrock is folded and faulted and is of Devonian age.

The underlying rocks are not as permeable as the limestone of Ecoregion 67. There is more soil erosion in Ecoregion 67b than in the Northern Limestone/Dolostone Valleys (67a). Inceptisols have

Figure: 3-72. Frederick Soils are weathered from Dolostone and Limestone. Depth to rock is greater than 6 feet. These soils are commonly used for drainfields. *(NRCS Soil Survey of Smyth County)* developed from residuum. Berks, Weikert, Sequoia and Poplimento soils are commonly found in this map unit. Soils derived from acid shale have lower fertility than the soils of Ecoregion 67a, which were derived from limestone. Within Ecoregion 67b, there is considerable soil variability, and some soils are more calcareous than others (Poplimento is an example). The boundaries of Ecoregion 67b are shown in figure 3-67. This mapping unit encompasses acidic to neutral, valley and low hill soils that developed on shales and siltstones. Steepness of slopes, shallow depth to bedrock and slow rates of absorption are limitations for drainfields.

67c. Northern Sandstone Ridges

Ecoregion 67c is characterized by high, steep, forested ridges with narrow crests. Most of the major ridges in Ecoregion 67 are found in Ecoregion 67c or in the Southern Sandstone Ridges (67h). The ridge-forming strata are composed of folded, interbedded Paleozoic sandstone and conglomerate. Other less resistant rocks, such as shale and siltstone, may form the side slopes. Ridge contour lines are straight and parallel, not crenulated like those of the Northern Dissected Ridges (67d).

Figure: 3-73. Sandstone colluvium over shale interbedded with sandstone in the 67c unit in Rockingham County in the Hampshire Formation. *(Photo by Tom Saxton)*

Inceptisols and Ultisols have commonly developed in the residuum. These soils vary significantly within a short distance as do rock type and elevation. Typically, the soils have low fertility and are sandy textured. Dekalb, Alticrest and Lehew soils are common. Soils with fragipans commonly develop in sandstone colluvium. Stoniness, depth to bedrock, wetness and impermeable layers associated with fragipans, and steepness of slope are limitations for onsite sewage disposal systems.

Figure: 3-74. A small cave has been exposed by down cutting of the Maury River in Rockbridge County. *(Photo by Tom Saxton)*

67d. Northern Dissected Ridges

Ecoregion 67d is composed of broken, dissected, almost hummocky ridges. Interbedded sedimentary rocks including siltstones underlie this region. Soils developed from this interbedded rock are mostly Inceptisols. Dekalb, Berks, Weikert, Calvin, and Lehew soils are common. Figure 3-67 shows the location of the broken, dissected wooded ridges, knobs, and minor valleys of Ecoregion 67d. They are morphologically distinct from the sharp ridges and narrow valleys of the Northern Sandstone Ridges (67c). Steepness of slope, stoniness and depth to bedrock are limitations for drainfields.

67f. Southern Limestone/Dolostone Valleys and Low Rolling Hills

Ecoregion 67f is a lowland characterized by broad, undulating, fertile valleys that are extensively farmed. Sinkholes, underground streams, and other karst features have developed on the underlying limestone/dolostone. Ordovician and Cambrian limestone and dolostone commonly underlie Ecoregion 67f. Interbedded with the carbonates are other rocks, including shale, which gives the ecoregion topographic and soil diversity. Alfisols and Ultisols have developed from the rock. Frederick, Groseclose, and Carbo are common soils. Figure 3-67 shows the boundaries of the Southern Limestone/Dolostone Valleys and Low Rolling Hills. This region has base-rich soil and muted terrain. Limestone, dolostone, and calcareous shale bedrock are characteristic. Soils weathered from limestone are often the best suited for onsite sewage disposal systems in the Valley and Ridge Physiographic Province. Depth to bedrock and slow rates of absorption are common limitations.

Figure: 3-75. Groseclose soils are weathered from interbedded limestone, siltstone and shale. They are often used for drainfields. *(Courtesy NRCS Soil Survey of Smyth County)*

67g. Southern Shale Valleys

Ecoregion 67g extends from the James River into Tennessee. It is characterized by rolling valleys and low hills and is underlain mostly by fine-grained rock. The terrain is often more rugged than that of Ecoregion 67b. Woodland occurs on steeper sites and farming is uncommon. The bedrock is folded and faulted, and is of Paleozoic age. The underlying rock is not as permeable as the limestone of Ecoregion 67f. There is more soil erosion in Ecoregion 67g than in 67f also. Inceptisols and Ultisols have developed from residuum. Groseclose, Berks, Weikert, Rough, Chiswell, and Gilpin soils are common. Soils derived from acid shale commonly occur in Ecoregion 67g and are less fertile than the soils of Ecoregion 67f, which were derived from limestone. However, within Ecoregion 67g there is considerable soil variability, and some soils are more calcareous than others. Figure 3-67 shows the boundaries of the Southern Shale Valleys (67g). They enclose acidic to neutral valley and low hill soils that developed primarily on interbedded shales and siltstones. Steepness of slopes, shallow depth to bedrock and slow rates of absorption are limitations for drainfields.

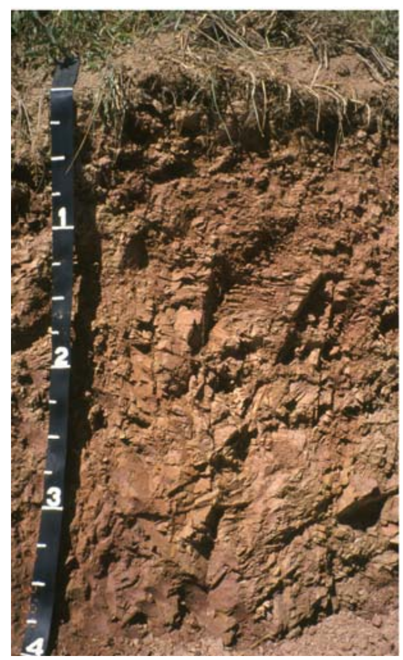


Figure: 3-76. Chiswell soils are weathered from shale and siltstone. Depth to rock is less than 20 inches. Conventional drainfields cannot be installed in this soil. *(Courtesy NRCS Soil Survey of Smyth County)*

67h. Southern Sandstone Ridges

Figure: 3-77. Sandstone colluvium over shale residuum. This soil has a perched water table. *(Photo by Tom Saxton)*

Ecoregion 67h is composed of high, steep, forested ridges with narrow crests. Most of the major ridges in Ecoregion 67 are found in ecoregions 67c and 67h. The ridge-forming strata are composed of folded, interbedded Paleozoic sandstone and conglomerate. Other less resistant rocks, such as shale and siltstone, form the side slopes. Inceptisols and Ultisols have commonly developed in the residuum. Lily, Wallen, Alticrest, and soils with fragipans commonly develop in sandstone colluvium. These soils vary significantly within a short distance, as do rock type and elevation. Soils are typically steep, stony, sandy textured, and low in fertility. Ridge contour lines are straight and parallel, not crenulated like those of the Southern Dissected Ridges and Knobs (67i). Stoniness, depth to bedrock, wetness and impermeable layers associated with fragipans, and steepness of slope are limitations for onsite sewage disposal systems.

67i. Southern Dissected Ridges and Knobs

Ecoregion 67i is composed of broken, dissected, almost hummocky ridges. It is morphologically distinct from the sharp ridges and narrow valleys of Ecoregion 67h and underlain by interbedded sedimentary rocks including siltstones. Folded, mostly Devonian age sedimentary rocks often underlie Ecoregion 67i. The soils developed from this interbedded rock are mostly Inceptisols and Ultisols. Berks, Chiswell, Calvin, Litz, Weikert, and Wallen soils are common. Figure 3-67 shows the location of the broken, dissected wooded ridges, knobs, and minor valleys of Ecoregion 67i. They are morphologically distinct from the sharp ridges and narrow valleys of the Southern Sandstone Ridges (67h). Steepness of slope, stoniness and depth to bedrock are limitations for drainfields.

Figure: 3-78. Stoniness and rock outcroppings prevent this area from being used for subsurface soil absorption systems. *(NRCS Soil Survey of Russell County)*

Figure: 3-79. Fragipan formed in sandstone colluvium is impervious and therefore unsuitable for effluent dispersal. The rock fragments are cemented by silica in a sandy matrix. *(Photo by Tom Saxton)*

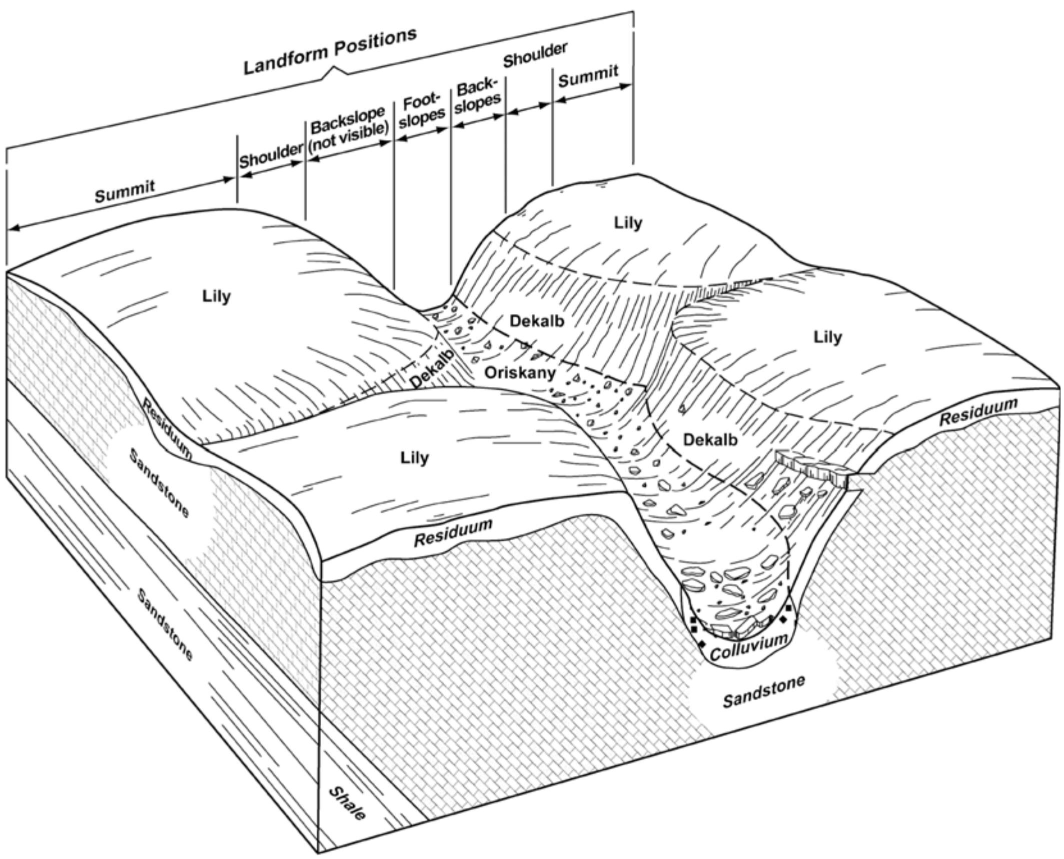


Figure: 3-80. Idealized landscape in the Sandstone Ridges mapping units. Lilly soils are 20 to 40 inches thick over sandstone rock. Dekalb soils are also 20 to 40 inches thick but weathered from a mixture of sandstone quartzite and shale. Oriskany soils are weathered from colluvial deposits. *(NRCS Soil Survey of Bland County)*

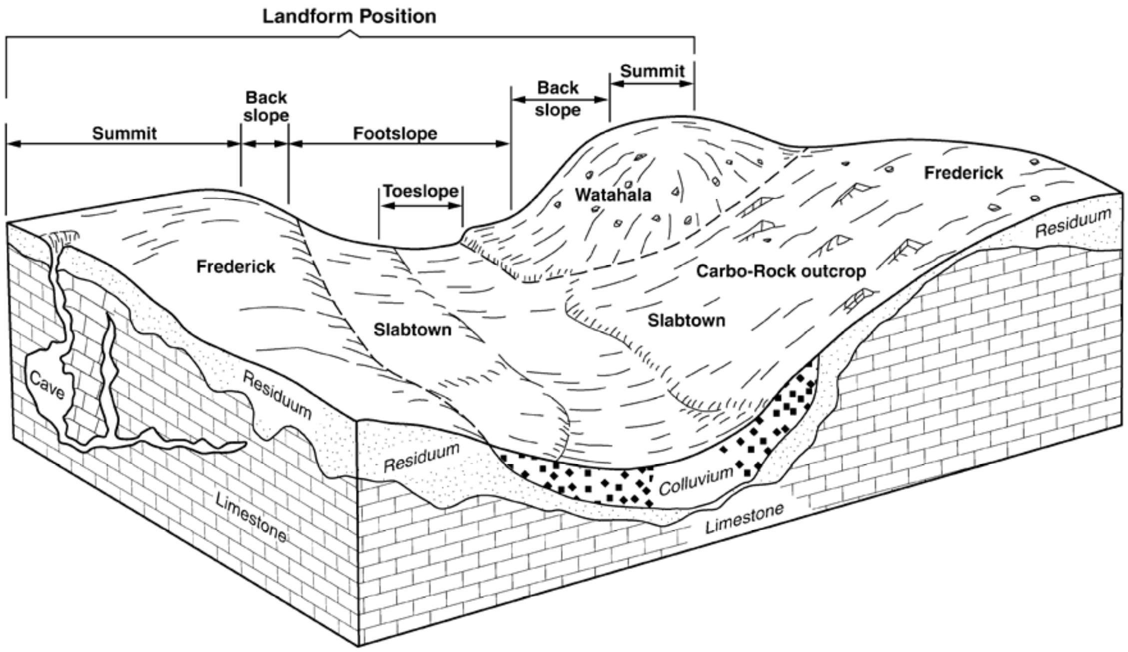
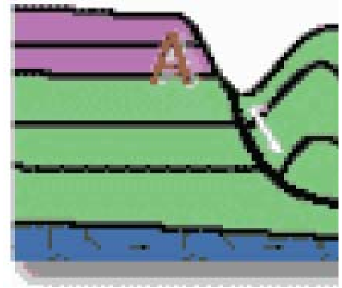


Figure: 3- 81. Idealized landscape in Limestone/Dolostone Valleys. Frederick soils are weathered from predominantly limestone and are well drained. Carbo soils are also derived from limestone and are well drained. However, Carbo soils are moderately deep (20 to 40 inches) to rock. Slabtown soils are weathered from colluvium and they are moderately well drained (1.5 to 3 feet to seasonal high water table). Watahala soils are weathered from cherty limestone and are gravelly. They are deep and well drained. *(NRCS Soil Survey of Bland County)*

The Appalachian Plateau province occupies the southwestern portion of the state. It lies to the northwest (A) of the Valley & Ridge province. The boundary between the two provinces, known as the Allegheny structural front in northern and central Virginia is where the large folds of rock found in the Valley & Ridge become smaller folds and flat lying rocks in the Plateau. Although some parts of the Plateau are relatively flat, there are many valleys and stream hollows, making much of the Appalachian Plateau very hilly and rugged. Wide folds in the Plateau were formed when thrust faults from the Valley & Ridge province didn't reach today's surface. The upper Paleozoic layers of the Plateau are rich in mineral resources like coal, natural gas, and petroleum. *(William & Mary Department of Geology; Appalachian Plateau for Students & Teachers; The Geology of Virginia)*



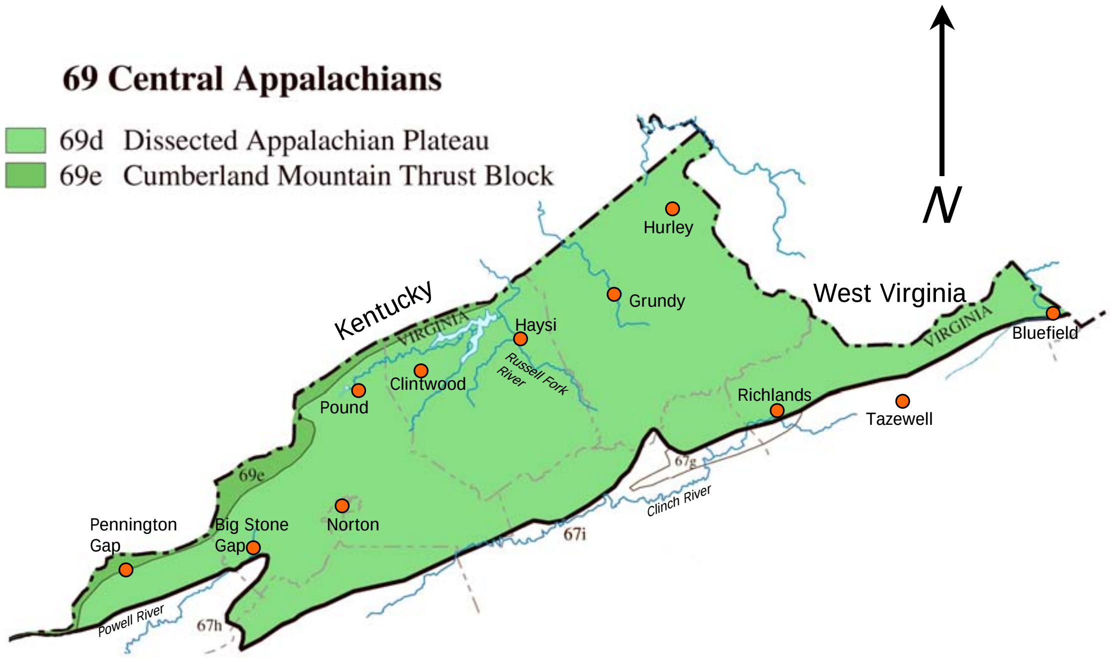


Figure: 3-82. Appalachian Plateau Ecoregions. *(EPA Level III Ecoregions of Virginia)*

Figure: 3-83. Unlike the Valley and Ridge, sedimentary bedrock in the Appalachian Plateau is mostly horizontal. *(Photo by Tom Saxton)*

69. Central Appalachians

Ecoregion 69 includes parts of south central Pennsylvania, eastern West Virginia, western Maryland, and southwestern Virginia. It is a high, dissected, and rugged plateau made up of sandstone, shale, conglomerate, and coal of Pennsylvanian and Mississippian age. A limestone valley and a few anticlinal ridges locally punctuate the plateau. Its soils have developed from residuum and are mostly Ultisols and Inceptisols. Elevations can be high

Figure: 3-84. Surface mine benches near Elkins Branch in Buchanan County. When working in these areas, one should be aware of disturbed and *man-influenced* soils. *(NRCS Soil Survey of Buchanan County)*

enough to insure a short growing season, a great amount of rainfall, and extensive forest cover. Bituminous coal mines are common and associated stream siltation and acidification have occurred. The boundaries of Ecoregion 69 are shown on figure 3-81. Its eastern boundary with the folded and faulted strata of the Valley and Ridge (67) occurs along the sandstone escarpment known as the Allegheny Front. There are two mapping units in Virginia; the Cumberland Mountains (69d) and the Cumberland Mountain Thrust Block (69e). Descriptions of the individual characteristics of these two ecoregions follow.

69d. Cumberland Mountains

The Cumberland Mountains (69d) is a strongly dissected region with steep slopes, very narrow ridgetops, and extensive forests. It is primarily underlain by flat-lying Pennsylvanian sandstone, siltstone, shale, and coal. Well-drained soils of low to moderate fertility have developed on the sedimentary rocks. Marrowbone, Shelocta, Gilpin, Highsplint (colluvium), Cloverflint (colluvium), Berks, and Matewan, soils are common and are Ultisols and Inceptisols. These soils are limited for drainfields by depth to rock, slope, stoniness and compaction due to mining equipment. There are also many mine spoil soils in the region. These soils are man-made from previous mining operations. They are not normally suitable for onsite wastewater disposal because they are considered to be fill material. However, very sandy spoil may be suitable on a case-by-case basis. The boundary between Ecoregion 69d and the Valley and Ridge (67) approximates a major structural topographical, lithological, elevational, and land use break.

Table: 3-6. Representative Soil Series in the Dissected Appalachian Plateau (69d)

Soil Series	Slope %	Depth to Rock	Textural Family	Drainage Class	Permeability Class	B Horizon Color	Comments
RESIDUUM on Ridges and Nose slopes							
SANDSTONE PARENT MATERIAL							
Marrowbone *Matewan#*	8-70	20-40	Coarse-Loamy	Well	Moderately rapid	Strong brown (7.5YR 5/6)	Narrow ridges, associated with rock outcrops
SHALE interbedded with fine-grained siltstone and sandstone PARENT MATERIAL							
Gilpin *Berks#*	8-80	20-40	Fine-loamy	Well	Moderate	Yellowish brown (10YR 5/6)	Wider, convex ridgetops
CLAY SHALE PARENT MATERIAL							
Wharton	8-25	40-72+	Fine	Mod. Well	Low to Mod. low	Brown (10YR 5/3)	On nearly level areas of wider ridges
COLLUVIUM derived from sandstone and shale on mountain slopes							
Shelocta *Highsplint#*	35-80	72+	Fine-loamy	Well	Moderate	Yellowish brown (10YR 5/6)	Concave mountain sides, foot slopes, and benches
Cloverlick	35-70	60+	Loamy-skeletal	Well	Mod. High	Dark Yellowish Brown (10YR 4/6)	Thick, dark surface layer on cool aspects
ALLUVIUM							
Grigsby	0-3	60+	Coarse-loamy	Well	High	Strong brown (7.5YR 4/6)	Floodplains and low terraces of major rivers
Philo	0-3	60+	Coarse-loamy	Mod. Well	Mod. High	Dark yellowish brown (10YR 4/4)	Recent alluvium on Floodplains
Craigsville	0-5	60+	Loamy-skeletal	Well	High	Dark yellowish brown (10YR 4/4)	Minor Floodplains, frequent flooding
MINE SOILS							
Cedarcreek *Kaymine**	0-80	60+	Loamy-skeletal	Well	Mod. High**	Olive brown (2.5Y 4/4)	Derived from shale, coal, siltstone and sandstone
Sewell *Fiveblock**	0-80	60+	Loamy-skeletal	Smwht. Excessive	High**	Dark yellowish brown (10YR 4/6)	Formed mostly in acid sandstone
Itmann *Stonecoal**	0-80	72+	Loamy-skeletal	Smwht. Excessive	High**	Black (10YR 2/1)	Coal refuse piles

Loamy-skeletal, Inceptisol counterpart

* Non-acid counterparts

** May be slow due to potential densic contacts

69e. Cumberland Mountain Thrust Block

The mostly forested Cumberland Mountain Thrust Block (69e) contains high, steep ridges, hills, coves, and narrow valleys. The Cumberland Mountain Thrust Block (69e) is mostly underlain by Pennsylvanian shale, siltstone, sandstone, conglomerate, and coal. Sedimentation from coalmines, coal washing, and logging as well as acidic mine drainage has decreased the biological integrity and productivity of surface waters. This mapping unit occupies a very small area in Virginia and is adjacent to Kentucky. The soils and limitations for onsite sewage disposal are the same as 69d.

Onsite Sewage Disposal

Due to the rugged topography including very steep, long mountain slopes, and narrow ridges with shallow soil to bedrock, flat land is at a premium for development in the Appalachian Plateau Physiographic Province. Yet, there are only small amounts of flat or nearly level land available along creeks and rivers in the area. These lands are flood prone and already occupied by houses or industries. Surface coal mining resulting in mountaintop removal has created large acreages of flat land. Despite this, reclaimed mine land is generally not suitable for onsite systems.

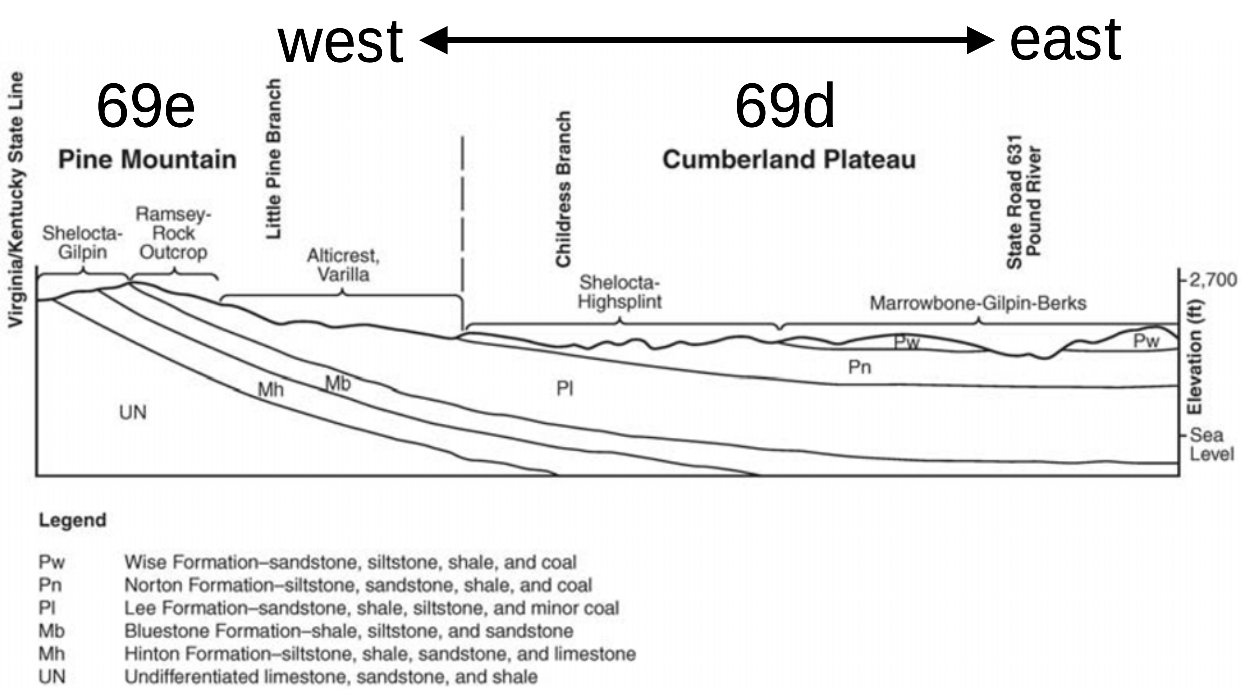


Figure: 3-85. Idealized cross-section of Dickenson County. *(NRCS Soil Survey of Dickenson County)*

Table: 3-7. Soil series found on the Pine Mountain Over-thrust.

Series	Slope %	Depth To Rock	Textural Family	B Horizon Color	Comments
Ramsey	35-80	10-20	Loamy	Yellowish brown (10YR 5/6)	On the tops and upper parts of dip slopes of Pine Mountain
Alticrest	15-80	20-40	Coarse-loamy	Strong brown (7.5YR 5/6)	Residuum from acid sandstone on the dip slopes of Pine Mountain
Varilla	15-55	48-60	Loamy-skeletal	Dark yellowish brown (10YR 4/6)	Stony sandstone colluvium found at the base slopes of Pine Mountain
Gilpin	8-80	20-40	Fine-loamy	Yellowish brown (10YR 5/6)	On convex dissected uplands; moderately permeable residuum from shale.
Shelocta	35-80	72+	Fine-loamy	Yellowish brown (10YR 5/6)	Shale and sandstone colluvium on concave mountain sides, foot slopes, and benches

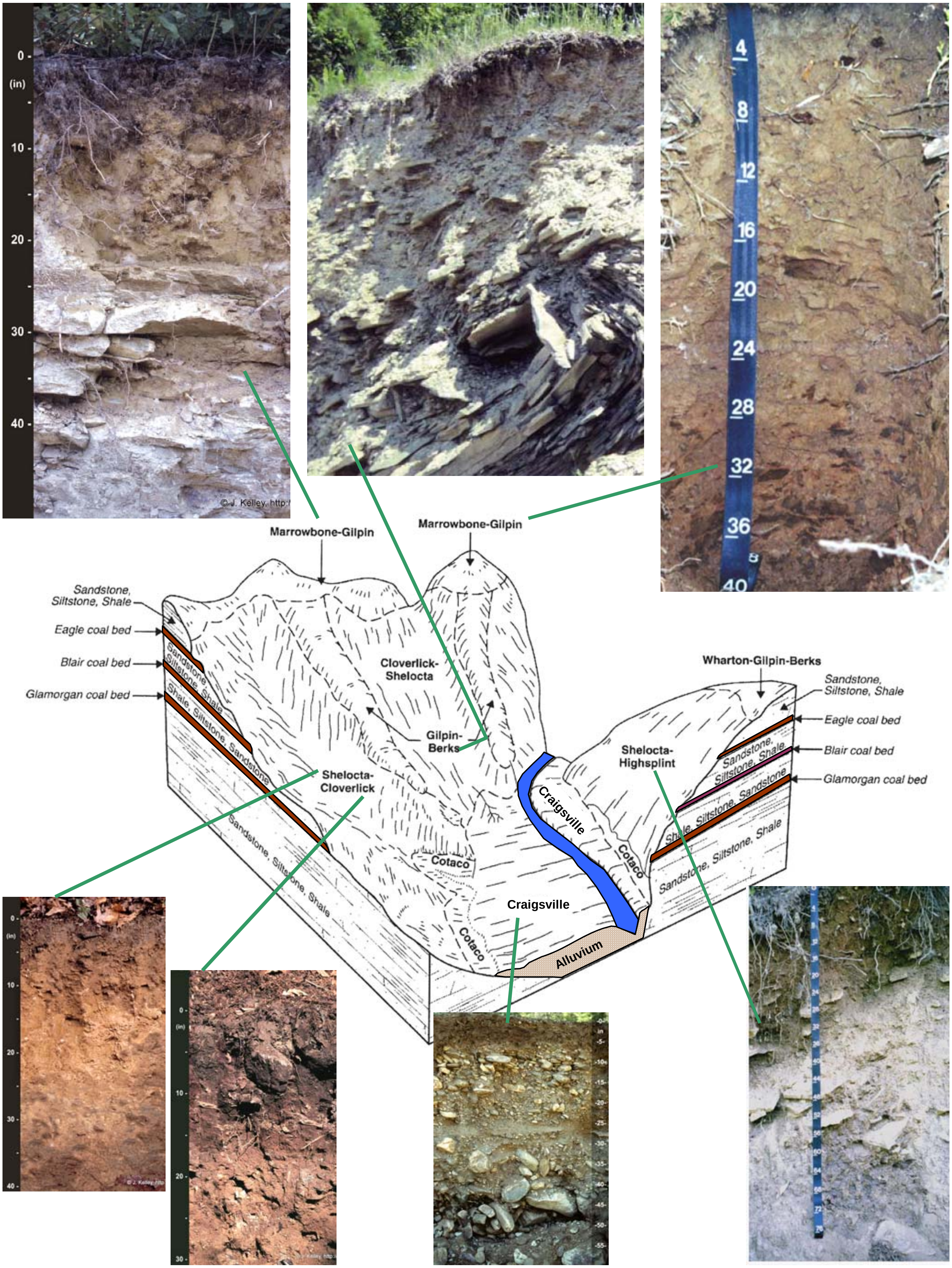


Figure: 3-86. Idealized landscape in the Appalachian Plateau. *(NRCS Soil Survey of Buchanan County, Cloverlick, Shelocta, Craigsville, and Marrowbone photos by John Kelly (http://soil science.info), Berks photo by NRCS Soil Survey of Clinton County Pennsylvania).*

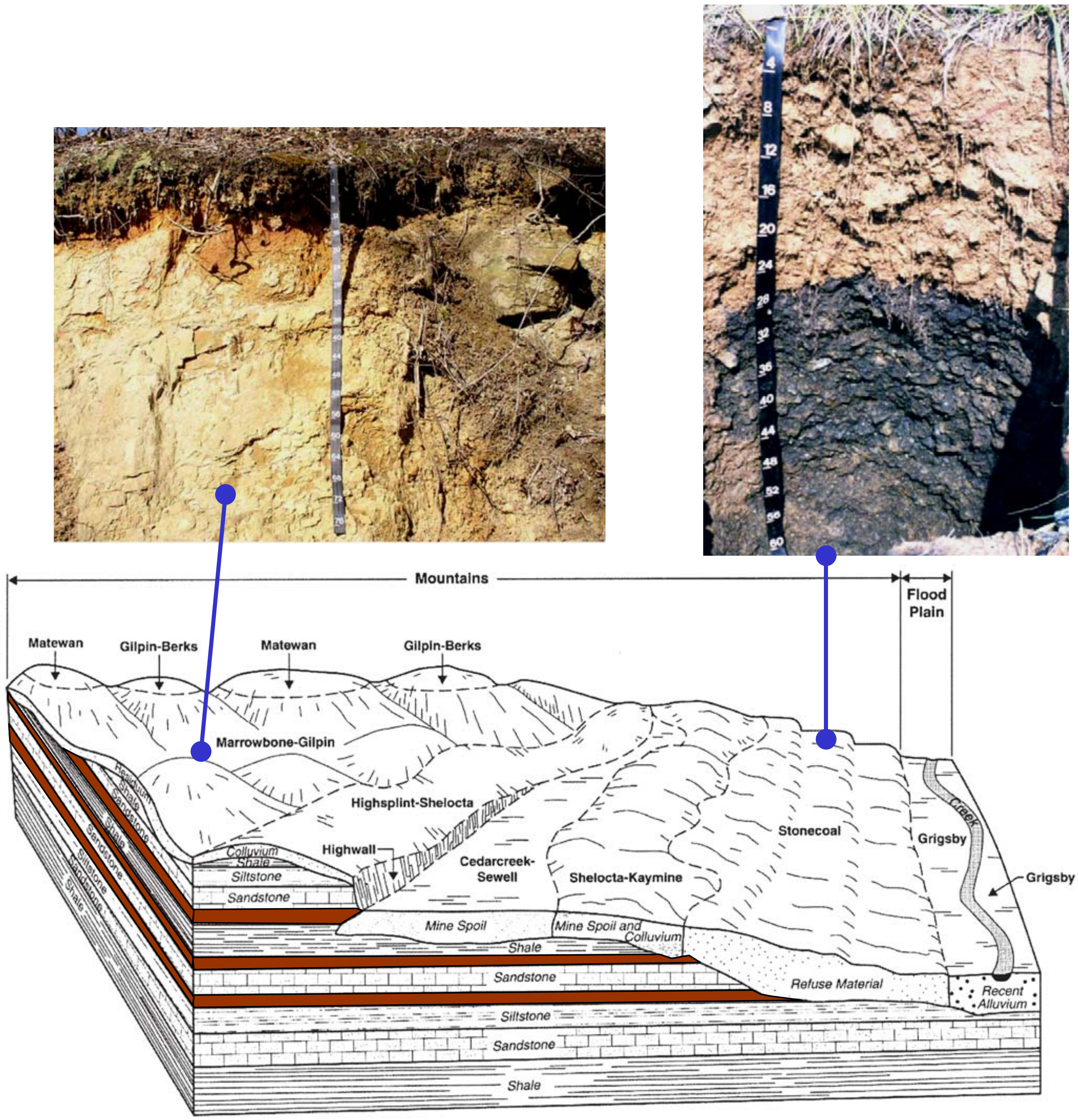


Figure: 3-87. Idealized landscape across a coal mining area in Russell County. Stonecoal is not a natural soil and may restrict water movement through the soil. *(NRCS Soil Survey of Russell County)*

The common residual parent materials in the Appalachian Plateau are sandstone, shale, and siltstone. These materials are flat bedded and can be generally found at consistent and predictable elevations throughout the regions. The surface and subsoil textures are a direct reflection of the parent material. For example, sandstone-derived soils typically have a sandy surface and subsoil layers, while shale derived soils will have silty textured horizons. Soils formed from sandstone are most extensive on the ridges and in the rocky areas of mountainsides. Two examples are Marrowbone and Matewan soils. Matewan often occurs as a complex with sandstone rock outcroppings occurring on shoulder slopes of the mountainside. Bedrock occurs between 20 and 40 inches in these two soils. Residuum from acid shale and siltstone is the parent material for Berks and Gilpin soils. These soils are permeable in their subsoil layers. However, bedrock occurs between 20 and 40 inches. Wharton soils are derived from mudstones (clayey shale) and are found on flat spots (less than 7% slopes) on the broader ridgetops. These soils have perched water tables overlying impermeable clay layers. They are moderately well drained. Alluvial parent materials are deposits along streams, which were laid down by floodwaters. They are of local origin along the small streams and larger streams. Soils derived from alluvium have variable soil characteristics and are influenced by the types of soils in the surrounding watershed. Examples are Grigsby and Philo soils.

Colluvial parent material deposits result when soil movement from higher slopes to lower slopes due to gravity or mass movement occurs. They dominantly are on middle and lower mountain slopes and are primarily moderately coarse textured, medium textured, or moderately fine textured. Examples are Cloverlick, Highsplint and Shelocta soils. These soils are very deep. Highsplint contains more than 35% by volume channers (loamy-skeletal). Cloverlick soils have relatively thick surface organic layers and are found on north and northeastern facing slopes and in coves.

By convention, the soils on the upper one-third (in elevation) of a typical mountain slope are dominantly residual. These landscapes include shoulders and upper sideslopes of the mountainside. The shallowest soils may occur on shoulder positions where the level bedded shale or sandstone breaks the ground surface. These soils are limited by shallow to very shallow depths to hard bedrock. Suitable soils for septic systems are usually prospected below this rock ledge, where deeper soil depths may be found.

Normally, the soils on the lower two thirds of a given mountainside are colluvial. These colluvial soils are deep to very deep to bedrock and are limited for septic system installation primarily by rock fragment content and excessive slopes (greater than 50 percent). However, deep relatively stone free soils often occur and may be found suitable for onsite sewage disposal systems.

The <u>2000 Sewage Handling and Disposal Regulations</u> define "fill" as *"soil transported and deposited by man as well as soil recently transported and deposited by natural erosion forces."* The regulations state: *"Placement of subsurface soil absorption systems in fill materials is generally prohibited except in specific situations including systems constructed in "fill material consisting of colluvial soil derived from sandstone (noncarbonaceous) in the mountainous area."* Although mentioned in the regulations, this practice is typically not implemented today.

Mine Soils

The nature of mine soils are a direct reflection of the type of overburden above the mined coal seam. This regolith consists of varying amounts of shale fragments, siltstone fragments, coal fragments, and sandstone fragments ranging in size from gravel to boulders. These soils are primarily coarse textured, moderately coarse textured, or medium textured. Examples are Kaymine and Sewell soils, which are udorthents, formed in urban areas where the soil has been disturbed.

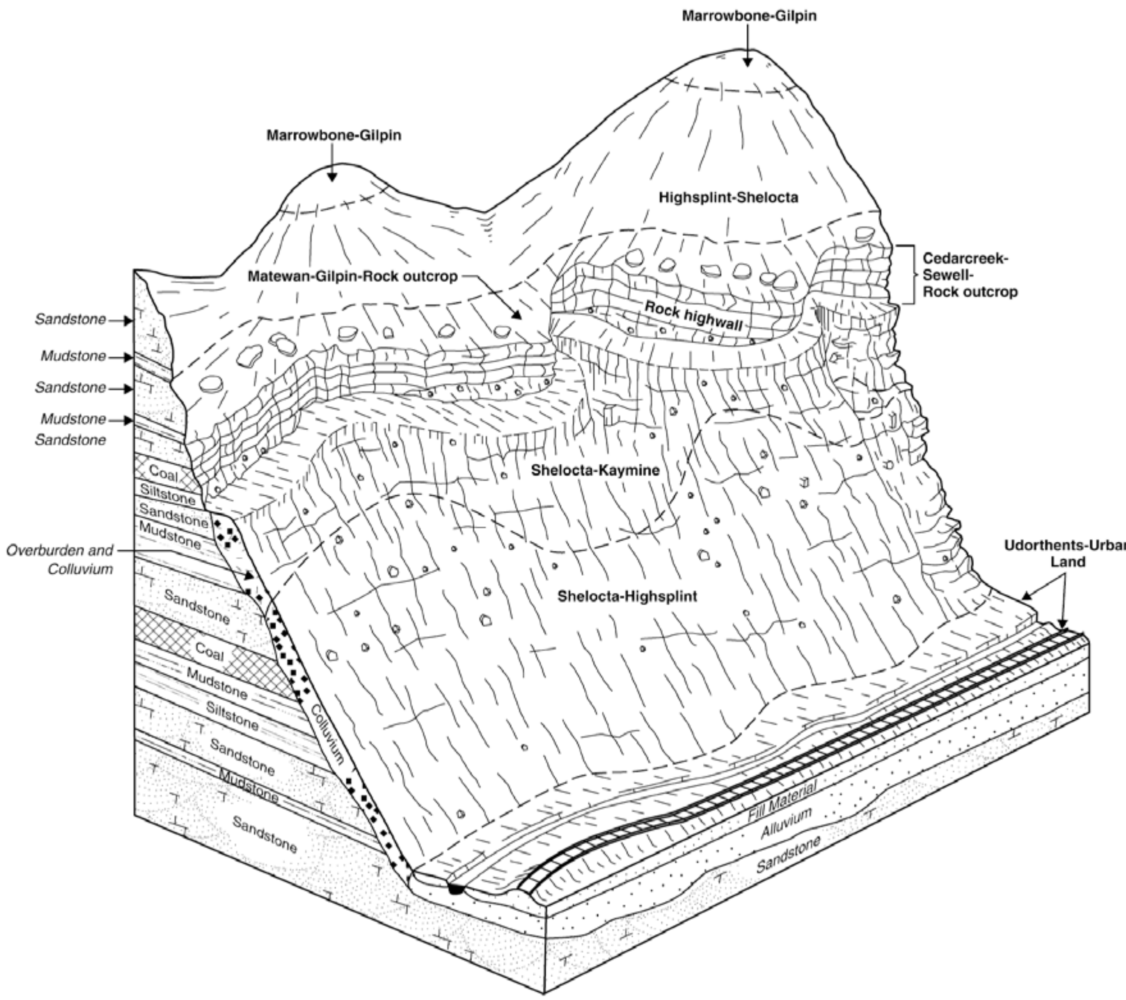


Figure: 3-88. Illustration of an area that has been surface mined for coal, showing a sequence of native residual and colluvial soils, mine soils, rock outcrop, and a single exposed highwall. The soils named on the land surface are shown in their natural relationship to each other and in their relationship to landform position and geologic strata. *(NRCS Soil Survey of Dickenson County)*

When compared with surrounding natural soils, mine soils have:

1) Higher rock fragment contents and poorer structure (Daniels and Amos, 1981, Thurman and Sencindiver, 1986.

2) Higher bulk density (up to 2.07g/cm3 for surface layers and 2.44 g.cm3 subsurface layers.

3) Low porosity in mine soils (26 to 38 percent pore space) compared to significantly higher porosities for natural soils from 35 to 50 percent pore space (Thurman and Sencindiver 1986).

4) Lower in saturated hydraulic conductivity.

5) Less organic and carbon water holding capacity.

Current Virginia Department of Health regulations do not allow conventional on-site wastewater systems (OWS) on reclaimed mine sites. The primary factor influencing mine soil variability is the mining equipment operations. Mine soil variability is not predictable based on factors such as landscape position and geologic pattern that typically are used to evaluate the spatial variability of natural soil properties. Subsurface mine soils can be highly variable within short distances, even when no expression of that variability is detectable at the surface. Mine soils can range from porous to heavily compacted, with limited capacity to absorb and move treated wastewater. Some mine soils contain subsurface voids (Haering, et al., 2004).

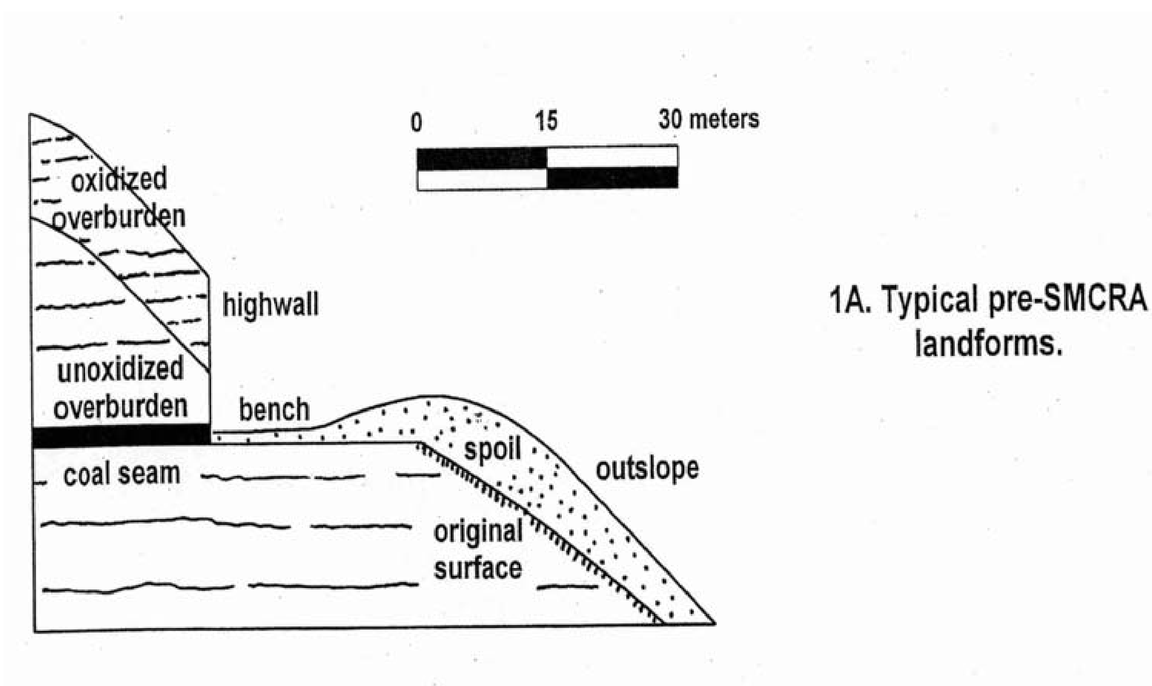


Figure: 3-89. Cross-section of typical pre-SMCRA bench/highwall /outslope landform. *(Kathryn Haering Research Associate Department of Crop and Soil Environmental Sciences Virginia Tech, 2004)*

Because contact of treated wastewater with soil surfaces is essential to further renovation, the presence of subsurface voids can be expected to severely limit the soil's wastewater renovation effectiveness. On existing mine sites, there is greater lateral variability of soil conditions over the area occupied by a hypothetical drainfield than would be typical in a similarly sized area of natural soil.

Thin weathered coal seams (locally known as coal blooms) commonly occur at depths less than 150cm under benches on steep slopes. These occur under rock outcrops or shallow soil layers as thin bands that can be contiguous over great distances, but may also be found as isolated spots. These layers often have slow permeability and are therefore limiting for onsite sewage disposal systems.

Mine Soil Landscapes

The passage of the federal Surface Mining Control and Reclamation Act of 1977 (SMCRA) resulted in major changes in coal mining and reclamation methods in the Appalachians. Prior to SMCRA, the "shoot and shove" method was used in contour mining (Haering et al., 2004). This resulted in 1) an exposed vertical rock column, or highwall directly above a 2) relatively flat bench covered with varying depths of blasted or bulldozed rocky spoils, and a 3) steep outslope composed of loose spoils that had been bulldozed over the edge of the bench (figure 3-88 (1a)) over the pre-existing slope. The tens of thousands of acres of pre-SMCRA land which remains today are classified as abandoned mine land.

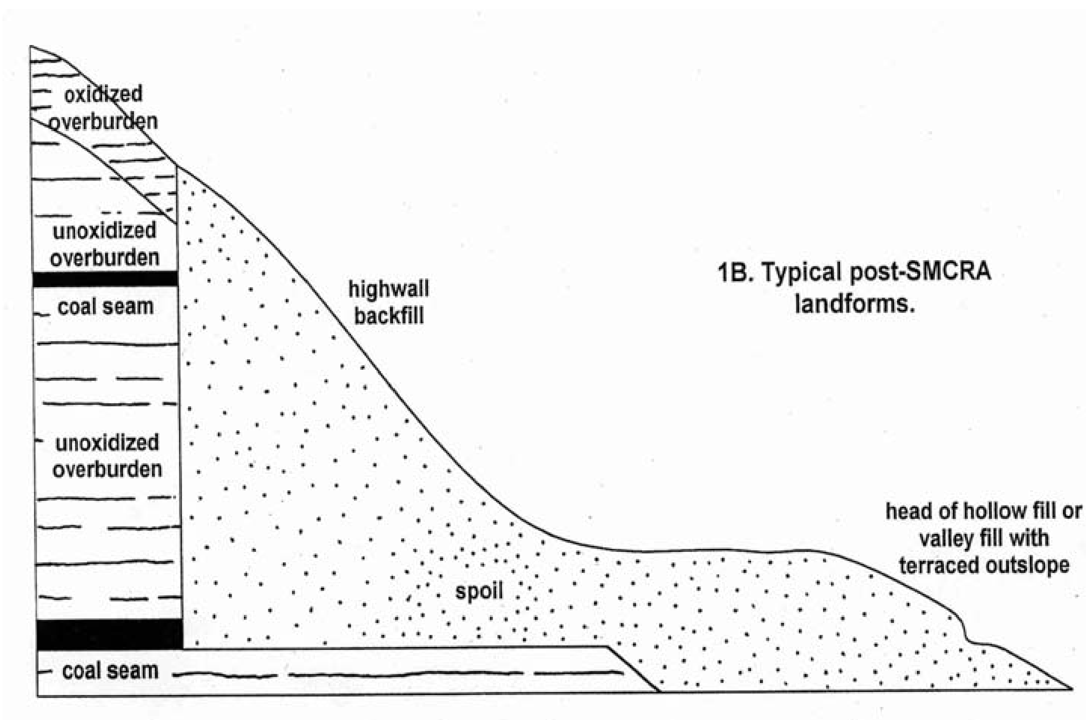


Figure: 3-90. Cross-section of typical post-SMCRA highwall backfilled and return to its approximate original contour. *(Kathryn Haering, Research Associate Department of Crop and Soil Environmental Sciences, Virginia Tech, 2004).*

The landforms generated by pre-SMCRA mining were long, sinuous, and relatively narrow flat benches and associated highwalls, which commonly continued on contour for several miles. Multiple mining benches were common, and sometimes two benches were close enough to one another that the outslope spoils from one bench continued down onto an immediately adjacent bench below (Haering, 2004). This left isolated islands of natural soil and undisturbed vegetation between.

Post 1977

The passage of SMCRA mandated that coal mined lands were to be returned as close as possible to approximate original contour, including backfilling highwalls (figure 3-90 (1B)) and revegetation was required. As mining technology improved, new areas on steeper slopes were mined for the first time, and many older mined areas have been extensively remined.

Mine Soil Morphology

Mine soils have been studied extensively in southwest Virginia, particularly at the Powell River Project in Wise County. More information and a list of publications can be found at http://www.prp.cses.vt.edu/Research_Results/Soil_Development.html

Generalized results from soil morphology research indicate that pedogenesis can occur rapidly in reclaimed mine soils:

- Distinct A and AC horizons can form in several years (7-8) (depending upon organic matter additions).
- B_w horizons form in 10 to 20 years in finer textured spoils (characteristic of Inceptisols).
- Development of subsurface horizons such as AC and B_w horizons appeared to be related more to rooting density, depth and fines (silt and clay) content than to mine soil age.
- Heavily compacted zones and densic layers (C_d) commonly occur near the soil surface due to traffic upon spoil placement.
- Densic layers are permanent unless tilled with a deep ripper.
- These compacted zones commonly perch water.
- Densic layers were often underlain by looser material with common bridging voids.
- A *sulfuric horizon* can form in areas where sulfidic materials have been exposed.

It is commonly assumed that mined landscapes contain a thick mantle of well and excessively drained coarse textured spoils. In reality, their internal drainage patterns are complex, and vary with reclamation methods. Densic contacts form from machinery resulting in perched water tables. These water tables create poorly and very poorly drained mine soils in depressional landscapes that collect surface runoff. Hydric soils are often found at the bench/highwall contact (figure 3-90 (1b)).

Research related to the use of mine soils for septic systems

Research on the use of mine soils for domestic wastewater renovation has been conducted by Ray Reneau and Charles Hagedorn, of the Department of Crop and Soil Environmental Sciences, since 1990. Research publications from the Powell River Project may be found here: http://www.prp.cses.vt.edu/Research_Results/Wastewater_Renovation.html

Daniels, W. L. and D. F. Amos. 1981. *Mapping, characterization and genesis of mine soils on a reclamation research area in Wise County, Virginia* . p. 261-275. In: Proc. 1981 Symposium on Surface Mining Hydrology, Sedimentology and Reclamation, Univ. of Ky., Lexington, KY.

Haering, K.C., Daniels, W.L. & Galbraith, J.M. 2004, Appalachian Mine Soil Morphology and properties: Effects of the Weathering and Mining Method. *Soil Science Society of America Journal*, 69: 1315-1325.

Thurman, N.C., Sencindiver, J.C. 1986, Properties, classification, and interpretations of mine soils at two sites in West Virginia. *Soil Science Society of America Journal*, 50: 181-185.

Transported Soils are abundant throughout Virginia, being found in all of the physiographic provinces. Transported soils on traditional depositional surfaces such as footslopes, toeslopes, terraces, alluvial plains, and marine terraces have been described in terms of the transported material from which they have weathered. These soils can be divided into two categories, colluvium (gravity formed) and alluvium (water deposited). Colluvium can be difficult to distinguish from alluvium. They are formed by similar events; water and gravity transport both. There are many soils weathered from transported material on divides and interfluves throughout Virginia. The mode of transport for these sediments is speculative. Landscape position gives the soil evaluator clues to the nature of the transported material. Topographic maps are often used to identify landscape positions and patterns of drainage before a site visit is made. Soil borings on site may be used to confirm landscape/geomorphic position. Most of the major cities in Virginia are built upon transported soils consisting of fans and terraces.

Intense soil formation is considered to have occurred during Miocene (5-23 mbp) (see figure 3-36 and 3-90), as well as cave formation and alluviation (Dietrich, 1990). Much weathering, erosion, and deposition also took place. Upland gravel deposits *(cappings)* were laid down during the Pliocene (1.8-5 mpb). Beach sands and gravels were deposited in the Pleistocene (1.8 mbp) and during episodes of high sea levels; Coastal Plain terrace formations were laid down. The climate changed in late Miocene to one that was favorable for dominantly physical weathering. There have been many major glacial periods in the last 700,000 years. These contrasting climates have created the greatest influence on the shaping of the landscape, although, Virginia was not glaciated. Alternating freezing, thawing, and snowmelt would cause run-off and fluvial erosion. The Pleistocene saw great fluviation and colluviation (Pavich, 1989). Terraces display the release of frost-bound debris during climatic change, such as periglacial times when large

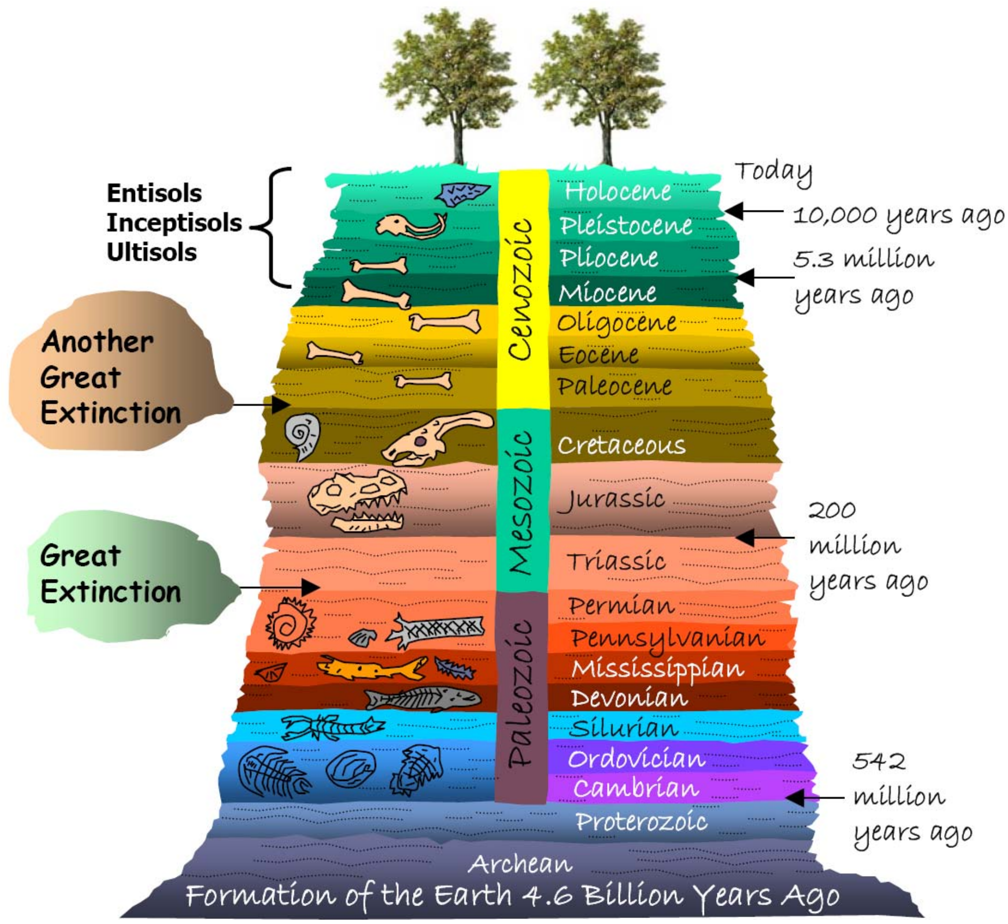


Figure: 3-91. Geologic Time scale simplified. *(TS)* sediment loads were deposited (Clark and Ciolkosz, 1988). Glacial advance promoted increased precipitation in Virginia. Warmer and drier climates would prevail during interglacial periods (Whitehead and Barghoorn, 1962).

"Gully planation" is the result of alternating erosion and colluviation between gullies and nose slopes (Mills, 1981). Material washes into gullies, thereby shielding them. They become more resistant to erosion than adjacent noses resulting in their elevating relative to the now eroding nose slopes. The original gully is now a nose slope and the cycle begins again. This concept is the "close-up" view of ***landscape inversion***. Similar processes occur with stream and river terraces. As the river down cuts, it leaves behind alluvium that ages and weathers and is ultimately left elevated relative to the stream. The higher in elevation (relative to the stream), the older and more developed the soil. Landscape inversion is a common explanation for the formation of transported soils. Parizek and Woodruff (1957) suggest that these soils may have developed as a result of ancient intermittent stream channels and gullies active during periods of erosion. Howard (1978) proposed that deposits of gravel on wide inner stream divides and interfluves were laid down in valleys by meandering or braided streams, associated with alluvial fans. Topography inversion then took place, leaving these deposits stranded on the ridge tops.

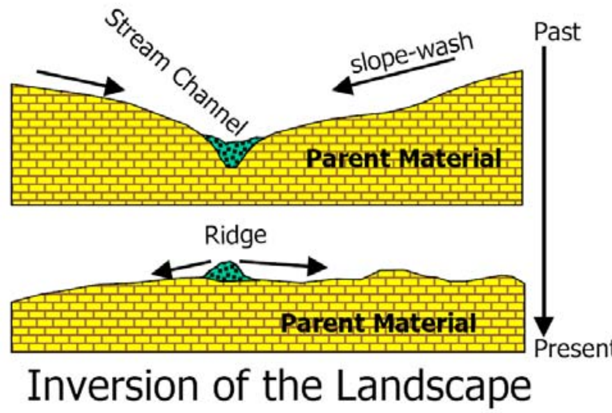


Figure: 3-92. Landscape inversion. What was once low becomes high due to *shielding* of the landscape by the more resistant deposits. *(TS)*

Alluvium

Floodplains are adjacent to streams and rivers where flooding deposits material in the channel. These areas differ from hillslope alluvium positions because the material has been carried from upstream floodwaters and *sorted* into similar sized particles. The particle size deposited depends on the energy of the floodwater.

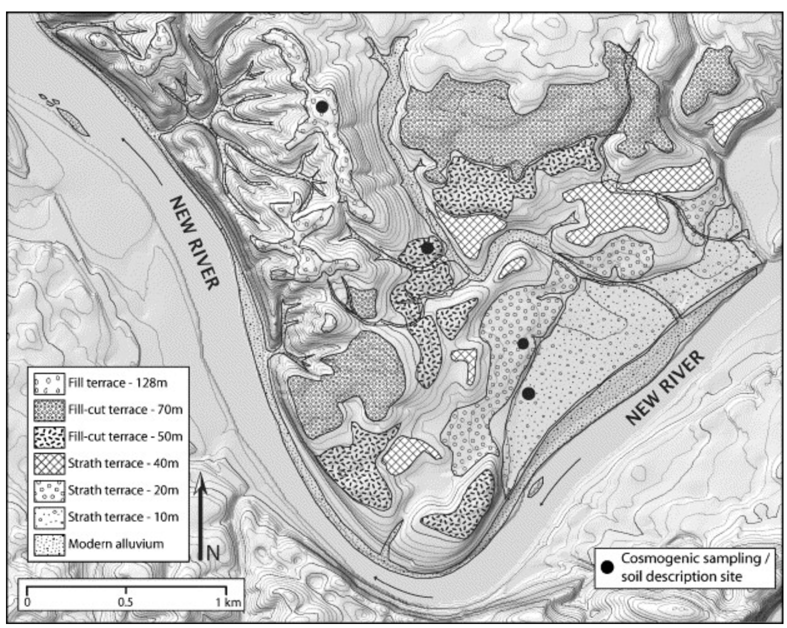


Figure: 3-93. Terraces on the New River near Blacksburg Virginia. (Dylan J. Ward, James A. Spotila, Gregory S. Hancock, John M. Galbraith. *New constraints on the late Cenozoic incision history of the New River, Virginia*, 10 May 2005)

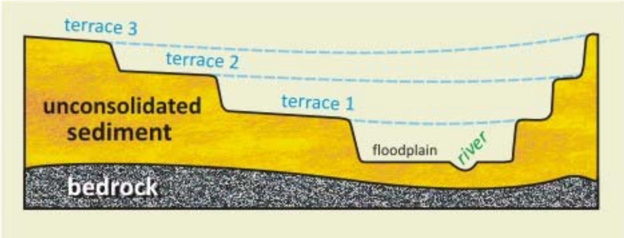


Figure: 3-94. Idealized sequence of terraces along a river. Soils in the floodplain are the youngest. Terrace 3 contains the oldest soils. Terrace 3 would be redder and contain more clay than Terrace 1 & 2. *(Callan Bentley, NVCC)*

Slowly receding water will drop out finer size particles, while swift moving water will deposit larger size particles, such as cobbles. These landscapes are normally flat areas adjacent to streams.

Alluvial soils are formed in layers from their deposition rather from weathering. Soil horizons are not distinct and may change due to texture or slight color differences. Soil drainage may range from excessively to poorly drained. Major problems are flooding and complete saturation of soils, which may result in both environmental and health hazards.

Fluvial terraces are elongated terraces that flank the sides of floodplains and fluvial valleys. These terraces are alluvial deposits (deposited by water) that are the former floodplains that have been left at a higher elevation by down cutting on rivers and streams. The younger terraces tend to be yellower while the older terraces become progressively redder, due to the increased age and weathering of the sediments. Older terraces can have better horizonation and higher clay content than younger terraces. The soils can range from well to poorly-drained with the better-drained soils closer to the stream and the poorer drained soils closer to the valley walls.

Figure: 3-95. Three terraces along the Snake River in Wyoming are evident. *(Photo by Tom Saxton)*

These terraces consist of a relatively level strip of land, called a “tread,” separated from either an adjacent floodplain, other fluvial terraces, or uplands by distinctly steeper strips of land called “risers.” These terraces lie parallel to and above the river channel and its floodplain. They are the remnants of earlier floodplains that existed at a time when either a stream or river was flowing at a higher elevation before its channel downcut to create a new floodplain at a lower elevation. *(http://en.wikipedia.org/wiki/Fluvial_terrace)* Studies on the New River have shown incision rates (down cutting) that average 43 meters per million years on average *(D. J. Ward, et al 2005)*. Therefore, one can see that terraces several hundred feet above the floodplain consist of very old soils.

Soils encountered in terraces are as complex as the deposits from which they formed. High-energy environments produce deposits of coarse material. Low energy fluvial deposits are fine textured. Rounded gravel deposits sometimes underlie terraces, which is an indicator of a lithologic discontinuity. These may pose problems if they are dense and compact. This compactness may result in perched water tables during the wet season. Fragipans (dense compacted/cemented horizon in soils) may occur in the mid level terraces and low terraces may be subject to flooding.

Figure: 3-96. Complex floodplain deposits are a function of the energy of transport. The gravelly deposits were deposited in a high-energy environment. This Snake River bank is approximately 12' tall. These are Entisols (young). The rivers in Virginia are older and these properties may be masked by weathering and age, but the principles are the same. *(Photo by Tom Saxton)*

Idealized River Terrace Sequence West of the Fall Zone and in the Upper Coastal Plain

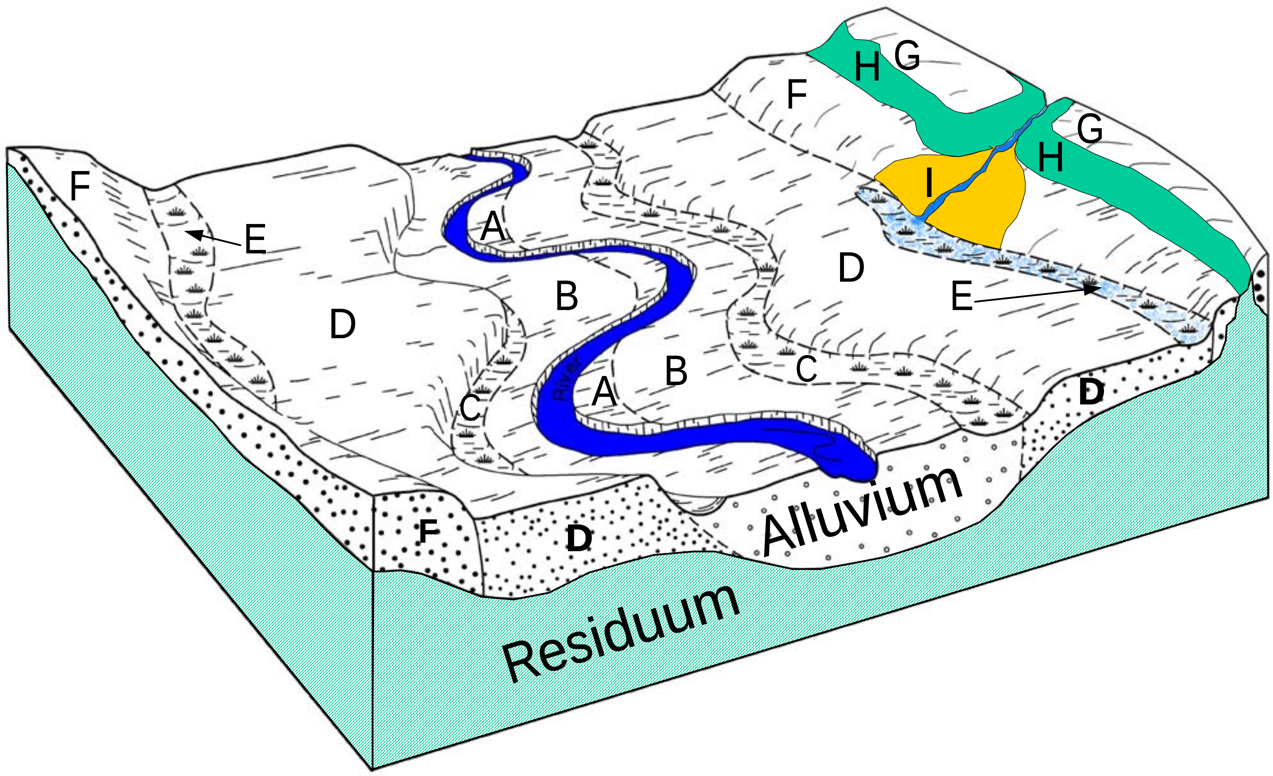


Figure: 3-97. **A** represents coarse textured levee deposits, which are normally Entisols but may also be Inceptisols or Mollisols.

B represents the floodplain, which is typically well drained near the river and becomes increasingly wetter with greater distance from the river. These soils are normally loamy textured fining with increasing distance from the river. They are Entisols, Inceptisols and Mollisols.

C is the back swamp, which is poorly to very poorly drained and fine textured Inceptisols, Entisols, Mollisols and occasionally Ultisols.

D is the low terrace and rarely floods. These soils are normally moderately well to well drained 2.5Y to 7.5YR fine loamy Ultisols and Alfisols.

E represents and old back swamp position and may be somewhat poorly to very poorly drained clayey Ultisols and Alfisols.

F represents the mid terrace and is composed of moderately well to well drained 7.5YR to 5YR clayey Ultisols and occasionally Alfisols.

G is the high terrace and is composed of extremely old, often palic, well drained, clayey, 2.5YR to 10R Ultisols. The higher the terrace; the older, the redder, and the greater the percentage of clay.

H represents areas where terrace deposits have eroded away leaving soils weathered from residuum.

I is a recent colluvial/alluvial fan that has subsequently formed from a mixture of colluviated terrace deposits and residuum. This fan is normally a coarse textured Entisol or Inceptisol and is moderately well drained. Ultisols with fragipans are also common especially in the mountains.

Table: 3-8.

Soil Series Commonly Mapped on Virginia Piedmont, Blue Ridge, Valley and Ridge and Appalachian Plateau River Terraces						
Land-scape	Series	Tax	Drainage	Subsoil Color	Subsoil Texture	Province
A	Buncombe	E	Ex	5YR-10YR	s-lfs	BR, P & CP
	Derroc	I	W	5YR-10YR	sl or l	R&V
	Galtsmill	M		7.5YR-10YR	sl-sil	P
B						
	Batteau	M	MW	7.5YR-2.5Y	sl-sicl	P
	Chewacla	E	SWP	5YR-2.5Y	variable	P
	Chagrin	I	W	7.5YR-10YR	sl-sicl	R&V
	Codorus	I	MW & SWP	7.5YR-10YR	l-sicl	BR & P
	Comus	I	W	7.5YR-10YR	fsl-sil	BR & P
	Congaree	E	W-MW	5YR-10YR	l-sicl	P & CP
	Craigsville	I	S-EX--W	5YR-10YR	sl-l	AP, R&V, BR
	Gladehill	M	W	7.5YR-10YR	sl-l	R&V
	Grigsby	I	W	7.5YR-10YR	sl-l	AP
	Ingledove	A	W	5YR-10YR	l-cl	R&V
	Irongate	M	MW	7.5YR-10YR	sl-sil	R&V
	Lobdell	I	MW	7.5YR-2.5Y	sl-sicl	R&V
	Orrville	I	SWP	10YR-5Y	sl-sicl	R&V
	Philo	M	MW	7.5YR-2.5Y	sl-sil	R&V, AP
	Pope	E	W	7.5YR-10YR	ls-scl	R&V, AP
	Riverview	E	W	7.5YR-10YR	sl-l	P & CP
	Speedwell	M	W	7.5YR-10YR	l-sil	P, R&V
	Sindion	M	MW	7.5YR-5Y	sl-sil	P, R&V
	Toccoa	E	W-MW	5YR-10YR	variable	P
	Wingina	M	W	7.5YR-10YR	fsl-sicl	P
	Wolfgap	M	W	7.5YR-10YR	l-cl	R&V
C	Atkins	I	VP	10YR-5Y	l-sil	BR, R&V
	Hatboro	I	P	10YR-5Y	fsl-sicl	BR & P
	Holly	I	VP-P	10YR-5Y	l-sil	R&V, AP
	Wahee	U	SWP	2.5Y	cl	P
	Wehadkee	I	VP-P	10YR-5Y	s-cl	P
	Yogaville	M	P	10YR-5Y	sl-sicl	P
D	Allegheny	U	W	7.5YR-2.5Y	scl, sil-cl	R&V, AP
	Alonzville	U	W	7.5YR-2.5Y	l-sicl	R&V
	Altavista	U	MW	7.5YR-2.5Y	l-cl	BR, P & CP
	Augusta	U	SWP	10YR-2.5Y	l-cl	P & CP
	Bannister	U	MW-SWP	7.5YR-2.5Y	scl-c	P
	Botetourt	A	MW	7.5YR-2.5Y	l-cl	R&V
	Cotaco	U	MW	5YR-2.5Y	l-sicl	R&V, AP
	Coursey	U	MW	5YR-2.5Y	l-cl	R&V
	Chavies	A	W	5YR-10YR	l-sil	
	Delanco	U	MW	2.5YE-2.5Y	scl-sicl	BR & P
	Dogue	U	MW	7.5YR-2.5Y	scl-c	P & CP
	Ebbing	A	MW	7.5YR-2.5Y	l-cl	R&V
	Elsinboro	U	W	2.5YR-7.5YR	l-cl	BR & P
	Ingledove	A	W	5YR-10YR	l-cl	R&V
	Mongle	A	SWP	10YR-2.5Y	l-sicl	R&V, BR, P

	State	U	W	7.5YR-10YR	l-d	BR, P & CP
	Wheeling	A	W	7.5YR-10YR	l-sicl	R&V
	Wickham	U	W	5YR-7.5YR	scl	BR, P & CP
E	Maurertown	A	P	10YR-5Y	sic-c	R&V
	Purdy	U	VP-P	10YR-5Y	sic-c	R&V
	Roanoke	U	P	10YR-5Y	cl-c	P & CP
	Tygart	U	SWP	10YR-2.5Y	sicl-c	R&V
	Worsham	U	P	10YR-5Y	cl-c	P
F	Cottonbend	U palic	W	2.5YR-10YR	l-cl	R&V
	Monongahela	U fragic	MW	7.5YR-2.5Y	scl-sicl	R&V
	Nicelytown	U palic	MW	10YR-2.5Y	l-sicl	R&V
G	Braddock*	U	W	10R –2.5YR	cl-sc	R&V
	Dyke*	U rhodic	W	10R-5YR	cl-sic	R&V
	Hiwassee	U rhodic	W	10R-2.5YR	cl-sc	BR & P
	Masada	U	W	2.5YR-10YR	cl-c	P & CP
	Shottower	U palic	W	10R-7.5YR	scl-c	R&V
	Turbeville	U palic	W	10R-5YR	cl-c	BR, P & CP
	Wintergreen**	U palic	W	10R-2.5YR	cl-sc	BR & P

* These soils are considered to have weathered from mountain colluvium, but were mapped on river terraces in many Valley and Ridge counties.

** Mixture of river terrace and colluvium at the foot of the Blue Ridge and river terrace where mapped in the piedmont.

Idealized River Terrace Sequence in the Middle and Lower Coastal Plain

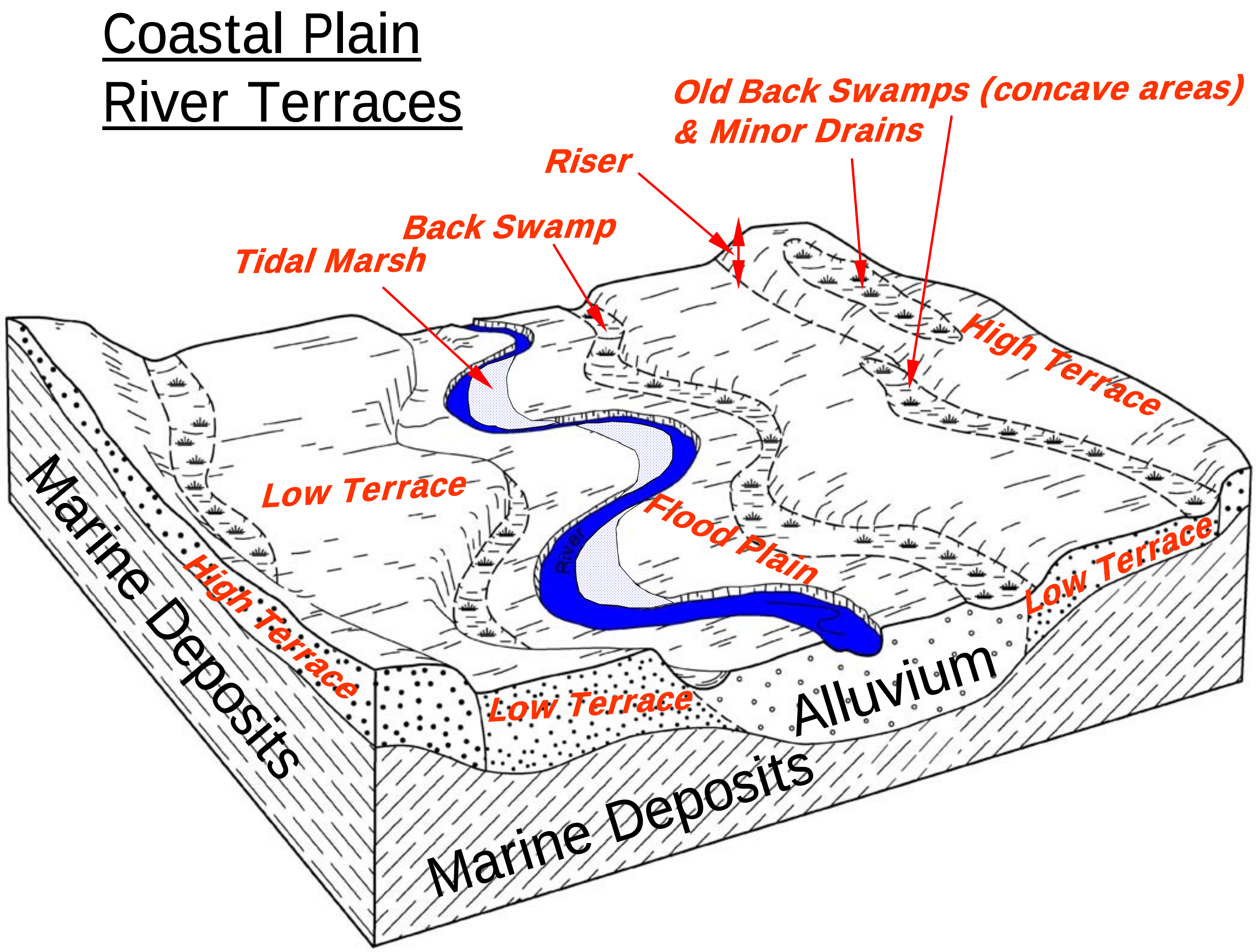


Figure: 3-98.

Tidal marshes are normally composed of a thick layer of organic material over mineral soils. They are permanently saturated.

Floodplains are young Entisols and Inceptisols. They are mostly sandy to loamy textured depending upon the velocity of the depositional environment.

Back swamps normally have finer textured soils than those found on other portions of the floodplain. They are also wetter.

Low terrace soils are older than soils on floodplains and are therefore more developed. They are Ultisols.

Risers are extremely variable due to the horizontality of Coastal Plain deposits. They are sandy to clayey textured.

High terraces are older than low terraces. They are also Ultisols and are fine loamy to clayey textured.

Table: 3-9.

Soil Series Commonly Mapped on Virginia Upper to Middle Coastal Plain River Terraces					
Landscape	Series	Tax	Drainage	Subsoil Color	Subsoil Texture
A	Buncombe	E	Ex	5YR-10YR	s-lfs
	Tarboro	E psamm		5Y-5GY	sic
B	Bibb	E	P	5Y- N/	sl
	Buncombe	E	Ex	5YR-10YR	s-lfs
	Catpoint	E psamm	S-EX	7.5YR-10YR	ls-s
	Chewacla	E	SWP	5YR-2.5Y	variable
	Congaree	E	W-MW	5YR-10YR	l-sicl
	Kinston	I	P	10Y-5Y	cl
	Riverview	E	W	7.5YR-10YR	sl-l
	Tarboro	E psamm	S-EX	10YR	ls-s
C	Chastain	I	P	10YR 6/1	c
	Chickahominy	U	P	10YR-5Y	cl-sic
	Levy	E	VPD	10YR-5G	sil-sic
	Roanoke	U	P	10YR-5Y	cl-c
	Wehadkee	I	VP-P	10YR-5Y	s-cl
D	Altavista	U	MW	7.5YR-2.5Y	l-cl
	Augusta	U	SWP	10YR-2.5Y	l-cl
	Dogue	U	MW	7.5YR-2.5Y	scl-c
	Nansemond	U	MW	10YR	fsl
	Newflat	U	SWP	10YR	c
F	Bojac	U	W	10YR	fsl
	Pamunkey	A	W	5YR	scl-cl
	State	U	W	7.5YR-10YR	l-d
	Wickham	U	W	5YR-7.5YR	scl
G	Caroline	U palic	W	5YR-10YR	cl-c
	Masada *	U	W	2.5YR-10YR	cl-c
	Turbeville *	U palic	W	10R-5YR	cl-c
* Mapped in Upper Coastal Plain only. Near the Fall Zone, piedmont residuum is often encountered.					
Riser	Remlik **	U arenic	W	7.5YR-10YR	fsl-scl
	Nevarc**	U	MW	5YR-2.5Y	scl-sic
** Not mapped in upper Coastal Plain					
Old Back Swamps & Drains	Chickahominy	U	P	10YR-5Y	cl-sic
	Roanoke	U	P	10YR-5Y	cl-c
	Wahee	U	SWP	2.5Y	cl

Table: 3-10.

Soil Series Commonly Mapped on Virginia Middle to lower Coastal Plain River Terraces					
Landscape	Series	Tax	Drainage	Subsoil Color	Subsoil Texture
Tidal Marsh	Bohicket	E	VPD	5Y-5GY	sl-sic
	Rappahannock	H	VPD	10YR-5GY	sil-c
Floodplain	Alaga	E psamm	S-EX	10YR	s
	Bibb	E	P	5Y- N/	sl
	Chipley	E psamm	SWP	10YR-5Y	s
	Congaree	E	W-MW	5YR-10YR	l-sicl
	Kinston	I	P	10Y-5Y	cl
	Leon	S	VP-P	5YR-10YR	s-ls
	Riverview	E	W	7.5YR-10YR	sl-l
	Seabrook	E	MW	10YR	s
	Tarboro	E psamm	S-EX	10YR	ls-s
Back Swamp	Chickahominy	U	P	10YR-5Y	cl-sic
	Levy	E	VPD	10YR-5G	sil-sic
	Osier	E psamm	PD	10YR	s
	Roanoke	U	P	10YR-5Y	cl-c
Low Terrace	Altavista	U	MW	7.5YR-2.5Y	l-cl
	Augusta	U	SWP	10YR-2.5Y	l-cl
	Conetoe	U	W	7.5YR	sl
	Dogue	U	MW	7.5YR-2.5Y	scl-c
	Eunola	U	MW	10YR	scl
	Munden	U	MW	10YR	l-sl
	Nansemond	U	MW	10YR	fsl
	Newflat	U	SWP	10YR	c
	Nimmo	U	PD	10YR	fsl
	Wahee	U	SWP	2.5Y	cl
Riser	Remlik	U arenic	W	7.5YR-10YR	fsl-scl
	Nevarc	U	MW	5YR-2.5Y	scl-sic
Old Back Swamps & Drains	Chickahominy	U	P	10YR-5Y	cl-sic
	Myatt	U	P	10YR-5Y	fsl-cl
	Ogeechee	U	P	10YR-2.5Y	scl-cl
	Rains	U palic	P	10YR-5Y	fsl-sc
	Roanoke	U	P	10YR-5Y	cl-c
High Terrace	Bojac	U	W	10YR	fsl
	Caroline	U palic	W	5YR-10YR	cl-c
	Pamunkey	A	W	5YR	scl-cl
	State	U	W	7.5YR-10YR	l-d

Colluvium

Colluvium is a type of parent material that moved down slope due to gravitational forces (in some cases water may play a role in initiation of the movement). Colluvium is heterogeneous, *unsorted* material of all particle sizes (from boulders to clay) with relatively little abrasion to round the particles. Consequently, colluvium consists of angular, subrounded, to rounded fragments of all sizes. *Colluvial* deposits are generally associated with mountainous areas, but may occur at considerable distances from their source. These soils are widespread and occur mainly in the Valley and Ridge, at the base of the Blue Ridge, and all throughout the Piedmont. In the Coastal Plain, these deposits tend to be small, recent and localized. Mass waste deposits move material in mass without any sorting. Slumps, debris flows and slope creep are examples. They will be discussed later in this section.

Distinguishing features include a uniform slope gradient at the base of mountains and randomly oriented rock throughout the profile. The depth to hard rock and thickness of the deposit are variable. Natural drainage ranges from well to poorly drained.

The contact (discontinuity) with the old land surface often develops a tight, compact layer, which restricts water movement. This restriction plus a flat landscape may result in seasonal perched water tables.

Figure: 3-99. Colluvium in Amherst County; note the random orientation of the rocks in the colluvium. *(Photo by Tom Saxton)*

Mass Waste Deposits

Creep is the slow downward movement of soil usually due to freeze thaw/ wet dry cycles causing a "heaving" or slight uplift of the soil. Creep occurs as the soil, which acts like a slow moving fluid (solifluction), creeps down the hill. Discontinuities will form at the slip

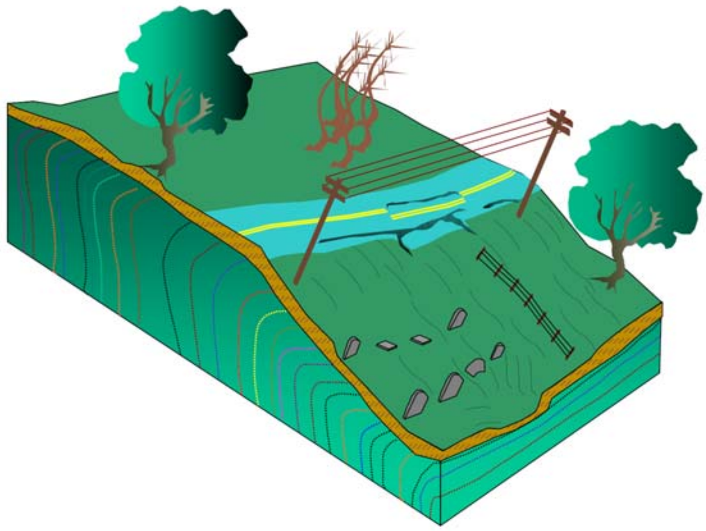


Figure: 3-100. Creep or soil/slope creep may cause unstable areas for construction. Down slope curved tree trunks are indicators of this process. *(Photo by Tom Saxton) (TS)*

contact, which will yield permeability rates slower than the soil texture might indicate.

Slumps are a mass movement process of slope failure, in which a mass of rock or unconsolidated material drops along a concave slip surface. Slump units move downslope as an intact block (without internal deformation or sorting of the landslide material) and frequently rotate backwards. Discontinuities will form at the slip contact, which will yield permeability rates slower than the soil texture might indicate.

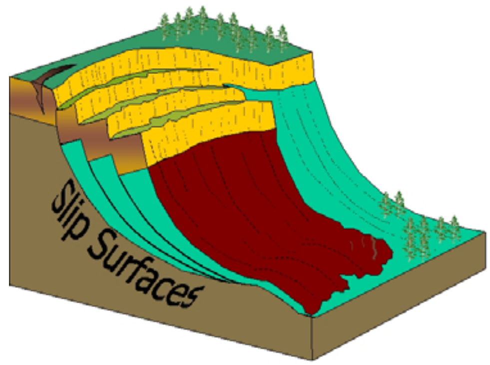


Figure: 3-101. The material in a slump has not been sorted by water and will therefore; resemble residual soils unless closely studied. Discontinuities will form at the slip surfaces. *(TS)*

Debris flows are a moving mass of loose mud, sand, soil, rock, water and air that travels down a slope under the influence of gravity. Some debris flows are very fast. In areas of very steep slopes they can reach speeds of over 100 miles per hour (160 km/hour). However, many debris flows are very slow, creeping down slopes by slow internal movements at speeds of just one or two feet per year (30 to 60 centimeters per year) *(http://geology.com/articles/debris-flow/)*. Discontinuities will form at the flow contact, which will yield permeability rates slower than the soil texture might indicate.

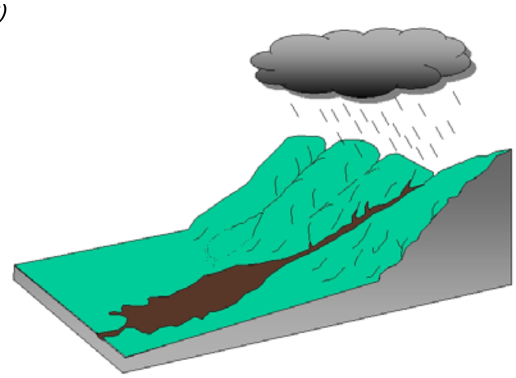
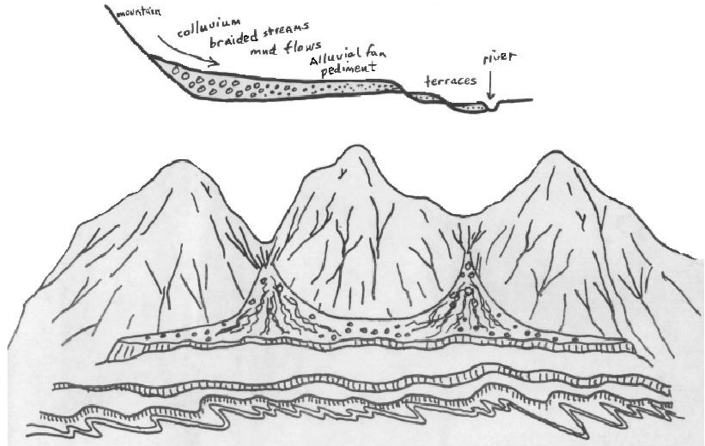


Figure: 3-102. Debris flow. *(TS)*

Fans are cone-shaped accumulations of alluvial/colluvial-deposited sediments, formed at the interface between steep hillslopes and flat valleys where streams exit confined channels.

Fans typically consist of the coarsest, often bouldery materials nearest the mountain and fine progressively away from the source. The lobe-shaped fans grow with younger fans streaming out between lobes of older fans. On the present landscape older fans occur as foothills. They are the most eroded and weathered uplands. Between the "lobes" of these fans and topographically below the scattered remnants of the older fans are less dissected and weathered fans. The inner, steeper portions of these fans are typically drained by braided streams, which begin to meander as slopes decline. This fluvial aspect of the fan makes it difficult to separate from the fluvial deposits of a through-flowing river except that the fans are coarser, less well sorted and composed wholly of locally derived materials. River terrace deposits are less coarse, better sorted and characterized by having gravel clasts derived from a distant source area. *(J. Howard 1978)*



From Howard; 1978

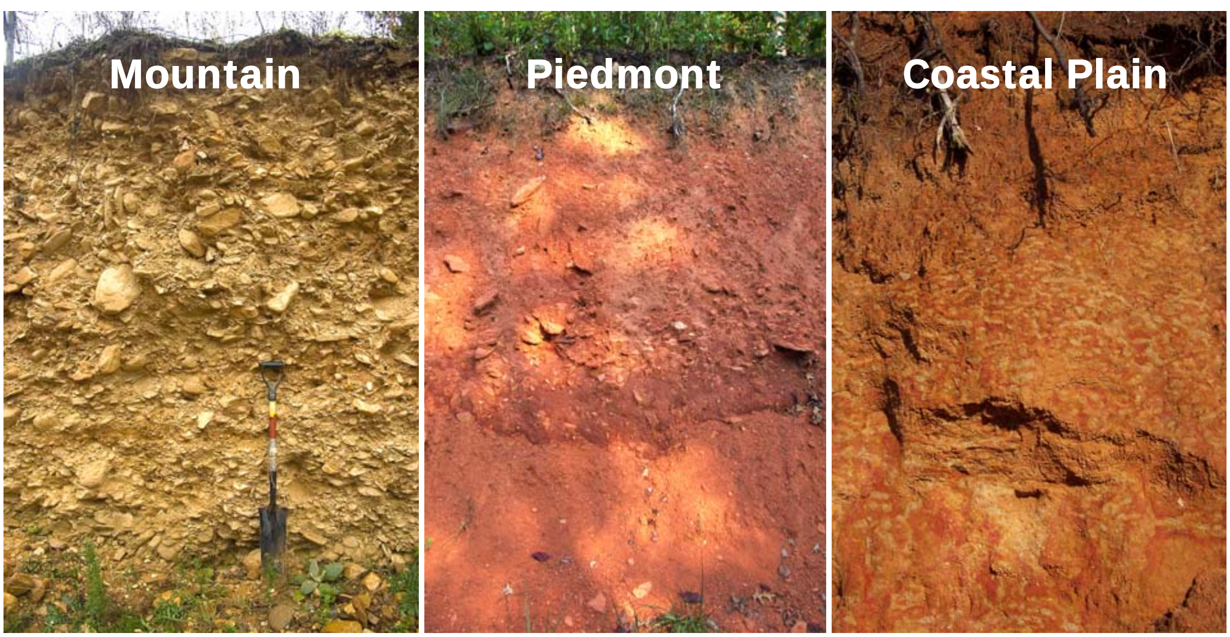
Figure: 3-103. Idealized Fan landscape in the eastern Blue Ridge of Virginia as conceived by Jeffrey Howard 1978.

Figure: 3-104. Small fan in Amherst County. *(Photo by Tom Saxton)*

Much of the Coastal Plain was formed as large delta or fan deposits. Rivers draining the western portion of the state released their sediment load once they encountered the low energy marine environment.

Fans are important for onsite sewage disposal system design because they may have limitations due to perched water tables formed as a result of the layering of the materials or they may contain fragipans.

Figure: 3-105. Braided streams have many meandering channels and islands. Fans immediately east of the Fall Line are thought ot have been deposited by braided streams much like this one in Wyoming.
(Photo by Tom Saxton)



FAN DEPOSITS

Figure: 3-106. Fan deposits from different areas of Virginia have characteristics that reflect source material and age of the deposit. *(Photos by Tom Saxton)*

Chapter 4
Field Description of Soils

Introduction

In order to assess a site for any type of land use, the soil must be described and features identified. This chapter will detail the methods for field and in some cases laboratory methods, to fully describe the soils at a given site.

Understanding and interpreting soils is an iterative process that begins with a soil description and leads towards an assessment of the soils suitability to carry out its proposed land use. Specifically, this chapter will focus on the skills needed to describe and interpret the soil including: profile description, wetness conditions, restrictive horizons, assess suitability, aerobic conditions and internal vs. external drainage. Evaluation of the soil is just one component of fully assessing a site. There are additional site factors and characteristics that must also be evaluated. These are discussed in Chapter 5.

Once the hole is dug/bored, decisions need to be made as to what should be described. The level of detail of this description will be related to the proposed land use. However, a soil description should include most if not all the following: horizon, depth, color, texture, features, consistence, (structure, pores and, roots-pit description). Each component of the description will aid in the overall interpretation, however, depending on land use, some will be more important than others. Since we are describing soils for the sole purpose of drainfield design, some soil properties may not be necessary to document unless the evaluator considers this characteristic important at the site for subsurface soil absorption system function; “reaction” is an example.

Soil Color

A conspicuous characteristic of soil is color. Important characteristics can be inferred from soil color. Well drained soils have uniform bright colors. Soils with a fluctuating water table have a multicolored pattern of gray, yellow, and/or brown colors. Organic matter darkens the soil and is typically associated with surface layers. Organic matter will mask all other coloring agents. Iron (Fe) is the primary coloring agent in the subsoil. The red to brown colors associated with well drained soils are the result of Fe oxide stains coating individual particles. Manganese (Mn) is common in some soils resulting in a very dark gray to black color. Several other soil minerals have distinct colors, which make their identification straightforward. For example, glauconite is green, Quartz has various colors but is often white or gray, feldspars range from pale buff to white, micas may be white, brownish black, or golden, and kaolinite appears gray to white.

2 VAC 5-610-490. Characteristics of soils that determine suitability.
A. Color. Color is a key indication of the suitability of a soil.

Color determination is subjective if just a verbal description is used. In general, each person will perceive color differently. Because of this, there is a need to standardize color notations. The Munsell Color System was created to promote consistency. In order to be able to standardize color, some basic understanding of the properties that govern it are needed. Recall that white light (or visible EM wavelengths) can be broken into the colors of the rainbow (ROYGBIV). Each spectral color (ROYGBIV) corresponds to a specific wavelength. The color we see is the wavelength that is reflected off the surface of what we are looking at. Thus, if we see a red object, the red wavelength is being reflected and all other colors are being absorbed. It is possible to measure the wavelength reflected off an object, but the equipment is expensive and not easily used in the field. Due to the expense, determining the spectral wavelength is not ideal.

History of Color/Science Behind Munsell system

In the early 1900s, work was done to make color description easier. The method devised used the artist's color wheel. Each pie wedge represented a particular spectral wavelength or HUE (R=Red etc.). These wedges could be further divided into smaller sections (1R = 10% Red, 10R = 100% Red). Typically, only the 25, 50, 75 and 100% are used (2.5, 5, 7.5, and 10). Hue refers to the dominant wavelength of light (red, yellow, green, etc.). The HUE does not tell the whole story. Value is also a component and refers to how light or dark the color is (gray scale).

Value indicates the degree of lightness or darkness of a color relative to gray. Value extends from pure black (0/) to pure white (10/) and is a measure of the amount of light that reaches the eye. Gray is perceived as about halfway between black and white and has a value notation of 5/. Lighter colors have values between 5/ and 10/; darker colors are between 5/ to 0/. Chroma is the relative purity or strength of the spectral color. Chroma indicates the degree of saturation of neutral gray by the spectral color. Chromas extend from /0 for neutral colors to

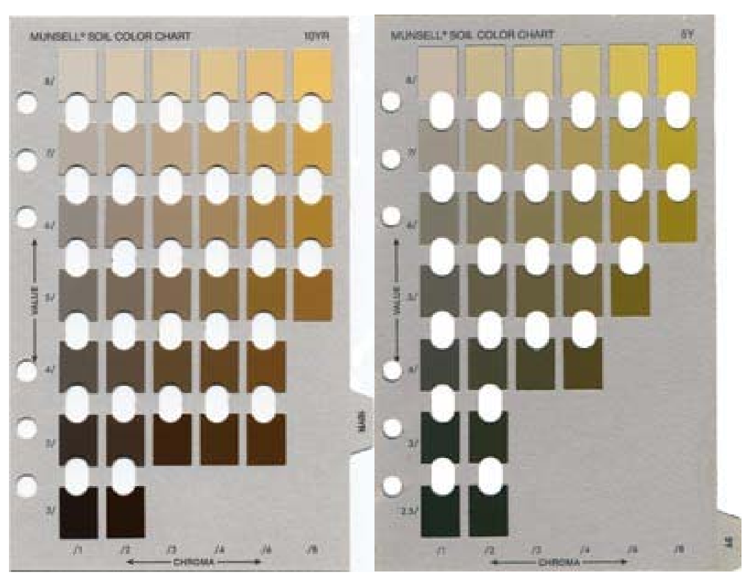


Figure: 4-1. Munsell Color Pages *(NRCS)*

/8 as the strongest expression of the color. The typical notation of color is an alphanumeric term of Hue Value/Chroma or 10YR 5/6. Some colors have symbols such as N 6/. These are totally achromatic (neutral color), and have no hue and no chroma, only a value.

Gley colors/pages are a specific group of colors that when observed in soils, generally mean the soil has formed under saturated conditions. However, some types of bedrock may also be these colors. The gley page is set up differently from the other pages. Hue is along the bottom; its value increases along the Y-axis. When the colors have a chroma of 0, hue is N. In other hues of gley color, the chroma is 1 or 2. Checking the face page will indicate which chroma is being used.

Methodology/How to Record Color

"Under field conditions, measurements of color are reproducible by different individuals within 2.5 units of hue (one card) and 1 unit of value and chroma. Rarely will the color of the soil sample be perfectly matched by any chip in the color book. The probability of a perfect match is less than one in one hundred. However, it should be evident which chips the sample color lies between and which chip is the closest match," (Chapter 3, Soil Survey Manual).

Colors should be recorded in a specific fashion. The soil should be moist. Although this is the most common way soil colors are recorded they can be recorded in the dry state. At all times, the moisture status of the sample should be noted. Always use a freshly exposed face or ped and record what is being colored. Do not crush or rub the soil before getting a color unless it is an organic sample. Colors must always be determined in natural light (direct sunlight). Furthermore, colors should not be determined late or early in the day as the sun angle can alter the observed color. Colors should never be determined under artificial light. Finally, color should not be determined when one is wearing sunglasses or tinted glasses.

Source of Soil Colors

Material	Composition	Color
Manganese	MnO_2	**Purplish Black**
Hematite	Fe_2O_3	**Red**
Goethite	FeOOH	**Yellow**
Hydrated Ferric Oxide	$Fe(OH)_3nH_2O$	**Red-Brown**

Figure: 4-2. Source of colors found in soil. *(NCSU)*

When describing colors, it is important to determine the variation in color throughout the soil. Matrix color is the color that occupies the greatest volume of the horizon. Some horizons have several colors; the color that appears the most is recorded first.

Wetness Features and Non-Wetness Characteristics of Soil Color

Redoximorphic features result from the reduction, oxidation, and translocation of Fe and/or Mn. Mottles *(** see Regulation quote)* are color patterns not related to soil wetness. They are often related to parent material, mineralogy, or weathering patterns. Other color patterns may be described separately for any feature such as peds, concretions, nodules, cemented bodies, filled animal burrows, etc. Gley colors are low chroma matrix colors with or without mottles. If the soil has a gley color, it is likely to be reduced and wet for much of the year. Likewise the percent of the given feature should be recorded.

Redoximorphic Features

INTRODUCTION

Soil color patterns are widely acknowledged as good long-term indicators of soil wetness conditions. The Sewage Handling and Disposal Regulations have long emphasized the need to accurately describe and document soil color to assess the type drainfield best suited to the site (Section 610-470.D and Section 610-490). As knowledge and understanding of soils has changed over time, there have been changes in terminology used to describe soil colors. In order to avoid confusion and to ensure that the latest and most accurate information is utilized in soil descriptions, this curriculum will serve as a guideline for professionals describing soils, or reviewing soils work submitted by others.

> **12 VAC 5-610-490. Characteristics of soils that determine suitability.**
>
> A. **Color**. Color is a key indication of the suitability of a soil.
> 1. Red and yellow *mottlings* may indicate slow internal drainage and may indicate a seasonal water table.
> 2. Gray and/or gray *mottlings* indicate seasonal water tables for at least three weeks duration.
> 3. Black appearance may be due to organic matter which has accumulated due to poor soil drainage.
>
> *Red mottlings in this context would be concentrations while yellow & gray would be depletions.*

FORMATION OF REDOX FEATURES

Basic Redox Reaction Principles

Redox features are formed from changes in redox conditions in saturated soil. These conditions include the reduction, oxidation and translocation of C, Fe, Mn, and S compounds. Oxidation is the production (loss) of electrons and reduction is the consumption (gain) of electrons. Electrons are negatively charged particles of an ion (e^-) that are taken from one substance and given to another. Electrons in redox reactions come from OM as it decomposes. The recipient of the electrons are these elements in the following sequence; Oxygen (O), Nitrogen (N), Manganese (Mn), Iron (Fe), Sulfur (S), and Carbon (C). These elements are reduced in reduction reactions by microbes in the order mentioned above. Electron acceptors in soil systems generally follow this scheme with increasing reduction potential:

Reduction sequence:

If air (O_2) is in the soil, the soil is aerobic. If all O_2 is removed, the soil becomes anaerobic. This happens when soils become waterlogged, anaerobic microbes deplete the oxygen:

$$4e^- + O_2 + 4H^+ \rightarrow 2H_2O$$

Once all O_2 is removed from the system, then the following anaerobic soil reactions occur in order from least to most reducing conditions:

Denitrification:

$$10e^- + 12H^+ + 2NO_3 \rightarrow N_2 + 6H_2O$$

Iron Reduction:

$$2e^- + 6H^+ + Fe_2O_3 \rightarrow 2Fe(II) + 3H_2O$$

Sulfate Reduction:

$$8e^- + 10H^+ + SO_4 \rightarrow H_2S + 4H_2O$$

Oxygen is depleted first, and then anaerobic microbes deplete nitrogen. Once all N is utilized, the microbes begin reducing Mn. After Mn is reduced, the microbes begin to deplete Fe and then finally sulfate.

Soil Features formed by *reduction* reactions		**Soil Features formed by *oxidizing* reactions**	
Element	Indicator	Element	Indicator
C	*organic matter accumulation*	C	*organic matter burn off and volatilization*
Fe (II)	*redox depletions*	Mn	*soft, black masses*
S	*rotten egg odor*	Fe (III)	*redox concentrations*

Note: there is no soil indicator for denitrification

Process of Redoximorphic Features Formation

In order for a soil to develop anaerobic conditions it must be saturated so that (most) all pores are filled with water. When this occurs, any dissolved O_2 that may be present in the soil water is rapidly removed (couple of days, or so) by respiration of microorganisms, roots, and soil fauna. An anaerobic condition is a condition in which oxygen is virtually lacking from the soil.

Prolonged anaerobic conditions change biogeochemical processes in the soil. This change in chemical processes results in distinctive soil morphological characteristics being present in most soils with a fluctuating water table. The most important of these are the results of: reduction, movement (translocation) and subsequent oxidation of iron and manganese, and accumulation of organic matter under anaerobic conditions. In most aerobic environments organic matter is rapidly oxidized and does not accumulate as readily as in wet soils. The first process results in the formation of redoximorphic features.

In topsoil horizons, organic matter controls soil color. In subsoil horizons, Fe and Mn oxides give soils their characteristic brown, red, yellow colors. When reduced, Fe and Mn are mobile and can be stripped *(depleted)* from the soil particles leaving the characteristic mineral grain color, usually a “grayish” color.

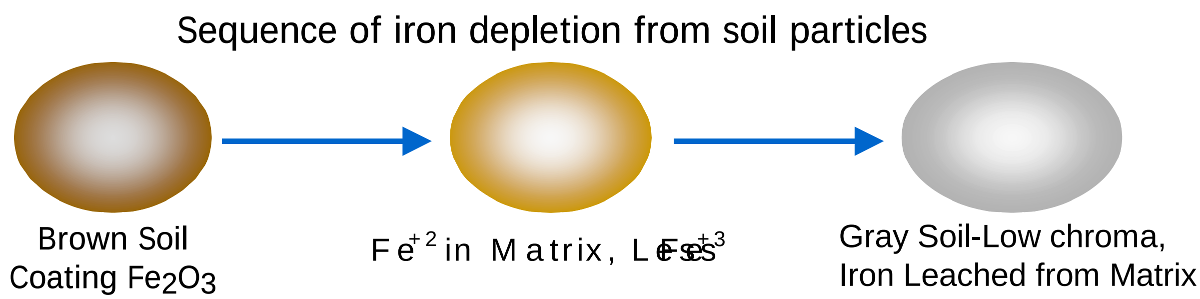
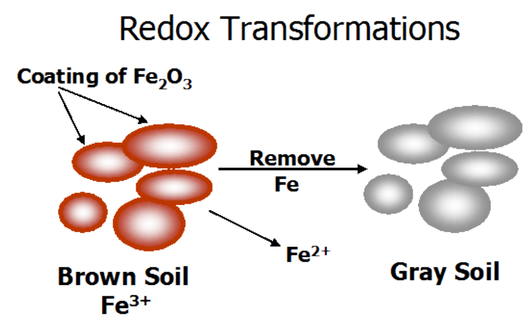


Figure: 4-3. Iron depletion from soil particles. *(Lindbo, NCSU)*

Most mineral soil grains are dominantly silica, so they are generally "colorless," i.e. gray or whitish, unless organic matter or Fe coats them (Iron (II)). Iron in its oxidized state, Fe (III) is called Ferric iron; reduced iron (Fe II) is called Ferrous iron. Iron II is more soluble (mobile) in soil solution than Fe (III). The ferrous state goes into solution during anaerobic conditions leaving areas depleted of iron and manganese. It is re-deposited or concentrated once the soil begins to reach an oxidized state.



$$2e^- + 6H^+ + Fe_2O_3 \rightarrow 2Fe(II) + 3H_2O$$

Figure: 4-4. Redoximorphic Transformations. *(David Lindbo, NCSU)*

Consider soil particles to be coated or painted with Fe-oxide paint (rust). This is similar to the way in which M&Ms *(NCSU metaphor)* are coated with a colorful candy shell. If the M&Ms get wet the shell is washed or dissolved off leaving the white candy shell beneath. Similarly the rusty coating on soil particles is dissolved off as the Fe^{3+} is converted to Fe^{2+}. The Fe^{2+} is colorless and soluble in water. The gray color that remains is the color of the mineral grains.

Sulfate reduction occurs as sulfate is converted to hydrogen sulfide gas, which smells like rotten eggs. Generally this odor is only encountered when the soil is saturated and reduced for sulfate.

Redoximorphic features, *formerly known as mottles*, are formed by changes in redox conditions in seasonally saturated soil, the reduction and oxidation of C, Fe, Mn, and S compounds, and the subsequent translocation of C, Fe, Mn, and S compounds. The best evidence of this process is to find features caused by reduction and oxidation in the same profile. The oxidized features are evidence of translocation. In order to form features:

- 1) *The soil must have anaerobic conditions (reduced and saturated - stagnant);*
- 2) *Must have Fe and/or Mn (electron acceptor);*
- 3) *Must have microbes (bugs);*
- 4) *Must have carbon (food for the bugs).*
- 5) *Must have the appropriate temperature*

Within the soil, reducing conditions may occur adjacent to organic matter. For example, Fe is reduced near a dead root after all the oxygen and nitrate is removed from the water.

The reduced Fe is soluble in water and diffuses away from the root area leaving gray minerals behind. As the reduced Fe interacts with the water that has not had all its oxygen removed it will reoxidize or rust, leaving a red rim around the reduced area in the middle. Since the bacteria are not mobile, the area of reduction will be near a carbon source.

Factors That Influence Iron/Manganese Reduction	
Saturation	*All pores must be filled with stagnant, oxygen-depleted water*
Duration of Saturation	*Soils must be saturated long enough to produce a reducing condition, which has been shown to be approximately 3 weeks (21 days) of continuous saturation*
Organic Matter	*Carbon (decaying roots and other plant debris) is a food source for bacterial microbes*
Temperature	*Microbes are generally active at temperatures above 5° C*
pH	*Microbes are generally active at pH values between 5.0 and 8.0*
Fe and/or Mn	*Without these, features will not form*

Iron and manganese reduction occurs when all of these factors are acting in concert. If any one factor is missing, Fe reduction is slowed down or stopped; therefore, the redox feature does not form. *Soils can be saturated without being reduced. Yet, soils cannot be reduced without being saturated.*

Soil Conditions That Will Inhibit Redox Feature Formation

There are soils with morphologies that are difficult to interpret and that seem inconsistent with the landscape, vegetation, or hydrology. Such soils include:

Soils with grayish or reddish parent materials
Disturbed soils, such as cultivated soils and soils in filled areas
Low amounts of organic carbon, generally, < 2% OM (i.e. sandy soils)
High pH, > 8 to 8.5, redox status is pH dependent
Cold temperatures, below "biological 0" (<5° C)
Research has shown that the concept of biological zero may not be valid as reduction occurs in "frozen" soils in Alaska; however, the rate of reduction is very slow.
Without Fe in the soil system, redox features will not form (i.e. some parent materials such as sand).
Aerated groundwater - soil may be wet (even saturated) but O_2 in the water prevents reduction (rainfall, fast moving floodwaters, slopes).

Soils may be saturated for several weeks continuously without being reduced due to the presence of dissolved oxygen or lack of carbon and iron (Oxyaquic conditions).

Contemporary versus Relict Redoximorphic Features

Redox features do not always indicate current hydrologic conditions. Relict redoximorphic features are no longer actively functioning due to geologic changes. These relict features can persist in the soil for thousands of years. Only on close examination is it evident that hydric soil morphologies do not exist. Example settings of relict redox features include: drained wetlands, and on marine terraces near areas of major topographic breaks in highly dissected coastal plain landscapes. Several morphological characteristics that can distinguish between contemporary and relict redoximorphic features are described below:

Figure: 4-5. Contemporary vs. Relict Features

1. Contemporary features may have nodules or concretions with diffuse boundaries, irregular surfaces, and if smooth and round surfaces exist, red to yellow corona *(halo)* should be present. Relict features may have nodules/concretions with abrupt boundaries and smooth surfaces without accompanying corona.

2. Contemporary hydric soils may have Fe depletions along stable macropores in which roots repeatedly grow that *are not* overlain by iron rich coatings (redox concentrations). Relict features may have Fe depletions along stable macropores in which roots repeatedly grow that *are* overlain by iron rich coatings (redox concentrations).

3. Contemporary redox features may have iron enriched redox concentrations with Munsell colors of 5YR or yellower with value and chroma 4 or more. Relict features may have iron enriched redox concentrations with colors redder than 5YR and value and chroma less than 4.

4. Contemporary pore linings may be continuous while relict pore linings may be broken

Remember that when you use the term mottle, you are communicating that those colors are not redoximorphic (due to wetness).

Figure: 4-6. Representation of relict vs. contemporary feature. *(D. Merritt)*

Background For Describing Soil Colors

When describing soil colors, the dominant color of a horizon is described (i.e., the soil matrix color). Any patterns of color that differ from the matrix have been referred to as mottles. However, the generic term 'mottle' may or may not give specific inference to a soil's drainage status and can lead to various interpretations between soil evaluators across and within the different physiographic provinces. For example, a "mottle" described in the Piedmont most likely has been inherited from the parent material while a 'mottle' previously described in the Coastal Plain usually indicates the soil has a fluctuating water table. There was a need to differentiate colors due to wetness from those arising from non-wetness features (e.g., parent material or lithochromic) because the same terminology has been used for both situations in the past.

> ** **12 VAC 5-610-470. Physical features.**
> D. Minimum depth to seasonal water table. As used herein, "seasonal water table" means that portion of the soil profile where a color change has occurred in the soil as a result of saturated soil conditions or where soil concretions have formed. Typical colors are gray **mottlings**, solid gray or black. The depth in the soil at which these conditions first occur is termed "seasonal water table."
>
> *You will note that the language in the regulations has not kept up with current scientific terminology. In this context, the term gray mottling should read gray iron depletion.*

Biochemical oxidation-reduction (redox) reactions control soil colors, contingent upon the amount of organic matter content, temperature, and soil water chemistry. Land use decisions are made daily based on interpretations of soil colors arising from redox reactions. Therefore, jargon and expressions used in the past to identify these reactions need to be correlated into current terminology. Phrases such as "parent material mottles" and "low chroma mottles", "drainage mottles" have been used to describe non-wet and wet situations, respectively. Those terms are now outdated (since 1992) and have been replaced by new terms outlined in the NRCS Field Book for Describing and Sampling Soils, Soil Taxonomy and The Soil Survey Handbook. These are the nationwide standards of reference that embody the state of current knowledge for making accurate soil descriptions. The correct terms are called redoximorphic features.

The *Field Book for Describing and Sampling Soils* (and the other documents mentioned) will promote proper soil color description and reporting. This will also aid in distinguishing soils that have a color pattern suggesting seasonal wetness versus those that are not wet. In order to standardize the terminology statewide, you must use these terms. These terms have replaced previous terminology and jargon:

Lithochromic mottles/colors replaced "parent material mottles" and do not indicate soil wetness
Redoximorphic features indicate soil wetness
Redox *depletions* replaced "low chroma mottles" and are not exclusively chroma 2; they may have any chroma that is lower in hue than the matrix
Redox *concentrations* replaced "reddish mottles" (bird's eye mottles)

TERMINOLOGY

Matrix Color is the color that occupies the greatest volume of the layer. Dominant color (or colors) is always given first among those of a multicolored layer. For only two colors, the dominant color makes up more than 50% of the volume. For three or more colors, the dominant color makes up more of the volume of the layer than any other color, although it may occupy less than 50%.

Mottles are areas of repetitive color change that differ from the matrix color. These colors are commonly lithochromic. Mottles exclude: redoximorphic features, clay films, organic stains and coats, sand and silt coats.

Variegated color pattern is too intricate (banded or patchy) with numerous, diverse colors to credibly identify dominant matrix colors. This term is generally applied to soils derived from weathered bedrock and or saprolites.

Figure: 4-7. Variegated soil colors *(TS)*

Figure: 4-8. Lithochromic colors; note the ***sharp*** *boundaries. (Photo by Tom Saxton)*

Lithochromic is a term used to describe colors and field identifiable features that are derived from and retain characteristics of the parent material. They were formerly described as parent material mottles. These colors formed from geological processes rather than soil forming processes. Low chroma lithochromic mottles are not indicative of wetness. However, lithochromic soil colors need careful evaluation for determining drainfield suitability because water table and soil wetness features may be masked or "lost" in the overall soil colors. There could be both lithochromic and redoximorphic features in a given horizon.

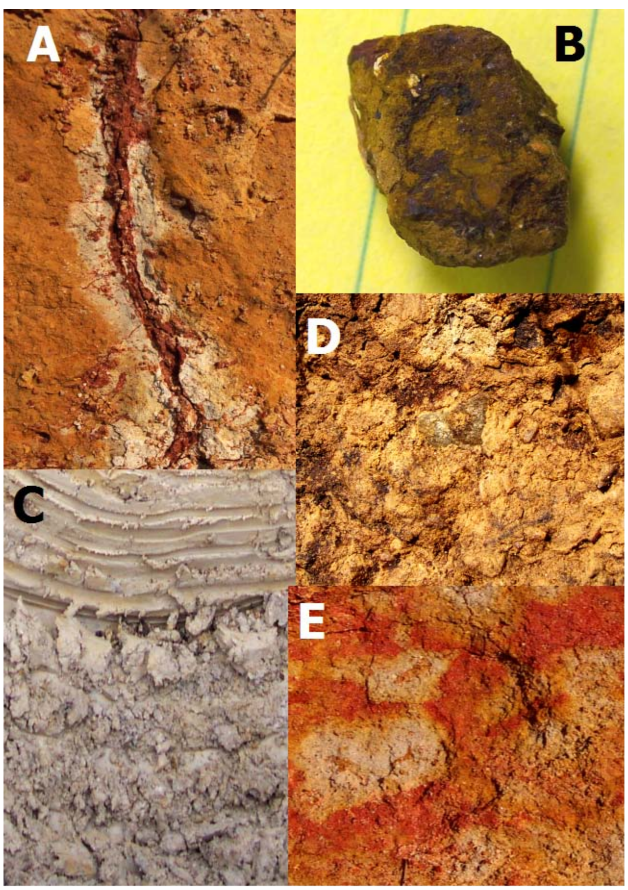


Figure: 4-9. **A**-Pore Lining, **B**-Nodule/Concretion, **C**-Gleyed matrix, **D**-Manganese masses and stains, **E**-red = **I**ron concentrations, gray/pale brown = **I**ron depletions; note the ***diffuse*** *boundaries. (TS)*

Figure: 4-10. Redoximorphic Features; note the ***diffuse*** *boundaries. (Photo by Tom Saxton)*

Redoximorphic (Redox) Features are a color pattern in a soil due to loss (depletion) or gain (concentration) of pigment compared to the matrix color. These colors are formed by oxidation/reduction of iron (Fe) and/or manganese (Mn) coupled with their removal, translocation, or accrual; or a soil matrix color controlled by the presence of iron in a reduced state. The composition and process of formation for a soil color or color pattern must be known or inferred before describing it as a redox feature. Because of this inference, redox features are described separately from other colors. Redox features generally occur in one or more of these settings:

Figure: 4-11. Oxidized rhizosphere in a reduced matrix *(gleyed)*. *(TS)*

a. In the soil matrix, unrelated to surfaces of peds or pores
b. On or beneath the surface of peds (i.e., soil structures)
c. As filled pores, linings of pores, or beneath the surface of pores

Redox Features include the following:
Redox Concentrations, Redox Depletions, Reduced Matrices, and Gleyed Matrices

Redox Concentrations - Localized zones of enhanced pigmentation due to an accrual of Fe-Mn oxides. Types of redox concentrations are:

Masses – Soft, noncemented bodies of enhanced pigmentation that have a redder or blacker color than the adjacent matrix. They are variable in shape and usually cannot be removed from the soil "intact".

Nodules or **Concretions** – Hard, cemented bodies of Fe-Mn oxides. Most nodules and concretions with sharp boundaries have stopped forming. Nodules and concretions are often relict (surviving remnants of natural phenomena). Concretions have concentric rings while nodules do not.

Pore Lining - Concentrations that may be either coatings on a pore surface or impregnations of iron into the matrix adjacent to the pore. These are described differently from oxidized rhizospheres, which are iron precipitations around living roots, typically found in wetland environments.

Redox Depletions - Localized zones of "decreased" pigmentation that are grayer, lighter, or less red than the adjacent matrix. Redox depletions include, but are not limited to chroma ≤ 2 colors. Depletions are used to define aquic conditions *(a reducing moisture regime in a soil that is virtually free of dissolved oxygen because it is saturated by groundwater or by water of the capillary fringe, Glossary of Soil Science Terms, 2008)* in *Soil Taxonomy* and are used extensively in the field to infer occurrence and depth of saturation in soils.

Types of redox depletions are:

Iron Depletions - Localized zones that have one or more of the following: a yellower, greener, or bluer hue; a higher value or a lower chroma than the matrix color. Color value is normally ≥ 4. Loss of pigmentation results from the loss of Fe and/or Mn. Clay content equals that in the matrix.

Clay Depletions - Localized zones that have: either a yellower, greener, or bluer hue, a higher value, or a lower chroma than the matrix color. Color value is normally ≥ 4. Loss of pigmentation results from a loss of Fe and/or Mn and clay. Silt coats or skeletans commonly form as depletions, but can be non-redox concentrations if deposited as flow material in pores or along faces of peds.

Reduced Matrix – An entire soil horizon that is a redox depletion. Over half of the horizon has an insitu matrix chroma ≤ 2 due to the presence of Fe^{+2}. The color of a sample becomes redder or brighter (oxidizes) when exposed to air. The color change usually occurs within 30 minutes.

Gleyed Matrix - A soil horizon that has an insitu matrix color found in the Gley pages in the Munsell Color Chart. These colors can be bluish, greenish, or purplish hues of gray colors, probably due to iron associated with a carbonate, phosphate, or sulfate anion. Gleyed matrices are a sign of permanent saturation.

DESCRIBING SOIL COLORS

Conditions for measuring soil color

The visual impression of color from the standard Munsell notation is accurate only under standard conditions of light intensity and quality. Color determination may be inaccurate early in the morning or late in the evening. When the sun is low in the sky the light reaching the sample and the light reflected is redder than at midday. Colors also appear different in the subdued light of a cloudy day than in bright sunlight. With practice, compensation can be made for the differences unless the light is so subdued that the distinctions between color chips are not apparent. The intensity of light is especially critical when matching soil to chips of low chroma and low value.

Soil moisture status should be recorded because the color value of most soil material becomes lower after moistening. The water state is either "moist" or "dry." The soil should not be moistened to the extent that glistening takes place. Color determinations of wet soil may be in error because of the light reflection of water films. An example, for which a standard broken state of the sample has been specified, might read brown (10YR 4/3) moist, or brown (10YR 5/3) dry.

Description of Soil Color Protocol

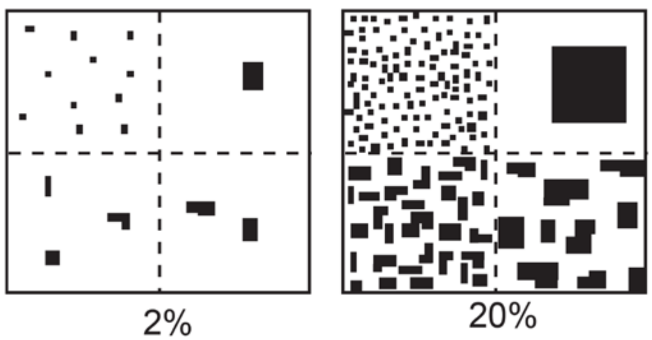
1. Matrix colors

The Matrix Color, the color that is described first, occupies the greatest volume of the layer. Dominant color (or colors) is/are always given first among those of a multicolored layer. It is judged on the basis of colors of a broken sample. For only two colors, the dominant color makes up more than 50 percent of the volume. For three or more colors, the dominant color makes up more of the volume of the layer than any other color, although it may occupy less than 50 percent. The expression "brown <u>with</u> yellowish brown and grayish brown" signifies that brown is the dominant color. It may or may not make up more than 50 percent of the layer.

In some layers, no single color is dominant and the first color listed is not more prevalent than others. The expression "brown <u>and</u> yellowish brown with grayish brown" indicates that brown and yellowish brown are about equal and are co-dominant. If the colors are described as "brown, yellowish brown, and grayish brown," the three colors make up nearly equal parts of the layer. Use the term *variegated* for color patterns too intricate (banded or patchy) with numerous, diverse colors to credibly identify dominant matrix colors.

Table: 4-1. Mottles & Features - quantity (percent of area covered) *(NRCS)*

Quantity Class	Abbreviation	Criteria (% area covered)
Few	(f)	<2% of surface area
Common	(c)	2-20% of surface area
Many	(m)	≥20% of surface area



2. Redox, Lithochromic colors, mottles and other color features

Description of redox features and lithochromic colors are written after the matrix color during the descriptive process. You <u>must</u> record the quantity, size, contrast, color, and location (i.e. along macropores or within matrix) shape, boundaries, and hardness of the features. Additional descriptions of the moisture state (either moist or dry), shape, hardness, and boundary of soil colors are necessary when determining if it is a redox or lithochromic color. Documentation of the actual percent using the aerial percentage coverage charts in the Munsell color chart book is preferred.

If the redox features are fine and faint so that they cannot be compared easily with the color standards, the Munsell notation should be omitted and is most likely not significant.

Size

Size refers to dimensions as seen on a plane surface. If the length of a mottle or feature is not more than two or three times the width, the dimension recorded is the greater of the two. If the mottle is long and narrow, as a band of color at the periphery of a ped, the dimension recorded is the smaller of the two and the shape and location are also described.

Table: 4-2. Size classes for Features *(NRCS)*

Class	Abbrev.	Size
Fine	1	< 2mm
Medium	2	2 to < 5mm
Coarse	3	5 to < 20mm
V. Coarse	4	20 to < 76mm
E. Coarse	5	≥ 76mm

Contrast

Contrast refers to how easy it is to see a feature as compared to the matrix. There are three classes of contrast; faint, distinct, and prominent. Faint contrast is evident only on close examination. Distinct contrast is readily seen but similar to the color to which compared. Prominent contrast strongly contrasts with the colors to which they are compared (Table: 4-3).

Table: 4-3. Contrast chart *(NRCS)*

Contrast Class	Code	Difference in Color Between Matrix and Mottle			
		Hue	Value		Chroma
Faint	F	same	0 to <2	and	<1
Distinct	D	same	>2 to <4	and	<4
		or			
		same	<4	and	>1 to <4
		1 page	<2	and	<1
Prominent	P	same	>4	or	>4
		1 page	>2	or	>1
		2+ page	>0	or	>0

Location - Describe the location of the redox feature within the horizon

Matrix:
Not associated with pores
In matrix around depletions
In matrix around concentrations

Peds: (repeating soil structural units)
Infused into matrix along ped faces
On horizontal or vertical ped faces

Pores:
On surfaces lining pores
On surfaces along root channels
Infused into the matrix adjacent to pores

Other:
In cracks
At top of a horizon
Around rock fragments
On bottom of rock fragments
Around slickensides
Along stratified surfaces

Table: 4- 4. Examples of contrasts *(NRCS)*

Matrix	Feature	Contrast
10YR 4/4	10YR 6/3	Faint
10YR 6/4	10YR 4/2	Distinct
10YR 5/6	10YR 4/1	Prominent
10YR 5/4	5YR 5/3	Distinct

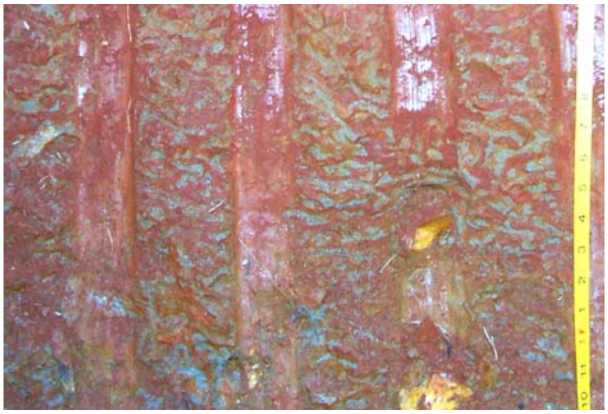


Figure: 4-12. Reticulate color pattern is usually associated with redox features in VA. *(TS)*

Shape is described by common words such as streaks, bands, tongues, tubes, and spots.

Cylindrical - tubular and elongated bodies e.g., in-filled wormholes
Dendritic - elongated branched bodies
Irregular - bodies of non-repeating spacing and shape
Platy - thin lenses (e.g.) lamellae
Reticulate - crudely interlocking bodies with similar spacing
Spherical - well rounded to crudely spherical bodies

Table: 4-5. Redox Hardness *(NRCS)*

Hardness - Describe the relative force required to crush the Redox feature *(primarily used for nodules and concretions)*

Dry	Moist	Cementation Class	Field Failure
Loose	Loose	N/A	not obtainable
Soft	Very Friable	Non-cemented	very slight force[1]
Slightly Hard	Friable	Ext. weakly cemented	slight force[1]
Mod. Hard	Firm	V. weakly cemented	moderate force[1]
Hard	Very Firm	Weakly cemented	strong force[1]
Very Hard	Extr. Firm	Mod. cemented	mod force[2]
Extr. Hard	Slightly Rigid	Strongly cemented	Full body weight
Rigid	Rigid	v. strongly cemented	Hammer blow
V. Rigid	V. Rigid	Indurated	Strong Hammer blow

[1] force between fingers [2] force between hands

Boundaries are the gradation between the feature and the matrix color and may be described as:

Sharp	color changes in less than .1mm, gradation is not discernable with the naked eye, and has an abrupt boundary even under a 10x hand lens
Clear	color changes within .1 to <2mm, gradation is visible without a 10x hand lens
Diffuse	color changes are greater than 2mm, gradation is easily seen without a 10x hand lens

Conventional Methods for Reporting Colors for Soil Features

This section will put together information from the previous section to form a complete color description. Colors will first have to be evaluated as either lithochromic or as a redoximorphic feature.

Lithochromic or Redoximorphic Color?

Lithochromic colors will have sharp edges along the boundaries of the mottled material *(may need a hand lens)*. Lithochromically mottled material follows geologic structure *(it may be extractable with a knife)*. Redoximorphic colored material may span geologic structure. Redoximorphic colored material is gradational and random. Coastal Plain sediments have no rock structure, but the color patterns often follow stratification from the original depositions and subsequent secondary mineral precipitation of Fe and Mn leached from above.

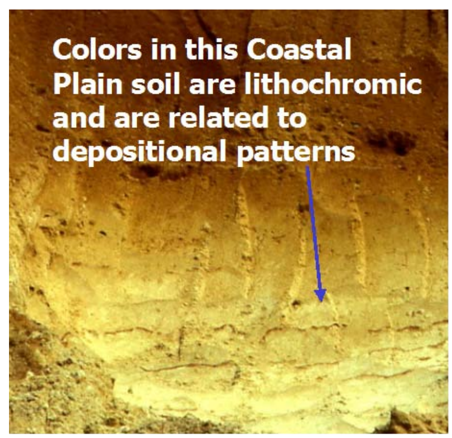


Figure: 4-13. Stratification in a Coastal Plain Soil. *(Photo by C. D. Peacock, Jr.)*

When evaluating a soil for water table indicators, it is important to examine the whole soil profile. Redox depletions will often relate to concentrations somewhere in the soil profile.

Lithochromic vs. Redox

***Remember:* when you use the term mottle (only), you are communicating that these colors are not redoximorphic features due to wetness.**

The following are examples of correct convention and nomenclature for documenting soil colors:

Example: *Bt_2 32-48" yellowish brown (10YR 6/8) mottled with red (2.5YR 4/8); clay loam.*
This red color is not a redoximorphic feature (concentration) because the term "mottle" is used. It is a lithochromic color.

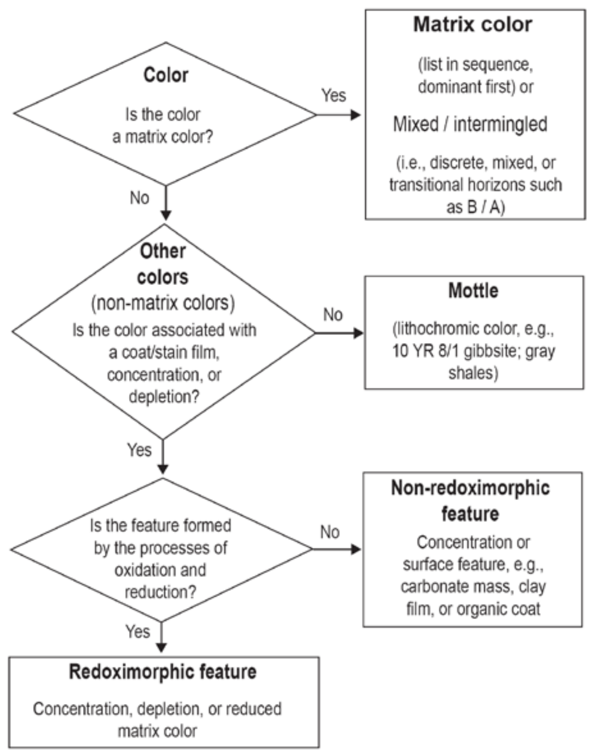
Example: *Bt_2 32-48" yellowish brown (10YR 6/8) with red (2.5YR 4/8) concentrations; clay loam.*
This red color is a redoximorphic feature because the term concentration was used.

Figure: 4-14. Lithochromic colors follow geologic patterns; note the ***sharp*** *boundaries. (TS)*

Example: *Bt_2 32-48" yellowish brown (10YR 6/8) mottled with gray (10YR 6/1); clay loam.*
This gray color is not a redoximorphic feature (depletion) because the term "mottle" is used. It is a lithochromic color. It may be advisable to describe this as a lithochromic mottle to avoid confusion: i.e.
Bt_2 32-48" yellowish brown (10YR 6/8) mottled with gray (10YR 6/1) lithochromic mottles; clay loam

Example: *Bt_2 32-48" yellowish brown (10YR 6/8) with gray (10YR 6/1) depletions; clay loam.*
This gray color is a redoximorphic feature because the term depletion was used.

Figure: 4-15*.* Decision Flowchart for Describing Colors for Soil Matrix and Soil Features *(NRCS)*



NOTE: *Reduced Matrix* color is described as a *Matrix Color* and in the associated "(Soil Color) - Location or Condition Described Table."

Lithochromic

Example of correct convention for describing low-chroma lithochromic colors:

Common fine distinct grayish brown (10YR 5/2) lithochromic mottles (or colors)

Red (2.5YR 4/8) with common fine distinct grayish brown (10YR 5/2) lithochromic mottles.

If nothing is stated, it is implied that all mottles are lithochromic, but in the case of low chroma mottles, it may be safest to be stated as lithochromic to avoid confusion.

High chroma lithochromic colors would still be described as mottles. The term lithochromic is implied.

Example of correct convention:

Common fine distinct strong brown (7.5YR 5/6) mottles

Red (2.5YR 4/8) with common fine distinct strong brown (7.5YR 5/6) mottles

Redox Concentrations

Concentrations form where iron has been redistributed or concentrated. They are the location of precipitated iron that was once in solution. Redox concentrations include masses, pore linings, nodules and concretions.

Examples of correct convention:

Common fine distinct strong brown (7.5YR 5/6) redox concentrations
or

Common fine distinct strong brown (7.5YR 5/6) concentrations of iron and manganese
or

Common fine distinct strong brown (7.5YR 5/6) concentrations (preferred, Mn and Fe concentrations are implied))

Yellowish brown (10YR 5/4) with common fine distinct strong brown (7.5YR 5/6) concentrations

Masses

Table: 4-6. Suggested color guidelines for distinguishing an Fe from a Mn mass. *(NRCS)*

Value	Chroma	Mass
≤ 2	≤ 2	Mn
> 2 and ≤ 4	> 2 and ≤ 4	Fe and Mn
> 4	> 4	Fe

Masses are usually soft, and found within the matrix. Red masses are dominated by iron. Darker colored masses are dominated by Manganese. Iron and Mn commonly occur in combination and field identification of distinct phases is difficult. Manganese masses are not to be confused with burnt wood chips or decayed organic matter and must be at least slightly effervescent with hydrogen peroxide (H_2O_2).

Example of correct convention:

Common medium prominent black (10YR 2/1) soft masses of manganese

Red (2.5YR 4/8) with common medium distinct dark brown (7.5YR 3/4) soft masses of iron and manganese

Pore Linings

Redox concentrations as pore linings in root channels are not the same as oxidized rhizospheres, which require living roots.

Example of correct convention:

Few prominent strong brown (7.5YR 5/6) concentrations lining root channels

Red (2.5YR 4/8) with few prominent strong brown (7.5YR 5/6) concentrations lining root channels

Nodules and Concretions

Contemporary nodules and concretions should be irregular shaped with a diffuse oxidized boundary *"halo"* or *"corona."* Concretions usually have concentric rings, are formed from similar material within which they are found and may have a nucleus composed of something different; nodules do not have rings and are composed of different material.

Figure: 4-16. Concretion above. Concretions may have concentric rings, nodules do not. *(TS)*

Examples of correct convention:

Common, fine and medium iron-manganese concretions
or

Few dark brown (10YR 3/3) and black (10YR 2/1) concretions
or

Many fine to coarse black (10YR 2/1) ferromagnesian nodules
or

Red (2.5YR 4/8) with many fine to coarse black (10YR 2/1) ferromagnesian nodules

Redox Depletions

Occur where the water table moves up and down in the profile depleting iron from within peds and then precipitating the iron on ped faces. Depletions form where the iron has been stripped away *(depleted)* leaving the mineral grain color. Depletions in A horizons may have a value of less than 4. Depletions found in transported materials such as the coastal plain and piedmont cappings often have chromas of 3 and 4.

Examples of correct convention:

Common fine distinct light brownish gray (10YR 6/2) iron depletions
or

Many, medium and coarse, distinct very dark gray (10YR 3/1) redoximorphic depletions
or

Many medium distinct light brownish gray (10YR 6/2) depletions (preferred)

Red (2.5YR 4/8) with many medium distinct light brownish gray (10YR 6/2) depletions

It is possible to have redox depletions that are not gray (figure 4-17). For example, a possibly red parent material soil with 3 or 4 chroma feature colors. If one was sure these colors formed as a result of saturation and reduction they should be considered redox depletions.

Table: 4-7. Reduced Matrix Table *(NRCS)*

Value > or = 5, Chroma < or = 1
Value > or = 6, Chroma < or = 2
Value 4, Chroma 1 or 2
Value 5, Chroma 2

Horizon designation should have a "g" suffix – Bt_g, C_g, Bt_{g_2}, etc.

Figure: 4-17. Randomly oriented rounded gravels indicate that the parent material for this soil is colluvium in Amherst County. The pale colors (depletions) indicate restricted permeability at the base of the colluvial deposit that may have a perched water table. These depletions are not gray, but they provide the evaluator clues about permeability. *(Photo by Gary Gilliam, EH Supervisor)*

Soil Texture and Particle Size Distribution

Why is Texture important?

Texture or particle size is used to estimate the infiltration rate of water into the soil *(perk)* for designing on-site systems. Texture, itself, only refers to the amount of sand, silt and clay in the soil. The practitioner infers from this information what the pore size distribution is and subsequently infers the rate at which water will flow through the soil. Texture by itself is not enough to determine permeability; it simply helps to define the range of permeability.

12 VAC 5-610-490. Characteristics of soils that determine suitability.

B. **Texture**. The term texture refers to the relative proportion of various size groups of individual soil grains in a mass of soil. Specifically, it refers to the proportion of sand, silt, and clay.

1. Soil Classification. For the purpose of this chapter soils have been categorized into four groups based on texture as follows:

a. Texture Group I - sand and loamy sand;

b. Texture Group II - sandy loam, loam, and sandy clay loam.
Texture Group II soils are subdivided into Texture Group IIa and IIb soils. Texture Group IIa soils consist of sandy loam soils with percolation rates less than 31 minutes per inch and no structure development. The remainder of soils within this texture group are Texture Group IIb soils.

c. Texture Group III - silt loam, clay loam, silty clay loam; and

d. Texture Group IV - sand clay, silty clay and clay.

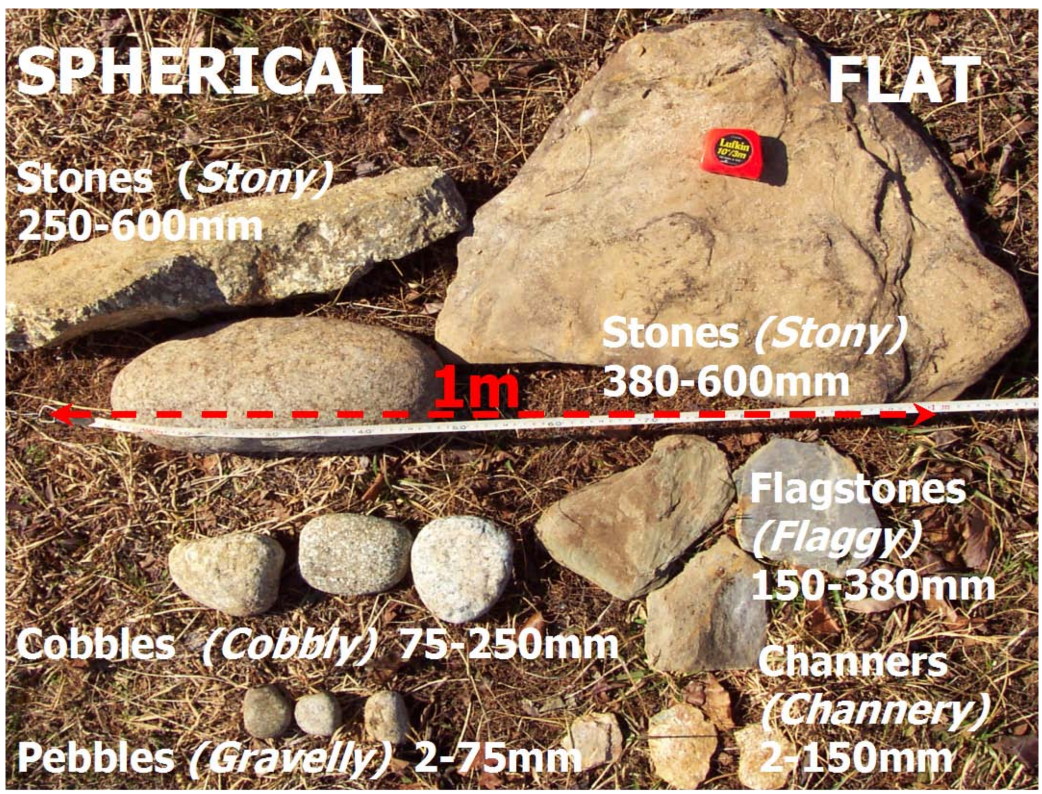


Figure: 4-18. Relative sizes of coarse fragments. *(Photo by Tom Saxton)*

Particle size distribution describes the abundance of the various size particles that constitute the mineral portion of soil materials. The finer size fractions are called the fine earth fraction (smaller than 2 mm diameter). The larger particles (pebbles, cobbles, stones, and boulders) are called rock fragments. The term “coarse fragments” excludes the stones and boulders classes in the rock fragments. Particle-size distribution of the fine earth fraction is determined in the field mainly by feel.

The content of rock fragments is determined by estimating the proportion of the soil volume they occupy *(USDA NRCS).*

Rock Fragments

Rock fragments are unattached pieces of rock 2 mm in diameter or larger that are moderately cemented or more resistant to rupture. Rock fragments include all sizes that have horizontal dimensions less than the size of a pedon (approximately 3.5 m). Rock fragments are described by size, shape, and for some, the kind of rock. The classes are gravels, cobbles, channers, flagstones, stones, and boulders. If a size or range of sizes predominates, the class is modified, as for example: *"fine gravels*", *"cobbles 100 to 150 mm in diameter," "channers 25 to 50 mm long."* The terms *"gravel"* and *"cobble"* are usually restricted to rounded or subrounded fragments; however, they can be used to describe angular fragments if they are not flat. Words like chert, limestone, and shale refer to a kind of rock, not a piece of rock. The composition of the fragments can be given: *"chert pebbles," "limestone channers."* The upper size of gravel is 3 inches (76 mm).

Shape and size[1]	Noun	Adjective
Spherical, cubelike, or equiaxial:		
2-75 mm diameter	Pebbles	Gravelly
2-5 mm diameter	Fine	Fine gravelly
5-20 mm diameter	Medium	Medium gravelly
20-75 mm diameter	Coarse	Coarse gravelly
75-250 mm diameter	Cobbles	Cobbly.
250-600 mm diameter	Stones	Stony.
≥600 mm diameter	Boulders	Bouldery.
Flat:		
2-150 mm long	Channers	Channery.
150-380 mm long	Flagstones	Flaggy.
380-600 mm long	Stones	Stony.
≥600 mm long	Boulders	Bouldery.

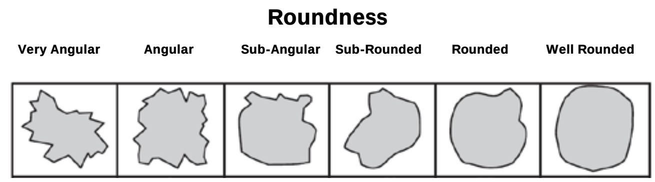


Figure: 4-19. The roundness of the fragments may be indicated as angular (sharp edges), subrounded (detectable flat faces with well-rounded corners), and rounded (flat faces absent or nearly absent). *(NRCS)*

Remember: *channers are flat, cobbles and gravels are rounded.*

Soil Texture

Soil texture refers to the weight proportion of the separates for the less than 2 mm fraction as determined from a laboratory particle-size distribution. Three main sizes of particle constitute this part of the soil; sand, silt and clay. The relative percentage of each of these determines the soil texture. Field estimates should be checked against laboratory determinations and the field criteria should be adjusted as necessary. The texture of soil is given to tell as much as possible about a soil in a few words. With texture given,

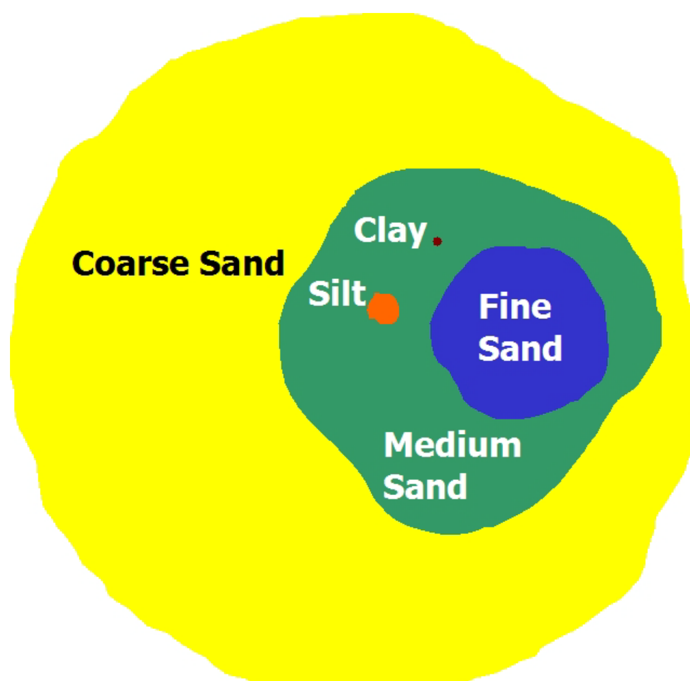


Figure: 4-20. Relative size of particles in the *Fine-Earth Fraction. (TS)* approximations and estimates can be made of many properties of a soil, such as bearing value, water-holding capacity, susceptibility to frost heave, adaptability to soil-cement construction, etc.

Soil Texture Classes Defined

The texture classes are sands, loamy sands, sandy loams, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. Sands are subdivided into coarse sand, sand, fine sand, and very fine sand. Subclasses of loamy sands and sandy loams that are based on sand size are named similarly *(See table: 4-11 for abbreviations)*. A texture triangle *(see figures: 4-20, 4-21, and 4-22)* is used to resolve problems related to word definitions of the textures.

Table: 4-8. Soil Texture

Percentages				
Texture Class	%Sand	%Silt	%Clay	Examples
sand	>85	<15	<10	90-6-4
loamy sand	70-90	<30	<15	85-10-5 or 80-12-8
sandy loam	43-85	<50	<20	75-15-10 or 50-45-5
sandy clay loam	45-80	<28	20-35	65-10-25
clay loam	20-45	15-53	27-40	32-33-35
sandy clay	45-65	<20	35-55	45-10-45
loam	23-52	28-50	7-27	45-40-15
silt loam *(either)*	20-50	50-80	<12	15-75-10
(or)	<38	50-88	12-27	25-55-20
silt	<20	>80	<12	5-90-5
silty clay loam	<20	40-73	27-40	10-55-35
silty clay	<20	40-60	40-60	10-40-50
clay	<45	<40	<40	10-30-60
(<) less than		(>) greater than		

Instructions for Estimating Soil Texture by Feel

The feel and appearance of a soil sample illustrate factors used in determining the texture of a soil in the field and also assist in field classification work. Note that forming a cast of soil, dry and moist, in the hand and pressing a moist ball of soil between the thumb and finger constitute two major field tests to judge soil texture.

Figure: 4-21. Making a long ribbon indicates a clayey texture. *(NRCS)*

Sand: Individual grains can be seen and felt readily. Squeezed in the hand when dry, this soil will fall apart when the pressure is released. Squeezed when moist, it will form a cast that will hold its shape when the pressure is released but will crumble when touched.

Sandy loam: Consists largely of sand, but has enough silt and clay present to give it a small amount of stability. Individual sand grains can be seen and felt readily. Squeezed in the hand when dry, this soil will fall a part when the pressure is released. Squeezed when moist, it forms a cast that will not only hold its shape when the pressure is released but will withstand careful handling without breaking. The stability of the moist cast differentiates this soil from sand.

Table: 4-9. Fractions that make up the fine-earth fraction of soil materials. USDA size separates for the fine-earth fraction (mineral soil materials <2 mm). *(NRCS)*

Class	**Size (mm)**
Very coarse sand	2.0 to 1.0
Coarse sand	1.0 to 0.5
Medium sand	0.5 to 0.25
Fine sand	0.25 to 0.10
Very fine sand	0.10 to 0.05
Silt	0.05 to 0.002
Clay	<0.002

Loam: Consists of an even mixture of sand and silt, and contains a considerable amount of clay. It is easily crumbled when dry and has a slightly gritty, yet fairly smooth feel. It is slightly plastic. Squeezed in the hand when dry, it will form a cast that will withstand careful handling. The cast formed of moist soil can be handled freely without breaking.

Table: 4-10. Soil texture for sandy textures *(NRCS)*

Percent Sand Size Separates for Sandy Textures						
Texture Class	VCOS	COS	MS	FS	VFS	Percent Silt & Clay
coarse sand	>25		<50	<50	<50	<15% silt
sand	>25			<50	<50	<10% clay
fine sand	*(either)*			>50		Total silt plus clay less than or equal to 15%
	(or) <25				<50	
very fine sand					<50	
loamy coarse sand	>25		<50	<50	<50	<30% silt
loamy sand	>25			<50	<50	<15% clay
loamy fine sand	*(either)*			>50		Total silt plus clay between 10% and 30%
	(or)				<50	
loamy very fine sand					>50	
coarse sandy loam	>25		<50	<50	<50	<50% silt
sandy loam	>30 *(but <25% VCOS)*			<30	<30	<20% clay
fine sandy loam	*(either)*			>30	<30	Total silt plus clay between 15% and 57%
	(or) 15-30					
very fine sandy loam	*(either)*				>30	
	(or) <15			>40	*(or at least ½ VFS)*	

Silt loam: Consists of a moderate amount of fine grades of sand, a small amount of clay, and a large quantity of silt particles; lumps in a dry, undisturbed state appear quite cloddy but they can be pulverized readily; the soil then feels soft and floury. When wet, silt loam runs together and puddles. Either dry or moist casts can be handled freely without breaking. When a ball of moist soil is pressed between thumb and finger, it will not press out into a smooth, unbroken ribbon but will have a broken appearance.

Clay loam: A fine-textured soil, which breaks into clods or lumps, that are hard when dry. When a ball of moist soil is pressed between the thumb and finger, it will form a thin ribbon that will break readily, barely sustaining its own weight. The moist soil is plastic and will form a cast that will withstand considerable handling.

Clay: A fine-textured soil that breaks into very hard clods or lumps when dry, and is plastic and unusually sticky when wet. When a ball of moist soil is pressed between the thumb and finger, it will form a long ribbon.

Soil texture can be estimated by feel using the following procedure and key. Place approximately 25 grams of soil in the palm of your hand. Add water drop wise and knead to break down aggregates. Soil is at the proper consistency when plastic and moldable like moist putty.

Table: 4-11. Textural classes and corresponding symbols *(NRCS)*

Symbol	Class
cos	coarse sand
s	sand
fs	fine sand
vfs	very fine sand
lcos	loamy coarse sand
ls	loamy sand
lfs	loamy fine sand
lvfs	loamy very fine sand
cosl	coarse sandy loam
sl	sandy loam
fsl	fine sandy loam
vfsl	very fine sandy loam
l	loam
sil	silt loam
si	silt
scl	sandy clay loam
cl	clay loam
sicl	silty clay loam
sc	sandy clay

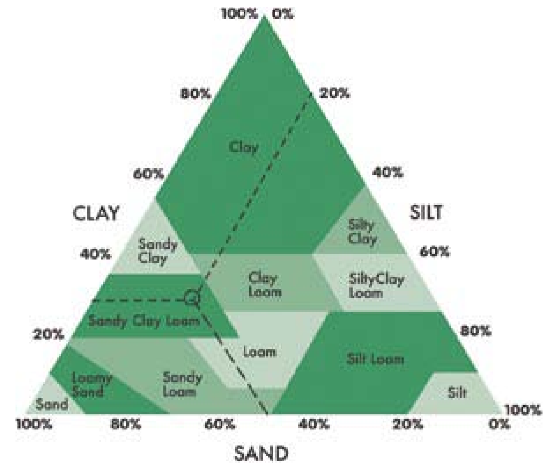


Figure: 4-22. What texture would 50% sand, 30% clay and 20% silt represent? *Sandy clay loam. (NRCS)*

Soil materials behave in different ways depending upon the shape and size of the sand fraction, and the mineralogy of the clay fraction. Some sand fractions are flat in shape and will feel smooth (mica particles for example). Fine and very fine sand will behave in a manner similar to silt-sized particles. Clay fractions with appreciable smectite minerals will form long ribbons even with less than 40% clay.

12 VAC 5-610-490. Characteristics of soils that determine suitability.

2. The **soil texture** shall be estimated by field testing. The field test that shall be applied is contained in APPENDIX F and is entitled "Field Guide to Soil Texture Classes." Laboratory estimation of texture by sieve and sedimentation analysis may be substituted for the field test at the owner's request and expense. Samples shall be collected by the laboratory under supervision of the district or local health department.

C. Permeability. The term permeability pertains to the characteristics of the soil that enable water or air to move through its pores. The permeability of a soil profile may be limited by the presence of one nearly impermeable horizon, even though the others are permeable.

1. Estimated rates. The soil classifications contained in subdivision B 1 of this section have been assigned the following estimated rates in minutes per inch for the purpose of design. These rates may be modified when experience has shown that because of soil structure the texture group has a demonstrated rate different from that assigned.

    a. Texture Group I - up to 16;
    b. Texture Group IIa - 17 to 30;
    c. Texture Group IIb - 31 to 45;
    d. Texture Group III - 46 to 90; and
    e. Texture Group IV - equal to or greater than 91.

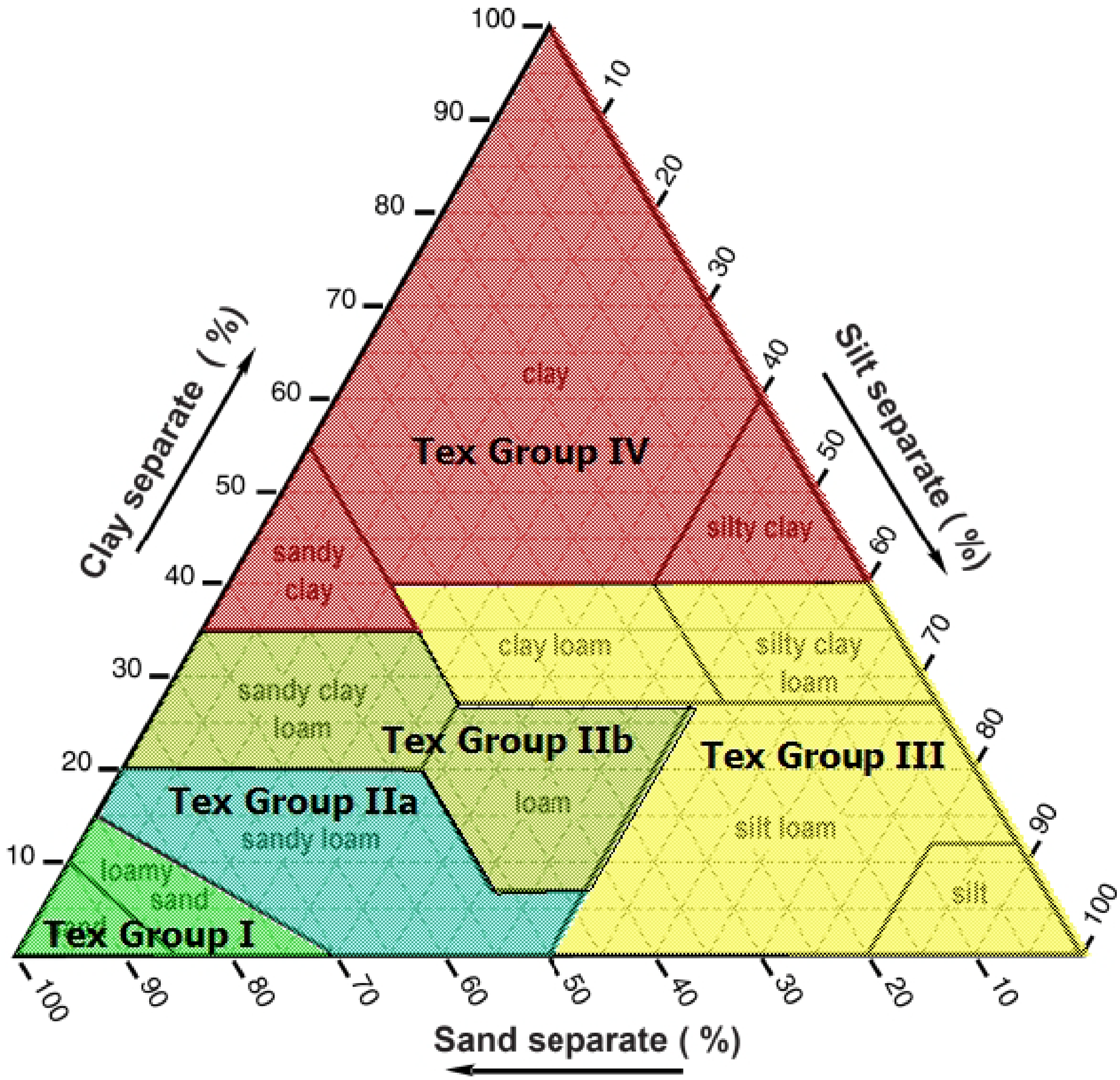


Figure: 4-23. Soil Texture Groups; texture groups are a Virginia Department of Health designation used to bracket estimated percolation rates. They are not Soil Science terms. *(VDH)*

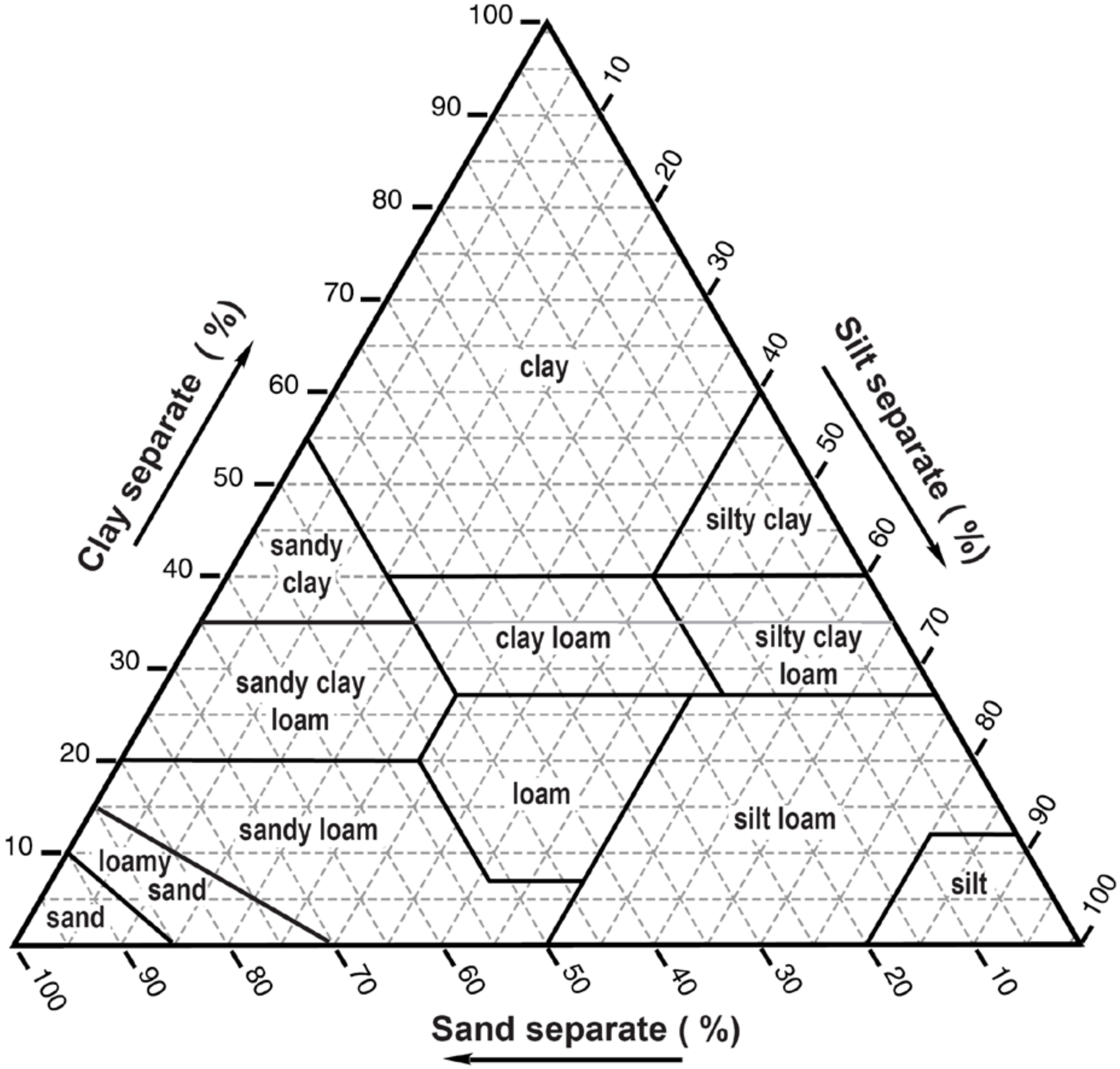


Figure: 4-24. Textural Triangle *(NRCS)*

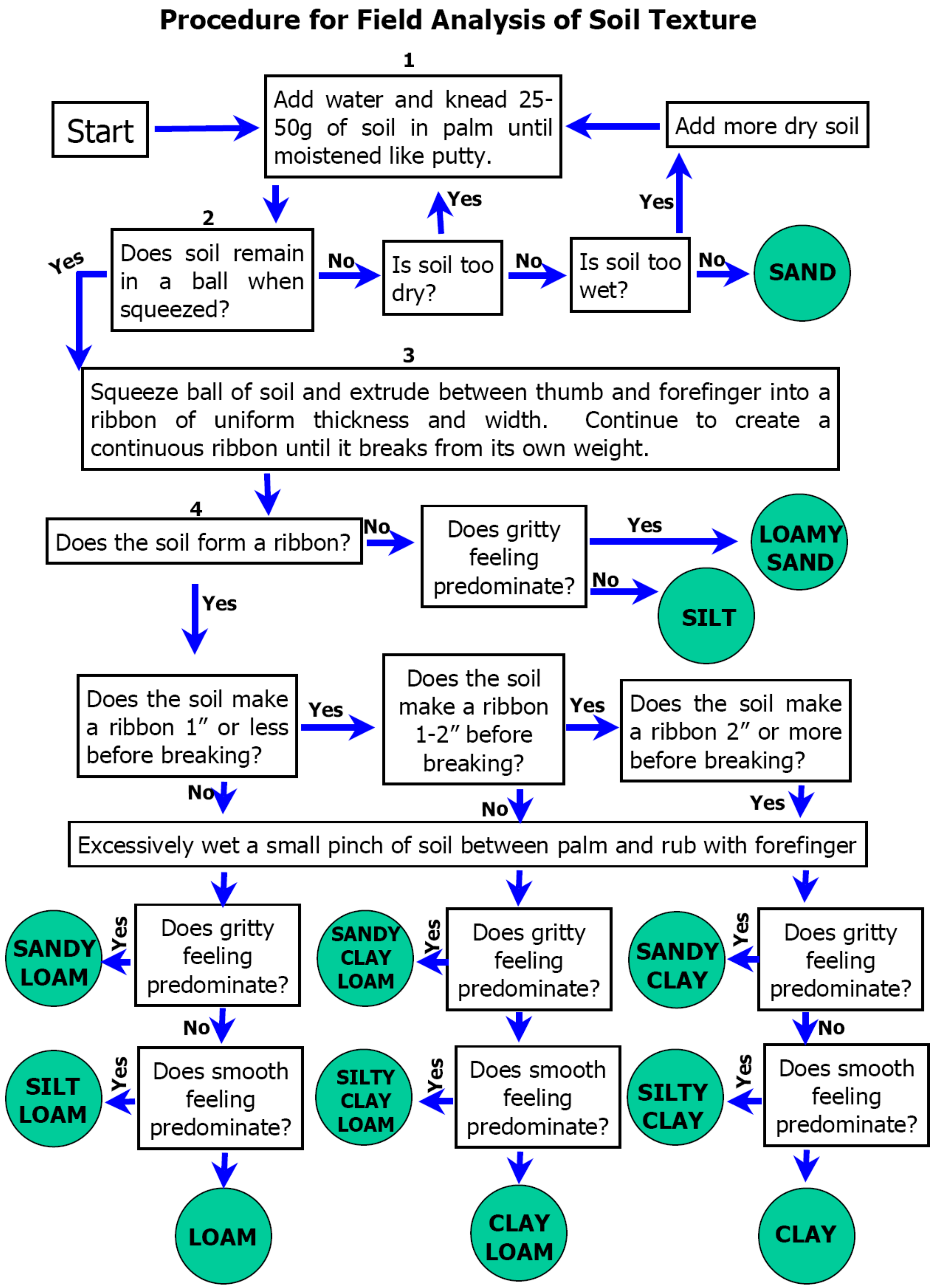


Figure: 4-25. Textural Flow Chart *(TS)*

Using Rock Fragment Modifiers


Figure: 4-26. Very channery silt loam. *(Photo by Tom Saxton)*

Rock fragments are unattached pieces of rock 2 mm in diameter or larger that are moderately cemented or more resistant to rupture. Rock fragments include all sizes that have horizontal dimensions less than the size of a pedon. Rock fragments are described by size, shape, and, for some, the kind of rock. The classes are *pebbles, cobbles, channers, flagstones, stones,* and *boulders.* If a size or range of sizes predominates, the class is modified, as for example: *fine pebbles*, *cobbles 100 to 150 mm in diameter*, *channers 25 to 50 mm long*.

If more than 15% rock fragments (by volume estimate) occur in a soil horizon the soil texture class is modified with a rock fragment abundance modifier. The adjective form of a class name of rock fragments is used as a modifier of the textural class name: "gravelly loam." The following classes based on volume percentages are used:

Less than 15 percent: No adjective or modifier terms are used.

15 to 35 percent: The adjective term of the dominant kind of rock fragment is used as a modifier of the textural term: "gravelly loam," "channery loam," "cobbly loam."

35 to 60 percent: The adjective term of the dominant kind of rock fragment is used with the word "very" as a modifier of the textural term: "very gravelly loam," "very flaggy loam."

More than 60 percent: If enough fine earth is present to determine the texture class the adjective term of the dominant kind of rock fragment is used with the word "extremely" as a modifier of the textural term: "extremely gravelly loam."

Table: 4-12. Symbols and adjectives used to modify textural class names with greater than 15% rock fragments. *(NRCS)*

Symbol	**Adjective**
by	bouldery
byv	very bouldery
byx	extremely bouldery
cb	cobbly
cbv	very cobbly
cbx	extremely cobbly
cn	channery
cnv	very channery
cnx	extremely channery
fl	flaggy
flv	very flaggy
flx	extremely flaggy
gr	gravelly
grc	coarse gravelly
grf	fine gravelly
grv	very gravelly
grx	extremely gravelly
st	stony
stv	very stony
stx	extremely stony

If there is too little fine earth to determine the texture class the terms "gravel," "cobbles," "stones," and "boulders" are used in the place of fine earth texture. Example of correct convention for describing coarse fragments:

Figure: 4-27. Extremely cobbly coarse sandy loam. *(TS)*

Table: 4-13. Conventions for using Rock Fragment Texture modifiers and for using textural adjectives that convey % volume ranges for Rock Fragments; Size and Quantity. *(NRCS)*

Fragment Content % By Volume	Rock Fragment Modifier Usage
<15	No texture adjective is used, noun only; e.g., *loam*.
15 to <35	Use adjective for appropriate size; e.g., *gravelly*.
35 to <60	Use “very” with the appropriate size adjective; e.g., *very gravelly*.
60 to <90	Use “extremely” with the appropriate size adjective; e.g., *extremely gravelly*.
≥90	No adjective or modifier. If ≤ 10% fine earth, use the appropriate noun for the dominant size class; e.g., *gravel*. Use Terms in Lieu of Texture.

Yellowish red (5YR 4/6) channery silt loam

Red (2.5YR 4/6) gravelly loam

Strong brown (7.5YR 4/6) cobbly sandy loam

Soil Organic Matter Determinations

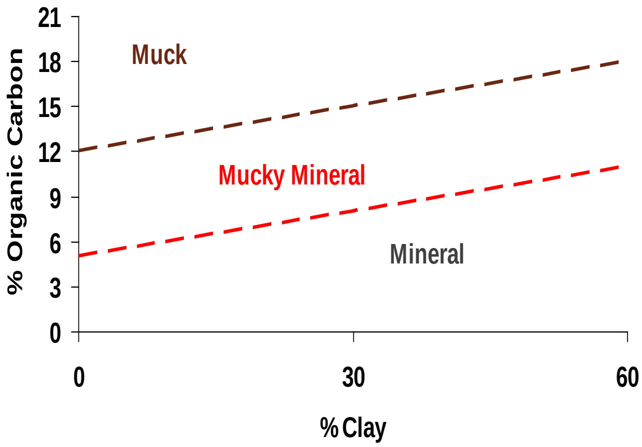


Figure: 4-28. Organic Carbon relationship to organic soil classes. *(NCSU)*

It is important to be able to tell the difference between organic and mineral material as this could affect interpretations. This is especially true when separating a somewhat poorly drained site versus a poorly drained soil. Specifically, muck and mucky mineral horizons often suggest wet soil conditions, whereas a dark A horizon may not. Thus the difference between these two materials can influence one’s final interpretation of the site. This issue is especially important in lower coastal plain soils when separating somewhat poorly drained from poorly drained soils.

Organic Carbon influences soil by acting as a coloring agent, improving the water holding capacity, increasing fertility, and improving aggregation. Organic matter may feel smooth (like silt) and sticky (like clay) and therefore interfere with your texture by feel. Organic

Types of OM	Designation	Description	Percent rubbed fiber
Sapric *(muck)*	Oa	Very decomposed	<17 %
Hemic *(mucky peat)*	Oe	Decomposed	17-40%
Fibric *(peat)*	Oi	Slightly decomposed	>40%

Table: 4-14. Terms for organic matter *(NRCS)*

matter is approximately 1.77x the organic carbon content. A soil is divided into 3 classes based on the organic carbon content related to clay; muck, mucky mineral, and mineral.

12 VAC 5-610-490. Characteristics of soils that determine suitability.

A.

3. Black appearance may be due to **organic matter** which has accumulated due to poor soil drainage.

Organic matter content may be determined in the lab or in the field. For field determination it is best to have known standards to calibrate yourself. In addition to the amount of organic matter, it may be necessary to determine how decomposed the materials is. There are 3 types of soil organic materials; in order to identifying organic soil type rub moist sample between fingers 10 times. Examine material with hand lens and look for fibers, not live roots, and estimate percent fibers remaining. Fibers are smaller than 2 cm (approx. 1") and show cellular structure.

Figure: 4-29. Sapric material is designated as an Oa horizon. *(Photo by Tom Saxton)*

Soil Structure

Soil structure is another aspect of a soil description that must be considered in order to evaluate a soil for its ability to treat and dispose of wastewater. Soil structure relates to the bigger picture of how water will move in the soil. Soils with a good texture may be foiled by a poor structure. One definition of soil structure is the grouping of individual soil particle into a larger grouping. You can also thinks of structure as a brick house in that the brick, mortar and cement are the particles (i.e. texture) and the completed house is the structure. We are concerned about structure because of its relation to land use. Take for example, a soil with a structure that does not allow roots to penetrate deeply into the soil. Agricultural crops will suffer water stress, as the plants will be unable to utilize water deep in the soil profile since their roots cannot penetrate as far. Shallow rooting of trees may result in tree throw during windy conditions because the tree may not be well

Structureless soils are broken into 2 official groups; Single Grain, Massive and Massive - Rock Controlled Fabric (in Virginia its commonly called rock controlled structure). Single grain refers to sands whereas massive refers to any soil that does not break apart into any predictable and repeatable type or shape. Massive rock controlled fabric is used for soil developed from saprolite. Unlike simple massive structure, rock controlled fabric has a preferred orientation of the minerals. The material may easily break into the individual mineral grains.

Artificial structure is structure that is created by disturbance. In regards to on-site systems this may be detrimental, as it often will restrict water movement.

Size is broken into 5 groups. The actual size ranges vary depending on the type of structure. Note that platy refers to thickness and prismatic refer to diameter. In describing plates, "thin" is used instead of "fine" and "thick" instead of "coarse."

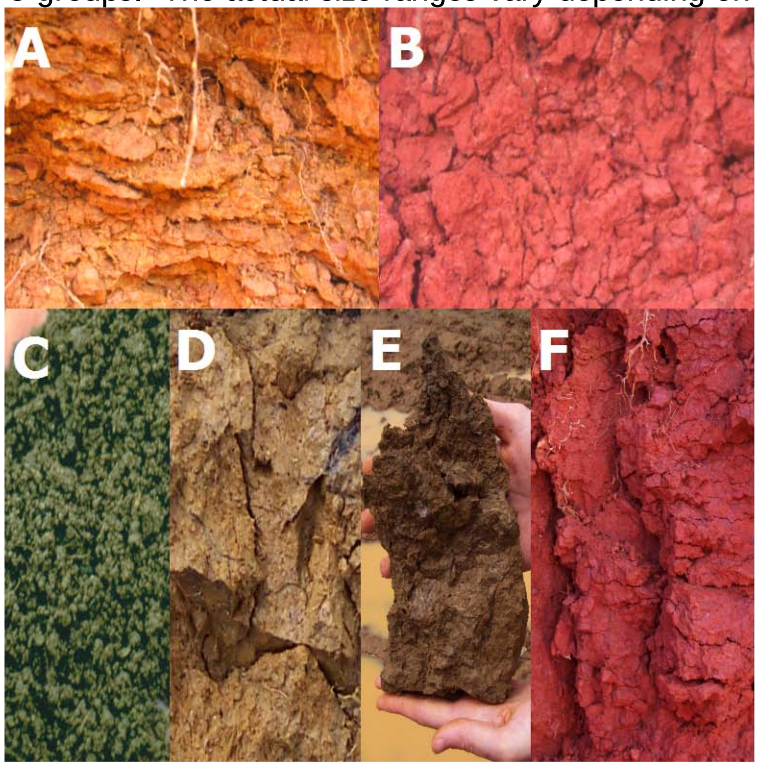


Figure: 4-31. Structure Types; **A**-Platy, **B**-Blocky *(subangular)*, **C**-Granular, **D**-Blocky *(angular)*, **E**-Prismatic, **F**-Compound Structure-Prismatic parting to Platy. *(TS)*

Grade refers to how well expressed or how stable the structure is. There are 4 groups of structure grade (0-3). All structureless soils have a grade of 0. The others range from 1 to 3. Structureless soils have no discrete units observable in place or in hand sample. Weak structured soils have units that are barely observable in place or in a hand sample. Moderate structured soils have well-formed units that are evident in place or in a hand sample. Strong structured soils have units that are distinct in place (undisturbed soil), and separate cleanly when disturbed.

Table: 4-16. Soil Structure Grade; *Cannot be determined with an auger (NRCS)*

Grade	Abbreviation	Criteria
Structureless	0	No discrete units observable in place or in hand sample.
Weak	1	Units are barely observable in place or in a hand sample.
Moderate	2	Units well-formed and evident in place or in a hand sample.
Strong	3	Units are distinct in place (undisturbed soil), and separate cleanly when disturbed.

Compound structure is described when smaller structural units are held together to form larger units. For example a soil may be described as having *"Moderate coarse prismatic structure parting to strong medium platy structure."* This means that subangular blocky is the primary structure and prismatic is the secondary structure.

Structure Formation

The formation of structure in soils has not received the level of scrutiny proportional to its importance to land use or water management. Much of the research that has been done has to do with tillage and surface layers. These studies are concerned with both formation and destruction of structure as it relates to agronomic concerns. Similarly, research on salt affected soils deals with how soils disperse and structure is destroyed.

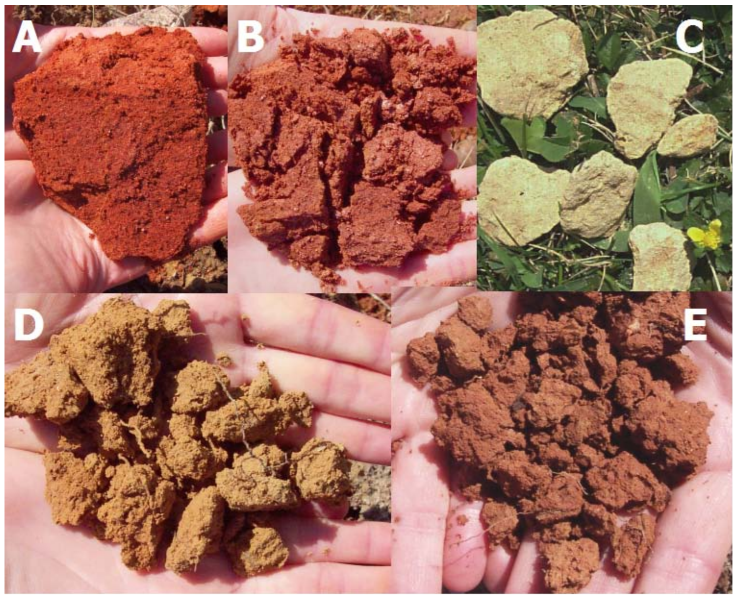


Figure: 4-32. Structure types, and grade: **A**-massive, **B**-weak coarse subangular blocky, **C**- strong medium platy, **D**-moderate coarse subangular blocky, **E**-strong medium and coarse subangular blocky. *(TS)*

Structure formation is related to the following three components: physical, chemical and biological processes at work in the soil. The physical processes that affect structure are; illuviation/eluviation, freeze/thaw, compaction, disruption (mechanical, natural i.e. slope movement), and wet/dry – shrink/swell. Eluviated zones generally have weaker structure or are structureless. Stronger structure is evident in illuviated zones because the illuviated material will help define the structure units by coating and stabilizing peds. Even if the material does not have a high amount of expandable clay minerals, desiccation will cause cracks to form. These cracks may become stabilized as clay, oxides or organic matter move through and/or coats them. When expandable clays are present their action can help define and form wedge structure.

In regions that experience freezing of the ground surface structural development may be affected or increased. In some ways this is similar to shrink/swell in that the soil is compacted and uplifted. The compaction forms ped faces which, if stabilized may form structural units. However the next freeze/thaw cycle could destroy the original feature. Fe oxides may coat and bridge particles. These oxides may be attached to clay or other particle charges. The oxides may help define a weak subangular blocky structure. Similar to oxides, organic acids will coat and stabilize. Commonly these acids will overwhelm the particles and cement the particles in the horizon together. Biological influence generally enhances soil structure. Microbes and fungus add to structure by their by-products, their mediation of redox reactions (Fe oxides), and binding particles together. This phenomenon is most common in the A horizon (topsoil) but can occur wherever enough carbon is present for food. Plant roots can be quite important to structure formation. In weak structure soils they create larger pores. The pores may be reused and coalesce to form ped faces. Root exudates help stabilize the pores. Bacteria etc. consume the exudates and further stabilize the faces/pores. Root growth physically compresses the voids. In well-structured soils they follow the path of least resistance. Large roots can cause by pass flow. Insects may act in a similar way to roots. Ants and termites can form stable channels. Fecal pellets may appear as strong very fine granular structure; particularly in forested A horizons. Other large organisms have a similar affect as insects. Crayfish burrows extend over 4 feet into the soil. When a burrowing organism's passage becomes filled with soil it is called a krotovina. Within a krotovina a weak to moderate structure is often found.

Most structure is formed by the interaction of all 3 components. Despite its importance to land use little research has been done on the formation of structure beyond that related to tillage and agronomic factors.

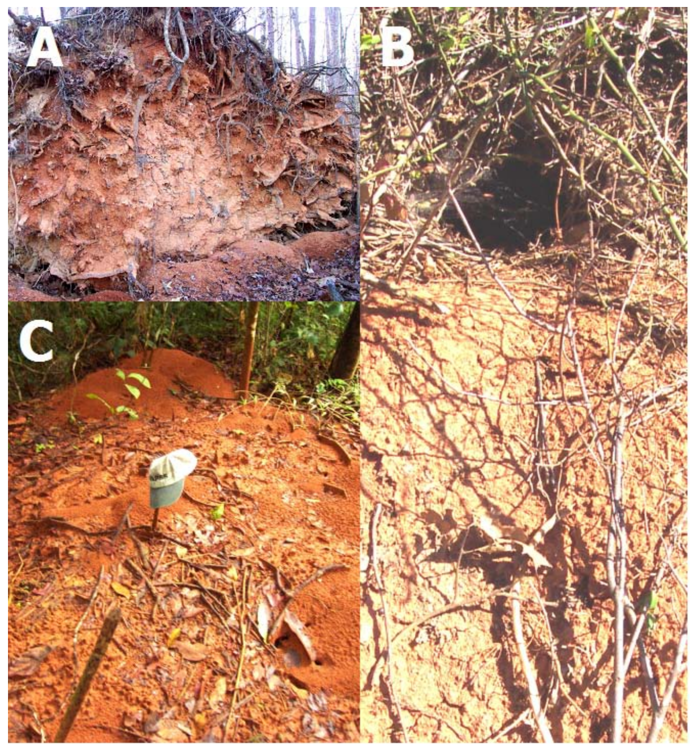


Figure: 4-33. Living organisms affect soil structure. **A**-tree roots, **B**-animal burrows**, C**-ant hills. *(TS)*

Soil Structure Deformation

Compaction generally results in denser soil maybe even structureless. Compaction due to farm implements or traffic often results in a platy plow or traffic pan. If present, these should be disrupted throughout the drainfield as they may channel water into the trenches. If left alone, temporary perching may occur. Water may flow across these pans and into the disturbed area of the trenches. During construction, the backhoe may smear the sidewalls of the trench resulting in decreased infiltration and poor performance.

12 VAC 5-610-700. Site preparation and alteration.
A. Preservation of **soil structure**. The preservation of the original structure of the soil in the area selected for placement of the absorption trenches is essential to maintaining the percolative capacity of the soil.

2. Soil compaction. Special caution shall be taken in allowing wheeled and tracked vehicles to traverse the area selected for placement of the absorption systems before, during and after construction of the trenches, especially during wet weather. Precaution is especially important where Texture Group III and IV soils are involved. Alteration of soil structure by movement of vehicles may be grounds for rejection of the site and/or system or revocation of the permit.

Slope movement can disrupt structure or prevent it from forming. Although some soils may have enough clay to qualify as an argillic horizon there may not be clay coatings present as constant creep allows only a weak subangular blocky structure to be formed. This phenomenon also illustrates that time is a factor in structure formation, as the older more stable soils will have a better-developed structure.

The soil water chemistry affects structure as well. As with physical influences these affects can be both positive and negative. Flocculation is the bringing of the particles close together and is enhanced by polyvalent cations (Al^{+++}, Ca^{++}, etc.). These charged particles cause small soil elements to clump or "floc" together. The flocculated units may form some of the initial building blocks for structural units.

Soil Structure-Water Movement relationships

Should soil structure be a factor in land use management? The answer should be obvious as structure plays an important role in water and gas movement in the soil. In on-site wastewater management structure plays a significant role in water movement and in the determination of the permeability by the soil evaluator. As the soil goes from granular to platy and massive the structural porosity decreases thus conductivity (permeability) decreases. Texture relates to the microporosity whereas structure relates to macroporosity. The type of structure has a profound impact on how water will move through the soil. In dealing with a septic system remember that under the trench the water flow must be unsaturated through aerobic soil for proper treatment to occur. However, water moves out from the trench into the soil by saturated flow. This means that flow out of the trench bottom is controlled by the structural macropores at first. Flow from the trench is not a simple one-dimensional flow. Sidewalls only play a role to the depth at which they are ponded. In a conventional system this should be minimal. It will be more important in serial distribution or pressure dosed systems. Once flow leaves the zone of saturation it will become unsaturated flow. Although matric potential can draw the flow in any direction (highest potential to lowest potential) the majority of the flow is still vertical. Once the water/effluent reaches the ground water (or restriction) the flow will become gradient driven, generally lateral. A well-structured soil will conduct water away faster as the larger voids will have a greater conductivity and may allow for deeper flow.

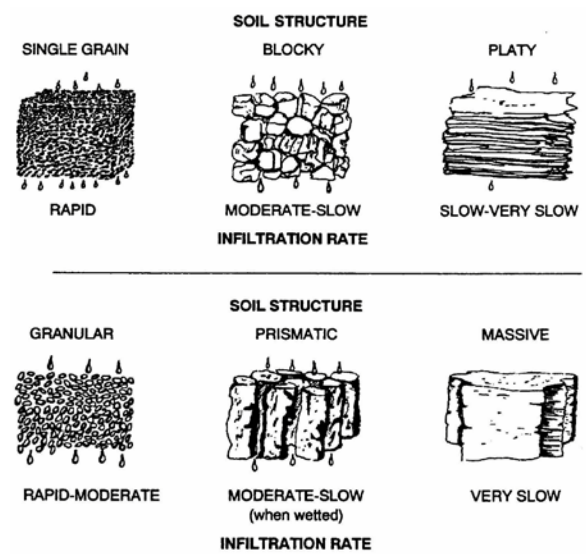


Figure: 4-35. Soil Structure and water movement. *(NRCS)*

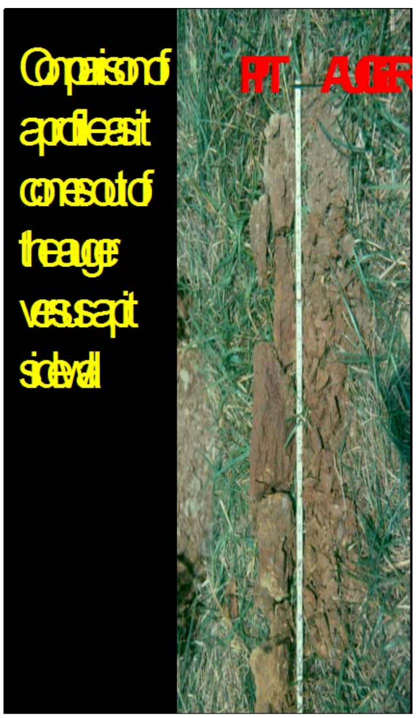


Figure: 4-34. Structure cannot be determined with an auger. *(Photo by Carl D. Peacock, Jr.)*

Furthermore, flow or diffusion of air (oxygen) will be enhanced by the better structure thus improving treatment.

Use of structure to Estimate loading (perc) rates

As with any evaluation, once the fieldwork is done, the real work begins in regards to interpretation. Structure may be used to estimate the permeability *(perc rate)* of the soil. But this estimate is based on textural group first. This gives the range. Next the estimated permeability is adjusted for structure. Finally, the permeability is adjusted for other factors. Permeability adjustments may be based on structure grade. Once a range is established start in the middle of that range. Increase the estimated permeability for strong structure, decrease for weak structure. Adjustments for size are also acceptable. Finer sized structural units would indicate increased permeability and larger sized structural units would indicate decreased permeability. Some types of structure may be recognizable during boring such as platy structure. However, structure *cannot* be accurately quantified in an auger boring. Structure should be viewed in a pit. Structure should be assessed in the field with an eye for how water will flow through the soil. Water movement can best be determined by observing ped faces, root quantity and penetration. The relationship between structure and water movement is complex and differs depending on moisture content.

> **12 VAC 5-610-490. Characteristics of soils that determine suitability.**
> C.
> 1. Estimated rates. The soil classifications contained in subdivision B 1 of this section have been assigned the following estimated rates in minutes per inch for the purpose of design. These rates may be modified when experience has shown that because of **soil structure** the texture group has a demonstrated rate different from that assigned.

Soil Consistence

Evaluation of soil consistence helps to refine our understanding of how water and wastewater may move through the soil. Soil consistence is used as a proxy to estimate the shrink-swell capacity of the soil and thus its mineralogy. Aspects of consistence are used to determine if the horizon or soil will have a low permeability. Consistence is the degree and kind of cohesion and adherence that soil exhibits, and/or the resistance of soil

> **12 VAC 5-610-700. Site preparation and alteration.**
>
> A. Preservation of **soil structure**. The preservation of the original structure of the soil in the area selected for placement of the absorption trenches is essential to maintaining the percolative capacity of the soil.
> 1. Prohibition on construction. Subsurface soil absorption systems shall not be constructed in Texture Group III and IV soils during periods of wet weather when the soil is sufficiently wet at the depth of installation to exceed its **plastic limit**. For the purpose of this chapter, the plastic limit of a soil <u>shall be considered to have been exceeded</u> when the soil can be rolled between the palms of the hands to produce threads 1/8 inch in diameter without breaking apart and crumbling.
> 3. **Soil smearing**. Excavating equipment utilized to construct the absorption system shall be so designed as not to compress or smear the sidewalks or bottom of the system. Excessive smearing of the usable absorption trench sidewalls or bottom during construction may result in irreversible damage to the soil infiltrative surface and may be grounds for rejection of the site and/or system.

to deformation or rupture under applied stress. Moisture content strongly influences soil consistence. There are five ways to record consistence in the field: Rupture Resistance, Manner of Failure, Stickiness, Plasticity, and Penetration Resistance. Each type is recorded at specific moisture contents or within given moisture content ranges resulting in a measure of the strength of the soil to withstand an applied stress. Separate classes are made for: blocks, peds, clods, surface crusts, and surface plates. Moisture content is also considered: Dry and Moist. Cementation classes are obtained by submergence of overnight air-dried samples for at least 1 hour before the test. Calibrating one's fingers against known standards is needed in order to estimate the force being applied.

The *Field Book for Describing and Sampling Soils* describes the specific force that corresponds with each class. A 1-inch to 1.5-inch (2.5 to 3.1 cm) cube should be used. Or a plate 3/8 inches to 5/8 inches (1.0 –1.5 cm) long by ¼ inch (0.5 cm) thick. The rate of change and physical condition soil attains when subjected to compression is the object of this determination. Samples are moist or wetter. Three failure classes are determined: Brittleness, Fluidity, and Smeariness. Each class uses a different sample size.

Rupture resistance is a measure of the strength of soil material to withstand an applied stress. Different classes are provided for dry and moist block-like specimens. The block-like specimen should be 1 inch to 1.5 inches (2.5 to 3 cm) on edge. The specimen is compressed between the thumb and forefinger, between both hands, or between a foot and a non-resilient flat surface. If a specimen resists rupture by compression, a weight is dropped onto it from increasingly greater heights until it ruptures. Failure occurs at the initial detection of deformation or rupture. Stress applied by hand should be over a 1-second period. Rupture classes exceeding friable (firm or greater) are considered limiting for onsite wastewater treatment. The relativity of consistency: A very friable horizon overlying a firm horizon could perch water. Example:

Table: 4-17. Rupture resistance classes for block-like specimens. *(NRCS)*

Dry class	**Moist class**	**Operation**
Loose	*Loose*	*Specimen not obtainable*
Soft	*Very friable*	*Very slight force between fingers*
Slightly hard	*Friable*	*Slight force between fingers*
Moderately hard	*Firm*	*Moderate force between fingers*
Hard	*Very firm*	*Strong force between fingers*
Very hard	*Extremely firm*	*Moderate force between hands*
Extremely hard	*Slightly rigid*	*Foot pressure full body weight*
Rigid	*Rigid*	*Blow of <3J but not body weight*
Very rigid	*Very Rigid*	*Blow of ≥ 3J*

Note: hitting a nail with a hammer requires approximately 100J

Table: 4-18. Manner of failure classes. *(See Manner of Failure on the next page)* *(NRCS)*

Class	**Criteria**
Brittle	*Block ruptures abruptly (pops or shatters)*
Semi-deformable	*Block ruptures before compression to < ½ original thickness*
Deformable	*Block ruptures after compression to ≥ ½ original thickness*
Non-fluid	*No soil flows through fingers with full compression*
Slightly fluid	*Some soil flows through fingers, most remains in palm, after full pressure*
Moderately fluid	*Most soil flows through fingers, some remains in palm, after full pressure*
Very fluid	*Most soil flows through fingers, very little remains in palm, after gentle pressure*
Non-smeary	*At failure, block does not change abruptly to fluid, fingers do not skid, no smearing occurs*
Weakly smeary	*At failure, block changes abruptly to fluid, fingers skid, soil smears, little or no water remains on fingers*
Moderately	*At failure, block changes abruptly to fluid, fingers skid, soil smeary smears, some water remains on fingers*
Strongly smeary	*At failure, block changes abruptly to fluid, fingers skid, soil smears and is slippery, water easily seen on fingers*

sandy loam overlying clay with firm consistence. This will perch water; the design may need to be adjusted to accommodate these characteristics (i.e. lgmi).

Manner of failure (Table: 4-18) is the rate of change and the physical condition soil material attains when subjected to compression. Manner of failure is dependent upon water state; soil materials are moist or wetter. To evaluate the manner of failure, a block-like specimen 1 inch to 1.5 inch (2.5 to 3cm) on edge is pressed between thumb and forefinger and/or a handful of soil material is squeezed in a hand. Samples that are fluid and/or smeary present potential problems for onsite wastewater systems. They may be unstable (flow) or result in excessively smeared sidewalls during installation.

Stickiness is the capacity of soil material to adhere to other objects. A sample of soil is crushed in the hand; water is applied while manipulating with thumb and forefinger. Stickiness is estimated at the moisture content that displays maximum adherence between thumb and forefinger.

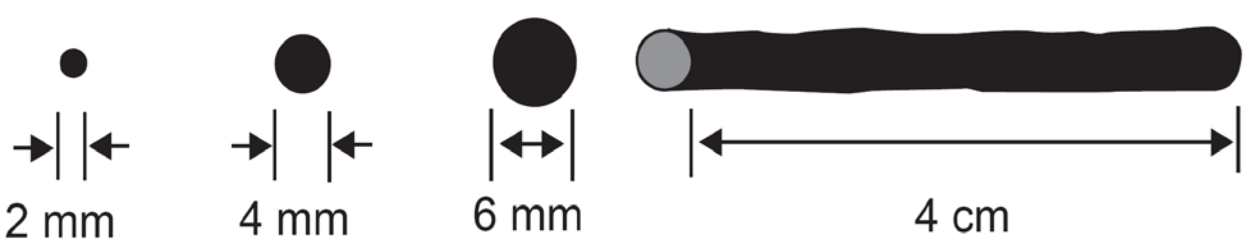
Table: 4-19. Stickiness classes *(NRCS)*

Class	**Criteria**
Non-sticky	Little or no soil adheres to fingers after release of pressure.
Slightly sticky	Soil adheres to both fingers after release of pressure with little stretching on separation of fingers.
Moderately sticky	Soil adheres to both fingers after release of pressure with some stretching on separation of fingers.
Very Sticky	Soil adheres firmly to both fingers after release of pressure with much stretching on separation of fingers.

Plasticity is the degree to which puddled or reworked soil material can be permanently deformed without rupturing. The evaluation is made by forming a roll (wire) of soil at the water content where the maximum plasticity is expressed.

Table: 4-20. Plasticity classes *(NRCS)*

Class	**Criteria**
Non-plastic	*Will not form a 6mm diameter roll, or if formed, cannot support itself if held on end.*
Slightly plastic	*6mm diameter roll supports itself; 4mm diameter roll does not.*
Moderately plastic	*4mm diameter roll supports itself; 2mm diameter roll does not.*
Very plastic	*2mm diameter supports itself.*



In order to utilize Consistence data, some idea of what consistence is related to will help. Perhaps the most critical relations to discuss are water movement, clay mineralogy, and overall management. Essentially as consistence increases, the rate of water movement decreases.

12 VAC 5-610-700. Site preparation and alteration.
A.
1. Prohibition on construction. Subsurface soil absorption systems shall not be constructed in Texture Group III and IV soils during periods of wet weather when the soil is sufficiently wet at the depth of installation to exceed its **plastic limit**. For the purpose of this chapter, the plastic limit of a soil shall be considered to have been exceeded when the soil can be rolled between the palms of the hands to produce threads 1/8 inch in diameter without breaking apart and crumbling. *1/8 inch = 3mm*

Clay Mineralogy (& Consistence)

The relation to water movement is in part due to the clay mineralogy. In order to understand the role clay mineralogy plays in consistence and thus water movement, one must understand some of the properties of the clay minerals. The role of parent material is paramount in the formation of clay minerals (secondary product of weathering). The 1:1 minerals are usually weathered from acidic or felsic parent materials. The expanding 2:1 minerals are usually weathered from basic or mafic parent material. Parent material plays the biggest part of whether the soil will be expansive *(shrink-swell soils).*

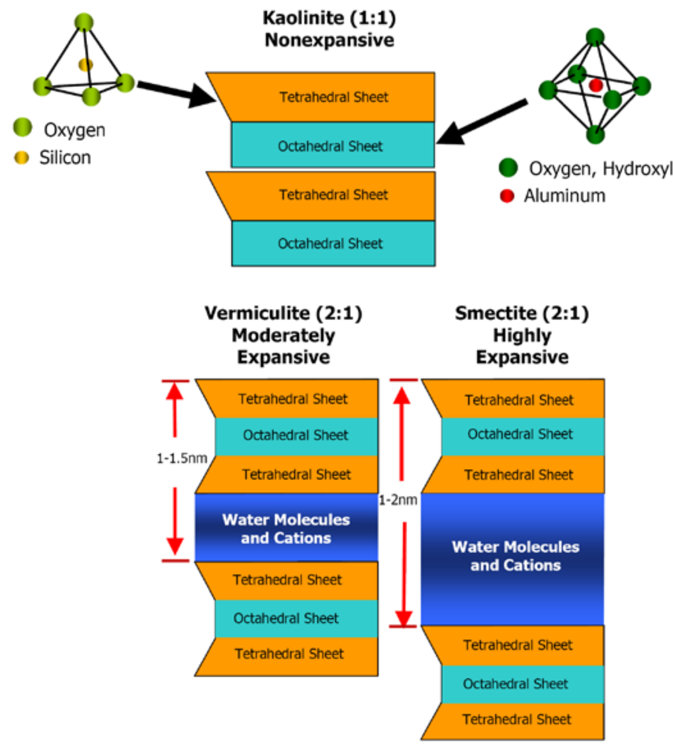
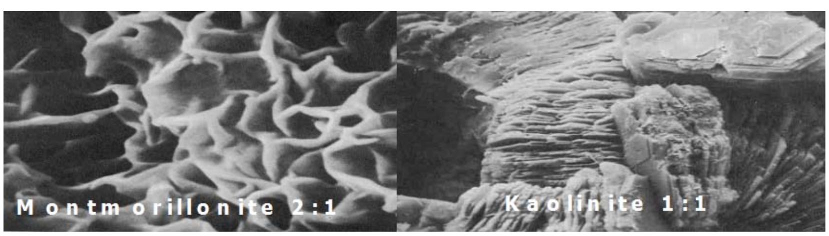


Figure: 4-36. Clay Structure or peanut butter sandwich? Bread is orange, peanut butter is teal. *(TS)*

Silica Tetrahedron have four sides, four oxygen molecules and one silica (Si^{+4}). Aluminum Octahedron have eight sides with Al^{+3}. These are bound together by shared oxygen molecules into different layers. 1:1 clays are like an open face sandwich with one silica tetrahedron to one aluminum octahedron. The main 1:1 mineral is Kaolinite. 2:1 clays are like a sandwich with two slices of bread; two silica tetrahedrons *(bread)* to one aluminum octahedron *(filling)*. The 2:1 clays can be broken into 2 groups: expansive, and non-expansive. In the non-expansive 2:1 clays, the layers are held together strongly so that



http://www.evsc.virginia.edu/~alm7d/soils/handouts/grainpics.html

Figure: 4-37. Microscopic image of clay types. *(www.evsc.virginia.edu)* neither water nor a change in the interlayer cations causes them to swell. Examples of non-expansive 2:1 clays are: illite, chlorite and vermiculite (slightly expansive). The expansive 2:1 clays are bound together by very weak hydrogen bounds (easily broken). These minerals will swell upon wetting. Smectites are one group of expandable or shrink-swell clays.

Minerals may expand as water is added. Water is dipolar; which simply means it can be attracted to a net negative charge or a net positive charge. Since clays are negatively charged, water will be attracted to the minerals. Water carries many different ions in soil solution. It will form a hydrated shell or layer around these ions, such as Na, Ca, and Mg etc. As this hydrated ion is sorbed onto the particle it will push the layers apart. Water has a physical size, thus when it gets between the layers it will force them to move apart.

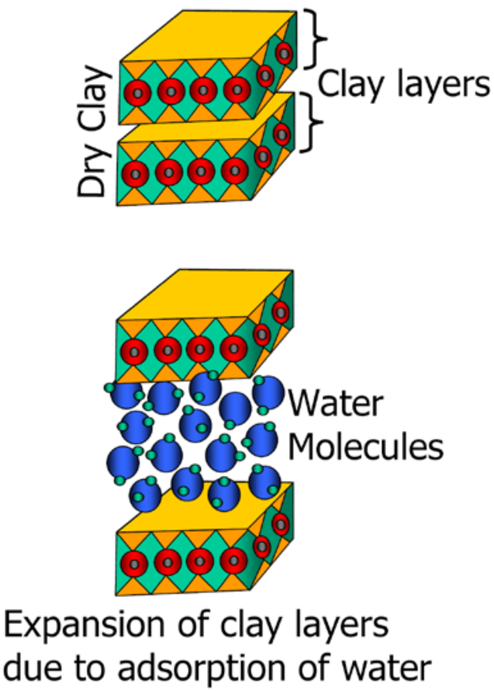


Figure: 4-38. Expansion of clay layers by water. *(TS)*

Other than consistence in the field, the only other method to determine the mineralogy of the soil is via lab procedures. Various laboratory procedures such as x-ray diffraction, mineralogy, COLE, Atterburg limits, and plasticity index are used alone or in combination to determine the extent of shrink-swell potential in a soil. No one procedure is definitive.

Stress surfaces (pressure faces) are smoothed or smeared surfaces. They are formed through rearrangement as a result of shear forces. They may persist through successive drying and wetting cycles.

12 VAC 5-610-120. Definitions.
"Shrink-swell soils" means soils with horizons that contain montmorillonite and other clays that excessively shrink upon drying and swell upon wetting.

12 VAC 5-610-490. Characteristics of soils that determine suitability.
F. **Shrink-swell soils**. Shrink-swell soils may exhibit satisfactory percolation rates when dry and therefore must be thoroughly wetted before a percolation test is performed.

12 VAC 5-610-593. Physical features.
9. **Shrink-swell soils**. When soils containing horizons with shrink-swell characteristics (see definitions in 12 VAC 5-610-120) have been identified, they shall be rejected for use for subsurface soil absorption systems.

12 VAC 5-610-960.
6. When the depth to a restriction, **shrink-swell soils** or a water table is less than 24 inches, pretreatment sufficient to produce a secondary quality effluent may be used to reduce these distances as shown in Table 4.4.

Slickensides are stress surfaces that are polished and striated and usually have dimensions exceeding 5 cm. Slickensides are produced by relatively large volumes of soil sliding over one another. They are common below 50 cm in swelling clays, which are subject to large changes in water state.

Figure: 4-39. Pressure faces *(stress surfaces)* with (vertical) striations *(slickensides)* shown above the pencil are indicators of high to very high shrink-swell potential. Soils (shrink-swell) with these features are limiting for onsite water treatment.

Figure: 4-40. Slickensides are formed when the surfaces rub against one another, causing sand grains to scratch the surfaces. Slickensides in this photograph are parallel lines or striations. Note the sand grains. A hand lens may be necessary to see these in some soils. Slickensides are an indicator that this is a shrink-swell soil.
(Photo by Darrin Doss, EHS)

Soil Horizons

While weathering, a soil slowly develops features that can be recognized and documented. Understanding these features will help one understand water movement through soils for onsite wastewater systems. In Virginia, we are required to document soil profiles during a site evaluation. This section encompasses all the previous sections and describes the correct conventions for documenting these features.

> **12 VAC 5-610-480. Soil profiles and patterns.**
> A. General. The purpose of determining the soil profiles and patterns is to identify the soil characteristics that affect installation of a subsurface soil absorption system.
> B. Soil profile. A soil profile is a vertical section of the soil throughout all its **horizons**.

The first features to be documented are the soil *"layers"* or as soil scientists call them, *Horizons.* In most soils, three kinds of symbols are used in combination to designate horizons and layers. These are capital letters, lower case letters, and Arabic numerals; capital letters are used to designate master horizons and layers; lower case letters are used as suffixes to indicate specific characteristics of the master horizon and layer; Arabic numerals are used both as suffixes to indicate vertical subdivisions within a horizon or layer and as prefixes to indicate discontinuities.

The prime symbol (') is (rarely in Virginia) used to indicate the second occurrence of an identical horizon descriptor(s) in a profile or pedon; e.g., A, **E**, Bt, **E´** Btx, C. The prime does not indicate either buried horizons (which are denoted by a lower case "b"; e.g., Bt_b), or lithologic discontinuities (denoted by numerical prefixes). Double and triple primes are used to denote subsequent occurrences of horizon descriptors in a pedon; e.g., A, E, Bt, **E´** , Btx, **E˝**, Cd *(Field Book for Describing and Sampling Soils).*

Master Horizons and Layers

O horizons-Layers: *dominated by organic material.*

Organic layer formed at the surface. Consists of leaves, needles, and twigs in various stages of decomposition. In Virginia, on upland wooded sites, the O layer is ½-3 inches thick. Virginia's climatic conditions oxidize organic matter quickly. In Virginia, if a site has a thick O layer, it may be in a wet landscape (drainageway, swamp, etc.). Organic soils generally contain 20% or more organic matter. The top of the O horizon is the beginning of the profile thickness (i.e. O (horizon) 0-3 inches).

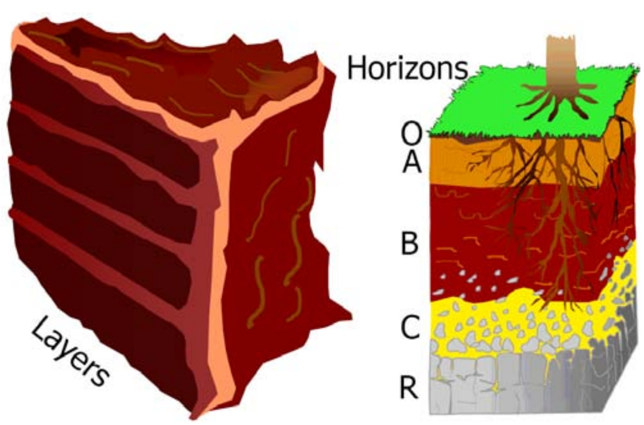


Figure: 4-41. Just like the layers of a cake, soils have layers called Horizons. *(TS)*

A horizons: Mineral horizons that formed at the surface or below an O horizon that exhibit obliteration of all or much of the original rock structure and (i) are characterized by an accumulation of humified organic matter intimately mixed with the mineral fraction and not dominated by properties characteristic of E or B horizons; or (ii) have properties resulting from cultivation, pasturing, or similar kinds of disturbance. It is the zone of maximum biological activity. It is darker in color (lower Munsell values) than underlying horizons. It commonly has coarser textures (less clay) than underlying horizons. In Virginia, organic matter content in the A horizon ranges from 1-5%. Soil structure is usually granular or crumb (like crushed cookies/crackers). In Virginia, the A horizon is usually thin or may be missing due to erosion. If the site has a thick A, the site may be in a drainageway. If the soil has been plowed, cultivated or disturbed by man, it is designated as an Ap horizon. The A horizon is often referred to as *"topsoil"*.

E horizons: Mineral horizons in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these, leaving a concentration of sand and silt particles of quartz or other resistant materials. It is a mineral subsurface horizon, a zone of intense *eluviation* (leaching or removal). It is primarily characterized by a loss of clay, iron, and constituents that may be moved by water. The E horizon has higher values and chromas than overlying A horizons (lighter in color). It is also lighter in color and not as brown as underlying B horizons. This horizon has coarser textures than underlying B horizons. The organic matter content is minimal (0-.5%). The soil structure is usually granular if textures are coarse, but may be platy or massive. It may not have formed or be missing in many soils due to erosion. Thick E horizons often denote soils weathered from transported material. Remember, the E horizon is one in which things *leave* or *eluviate (eluviation).*

B horizons: Mineral subsoil horizon; zone of *illuviation* (accumulation). Contains maximum accumulation of clay, iron, etc. deposited by percolating water. Structure is subangular blocky, angular blocky, prismatic, or platy. B horizons found on uplands are redder or browner and have more clay than A and E horizons. They may be gray at wet sites where reduction has occurred. They have negligible organic matter. Thick, clay enriched B horizons take thousands/millions of years to develop. Horizons that formed below an A, E, or O horizon and are dominated by obliteration of all or much of the original rock structure and show one or more of the following:

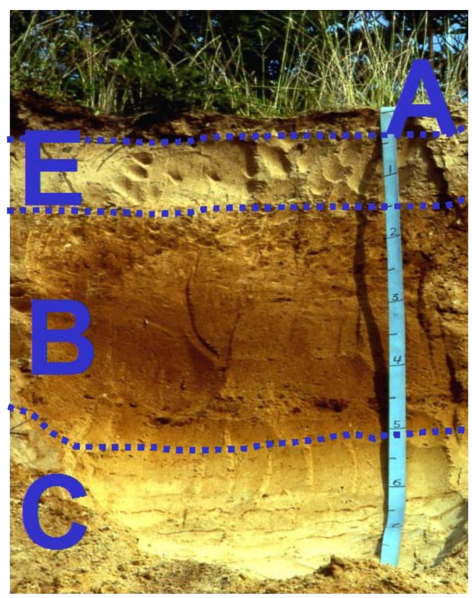


Figure: 4-42. Soil Profile in Northampton County. *(Peacock)*

1. illuvial concentration of silicate clay, iron, aluminum, humus, carbonates, gypsum, or silica, alone or in combination;
2. evidence of removal of carbonates;
3. residual concentration of sesquioxides;
4. coatings of sesquioxides that make the horizon conspicuously lower in value, higher in chroma, or redder in hue than overlying and underlying horizons without apparent illuviation of iron;

5. alteration that forms silicate clay or liberates oxides or both and that forms granular, blocky, or prismatic structure if volume changes accompany changes in moisture content;
6. or brittleness.

In VA, *strongly* expressed Bt horizons and *weakly* expressed Bw horizons are the most common. Remember, the B horizon is one in which things *pile* up and *accumulate* (illuviation). The B horizon is often referred to as *"subsoil"*.

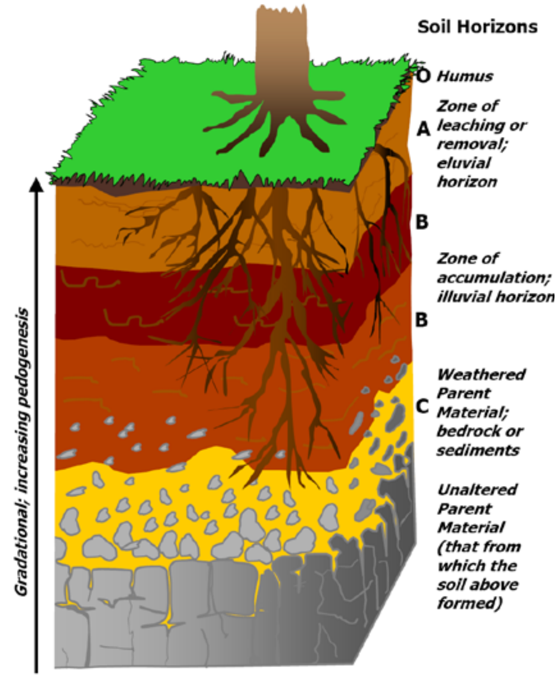


Figure: 4-43. Horizonation *(TS)*

C horizons or layers: Horizons or layers, excluding hard bedrock, that are little affected by pedogenic processes (soil forming processes) and lack properties of O, A, E, or B horizons. The material of C horizons may be either like or unlike that from which the *solum* (A through B horizons) presumably formed. The C horizon may have been modified even if there is no evidence of pedogenesis. It lacks properties of the O, A, E, and B horizons. It is commonly called the parent material and is mostly composed of mineral layers which include: weathered, diggable rock (Cr), sediments, saprolite, and geologic layers. It is the zone of minimal biological activity compared to upper horizons. C horizons are structureless - massive or rock controlled (Cr horizons); they may be single grained in sandy textures.

R layers: Hard bedrock: granite, limestone, sandstone, schist, gneiss, basalt, metabasalt, greenstone, etc. It has geologic features (hardness, strike, dip); it is attached to the earth; it has volume and continuity. The R horizon may have cracks and crevices. It does not have soil structure, but it may have rock-controlled or depositionally controlled structure. It cannot be dug with hand tools or most light equipment.

12 VAC 5-610-120. Definitions.
"Rock" or **"bedrock"** means continuous, coherent, lithologic material that has relative hardness depending on the degree of weathering. Bedrock has characteristics such as strike, dip, jointing, and lithological compositions. Structure and water movement are rock controlled. Bedrock grinds with an auger, and mechanical penetration is more difficult or prevented as the material gets harder.

Transitional Horizons

Two kinds of transitional horizons are recognized. In one, the horizon is dominated by properties of one master horizon but has subordinate properties of another. Two capital latter symbols are used, such as AB, EB, BE, or BC. The master horizon symbol that is given first designates the kind of master horizon whose properties dominate the transitional horizon. In the other, distinct parts of the horizon

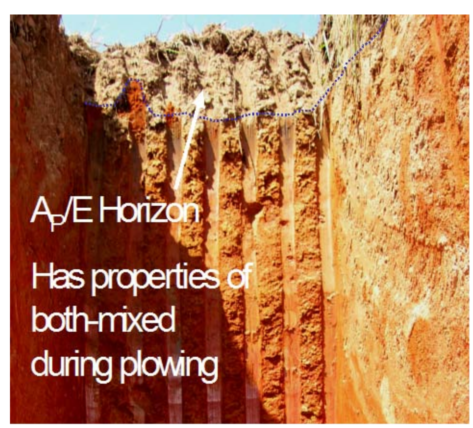


Figure: 4-44. Ap/E Horizon in Botetourt County. *(Photo by Tom Saxton)* have recognizable properties of the two kinds of master horizons indicated by the capital letters. The two capital letters are separated by a virgule (/), as E/B, B/E, or B/C. The first symbol is that of the horizon that makes up the greater volume.

AB A horizon with characteristics of both an overlying A horizon and an underlying B horizon, but which is more like the A than the B.

EB A horizon with characteristics of both an overlying E horizon and an underlying B horizon, but which is more like the E than the B.

BE A horizon with characteristics of both an overlying E horizon and an underlying B horizon, but which is more like the B than the E.

BC A horizon with characteristics of both an overlying B horizon and an underlying C horizon, but which is more like the B than the C.

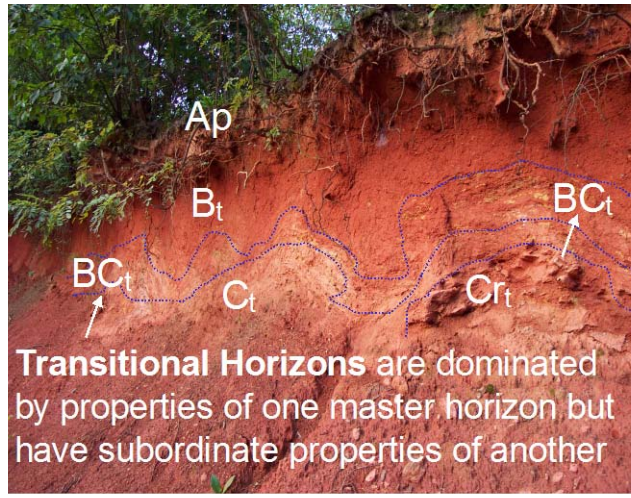


Figure: 4-45. Transitional Horizons in Appomattox County. *(Photo by Tom Saxton)*

CB A horizon with characteristics of both an overlying B horizon and an underlying C horizon, but which is more like the C than the B.

E/B A horizon comprised of individual parts of E and B horizon components in which the E component is dominant and surrounds the B materials.

B/E A horizon comprised of individual parts of E and B horizon in which the B component is dominant and surrounds the E component.

B/C A horizon comprised of individual parts of B and C horizon in which the B horizon component is dominant and surrounds the C component.

Subordinate Distinctions Within Master Horizons and Layers

a Highly decomposed organic material where rubbed fiber content averages <1/6 of the volume.

b Identifiable buried genetic horizons in a mineral soil.

c Concretions or nodules with iron, aluminum, manganese or titanium cement.

d Physical root restriction, either natural or manmade such as dense basal till, plow pans, and mechanically compacted zones.

e Organic material of intermediate decomposition in which rubbed fiber content is 1/6 to 2/5 of the volume.

g Strong gleying in which iron has been reduced and removed during soil formation or in which iron has been preserved in a reduced state because of saturation with stagnant water.

h Illuvial accumulation of organic matter in the form of amorphous, dispersible organic matter-sesquioxide complexes.

i Slightly decomposed organic material in which rubbed fiber content is more than about 2/5 of the volume.

m Continuous or nearly continuous cementation or induration of the soil matrix by carbonates (km), silica (qm), iron (sm), gypsum (ym), carbonates and silica (kqm), or salts more soluble than gypsum (zm).

Figure: 4-46. Subscript “m” in Surry County. *(TS)*

p Plowing or other disturbance of the surface layer by cultivation, pasturing or similar uses.

r Weathered or soft bedrock including saprolite; partly consolidated soft sandstone, siltstone or shale; or dense till that roots penetrate only along joint planes and are sufficiently incoherent to permit hand digging with a spade.

s Illuvial accumulation of sesquioxides (aluminum or iron oxides) and organic matter in the form of illuvial, amorphous, dispersible organic matter-sesquioxide complexes if both organic matter and sesquioxide components are significant and the value and chroma of the horizon are >3.

ss Presence of slickensides.

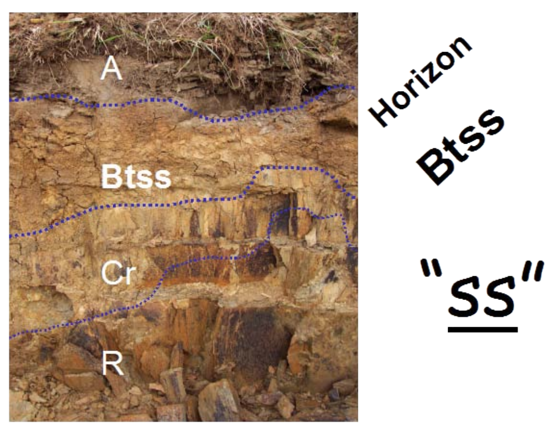


Figure: 4-47. Slickensides-shrink swell horizons *(ss)* in Albemarle County. *(Photo by Tom Saxton)* t Accumulation of silicate clay that either has formed in the horizon and is subsequently translocated or has been moved into it by illuviation.

v Plinthite which is composed of iron-rich, humus-poor, reddish material that is firm or very firm when moist and that hardens irreversibly when exposed to the atmosphere under repeated wetting and drying.

w Development of color or structure in a horizon but with little or no apparent illuvial accumulation of materials.

x Fragic or fragipan characteristics that result in genetically developed firmness, brittleness, or high bulk density.

Bx
Horizon

Fragipan

Root and water restrictive

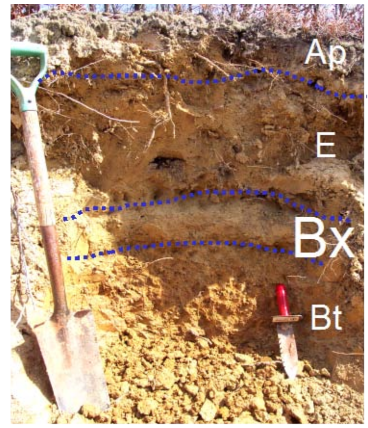


Figure: 4-48. Fragipan in Bath County. *(TS)*

Conventions for Using Letter Suffixes: Many master horizons and layers that are symbolized by a single capital letter will have one or more lower case letter suffixes. The following rules apply:

Letter suffixes should immediately follow the capital letter.

More than three suffixes are rarely used.

When more than one suffix is needed, the following letters, if used, are written first: a, e, h, i, r, s, t, and w. Except for the Bhs or Cr_t horizons, none of these letters are used in combination in a single horizon.

If more than one suffix is needed and the horizon is not buried, these symbols, if used, are written last: c, d, f, g, m, v, and x. Some examples: Btg, Bkm, and Bsm. If a horizon is buried, the suffix "b" is written last. Suffix "b" is used only for buried mineral soils.

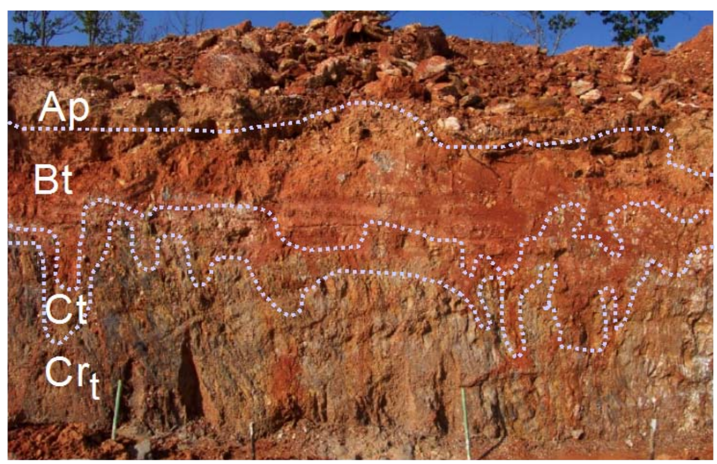


Figure: 4-49. Sample horizons in Campbell County *(Tatum Soil Series). (Photo by Tom Saxton)*

A B horizon that has significant accumulation of clay and also shows evidence of development of color or structure, or both, is designated Bt ("t" has precedence over "w," "s," and "h"). A B horizon that is gleyed or that has accumulations of carbonates, sodium, silica, gypsum, salts more soluble than gypsum, or residual accumulation or sesquioxides carries the appropriate symbol—g, k, n, q, y, z, or o. If illuvial clay is also present, "t" precedes the other symbol: Btg.

Suffixes "h," "s," and "w" are not normally used with g, k, n, q, y, z, or o.

Vertical Subdivision: Commonly a horizon or layer designated by a single letter or a combination of letters needs to be subdivided. The Arabic numerals used for this purpose always follow all letters. Within a C, for example, successive layers could be C_1, C_2, C_3, and so on; or, if the lower part is gleyed and the upper part is not, the designations could be C_1-C_2-Cg_1-Cg_2 or C-Cg_1-Cg_2-R.

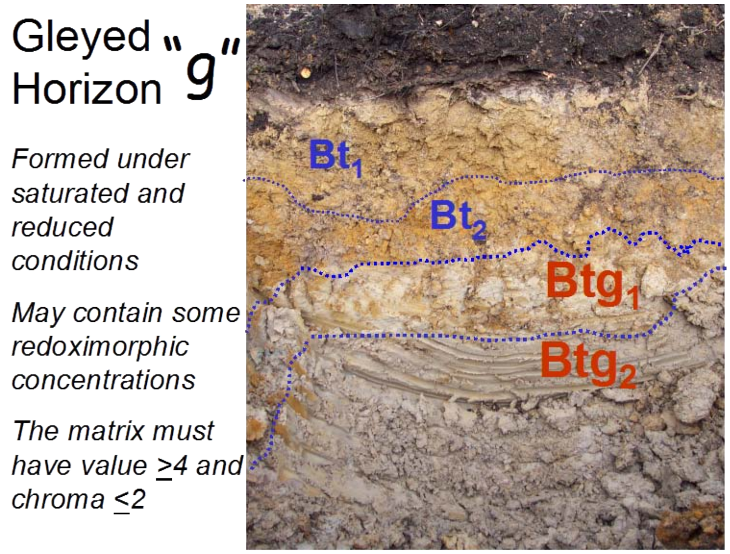


Figure: 4-50. Gleyed horizons in Surry County *(Peawick Soil Series). (Photo by Tom Saxton)*

These conventions apply whatever the purpose of subdivision. In many soils, horizons that would be identified by one unique set of letters are subdivided on the basis of evident morphological features, such as structure, color, or texture. These divisions are numbered consecutively. The numbering starts with 1 at whatever level in the profile any element of the letter symbol changes. Thus Bt_1-Bt_2-Btg_1-Btg_2 is used, not Bt_1-Bt_2-Btg_3-Btg_4. The numbering of vertical subdivisions within a horizon is not interrupted at a discontinuity (indicated by a numerical prefix) if the same letter combination is used in both materials: $Btss_1$-$Btss_2$-$2Btss_3$-$2Btss_4$ is used, not $Btss_1$-$Btss_2$-$2Btss_1$-$2Btss_2$.

Lithologic Discontinuities

What Does a Discontinuity Represent to the Onsite Wastewater Program?

A lithologic discontinuity represents a change in lithology or sediment type. It may also mark a zone of non-deposition or erosion. Wastewater and natural water passing through a soil will be impeded (slow down) as it encounters a discontinuity. This is due to restricted permeability as a result of texture, structure, porosity, consistence, or combinations of these. The degree to which this occurs varies greatly from site to site. In some cases, water may *"perch"* above the discontinuity creating a perched water table. In others, the rate may be reduced to a degree not consistent with other properties such as texture. At times, it may be necessary to install a lateral groundwater

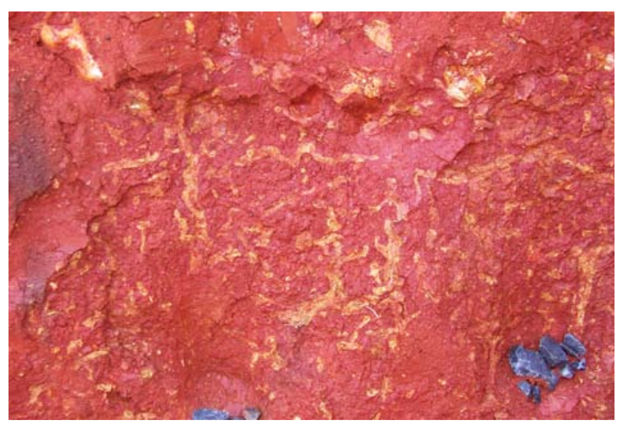


Figure: 4-51. Perched water table as evidenced by redox features above a discontinuity in Bedford County *(Appomattox Soil Series). (TS)* movement interceptor (LGMI) at the discontinuity.

Discontinuities occur in every county in the state of Virginia. It is very important that we learn to recognize these often obscure features and to document them. The occurrence of discontinuities does not necessarily imply that a drainfield cannot be installed at the site. Ultimately, we must recognize them so that we may determine their significance to the impedance of wastewater and design accordingly.

Figure: 4-52. Discontinuity near Midlothian (Bill Kitchel, LPSS). Ancient James River deposits above Cretaceous Coastal Plain deposits. *(TS)*

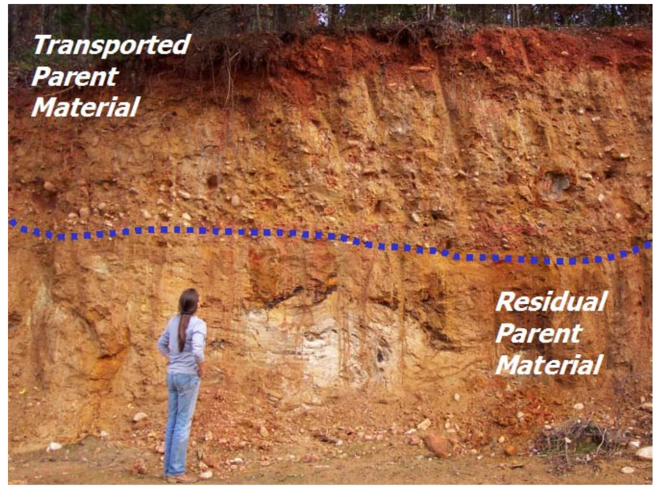


Figure: 4-53. Discontinuity (Ruby Shipman, EHS) in Appomattox County. Schist residuum beneath colluviated river terrace. *(TS)*

Describing Discontinuities: In mineral soils, Arabic numerals are used as prefixes to indicate discontinuities. Wherever needed, they are used preceding A, E, B, C, and R. Prefixes are distinct from Arabic numerals used as suffixes to denote vertical subdivisions. These designations are most often used in Virginia when describing profiles developed from transported materials (*capping* – local jargon for soils derived from materials that have been moved from their place of origin and deposited elsewhere on top of residuum). A discontinuity is a significant change in particle-size distribution or mineralogy that indicates a difference in the material from which the horizons formed and/or a significant difference in age, unless that difference in age is indicated by the suffix "b." Symbols to identify discontinuities are used only when they will contribute substantially to the reader's understanding of relationships among horizons. Stratification common to soils formed in alluvium is not designated as discontinuity, unless particle size distribution differs markedly (strongly contrasting particle-size class, as defined by Soil Taxonomy) from layer to layer even though genetic horizons have formed in the contrasting layers.

Figure: 4-54. Discontinuity in Augusta County. Note the abrupt textural change at the contact. Transported soils above, shale residuum below. This is a fan deposit. *(TS)*

Where a soil has formed entirely in one kind of material, a prefix is omitted from the symbol; the whole profile is material 1. Similarly, the uppermost material in a profile having two or more contrasting materials is understood to be material 1, but the number is omitted. Numbering starts with the second layer of contrasting material, which is designated "2." Underlying contrasting layers are numbered consecutively. Even though a layer below material 2 is similar to material 1, it is designated "3" in the sequence. The numbers indicate a change in the material, not the type of material. Where two or more consecutive horizons formed in one kind of material,

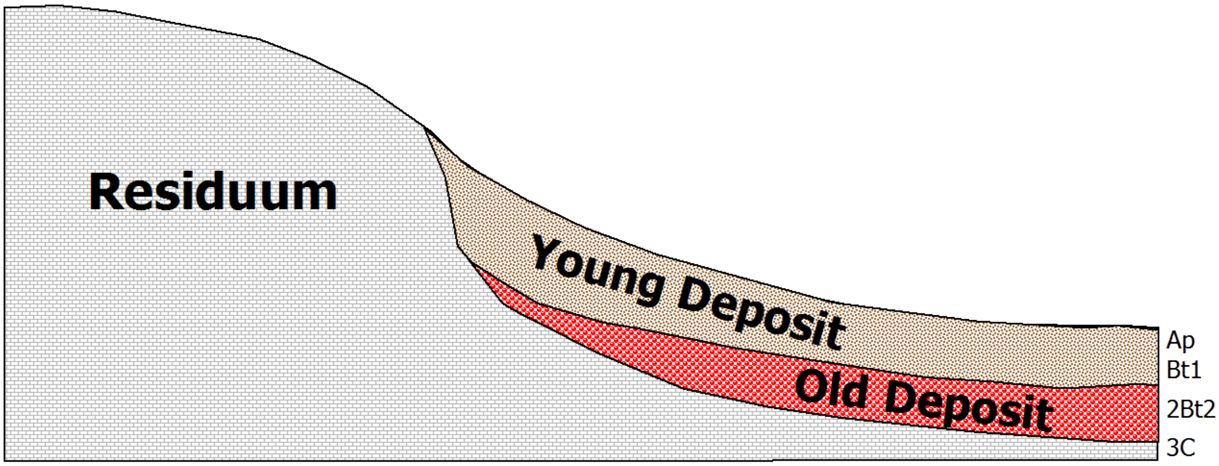


Figure: 4-55. Multiple depositional events of colluvium. Note Arabic numerals indicate different depositional materials at discontinuities. Water may slow down above these layers. *(TS)*

the same prefix number is applied to all of the horizon designations in that material: Ap-E-Bt_1-$2Bt_2$-$2Bt_3$-2BC. The number of suffixes designating subdivisions of the Bt horizon continues in consecutive order across the discontinuity. If an R layer is below a soil that formed in residuum and the material of the R layer is judged to be like that from which the material of the soil weathered, the Arabic number prefix is not used. If it is thought that the R layer would not produce material like that in the solum, the number prefix is used, as in A-Bt-C-2R or A-Bt-2R. If part of the solum formed in residuum, "R" is given the appropriate prefix: Ap-Bt_1-$2Bt_2$-$2Bt_3$-$2C_1$-$2C_2$-2R. Buried horizons (designated "b") are special problems. A buried horizon is obviously not in the same deposit as horizons in the overlying deposit. Some buried horizons, however, formed in material lithologically like that of the overlying deposit. A prefix is not used to distinguish material of such buried horizons. If the material in which a horizon of a buried soil formed is lithologically unlike that of the overlying material, the discontinuity is designated by number prefixes and the symbol for a buried horizon is used as well: Ap-Bt_1-Bt_2-BC-C-2ABb-$2Btb_1$-$2Btb_2$-2C. Not everyone agrees on the degree of change required for a lithologic discontinuity. No attempt is made to quantify lithologic discontinuities. The discussion below is meant to serve as a guideline. Several lines of field evidence can be used to evaluate lithologic discontinuities. In addition to mineralogical and textural differences that may require laboratory studies, certain observations can be made in the field. These include but are not limited to the following:

1. **Abrupt textural contacts.** — An abrupt change in particle-size distribution, which is not solely a change in clay content resulting from pedogenesis, can often be observed.
2. **Contrasting sand sizes.** — Significant changes in sand size can be detected. For example, if material containing mostly medium sand or finer sand abruptly overlies material containing mostly coarse sand and very coarse sand, one can assume that

there are two different materials. Although the materials may be of the same mineralogy, the contrasting sand sizes result from differences in energy at the time of deposition by water and/or wind.

3. **Bedrock lithology vs. rock fragment lithology in the soil.** — If a soil with rock fragments overlies a lithic contact, one would expect the rock fragments to have a lithology similar to that of the material below the lithic contact. If many of the rock fragments do not have the same lithology as the underlying bedrock, the soil is not derived completely from the underlying bedrock.

4. **Stone lines.** — The occurrence of a horizontal line of rock fragments in the vertical sequence of a soil indicates that the soil may have developed in more than one kind of parent material. The material above the stone line is most likely transported, and the material below may be of different origin.

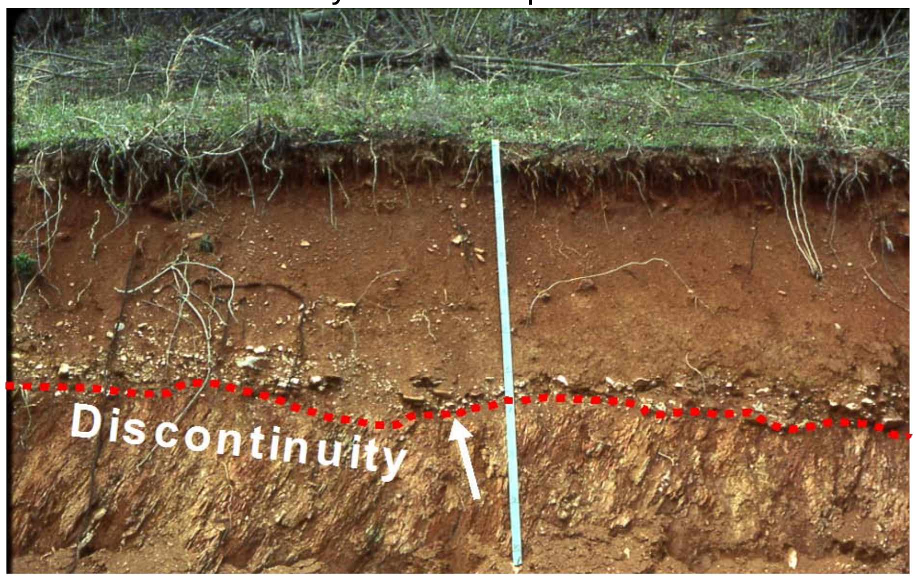


Figure: 4-56. Stone line immediately above the discontinuity. Residuum weathered from schist below the stone line. *(Photo by W.J. Edmonds)*

5. **Inverse distribution of rock fragments.** — A lithologic discontinuity is often indicated by an erratic distribution of rock fragments. The percentage of rock fragments decreases with increasing depth. This line of evidence is useful in areas of soils that have relatively unweathered rock fragments.

6. **Rock fragment weathering rinds.** — Horizons containing rock fragments with


Figure: 4-57. Discontinuity in Surry County. Heavy clayey textures in the upper portion of the profile underlain by an iron pan (red colored; subscript *"sm"*) and finally, a loamy sand C horizon at the bottom of the pit. *(Photo by Tom Saxton)*

no rinds that overlie horizons containing rocks with rinds suggest that the upper material is in part depositional and not related to the lower part in time and perhaps in lithology.

7. **Shape of rock fragments.** — A soil with horizons containing angular rock fragments overlying horizons containing well-rounded rock fragments may indicate a discontinuity. This line of evidence represents different mechanisms of transport (colluvial vs. alluvial) or even different transport distances.
8. **Soil color.** — Abrupt changes in color that are not the result of pedogenic processes can be used as indicators of discontinuity.
9. **Micromorphological features.** — Marked differences in the size and shape of resistant minerals in one horizon and not in another are indicators of differences in materials.

In organic soils, discontinuities between different kinds of layers are not identified. In most cases, the differences are shown by the letter suffix designations if the different layers are organic or by the master symbol if the different layers are mineral.

If the site evaluator anticipates an affect to water movement as a result of the discontinuity (redoximorphic features above the discontinuity), the discontinuity must be identified and documented in the soil profile description.

Summary: Soils with discontinuities infer the soils have developed in transported materials. The mode of transport could have been colluvial (gravity, creep, solifluction, etc.); alluvial (rivers, streams, and drainageways); marine (oceans, seas, and marshes); eolian (wind deposits) or combinations of any of these. Discontinuities are common throughout every physiographic province in Virginia.

Figure: 4-58. Discontinuity along the Staunton (Roanoke) River consists of river deposits (terrace) over metamorphic rock (schist) residuum. Note the cobbles in the river deposits. *(TS)*

Figure: 4-59. Note the stone line at the discontinuity in Campbell County. Multiple depositional events that consist of colluvium overlying stream terrace deposits have occurred here. *(Photo by Tom Saxton)*

Figure: 4-60. Discontinuities near Troutville. There are two clearly visible depositional events represented by two discontinuities. *(Photo by Tom Saxton)*

Sample Horizons and Sequences *(NRCS)*

The following examples illustrate some common horizon and layer sequences of important soils and the use of Arabic numerals to identify their subdivisions. The examples were selected from soil descriptions on file and modified to reflect present conventions.

Mineral soils

A1-A2-Bw-BC-C

Ap-A-Bw-Bk-Bky1-Bky2-C

Ap-A-Bw1-Bw2-BC-Ab-Bwb1-Bwb2-2C

Ap-A-E-Bt1-Bt2-BC-C

A-AB-BA-Btg-BCg-Cg

Oi-Oa-E-Bs1-Bs2-BC-C

Ap-E-Bhs-Bs-BC-C1-C2

Oi-A-E-BE-Bt1-Bt2-B/E-Btx1-Btx2-C

A1-A2-A3-2Bt1-2Bt2-2Bt3-2BC-2C

Ap-E-B/E-Bt1-Bt2-C

A-E-Bt1-Bt2-B/E-B't1-B't2-B't3

Oi-A1-A2-BA-Bt1-Bt2-BC-C

Ap-E-Bt-Btc-Btv1-Btv2-BC-C

A-Bt-Bk1-Bk2-C

A-Bw-Bq-Bqm-2Ab-2Btkb-3Byb-3Bqmb-3Bqkb

Ap-Bw1-Bw2-C-R

Ap-Bw-E-Bx1-Bx2-C

Ap-AB-Bg1-Bg2-BCg-Cg

Ap-C-Ab-C'

Ap-A-AC-C1-C2

Organic soils

Op-Oa1-Oa2-Oa3-C

Oi1-Oi2-Oi3-Oe

Oi-C-O'i1-O'i2-C'-Oe-C'

Oi-Oa-R

Fill Material

Only natural soil shall be used for onsite wastewater treatment systems. Fill material must not be used for subsurface soil absorption systems due to its poor capacity to transmit effluent. When man has moved soil, *"made land,"* the structural units and pores are truncated and there is no longer continuity throughout the soil. When fill material is deposited over natural soil, a textural/structural discontinuity is formed at the interface between the two. Water transmission through this zone is impeded and may perch. The *made land* will totally saturate before the water will move through the contact between the fill material and the natural soil.

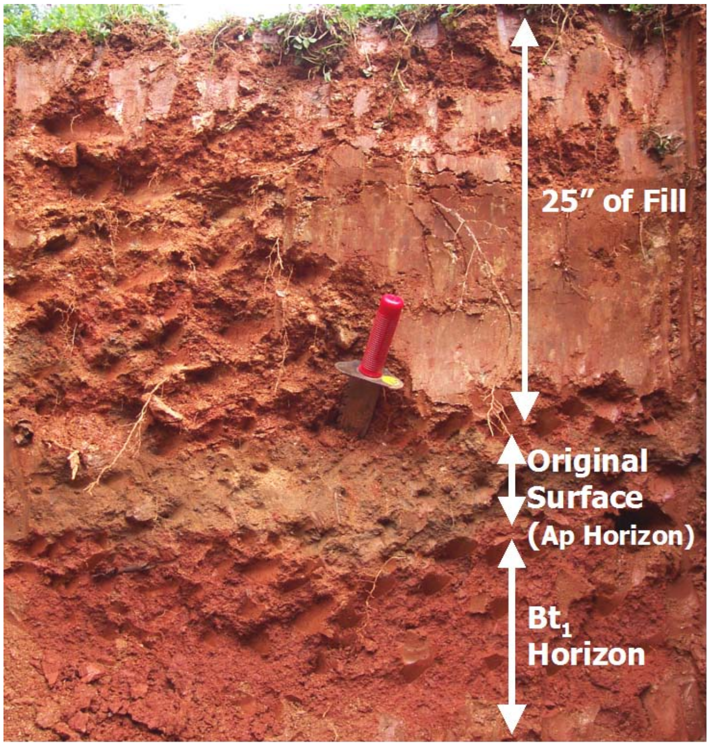


Figure: 4-61. This fill was spread over an existing drainfield after a basement was cut into the hillside in Altavista, VA. *(TS)*

12 VAC 5-610-470. Physical features.

C. **Fill material**. Fill material means soil transported and deposited by man as well as soil recently transported and deposited by natural erosion forces. Recent natural soil transportation and deposit is evidenced by one or more of the following:

1. No or indistinct soil horizons;
2. Depositional stratification;
3. Presence of a buried organic layer; and
4. Position in the landscape.

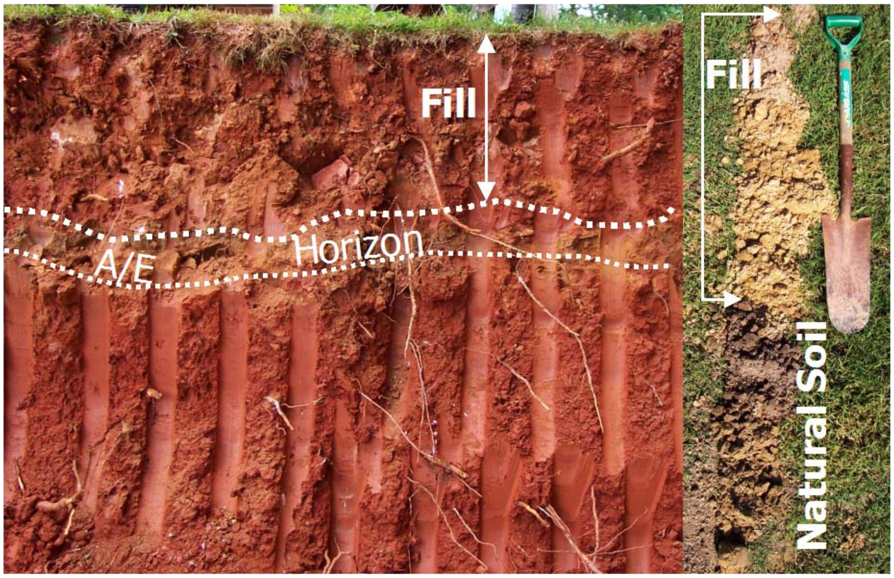


Figure: 4-62. Fill material overlying natural soil in Lynchburg. Note the dark color of the buried A horizon in the right profile in Prince George County. *(TS)*

Roots

Quantity, size, and location of roots in each layer commonly are recorded. Using features of the roots: length, flattening, nodulation, lesions, and the relationships to special soil attributes or to structure, may be recorded as notes. Quantity of roots is described in terms of numbers of each size per unit area. The class placement for quantity of roots pertains to an area in a soil horizon unless otherwise stated. It is desirable to have class separation at an abundance level where there are sufficient roots to exploit much of the soil water that is present in the withdrawal range of the plant over the growing season.

Table: 4-21. Root Classes *(NRCS)*

Quantity Classes:

Very few	*<0.2 per 1cm²*
Few	*<1 per 1cm²*
Moderately few	*0.2 to 1 per 1cm²*
Common	*1 to 5 per 100cm² (10cm on a side)*
Many	*5 or more per 100cm² (10cm on a side)*

Size Classes:

Very fine	*<1mm*
Fine	*1 to 2mm*
Medium	*2 to 5mm*
Coarse	*5 to 10mm*
Very coarse	*>10mm*

The location of roots within a layer may be described in relation to other features of the layer. Relationships to layer boundaries, animal traces, pores, and other features are described as appropriate. The description may indicate, for example, whether roots are inside structural units or only follow parting planes between structural units. Descriptive terms for roots are listed in a consistent order. Quantity, size, location is a convenient order: *"Many very fine and common fine roots"* implies that roots are uniformly distributed, since location is not given. This contrasts to examples that provide locational information such as *"common very fine and common fine roots concentrated along vertical faces of structural units"* or *"common very fine roots inside peds," "many medium roots between structural units."* Root traces (channels left by roots that have died) and the dead roots themselves are sometimes clues to soil properties that change with time. Root traces in deep layers may persist for years. Many of these traces have organic coatings or linings. They may occur below the normal rooting depth of annual crops. This suggests that they were left by deeper-rooted plants, perhaps native perennials. The presence of dead roots below the current depth of rooting

Figure: 4-63. Horizontal orientation and flattening of roots due to platy structure immediately above a discontinuity. *(TS)* may indicate a change in the soil water regime. The roots may have grown normally for a few years, then killed when the soils were saturated for a long period.

In addition to recording the rooting depths at the time of observation, generalizations about the rooting depth may be useful. These generalizations should emphasize very fine and fine roots, if present, because these sizes are active in absorption of water and nutrients. Generalizations such as horizontally oriented roots or flattened roots are especially appropriate for recognizing potentially limiting or restrictive soil horizons during drainfield design. If roots cannot penetrate a layer/horizon, effluent cannot be expected to effectively transmit through this zone either.

Figure: 4-64. Roots growing along a lithologic fracture surface indicate effluent will travel along these fractures, but not through the paralithic (Cr) material. *(Photo by Tom Saxton)*

PORES

Pore space is a general term for voids in the soil material. The term encompasses matrix, nonmatrix, and interstructural pore space. Matrix pores are formed by the agencies that control the packing of the primary soil particles. These pores are usually smaller than nonmatrix pores. Additionally, their aggregate volume and size distribution may, as in a soil horizon or layer with high extensibility *(shrink-swell)*, change markedly with water state. Nonmatrix pores are relatively large voids that are expected to be present when the soil is moderately moist or wetter, as well as under drier states. The voids are not bounded by the planes that delimit structural units. Interstructural pores, in turn, are delimited by structural units. Inferences as to the interstructural porosity may be obtained from the structure description. Commonly,

Figure: 4-65. Vertical continuity of an abandoned root channel (pore). *(TS)*

Table: 4-22. Pore Classes *(NRCS)*

Quantity Classes:

Few	*<1 per 1cm^2*
Common	*1 to 5 per 100cm^2 (10cm on a side)*
Many	*>5 per 100cm^2 (10cm on a side)*

Size Classes:

Very fine	*<1mm*
Fine	*1 to 2mm*
Medium	*2 to 5mm*
Coarse	*5 to 10mm*
Very coarse	*>10mm*

interstructural pores are at least crudely planar. Nonmatrix pores may be formed by roots, animals, action of compressed air, and other agencies. The size of the distribution of nonmatrix pores usually bears no relationship to the particle size *(texture)* distribution and the related matrix pore size distribution. For water movement at low suction and conditions of satiation, the nonmatrix and interstructural porosity have particular importance. Nonmatrix pores are described by quantity, size, shape, and vertical continuity--generally in that order. Quantity classes pertain to numbers per unit area. Most nonmatrix pores are either vesicular (approximately spherical or elliptical), or tubular (approximately cylindrical and elongated). Some are irregularly shaped.

Vertical continuity has extreme importance in assessing the capacity of the soil layer to transmit free water vertically. As one may imagine, pores that extend vertically through horizons would aide in the transmittal of effluent through the soil. Special aspects are noted, such as orientations in an unusual direction, concentration in one part of a layer, or such special conditions as tubular pores that are plugged with clay at both ends. Some examples of descriptions of pores are *"many fine tubular pores," "few fine tubular pores and many medium tubular pores with moderate vertical continuity," "many medium vesicular pores in a horizontal band about 1 cm wide at the bottom of horizon."*

Chapter Review

Understanding Concepts

1) What is the primary coloring agent in the subsoil?

2) True/False — Normally, a soil color may be perfectly matched to a color chip in the Munsell Color Book.

3) Explain the formation of an iron depletion.

4) List two types of redox concentrations and explain what they are.

5) True/False — It is accepted practice to wear sunglasses when coloring soil.

6) If a soil color was 10YR 6/2 and had sharp boundaries, would it be a lithochromic color or a redoximorphic feature indicating a water table?

7) If a soil color was described as 2.5YR 4/8 with common medium distinct 10YR 6/2 mottles; should one be concerned that there may be a water table in this soil?

8) A rotten egg odor is an indicator of ________________________________.

9) Is this a true statement?
Soils can be reduced without being saturated, but they cannot be saturated without being reduced.

10) True/False — Texture Group is a USDA Soil Science term.

11) Soil texture is based upon the relative percentage of _______________________.

12) What shape are channers, cobbles and gravels?

13) Which of these structure types enables water to move more freely?
Platy or *Blocky*

14) True/False — Structure may be determined with an auger or in a pit.

15) If a soil description indicated the presence of *slickensides*, would it be suitable for a drainfield? Why or why not?

16) A young soil would be expected to have a *thick* or *thin* B horizon?

17) True/False — An E horizon is one in which things have accumulated.

18) Which horizon is considered to be the *parent material?*

19) List the subordinate horizons that may lead to issues in the onsite world. Explain what characteristics of that horizon lead you to this conclusion.

20) True/False It is common to use more than 4 suffixes.

21) How is water movement affected by a discontinuity and why do we care?

22) What might *root flattening* imply about water movement through soil?

23) True/False Water will easily pass from fill material into the natural soil beneath.

24) True/False It is possible to have multiple discontinuities within one soil profile.

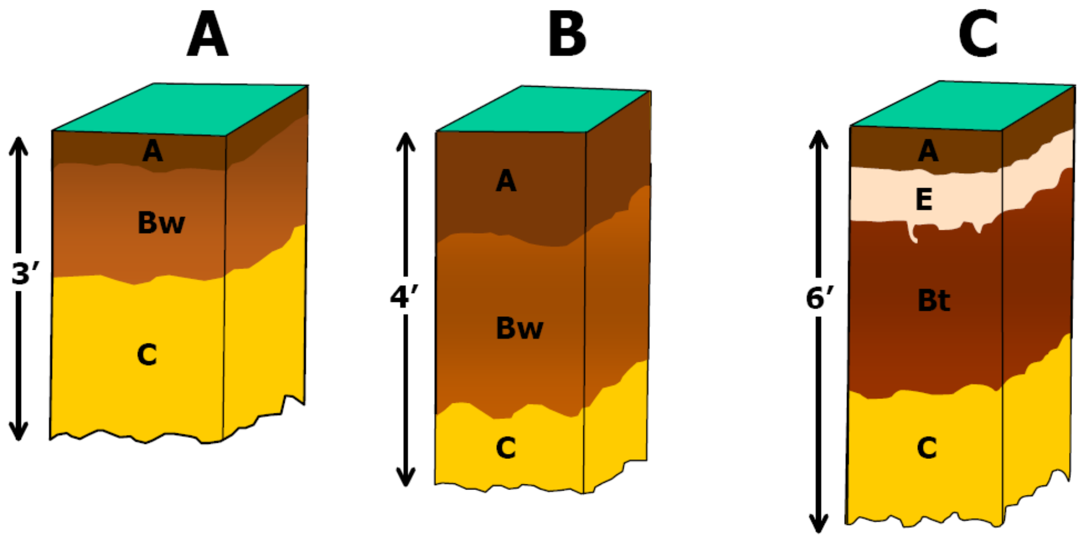
25) Look at Figure: 4-55 on page 51. This soil pit was in Surry County. It is in the Coastal Plain Physiographic Province. The upper profile is composed of clayey textured sediments while the lower is sandy. Consider: *Parent Material* in Chapter 1, *Redoximorphic Features* in this chapter, *Discontinuities* in this chapter.

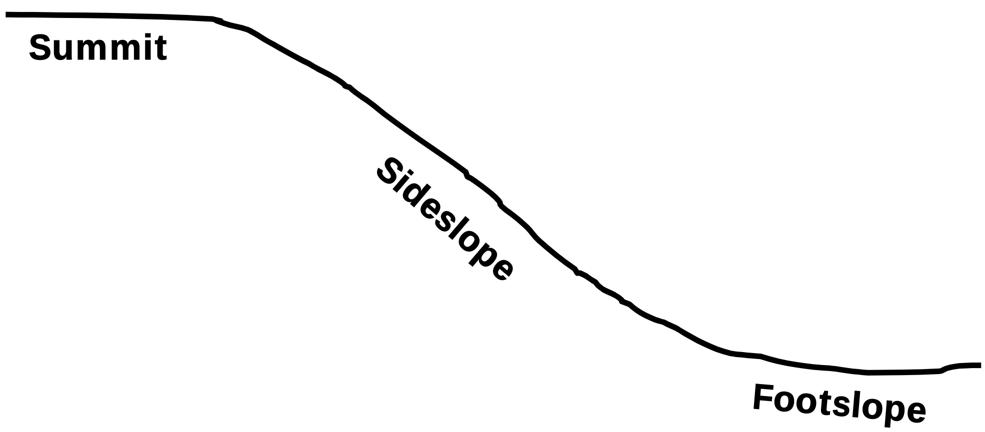
a. Speculate how this soil may have been formed with these differing sediments and under what conditions did it form?

b. How/why did the *sm horizon* (iron pan see Figure: 4-44 page 46) form at the contact between the clayey and sandy sediments? The iron pan is cemented (cemented with iron) sandy material. During Colonial times, this material was sometimes mined if the concentration of iron was great enough.

c. How would you evaluate this soil for onsite wastewater disposal system?

Critical Thinking





Which soil profile would correspond to which portion of the slope?

1) Summit: ________________ 2) Footslope: ________________

3) Sideslope: ________________

4) Which profile is best suited for a drainfield and why?

5) Which site is worst suited and why?

Label the soil profile with the appropriate *transitional horizons*, *prefixes* and or *suffixes.*

6)

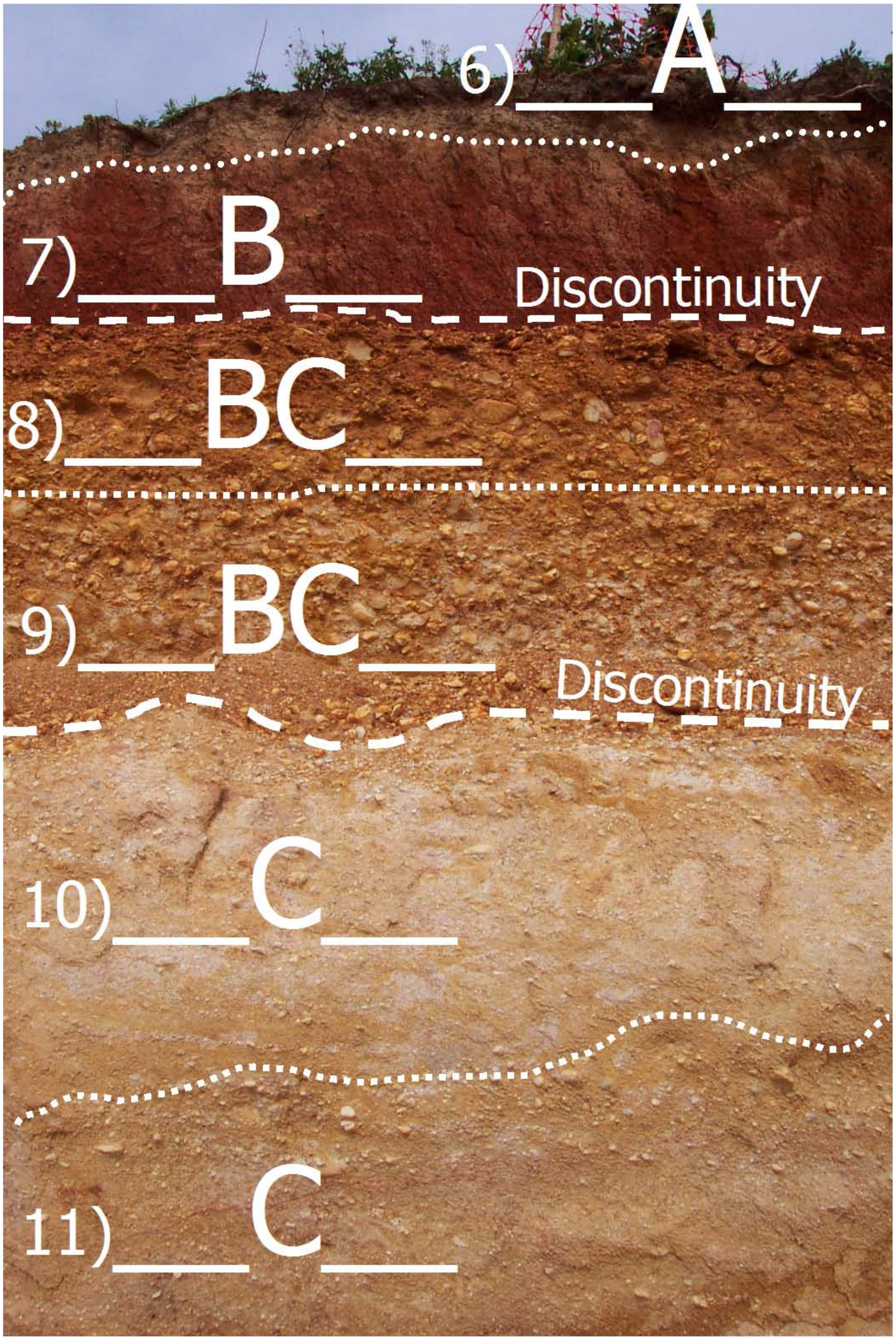
7)

8)

9)

10)

11)



12) What is the parent material of this soil? You may need to zoom in to make this determination.

13) What are some clues that lead you to your answer above?

14) Are there issues/soil properties with this soil that might affect an onsite wastewater disposal system evaluation? If so, what are they?

Hint: From the same site

Chapter 5
Conducting Site and Soil Evaluations

The purpose of a site evaluation is to understand the soil system and the hydrology of the site, to predict wastewater flow through the soil and into subsurface materials, and to establish a preliminary design for a subsurface absorption system that compliments the soil system and the hydrology of the site. The evaluation process is intended to allow for the collection and documentation of information sufficient to determine the potential for a site to support an onsite wastewater system. A site evaluation should follow a systematic approach that includes the description of surface characteristics, the description of subsurface characteristics, the interpretation of these characteristics for use in a subsurface absorption system, and the documentation of all results.

The process of data collection, evaluation, and design is often repeated several times for each system. During each repetition, new information is obtained and a new design is tried until a design is developed that provides the best match with the site conditions. The comprehensive site evaluation requires considerable expertise by the evaluator. The evaluator must have substantial knowledge about soil science, geology, subsurface absorption system design, and environmental health. This systematic approach to site evaluation is discussed in the following sections.

Sections

12 VAC 5-610-450. General.
Soil evaluation for a subsurface soil absorption system shall follow a systematic approach including consideration of physiographic province, topography, available area, degree of slope, and soil profile (thickness of each horizon, color, permeability, and texture). The evaluation is intended to document sufficient information to conclude whether or not the site can accommodate an onsite sewage treatment and dispersal system listed in Part IV (12 VAC 5-610-591 et seq.) of this chapter. The topography, available area, seasonal water table, drinking water supplies, bodies of water, shellfish growing areas, soil horizon, depth, rate of absorption, or combination of any of the above shall be considered in such evaluation.

Preliminary Documentation

All readily available information about the site should be obtained and reviewed prior to visiting the site. This information may include the following:

A survey or other documentation showing the boundaries of the site

A topographic map or topographic survey

Planned, or existing, location and size of the house or structure

Planned, or existing, location of wells, water lines, buried utilities, and easements

Information required for determining wastewater characteristics such as number of bedrooms, number of employees, and biological oxygen demand of wastewater

A soil survey such as those prepared by the U.S.D.A. Natural Resource Conservation Service

Geological maps

Adjacent, or previous, subsurface soil absorption system evaluations, designs, or permits

Adjacent, or previous, well permits

Location and type of regulatory buffer zones that may impact soil absorption systems

Site documentation used to characterize the site such as logs and locations of borings

Topographic Maps

Topographic maps show the topography of the Earth. They show elevation, which is the elevation above sea level. Sea level is 0. Contour lines are lines that connect points of equal elevation on a topographic map. The intent is to show a three-dimensional surface in two-dimensions. You must learn to understand and interpret these kinds of maps, especially when reviewing proposed subdivisions.

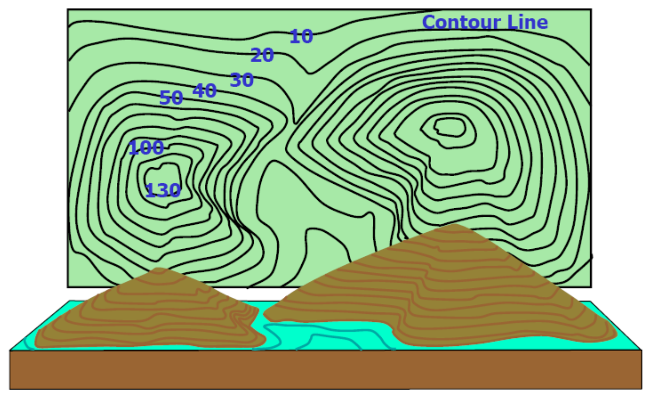


Figure: 5-1. A three-dimensional surface shown in two-dimensions. *(TS)*

Basic Topographic Map Concepts

1. Contour lines never cross

2. All points along a contour line represent the same elevation above sea level

3. The closer the lines, the steeper the slope of the land

4. Lines that cross streams and valleys are V-shaped with the point pointing uphill

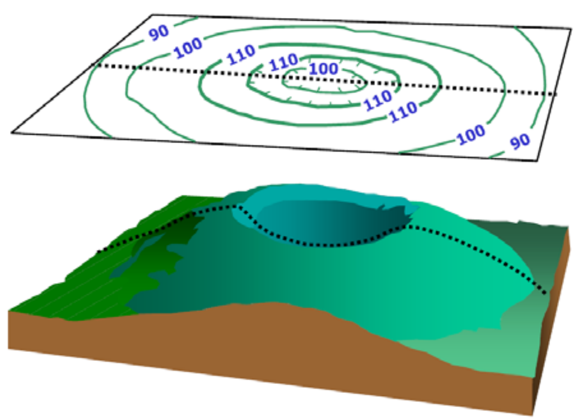


Figure: 5-2. Depressions are shown with cross-hatch marks drawn perpendicular to the interior of the contour line. Drainfields must not be constructed in the lowest portion of a depression. There are depressions in the Coastal Plain & west of the Blue Ridge (karst). They often fill with water during the wet season. *(TS)*

5. Contour lines form closed circles around tops of hills, mountains, and depressions

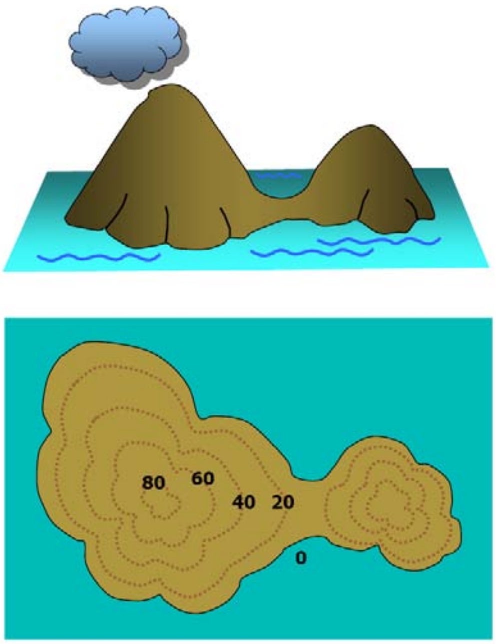


Figure: 5-3. The drawing above shows the surface as it exists in nature. The sketch below is of the same surface. The contour interval is 20. *(TS)*

6. Depressions are marked with short, straight lines inside the circle, pointing downslope toward the center of the depression

The difference in elevation from one contour line to the next is called the contour interval. Topographic maps may be confusing to read when first encountered. However, they may represent the best tool for reviewing a site before going to the field.

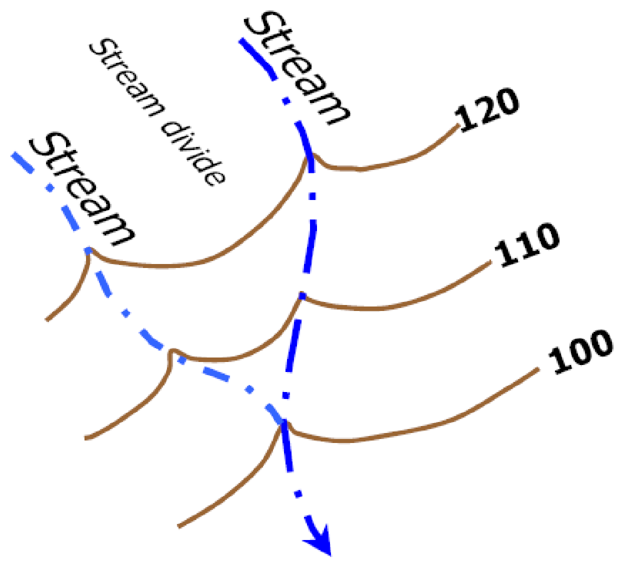


Figure: 5-4. Contour lines should form abrupt angles ("Vs") where they cross streams and smooth curves where they traverse stream divides. *(TS)*

It is possible to calculate slope from a topographic map. The accuracy of this calculation depends upon map scale and contour interval of the map. But this can be a handy way to make a quick estimate, especially when reviewing submitted work. Look at the figure with the hand holding the pencil. If the scaled distance between the 560' contour interval and the 520' contour interval was 100'. What would the percent slope be across that area? First, the relief must be calculated. The *relief* is the elevation distance between the lowest and highest area of interest on the map. In this case, the relief or "fall" would be 560' – 520' = 40'. The percent slope is Rise over Run times 100%. What is the rise and what is the run? The rise is the relief (40'). The run is the scaled distance (100').

Rise	*Run*	*%*

(40' ÷ 100') X 100 = 40% slope

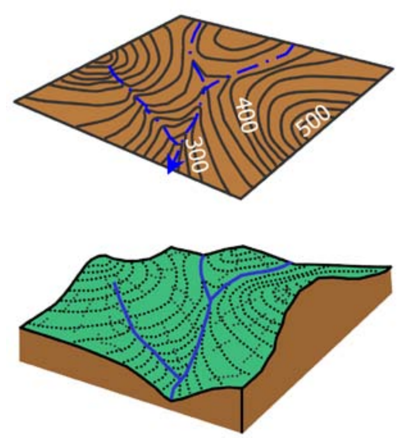


Figure: 5-5. Notice the upside down "Vs" indicate the upslope direction of drainageways. *(TS)*

Contour intervals are not the same on all maps. They are normally relative to the steepness of an area. In Virginia, the U. S. Geological Survey (USGS) contour intervals are normally 5 feet near the coast, 10 feet in the piedmont and upper/middle coastal plain, 20' in low mountainous areas and potentially 40' in very steep mountainous areas. When looking at these maps, it is very important to be aware of the contour interval. A flat looking site on a 20' contour interval will be steep compared to a flat site on a 5' contour interval map. Subdivision proposals must have contour lines shown in the proposed drainfield area. These are expected to be no less than 2' contours. The purpose for this is to ensure the office reviewer has a sense of the landscape and whether the proposed site is on contour. This also enables the designer to check their fieldwork prior to submittal. USGS topographic maps also have *index* contours. They are usually darker or a different color. Index contours are usually located at every fifth line. They make reading the map easier.

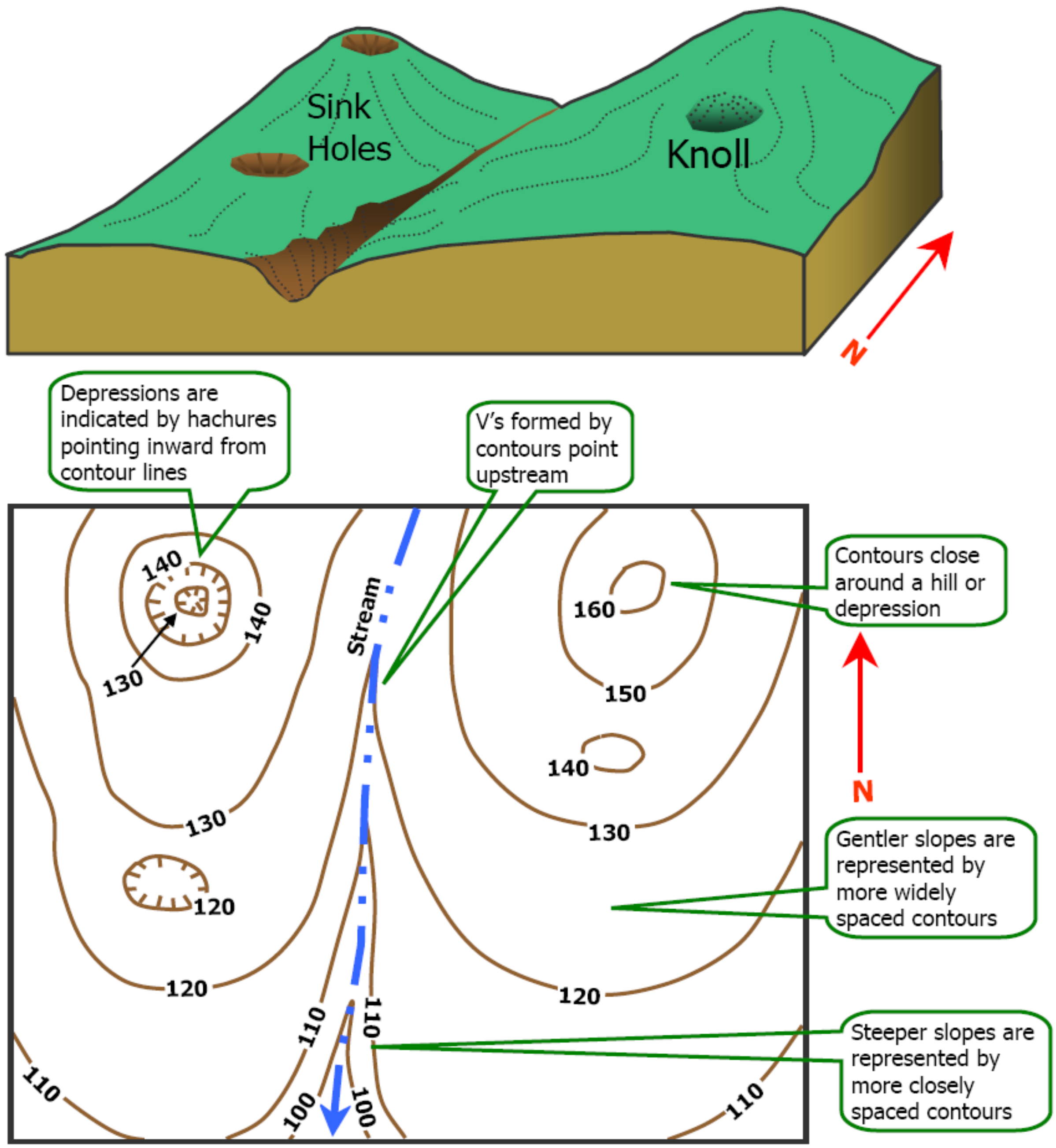


Figure: 5-6. Topographic maps. The upper sketch is in 3-dimensions, the lower is in 2-dimensions. *(TS)*

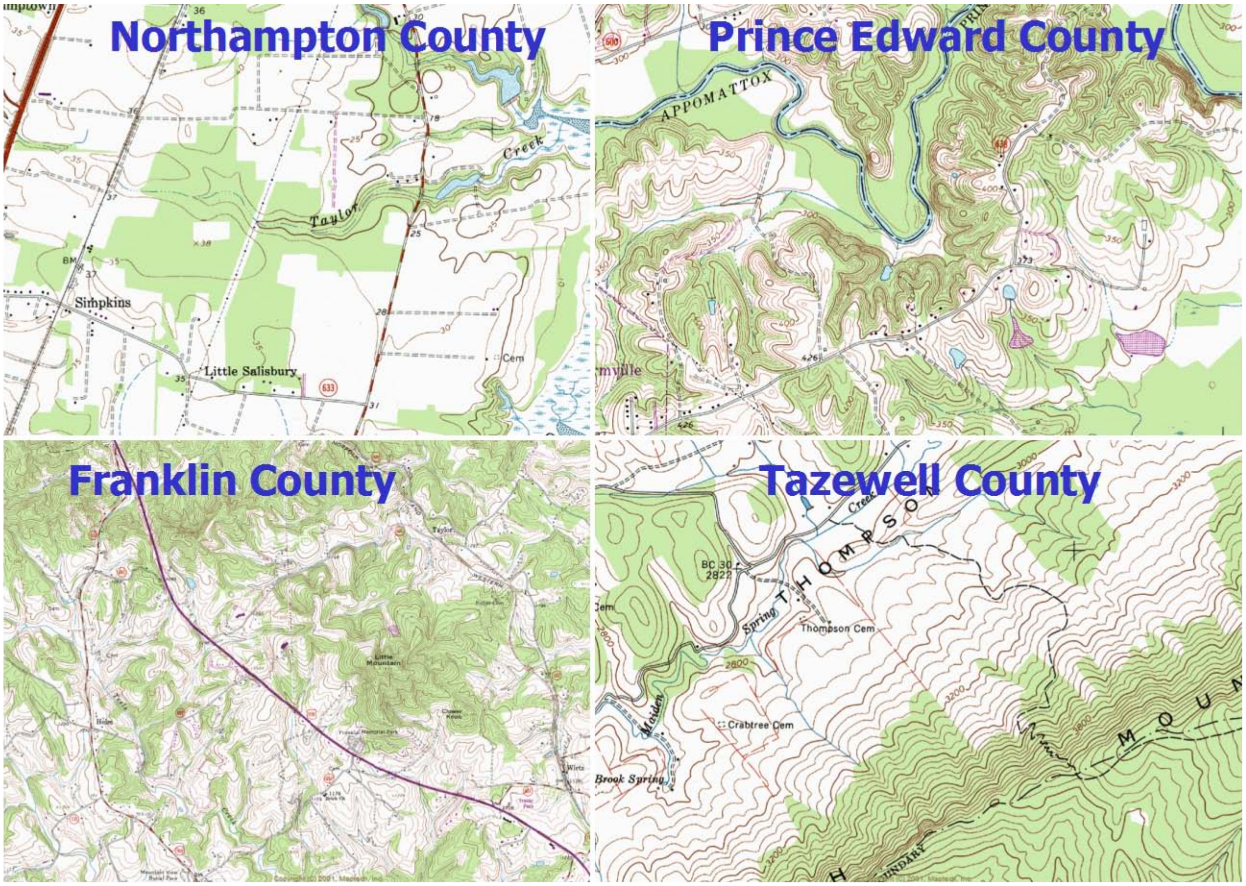


Figure: 5-7. Each map uses a different contour interval due to the relief in that area. Can you determine each? Northampton-5', Prince Edward-10', Franklin-20', Tazewell-40'. *(USGS)*

Map Scale

Topographic maps, survey plats and permit drawings are drawn to *scale*. A scale compares the distances on the map to actual distances in the field. Map scales are the ratio of length on a map to length on the ground; the ratio is unitless. For example, 1 inch on a topographic map might equal 24,000 inches on the ground or 1:24,000 map scale. This could be feet, centimeters, etc. It is the ratio 1:24,000. If the unit inch is used; 24,000 inches divided by 12 inches in a foot equals 2,000 feet. This map scale is 1 inch (on the map) equals 2,000 feet (on the ground) or

What is the contour interval on this proposed subdivision?

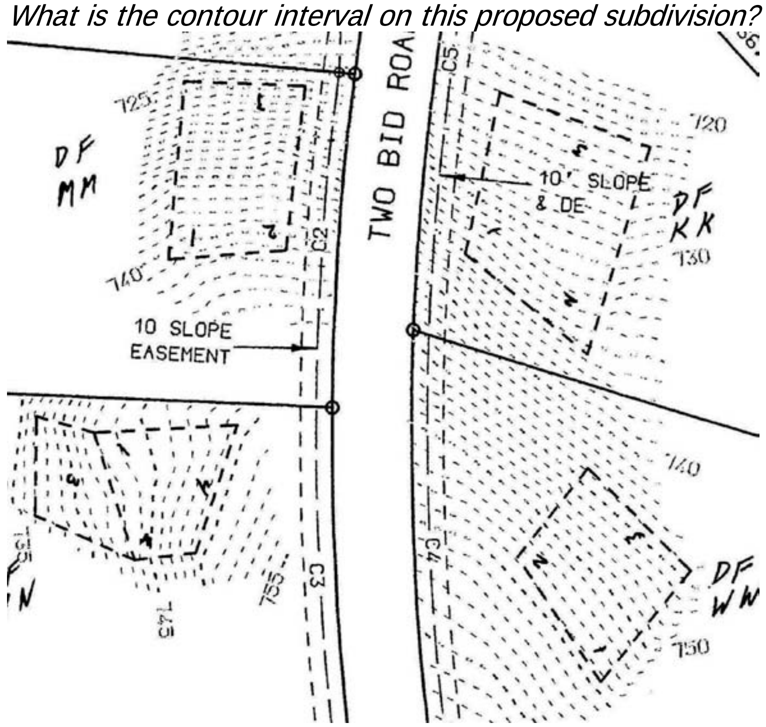


Figure: 5-8. *One foot. This makes it easy to determine whether the sites have been designed in accordance with the landscape and contour. (TS)*

1"= 2,000'. Using an engineer's scale (ruler), the twenty scale has one inch subdivided into twenty parts. This would show major increments of 2,000 feet with each small "tick" mark representing 100 feet. This scale is appropriate to use on 1:24,000 topographic maps (1" = 2,000').

One of the most common plat scales in the onsite world is one-inch equals fifty feet (1" = 50'). The fifty (50) scale (ruler) is used to read distances at this map scale. An inch is divided into fifty parts. Each little "tick" mark represents one foot at this scale. The fifty scale may also be used to read distances on a map that are 1" = 500' (in this case, each "tick" mark represents 10') or 1" = 5,000' (ticks X 100'), etc.

A very common task the site evaluator performs daily is adjusting plats to different scales. The ability to do this is a simple skill. But its importance cannot be over estimated. Using scale drawings is the best way to eliminate errors while drafting permits. It is best to do all drawings to scale. This gives the contractor the homeowner or any user the ability to see a true representation of the evaluator's design and mistakes will quickly become evident. For example, many homeowners do not know the location of their property lines. They may flag a line for the evaluator, but that doesn't mean it is correct. Triangulations from known survey points and subsequent scale drawings will verify whether the design is located entirely on the property.

Scaling Plats and Drawings

Many times, the evaluator may be provided with a plat that has been copied and faxed and the scale has been distorted or changed. A good copy machine and this simple procedure will enable the evaluator to convert a plat to any scale:

1) Using an engineer's scale (ruler), measure a known distance on the plat using the scale with which one intends to draw *(for instance use the "50" scale if a scale of 1" = 50' is desired)*.

2) If the evaluator intends to blow up (enlarge) the plat, divide the large measurement by the small measurement.

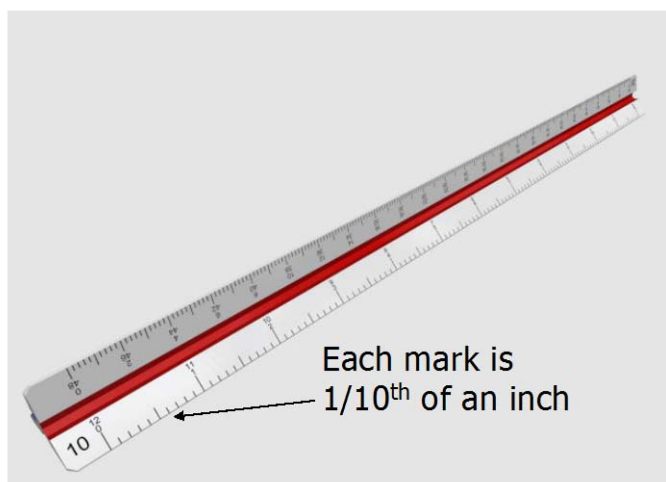


Figure: 5-9. An inch is divided into decimals of an inch with an Engineer's scale. An inch is divided into ten parts on the "10" scale; twenty parts on the "20", thirty parts on the "30" and so on. *(TS)*

3) If the intent is to reduce the plat, divide the small number by the large.

4) Multiply either of #2 or #3 by 100 to derive the percentage setting for the copy machine.

For example, a 1938 plat shows that one property line is 100' long. The evaluator wishes to draft a construction permit at a scale of 1" = 50'. The "50" scale is used to measure the 100' distance on the plat. The distance measures 50' with this scale. The known (written on the plat or field measured by the evaluator) distance is 100'.

(100' ÷ 50') X 100% = 200%

Set the copy machine to 200 percent and copy the plat. It will enlarge the drawing to 1" = 50'. Care must be taken to check the remaining dimensions on the plat. There are often small errors in the original, especially if it has been scanned or faxed, that become amplified when the drawing is enlarged. It may be necessary to redraw these to the correct distances during the re-drafting process.

At times it may be necessary to determine the scale of a map or plat. This may be accomplished by using the "10" scale. Simply measure a known distance on the map or plat with the "10" scale which is 1 inch with ten divisions. Each division or "tick" is 1/10th of an inch *(decimals of an inch)*. Then divide the known distance by the measured distance to calculate the number of units per inch.

Known Distance ÷ Measured Distance = Units per inch

For example, one property boundary on a plat is labeled 100'. Using the engineer's scale, it measures 1.2 inches. 100 ÷ 1.2 = 83.3. This means that this plat has a scale of 1" = 83.3'. Clearly, the map has been distorted during reproduction and may require adjusting with the copy machine. This can be a handy way to scale distances while in the field with a plat that is no longer a standard scale.

Aerial Photography

Photographs of the Earth's surface are taken from aircraft and satellites. These photographs show ground features present at the time the photograph was captured. Many county GIS systems now utilize these photos as the map base for their tax maps. These maps can be extremely useful when plats are not available. There are different kinds of aerial photographs. A few examples are discussed below.

Figure: 5-10. True-color aerial photo in Spotsylvania. Can you determine what is the land use? *(Goggle Earth)*

Orthophotos are aerial photographs which have been geometrically "corrected" so as to be usable as a map. In other words, an orthophoto is a simulation of a photograph taken from an infinite distance, looking straight down. It corrects for the curviture of the Earth and other deformations. Remember, the Earth is spherical and it is not flat; maps are. Orthophotos correct for this.

Color infrared photography assigns colors to reflected heat. The visible spectrum is not shown, but the reflected heat is displayed. For instance, water may be dark blue or black because it absorbs heat. Pine trees may be red because they reflect heat. This is an indication of the released heat from the object. These photographs may be more revealing for certain uses.

When using an aerial photograph for a construction drawing, care must be taken to account for shadows, descrepancies due to relief of the landscape and curvature of the Earth. However, they can be of great benefit when showing many small details that are too numerous to triangulate.

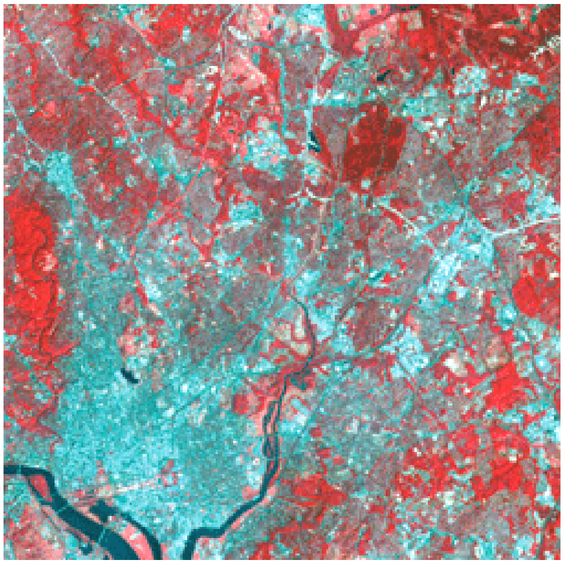


Figure: 5-11. False-color infrared of Washington DC. Man-made surfaces absorb heat (light blue) while vegetative surfaces reflect heat (red). The Potomac River absorbs most of the heat it receives (dark blue). *(NASA)*

Most photographs are taken in the winter. Therefore, dark-colored trees are usually coniferous whereas, light colored are deciduous. Eroded fields may appear reddish or tan (light colors) whereas, pastured fields are darker.

These photographs may be helpful in determining past land uses. A landowner requested a Safe, Adequate and Proper evaluation for connection to an existing sewerage system. The EHS reviewed old aerial photograhy on the county GIS only to discover the area had recently been wooded. Upon further questioning, the applicant confessed the drainfield was installed recently without a permit.

Stereophotography is a method of photography in which the photographs are taken from different positions. When using this method, two photos shot from slightly different angles are superimposed on one another. With the use of a stereoscope, the Earth's surface may be viewed in three-dimensions enabling the viewer to see different landscapes. This has been the common method for making soil maps since the early part of the last century.

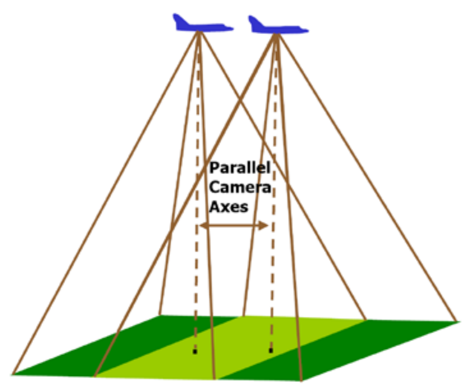


Figure: 5-12. Stereo pairs enable 3-D visualization of the Earth's surface. *(TS)*

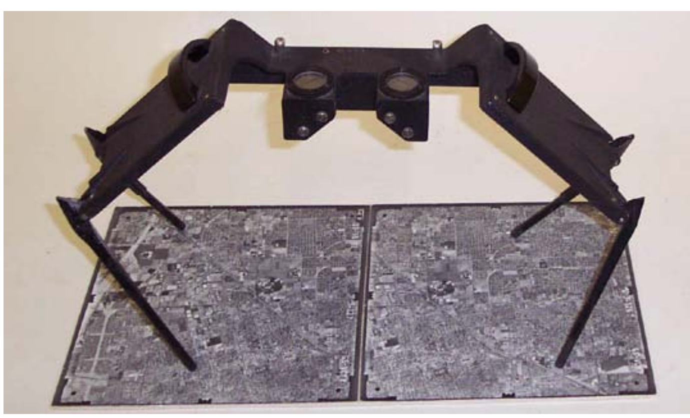
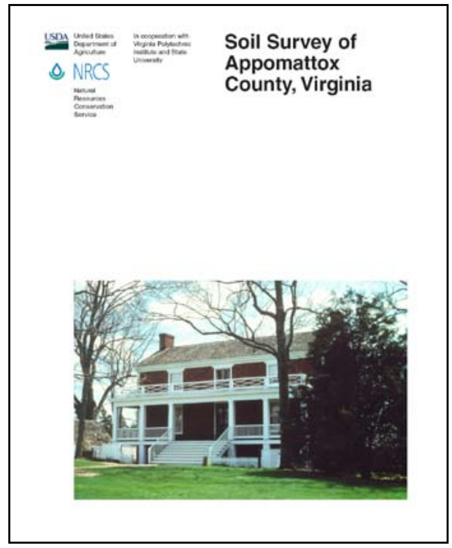


Figure: 5-13. A stereoscope allows the viewer to see stereo pairs in three-dimensions. The lenses enable the eyes to superimpose the images together into one view. *(USGS)*

Soil Surveys



Soil Surveys are a systematic approach to recording and mapping soils and landscape features in a particular area. In Virginia, this area is a county. Soil surveys contain information that would be helpful in land use planning in survey areas. They include predictions of soil behavior for selected land uses. The surveys highlight soil limitations, improvements needed to overcome the limitations, and the impact of selected land uses on the environment. The use of a soil survey prior to visiting a site or to answer questions after a site visit may be very helpful. While not accurate to a degree that can be used to design drainfields, the soil survey map can help the site evaluator determine the "norm" for the area. The Natural Resource Conservation Service (NRCS) is responsible for soil mapping in the United States. Information and online Soil Surveys are available at: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm.

Soil surveys are designed for many different users. Farmers, foresters, and agronomists can use the surveys to evaluate the potential of the soil and the management needed for maximum food and fiber production. Planners, community officials, engineers, developers, builders, and home buyers can use the surveys to plan land use, select sites for construction, and identify special practices needed to ensure proper performance.

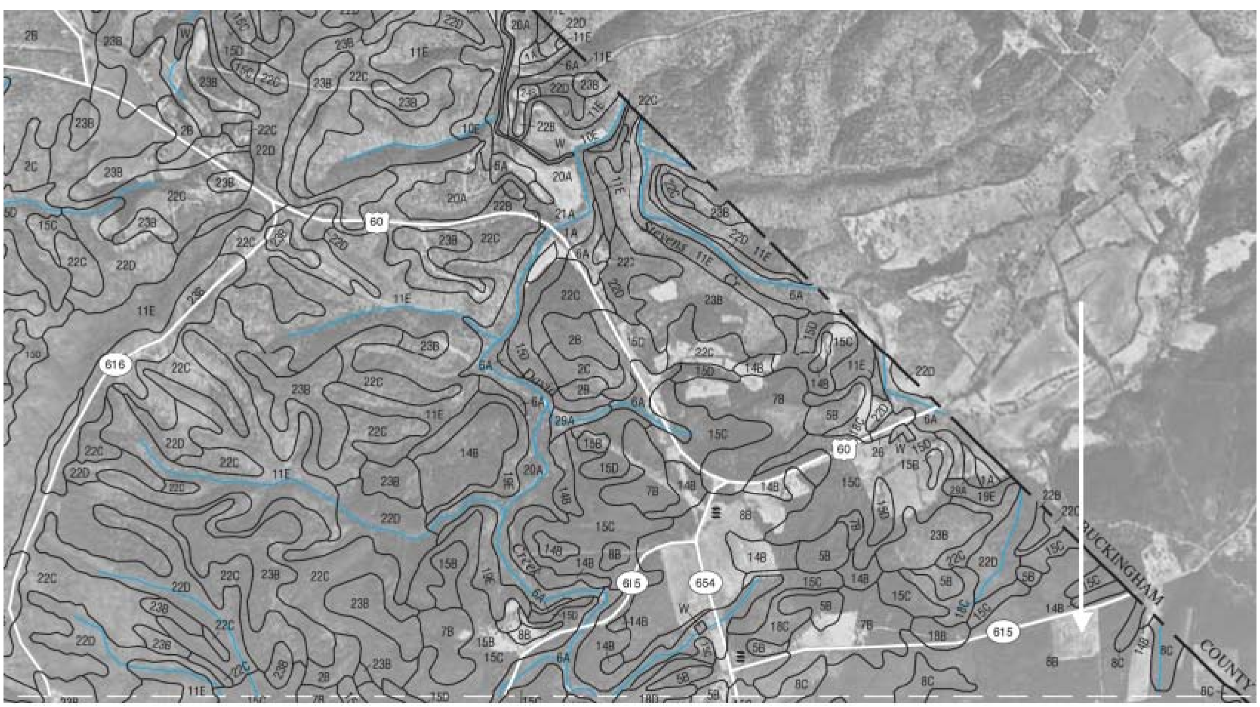


Figure: 5-14. This is a segment of a soil map taken from the *Soil Survey of Appomattox County*. Each mapping unit is delineated with a symbol inside. This symbol is the name of the mapping unit. Streams are in blue on this map. The map is shown on an aerial photograph map base. Notice there are no soil lines across the county line in Buckingham. *Notice mapping unit 8B on the bottom right hand corner, what might the properties of this soil be as it relates drainfield siting?*

Conservationists, teachers, students, and specialists in recreation, wildlife management, waste disposal, and pollution control can use the surveys to help them understand, protect, and enhance the environment. The information in a soil survey is intended to identify soil properties that are used in making various land use or land treatment decisions. Soil Surveys are not site-specific and cannot be substituted for a detailed onsite soil evaluation.

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Many soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited for basements or underground installations. These and many other soil properties that affect land use are described in soil surveys. The location of each soil is shown on detailed soil maps. Each soil in the survey area is described, and information on specific uses is given.

Limitations listed in soil survey tables do not necessarily represent characteristics of soils consistent with the *Sewage Handling and Disposal Regulations*. In other words, the criteria utilized to rate soils for septic systems in soil surveys is different than what is used in the Sewage handing and Disposal Regulations. Therefore, it is best to learn the soil names in your area and to become familiar with their characteristics and how they relate to onsite wastewater designs.

SYMBOL	NAME
1A	Altavista loam, 0 to 2 percent slopes, occasionally flooded
2B	Appomattox-Cullen complex, 2 to 7 percent slopes
2C	Appomattox-Cullen complex, 7 to 15 percent slopes
3A	Batteau loam, 0 to 2 percent slopes, frequently flooded
4B	Beckham clay loam, 2 to 7 percent slopes
4C	Beckham clay loam, 7 to 15 percent slopes
4D	Beckham clay loam, 15 to 25 percent slopes
5B	Cecil sandy loam, 2 to 7 percent slopes
6A	Chewacla loam, 0 to 2 percent slopes, frequently flooded
7B	Cullen clay loam, 2 to 7 percent slopes
8B	Iredell loam, 2 to 7 percent slopes
8C	Iredell loam, 7 to 15 percent slopes

Figure: 5-15. Excerpt from the soils legend of the *Soil Survey of Appomattox County.* There are 24 Soil Series and 51 Mapping Units in this particular soil survey.
See 8B description on the next page.

Each soil is classified through a classifications system called Soil Taxonomy. This begins with large groupings and eventually narrows down to what is called a Soil Series. Soil Series are often named for areas in which that particular soil was first encountered and described. There are many characteristics that separate different soils series. Many are the same types of properties that onsite soil evaluators use when determining the suitability of a site for a wastewater disposal system. Examples are depth to rock, soil color, depth to water table, texture, mineralogy, soil chemistry, and many more. Once an evaluator is familiar with an area, the properties that are used to separate soils into soil series become evident. Soil series have ranges of characteristics. For instance, the texture of the Bt horizon in a specific soil series may be a clay, clay loam or silty clay loam. The color allowed may range form 5YR to 2.5YR. The depth to bedrock allowed may range from 40-60 inches. Usually, a major separating factor is the parent material. A soil series derived from a transported parent material would be different than one weathered from residuum. Knowing the soil series helps in communication to others and also helps one to understand the expected or natural variability of an area. Look through the tables on the following pages from a soil survey and determine how many listed soil characteristics would influence a site evaluation in this soil.

From the *Soil Survey of Appomattox County*
Mapping Unit Description:

8B—Iredell loam, 2 to 7 percent slopes (B)

Setting

Major land resource area: Southern Piedmont (MLRA 136)
Landform: Hillslopes
Position on the landform: Interfluves

Map Unit Composition

Iredell and similar soils: Typically 90 percent, ranging from about 85 to 95 percent

Typical Profile *(Abbreviated)*

Surface layer:
0 to 5 inches—dark yellowish brown loam
Subsoil:
5 to 23 inches—yellowish brown clay
Substratum:
23 to 43 inches—yellowish brown, very pale brown, and dark olive gray silt loam
Soft bedrock:
43 to 63 inches—dark olive gray, yellowish brown, and very pale brown schist bedrock
Hard bedrock:
63 to 73 inches—schist bedrock

Minor Components

Dissimilar components:
• Cullen soils, which are well drained and in landscape positions similar to those of the Iredell soil
• Louisburg soils, which are well drained to excessively drained and are in landscape positions similar to those of the Iredell soil
• Mecklenburg soils, which are well drained and in landscape positions similar to those of the Iredell soil
• Poindexter soils, which are well drained and on backslopes
• Wedowee soils, which are well drained and in landscape positions similar to those of the Iredell soil
Similar components:
• Soils that are moderately deep to weathered bedrock and are in landscape positions similar to those of the Iredell soil

Soil Properties and Qualities

Available water capacity: Moderate (about 6.9 inches)
Slowest saturated hydraulic conductivity: Low (about 0.00 in/hr)
Depth class: Deep (40 to 60 inches)
Depth to root-restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Moderately well drained
Depth to seasonal water saturation: About 1.0 foot to 2.0 feet
Water table kind: Perched
Flooding hazard: None
Ponding hazard: None
Shrink-swell potential: Very high
Runoff class: Very high
Surface fragments: None
Parent material: Residuum weathered from igneous and metamorphic rock

Use and Management Considerations

Cropland

Suitability: Moderately suited to grass-legume hay; poorly suited to corn, soybeans, and wheat; not suited to alfalfa hay and tobacco
• The rate of surface runoff, the erosion hazard, and the amount of nutrient loss are increased because of the slope.
• The high clay content restricts the rooting depth of crops.
• The seasonal high water table restricts equipment operation, decreases the viability of crops, and interferes with the planting and harvesting of crops.

8B—Iredell loam, continued

Pasture
Suitability: Moderately suited to pasture
• The hazard of erosion, the rate of surface runoff, and the amount of nutrient loss are increased because of the slope.
Woodland
Suitability: Poorly suited to loblolly pine
• Proper planning for timber harvesting is essential in order to minimize the potential negative impact to soil and water quality. A timber harvest plan should include general adherence to all applicable best management practices.
• Soil wetness may limit the use of log trucks.
• The slope may restrict the use of some mechanical planting equipment.
• The low strength of the soil interferes with the construction of haul roads and log landings.
• The low strength of the soil may create unsafe conditions for log trucks.
• The stickiness of the soil increases the difficulty of constructing haul roads and log landings when the soil is wet.
• The stickiness of the soil reduces the efficiency of mechanical planting equipment.
• The stickiness of the soil restricts the use of equipment for site preparation to the drier periods.
Building sites
• The seasonal high water table may restrict the period when excavations can be made.
• Shrinking and swelling of the soil may crack foundations and basement walls.
• The high content of clay in the subsurface layer increases the difficulty of digging, filling, and compacting the soil material in shallow excavations.
Septic tank absorption fields
• The seasonal high water table greatly limits the absorption and proper treatment of the effluent from conventional septic systems.
• Slow water movement limits the absorption and proper treatment of the effluent from conventional septic systems.
Local roads and streets
• The seasonal high water table affects the ease of excavation and grading and reduces the bearing capacity of the soil.
• Shrinking and swelling restrict the use of the soil as base material for local roads and streets.
• The low strength of the soil is unfavorable for supporting heavy loads.

Interpretive Groups
Prime farmland: Not prime farmland
Land capability class: 2e
Virginia soil management group: KK
Hydric soil: No

Iredell Series
Physiographic province: Southern Piedmont
Landform: Hillslopes
Parent material: Residuum weathered from igneous and metamorphic rock
Drainage class: Moderately well drained
Slowest saturated hydraulic conductivity: Low
Depth class: Deep
Slope range: 2 to 15 percent

Associated Soils
• Louisburg soils, which have a shallower solum than the Iredell soils and are in similar landscape positions
• Mecklenburg soils, which have a subsoil that is redder than that of the Iredell soils and are in similar landscape positions
• Poindexter soils, which have a solum that is shallower than that of the Iredell soils and are in similar landscape positions

Taxonomic Classification
Fine, mixed, active, thermic Oxyaquic Vertic Hapludalfs

Typical Pedon

Iredell loam, 2 to 7 percent slopes; located in an area of pasture, about 833 yards east-southeast (97 degrees) of the junction of Highways VA-604 and VA-727 and 1.6 miles east-northeast (59 degrees) of the junction of Highways VA-679 and VA-604.

Ap—0 to 5 inches; dark yellowish brown (10YR 4/4) loam; moderate fine subangular blocky structure; friable, slightly sticky, slightly plastic; many fine and medium roots; 5 percent angular quartz gravel and 5 percent angular schist channers; strongly acid; gradual smooth boundary.

Btss—5 to 23 inches; yellowish brown (10YR 5/6) clay; moderate medium prismatic structure parting to moderate medium and coarse angular blocky; very firm, very sticky, very plastic; many fine, medium, and coarse roots; common distinct slickensides (pedogenic) and common prominent clay films on all faces of peds; slightly acid; clear smooth boundary.

C—23 to 43 inches; yellowish brown (10YR 5/6), very pale brown (10YR 8/3), and dark olive gray (5Y 3/2) silt loam; massive; friable, moderately sticky, slightly plastic; few fine and medium roots; neutral; clear smooth boundary.

Cr—43 to 63 inches; dark olive gray (5Y 3/2), yellowish brown (10YR 5/6), and very pale brown (10YR 8/3) slightly weathered chloritic schist bedrock.

R—63 to 73 inches; hard chloritic schist bedrock.

Range in Characteristics

Solum thickness: 20 to 40 inches
Depth to soft bedrock: 40 inches or more
Depth to hard bedrock: 60 inches or more
Rock fragments: 0 to 15 percent in the Ap and Bt horizons; 0 to 10 percent in the C horizon
Reaction: Strongly acid to neutral in the A and Ap horizons; moderately acid to slightly alkaline in the Bt horizon; neutral to moderately alkaline in the C horizon

A horizon (where present):
- Hue—10YR to 5Y
- Value—4 or 5
- Chroma—2 to 4
- Texture—loam

Ap horizon:
- Hue—10YR to 5Y
- Value—4 or 5
- Chroma—2 to 4
- Texture—loam

Btss horizon:
- Hue—10YR or 2.5Y
- Value—4 or 5
- Chroma—3 to 6
- Texture—silty clay or clay

C horizon:
- Hue—10YR to 5Y; or neutral in hue and has value of 4 to 8
- Value—4 to 8
- Chroma—1 to 8
- Texture—sandy loam, silt loam, loam, or sandy clay loam

Cr horizon (where present):
- Hue—10YR to 5Y; or neutral in hue and has value of 4 to 8
- Value—4 to 8
- Chroma—1 to 8
- Texture—weathered mafic rocks that crush easily to sandy loam, sandy clay loam, silt loam, or loam Note: Some pedons of the Iredell soils in Appomattox County have more clay in the Bt horizon than is allowed in the range of characteristics for the series. This difference, however, does not significantly affect the use and management of the soils.

From the *Soil Survey of Appomattox County*

Figure 10.—A profile of an Iredell soil. These moderately well drained, deep soils are derived from mafic rock and occur on hillslopes. Wetness and the shrink-swell potential are limitations in areas of the Iredell soils.

Documentation at the Site

Suggested Equipment

- Auger *(not a screw auger)*
- Calculator
- Clinometer *(A device to determine grade)*
- Clipboard
- Compass
- Level, Theodolites
- GPS
- Color book
- Water bottle
- Field book for describing soils
- Flagging
- Stakes
- Measuring wheel
- String lines
- Soil knife
- Tape measures
- Shovel
- Camera

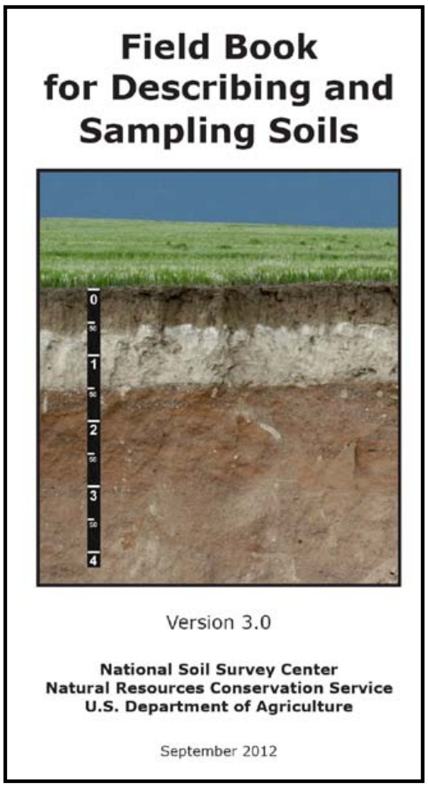


Figure: 5-16. The most comprehensive field guide available.

Figure: 5-17. Equipment used during site evaluations. *(TS)*

Surface Characterization

Surface characterization should include the identification and documentation of all existing and proposed features that may impact the ability of a site, or portion thereof, to support a subsurface soil absorption system. The following features should be documented over the entire area available for evaluation unless a specific system or area is proposed or identified:

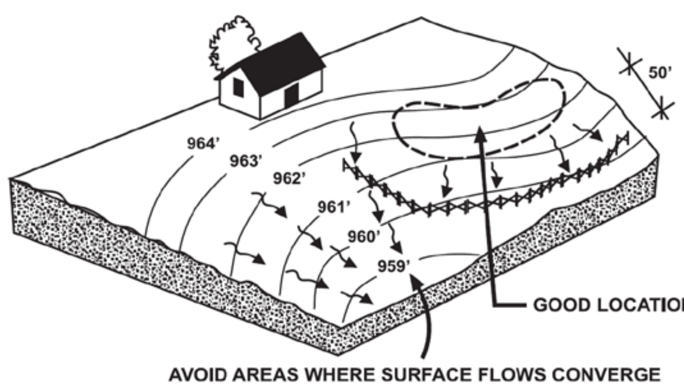


Figure: 5-18. General considerations for drainfield site location on a slope. *(EPA)*

Water Features	Landscape Features
Water supply sources within 200 feet of a proposed system and structure it serves *Water lines* *Wells* *Cisterns* *Springs* *Reservoirs* *Other water sources used for animal or human consumption* *Water bodies within 200 feet of a proposed system and structure it serves* *Storm water management facilities* *Streams (intermittent and perennial)* *Lakes* *Rivers* *Shellfish waters* *Evidence of surface ponding within 200 feet of the proposed system and structure it serves* *Other water bodies*	*Marshes* *Swamps* *Probable wetlands within 200 feet of a proposed system and structure it serves* *Rock outcrops within 50 feet of a proposed system and structure it serves* *Percent slope over the proposed system or area. Multiple values and corresponding locations shall be reported for single systems proposed on two or more different slopes.* *Landscape Features within 100 feet of the proposed system and structure it serves* *Type of landforms described later in this chapter* *Excessively steep slopes and/or abrupt slope changes* *Concave slope shapes* *Depressions* *Sink holes (includes the center and outer boundary)* *Flood plains* *Gullies, rills, and other erosional features* *Other landscape features identified as limiting factors for design or placement of subsurface soil absorption systems*
Man-Made Features	**Vegetation**
Physical improvements within 100 feet of the proposed system and structure it serves *Structures* *Building foundations* *Utility lines (underground and overhead)* *Agricultural drainage tile* *Drainage ditches* *Cuts or embankments* *Disturbed, compacted, or filled soil areas* *Existing subsurface soil absorption systems and associated components* *Other physical improvements identified as limiting factors for design or placement of subsurface soil absorption systems* *Current land use and management within 100 feet of the proposed system and structure it serves*	*General category of vegetation (forest, agricultural field, etc.)* *Type of vegetation present (hydrophilic or hydrophobic)* *Size of vegetation (i.e., old growth vs. newly planted trees)*

12 VAC 5-610-470. Physical features.

A. Physical features including soil features, slope, depth of rock, the location of rock outcrops, drainage ways, marshes, swamps, sink holes, flood plains, artificial drainage systems, and various structures and topographic features found in Tables 4.1 through 4.4 shall be fully and accurately documented in writing as part of the site and soil evaluation.

Landforms and Landscapes

The Virginia Sewage and Handling and Disposal Regulations (2000) require that any onsite wastewater system be installed in a suitable landscape position. The Yes or No determination relies upon the evaluator to make a decision on whether any onsite system will be negatively impacted by placing the system in or on a landform that is considered unsuitable. According to the Regulations, unsuitable landforms may include: Marshes and Swamps, Steep Slopes, Drainageways, Fill Material, Sink Holes, Flood Plains, and Alluvial and Colluvial deposits.

In Chapter 2, you will find Guidance and Best Management Practices for terms, definitions, and concepts that can be used in describing and documenting the physical earth. These are the settings, likely found in Virginia that an onsite wastewater system will be placed on or in.

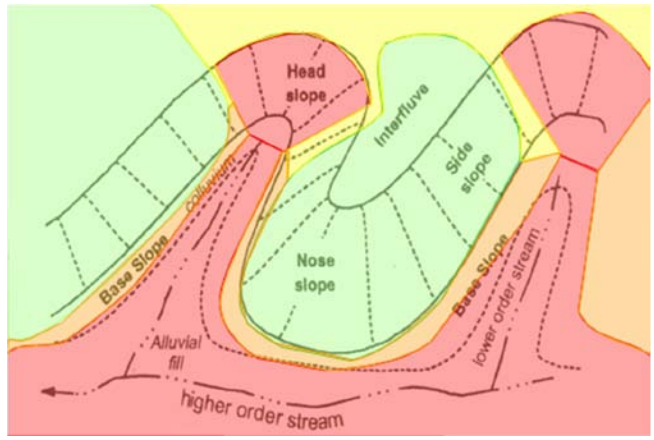


Figure: 5-19. Suitability of geomorphic component for subsurface soil absorption systems. *(NCSU, David Lindbo)*

The areas in shaded in red on these diagrams are not landscapes that would be considered for drainfield location due to propensity to collect water. Areas shaded in dark green characteristically disperse surface water and are well suited for drainfield sites. Areas in yellow may require additional design considerations to be used. Orange-shaded areas are marginally suited for onsite wastewater disposal.

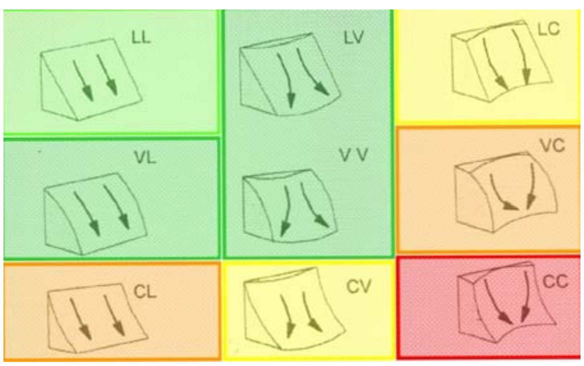


Figure: 5-20. Suitability of slope shape for subsurface soil absorption systems. Red is unsuitable. L= linear, V = Convex, C = Concave *(NCSU, David Lindbo)*

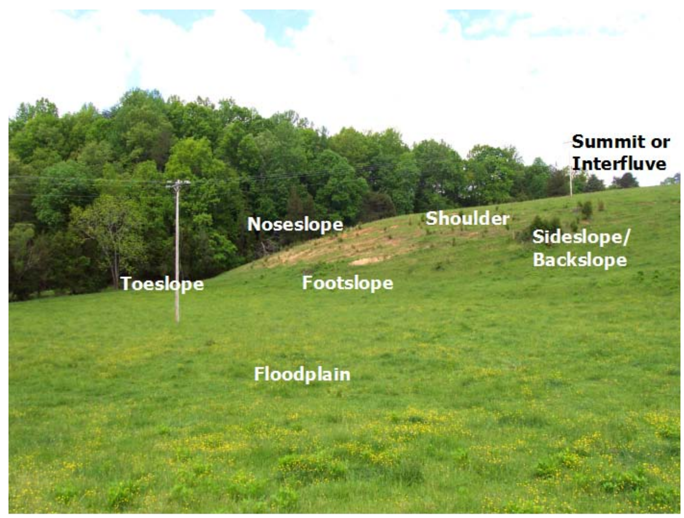


Figure: 5-21. Lower landscapes collect water, whereas higher convex landscapes disperse water. *(Photo by Tom Saxton)*

Slope

Slope gradient is a primary factor in determining drainfield trench bottom depth in the Regulations. Simply stated, the steeper the slope the deeper the drainfield. Best management practice in the field is to measure the slope gradient before any soil evaluations are conducted and then determine what the minimum drainfield trench bottom depth should be.

12 VAC 5-610-593. Physical features.
3. **Slope**. Subsurface soil absorption trench systems shall not be placed on slopes greater than 50% unless terraced. Criteria for other types of onsite systems are contained in Tables 4.3 and 4.4. or impervious strata (See Tables 4.3 and 4.4 of this chapter).

To determine minimum trench bottom depth for an in-ground system on slopes greater than 9%, the following formula may be used:

$$\text{Minimum depth } (x) = \{(\text{slope} - 8)/2\} + 18 \text{ inches}$$

To determine minimum trench bottom depth for a shallow placed system on slopes greater than 9%, the following formula may be used:

$$\text{Minimum depth } (x) = \{(\text{slope} - 8)/2\} + 12 \text{ inches}$$

12 VAC 5-610-950. Absorption area design.
F. ***Lateral separation of absorption trenches***. The absorption trenches shall be separated by a center to center distance no less than three times the width of the trench for slopes up to 10%. However, where trench bottoms are two feet or more above rock, pans and impervious strata, the absorption trenches shall be separated by a center to center distance no less than three times the width of the trench for slopes up to 20%. The minimum horizontal separation distance shall be increased by one foot for every 10% increase in slope. In no case shall the center to center distance be less than 30 inches.

Slope length exerts control over surface water runoff and potential accelerated water erosion and accompanying sediment deposition. The rate and direction of wastewater movement will also be affected by slope length, though the most overt role slope length will play in the onsite wastewater program is to affect the configuration and dimension of a drainfield.

Slope aspect is the direction toward which the land surface faces. Direction is expressed as an angle between 0 degrees and 360 degrees. Slope aspect has an important affect on soil development, soil temperature and moisture, but essentially plays no role in ultimate regulatory drainfield site suitability. However, aspect should be a design consideration on north-facing slopes, especially in mountainous regions. Larger footprints may be advisable to overcome the naturally more moist conditions. Dark thick organic-rich surfaces are also an indication of this characteristic.

12 VAC 5-610-470. Physical features.
C. Profile holes.
4. *Number and location of profile holes*. A minimum of five holes is necessary to determine the design requirements of an area for the placement of absorption trenches. Where there is uniform topography and the profile holes exhibit a uniform profile, a minimum of three holes is necessary. The size of the area investigated shall be based on the soil texture group encountered. As a minimum, holes shall be placed to be representative of the area under consideration for placement of the absorption trenches.

Number of sampling points

The number of sampling points evaluated should be sufficient to accurately characterize the depth(s) and extent of all limiting conditions as well as identify any variability in subsurface conditions that may impact the operation or performance of a subsurface soil absorption system.

If more than one area is required to achieve the required square footage for a system, each area should be evaluated with a minimum of five sampling points. Repair areas that are contiguous with the proposed installation area are not considered separate areas for the purpose of determining the number of sampling points.

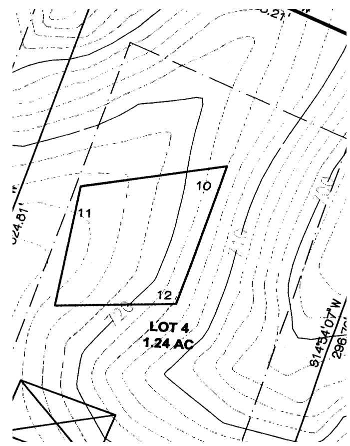


Figure: 5-22. This complex landscape is clearly not represented with sampling points. How many landscape components do you see within the proposed footprint?

In situations where a large area is proposed or utilized, additional sampling points are typically required. The number of sampling points to be investigated will be determined on a case-by-case basis. The number of sampling points should be large enough to provide a reasonable assurance that the full range of variability typically encountered in similar soil and site conditions can be observed and described.

Sampling point location

Sampling points should be located in the area or areas foreseen to be the most likely to support the proposed system. This is typically the area or areas determined to be the most favorable for placement of a subsurface soil absorption system based on the information discerned from the preliminary documentation and surface characterization procedures.

Sampling points should be located as close as practical to the probable center and probable corners of the subsurface soil absorption system.

The location of sampling points should be sufficient to provide a reasonable assurance that the full range of variability typically encountered in similar soil and site conditions can be observed and described.

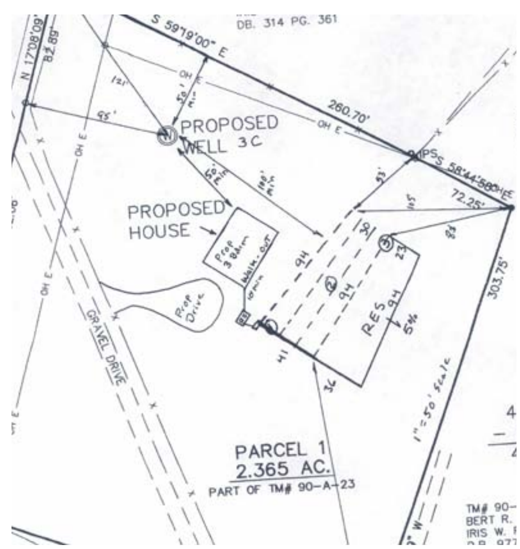


Figure: 5-23. There are no borings located in this reserve area. The borings are in a straight line. Geologic features often follow straight lines, which could lead to incorrect assumptions and design decisions. Do you see other issues?

Additional sampling point locations may be required if subsurface conditions are discovered during the initial subsurface characterization process that negatively impact the planned placement of a subsurface soil absorption system.

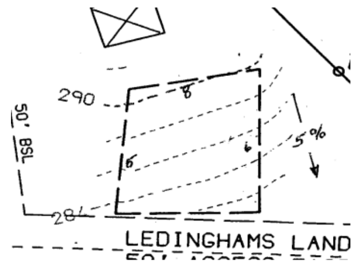


Figure: 5-24. Insufficient number of borings and poor placement leaves nearly 40% of this proposed drainfield undocumented. Is this Drainfield on contour?

When test pits are used to facilitate the evaluation, they should be constructed in locations and orientations that minimize soil disturbance within the absorption area while still providing an accurate representation of the subsurface conditions within the proposed site. When possible, pits should be constructed on contour to minimize “short circuiting” of future absorption trenches. In this scenario, the evaluation pit could connect two absorption trenches, thereby allowing wastewater to flow from the upslope trench into the downhill trench. This would increase the hydraulic load and result in premature failure of the lower trench.

In situations where a large area is to be characterized, the location of sampling points should be determined on a case-by-case basis. The location of sampling points must be sufficiently diverse to provide a reasonable assurance that the full range of variability typically encountered in similar soil and site conditions can be observed and described.

Subsurface Characterization

Subsurface characterization should include the identification and documentation of all subsurface features that may impact the ability of a site to support a subsurface soil absorption system.

Depth of sampling points

All sampling points should be excavated and described to a depth that is sufficient to determine that the minimum vertical separation distance is achieved between the lower limit of the proposed system and all limiting features in the soil. Evaluations to deeper depths should be made if supporting information related to site suitability can be obtained from observations through or into a limiting feature.

Figure: 5-25. Excavating safety standards must be observed when utilizing test pits for sampling points. Pits may cave in; great caution must be employed during pit evaluations.
(Photo by C. M. Allison, Jr., OSE)

A minimum evaluation depth of 5’ feet is required in soils that exhibit no limiting features within 5 feet of the ground surface. The minimum observation depth can be reduced when auger refusal (you are unable to continue the boring due to rock fragments, roots, etc.) makes deeper excavations impractical. If this occurs, the depth of refusal is considered to be a restriction when determining vertical separation distances unless an additional documented sampling point (or points) within a close proximity to the area of refusal verifies that the refusal is not evidence of a limiting feature.

> **12 VAC 5-610-470. Physical features.**
> C. Profile holes.
> 3. ***Depth of profile hole***. The minimum depth of the profile hole shall be five feet unless prevented or made unnecessary by some physical feature of the soil such as gray coloration, rock or when a potential horizon is found at a lesser depth. Where a potential soil horizon is considered for use, the soil evaluation shall be extended below the potential horizon to assure that there is no interference with seasonal water table, rock or impervious strata (See Tables 4.3 and 4.4 of this chapter).

Soil Descriptions and Site Documentation

A soil profile description is a narrative photograph of a soil. Anyone with soil knowledge should be able to understand the characteristics of a soil once they have reviewed the soil profile description. If the reviewer looks at a soil description and cannot determine why the site is suitable or not suitable for a conventional sewerage system, the description is clearly inadequate.

Onsite wastewater disposal site evaluations and soil profile descriptions should be sufficient to describe the basic characteristics of the site and the soil. Characteristics that may indicate how water will move over and through the soil are especially important. Examples of these are: landscape position, drainageways, redoximorphic features, texture, structure, parent material, and consistence. Other soil features may be important on a case-by-case basis. For example, if roots are discovered to be growing horizontally (in a pit), then a detailed description of this is very important because it may indicate a restriction or restrictive horizon. If an old roadbed bisects the proposed footprint of the drainfield, this may affect surface water movement and should be considered.

Figure: 5-26. Examples of items important to document during a site evaluation; soil colors, landscape, landscape features (drainageway) and roots that have a growth pattern indicative of a soil related issue. *(Photos by Tom Saxton)*

Soil evaluations by Pit vs. Auger borings

Some characteristics are nearly impossible to interpret with an auger. This is especially true for soil structure. However, platy structure may be identified during boring when the soil is dry because of the way the soil augers, or how it feels. The size and grade of the plates are not definable, but the existence of the plates may be recognized and documented. It is appropriate to describe platy structure with an auger, but without the structure modifiers (i.e. strong, weak, medium, fine, etc.). When reviewing documentation that includes soil structure evaluated with an auger, it should be discounted.

Accurately identifying depth to paralithic (Cr) material is difficult using an auger in some cases. Certain soil landscapes may harbor *"floaters"* which is jargon for isolated rock fragments such as channers and stones that are isolated from the bedrock. These isolated rock fragments may seem to be bedrock (or Cr) when using an auger. In these areas, you may help your client by requesting a backhoe. If there is soil beneath the floater and it is disconnected from the parent bedrock, then it is considered to be a coarse fragment in the soil and is not limiting unless the percentage is high. When in doubt, call for a backhoe. Much more of the soil is visible in a pit. Again, construct the pit on contour.

Recording Soil Profile Data

Soil descriptions should be sufficiently detailed to characterize the water movement capacity of the soil. Too much is better than too little. See the soil profile description examples later in this section. A soil description form is helpful to remind the evaluator which characteristics should be recorded (see form at end of section).
It is inappropriate to use abbreviations in soil profile documentation unless they are conventional abbreviations used by the USDA. For example, c2D 2.5YR 4/6 mottles is common medium distinct 2.5YR mottles. These are defined abbreviations that have a specific meaning. See The NRCS *Field Book for Describing and Sampling Soils* and Chapter 4 in this document for approved abbreviations.

> *Soil descriptions should be completed following the guidelines set forth in the:*
> *Soil Survey Manual, U.S. Department of Agriculture Handbook 18 (most recent version)*
>
> *All observable soil features that relate to subsurface soil absorption system suitability should be described and reported. The minimum soil features that shall be described and reported in each sampling point include the following:*
>
> > *Master and transitional horizons with appropriate subordinate distinctions*
> > *Thickness of horizons*
> > *Moist color of matrix using the Munsell color chart designations*
> > *Moist color of mottles using the Munsell color chart designations*
> > *Abundance, size and contrast of mottles*
> > *Moist color of redoximorphic features using the Munsell color chart designations*
> > *Abundance, size and contrast of redoximorphic features*
> > *Texture*
> > *Consistence*
> > *Other observed soil features that may relate to suitability of soils for use in a subsurface soil absorption system*
>
> *Specific soil features shall be described using test pits when they play a paramount role in determining site suitability. These features include the following:*
>
> > *Soil structure by grade, size, and type*
> > *Volumetric percentage, size, and shape of rock fragments*
> > *Roots*
> > *Pores*

The parent material from which the soil was formed should be documented. If more than one parent material contributed to the soil formation, each one should be described. In cases where residuum is the parent material, the probable rock type (or types) should also be described. If the rock type is of a mafic character, it should be noted as such.

Clay mineralogy should be estimated or measured in soils that have textures described as clay, silty clay, or sandy clay within the sampling depth.

The depth to free water. This is the depth from which water may flow into the pit or auger boring. Allow, the auger boring to fill while working on the lot and record the final depth from the surface of the ground to the top of the water column.

The soil water state for all soil horizons when any portion of the soil profile approaches field capacity.

Unless the soil horizon has a major influence on water movement, multiple thin horizons should not be delineated. Normally, horizons are more than 4 inch thick. Prominent differences that occur, such as thin lenses or strata may be included within the narrative of the horizon in which they are found. For example, a two-inch thick Cr stratum within the C horizon could be described within the C horizon narrative as a 2 inch thick paralithic stratum from 42-44 inches.

Example Soil Profile Descriptions

The following soil descriptions are the same soil described at different levels of detail.

This is a profile taken from an NRCS Soil Series description. It is well written and thorough. There may be more information than is needed for a standard drainfield evaluation. Would this soil be suitable for a drainfield?

Oi	0-1 *(inches)*	Slightly decomposed oak, maple, and beech leaves, twigs and shortleaf pine needles
Oa	1-2 *(inches)*	Highly decomposed organic matter with rubbed fiber content approximately 10%
A	2-4 *(inches)*	Dark brown (7.5YR 3/3) sandy loam; few fine distinct yellowish red (5YR 5/8) mottles; moderate medium granular structure; friable; many very fine, fine and medium roots; strongly acid; clear wavy boundary.
E	4-9 *(inches)*	Light yellowish brown (10YR 6/4) sandy loam; weak coarse granular structure; friable; many very fine, fine and medium roots; strongly acid; abrupt smooth boundary.
B/E	9-13 *(inches)*	Reddish yellow (5YR 6/8) loam with common distinct pockets of yellowish brown (10YR 5/6) sandy loam; weak fine and medium subangular blocky structure in the B component of the horizon, and weak coarse granular structure in the E component of the horizon; friable; many fine and medium roots; strongly acid; abrupt smooth boundary.
Bt_1	13-23 *(inches)*	Red (2.5YR 4/6) clay; few fine faint red (2.5YR 4/8) and few fine faint (5YR 4/6) mottles; moderate fine and medium subangular structure; friable, slightly sticky, slightly plastic, common distinct yellowish red (5YR 5/6) clay films on faces of peds; common very fine tubular pores; common fine and medium roots; few fine and medium mica flakes; strongly acid; gradual wavy boundary.
Bt_2	23-31 *(inches)*	Red (2.5YR 4/6) clay; moderate fine, medium and coarse subangular blocky structure; firm slightly sticky, slightly plastic; common distinct yellowish red (5YR 5/6) clay films on faces of peds and in pores; common fine tubular pores; few fine and medium roots; common fine and medium mica flakes; moderately acid, clear wavy boundary.
Bt_3	31-46 *(inches)*	Red (2.5YR 4/6) clay loam; common medium prominent strong brown (7.5YR 5/6), few fine prominent reddish yellow (7.5YR 7/8), and common medium prominent black (10YR 2/1) lithochromic mottles;

		moderate fine and medium subangular blocky structure; friable, slightly sticky; few distinct yellowish red (5YR 5/6) clay films mostly on vertical faces of peds; few fine tubular pores; many fine and medium mica flakes; moderately acid; clear wavy boundary.
BC	46-55 *(inches)*	Red (2.5YR 4/6) clay loam; many medium prominent strong brown (7.5YR 5/6), common medium prominent reddish yellow (7.5YR 7/8), common medium distinct white (N9/), and common medium prominent black (10YR 2/1) lithochromic mottles; weak medium subangular blocky structure; friable; 5% angular quartz gravel and 5% weathered angular quartz monzanite augen gneiss fragments concentrated in the lower portion of the profile in seams dipping 35 degrees to the south; many fine and medium mica flakes; moderately acid; clear wavy boundary.
C_1	55-65 *(inches)*	Multicolored red (2.5YR 4/6), strong brown (7.5YR 5/6), reddish yellow (7.5YR 7/8), yellowish red (5YR 4/6), weak red (2.5YR 4/2), white (N8/), and black (10YR 2/1) loam saprolite; massive, friable; 5% quartz gravel in vertical seam and 5% slightly weathered angular quartz monzonite augen gneiss channers dipping 35 degrees to the south; many fine, medium, and coarse mica flakes; moderately acid, gradual wavy boundary.
C_2	65-72 *(inches)*	Multicolored red (2.5YR 4/6), strong brown (7.5YR 5/6), reddish yellow (7.5YR 7/8), yellowish red (5YR 4/6), weak red (2.5YR 4/2), white (N8/), and black (10YR 2/1) fine sandy loam saprolite; massive, friable; 5% quartz gravel in vertical seam and 10% slightly weathered angular quartz monzonite augen gneiss channers dipping 35 degrees to the south; many fine, medium, and coarse mica flakes; moderately acid.

This is a profile description used for a drainfield evaluation. Properties normally associated with water movement are described to a degree that allows the reader to understand the constraints imposed by this soil. Do you think this site was used?

A	2-4 *(inches)*	Dark brown (7.5YR 3/3) sandy loam; few fine distinct yellowish red (5YR 5/8) mottles; friable; many very fine, fine and medium roots.
E	4-9 *(inches)*	Light yellowish brown (10YR 6/4) sandy loam.
B/E	9-13 *(inches)*	Reddish yellow (5YR 6/8) loam with common distinct pockets of yellowish brown (10YR 5/6) sandy loam; friable.
Bt_1	13-23 *(inches)*	Red (2.5YR 4/6) clay; few fine faint red (2.5YR 4/8) and few fine faint (5YR 4/6) mottles in the upper part of the horizon; firm; common distinct yellowish red (5YR 5/6) clay films on faces of peds and in pores.
Bt_2	23-46 *(inches)*	Red (2.5YR 4/6) clay loam; common medium prominent strong brown (7.5YR 5/6), few fine prominent reddish yellow (7.5YR 7/8), and common medium prominent black (10YR 2/1) mottles; firm grading to friable in the lower part of the horizon; few distinct yellowish red (5YR 5/6) clay films.
BC	46-55 *(inches)*	Red (2.5YR 4/6) clay loam; many medium prominent strong brown (7.5YR 5/6), common medium prominent reddish yellow (7.5YR 7/8), common medium distinct white (N9/), and common medium prominent black (10YR 2/1) mottles; friable.
C_1	55-72 *(inches)*	Multicolored red (2.5YR 4/6), strong brown (7.5YR 5/6), yellowish red (5YR 4/6), weak red (2.5YR 4/2), white (N8/), and black (10YR 2/1) loam & fine sandy loam; friable.

This description was submitted with a permit package to the Health Department. It is clearly insufficient and should be suspect for accuracy. Would you feel confident installing a drainfield here?

Ap	0-46 *(inches)*	Brown loam
B	46-52 *(inches)*	Red silt loam
C	52-72 *(inches)*	Red loam

Time constraints and practicality may influence the degree of detail documented at a given site. However, under-documentation could be considered negligent. At a minimum, the reviewer must be clear about the soil properties and why the design was presented. If this information is not clear from the soil description, it has not been documented sufficiently.

Soil Limitations

Soil Description Sheet

Name:						Date:		Land Use:		
Location:						Slope:		Vegetation:		
								Soil Name:		
Layers		Estimate Drainage Conditions		Estimate Permeability						
Horizon	Depth (inches)	Dominant Color	Redox Features (Type, Quantity, Size, Contrast, Color)	Texture	Structure (Grade, Size, Type)	Consistence	Coarse Fragments	Boundary	Roots	Remarks
Nature of Limiting Condition: Depth to Limiting Condition:						Notes:				

Figure: 5-27. Typical profile description form. *(NRCS)*

All the definitions and concepts stated below provide guidance for determining whether a layer, horizon, or soil and rock materials in the soil will preclude the siting of a drainfield or help determine the appropriate standoff distance. The Regulations require that there be an 18-inch or 12-inch separation distance from drainfield trench bottom to a known bedrock or impervious layer. A soil restriction is somewhat more subjective and allows for some interpretation in the field on the degree or severity of a soil restriction.

Bedrock instead of "rock" is the preferred term and it infers that the material is totally dominated by high rock content and the properties of rock. Bedrock can be hard (R horizons) or weathered and relatively soft (Cr horizons). Bedrock can have two opposing effects on wastewater. First, if the bedrock is very coherent and solid with few fractures

Definitions:
Rock or Bedrock—*means continuous, coherent, lithologic material that has relative hardness depending on the degree of weathering. Bedrock has characteristics such as strike, dip, jointing, and Lithological compositions. Structure and water movement are rock controlled. Bedrock grinds with an auger, and mechanical penetration is more difficult or prevented as the material gets harder.*

12 VAC 5-610-490. Characteristics of soils that determine suitability.
D. **Soil restrictions**. A soil restriction is a feature in the soil that impedes the percolation of water. Restrictions generally consist of a layer of soil horizon within a soil that is firmly compacted or is very rich in clay. Soils containing restrictions may require verification of the percolation rate by percolation tests. Examples of restrictions are listed below.

12 VAC 5-610-593. Physical features.
10. **Soil restrictions**. Soil restrictions in themselves may form the basis for outright rejection of the site.

and joints, then wastewater can be prevented or severely limited from entering the soil, resulting in ponding of the wastewater. Or, if the bedrock is highly fractured and jointed, wastewater can rapidly move through the rock materials, resulting in minimal retention and treatment of the wastewater. Bedrock may contain a very small amount of soil materials in fractures and joints; however, soil content is insignificant and does not affect the features and properties of bedrock.

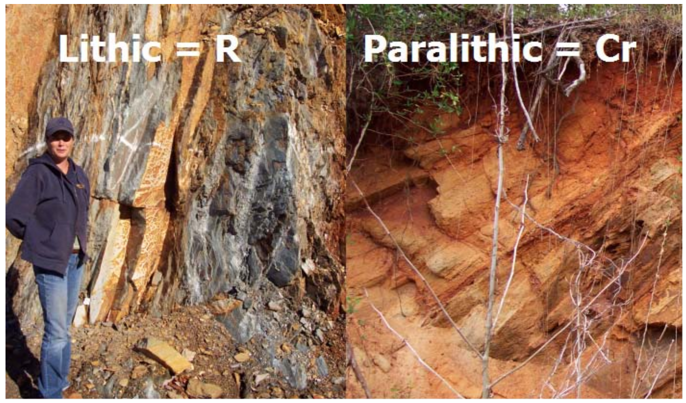


Figure: 5-28. Schist bedrock (R) versus weathered schist bedrock (Cr). *(Photos by Tom Saxton)*

Best management practices for documenting bedrock in the field are to identify the lithology of the bedrock (i.e. granite, limestone, etc); note whether the bedrock is tilted from the horizontal plane by estimating the incline in degrees, (i.e. tilted at 45 degrees); note the presence and relative abundance of bedrock fractures and joints; note whether the bedrock appears to be readily pervious to groundwater and wastewater based on abundance of fractures and joints, lack of soil materials "clogging" the fractures and joints, and lack or absence of redoximorphic features at the soil and bedrock interface.

Definitions:
Impervious Strata—*means soil or soil materials with an estimated or measured percolation rate in excess of 120 minutes per inch.*

Conversely, impervious or relatively impervious bedrock may be identified because it has no or minimal fractures and joints; the bedrock materials are "clogged" with soil materials that have redoximorphic features, especially chroma 2 or less iron depletions and red or yellowish red iron accumulations; there is a clay enriched build-up at the soil-bedrock interface that is caused by the stoppage of downward illuviation of clay materials suspended in percolating groundwater; or there is groundwater in a pit or auger hole that penetrates into a bedrock layer. In order to accurately assess bedrock characteristics, backhoe pits are commonly used in the Blue Ridge, Ridge and Valley, and Cumberland Plateau portions of the state.

Figure: 5-29. The presence of horizontally oriented roots may be an indication of a *restriction* or *restrictive* horizon. In this case, the roots follow the base of fill material. Do you see anything else of concern in this photo? *(Photo by Tom Saxton)*

Restrictive horizons contain soil materials that impede or slow the movement of groundwater, especially downward. This impedance or slowing may be because the soil materials are dense, compact, firm in place, somewhat cemented together, clay enriched, compacted by man related activities (such as plowing and using heavy machinery), or have poor structure (such as platy, prismatic, or massive). Noting these characteristics in the field provides a rationale for calling soil horizons or soil materials restrictive. It must also be noted that: all impervious horizons are restrictive, but not all restrictive horizons are impervious.

Some restrictive horizons may be used for a drainfield, but this depends on the severity of the restriction. In some cases, a percolation or K_{sat} test may be needed to determine if a restrictive horizon will adequately absorb and transmit water and ultimately wastewater.

Impervious horizons generally have field characteristics similar to restrictive horizons. Often, there may be numerous negative characteristics that lead one to conclude the horizon is impervious. For example, the horizon has a heavy clay texture, there are redoximorphic features present, and the soil structure is massive or prismatic. As with a restrictive horizon, an impervious horizon may require a percolation or K_{sat} test, assuming the only soil evaluation question left is whether the soil will take water at a suitable rate. However, if there is evidence of a perched water table, K_{sat} data is mute.

12 VAC 5-610-120. Definitions.
"Shrink-swell soils" means soils with horizons that contain montmorillonite and other clays that excessively shrink upon drying and swell upon wetting.

12 VAC 5-610-593. Physical features.
9. **Shrink-swell soils**. When soils containing horizons with shrink-swell characteristics (see definitions in 12 VAC 5-610-120) have been identified, they shall be ***rejected*** for use for subsurface soil absorption systems.

Shrink Swell Soils occur throughout Virginia and are a common problem in the building industry. These expansive soils can cause considerable more damage to structures and

Richmond Times-Dispatch

unday, February 2, 1992 | Richmond, Virginia 23293 | 142nd Year, No. 33 | ★—★ $1.2

Shrink-swell soils may lead to mortgage problems

Mark Holmberg
f writer

he shrink-swell soil that has snapped foundations in esterfield County now has broken a contract on a new ne, leaving the angry builder "holding the bag" and home buyers scrapping for their down payment.
n a highly unusual move, the national lending firm roved the mortgage for the new home built in tern Chesterfield County's shrink-swell soil basin — r to reject the loan a month later.
he approved loan was denied last fall after the spective home buyers, concerned about the soil un- their new house, paid for soil testing and sent the ettling results to the lender.
he tests found that the soil anchoring the home had

"It would be rather scary to think we couldn't trust the building inspection system."
— Mark S. Kittrell, Virginia Mortgage Bankers Association

a "critical" potential to shrink and swell with moisture changes — a situation known to have cracked foundations and tipped chimneys in the area. The engineer concluded that the foundation was not built to the state building code's provision for problem soil, effective since 1988.

Now Stan and Teresa Johnson, who were released from their contract with the builder by the loan denial, want their $2,000 down payment back, plus $2,900 they paid to have new carpet and lights installed.
But the builder, C. Richard Dobson, isn't sure they deserve it. He says they "panicked" over the highly

publicized shrink-swell soil, and convinced the mortg firm that the house was unfit collateral. While he adm the problem soil exists under the Woodlake home, says he has made changes to alleviate future problem
"Is it fair for them to get up and walk and leave holding the bag?" asks Dobson, who says he's built homes in the Woodlake area.
The ripples from what normally would be consider a minor contract dispute may have "opened a Pandor box," said Stanley M. Vickhouse, the president of Richmond Mortgage Bankers Association.
Vickhouse said this is the first time he has heard o mortgage lender denying a loan based on a potential but currently non-existent — structural problem

Continued on page 2, col. 3

Figure: 5-30. Shrink Swell Soils have considerations beyond wastewater.

highways than other natural disasters combined. Damage ranges from minor cracking in exterior walls to major displacement of the structure. Soils with estimated high shrink-swell potential range from the well-drained, red Frederick soils of the limestone valley in western Virginia to the poorly drained, gray Waxpool soils in northern Virginia and the clayey Peawick soils of the coastal plain. What properties do these disparate soils have in common that predisposes them to shrink-swell behavior? Research conducted by Dr. Pamela J. Thomas (VA Tech 1998) focused on this fundamental question. She discovered that several soil properties were correlated with predicted shrink-swell potential -- swelling 2:1 minerals (smectite and vermiculite), swell index, liquid limit, and CEC. Using absolute values of these four soil properties she developed an *Expansive Soil Index (ESI),* which assesses soils for shrink-swell risk. High *ESI* values indicate high shrink-swell soils. Her researches lead to greater understanding and subsequent building code requirements concerning these types of soils.

(Information courtesy of Dr. Pamela J. Thomas, 1998.)

Table 3.1. Classification and estimated shrink-swell potential of selected soil series.

Physiographic Province	Parent Material	Soil Series	Classification†	Shrink-Swell Potential‡
Valley and Ridge	limestone	Frederick	mixed, Typic Paleudult	high
		Carbo	mixed, Typic Hapludalf	very high
Piedmont	granite gneiss	Cecil	kaolinitic, Typic Kanhapludult	moderate
	hornblende gneiss	Iredell	smectitic, Typic Hapludalf	very high
Triassic Basins	diabase (diorite)	Jackland	smectitic, Aquic Hapludalf	very high
		Waxpool	smectitic, Aeric Ochraqualf	very high
		Davidson	kaolinitic, Rhodic Kandiudult	moderate
	thermal shale	Kelly	vermiculitic, Aquic Hapludalf	high
	sandstone/shale	Creedmoor	mixed, Aquic Hapludult	high
		Mayodan	mixed, Typic Hapludult	high
Coastal Plain	marine	Craven	mixed, Aquic Hapludult	moderate
	fluvial	Peawick	mixed, Aquic Hapludult	high

†All soils are in the fine family particle-size class (350 to 600 g kg^{-1} clay).
‡Soil Survey Staff. 1997. Map unit interpretation records database.

Figure: 5-32. Table of Shrink Swell Soil Series in Virginia from Pamela Thomas's 1998 PhD Thesis *Quantifying Properties and Variability of Expansive Soils in Selected Map Units,* VA Tech.

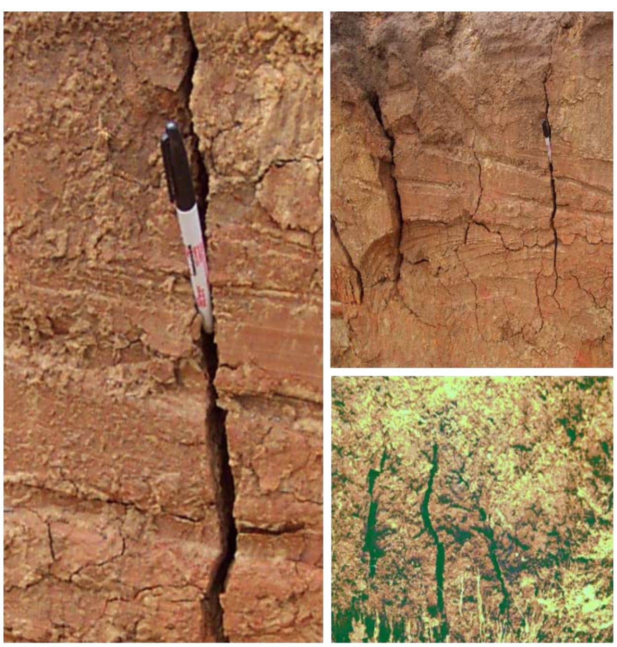


Figure: 5-33. Cracks are evidence that this soil has shrink-swell properties. *(Photos by Tom Saxton) (Lower right photo courtesy of Jay Conta)*

Figure: 5-31. Shrink Swell soils exert tremendous force against foundations. *(Photo by Tom Saxton)*

Water Table, Redoximorphic Features, and Free Water

Determining if a soil is wet is one of the most important standards in the onsite wastewater program. Soil wetness will have a profound effect on the ability of the soil to treat and dispose of wastewater in a safe and acceptable manner. And because most drainfields that are approved and installed receive minimal to no attention unless they malfunction hydraulically, it is vital to accurately document soil wetness in the initial soil/site evaluation process to insure long-term performance of the system.

> **12 VAC 5-610-470. Physical features.**
> D. Minimum depth to **seasonal water table**. As used herein, "seasonal water table" means that portion of the soil profile where a color change has occurred in the soil as a result of saturated soil conditions or where soil concretions have formed. Typical colors are gray mottlings, solid gray or black. The depth in the soil at which these conditions first occur is termed "seasonal water table."

Best management practice nationwide and generally worldwide now uses the term "redoximorphic features" instead of water table to refer to soil wetness. Redoximorphic features are defined as "soil properties associated with wetness that result from the reduction and oxidation of iron and manganese compounds in the soil after saturation with water and desaturation, respectively", (Glossary of Soil Science Terms, SSSA, 1996).

Free Water in the Soil is water that is at zero or positive pressure, not held or bound by soil tension, and is free to move with gradient and gravity. This is the groundwater that seeps into a freshly dug backhoe pit or auger hole. Free water in a pit or auger hole is one of the most difficult factors to interpret when all the other soil features meet the Regulations. Best management practices would include recording the level where free water is first encountered when boring a new hole; recording the final free water level upon conclusion of the site evaluation; and trying to tie free water level to some observable feature in the soil such as chroma 3 and 4 redox features, presence of manganese oxides, soil density and compaction, or the is soil located on a marginal landform such as a toeslope. One of the best field practices is to document the free water level in an auger hole today (informal water table study), and then return at least weekly for 3 to 4 weeks to document the level. The original holes can be used if they stay open,

> **12 VAC 5-610-593. Physical features.**
> 11. **Free standing water**. The presence of free standing water in a profile hole may be grounds for rejection of the site.

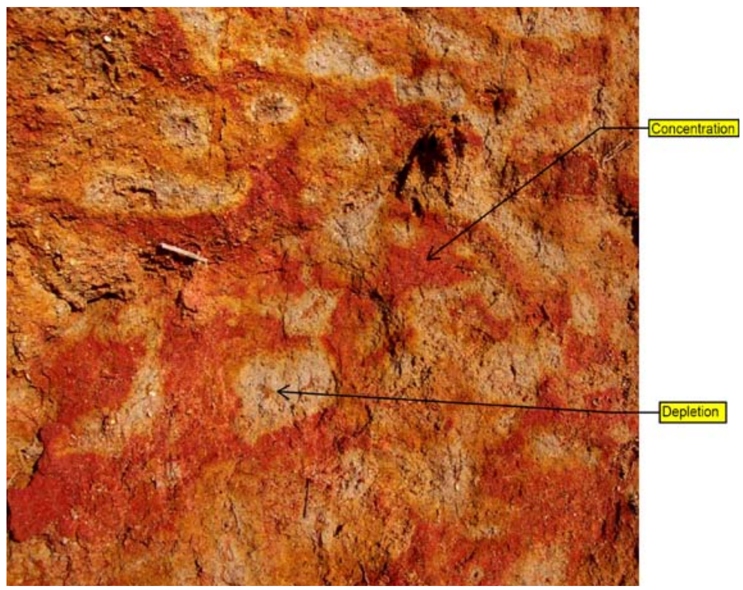


Figure 5-34. Redoximorphic Features *(Prince George County). (Photos by Tom Saxton)*

> **12 VAC 5-610-490. Characteristics of soils that determine suitability.** A.
> 2. Gray and/or gray mottlings indicate seasonal water tables for at least **three weeks duration**.

but if not, new holes can be dug each week and the free water level documented after a reasonable time has been spent at the site.

Oxyaquic Conditions is a soil wetness term that best describes soils that are periodically saturated for relative long durations, but do not develop or have significant redox features, especially chroma 2 or less iron depletions. Best management practice would include monitoring these soils with an informal water table study (described above) for at least 3 to 4 weeks duration. The criterion for oxyaquic conditions is the level in the soil within 40 inches of the ground surface that is saturated for 20 days consecutively or 30 days cumulatively.

Chroma 3 and 4 Depletions typically are small, splotchy zones of lighter colors where iron/manganese oxides have been stripped out. It is a given that chroma 3 and 4 redoximorphic features represent soil wetness. Long-term research has proven that chroma 2 or less redox features are indicative of soil conditions where there has been intensive saturation and reduction of iron and manganese. The presence of chroma 2 or less redox features strongly implies that all factors that go into the reduction-oxidation process have been highly functional and optimal. By the same token, chroma 3 and 4 redox features may represent soil conditions that are as wet as chroma 2 or less features; however, some of the factors that go into the redox process may be lacking or less than optimal. For example, the soil temperature may be too cold for effective microbial activity; soluble organic matter may be lacking or too low to fuel the reducing microbes; the soil is saturated but reducing conditions are thwarted or minimized by oxygenated groundwater; or the soil just isn't saturated long enough to form chroma 1 and 2 redox features. In any event, note the hue, value, and chroma of the chroma 3-4 features; note the relative abundance (few-less than 2% of surface area covered, common 2 to 20% surface area covered, and many-greater than 20% surface area covered).

Figure: 5-35. Chroma 3 & 4 depletions and red concentrations are indications of soil wetness. *(Photo by Gary Gilliam, EH Supervisor)*

Inherited Soil Colors some soils have dominant matrix colors that are inherited from the parent rock or material from which the soil develops. Examples are the reddish brown colors inherited from the Triassic red beds and the black-gray colors inherited from graphite schist. The reddish brown colors do not necessarily represent a soil that is highly well drained and oxidized; the black-gray colors do represent a soil that is wet and poorly drained. Best management practices are to inspect the soils carefully to look for any other redox features, such as iron segregation (bright) mottles in the graphite material and pinkish gray colors in the red bed materials. In addition, because redox features may be masked in soils that inherit their colors from the parent rock, it is a must to locate any drainfield on a suitable upland landform. Footslope and toeslope landforms may be wetter than soil conditions would imply.

Relict Soil Features are soil features that formed under long-ago wetness regimes of saturation and reduction, but are not wet under present day circumstances. Relict features commonly formed on landscapes that were at one time relatively flat. During geologic and geomorphic dissection and down cutting of the flat landscapes, the water table was permanently lowered and the gray depletions and colors are left "high and dry." Some relict soil features may be suitable for a drainfield if it can be determined they truly are a product of past times. This may include a more field detailed analysis, or conducting a two year water table study, and/or conducting K_{sat} tests if there is any question that the relict features may have formed because of restrictive or slow permeability.

Red and yellow as well as yellowish red, strong brown and yellowish brown iron concentrations commonly indicate a soil has slow or restrictive permeability and is typically associated with a fluctuating water table in transported soil materials. Soils, which have yellowish red, or strong brown redox concentrations in the subsoil indicate slow or restrictive permeability caused by poor soil structure, discontinuities, and/or density and compaction of the soil materials.

12 VAC 5-610-490. Characteristics of soils that determine suitability.
A. *Color*. Color is a key indication of the suitability of a soil.
1. Red and yellow mottlings may indicate slow internal drainage and may indicate a seasonal water table.
2. Gray and/or gray mottlings indicate seasonal water tables for at least three weeks duration.
3. Black appearance may be due to organic matter which has accumulated due to poor soil drainage.

Gray matrix and/or gray redox depletions indicate that all conditions were right for grays to form, including saturation of the soil. The abundance of gray redox features appears to indicate how long a soil is reduced, and not so much to how long the soil is saturated, (Vepraskas, 1992). Though the Regulations state that gray redox features indicate a seasonal water table for at least three weeks duration, current research implies the duration of a water table is best measured directly by a water table study.

Figure: 5-36. Gray (depleted) matrix with oxidized rhizosphere indicates this soil is saturated for long periods of time.
(Photo by Tom Saxton)

Black colors in the soil commonly are commonly associated with organic matter. Organic matter is typically broken down and oxidized relatively quickly in most upland Virginia soils (think about hardwood mulch applied around your house that rapidly breaks down in a year or two). Consequently, organic content in most of the Virginia soils on upland landforms will range from 1 to 5 percent. When a soil is encountered with high organic matter content, it is usually located in a drainageway or concave landform. In this type landform, higher organic matter content is present because of higher vegetative growth, slower rate of decomposition, and increased organic matter accumulation.

Figure: 5-37. Thick dark surfaces rich in organic matter may indicate a low wet landscape.
(Photo Bill Kitchel)

Best management practice when encountering soils with high organic matter content and/or overly thickened A horizons is to slow down the soil/site evaluation process and determine what kind of landform is present. Also, since dark-colored organic matter content can mask soil wetness features, examine the soils for other wetness clues such as yellowish brown iron concentrations in the A horizon that are commonly around fine and very fine root channels/pores; look for very small Fe/Mn concretions; examine a nearby soil on an upland position and compare it to the high organic matter soil; if there is doubt about the wetness of a soil relatively high in organic matter content, make sure the drainfield does not encroach into one of the marginal landforms such as a footslope, toeslope, or upper reaches of a drainageway.

A strong case can be made that ANY redox features should be used to indicate the seasonal water table in transported soils. Poor landscape positions (lower sideslopes; footslopes; sites with long upslope watersheds; broad uplands lacking good surface drainage) will be wetter than their soil colorings might indicate. Soils located on crest or narrow summit landscape positions may be significantly drier than their potentially relict colors might indicate.

Loading Rate

The recommended *loading rate* is the amount of wastewater that is proposed to be applied to an area of soil per day. The loading rate must be assigned correctly so that the size of the soil absorption system is adequate. Overestimation of the loading rate capacity of a soil can invite premature failure of the system.

In Virginia, soils normally have layers of differing permeability. Assigning an estimated percolation rate (EPR) to a given soil horizon is done by estimations based upon soil features. This is an iterative process, which involves a series of adjustments to the EPR before arriving at a design rate. Soil texture is merely a part of this process and it may be used as a baseline reference in which to begin to assign an EPR. Soil structure is also an important feature. Soil structure controls the flow of fluids and gasses in soils. Features such as soil structure can only be readily identifiable via a fresh soil pit. Other soil properties, along with structure, should be assessed with respect to estimating the rate at which gravitational water will flow through the soil. Features associated with roots and ped faces also provide information that may lead to reliable estimates.

The starting point for determining the recommended loading rate shall be the value derived when estimating hydraulic conductivity. This estimation may be based upon a combination of qualitative and quantitative values. The evaluator is encouraged to be conservative in assigning the recommended loading rate. Quantitative data such as K_{sat} procedures and

Table: 5-1. Porosity of Soil

	Coarse-Textured	Fine-Textured
Total Porosity	Smaller	Larger
Pore Sizes	Larger	Smaller
Holding Water	Loose	Tight
Drainage	Fast	Slow
Air Exchange	Easy	Difficult

percolation tests should not be used exclusively to derive this rate. Site considerations and the soil profile information must also be considered. The recommended loading rate may be decreased when the available area is not limited and the evaluator believes that the life expectancy of the system would be significantly increased by installing a larger system.

The relationship between structural, biological, and other physical properties and water movement is complex and interrelated. Biologic factors such as roots will play a major role in water movement because roots tend to improve structure. In some cases, water will move rapidly along old root channels. Animal burrows transmit water rapidly, but are generally not prevalent enough in subsoil horizons to play a critical role in water movement thought the entire horizon. Obstruction to root penetration is a clue to the permeability of a horizon. The obstructing layer will most likely have slow permeability and sometimes high bulk density values.

Soil water movement will differ depending on moisture content. Dry soils will have open inter-structural cracks and voids, which will transmit water very rapidly. Void spaces will be reduced with increasing moisture content. Soils with shrink swell characteristics will have voids that close almost completely when satiated. In the absence of structure, such as found in a fluvial deposit or coastal plain C horizon, texture will dominate the flow of liquids.

Consistency often relates to mineralogy and may be associated with soil bulk density. In general, the more firm a given horizon, the less permeable due to its higher bulk density. Friable soil horizons often have low bulk densities and are consequently more permeable. An example of an exception may be a horizon with strong medium angular blocky structure and very firm individual peds. In this case, the structure would dominate the rate of water flow.

A generalized procedure to assign an estimated percolation rate is outlined below:

1) Base the initial percolation rate upon the identified textural group (See *12 VAC 5-610-490. Characteristics of soils that determine suitability. C. 1.* in the regulations). This section relates texture groups to percolation rates. Once a range is established, choose a value in the middle of that range.

2) Adjust the EPR consistent with landscape factors. If the landscape morphometry is a linear or convex slope, there should be no change in EPR. If the landform is concave, (i.e. upper concave linear or near the transition from lower sideslope to footslope) the estimated percolation rate should be increased. Concave-concave positions (see Figure 5-20) are unsuitable landscapes for drainfields. Also see Chapter 2 and the NRCS *Field Book for Describing and Sampling Soils* for more information on landscape morphometry.

3) Adjust the EPR for structure type, size and grade. Decrease the estimated percolation rate for strong structure and finer peds sizes because smaller more defined peds will transmit water more rapidly than less well-defined larger peds.

Conversely, increase the EPR for weaker soil structure and larger structural units. Increase the EPR for prismatic structure. Strong platy structure generally has rates in excess of 120 minute per inch. Massive structure with fine textures may have unacceptable rates.

4) Adjust the EPR for moist and wet consistency. In general, as plasticity and stickiness increase, estimated percolation rates would be expected to increase.

Table: 5-2 Consistence related to estimated percolation rates

Stickiness Class	EPR
Non-Sticky	*decrease*
Slightly Sticky	*decrease to no change*
Moderately Sticky	*no change to increase*
Very Sticky	*increase*

Plasticity Class	EPR
Non-Plastic	*decrease*
Slightly Plastic	*decrease to no change*
Moderately Plastic	*No change to increase*
Very Plastic	*increase*

Resistance to Failure	EPR
Loose, very friable, friable	*decrease*
Friable to firm	*no change*
Very firm and firmer	*unsuitable*

5) Adjust the EPR for the usable depth below the trench bottom (soil restrictions or wetness). The closer the trench bottom is to a restriction, the less total volume of soil for disposal and treatment of the effluent. To compensate for the loss of soil volume, increase the estimated percolation rate.

If the volume of soil is large decrease the EPR

If the volume of soil is small increase the EPR

Most Virginia soils have argillic horizons (B_t). Ped surfaces are often indicators of long-term water movement. Generally, strong brown to red ped colors indicate that the clay suspended in water is moving freely without interruption. Brown or pale brown ped faces usually indicate slow rates of water transmission.

6) Mafic saprolites can be friable but may have failing rates due to their smectitic mineralogy. These saprolites are suspect and should not be used.

Table: 5-3. Estimated loading rates based upon soil properties

Soil morphological features, especially structure, texture, and consistence, are generally the best predictors of the soil's long term capacity to absorb and transmit wastewater and groundwater. When assigning loading rates, the entire soil profile must be considered in context with landscape position, parent material, and any limiting feature. Consistence is a measure of how well soils adhere to itself under an applied stress and is best evaluated in a moist state. In general soil permeability is enhanced with increased friability. For layers in which loading rates that exceed their historical soil textural group loadings, fresh backhoe pits should be used to evaluate soil morphological features.

Texture	Structure		Estimated Perc	Hydraulic Loading Rate (gpd/ft2)					
	Shape	Grade	Rate	TL1		TL2		TL3	
			MPI	Gravity	PD	Gravity	PD	Pads	Trench Max
Coarse Sand, Sand, Loamy Sand	Single Grain	Structureless	5	0.91					
Fine sand, Very Fine Sand, Loamy Fine Sand, Loamy Very	Single Grain	Structureless	5--10	0.9-0.83					
Coarse Sandy Loam, Sandy Loam	Granular	Wk-Strong	15	0.76					
	Prismatic, Blocky	Weak	25	0.63					
		Moderate, Strong	20	0.68					
	Massive	Structureless	25	0.63					
Fine Sandy Loam, Very Fine Sandy Loam	Granular	wk-strong	25	0.63					
	Prismatic, Blocky	Weak	30-40	0.57-0.48					
		Moderate, Strong	25-35	0.63-0.52					
	Massive	Structureless	30-45	0.57-0.44					
Loam, Sandy Clay Loam	Granular	Wk-Strong	25-35	0.63-0.52					
	Prismatic, Blocky	Weak	40-45	0.48-0.44					
		Moderate	35-40	0.52-0.48					
		Strong	30-40	0.57-0.48					
	Massive	Structureless	45-55	0.44-0.36					
Silt, Silt Loam	Granular	Wk-Strong	35-50	0.52-0.40					
	Blocky	Weak	60-75	0.33-0.25					
		Moderate	55-70	0.36-0.28					
		Strong	50-60	0.40-0.33					
	Prismatic	Weak	70-80	0.28-0.23					
		Moderate	60-75	0.33-0.25					
		Strong	55-70	0.36-0.28					
	Massive	Structureless	70-90	0.28-0.19					
Silty Clay Loam, Clay Loam	Blocky	Weak	70-90	0.28-0.20					
		Moderate	60-75	0.33-0.25					
		Strong	55-70	0.36-0.28					
	Prismatic	Weak	105-120+	0.14-0.00					
		Moderate	75-95	0.25-0.17					
		Strong	70-90	0.28-0.19					
	Massive	Structureless	120+	0					
Sandy Clay, Clay, Silty Clay	Blocky	Weak	100-120+	0.16-0.0					
		Moderate	80-100	0.23-0.16					
		Strong	70-90	0.28-0.19					
	Prismatic	Weak	120+	0					
		Moderate	100-120	0.16-0.0					
		Strong	85-100	0.21-0.16					
	Massive	Structureless	120+	0					
Saprolite	Felsic	Loamy Sand	5--10	0.91-0.83					
		Sandy Loam	10--20	0.83-0.68					
		Loam	15--25	0.76-0.63					
		Sandy Clay Loam	30-45	0.57-0.44					
		Silt Loam	45-65	0.44-0.3					
	Intermediate	Any Texture	*	*					
	Mafic	Any Texture		0					

1) Platy Structure is unsuitable for all textures except for weak platy in coarse sandy loams and sandy loam
2) If the moist consistence is very firm or firmer; very sticky and or very plastic; or cementation class is moderate or stronger; or moderate or stronger brittleness; the soil is unsuit
3) The soils are unsuitable if they are in the clayey particle size family having more smectite by weight than any other singe kind of clay mineral.
4) Saprolites with mixed minerology (between 10 and 40% ferromagnesian minerals) field confirmation of permeability is required.
5) Red and yellow redoximorphic features generally indicate restricted permeability in most transported soils

Saturated Hydraulic Conductivity

Water movement in soil is controlled by two factors: 1) the resistance of the soil matrix to water flow and 2) the forces acting on each element or unit of soil water. Darcy's law, the fundamental equation describing water movement in soil, relates the flow rate to these two factors. Mathematically, the general statement of Darcy's law for vertical, saturated flow is:

$$Q/At = -K_{sat}\, dH/dz$$

where the flow rate Q/At is what soil physicists call the flux density, i.e., the quantity of water Q moving past an area A, perpendicular to the direction of flow, in a time t. The vertical saturated hydraulic conductivity K_{sat} is the reciprocal, or inverse; of the resistance of the soil matrix to water flow. The term dH/dz is the hydraulic gradient, the driving force causing water to move in soil, the net result of all forces acting on the soil water. Rate of water movement is the product of the hydraulic conductivity and the hydraulic gradient.

Saturated hydraulic conductivity cannot be used to describe water movement under unsaturated conditions. Therefore, permeameter tests must be performed for a duration needed to saturate the soil. If a K_{sat} test is performed during wet conditions, the time frame will be less than if the test was performed in drier conditions. If performed during dry conditions, the time will be much longer to reach a stabilized flow rate. Only then may the test be considered valid. In Virginia, we currently do not have regulatory requirements for performing K_{sats}. However, recommendations by the manufacturer of the device and scientific conventions must be followed for the test to be considered valid.

Figure: 5-38. Two types of constant head permeameters commonly used in Virginia; the *Amoozemeter* (left) and the *Johnsonmeter* (right). *(Photos by Tom Saxton)*

Hydraulic conductivity is a highly variable soil property. Measured values easily may vary by 10-fold or more for a particular soil series. Values measured on soil samples taken within centimeters of one another may vary by 10-fold or more. In addition, measured hydraulic conductivity values for a soil may vary dramatically with the method used for measurement. Laboratory determined values rarely agree with field measurements, the differences often being on the order of 100-fold or more. Field methods generally are more reliable than laboratory methods.

Because of the highly variable nature of soil hydraulic conductivity, a single measured value is an unreliable indicator of the hydraulic conductivity of a soil. An average of several values will give a reliable estimate, which can be used to place the soil in a particular hydraulic conductivity class. Log averages (geometric means) should be used rather than arithmetic averages because hydraulic conductivity is a log normally distributed property. The antilog of the average of the logarithms of individual conductivity values is the log average, or geometric mean, and should be used to place a soil into the appropriate hydraulic conductivity class. Log averages are lower than arithmetic averages.

Normally, for drainfield evaluation, the slowest reading obtained during a test is used for design. Since there are regulatory requirements for percolations tests, it is reasonable to follow these requirements when using hydraulic conductivity tests. For standard percolation tests (perk test) a minimum of three tests must be performed in the proposed drainfield footprint. If the difference between results is more than 30 minutes per inch apart, then five tests (minimum) are required.

Figure: 2-39. Performing a Percolation *(perk)* Test. *(Photo by Tom Saxton)*

However, hydraulic conductivity tests and percolation tests do not measure the same thing and are not necessarily indicative of the same properties of the soil. Hydraulic conductivity is a *constant head test*, whereas, a perk test is a *falling head test*. In other words, a steady column (head) of water is maintained during a K_{sat} test. This is not the case with the standard perk test. In that case, a six-inch column of water is allowed to totally soak into the soil before adding water again. So the head "falls" during the course of the procedure. What the two methods share in common is a representation of the degree to which water will move into the soil. A soil that perks slowly will also yield slow results during a K_{sat} procedure and conversely. Table 5-4 was developed to estimate the relationship between K_{sat} (centimeters/hour) and minutes per inch. This table has not been further verified outside Virginia and was developed by a mixture of quantitative and qualitative procedures. It is not a regulatory document.

For further information on recommended methodology for performing saturated hydraulic conductivity tests, see Appendix: K_{sat} Determination Methodology.

Table: 5-4. Saturated Hydraulic Conductivity converted to minutes per inch.

Area Requirements for Absorption Trenches

Saturated Hydraulic Conductivity Rate (centimeters/day)	**	(Ft2/Bedroom) Gravity	(Ft2/Bedroom) LPD*	(Ft2/100 Gals) Gravity	(Ft2/100 Gals) LPD*
> 50.0	(005)	110	110	165	165
25.0 – 50.0	(010)	120	120	180	180
17.4 – 25.0	(015)	132	132	198	198
15.9 – 17.4	(020)	146	146	218	218
14.6 – 15.9	(025)	158	158	237	237
13.3 – 14.6	(030)	174	164	260	255
12.0 – 13.3	(035)	191	170	286	260
11.0 – 12.0	(040)	209	176	314	264
10.0 – 11.0	(045)	229	185	344	279
9.1 – 10.0	(050)	251	193	376	293
8.3 -- 9.1	(055)	275	206	412	309
7.6 -- 8.3	(060)	302	217	452	325
6.9 -- 7.6	(065)	331	228	496	342
6.4 -- 6.9	(070)	363	240	544	359
5.8 -- 6.4	(075)	398	251	596	375
5.2 -- 5.8	(080)	437	262	656	394
4.8 -- 5.2	(085)	479	273	718	409
4.4 -- 4.8	(090)	525	284	786	424
4.0 -- 4.4	(095)	575	288	862	431
3.6 -- 4.0	(100)	631	316	946	473
3.3 -- 3.6	(105)	692	346	1038	519
3.0 -- 3.3	(110)	759	379	1138	569
2.6 -- 3.0	(115)	832	416	1248	624
2.2 -- 2.6	(120)	912	456	1368	684

* Low Pressure Distribution ** Figures in parenthesis are for Standard Perk Test (min/in) from regulations

Proposed Changes to the Sewage Handling and Disposal Regulations, May 1989, page 64 ***(DRAFT PROPOSAL – MAY 2, 1997)***

Developed from field test and observations over a 5 year period by Carl D. Peacock, Jr., Research Associate and Eastern Virginia Interpretative Soil Scientist

Water Mounding

Commonly, an outward and upward expansion of the free water table caused by the addition of water beyond the soil's capacity to disperse it (essentially, the reverse of the cone of depression effect created by a pumping well). Mounding can alter groundwater flow rates and direction; however, the effects are usually localized and may be temporary, depending upon the frequency and duration of the surface and subsurface recharge events.

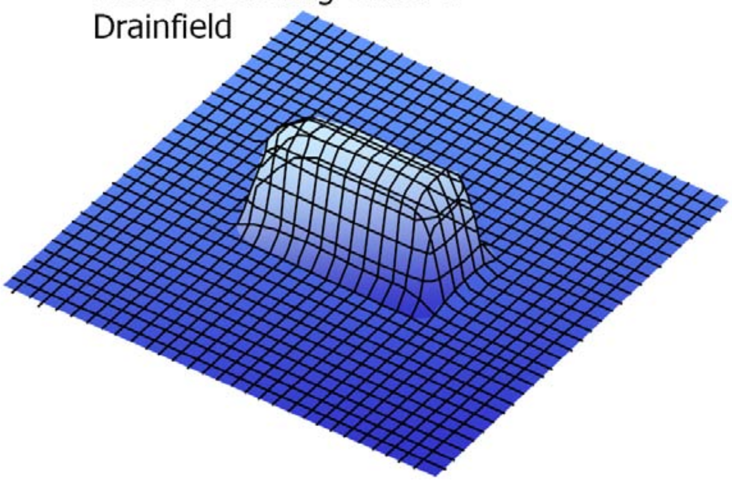


Figure: 5-40. Groundwater mounding *(TS)*

After treatment and percolation of the wastewater through the infiltrative surface biomat and passage through the first few inches of soil, the *wastewater plume* begins to migrate downward until nearly saturated conditions exist. The worst-case scenario occurs when the plume is mixing with an elevated water table. At that point, the wastewater plume will move in response to the prevailing hydraulic gradient, which might be lateral, vertical, or even a short distance upslope if ground *water mounding* occurs. Moisture potential, soil conductivity, and other soil and geological characteristics determine the direction of flow. Ground water mounding analyses may be necessary

12 VAC 5-610-250. Procedures for obtaining a construction permit for a sewage disposal system.

Type III Sewage Disposal Systems (>1000 GPD)

G.

2. Geographical and other features. Topography, elevations (contour lines), existing or proposed streets and all bodies of water, ditches, buildings, springs, cisterns and wells within 100 feet horizontally of the proposed sewage disposal system site and/or well, a ***water mounding*** analysis showing the impact of the proposed sewage system on ground water and all property lines shall be clearly shown.

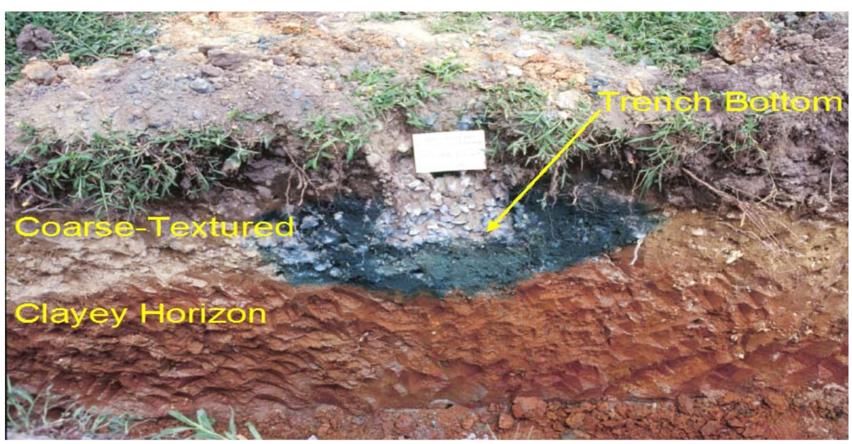


Figure: 5-41. Effluent mounding may occur when the effluent is discharged into a coarse textured soil overlying a fine texture soil horizon. *(NCSU)* to assess the potential for the saturated zone to rise and encroach upon the minimum acceptable separation distance between the drainfield and the saturated zone. The saturated zone where mounding occurs is above a restriction or restrictive horizon or feature. This feature is termed the *secondary design boundary* in the 2002 EPA *Onsite Wastewater Treatment Systems Manual* and must be considered during the site evaluation, especially for Type III Systems.

Ground water mounding analysis may be necessary to determine whether the hydraulic loading to the saturated zone *(secondary design boundary)*, rather than the loading to the infiltration surface, controls system sizing. If the secondary boundary controls design, the size of the infiltration surface, its geometry, and even how wastewater is applied will be affected. In systems that dispose of large volumes of water, mounding is especially of concern. In Virginia, soil studies must be extended to 4 feet below the installation depth for large systems (>1200 gpd/acre).

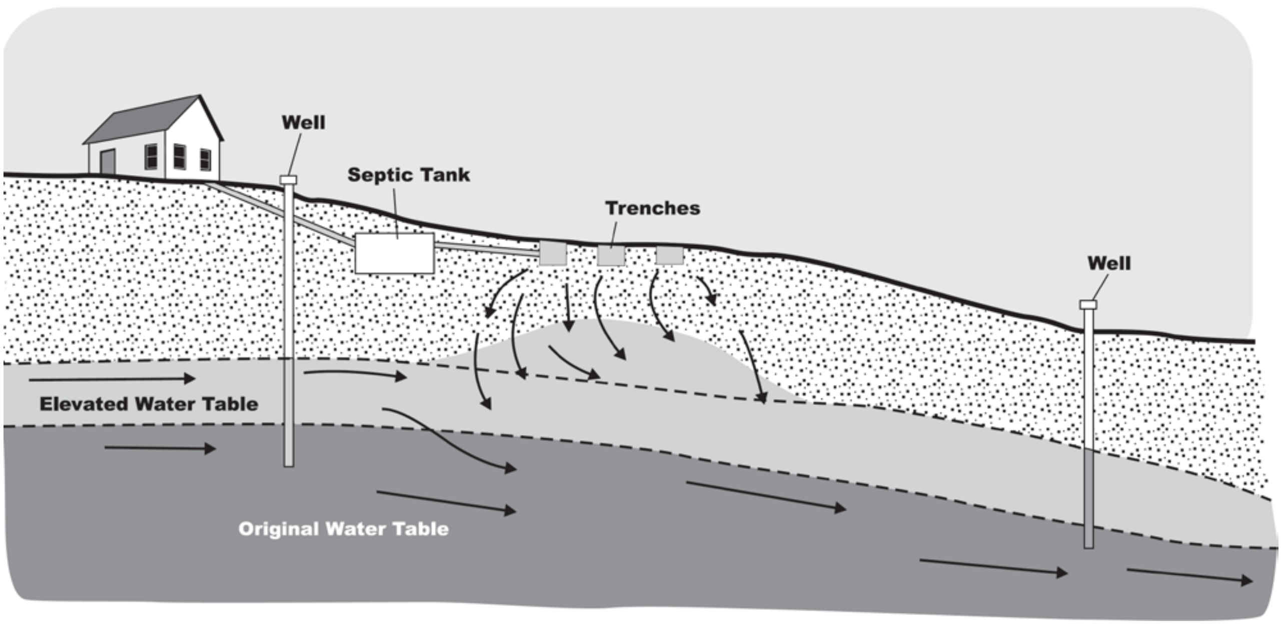


Figure: 2-42. Effluent mounding effect above the saturated zone. *(EPA 2002)*

Chapter Review

Understanding Concepts

1) What is the saturated hydraulic conductivity of the Iredell Soil Series? What does this mean?

2) What does the Btss Horizon in Iredell represent in the onsite world?

3) You have an old plat in hand and wish to blow it up on the copy machine. You must use 1” = 40’ scale. The property is 125’ wide and 200’ deep. The property line that is 200’ measures 2”. What percent would you set the copy machine to achieve 1” = 40’ ?

4) A topographic map has a contour interval of 10’. You have the map in hand, but no clinometer or hand level. How could you determine the slope?

5) Why do you think a screw auger is not allowed for soil evaluations in Virginia?

6) How would you recognize a concave depression on a topographic map?

7) What is the largest number of borings we are allowed to make on a site in Virginia?

8) What does it mean when contour lines cross one another?

9) What causes low chroma colors in wet soil? What are they called?

10) Brighter redder colors in the same soil are called what and what are they?

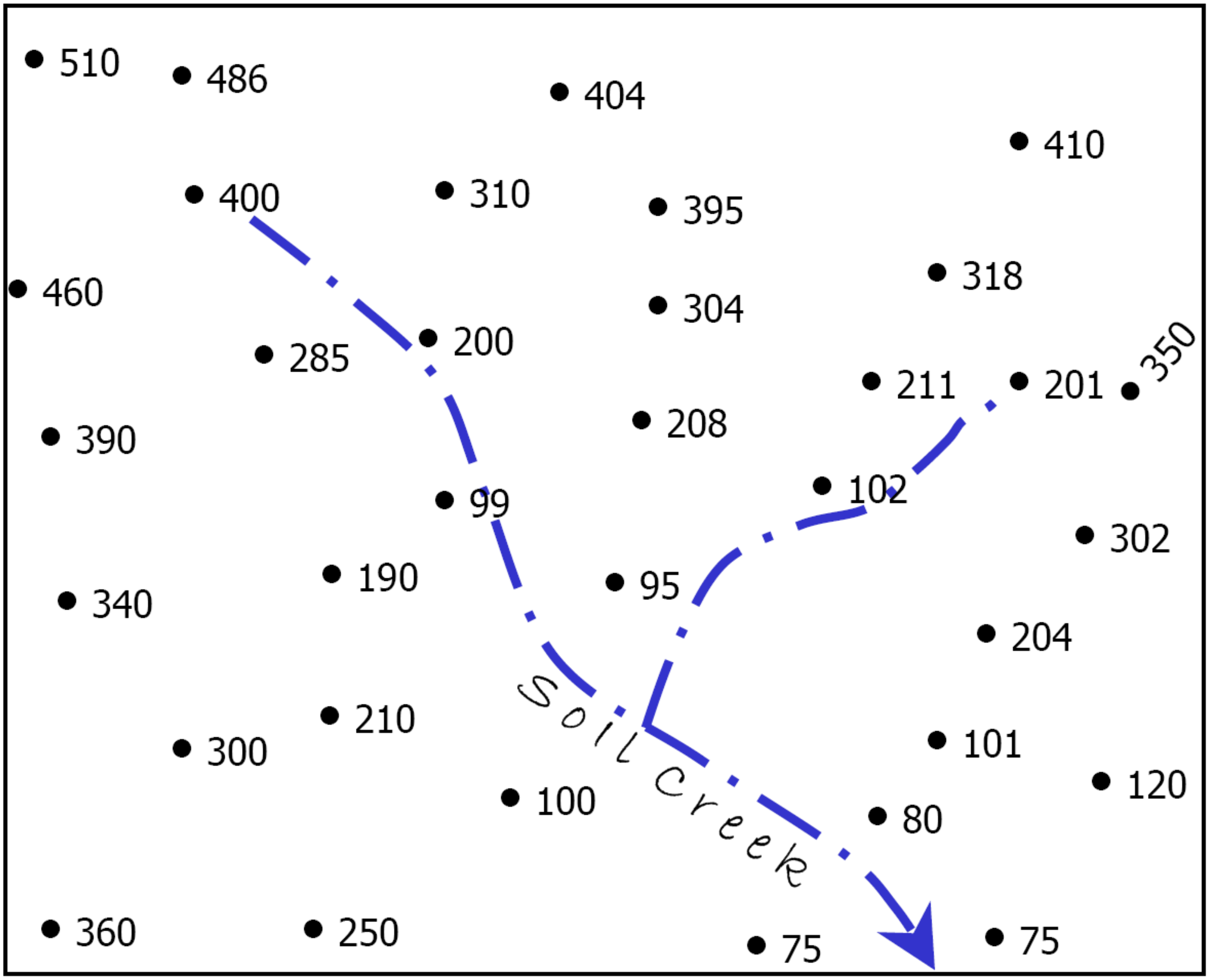
11) Number 9 and 10 above indicate something to consider in a drainfield design. What is it?

12) What is groundwater mounding and why is it important in the onsite world?

13) List as many characteristics of the Iredell Soil Series *(pages 5.11-13)* that you can find that would negatively affect its potential to be used for a drainfield. Do you think this soil is suitable for drainfields? Why, or why not?

Critical Thinking and Problem Solving

This map shows spot elevations, and a stream. Using a contour interval of 100 feet, construct a topographic map. Not all elevations will lie directly on a contour line. Interpolation between some elevations will be required.



Contour Interval = 100′

1) Indicate the steepest area (what would you name this landscape position?)
2) Indicate the flattest area (what would you name this landscape position?)
3) Show the lowest site (what would you name this landscape position?)
4) Show the highest site (what would you name this landscape position?)
5) Show two suitable areas for drainfields
6) Color/shade the areas of this map that you would avoid during a site visit due to poor topography/landscape position.

Soil Description Sheet											
Name:							Date:		Land Use:		
									Vegetation:		
Location:							Slope:		Soil Name:		
Layers		Estimate Drainage Conditions		Estimate Permeability							
Horizon	Depth (inches)	Dominant Color	Redox Features (Type, Quantity, Size, Contrast, Color)	Texture	Structure (Grade, Size, Type)	Consistence	Coarse Fragments	Boundary	Roots	Remarks	
Nature of Limiting Condition:						Notes:					
Depth to Limiting Condition:											

Using any two of the Soil Description(s) provided on the next pages. Fill out this form and answer the following questions (recommend using Soil Series from your physiographic province):

1) Is this soil transported, residual or both? Explain

2) What is the depth to redoximorphic features? _______ Or, does it have any? _________

3) What is the depth to bedrock (R-Cr)? _______ *If not there, use > than deepest depth.*

4) What is the depth to a restriction or restrictive features? _____ Or, are there any? _______

5) What are these restrictions or restrictive features *(if there are any)*?

6) How did you determine that these were restrictions/restrictive?

The following pages of Soil Series Descriptions are from the NRCS Soil Series database. Formatting and spelling are maintained from the source.

http://soils.usda.gov/technical/classification/osd/index.html

APPLING SERIES

The Appling series consists of very deep, well drained, moderately permeable soils on ridges and side slopes of the Piedmont uplands. They are deep to saprolite and very deep to bedrock. They formed in residuum weathered from felsic igneous and metamorphic rocks of the Piedmont uplands. Slopes range from 0 to 25 percent. Near the type location, mean annual precipitation is 45 inches and mean annual temperature is 60 degrees F.

TAXONOMIC CLASS: Fine, kaolinitic, thermic Typic Kanhapludults

TYPICAL PEDON: Appling sandy loam, in a cultivated field. (Colors are for moist soil unless otherwise stated.)

Ap--0 to 6 inches; brown (10YR 5/3) sandy loam; weak medium granular structure; very friable; common medium pores: common fine roots; about 10 percent angular quartz gravel; slightly acid; clear smooth boundary. (5 to 12 inches thick)

E--6 to 9 inches: light yellowish brown (10YR 6/4) sandy loam; weak medium granular structure; very friable; common medium pores; common fine roots; about 5 percent angular quartz gravel; slightly acid; clear smooth boundary. (0 to 5 inches thick)

BE--9 to 12 inches; yellowish brown (10YR 5/6) sandy clay loam; weak medium subangular blocky structure; friable; few fine roots; few fine flakes of mica; strongly acid; gradual smooth boundary. (0 to 7 inches thick)

Bt--12 to 48 inches; strong brown (7.5YR 5/6) clay; common medium distinct yellowish brown (10YR 5/6) and prominent red (2.5YR 4/8) mottles; moderate medium subangular blocky structure; firm; sticky and plastic; few fine and medium roots; few distinct clay films on faces of peds; few fine flakes of mica; strongly acid; gradual wavy boundary. (Combined thickness of the Bt horizon is 24 to 50 inches)

BC--48 to 53 inches; mottled red (2.5YR 4/8) and brownish yellow (10YR 6/8) sandy clay loam; weak medium subangular blocky structure; friable; slightly sticky and slightly plastic; few fine and medium roots; few bodies of saprolite; common fine flakes of mica; strongly acid; gradual wavy boundary. (0 to 30 inches)

C--53 to 80 inches; reddish yellow (7.5YR 7/6), red (2.5YR 4/8), and yellow (10YR 8/6) sandy clay loam that weathered from saprolite; massive; friable; common fine flakes of mica; very strongly acid.

PEAWICK SERIES

Soils of the Peawick series are very deep and moderately well drained with very slow permeability. They formed in clayey fluvial sediments on stream terraces of the Coastal Plain and Piedmont. Slopes range from 0 to 15 percent. Mean annual precipitation is about 45 inches, and mean annual temperature is about 58 degrees F, near the type location.

TAXONOMIC CLASS: Fine, mixed, active, thermic Aquic Hapludults

TYPICAL PEDON: Peawick loam--on a 2 percent slope in a loblolly pine plantation. (Colors are for moist soil.)

Oi--2 to 0 inches; undecomposed and partially decomposed leaves and twigs.

Ap--0 to 4 inches; yellowish brown (10YR 5/4) loam; massive; friable, slightly sticky, slightly plastic; many fine medium and coarse roots; extremely acid; clear smooth boundary. (0 to 14 inches thick)

Bt_1--4 to 10 inches; strong brown (7.5YR 5/6) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; many fine medium and coarse roots; many medium clay films on faces of peds; few medium distinct red (2.5YR 4/6) soft masses of iron accumulation; very strongly acid; gradual smooth boundary.

Bt_2--10 to 17 inches; yellowish brown (10YR 5/8) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; many fine medium and coarse roots; many medium clay films on faces of peds; few medium distinct red (2.5YR 4/8) soft masses of iron accumulation; very strongly acid; diffuse smooth boundary.

Bt_3--17 to 33 inches; yellowish brown (10YR 5/6) clay; moderate medium subangular blocky structure; firm, sticky, plastic; common fine and medium roots; many medium clay films on faces of peds; many medium distinct light gray (5Y 7/2) iron depletions and many medium distinct yellowish red (5YR 4/8) soft masses of iron accumulation; very strongly acid; diffuse smooth boundary.

Bt_4--33 to 47 inches; light gray (5Y 7/2) and yellowish brown (10YR 5/8) clay; moderate medium and coarse subangular blocky structure; firm, sticky, plastic; common fine and medium roots; many medium clay films on faces of peds; extremely acid; diffuse smooth boundary.

Bt_5--47 to 65 inches; yellowish brown (10YR 5/6) clay; weak medium subangular blocky structure; very firm, sticky, plastic; few fine and medium roots; many medium clay films on faces of peds; 1 to 2 percent black and brown concretions; many medium prominent light gray (5Y 7/2) iron depletions; extremely acid. (Combined thickness of the Bt horizon ranges from 30 to 70 inches or more.)

FREDERICK SERIES

The Frederick series consists of very deep, well drained soils formed in residuum derived mainly from dolomitic limestone with interbeds of sandstone, siltstone, and shale. They are on are nearly level to very steep uplands. Permeability is moderate. Slopes range from 0 to 60 percent. Mean annual precipitation is about 42 inches, and mean annual temperature is about 55 degrees F.

TAXONOMIC CLASS: Fine, mixed, semiactive, mesic Typic Paleudults

TYPICAL PEDON: Frederick silt loam on a 12 percent south southeast facing slope in a hayfield at an elevation of 2470 feet. (Colors are for moist soil.)

Ap--0 to 8 inches; brown (7.5YR 4/4) silt loam; moderate medium granular structure; friable, slightly sticky, slightly plastic; many fine roots; 3 percent coarse angular chert gravel; slightly acid; abrupt smooth boundary. (0 to 12 inches thick)

Bt_1--8 to 18 inches; red (2.5YR 4/6) silty clay; moderate medium subangular blocky structure; firm, moderately sticky and moderately plastic; common fine roots; many distinct red 2.5YR 4/8 clay films on faces of peds; 5 percent angular chert gravel; strongly acid; clear wavy boundary.

Bt_2--18 to 35 inches; red (2.5YR 4/6) clay; common medium distinct strong brown (7.5YR 5/6) soft rock masses; moderate medium subangular blocky structure; firm, moderately sticky, moderately plastic; few fine roots; many distinct red 2.5YR 4/8 clay films on faces of peds; 5 percent angular chert gravel; strongly acid; clear wavy boundary.

Bt_3--35 to 51 inches; red (2.5YR 4/6) clay; common medium distinct strong brown (7.5YR 5/6) and reddish yellow (7.5YR 8/6) soft rock masses; moderate medium subangular blocky structure; firm, moderately sticky, moderately plastic; many distinct red 2.5YR 4/8 clay films on faces of peds; 5 percent angular chert gravel; strongly acid; gradual wavy boundary.

Bt_4--51 to 72 inches; red (2.5YR 4/6) clay; common medium distinct reddish yellow (7.5YR 8/6) soft rock masses; moderate medium subangular blocky structure; firm, moderately sticky, moderately plastic; many distinct red 2.5YR 4/8 clay films on faces of peds; 10 percent angular chert gravel; strongly acid. (Combined thickness of the Bt horizon is 50 to 100 inches.)

CARBO SERIES

Soils of the Carbo series are moderately deep, well drained, and slowly permeable. They formed in material weathered from limestone bedrock. They are nearly level to very steep soils on uplands in the Appalachian Ridges and Valleys. Mean annual temperature is about 55 degrees F., and mean annual precipitation is about 40 inches. Slopes range from 2 to 65 percent.

TAXONOMIC CLASS: Very-fine, mixed, active, mesic Typic Hapludalfs

TYPICAL PEDON: Carbo silt loam - in a cultivated field on a 10 percent slope. (Colors are for moist soil.)

Ap--0 to 10 inches; dark brown (10YR 4/3) silt loam; moderate fine granular structure; friable; many fine and very fine roots; few fine pores; many worm casts and channels; 2 percent iron oxide concretions up to 1/4 inch in diameter; slightly acid; abrupt smooth boundary. (0 to 10 inches thick)

Bt_1--10 to 25 inches; strong brown (7.5YR 5/6) clay; common coarse distinct yellowish brown (10YR 5/8) mottles; moderate medium subangular blocky structure; firm, sticky, very plastic; common fine and very fine roots; few fine pores; thick continuous clay films on faces of peds; common worm casts and channels; 2 percent iron oxide concretions up to 1/2 inch in diameter; few black (N2/0) manganese oxide stains; moderately acid; clear smooth boundary.

Bt_2--25 to 32 inches; dark yellowish brown (10YR 4/4) clay; weak medium subangular blocky structure; firm, sticky; very plastic; few very fine roots; few fine pores; thick continuous clay films on faces of peds; few worm casts and channels; 2 percent iron oxide concretions up to 1/4 inch in diameter; common black (N2/0) manganese oxide stains; mildly alkaline; abrupt wavy boundary. Combined thickness of the Bt horizon range 10 to 35 inches.

R--32 inches; limestone bedrock.

SLAGLE SERIES

Depth Class: Very deep
Drainage Class (Agricultural): Moderately well drained
Internal Free Water Occurrence: Shallow to moderately deep, common
Flooding Frequency and Duration: None
Ponding Frequency and Duration: None
Index Surface Runoff: Negligible to very high, depending on slope
Permeability: Moderately slow or slow
Saturated Hydraulic Conductivity: Moderately low or moderately high, 0.42 to 4.2 micrometers per second
Shrink-swell Potential: Moderate
Landscape: Coastal Plains
Landform: Marine terraces, uplands
Geomorphic Component: Treads, hills
Hillslope Profile Position: Summits, shoulders, and backslopes
Parent Material: Marine deposits
Slope: 0 to 25 percent slopes
Elevation (type location): Unknown
Frost Free Period (type location): 203 days
Mean Annual Air Temperature (type location): 58 degrees F.
Mean Annual Precipitation (type location): 44 inches

TAXONOMIC CLASS: Fine-loamy, siliceous, subactive, thermic Aquic Hapludults

TYPICAL PEDON: Slagle fine sandy loam, on a 4 percent slope in a cultivated field. (Colors are for moist soil.)

Ap--0 to 9 inches; pale brown (10YR 6/3) fine sandy loam; weak fine granular structure; very friable, nonsticky, nonplastic; many fine medium and coarse roots; 3 percent rounded and angular gravel; very strongly acid; clear smooth boundary. (2 to 12 inches thick)

Bt_1--9 to 14 inches; yellowish brown (10YR 5/6) loam; weak medium subangular blocky structure; friable, slightly sticky, slightly plastic; common fine medium and coarse roots; few faint clay films on faces of peds; many medium faint very pale brown (10YR 7/4) clay depletions; 3 percent rounded and angular gravel; very strongly acid; gradual smooth boundary.

Bt_2--14 to 20 inches; yellowish brown (10YR 5/6) clay loam; weak medium subangular blocky structure; friable, sticky, plastic; common fine medium and coarse roots; few faint clay films on faces of peds; 3 percent rounded and angular gravel; very strongly acid; gradual smooth boundary.

Bt_3--20 to 30 inches; yellowish brown (10YR 5/8) clay loam; moderate medium subangular blocky structure; friable, moderately sticky, moderately plastic; common fine medium and coarse roots; many distinct clay films on faces of peds; many medium distinct light gray (10YR 7/1) iron depletions and many medium prominent yellowish red (5YR 5/8) irregularly shaped masses of oxidized iron; few fine flakes of mica; 3 percent rounded and angular gravel; very strongly acid; diffuse smooth boundary.

Bt_4--30 to 55 inches; yellowish brown (10YR 5/8), light gray (N 7/0) and light yellowish brown (2.5Y 6/4) sandy clay loam; weak medium subangular blocky structure; firm, moderately sticky, moderately plastic; few fine roots; many distinct clay films on faces of peds; few fine flakes of mica; yellowish brown colors are masses of oxidized iron and gray colors are iron depletions; 3 percent rounded and angular gravel; very strongly acid; diffuse smooth boundary. (Combined thickness of the Bt horizon is 20 to 60 inches.)

C--55 to 66 inches; yellowish brown (10YR 5/8) and light gray (N 7/0) sandy clay loam; massive; friable, slightly sticky, slightly plastic; few fine roots; few vertical clay flows; yellowish brown colors are masses of oxidized iron and gray colors are iron depletions; few fine flakes of mica; 3 percent rounded gravel; very strongly acid.

SPEARS MOUNTAIN SERIES

Depth Class: moderately deep
Drainage Class (Agricultural): well drained
Internal Free Water Occurrence: very deep, absent
Index Surface Runoff: low to high
Permeability: moderate
Landscape: piedmont
Landform: ridge, hill
Hillslope Profile Position: summit, shoulder, back slope
Geomorphic Component: interfluve, noseslope, sideslope
Parent Material: residuum weathered from schist, phyllite or other fine grained rock
Slope: 2 to 55 percent
Elevation (type location):
Mean Annual Air Temperature (type location): 55 degrees F.
Mean Annual Precipitation (type location): 45 inches

TAXONOMIC CLASS: Fine, mixed, semiactive, mesic Typic Hapludults

TYPICAL PEDON: Spears Mountain loam on a 9 percent slope, in a planted pine forest (Colors are for moist soil unless otherwise indicated.)

Ap--0 to 7 inches; yellowish brown (10YR 5/4) silt loam; weak coarse subangular blocky structure; friable, slightly sticky and non plastic; many fine, medium and coarse roots; 10 percent gravel; strongly acid (pH 5.3); gradual smooth boundary.

Bt--7 to 28 inches; red (2.5YR 4/6) clay; moderate fine and medium angular blocky structure; friable, sticky and slightly plastic; common fine, medium and coarse roots; 5 percent gravel; many medium distinct clay films on faces of peds; strongly acid (pH 5.3); abrupt irregular boundary.

Cr--28 to 60 inches; mottled reddish brown (2.5YR 4/4) and yellow (2.5Y 7/6) highly weathered sericite schist that crushes to silt loam.

JACKLAND SERIES

Soils of the Jackland series are very deep, moderately well drained and somewhat poorly drained with very slow permeability. They formed in residuum that weathered from diabase, basalt and gabbro of the Northern part of the Piedmont plateau. Slopes range from 0 to 15 percent. Mean annual precipitation is about 40 inches and mean annual temperature is about 55 degrees F.

TAXONOMIC CLASS: Fine, smectitic, mesic Aquic Hapludalfs

TYPICAL PEDON: Jackland silt loam on a 3 percent slope in a mixed hardwood and pine forest. (Colors are for moist soil.)

Ap--0 to 10 inches; yellowish brown (10YR 5/6) silt loam; moderate medium granular structure; friable, slightly plastic, slightly sticky; many fine, medium and coarse roots; 2 percent gravel and cobbles of diabase fragments; very strongly acid; clear smooth boundary. (2 to 12 inches thick)

BE$_t$--10 to 15 inches; dark yellowish brown (10YR 4/4) silt loam; moderate medium subangular blocky structure; firm, sticky, plastic; common fine and medium roots; few, fine, medium, and coarse, faint pale brown (10YR 6/3) iron depletions; many fine iron-manganese concretions; 2 percent diabase gravel and cobble; many distinct clay films on faces of peds; very strongly acid; clear smooth boundary. (0 to 10 inches thick)

Bt--15 to 30 inches; dark yellowish brown (10YR 4/4) clay; moderate coarse subangular blocky structure; very firm, very plastic, very sticky; few fine roots; common, fine and medium, distinct, gray (10YR 6/1) iron depletions; common fine and medium iron-manganese concretions; common prominent clay films on faces of peds; many pressure faces and slickensides; 1 percent diabase gravel and cobbles; very strongly acid; clear smooth boundary.

Bt$_{ss}$--30 to 35 inches; yellowish brown (10YR 5/6) clay; moderate coarse subangular blocky structure; very firm, very plastic, very sticky; few fine roots; common, fine and medium iron-manganese concretions; common prominent clay films on faces of peds; many pressure faces and slickensides; 1 percent diabase gravel and cobbles; very strongly acid; clear wavy boundary. (Combined thickness of the Bt horizon ranges from 10 to 35 inches.)

BC$_t$--35 to 40 inches; yellowish brown (10YR 5/6) clay loam; weak medium subangular blocky structure; firm, plastic, sticky; few fine roots; common fine and medium iron-manganese concretions; few distinct and prominent clay films on faces of peds; 1 percent diabase gravel and cobbles; very strongly acid; diffuse wavy boundary. (0 to 15 inches thick)

C--40 to 65 inches; multicolored brown, yellow, green, white and black sandy loam; massive; friable, slightly plastic, sticky; common black iron-manganese streaks; thick very plastic clay flows in crevices in the upper 15 inches; 3 percent diabase gravel and cobbles; slightly acid.

SASSAFRAS SERIES

DEPTH CLASS: Very deep
DRAINAGE CLASS: Well drained
PERMEABILITY: Moderate or moderately slow
SURFACE RUNOFF: Slow or medium
PARENT MATERIAL: Sandy marine and old alluvial sediments
SLOPE: 0 to 60 percent
MEAN ANNUAL AIR TEMPERATURE (type location): 52 degrees F.
MEAN ANNUAL PRECIPITATION (type location): 45 inches

TAXONOMIC CLASS: Fine-loamy, siliceous, semiactive, mesic Typic Hapludults

TYPICAL PEDON: Sassafras sandy loam, cultivated. (Colors are for moist soil).

Ap--0 to 9 inches; brown (10YR 5/3) sandy loam; weak very fine subangular blocky structure; very friable; slightly sticky, slightly plastic; few roots; strongly acid, abrupt smooth boundary. (0 to 12 inches thick)

BA--9 to 21 inches; yellowish brown (10YR 5/4) loam; moderate very fine to medium subangular blocky structure; friable; slightly sticky, slightly plastic; few roots; strongly acid; clear smooth boundary. (0 to 12 inches thick)

Bt_1--21 to 32 inches; brown (7.5YR 5/4) sandy clay loam; weak medium subangular blocky structure; friable, slightly sticky, slightly plastic; few clay films on faces of peds; very few roots; very strongly acid; clear smooth boundary.

Bt_2--32 to 40 inches; strong brown (7.5YR 5/6) sandy loam; weak thick platy structure parting to weak fine subangular blocky structure; friable; slightly sticky, slightly plastic; few clay films on faces of peds; very few roots; very strongly acid; abrupt smooth boundary. (Combined thickness of the Bt horizon is 10 to 20 inches.)

C_1--40 to 52 inches; strong brown (7.5YR 5/6) gravelly sandy loam; massive; friable; slightly sticky, nonplastic; very strongly acid; 3 percent small light yellowish brown (10YR 6/4) pockets of clay; clear smooth boundary.

C_2--52 to 70 inches; brownish yellow (10YR 6/8) loamy sand; single grain; loose;, nonsticky, nonplastic; 5 percent, by volume fine yellowish brown (7.5YR 5/8) gravel; extremely acid.

COTACO SERIES

The Cotaco series consists of very deep, moderately well or somewhat poorly drained, moderately permeable soils formed in loamy sediments of acid sandstone, siltstone, and shale origin in the Appalachian Ridges and Valleys. These soils are on foot slopes, colluvial fans, and low stream terraces. Slopes range from 0 to 20 percent. The average annual temperature is about 55 degrees F, and the average annual precipitation is about 48 inches near the type location.

TAXONOMIC CLASS: Fine-loamy, mixed, semiactive, mesic Aquic Hapludults

TYPICAL PEDON: Cotaco loam--cultivated--on a smooth concave 1 percent slope. (Colors are for moist soil.)

Ap--0 to 10 inches; dark grayish brown (10YR 4/2) loam; weak fine granular structure; very friable; many fine roots; about 2 percent pebbles; slightly acid; abrupt smooth boundary. (5 to 12 inches thick)

BA--10 to 16 inches; yellowish brown (10YR 5/4) sandy clay loam; weak medium subangular blocky structure; friable; many fine roots; many fine pores; many faint brown (10YR 5/3) iron depletions on ped faces and common medium prominent strong brown (7.5YR 5/6) iron concentrations throughout; few patchy clay films on peds; about 5 percent pebbles; slightly acid; gradual smooth boundary. (0 to 10 inches thick)

Bt_1--16 to 23 inches; yellowish brown (10YR 5/4) gravelly sandy clay loam; weak medium subangular blocky structure; friable; thin clay films on peds; common medium prominent light brownish gray (2.5Y 6/2) iron depletions and common medium distinct brown (7.5YR 4/4) and yellowish brown (10YR 5/8) iron concentrations throughout; 15 percent sandstone and shale pebbles and thin flat channers; strongly acid; gradual smooth boundary. (5 to 25 inches thick)

Bt_2--23 to 41 inches; grayish brown (2.5Y 5/2) gravelly clay loam; moderate medium subangular blocky structure; friable; thin clay films; many prominent yellowish brown (10YR 5/8) and brown (7.5YR 4/4) iron concentrations throughout; about 30 percent pebbles and dark reddish brown iron and manganese concretions; strongly acid; gradual smooth boundary. (0 to 30 inches thick)

C_1--41 to 46 inches; yellowish brown (10YR 5/4) gravelly clay loam; massive; friable; many medium distinct brown (7.5YR 4/4) iron concentrations and light brownish gray (10YR 6/2) iron depletions throughout; about 40 percent pebbles and iron and manganese concretions; strongly acid; gradual smooth boundary. (0 to 20 inches thick)

C_2--46 to 66 inches; yellowish brown (10YR 5/6) sandy clay loam; massive; slightly sticky; many fine and medium prominent gray (10YR 6/1) iron depletions and brown (7.5YR 4/4) iron concentrations throughout; 5 percent pebbles; strongly acid.

ALLEGHENY SERIES

The Allegheny series consists of very deep, well-drained, moderately permeable soils formed in alluvium on stream terraces, foot slopes and alluvial fans of the Appalachian Ridges and Valleys. Slopes range from 0 to 25 percent.

TAXONOMIC CLASS: Fine-loamy, mixed, semiactive, mesic Typic Hapludults

TYPICAL PEDON: Allegheny loam, 2 to 6 percent slopes, rarely flooded in cultivation. (Colors are for moist soil)

Ap--0 to 8 inches; dark yellowish brown (10YR 4/4) loam; weak medium subangular blocky structure parting to weak fine granular; very friable; many fine and medium roots; moderately acid; clear smooth boundary. (5 to 10 inches thick)

Bt_1--8 to 15 inches; yellowish brown (10YR 5/6) loam; moderate medium subangular blocky structure; firm; common fine roots; common fine tubular pores; many faint organic stains and common faint clay films on all surfaces of peds; strongly acid; gradual smooth boundary.

Bt_2--15 to 28 inches; yellowish brown (10YR 5/6) loam; moderate medium subangular blocky structure; firm; few fine roots; few fine tubular pores; common faint clay films on all surfaces of peds; strongly acid; gradual wavy boundary.

Bt3--28 to 33 inches; yellowish brown (10YR 5/6) loam; few medium distinct brown (10YR 5/3) and strong brown (7.5YR 5/8) mottles; moderate medium subangular blocky structure; firm; few fine roots; few fine tubular pores; common faint clay films on all surfaces of peds; strongly acid; gradual smooth boundary.

Bt_4--33 to 42 inches; yellowish brown (10YR 5/4) fine sandy loam; few medium faint brown (10YR 5/3) and few medium prominent strong brown (7.5YR 5/8) mottles; moderate medium subangular blocky structure; firm; few fine roots; few fine tubular pores; few faint clay films on all surfaces of peds; strongly acid; clear smooth boundary. (thickness of the Bt horizon ranges from 20 to 50 inches)

BC_1--42 to 55 inches; yellowish brown (10YR 5/4) fine sandy loam; weak very coarse prismatic structure parting to moderate medium subangular blocky; firm; few fine roots; few fine tubular pores; few faint clay films and silt coatings on all surfaces of peds; 15 to 30 percent brittleness; common fine prominent very dark grayish brown (10YR 3/2) moderately cemented spherical iron-manganese concretions in the matrix and common medium prominent strong brown (7.5YR 5/8) iron masses as irregular streaks along vertical surfaces of prisms; strongly acid; gradual smooth boundary.

BC_2--55 to 72 inches; yellowish brown (10YR 5/4) fine sandy loam; weak very coarse prismatic structure parting to moderate medium subangular blocky; firm; few fine roots; few fine tubular pores; few faint clay films and silt coatings on faces of peds; 20 to 40 percent brittleness; strongly acid; gradual smooth boundary. (thickness of the BC horizon ranges from 0 to 40 inches)

C--72 to 89 inches; yellowish brown (10YR 5/4) sandy loam; massive; firm; few fine distinct light brownish gray (10YR 6/2) irregular weakly cemented iron depletions and faint irregular weakly cemented iron masses in the matrix; strongly acid.

MAYODAN SERIES

The Mayodan series consists of very deep, well drained, moderately permeable soils that formed in residuum weathered from Triassic materials of the Piedmont uplands. Slopes range from 1 to 50 percent. Mean annual precipitation is 45 inches and mean annual temperature is 60 degrees near the type location.

TAXONOMIC CLASS: Fine, mixed, semiactive, thermic Typic Hapludults

TYPICAL PEDON: Mayodan sandy loam--forested. (Colors are for moist soil.)

A--0 to 3 inches; grayish brown (10YR 5/2) sandy loam; weak fine granular structure; very friable; many medium and coarse roots; strongly acid; clear smooth boundary. (2 to 12 inches thick)

E--3 to 12 inches; light yellowish brown (10YR 6/4) sandy loam; weak fine granular structure; very friable; many medium and coarse roots; strongly acid; clear smooth boundary. (0 to 12 inches thick)

BE--12 to 18 inches; strong brown (7.5YR 5/8) sandy clay loam; weak medium subangular blocky structure; friable; slightly sticky; slightly plastic; common fine and medium roots; few fine pores; few, faint clay films on faces of peds; strongly acid; clear smooth boundary. (0 to 8 inches thick)

Bt_1--18 to 36 inches; yellowish red (5YR 4/6) sandy clay; moderate medium subangular blocky structure; firm; sticky; slightly plastic; few fine and medium roots; common fine and medium pores; common, distinct clay films on faces of peds; few fine flakes of mica; strongly acid; gradual smooth boundary.

Bt_2--36 to 47 inches; yellowish red (5YR 4/6) sandy clay; many coarse distinct red (2.5YR 4/8) mottles; moderate medium subangular blocky structure; friable; sticky; plastic; few fine roots and pores; common, distinct clay films on faces of peds; few fine flakes of mica; few pockets of weathered fine-grained sandstone that crushes to clay loam; strongly acid; gradual smooth boundary. (Combined thickness of Bt horizon is 15 to 45 inches)

C--47 to 60 inches; dark red (2.5YR 3/6) and very pale brown (10YR 8/3) clay loam saprolite from fine-grained sandstone; massive; friable; strongly acid.

MONONGAHELA SERIES

The Monongahela series consists of very deep, moderately well drained soils formed in old alluvium derived largely from acid sandstone and shale on terraces of the Appalachian Ridges and Valleys. Permeability in the fragipan is moderately slow or slow. Slope ranges from 0 to 25 percent. Mean annual precipitation is about 45 inches, and mean annual air temperature is about 51 degrees F.

TAXONOMIC CLASS: Fine-loamy, mixed, semiactive, mesic Typic Fragiudults

TYPICAL PEDON: Monongahela silt loam - cultivated. (Colors are for moist soil.)

Ap--0 to 7 inches; dark grayish brown (10YR 4/2) silt loam; moderate fine granular structure; friable; many fine, and very fine roots throughout; slightly acid; abrupt smooth boundary. (6 to 10 inches thick)

BA--7 to 12 inches; yellowish brown (10YR 5/4) silt loam; weak fine subangular blocky structure; friable; common fine and very fine roots; slightly acid; clear smooth boundary. (0 to 7 inches thick)

Bt--12 to 22 inches; yellowish brown (10YR 5/6) silt loam; weak to moderate fine subangular blocky structure; friable; common fine and very fine roots; few fine distinct clay films on faces of peds; moderately acid; clear wavy boundary. (8 to 20 inches thick)

Btx_1--22 to 31 inches; yellowish brown (10YR 5/4) loam; weak coarse prismatic structure parting to weak coarse platy; firm; few fine distinct clay films on prism faces; common fine distinct yellowish brown (10YR 5/8) iron concentrations and light brownish gray (2.5Y 6/2) iron depletions; very strongly acid; clear irregular boundary. (7 to 14 inches thick)

Btx_2--31 to 42 inches; light yellowish brown (10YR 6/4) loam; weak very coarse prismatic structure parting to weak coarse platy; very firm, brittle; few fine distinct clay films on prism faces; many medium distinct yellowish brown (10YR 5/8) iron concentrations and light brownish gray (2.5Y 6/2) iron depletions; very strongly acid; clear wavy boundary. (8 to 15 inches thick)

Btx_3--42 to 52 inches; light yellowish brown (10YR 6/4) cobbly loam; weak very coarse prismatic structure parting to weak coarse platy; very firm, brittle; numerous fine pores; few fine distinct clay films on prism faces; many distinct yellowish brown (10YR 5/8) iron concentrations and light brownish gray (2.5Y 6/2) iron depletions; 25 percent sandstone cobbles; very strongly acid; clear wavy boundary. (0 to 12 inches thick)

C--52 to 65 inches; mixed strong brown (7.5YR 5/8) and light gray (N 7/) clay loam, pale yellow (2.5Y 7/4) crushed; massive; firm; 35 percent weathered shale, sandstone fragments and cobbles; very strongly acid.

DYKE SERIES

Soils of the Dyke series are very deep and well drained. They formed in colluvium. They are nearly level to steep soils on footslopes, fans, and high terraces. Mean annual temperature is about 53 degrees F and mean annual precipitation is about 40 inches. Slopes range from 0 to 35 percent.

TAXONOMIC CLASS: Fine, mixed, semiactive, mesic Typic Rhodudults

TYPICAL PEDON: Dyke loam – orchard (Colors are for moist soils.)

Ap--0 to 8 inches; dark reddish brown (5YR 3/4) loam; moderate very fine and fine granular structure; friable; many fine roots; 2 percent fine angular quartz gravel; strongly acid; abrupt smooth boundary. (0 to 12 inches thick)

Bt_1--8 to 14 inches; dark red (10R 3/6) clay; weak fine and medium subangular blocky structure; firm, sticky and plastic; few fine roots; 5 percent gravel of granodiorite, greenstone and 2 percent angular quartz gravel; thin patchy clay films; strongly acid; gradual smooth boundary. (6 to 16 inches thick)

Bt_2--14 to 36 inches; dark red (10R 3/6) clay; moderate fine and medium subangular blocky structure; firm, sticky and plastic; few fine roots; 2 percent gravel of granodiorite and greenstone; thin patchy clay films; strongly acid; gradual smooth boundary. (10 to 30 inches thick)

Bt_3--36 to 48 inches; dark red (10R 3/6) clay, many medium faint red (10R 4/6) mottles; weak medium subangular blocky structure; firm, slightly sticky, slightly plastic; thin patchy clay films; 15 percent gravel of granodiorite and greenstone; moderately acid; gradual smooth boundary. (5 to 12 inches thick)

2C--48 to 80 inches; red (2.5YR 4/6), dark red (10R 3/6), and strong brown (7.5YR 5/6) cobbly clay loam; 20 percent weathered yellowish brown and strong brown greenstone and granodiorite cobblestones and stones; 2 percent gravel of quartz; strongly acid.

APPOMATTOX SERIES

Depth Class: Very deep
Drainage Class (Agricultural): Well drained
Internal Free Water Occurrence: Moderately deep, common, thin or thick
Flooding Frequency and Duration: None
Ponding Frequency and Duration: None
Index Surface Runoff: Medium to very high
Permeability: Moderately slow
Shrink-Swell Potential: Moderate
Landscape: Piedmont upland
Landform: Low hill, fan
Geomorphic Component: Interfluve, head slope, side slope, and nose slope
Hillslope Profile Position: Summit, shoulder, backslope, footslope
Parent Material: Capping from mixed crystalline rock colluvium and old alluvium over residuum
Slope: 0 to 45 percent
Elevation (type location): Unknown feet
Frost Free Period (type location): 193 days
Mean Annual Air Temperature (type location): 57 degrees F.
Mean Annual Precipitation (type location): 46 inches

TAXONOMIC CLASS: Fine, mixed, semiactive, mesic Oxyaquic Hapludults

TYPICAL PEDON: Appomattox gravelly sandy loam (in an area of Appomattox-Cullen complex, 2 to 7 percent slopes), forested. (Colors are for moist soil, unless otherwise indicated.)

Ap--0 to 6 inches; brown (7.5YR 4/4) gravelly sandy loam; weak coarse subangular blocky and angular blocky structure; friable; many fine, medium, and coarse roots; 27 percent gravel; very strongly acid; clear smooth boundary. (0 to 14 inches)

Bt$_1$--6 to 9 inches; red (2.5YR 4/6) clay loam; weak fine medium and coarse subangular blocky structure; friable; slightly sticky, slightly plastic; many fine, medium, and coarse roots; few distinct clay films on faces of peds; 10 percent gravel; very strongly acid; clear smooth boundary.

Bt$_2$--9 to 36 inches; red (2.5YR 4/6) clay; weak fine and medium subangular blocky structure; friable; very sticky, plastic; common, fine, medium and coarse roots; common distinct clay films on faces of peds; 10 percent gravel; strongly acid; clear smooth boundary.

Bt$_3$--36 to 49 inches; red (2.5YR 4/6) clay; moderate thin and medium platy structure; firm; slightly sticky, slightly plastic; common distinct clay films on faces of peds; common medium and coarse distinct dark red (10R 3/6) and prominent yellowish brown (10YR 5/8) masses of oxidized iron; common medium prominent very pale brown (10YR 7/4) iron depletions; few fine roots; 10 percent gravel; strongly acid; clear smooth boundary.

Bt$_4$--49 to 80 inches; red (2.5YR 4/6) clay; moderate thin and medium platy structure; firm, slightly sticky, slightly plastic; few fine roots; common faint clay films on ped faces; common medium and coarse distinct dark red (10R 3/6) and prominent yellowish brown (10YR 5/8) masses of oxidized iron with sharp boundaries and light gray (10YR 7/2) iron depletions with sharp boundaries; 10 percent gravel; strongly acid; masses of oxidized iron and iron depletions are relic redoximorphic features. (Combined thickness of the Bt horizon is 35 to 60 or more inches.)

MATTAPONI SERIES

Depth Class: very deep
Drainage Class (Agricultural): moderately well drained to well drained
Internal Free Water Occurrence: moderately deep to deep, common
Index Surface Runoff: low to very high
Permeability: moderately slow
Landscape: Coastal Plain and Piedmont
Landform: uplands
Parent Material: fluvial and marine sediments on the Coastal Plain, fluvial sediments as capping on the Piedmont
Slope: 0 to 25 percent
Elevation (type location): 50 to 700 feet
Mean Annual Air Temperature (type location): 59 degrees F.
Mean Annual Precipitation (type location): 42 inches

TAXONOMIC CLASS: Fine, mixed, subactive, thermic Oxyaquic Hapludults

TYPICAL PEDON: Mattaponi sandy clay loam on a 10 percent convex slope in a naturally reseeded mixed pine and hardwood forests. (Colors are for moist soils.)

0i--1 to 0 inch; partially decomposed leaves and twigs.

Ap--0 to 8 inches; brown (10YR 4/3) sandy clay loam; moderate fine granular structure; very friable; many fine and medium roots; very strongly acid; abrupt smooth boundary. (0 to 12 inches thick)

Bt_1--8 to 14 inches; brownish yellow (10YR 6/6) sandy clay loam; moderate fine subangular blocky structure; friable, sticky, slightly plastic; common fine roots; few distinct clay films on faces of peds; very strongly acid; clear smooth boundary.

Bt_2--14 to 29 inches; reddish yellow (7.5YR 6/8) clay; moderate fine and medium subangular blocky structure; firm, sticky, plastic; common fine roots; few distinct clay films on faces of peds; very strongly acid; clear smooth boundary.

Bt_3--29 to 34 inches; yellowish brown (10YR 5/6) clay; moderate medium and fine subangular blocky structure; firm, sticky, plastic; common fine roots; few distinct clay films on faces of peds; very strongly acid; clear smooth boundary.

Bt_4--34 to 44 inches; brownish yellow (10YR 6/6) clay; moderate medium subangular blocky structure; firm, sticky, plastic; few fine roots; common prominent clay films on faces of peds; many medium and coarse red (2.5YR 5/6) areas of iron concentrations and many medium and coarse distinct light gray (10YR 7/1) iron depletions; very strongly acid; clear smooth boundary. (Combined thickness of the Bt horizon is 30 to 60 inches.)

C_1--44 to 56 inches; yellowish brown (10YR 5/6) clay; massive; very firm, sticky, very plastic; many medium distinct red (2.5YR 4/6) areas of iron concentrations and white (10YR 8/1) iron depletions; very strongly acid; abrupt smooth boundary.

C_2--56 to 68 inches; brownish yellow (10YR 6/6); sandy loam; massive, firm, 6 percent quartz gravel; many medium distinct light gray (10YR 7/2) and white (10YR 8/1) iron depletions; very strongly acid.

Chapter 6
Matching the System to the Soil and Site

The type of on-site wastewater system chosen for a parcel of land must meet the soil and site conditions of the property. *"The objective of a site investigation is to evaluate the characteristics of the area for their potential to treat and dispose of wastewater. A site evaluation should be done in a systematic manner to ensure the information collected is useful and is sufficient in detail"* (EPA Design Manual). The key to installing a reliable on-site system that minimizes pollution and disease is to identify suitable locations with a thorough site and soil evaluation. The evaluation determines suitability or points-out site limitations. *"Only after a site evaluation has been completed can the proper on-site system be designed"* (North Carolina Guidance Manual).

Sections

Matching the system to the site and soil is the ultimate goal of the site evaluation. In the end, this match is governed as much by the soil and site as by how the regulations are written. The condensed goal from the information gathered during the site evaluation (Chapter 5) is to derive three values: estimated percolation rate, installation depth, and center-to-center spacing. The entire objective of that chapter may be condensed into these three design parameters. These values are then used to design the system.

In some instances, site evaluation factors minimally comply with the regulations. When combining several of these minimum soil and site criteria, the chances of problems or drainfield failure increase. This concept is known as *Multiple Minimums* (Conta). For instance, a site may potentially function if there were only one minimum factor. But, the more factors that minimally meet the regulations, the higher the chances of drainfield malfunction.

Regulations and other pertinent information one should consider: Virginia Sewage Disposal Regulations (conventional and alternative), any applicable performance standards required for this specific case, soil and siting requirements. The regulations are designed to consider public health and water quality issues. In the end, the evaluator must remember that the soil beneath the trench must allow for aerobic treatment (figure 6-1) of effluent.

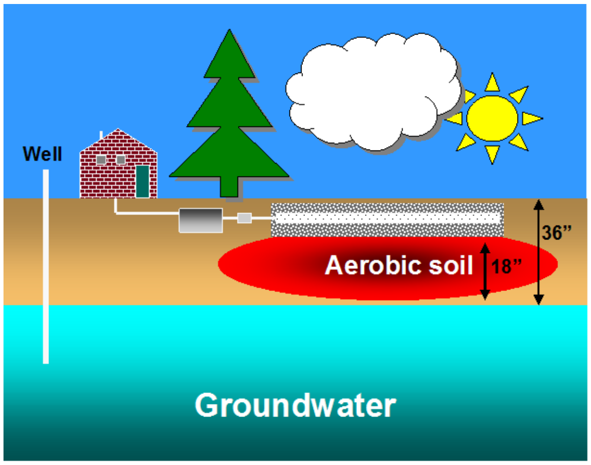


Figure: 6-1. Proper soil treatment requires that there be an aerobic zone (lots of O_2 and unsaturated) zone beneath the trench bottom. In Virginia, eighteen inches of aerobic soil beneath the trench are required to assure proper treatment of wastewater for conventional onsite systems. *(NCSU)*

At this point it is a good idea to verify if any other agency has regulation governing construction or other forms of site development. For example, some counties require additional reserve areas (figure 6-2) beyond the state minimums. Some have requirements for setback distances from certain drinking water reservoirs, etc. Ignorance of these requirements in localities can be disastrous.

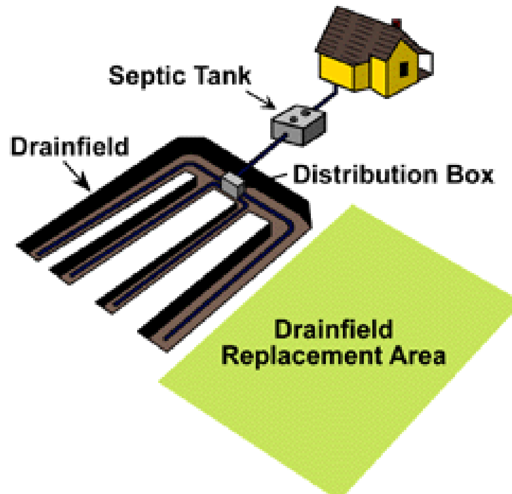


Figure: 6-2. In some VA counties, 100% reserve areas are required. *(EPA 2002)*

Soil evaluation reports should include profile description, site interpretation and give an idea about the variability expected on the site. Coupled with this information should be an assessment of the permeability at a specific depth through the proposed or designated area for the system. Additional information provided by the site/soil report should include; available space, set-backs, topography, drainage, features, well location, streams, etc. Included in the report should be a site sketch showing all off site features that could affect the system. In some cases linear loading and ground water mounding analysis may need to be investigated by the private sector.

Design Considerations

How does a septic system change the site hydrology? An onsite wastewater disposal system adds an *unnatural* amount of water to the site. The drainfield for a one-bedroom house is designed to discharge the equivalent amount of water per day to a ¼ inch precipitation event in a drainfield sized for a 45mpi soil. This is equivalent to 90 inches of rain per year over the drainfield. In Virginia, average precipitation is between 40-50 inches per year in most areas of the state. Adding the two together creates hydrology not unlike a rainforest. Therefore, the soil and the landscape must be able to absorb this water under unsaturated conditions and prevent water (effluent) from reaching the land surface.

Soil and Site Factors

Landscape and Slope

Figure: 6-3. This proposed footprint corner (blue flag) is too close to a drainage way. Would you expect the soils to be suitable here? What limiting soil features might one find on this landscape? *(Photos by Tom Saxton)*

These play an integral role in determining the type of system recommended for installation. Where extremely flat or extremely steep slopes are proposed for use, consideration should be given to the logistics of system installation. In some cases, slope may dictate that a specific type of system not be utilized. The practicality of installing trenches at shallow depths on extremely steep slopes and extremely flat slopes should be given specific attention. Landform configuration can also limit the ability of a site to support certain systems. The evaluator must understand the construction techniques and specific limitations of all approved systems in order to determine which systems can be supported on a particular landform. The practicality of installing trenches on very narrow landforms and in concave landforms should be given specific attention.

Concave landforms are more likely to accumulate water (figure 6-3 & 4) and result in wetter soil conditions than convex landforms. Convex landforms tend to encourage water to flow away and are typically drier than concave landforms. Flatter slopes tend to accumulate or hold more water than sloping sites. Therefore, convex landforms with steeper slopes are more suitable than flatter concave landforms for soil absorption systems. All other factors being equal, a system proposed on a convex steep slope may handle a higher loading rate than a system proposed on a flat concave slope. While there is no regulatory support for different design loading rates based upon landscape, from the technical perspective, Best Management Practices would suggest landscapes that are

The existing drainfield appears to be in a reasonable spot when there are dry conditions.

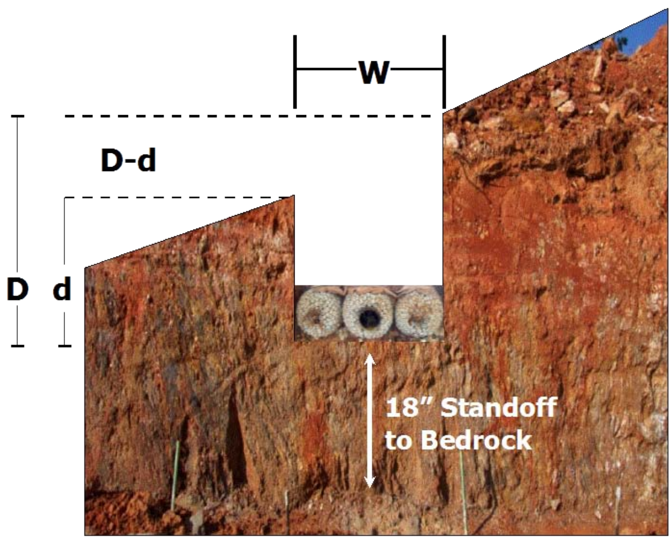
Figure: 6-4. Landscape position may in of itself dictate the success of a site. *(Photos by Tom Saxton)* acceptable, but possibly less than convex, should be designed with lower loading rates (larger drainfield).

Effect of Slope on Installation Depth

The depth of usable soil or saprolite to an unsuitable horizon; expansive mineralogy, restrictive horizon, soil wetness; rock, parent material, or unsuitable saprolite; and the steepness of the slope will determine the system option(s). A conventional system (3' wide gravel trench) on a level lot requires 36 inches of usable soil; 18-inch installation depth (minimum) plus 18-inch standoff. But on a 26% slope, the required soil depth would be 45 inches (Minimum depth (x) = {(slope -8)/2} + 18 (inches) or 12" (shallow-placed system)). On very steep tracts the difficulty of installation will determine the type of system chosen. It is very difficult, if not impossible to install a conventional (gravel) system on a 50 percent slope. Terracing of the site is required on slopes greater than 50 percent in Virginia.

Table: 6-1. Difference in upslope and downslope side of trenches by slope and trench widths on selected slopes.

Slope (%)	Trench Width (inches) 12	24	36
2.0	0.2	0.5	0.7
8.0	1.0	1.9	2.9
12.0	1.4	2.9	4.3
18.0	2.2	4.3	6.5
24.0	2.9	5.8	8.6
30.0	3.6	7.2	10.8
34.0	4.1	8.2	12.2
44.0	5.3	10.6	15.8
50.0	6.0	12.0	18.0



Example: for a trench width (W) of 36" and a slope of 30%, the difference between the upslope and downslope sides of the trench (D-d) is 10.8". For a trench depth (d) of 18" and a minimum separation from the trench bottom to the underlying bedrock of 18", the required minimum soil depth is:

18 + 18 + 10.8 = 46.8"

Figure: 6-5. Difference in depth in inches between upslope and downslope side of trench. *(Photo by Tom Saxton)*

12 VAC 5-610-950. Absorption area design.
F. Lateral separation of absorption trenches. The absorption trenches shall be separated by a center to center distance no less than three times the width of the trench for slopes up to 10%. However, where trench bottoms are two feet or more above rock, pans and impervious strata, the absorption trenches shall be separated by a center to center distance no less than three times the width of the trench for slopes up to 20%. The minimum horizontal separation distance shall be increased by one foot for every 10% increase in slope. In no case shall the center to center distance be less than 30 inches.

Aspect

Aspect is factor the site evaluator should consider in drainfield design in mountainous regions. Aspect, or the direction the slope faces, can affect soil development and soil moisture content. Although not mentioned in the regulations, aspect may play a critical role in determining a suitable location for a drainfield. Southern facing slopes are in general drier and have deeper soils than do northern facing slopes. Therefore, the evaluator should consider initiating the site evaluation on southern facing slopes to increase the chance of encountering deep, well drained soils.

North facing slopes can have darker, thicker A horizons than those found on southern exposures. The organic enriched layers related to the moist conditions are due to the lack of sun exposure. To account for moister conditions on north/northeastern facing slopes, the Best Management Practice would be to increase the estimated percolation rate and/or decrease the installation depth.

Lateral Flow and Groundwater Mounding

In looking at the entire soil profile, which horizon becomes the most critical to design? In essence all are critical, but the least permeable will be the so-called weakest link. Slope must also be considered in relation to lateral flow and mounding. Although we would like to think of the drainfield as only influencing or being influenced by the soil directly beneath; it is however, related to the surrounding soil and landscape. Therefore, evaluations should characterize the site and soil variability. We must consider three zones in the soil or site with regards to water movement. First is the *infiltrative surface* at the

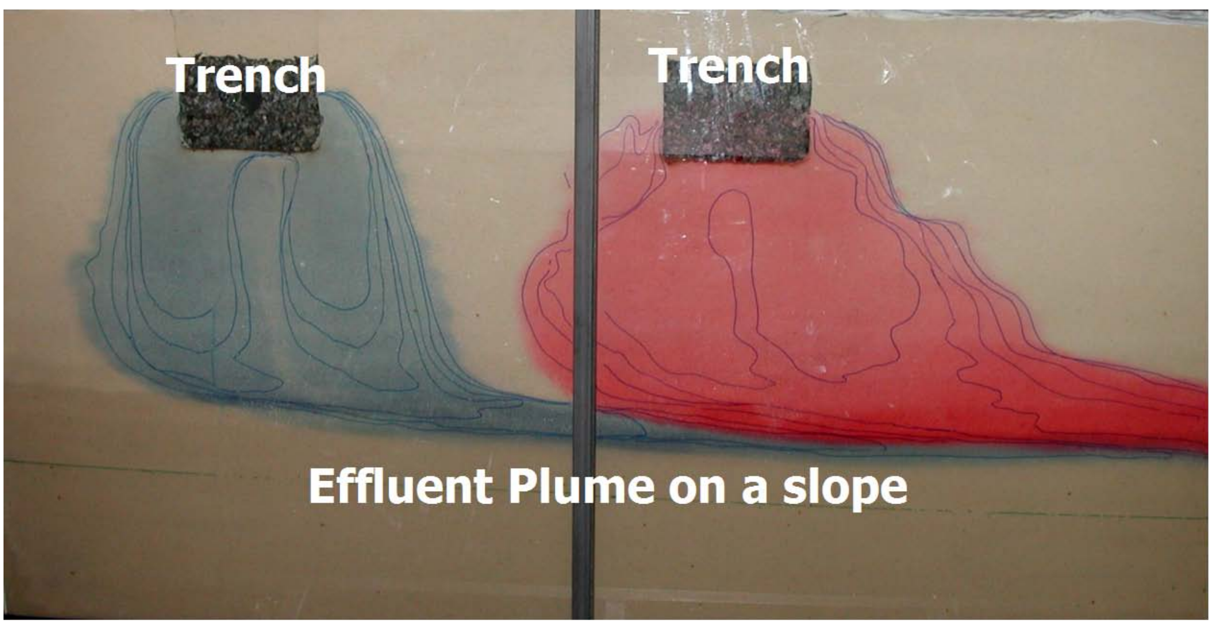


Figure: 6-6. The lateral window in which the effluent travels when dispersed on a sloping landscape. *(NCSU)*

trench bottom. Second is the *least permeable horizon* beneath the trench bottom. Third and final is the *lateral window* (figure 6-6 & 7) through which the water must eventually flow.

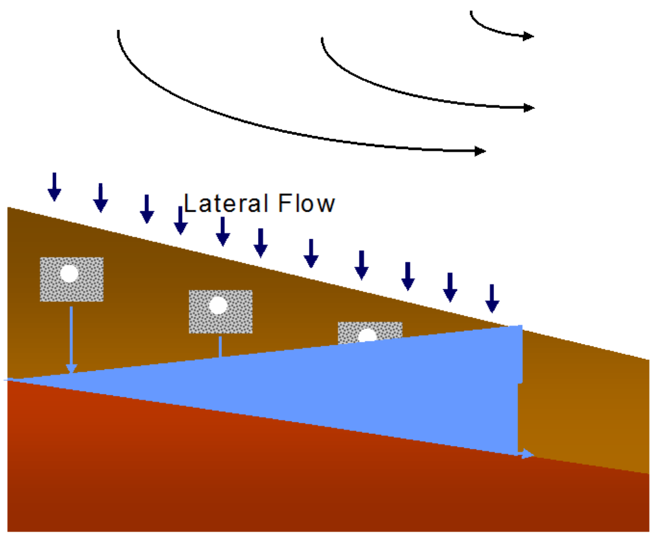


Figure: 6-7. The lateral "window" the effluent must flow through may cause mounding in downslope trenches. *(NCSU)*

Figure: 6-8. Ponding in trench due to mounding in Mecklenburg County. *(Photo by Tom Saxton)*

Groundwater mounding may result as the amount of water entering the area exceeds the capacity of the soil/site to disperse the water. The worst-case result of this would be ground water ponding in the trench or reaching the surface (figure 6-8). As slope of impermeable layers increases the gradient of the ground water increases and the actual mound may be less. However, down slope effects should be considered.

Vegetation

Vegetation can have a profound impact upon the operation of a system. Roots of most plant species will invade a drainfield, especially hydrophilic (water-loving) vegetative species. While the regulations require a 10-foot minimum separation distance, much greater distances are recommended if possible. Small roots from trees and large shrubs will extend to and beyond the plant drip-line and are concentrated at shallow depths in the soil (figure 6-9 & 9B). These roots will seek out the water and nutrients available in wastewater by invading drainfield components such as the septic tank, distribution box, and piping. Roots from a large maple may travel in excess of 50 feet to invade an onsite sewage disposal system. While not a regulatory requirement Best Management Practices suggest much greater distances than ten feet.

12 VAC 5-610-700. Site preparation and alteration.

B. Removal of vegetation. ***Vegetation*** such as maple, cottonwood, willows and other plant species with extremely hydrophilic (water loving) root systems shall be removed for a minimum of 10 feet from the actual absorption areas. Other trees should be removed from the absorption area.

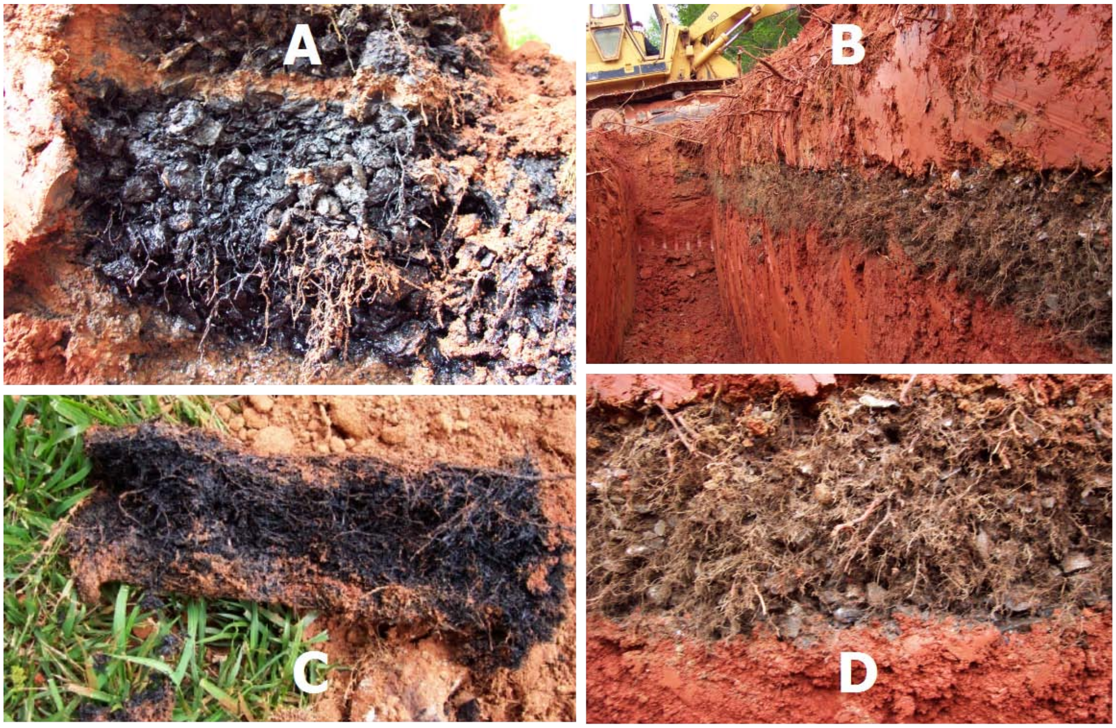


Figure: 6-9. Roots have invaded these drainfields. Photo "A" also shows flooding by sewage sludge due to poor septic tank maintenance. "B" and "D" show infiltration of roots throughout the entire drainfield. There were two large maple trees, one on either end of this drainfield. "C" is a root mass removed from a header pipe. *(Photos by Tom Saxton)*

Figure: 6-9B. Root invasion ultimately caused this drainfield to fail. *(Photos by Tom Saxton)*

Soil Properties

Soil Depth

This plays an integral role in determining the type and size of system recommended for installation. Where soils with extremely shallow depths are proposed for use, consideration should be given to the logistics of system installation and larger areas to aid in dispersal. In some cases, soil depth may dictate that a specific type of dispersal system not be utilized. It may also dictate that a specific level of pretreatment must be utilized.

Structure

Soil structure is the aggregation of soil particles into larger units called peds. The more common types of structure are granular, angular blocky, subangular blocky, and platy. Structureless soils include single-grain soils (e.g., sand) and massive soils. The grade, size, shape, and orientation of soil peds influence water movement in the soil profile. This is especially true in fine-textured soils. Smaller peds create more inter-pedal fractures, which provide more flow paths for percolating water. Grade (table 4-16), which defines the distinctness of peds, is important for establishing a soil-loading rate for wastewater dispersal. A soil with a “strong” grade of structure has clearly defined fractures or voids between the peds for the transmittance of water. The interpedal fractures and voids in a soil with a “weak” grade are less distinct and offer more resistance to water flow. Soils with a strong grade can accept higher hydraulic loadings than soils with a weak grade.

12 VAC 5-610-490. Characteristics of soils that determine suitability.
C.
1. Estimated rates. The soil classifications contained in subdivision B 1 of this section have been assigned the following estimated rates in minutes per inch for the purpose of design. These rates may be modified when experience has shown that because of ***soil structure*** the texture group has a demonstrated rate different from that

Platy (figure 6-10) and massive soils restrict the vertical movement of water. *(EPA Onsite Wastewater Treatment Systems Manual, 2002).* In some cases, soil structure may be more important than texture in determining water movement in soils.

Figure: 6-10. What does the horizontal feature in the middle of this collapsing basement cut imply about soil structure? “Platy” *(Photo by Tom*

Permeability

The estimated percolation *(perc-*jargon*)* rate in minutes per inch and the daily flow will determine the system size. For example, a conventional system (gravel trench) with an estimated percolation rate of 45 minutes per inch and a daily flow of 450gpd will require 344 linear feet of 3-foot wide trenches or 1032 ft^2 of drainfield.

The *percolation* rate chosen is determined by the soil/site conditions and by the type of system under consideration. For example, a loam-textured soil would have an estimated percolation rate of 31-45mpi. However, the dimensions of the footprint may change depending upon the dispersal method and or the level of treatment. The site evaluator should work closely with the designer to determine the appropriate footprint for the given site, system, and regulation as applicable.

The property owner or his representative must be given the results of the soil /site evaluation. If the site can be permitted, the wastewater system option(s) for the property must be presented and explained to the applicant. Any options for an unsuitable site must be provided to the applicant. Some types of systems may require additional study. For example, mass drainfields (discharge in excess of 1200gpd per acre) have additional requirements. Saturated hydraulic conductivity tests at the proposed installation depth and at the most restrictive horizon within a 4-foot zone beneath the proposed installation depth are required for mass drainfields.

Coarse Material

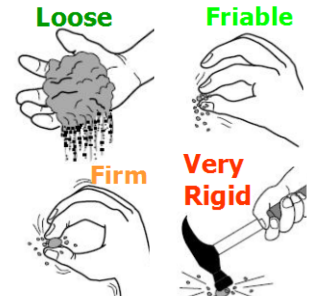
Figure: 6-11. Is it possible to achieve treatment in 50 linear feet of these cobbles before the effluent reaches the stream? *(Photos by Tom Saxton)*

While the Virginia Sewage Handling and Disposal Regulations do not have specific requirements regarding coarse fragments, Best Management Practices and protection of the environment would suggest careful consideration when encountering these soils. Commonly, this material is located on floodplains and alluvial fans of high velocity streams. They are very young and have not developed soil characteristics that enable treatment of effluent. These deposits will act as conduits to the nearby stream. In very coarse soils, water can travel so rapidly through the profile that it does not contact enough surfaces to provide good wastewater treatment. Coarse soils allow rapid disposal of wastewater, but treatment may be inadequate. Soils with even a small amount of fine particles can provide excellent waste treatment if the wastewater contacts the particle surfaces. Contrary to what Section 610-490 prescribes; Best Management Practices would suggest that treatment and/or the use of an unsaturated flow distribution system be considered if there is no alternative to using such a site.

12 VAC 5-610-490. Characteristics of soils that determine suitability.
D.
2. ***Stoniness***. The term stoniness pertains to the relative proportions of stones present in a soil. Stoniness reduces the soil volume for absorption, and therefore, may require a larger subsurface soil absorption field than would be indicated by soil texture.

Consistence

In general, this refers to attributes of soil as expressed in degree of cohesion and adhesion, or in resistance to deformation or rupture. Consistence includes the resistance of soil material to rupture; the resistance to penetration; the plasticity, toughness, or stickiness of puddled soil material; and the manner in which the soil material behaves when subjected to compression. Consistence is highly dependent on the soil-water state. Rupture classes that exceed friable (firm or greater) tend to impede or block subsurface wastewater flows. These soils can become cemented when dry and can exhibit considerable plasticity when wet. Soils that exhibit very firm and extremely firm consistence are not recommended for conventional infiltration systems *(EPA Onsite Wastewater Treatment Systems Manual, 2002)*. During construction, the drainfield trenches must not be installed during wet conditions. Failure to heed this requirement may lead to *smearing* and *compaction* resulting in a reduction of the soil's infiltrative capacity. Other than in extremely sandy soils (texture group I), a rule of thumb is that if the soil has enough moisture to form a soil ribbon and make a texture determination, it is moist enough to smear and compact. Therefore, installation of the drainfield should be delayed until the soil is drier.



12 VAC 5-610-700. Site preparation and alteration.

A. Preservation of ***soil structure***. The preservation of the original structure of the soil in the area selected for placement of the absorption trenches is essential to maintaining the percolative capacity of the soil.

1. Prohibition on construction. Subsurface soil absorption systems shall not be constructed in Texture Group III and IV soils during periods of wet weather when the soil is sufficiently wet at the depth of installation to exceed its plastic limit. For the purpose of this chapter, the plastic limit of a soil shall be considered to have been exceeded when the soil can be rolled between the palms of the hands to produce threads 1/8 inch in diameter without breaking apart and crumbling.

2. ***Soil compaction***. Special caution shall be taken in allowing wheeled and tracked vehicles to traverse the area selected for placement of the absorption systems before, during and after construction of the trenches, especially during wet weather. Precaution is especially important where Texture Group III and IV soils are involved. Alteration of soil structure by movement of vehicles may be grounds for rejection of the site and/or system or revocation of the permit.

3. ***Soil smearing***. Excavating equipment utilized to construct the absorption system shall be so designed as not to compress or smear the sidewalks or bottom of the system. Excessive smearing of the usable absorption trench sidewalls or bottom during construction may result in irreversible damage to the soil infiltrative surface and may be grounds for rejection of the site and/or system.

Restrictive Horizons

Soil properties like penetration resistance, rooting depth, and clay mineralogy are important indicators of soil porosity and hydraulic conductivity. Penetration resistance is often correlated with the soil's bulk density. *Bulk density* is the measure of the weight (mass) of the soil per unit bulk volume (g/cc). The greater the penetration resistance, the more compacted and less permeable the soil is likely to be. Rooting depth is another measure of bulk density and also soil wetness. Clay minerals such as

Figure: 6-12. Increased bulk density below these roots forces them to grow horizontally. *(Photo by Tom Saxton)* montmorillonite, which expand when wetted, reduce soil permeability and hydraulic conductivity significantly.

The depth that restrictive layers are encountered is important because these layers retard or stop water flow. So, even if you have described the soil to five feet, if there is a restriction starting at sixteen inches, the *effective depth of soil* useable for wastewater treatment and disposal is only sixteen inches! The degree of limitation within various types of restrictive layers may vary. Therefore, the evaluator should not only understand that a restrictive layer is present, but should also determine the impact that the layer may have on the functioning of a proposed soil absorption system (figure 6-13). When the thickness or lateral continuity, or density of a restriction is in question, field testing (saturated hydraulic conductivity or percolation tests) should be performed.

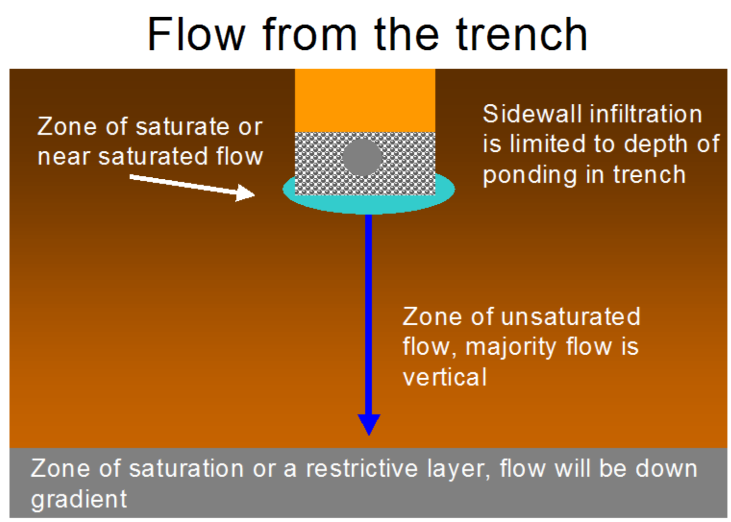


Figure: 6-13. Vertical flow in a trench *(NCSU)*.

Types of Restrictions

Bedrock is always considered a restriction with respect to subsurface soil absorption systems. It is designated R or Cr.

Pans and Cemented Layers are always considered a restriction with respect to subsurface soil absorption systems. One or more of the following items typically indicates the presence of a pan or cemented layer. It meets the qualifications for subordinate soil horizon designation of *d (densic layer), m (strong cementation), v (plinthite), x (fragipan)* or a combination of firmness, brittleness, and a higher bulk density than adjacent layers. The horizon may have vesicular pores and/or platy or prismatic structure. It may have massive structure when not associated with saprolite.
Root penetration may be restricted. It is not unusual to have gravels in a pan or dense layer, but that is not necessarily an indicator of increased permeability. In this case, this layer is dense and restrictive.

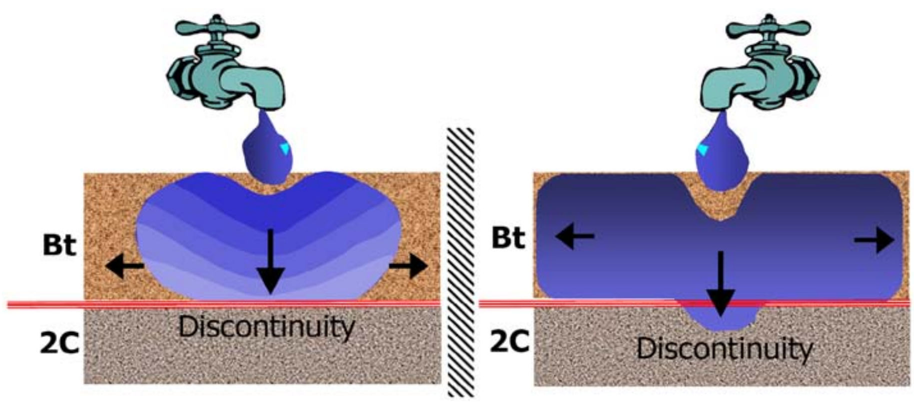


Figure: 6-14. A discontinuity at the Bt/2C contact impedes the downward flow of water. Therefore, the water moves laterally until the entire area is saturated before it moves downward. This may also be true for other kinds of restrictions. *(TS)*

Discontinuities are not always considered a restriction with respect to subsurface soil absorption systems (figure 6-14). However, they are usually at least restrictive. The presence of one or more of the following items may indicate the presence of a restriction due to a discontinuity:

A stone line associated with a horizon boundary

Redoximorphic features associated with the contact between two soil horizons

Significant differences in soil moisture content observed in adjacent soil horizons

Significant differences in soil texture observed in adjacent soil horizons

Significant changes in sand size in adjacent soil horizons

Rock fragments don't have the same lithology as the underlying bedrock

Changes in the shape of rock fragments (e.g. round gravels overlying a horizon with angular rock fragments)

Significant differences in soil structure or matrix color observed in adjacent soil horizons when textures are similar

Strongly Contrasting Textures are not always considered a restriction with respect to subsurface soil absorption systems (figure 6-14). The presence of one or more of the following items may indicate the presence of a restriction:

Adjacent soil horizons with textures that are not adjacent to each other on the U.S.D.A. textural triangle

Horizon boundary described as abrupt

Redoximorphic features associated with the contact between two soil horizons

Significant differences in soil moisture content observed in adjacent soil horizons

Very High & High Shrink Swell Soils are considered to be a restriction with respect to subsurface soil absorption systems.

One or more of the following items may indicate the presence of high or very high shrink swell soils:

Presence of slickensides

High clay content with unusually long ribbons when texturing

Estimated clay mineralogy class dominated by 2:1 clays

Mafic or mixed mineralogy rock types as the probable parent material

Saprolite with mafic mineral or color indicators (shades of black, green, or olive)

Presence of pressure faces

Presence of sand coated ped faces in a Bt soil horizon

Figure: 6-15. Not only are shrink-swell unsuitable for onsite wastewater systems, they have severe limitations for other uses as well. *(Photo by Tom Saxton)*

Figure: 6-16. The presence of slickensides indicates smectitic clays that have a high or very high potential for shrinking and swelling. *(Photo by Tom Saxton)*

Figure: 6-17. Slickensides indicate the presence of smectitic clays that have a high or very high potential for shrinking and swelling. *(Photo by Tom Saxton)*

Figure: 6-18. Pressure faces may also indicate shrink swell soils. *(Photo by Tom Saxton)*

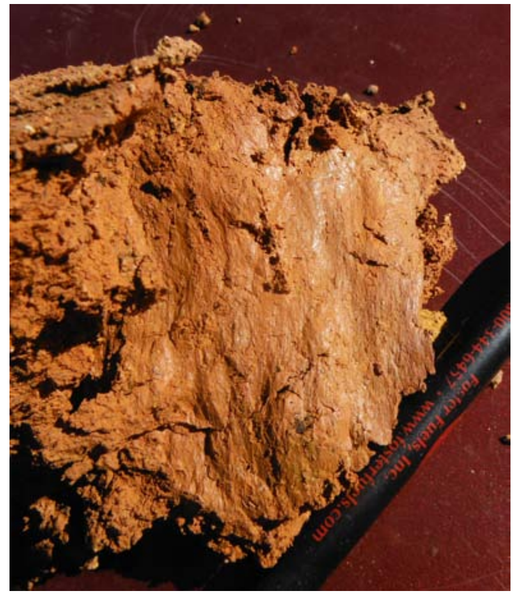


Figure: 6-19. This wall is collapsing due to an unstable footing in shrink-swell soils. *(Photo by Tom Saxton)*

Figure: 6-20. This wall is cracking due to shrink-swell soils. *(Photo by Tom Saxton)*

Designing for Restrictive Horizons

Soils with restrictive features have limited air and liquid exchange and movement. Therefore, these soils will have limited capacity to remove and to renovate wastewater effluent. The regulations acknowledge that soils with restrictive layers should require several safety factors that are greater than the standard drainfield. To compensate for the soil restriction, several soil features are required as shown in the regulation text box below:

12 VAC 5-610-950. Absorption area design.
C. Placement of absorption trenches below soil restrictions. Placement of the soil absorption trench bottom below soil restrictions as defined in 12 VAC 5-610-490 D, whether or not there is evidence of a perched water table as indicated by free standing water or gray mottlings or coloration, requires a special design based on the following criteria:

1. The soil horizon into which the absorption trench bottom is placed shall be a Texture Group I, II or III soil or have an estimated or measured percolation rate of less than 91 minutes per inch.

2. The soil horizon shall be a minimum of three feet thick and shall exhibit no characteristics that indicate wetness on restriction of water movement. The absorption trench bottom shall be placed so that at least two feet of the soil horizon separates the trench bottom from the water table and/or rock. At least one foot of the absorption trench sidewall shall penetrate the soil horizon.

3. A lateral ground water movement interceptor (LGMI) shall be placed upslope of the absorption area. The LGMI shall be placed perpendicular to the general slope of the land. The invert of the LGMI shall extend into, but not through, the restriction and shall extend for a distance of 10 feet on either side of the absorption area (See 12 VAC 5-610-700 D 3). *

4. Pits shall be constructed to facilitate soil evaluations as necessary.

** See LGMI Section later in this chapter*

Soil Wetness

Redoximorphic features are used to identify aquic moisture regimes in soils. Features of soil wetness occur when the soil is saturated with water during long periods, an indicator of possible restrictive horizons, seasonal high water tables, or perched water tables. The presence of redoximorphic features suggests that the surrounding soil is periodically or continuously saturated. This condition is important to identify because saturated soils prevent re-aeration of the *vadose zone* (unsaturated)

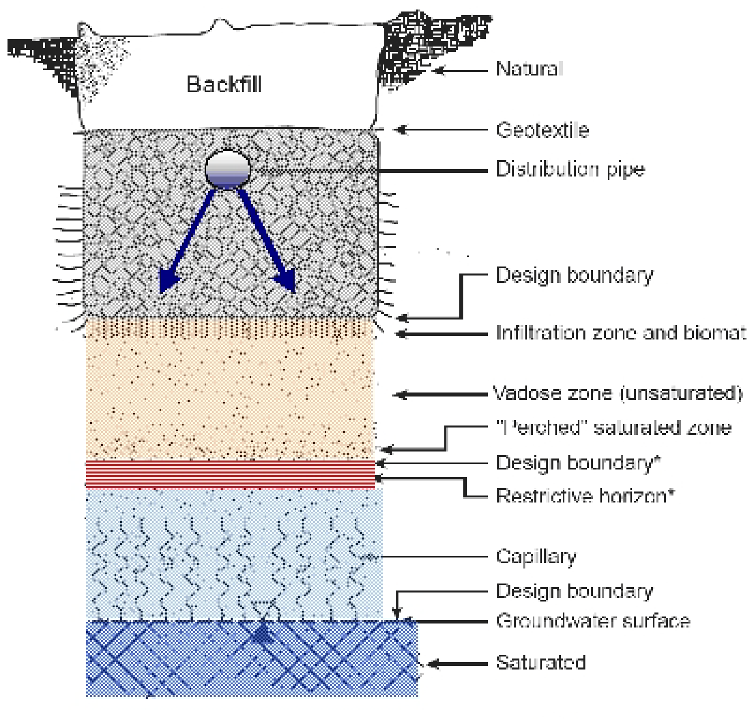


Figure: 6-21. Subsurface wastewater infiltration system design/performance boundaries. *(EPA)* (figure 6-18) below infiltration systems and reduce the hydraulic gradients necessary for adequate drainage. Saturated conditions can lead to surfacing of wastewater or failure due to significant decreases in soil percolation rates.

Wetness plays an integral role in determining the type of system recommended for installation. Where soils with extremely shallow water tables are proposed for use, consideration should be given to the logistics of system installation, the dispersal technology, and the level of pretreatment. In some cases, the depth to water table may dictate that a specific type of dispersal system not be utilized. It may also dictate that a specific level of pretreatment must be utilized.

Soil and Site Disturbance

While installing at shallow depths is allowed and soils often have good permeability near the surface, the drainfield will be subject to physical damage (figure 6-18B). It is also more susceptible to root invasion. Tree throw, vehicular traffic (lawnmowers, cars truck, etc.) may damage the system. Best Management Practices would suggest these factors be considered in the design. For instance, fencing the area may protect it from physical damage. The site may be easily damaged if worked with excavating equipment during wet periods or even at all. Best Management Practices would suggest requirements such as hand removal of vegetation and leaving stumps in place.

12 VAC 5-610-700. Site preparation and alteration.

2. ***Soil compaction***. Special caution shall be taken in allowing wheeled and tracked vehicles to traverse the area selected for placement of the absorption systems before, during and after construction of the trenches, especially during wet weather. Precaution is especially important where Texture Group III and IV soils are involved. Alteration of soil structure by movement of vehicles may be grounds for rejection of the site and/or system or revocation of the permit.

3. ***Soil smearing***. Excavating equipment utilized to construct the absorption system shall be so designed as not to compress or smear the sidewalks or bottom of the system. Excessive smearing of the usable absorption trench sidewalls or bottom during construction may result in irreversible damage to the soil infiltrative surface and may be grounds for rejection of the site and/or system.

Figure: 6-22. Compaction during construction of this shallow system on a 30% slope may reduce the lifespan of the system. *(Photo by Tom Saxton)*

Design Configurations

An on-site system that is a good match with the soil and site conditions should function properly for a long time, as long as it isn't abused or neglected. No system will function for long when daily flows are exceeded, the characteristic of the effluent changes, no maintenance is performed, or components are damaged. Conventional drainfields are (in effect) designed to fail through a process often referred to as *creeping failure*. Effluent enters a trench and is absorbed into the first few feet of soil. As the system ages, the soil becomes less permeable in this saturated anaerobic portion of the trench, consequently, effluent creeps further into the trench; whence, the term creeping failure.

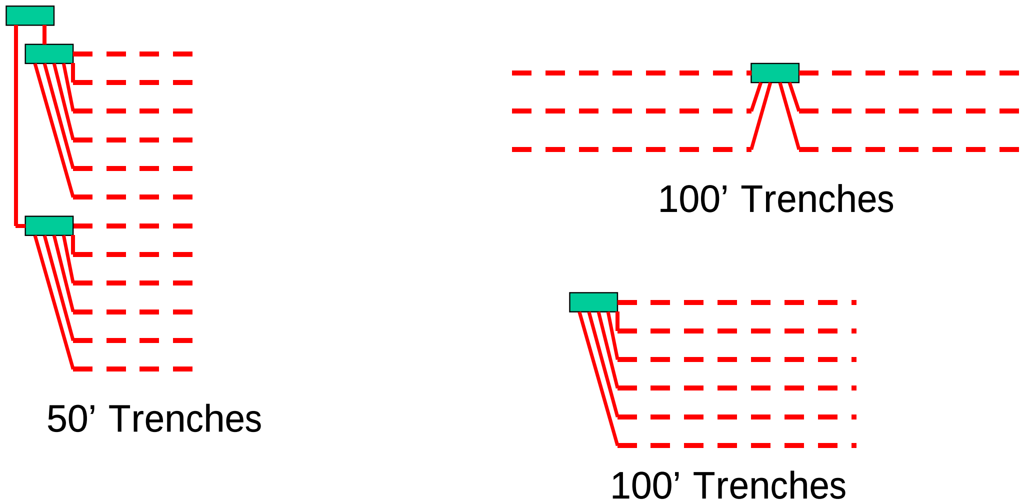


Figure: 6-23. These drainfields are all the same square footage. Which drainfield configuration is better for the hydraulic loading of the soil and slope?

There are many considerations in figure 6-23 above. The drainfield on the left will result in greater *slope (linear)* hydraulic loading on the down hill side of the drainfield (see figures 6-24 and 6-25). However, since there are more trenches and effluent is dispersed in the first few feet of a trench, the *soil-loading* rate may actually be less due to the increased surface area at the beginning of the trenches. This is because the same amount of wastewater is spread over more trenches. The effluent rarely flows more than a few feet into a drainfield until a biomat begins to form at the soil interface. Therefore, the infiltrative surface of the drainfield with 50-foot trenches may remain aerobic for a longer period of time than the other two designs. However, this is slope dependent. A steeper slope may result in greater hydraulic loading downhill, whereas a flatter landscape would be less.

Of the two drainfields on the right, the bottom will lead to greater downslope hydraulic loading. The top right drainfield will load the slope less than any of the three and is the best-suited design for steep slopes.

If the soil is permeable, the slope hydraulic loading is of less concern. However, if the soil has a restriction or is slowly permeable, effluent will move laterally and slope (linear) hydraulic loading will be a problem. Each of these designs has merit, depending upon site conditions. One design does not fit all sites.

Once again, consider the 3 zones of infiltration or infiltrative surfaces of a septic system. Zone A is the trench bottom and biomat, zone B is the most limiting soil zone somewhere below the trench, and zone C is the “window” or horizontal zone that water must move through as it moves down gradient from the system. The ability to keep the system aerobic will depend on not exceeding the hydraulic conductivity of the most limiting of these layers. Therefore, the most limiting layer is the one that must be considered for design purposes. The traditional design of a septic system uses many short trenches for the system. The lateral flow away from the system has to pass through a narrow window down slope. By increasing the length of the drainfield along the slope by using fewer, longer trenches, the effluent is spread over a wider window. For example, perhaps 1 or 2 long trenches may overcome the limitation of the down slope window. Unfortunately, drainfield configuration is rarely this simple as it is generally constrained by lot size and shape. While not a regulatory requirement, Best Management Practices would suggest that slope as well as restrictions be considered when choosing a design configuration.

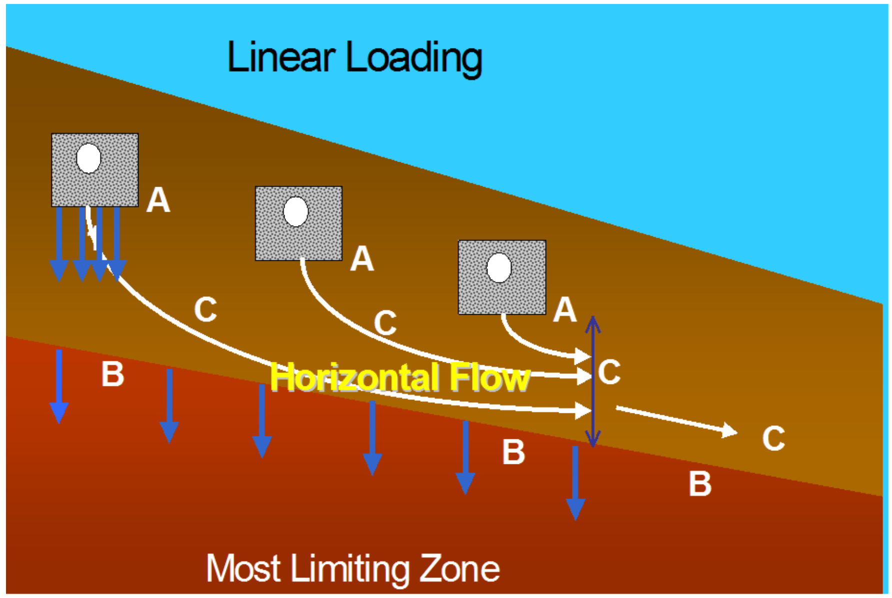


Figure: 6-24. On any given septic system 3 zones of infiltration or infiltrative surfaces need to be considered. Zone A is the trench bottom and biomat, zone B is the most limiting zone below the trench, and zone C is the “window” or horizontal zone that water must move through as it moves down gradient from the system. The ability to keep the system aerobic will depend on not exceeding the hydraulic conductivity of the most limiting of these layers (B). The most limiting layer is the zone that must be considered for design purposes. *(NCSU)*

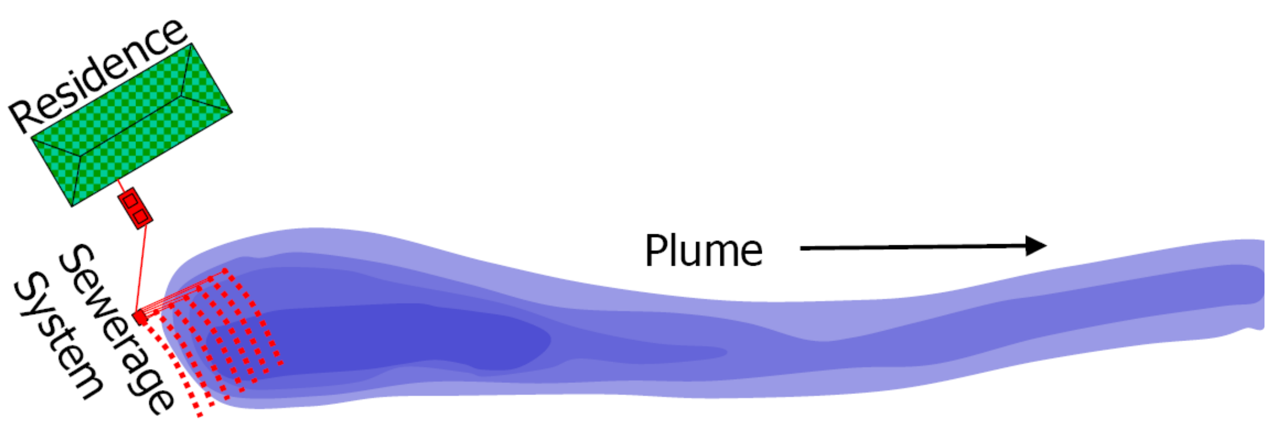


Figure: 6-25. Linear loading results in an effluent plume down gradient of the disposal system. *(TS)*

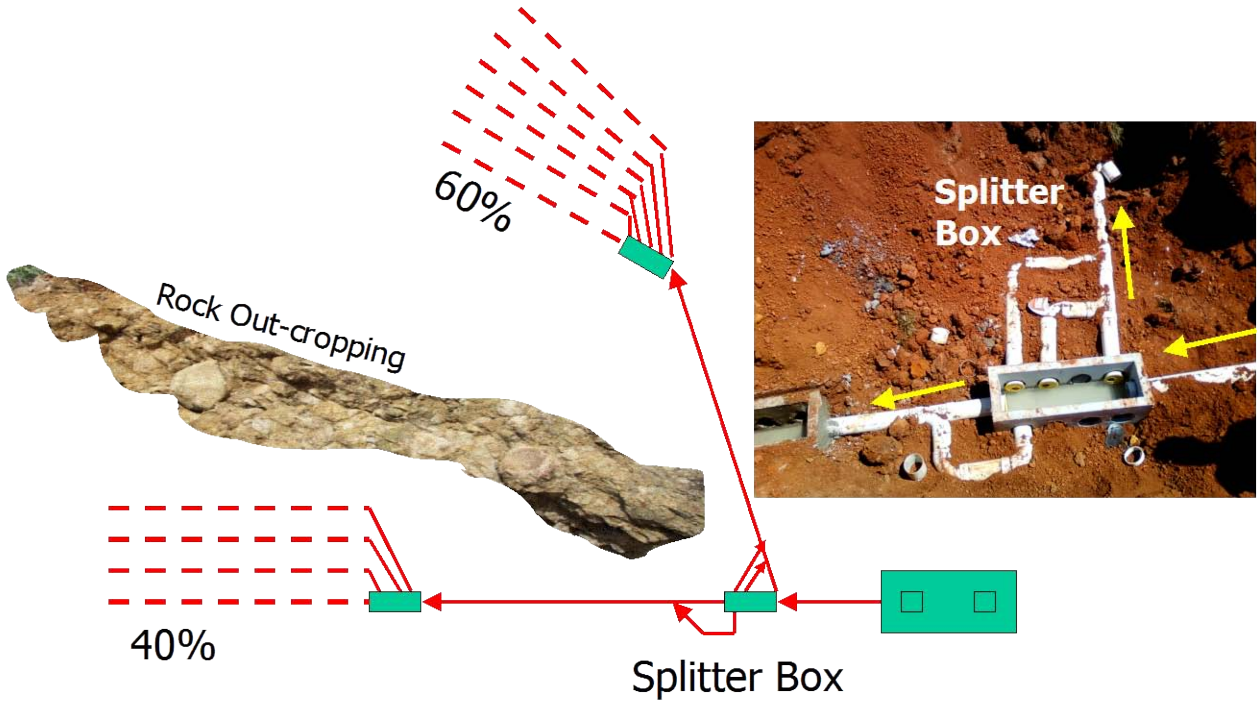


Figure: 6-26. This configuration was necessary due to the rock outcropping or possibly a discontinuous soil feature. The drainfield is divided into cells. The cell on the left is 2/5ths or 40%; the one at the top is 3/5ths or 60%. The system is divided into five pipes leaving the splitter box. Three leave the splitter box at the top to the 60% cell. Two leave the splitter box towards the 40% cell. This is an inexpensive method to utilize suitable soil areas that may be small and disconnected. *(TS)*

Do you see an issue here for a gravity system?

This configuration has more than 12 splits and would require enhanced flow (see Section 610-930 below).

12 VAC 5-610-930. Gravity distribution.

A. Enhanced flow distribution. Enhanced flow distribution is the initiation of the effluent flow to the distribution box by pump or siphon for the purpose of assuring more uniform flow splitting to the percolation lines. Enhanced flow distribution shall be provided on systems where the flow is split more than ***12 times*** or the system contains more than 1200 linear feet of percolation lines. For the purpose of this chapter, enhanced flow distribution is considered to produce unsaturated soil conditions.

Reviewing Work by Others

Whether you are a private or public sector evaluator, you will be confronted with past site evaluations and approvals or the need to review new ones. The ability to recognize difficulties from the desk is an invaluable time saver. At the very least, questionable plat configurations and contours may lead one to the field to verify the accuracy of the plat and or the proposed design. It is often difficult to determine the source of an error. It may be survey error or it may be an error in design. But, the designer (permitter) is ultimately responsible for the submittal. Many sites may have been approved when the department was short-staffed and there was not time to field-check potential mistakes. Or, someone that is no longer legally qualified to represent the design may have evaluated the site.

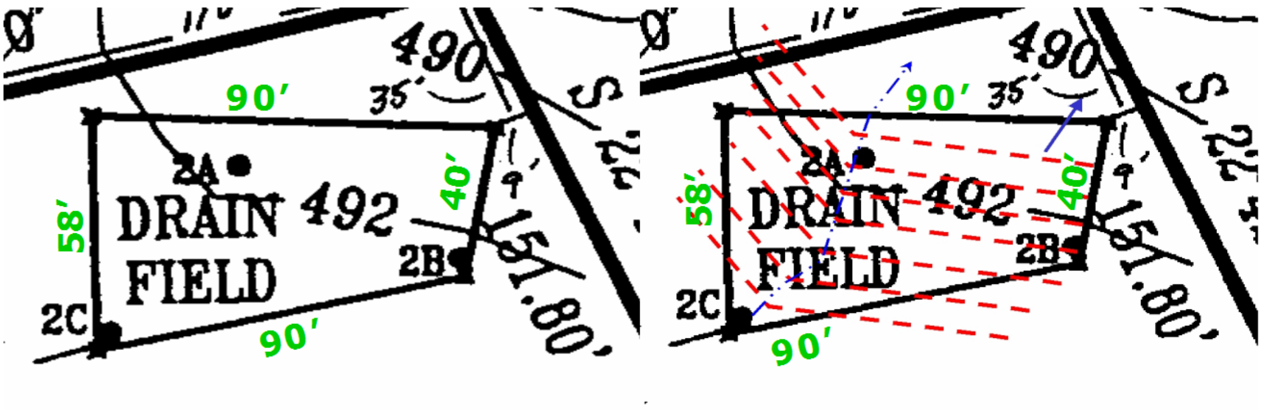


Figure: 6-27. The plat on the left is an approved drainfield footprint. Four trenches on 9-foot centers, 86 feet long must fit inside this footprint. Will they fit? Notice the contour line (only one in the drainfield). The blue arrow to the right represents the slope direction. The red lines represent contour lines had more been shown. What do the contours reveal about the landscape? There is a natural drainageway within the footprint. Four trenches 90 feet long will not fit in this footprint. Even if there were not a drainageway in the footprint, the drainfield would not fit due to the angle of the contours relative to the proposed footprint. Do you think the area is adequately represented with soil borings?

The current evaluator should revisit everything. Past recommendations and designs may be helpful, but ultimately, the current designer will be responsible for the work holding their signature, whether a public or private sector evaluator. There are no regulatory requirements for this. You are allowed to pass on work performed by others. However, Best Management Practices would suggest that you sign your own work. You are the licensee. Your *credentials are at stake* and you are responsible for the final product.

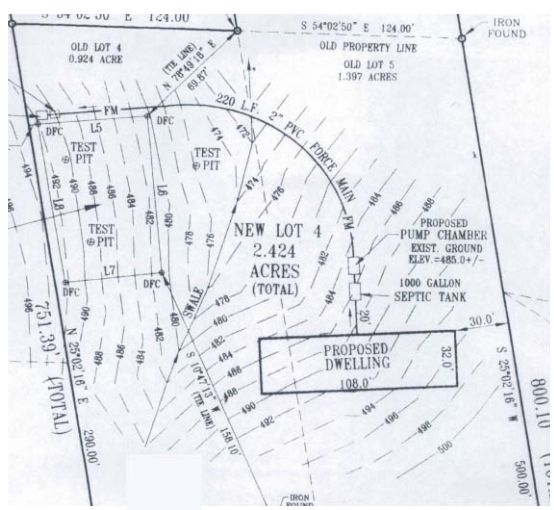


Figure: 6-28. The topographic lines shown on this plat make reviewing this site easy.

The ability to read and interpret topographic maps (Chapter 5) is invaluable when performing a desk review. If you have difficulty with this skill, review Chapter 5 and ask for help. Remember that you are viewing a 3-dimensional surface in 2-dimensions. The topographic lines will enable the reviewer to determine slope, contour and landscape features, such as drainageways, from the office.

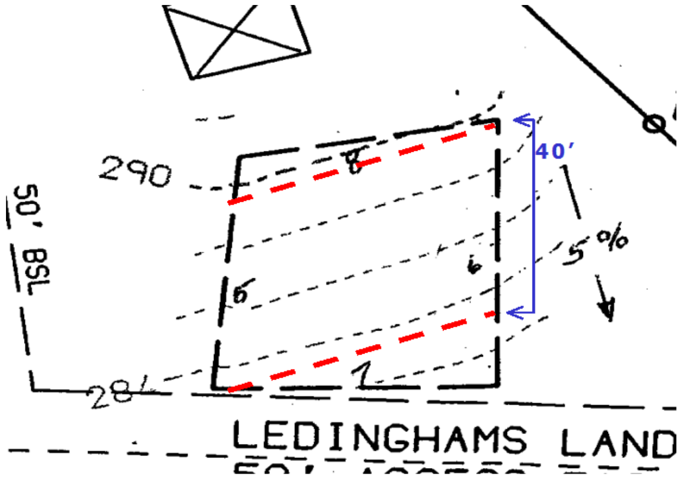


Figure: 6-29. This drainfield footprint requires 6 trenches. Will they fit? Due to poor determination of contour during the site evaluation, the designer has not certified a footprint sufficiently large enough for their proposed design. Is the 5% slope correct on the slope arrow based upon contours? There is approximately 6' of fall (290 – 284) in 40'; (6÷40) X (100) = 15% slope. The proposed installation depth is 18". There is a water table at 36". Based upon this desk review, can a conventional system be installed here? No, (15% - 8)/2 + 18" = 21" required installation depth. This leaves a 15" standoff to the water table. Clearly, a field review is needed to verify the errors: the 5% slope shown on the sketch may be correct and the contouring could be in error. In that case, a conventional system may be possible.

LGMI

An LGMI is a lateral groundwater movement interceptor and is commonly referred to as a *French Drain* or *Curtain Drain* (figure 6-26). It is used to divert surface and subsurface water away from a drainfield. It is constructed much like a drainfield trench, is installed upslope of the drainfield area, and the LGMI pipe must eventually be brought to the land surface (daylight) so it can discharge collected water. The trench bottom is anchored in a restrictive layer or restriction. A perforated pipe is located at the trench bottom and the trench is back-filled with aggregate. Once the LGMI

12 VAC 5-610-700. Site preparation and alteration.
D.
3. Lateral ground water movement interceptors (***LGMI***, e.g., French drains) may be required to divert ground water movement away from the absorption area site. The LGMI shall be placed perpendicular to the general slope of the land and generally parallel to the absorption trenches. A tight drain from the LGMI shall be constructed to discharge into a natural or manmade drainage way.

12 VAC 5-610-950. Absorption area design.
C.
3. A lateral ground water movement interceptor (***LGMI***) shall be placed upslope of the absorption area. The LGMI shall be placed perpendicular to the general slope of the land. The invert of the LGMI shall extend into, but not through, the restriction and shall extend for a distance of 10 feet on either side of the absorption area (See 12 VAC 5-610-700 D 3).

I. Lateral ground water movement interceptors. Where subsurface, laterally moving water is expected to adversely affect an absorption system, a lateral ground water movement interceptor (***LGMI***) shall be placed upslope of the absorption area. The LGMI shall be placed perpendicular to the general slope of the land. The invert of the LGMI shall extend into, but not through, the restriction and shall extend for a distance of 10 feet on either side of the absorption area.

can no longer possibly collect effluent from the drainfield trenches, a non-perforated pipe is used and aggregate is no longer required.

The regulations do not require specific design criteria for the construction of an LGMI. Using a two-foot or three-foot wide trench is an unnecessary cost. The width of the trench only needs to be sufficient to allow the insertion of the pipe and gravel (aggregate). In coarse-textured soils, plastic is often used (figure 6-31) to seal the bottom and downslope wall of the trench. In fine-textured soils, the plastic is not as critical.

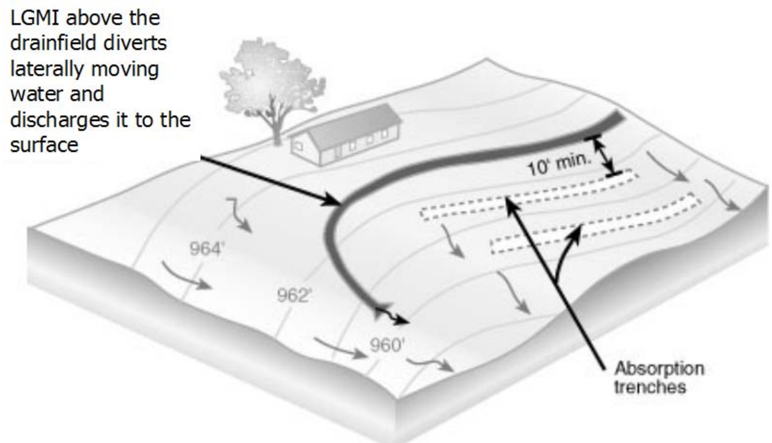


Figure: 6-30. Lateral groundwater movement interceptors divert upslope runoff and groundwater from the drainfield area. *(EPA)*

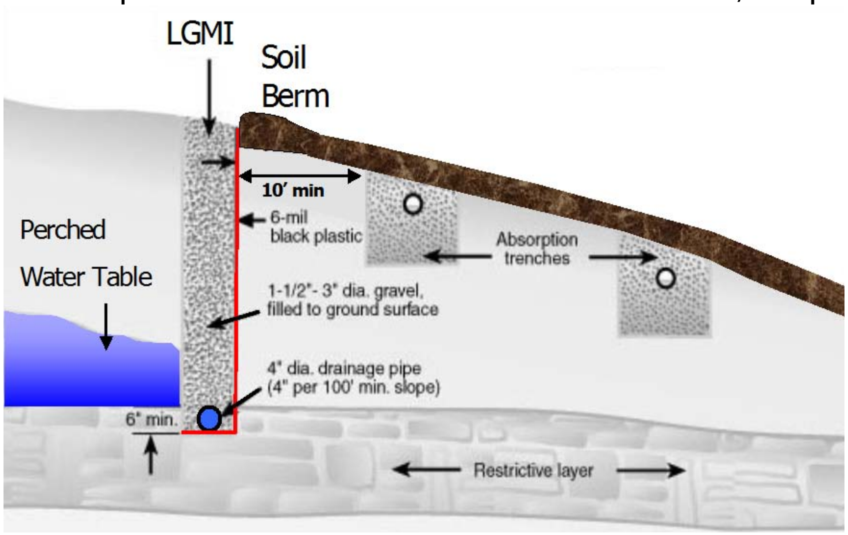


Figure: 6-31. A vertical man-made discontinuity is constructed to capture free water and divert it to a discharge point. *(EPA)*

When it is necessary to divert surface and subsurface water flows, the LGMI aggregate is brought to the ground surface (figure 6-28). Where surface or upslope runoff waters are not an issue of concern, aggregate is not brought to the surface and at least 5 to 6 inches of suitable soil covers the top of the aggregate, allowing the establishment of a good vegetative cover.

The objective of the LGMI is to break the continuity of the lateral flow of groundwater and divert it to a discharge point. The lateral flow is normally present due to a restrictive feature in the soil such as a discontinuity, which perches water and forces it to move laterally rather than vertically. The LGMI intercepts this water so that it doesn't flood the drainfield trenches.

Figure: 6-32. Ground level of an LGMI. *(Photo by Jay Conta)*

Artificial Drainage

Ditching or tile drainage is a common way to deal with high water under a septic system in areas utilizing soil drainage management (i.e. Virginia Beach, Chesapeake; figure 6-30). Digging a ditch may lower the water table provided the ditch has an outlet and is free flowing (figure 6-29). If open ditches are impractical or undesirable the same effect can be attained by using drain tile with a gravity outlet to lower the water table. In order for ditches or perimeter drainage to work, the soil must be of a high enough conductivity and transmissivity to function.

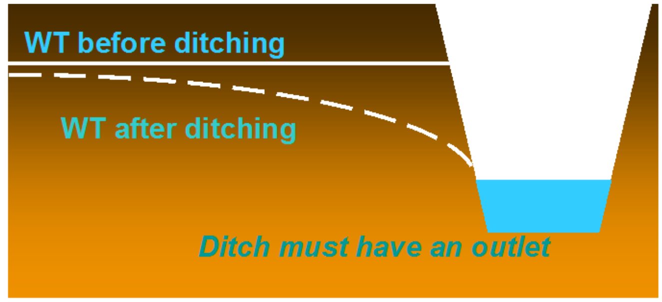


Figure: 6-33. Ditching to lower the water table. *(NCSU)*

12 VAC 5-610-470. Physical features.

E. **Artificial drainage**. Where soils are artificially drained, soil coloration may no longer be an accurate indicator of the position of the seasonal water table. Three types of artificial drainage systems which are generally considered are as follows:

1. A water table depressor system of buried conduits, i.e., agricultural drainage tile;
2. A lateral ground water movement interceptor is a buried conduit for the purpose of intercepting lateral ground water movement, i.e., a French drain; and
3. Open ditches with the bottom elevation of the ditch below the seasonal water table.

In practice, drainage ditches are often put in for agricultural purposes. Since agricultural land needs to be drained only during the growing season these ditches may not work appropriately during the winter. Furthermore, an environmental BMP on flat agricultural land is to use water control structures to hold back water and nutrients. This may raise the water table several miles behind the outlet, therefore, negating any benefit of drainage to the septic system.


Figure: 6-34. Ditching to lower the water table in VA Beach and Chesapeake. White arrows point towards ditches. *(Google Earth top)*

The lateral effect of a drainage ditch depends on the permeability of the material being drained. Sandy soils are more permeable than silty soils; therefore, the sandy material will tend to drain faster than the finer textured soils. Since sandier soils are more permeable and are easier to drain, the distance between agricultural tiles or ditches may be greater and still effectively lower the seasonal high water table.

There are several critical considerations for drainage; conductivity of underlying material, zone of influence – draw down, depth of the ditch/outlet for the drain, long-term maintenance of water lowering system, drainage area, and topographic position. All these will combine to lead to a success or failure of the drainage system. Furthermore, open ditches in sandy soils can rapidly drain the land due to the permeability of the soil. But, wet sand is unstable, so the ditches may collapse or the wet sand may flow into the ditch rendering it useless. Maintaining open ditches with proper gradient is critical.

A Soil Drainage Management Plan (SDMP) is designed to use artificial drainage to lower the seasonal water table to a level that can accommodate a drainfield. For example, the

12VAC5-610-600. General.

It is the policy of the department to grant sewage disposal system permits for private residential systems utilizing subsurface soil absorption whenever such permits can be granted without endangering public health. Many soils are limited in their ability to accept sewage by high seasonal water tables. Some soils can accept sewage when an adequate local plan for soil drainage exists. When a political subdivision enters into a **Soil Drainage Management** Contract with the department and subsequently develops Soil Drainage Management Plan(s) in an area in which soils respond to artificial drainage and the plan is acceptable to the department, the department will consider the approval of subsurface soil absorption systems in soils that were previously unacceptable because of high seasonal water tables.

requirements for an SDMP in Chesapeake are a minimum 3-acre lot with ditching on all 4 sides of the drainfield area. The Department of public works reviews ditching plans and is responsible for enforcing ditch maintenance in Chesapeake. An exception to this 4-ditch requirement is that one of the ditches is allowed to be a French drain (LGMI), an underground drainage line designed to drain surface water away from the drainfield. These fours ditches must be capable of draining the site (i.e., have “outfall”). Either an engineer or land surveyor is qualified to determine whether or not sufficient outfall is present. Except for the seasonal high water table, all other criteria used to establish drainfield suitability and size are the same for a lot utilizing SDMP.

Because of the increased manpower and expense requirements, most Virginia localities have not entered into a Soil Drainage Management Contract. For the vast majority of the state, it is not possible to install a soil drainage system on an individual lot and guarantee that it will be maintained and that it will *continuously* lower the seasonal high water table, and so allow a drainfield to function properly.

Best Management Practices and protection of the environment would suggest careful consideration when installing systems in an area with a high water table whether ditched or not. Simply ditching an area does not mean that the water table will be lowered significantly. Soils that have slow lateral transmissivity of water may not be suitable for this type of procedure. Saturated hydraulic conductivity tests and modeling may be necessary to determine if a site is suitable for a drainage management plan.

Discharge Systems

These are systems that do not use soil for treatment and dispersal of effluent. They may only be used when there is no onsite soil solution. Wastewater is treated, disinfected and discharged to the surface, usually in a natural drainageway or stream. The site must be thoroughly evaluated and deemed to not have soils suitable for any kind of system. The excerpt from the 1992 Discharge Regulations and the Code of Virginia below, imply that only certified professional soil scientists or VDH personnel are qualified to determine the suitability of a site for a discharge system.

Best Management Practices suggest that many documented soil borings and possibly a soil map be drafted to accompany a report that requests a Discharge Permit. The soil descriptions should make it clear why this permit is the only option. A letter stating that a lot is not suitable is insufficient documentation for issuing this kind of permit. Discharge Permits are a last resort for onsite wastewater treatment.

Commonwealth of Virginia State Board of Health Alternative discharging sewage treatment regulations for individual single family dwellings. July 30, 1992

12 VAC 5-640-30. Scope of regulations.
C. Evaluation of other options required. The department will not issue a permit to construct a discharging system, unless all options for onsite sewage treatment and disposal have been evaluated and found unsatisfactory. The consideration of all options include site evaluation(s) by the department and when appropriate, a report prepared by a person having a special knowledge of soil science as defined in 54.1-2200 of the Code of Virginia *(see below)* and the methods and principles of soil evaluation as acquired by education or experience in the formation, description and mapping of soils indicating that no sewage disposal site exists on that property. Options include a conventional onsite septic system using a pump, low pressure distribution (LPD), or an elevated sand mound or other systems which may be approved by the department under the Sewage Handling and Disposal Regulations, 12 VAC 5-600-10 et seq.

Code of Virginia § 54.1-2200. Definitions.

As used in this chapter, unless the context requires a different meaning:

"Board" means the Board for Professional Soil Scientists, Wetland Professionals and Geologists.

"Department" means the Department of Professional and Occupational Regulation.

"Eligible soil scientist" means a person who possesses the qualifications specified in this chapter to become certified.

"Practice of soil evaluation" means the evaluation of soil by accepted principles and methods including, but not limited to, observation, investigation, and consultation on measured, observed and inferred soils and their properties; analysis of the effects of these properties on the use and management of various kinds of soil; and preparation of soil descriptions, maps, reports and interpretive drawings.

"Soil" means the groups of natural bodies occupying the unconsolidated portion of the earth's surface which are capable of supporting plant life and have properties caused by the combined effects, as modified by topography and time, of climate and living organisms upon parent materials.

"Soil evaluation" means plotting soil boundaries, describing and evaluating the kinds of soil and predicting their suitability for and response to various uses.

"Soil science" means the science dealing with the physical, chemical, mineralogical, and biological properties of soils as natural bodies.

"Soil scientist" means a person having special knowledge of soil science and the methods and principles of soil evaluation as acquired by education and experience in the formation, description and mapping of soils.

"Virginia certified *(licensed 2013)* professional soil scientist" means a person who possesses the qualifications required for certification by the provisions of this chapter and the regulations of the Board and who has been granted certification by the Board.

Safety Concerns/Issues

While conducting site and soil evaluations can be enjoyable and educational, there are risks if care is not taken to address safety concerns. These risks can be of a personal nature, or relate to safe use of equipment.

Personal Health Issues

Soil and site evaluations must be done outdoors, and so exposes the evaluator to the elements. Virginia summers are notoriously hot and humid. Dehydration occurs with a weight loss of as little as 2 percent of body weight, yet the body's thirst mechanism does not kick in until you have lost at least 3 percent of body weight. That means that by the time you notice you are really thirsty, you are already dehydrated! So, drink water prior to going to the field, during the evaluation and after you are done. Current recommendations are that you should drink 7-10 ounces of water (or a sports drink) every 10-20 minutes during outdoor work, to maintain hydration- drink beyond your thirst. After completing your work, drink approximately 20-24 ounces of sports drink per pound of weight lost. The fluids you drink should be cooler than the outdoor temperature and flavored (to promote fluid replacement). Beverages containing caffeine, alcohol or carbonation should be avoided (because of the high risk of dehydration associated with excess urine production).

In addition to the dehydration issue, summer is the most likely time when you will be overexposed to the sun and risk sunburn or skin cancer. Know your limits- some people are more prone to sunburn and should take extra care to use a higher SPF number in their sunscreen, or wear long sleeved shirts and long pants. And don't forget your head- wear a hat which will cover your ears and face, and which will help keep the heat load off your head.

Unfortunately, insects just come with warm weather. But some are a bigger health concern than others. Mosquitoes are not only pesky, but can carry disease. If working in areas with mosquitoes, use insect repellent to help reduce your exposure to West Nile Virus. And be sure to use a spray with a high DEET content when in tick-infested areas. Ticks can transmit Lyme disease and Rocky Mountain Spotted Fever, both of which have serious health risks and can result in permanent disability or even premature death.

Checking Things Out Prior to Digging

If you are going to evaluate the soil you need to be sure it is safe to dig. Remote, undeveloped sites should be safe but when looking at repairing a failing drainfield or digging in a more urban setting, you need to contact Miss Utility prior to digging. They will mark with spray paint the location of any and all underground utilities at the site, so you know where it is safe to dig. Along the lines of safety, you should always check overhead (figure 6-31) when working at a site, to be sure you avoid overhead utility lines.

Safe Use of Equipment- Augering

In Virginia, the majority of soil studies will involve using a soil auger. Remembering a few simple things will help you stay healthy and safe. Be sure to use the right sized auger for your body size. If you are 4-ft, 6-inches tall, don't use a 6-ft auger to dig. You want to use your strong muscles when augering- the chest, arm and leg muscles. Using an auger that is too tall for you means you are going to start the borehole by reaching up high to twist the auger into the ground, and so will use the weaker shoulder muscles. And when you have augered deep in the ground and are nearly at the handle, avoid bending over to twist the auger or to pull it out of the hole. Instead, kneel down and turn or lift the auger. Use your strong muscles to dig, and prevent back injury.

Figure: 6-35. Notice the power line above the auger. *(Tom Saxton)*

Figure: 6-36. There may be underground cables associated with this satellite dish. *(Jay Conta)*

Avoid forcing the auger when digging. When stopped on a root or rock in the ground, don't try to force the auger to get past the obstruction- you might break the equipment or hurt yourself. When auger refusal prevents you from advancing the borehole any deeper, just move over and start another boring, and save your back.

Avoid over-augering. If you keep twisting the auger too many times, you will just pack the soil into the bucket and make it very difficult to remove. Make your work easier- just turn the auger handle 3 to 4 times, and you will have a full bucket of soil that is easy to remove and examine.

When you have a full bucket of soil, you will invert the auger and firmly strike the auger handle on the ground to loosen and remove the soil from the bucket. Remember two key items: first, never stand behind a person augering; when the hole digger attempts to empty the bucket they may bring the handle down on your foot and break your toe or hit your head; second, be sure when you strike the handle on the ground to hit the entire handle flat on the ground- do not hit the end of the handle on the ground, or you will stress the metal where it attaches to the auger shaft and break the auger.

The auger is designed so that the teeth extend wider than the diameter of the auger barrel. That's so the hole excavated by the twisting of the auger is of larger diameter than the barrel of the auger bucket. When digging in clayey soils, especially when they are wet, if the teeth of the auger do not extend well beyond the diameter of the bucket, the moist soil can adhere to the outside of the bucket. That can make it very difficult to pull the auger out of the ground, and greatly increase the risk of back injury. So, when the teeth on the auger get worn or a piece breaks off, sharpening the auger teeth only decreases the diameter of the borehole and increases your risks of back injury. Worn equipment means you work harder at every hole you bore, and increases the chances of hurting yourself. Worn auger teeth mean you should take the bucket to an experienced blacksmith (one who has worked on auger repairs before) and have new teeth welded on the bucket.

Figure: 6-37. Deep excavations may cave in especially from the vibrations of machinery. *(Erik Severson)*

Safe Use of Equipment- Backhoe Pits

In some cases, it is not possible to do a thorough soil evaluation using a soil auger because stones prohibit auger penetration. In that case, the use of a backhoe is required. While a backhoe pit allows more soil to be studied when compared to an auger borehole, there are risks with pits. The U.S. Department of Labor and Industry- Occupational Safety and Health Administration (OSHA) has adopted procedures for safety requirements in an attempt to improve workplace safety. Numerous experts from government, universities, and industry worked closely with OSHA to develop a soil classification system for trenching and excavation, specifications for sloping and benching, design of shoring, and other protective systems. The result is OSHA requirements; it is the legal responsibility of contractors and owners to know and implement these provisions in the workplace.

Figure: 6-38. Pits often cave in. *(Charles Allison)*

Key points to remember when utilizing backhoe pits:

Any and all excavations have the potential to be dangerous.

Filled or disturbed sites are especially unstable and dangerous (susceptible to collapse).

Wet, sandy soils are unstable and dangerous (susceptible to collapse).

Clayey soils with strong structure (i.e., clearly defined planes of weakness between peds), especially when wet, are susceptible to collapse.

Piling excavation spoil immediately adjacent to the pit adds to instability in the pit, making it more susceptible to collapse.

Figure: 6-39. This could be a dangerous and costly mistake. *(Steve Thomas)*

DO NOT enter a pit with a running backhoe machine adjacent to the pit. The vibrating adds to instability, making it susceptible to collapse.

Combining two or more of the above-mentioned RISK FACTORS greatly increases the danger of collapse.

Excavations should be no more than 4.5-5 feet deep if you are standing in the pit. Kneeling down in the pit is dangerous.

DO NOT enter a pit deeper than 5 feet unless proper shoring (pit wall stabilization) is in place.

DO NOT ride in the backhoe bucket down into a deep pit.

DO NOT enter a pit after a collapse in an attempt to rescue someone. The site is already unstable and could again collapse, risking your life.

DO NOT attempt to rescue someone trapped in a collapsed excavation by using a backhoe, as this might lead to further injury or death.

REMEMBER, it will most likely be a body recovery effort, not a rescue, when attempting to remove someone trapped in a collapse.

Soil evaluators have been killed in pits during site evaluations in Virginia

Figure: 6-40: This contractor had a bad and expensive day ($1200). He did not call MISS Utility. Fortunately, no one was injured. *(Photo by Tom Saxton)*

Chapter Review

Understanding Concepts

1) How much aerobic soil is required beneath a trench for a conventional onsite sewage disposal system?

2) What hydrological ecosystem is similar to a drainfield?

3) What constitutes a mass drainfield? How are soil studies different for mass drainfields?

4) Which is more important in determining the property of a soil with regards to water movement: Structure or Texture?

5) What is one type of structure that is especially restrictive? Why?

6) What attribute of a soil is affected when a drainfield is installed during wet conditions and *soil smearing* has occurred?

7) True / False High Bulk Densities are an indication of the suitability of a soil for onsite wastewater disposal systems.

8) A line of subrounded stones occurs immediately below redoximorphic features in a soil. This is an indication of a ______________________________________?

9) List two characteristics of a shrink swell soil.

10) True / False Cr is a restriction.

11) True / False Coarse cobbly soils provide good treatment for effluent.

12) True / False A ten foot separation distance between hydrophilic vegetation and a sewerage system is a sufficient distance to ensure that roots will not invade a drainfield.

13) What specific design criteria are there for LGMIs in the Sewage Handling and Disposal Regulations?

14) True / False Ditching an area will lower the water table significantly and to a degree sufficient for the installation of a drainfield.

Critical Thinking and Problem Solving

1) If you worked in a county that had 100% reserve requirements. How would your work be different? Would you need to bore as many holes?

2) What are the three zones to be considered with regards to the site and water movement? Explain how the designer might accommodate each in their design. Give specific examples.

3) Explain the hydrological difficulties associated with installing trenches on sloping terrain.

4) If a soil was described as having 10YR 6/2 mottles at 32 inches, would a conventional system be appropriate? Explain.

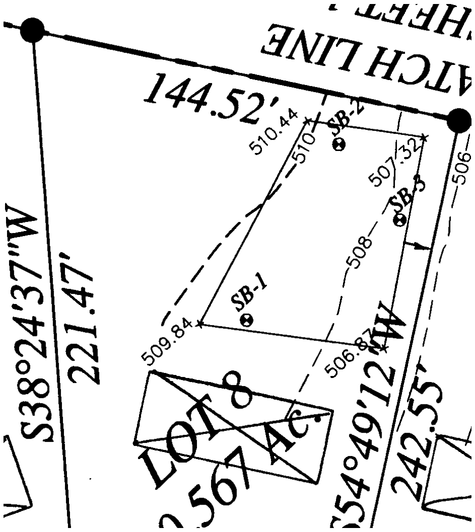
5) If an evaluator suspects a restrictive layer, what should be done?

6) A soil profile has a 22-inch E horizon that is loamy sand. It overlies a well-drained clay loam horizon. Would it be appropriate to install this drainfield at 18-inches in order to take advantage of the loamy sand texture? Why or why not, explain?

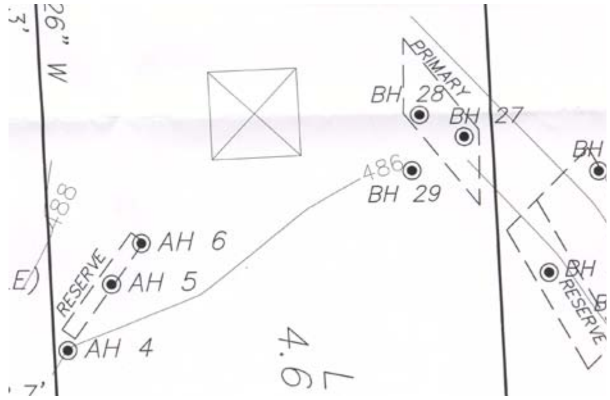
7) What considerations are there when installing very shallow? What might be done to protect the site? Explain and give examples.

8) How would you design a system installed in exactly the same soil with the same texture group, but on different shaped landscapes; convex versus flat/slightly concave?

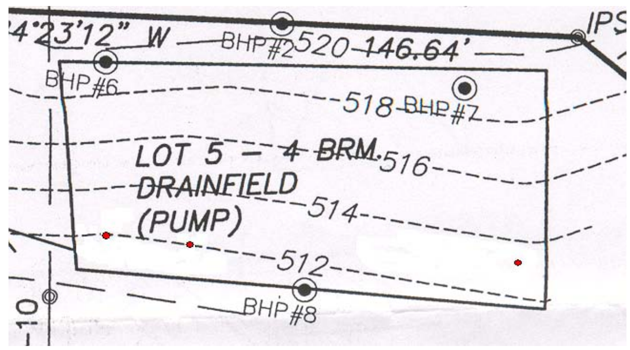
9) Explain the concept of creeping failure in your own words.



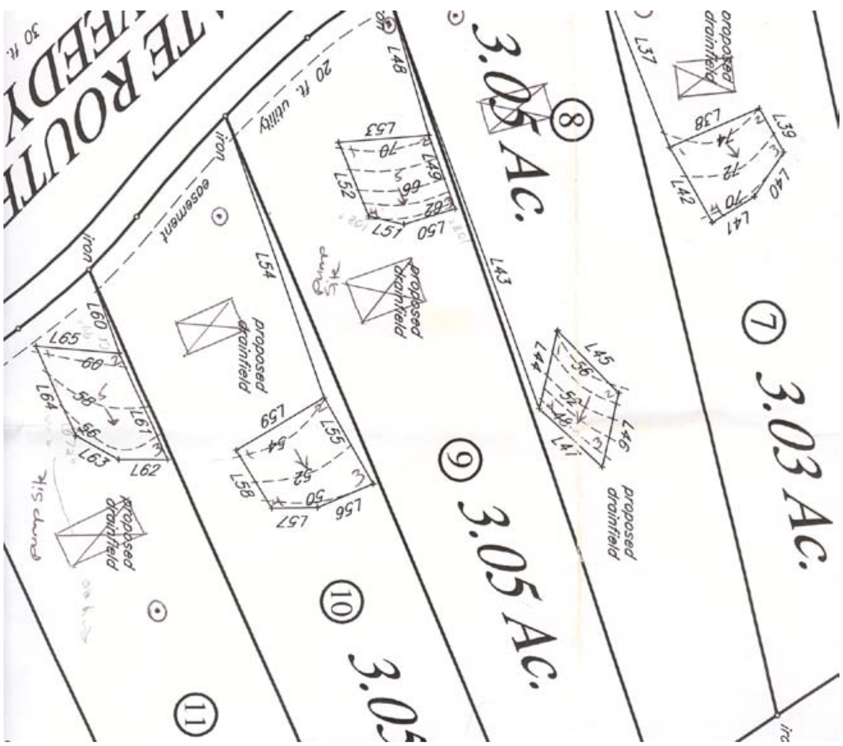
10) Do you see any issues with this proposed footprint? If so, explain.



11) Do you see any issues with this proposed footprint? If so, explain.



12) Do you see any issues with this proposed footprint? If so, explain.



13) Are these drainfield footprints located upon concave or convex landscapes? Do you see any issues with any of these proposed footprints? If so, explain by lot.

Chapter 7
Failing Onsite Sewage Disposal Systems

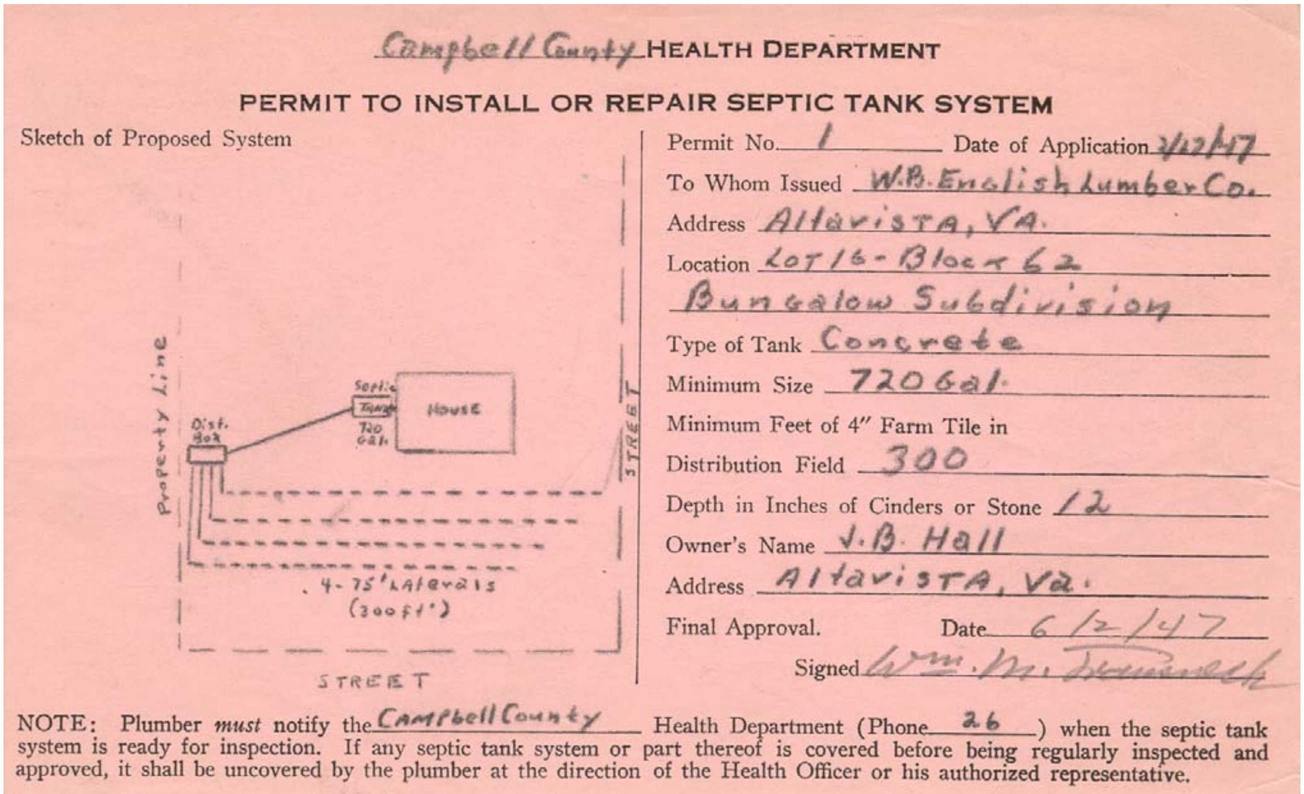
Failures may tax the emotions of the evaluator more than any other issue when working in the onsite world. People are currently living in the homes and have everyday budgets they must provide for. They did not plan for the added expense of a new sewerage system. Many of these failed systems were installed in situations (landscapes, soils, water usage, dimensions of the components, etc.) that do not meet current requirements for subsurface soil absorption systems. When the evaluator goes to the site and is inundated by pleads of emotion from the customer, it is difficult to maintain connection to the requirements of today. At times, empathy may be the evaluator's biggest enemy.

Many repairs are emergency situations. Usually, in these cases, sewage is backing into the home or surfacing on the surface of the ground and the system is nearly unusable. Sewage may be flowing onto the neighbor's property or across a playground. Litigation may be in play also.

The evaluator is faced with "patch up" type repairs versus an entirely new sewage disposal system. It is imperative that he/she becomes intimate with the property and the existing system prior to making construction decisions. Is there a suitable site for a new system? How old is the house? Is there room for a repair 40 years from now (if the house appears that it will last that long)? Does the evaluator have enough information to make a decision? Are the necessary components uncovered so that the decision can be made? From what materials are the current components constructed? Does the evaluator know the exact boundaries of the property? What are the soil conditions? What is the landscape? Are there straight pipes? What's the status of the neighboring properties? Wells? What is the hydrology of the property?

Nature of Failures

There are four primary causes of failures: hydraulic overloading, physical component failure due to stress or deterioration, unsuitable landscape position, and unsuitable soil conditions. *(Adapted from Beth Manghi, 2009)* Failures usually occur as a result of multiple minimum conditions occurring at the same time. For example, if the soil is slowly permeable, the system may function normally when two people are at home. But when family visits for the weekend, the system fails. In this case, there are two minimums, hydraulic overloading (when the family visits) and slowly permeable soils. The two minimums combined create the situation coined by Jay Conta, VA Tech Soil Scientist as *"multiple minimums"*. Most failures that occur are related to this term.



Campbell County HEALTH DEPARTMENT

PERMIT TO INSTALL OR REPAIR SEPTIC TANK SYSTEM

Sketch of Proposed System

Permit No. 1 Date of Application 2/12/47

To Whom Issued W.B. English Lumber Co.

Address Altavista, VA.

Location Lot 16 - Block 62 Bungalow Subdivision

Type of Tank Concrete

Minimum Size 720 Gal.

Minimum Feet of 4" Farm Tile in Distribution Field 300

Depth in Inches of Cinders or Stone 12

Owner's Name J. B. Hall

Address Altavista, Va.

Final Approval. Date 6/2/47

Signed Wm. M. [illegible]

NOTE: Plumber *must* notify the Campbell County Health Department (Phone 26) when the septic tank system is ready for inspection. If any septic tank system or part thereof is covered before being regularly inspected and approved, it shall be uncovered by the plumber at the direction of the Health Officer or his authorized representative.

Figure: 7-1. First permit in Campbell County Virginia.

Things have changed since 1947. There is very little information on this permit that will help during a repair. But the configuration of the old system may be helpful, if it was installed as permitted. In 1947, the soils were not a consideration. If the health officer were to dig a hole, they would not understand soil characteristics. There were no regulations as we know them and the objective at that time was to provide for indoor plumbing and avoid sewage on the surface of the ground. Many old permits called for gray water straight pipes. The installed system may be considerably different than the old permit drawing.

Table: 7-1. Failure matrix for multiple minimums. First listed are most common. Any two or more may qualify as a *multiple minimum*. *(Term attributed to Jay Conta)*

Hydraulic Overload	Physical Component Failure	Unsuitable Landscape	Unsuitable Soil Conditions
Leaking fixtures	Tree roots	Drainageway	Slowly Permeable
Basement drain connected to system	Flushable wipes used, may catch on rough pipe and clog system	Generally concave	Shrink-swell
Air conditioning condensation pipe connected	Orangeburg pipe has collapsed (sewer, Ts, conveyance, headers)	Footslope	Perched water table
Hot Tub	Cast iron pipe has rusted through (sewer, Ts)	Low terrace	Bedrock
Too many loads of laundry per day	Concrete tile pipes have dissolved	Foot of long side slope	Fill material
Long showers (teenagers)	Tees fallen off	Headslope	Installed in BC horizon
Sump Pump connected	Tank never pumped	Toeslope	Surface of the ground higher than lowest plumbing fixture (could fit any of these)
Water treatment system connected	Crushed component during grading		
	D-Box dissolved		
	Grease		
	Bath beads		
	Water softeners		

Diagnosing the problem

The homeowner should have the site prepared before the evaluator arrives. At a minimum, the septic tank and distribution box should be uncovered. Humans do not have x-ray vision and it is a waste of everyone's time when these things are not readily observable.


Figure: 7-2. You must investigate thoroughly to find the problem. *(Photo from Gary Gilliam, EH Supervisor & Sarah Lewis, EHS)*

Look, listen, smell, and feel for any clues that may lead to potential causes of failure. Document observations and steps taken with digital photography, on the site sketch, and in the file. A good approach to assessing a repair is to move along the system in stages: house to tank, tank to distribution box, and distribution box to trenches. Keep in mind that one component may influence another. *(Adapted from Beth Manghi, 2009)*

Another essential element that the specialist must check for is leaking toilets or fixtures. The leaking toilet is one of the most common and overlooked causes of unintended water waste. Be sure to ask the homeowner if they have any toilets which "hang-up" or "run-on" after being flushed, or in some way do not operate properly. Because homeowners are not always aware of these problems, the evaluator should ask to re-check all the toilet fixtures. One way of checking a toilet for leaks is to put a drop of food coloring or vegetable dye in the toilet tank and wait ten minutes to see if it leaks into the bowl. If the coloring leaks into the bowl, the plunger ball in the toilet is the most probable cause of the leak. Another is to shut off the water supply to the toilet. Check the tank later to determine if the water level in the tank has gone down.

Ask the homeowner about leaking faucets or faucets that are difficult to shut-off. Ask permission to double-check these. This can be conveniently done while checking for leaking toilets. A plumber should replace the washers on dripping faucets. Either a leaking toilet or faucet may increase wastewater flows sufficient to cause system failure. Be sure to thoroughly investigate the home for leaks before proceeding further with the evaluation. *(1992 VDH Drainfield Repair Resource Manual)*

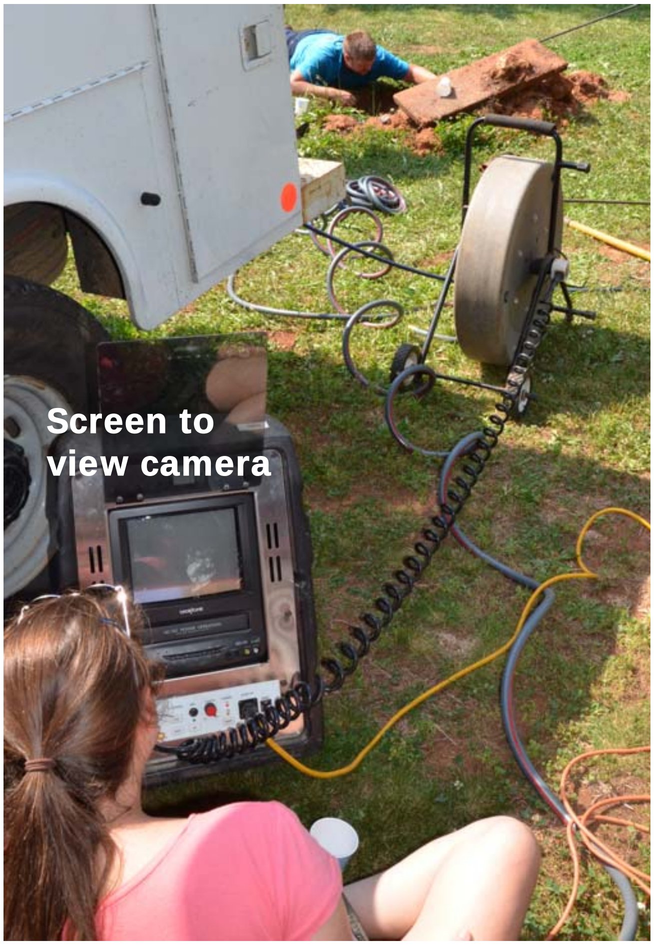


Figure: 7-3. The man in the blue shirt is pushing the camera into the header lines from the distribution box, while the evaluator watches the screen to determine the condition of the system. *(Photo by Tom Saxton)*

Communication with the owner is extremely important. Interview them about their lifestyle habits. Do they own a Jacuzzi or garbage disposal, etc.? How many people live in the home? What are their ages? Young people tend to use more water and are not usually as worried about what happens after a flush. Are people home during the day using water? Advise them to spread out water use, especially laundry and install water saving devices, such as water saving showerheads.

A camera may be the most useful tool for evaluating an existing system. The camera is inserted in the pipe to be evaluated by means of a stiff wire cable. This is pushed through the system like a plumber’s snake while the evaluator watches on a screen; much like a colonoscopy. In this way, the system may be valuated without the damage and expense of digging up the yard. Any blockages or damage may be seen. The cable has measurements so the location of the needed repair can be determined. Often, one may be confused by how long a system has lasted when, otherwise, all site indicators point towards a short lifespan. Interview and investigate under every bush and in every ditch. There may be a stopped up overflow straight pipe on the distribution box that is unknown to the current owner. The sump pump may collect overflow and pump it to the yard (see sump pump figure 7-5). The kitchen sink may not be connected to the system. The washing machine may not be connected. Probe the trenches. Are they wet or dry? If they are dry, then water is not getting to them and there may be stoppage in a sewer line or conveyance line. Roots may have invaded these pipes. If they are wet, the system is hydraulically overloaded. If the system is overloaded, is it due to something in the house or is it a soil drainfield issue, or both?

A remedy to the problem cannot be accurately derived until the cause is established. Multiple visits to the site may be required. Several days of reflection may yield otherwise, unknown solutions. A midnight epiphany may solve the problem.

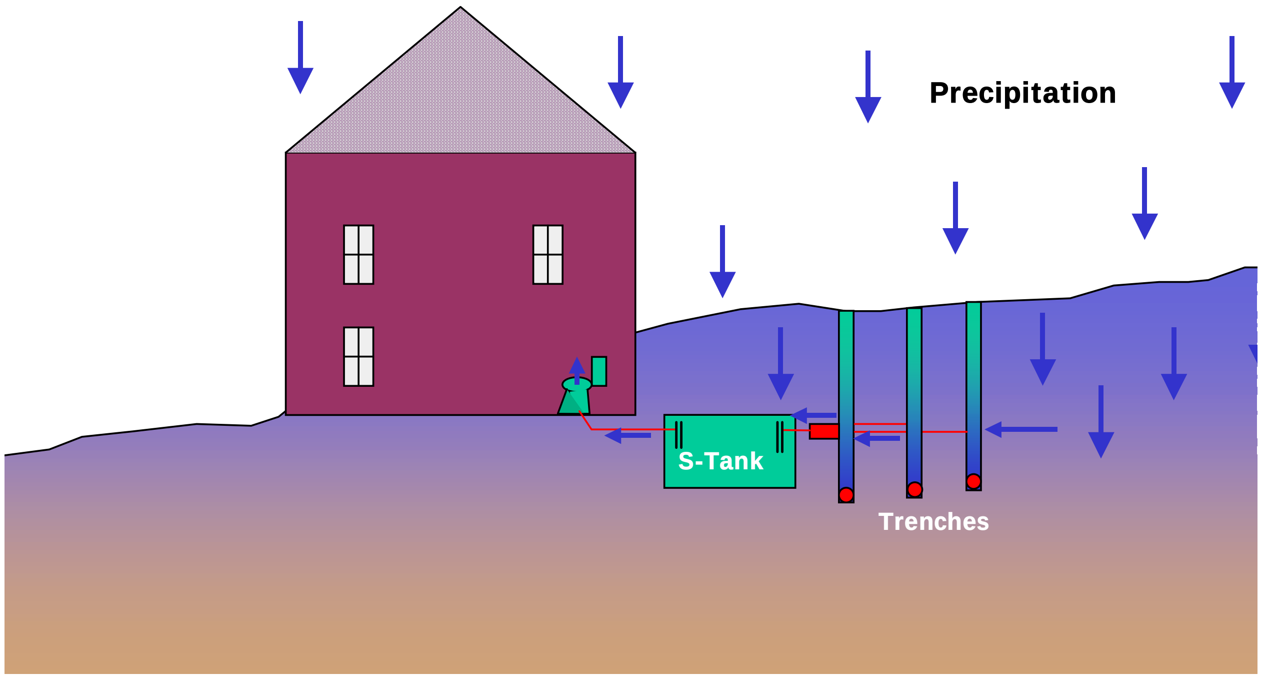
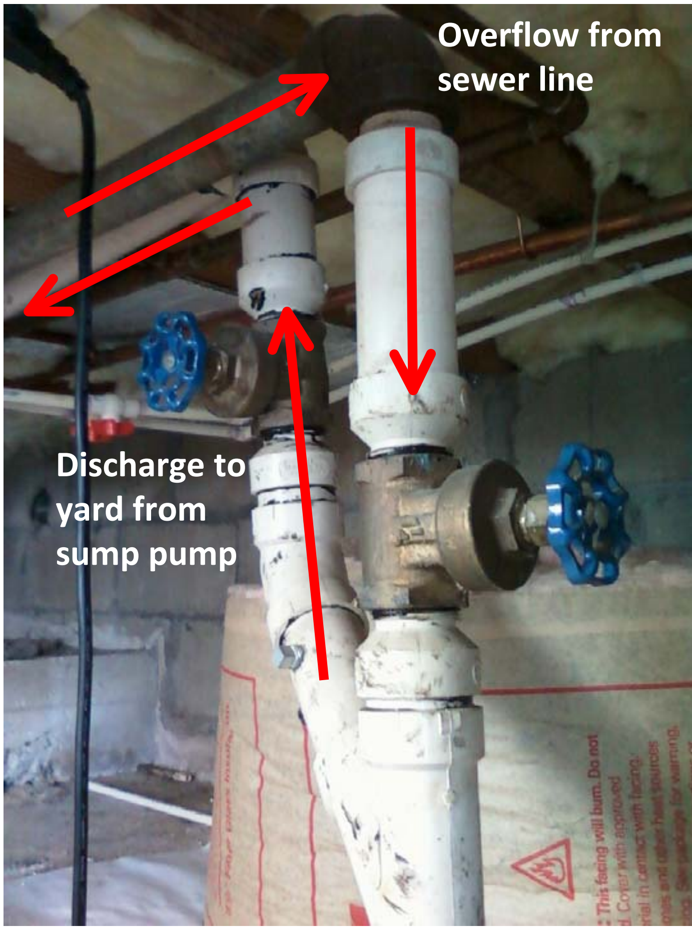
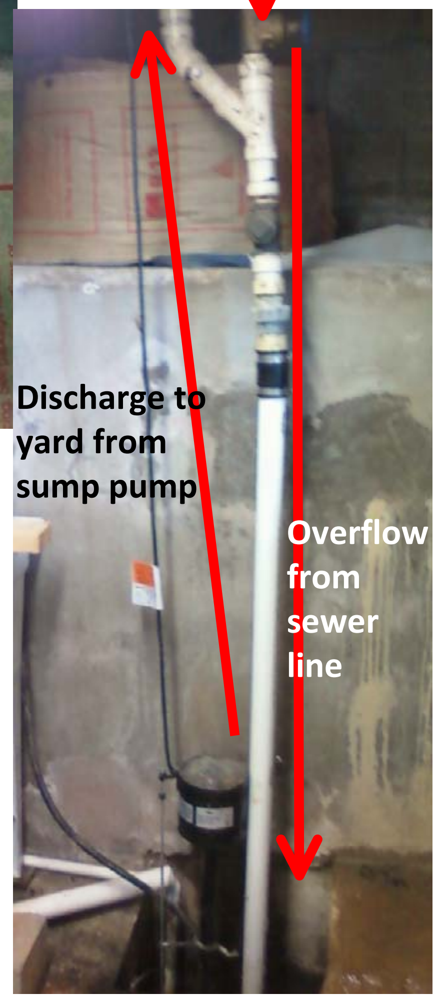


Figure: 7-4. The surface of the ground over the trenches is higher than the floor level of the lowest plumbing fixture. In this case, during heavy precipitation events or long wet spells, water may back into the lowest plumbing fixture. The soil is saturated and the easiest escape for this hydraulic gradient is in the house. *(TS)*



Discovered during a repair that ultimately became an HB930



When water backs into this house from the failing drainfield, usually during precipitation events, the valve on the right can be opened. This allows sewage to flow down into the sump pump chamber. Then the valve is shut and the sump pump sends it back out into the road ditch.

Figure: 7-5. Bad solution to a problem. The soils at this site have perched water tables. During heavy precipitation events, the water floods the drainfield causing the effluent to back into the house. When this happens, the owner opens the valve so that the water flows into the sump pump hole in the basement floor rather than backing into plumbing fixtures. Once the sump pump hole has filled with effluent, the valve is closed and the sump pump sends it to the road ditch. This drainfield was installed in 1947. The evaluator was in a quandary about the longevity of the system, considering the soil conditions, until this system was discovered. *(Photos by Tom Saxton)*

12 VAC 5-610-120. Definitions.

"Grandfathered lot" means:
1. Any lot upon which no permit has been issued and which is in a subdivision approved by the department prior to July 1, 2000, in accordance with a local subdivision ordinance. Individual lots may or may not have been evaluated; or
2. Any lot, parcel, or portion thereof with ***a previously issued permit*** or a specific written approval (not including a certification letter) from the department.

(Note☺
Because of the definition of *"Grandfathered"* a repair lot may be considered a *"Grandfathered"* lot.

12 VAC 5-610-70. Grandfather clause.

A. Any owner of a *grandfathered lot* may submit an application for a construction permit according to the procedure in 12 VAC 5-610-250. The local health department may perform a site and soil evaluation in accordance with Part III (12 VAC 5-610-450 et seq.) of this chapter and a permit shall be issued for a system, which *complies to the greatest extent possible* with this chapter provided that the site and soil conditions would not preclude the successful operation of the system. *Whenever the site and soil conditions on a grandfathered lot do not substantially comply with the requirements in Part IV (12 VAC 5-610-591 et seq.) of this chapter for a septic tank effluent system, **secondary treatment** will be required* in the system design. In no case may the separation distance between the subsurface absorption system and a drinking water supply be less than the separation distance established in the regulations in effect at the time the grandfathered lot was approved (subdivision approval) or when the first permit was issued for the grandfathered lot.

B. Certification letters may not be issued in lieu of permits under the grandfather clause.

C. All permits issued under the *grandfather clause which do not substantially comply* with the provisions of this chapter *shall be considered conditional permits* in accordance with 12 VAC 5-610-250 J. A statement approved by the division shall be recorded and indexed in the grantor index of the land records of the circuit court having jurisdiction over the site of the sewage treatment and disposal system. The statement shall indicate that the permit is issued under the grandfather clause and that *the site and soil conditions do not substantially comply with the current regulations* and may contain such other information as the division deems appropriate to serve notice to future owners of the unique nature of grandfathered lots.

(Note:) The following may be deduced from the previous Regulatory passages:

If the lot with the failing system was permitted in the past, then it is considered "Grandfathered".

If the repair lot is "Grandfathered", then whenever the site and soil conditions do not substantially comply with the regulations, secondary treatment is required. If secondary treatment is considered a hardship, then the manager may waive treatment.

However, in 2004, HB 930 (see HB 930 section) was passed by the General Assembly. This codified the above and gives the homeowner the opportunity to request a waiver.

Figure: 7-6. This is a septic tank that had not been used for 25 years. Roots invaded the septic tank through the mid-seam. The roots show that the tank was leaking. It is necessary to see things and not just guess. *(Photo by Tom Saxton)*

Septic Tank

The performance of the septic tank is influence by a number of factors: water use, chemical cleansers, surface water, etc. If the evaluator arrives on the site and is having difficulty finding the tank, often times look for areas of poor grass growth or identify where the plumbing comes out of the house. However, if the tank is leaking or overflowing, then the area above the tank may have more vegetative growth. Human behavior has a direct affect on the performance of the septic tank. When the septic tank is not pumped regularly, the scum and sludge layers begin to fill the tank and cause back up into the house or clogging of other components. Remind the owner that pumping every 3-5 years is optimal. Excessive water use may lead to hydraulic overload of the entire system. Investigate how much water the occupants are actually using. Contact the water authority, if they are connected to a municipal supply, to determine water use. Pouring grease into the septic tank or using a garbage disposal increases the organic load entering the tank and

Table: 7-2. Suggested Septic Tank Pumping Frequency *(EPA, 1993)*

Tank size (gal)	**Household size, number of people**									
	1	2	3	4	5	6	7	8	9	10
	Pumping frequency, years									
500	5.8	2.6	1.5	1	0.7	0.4	0.3	0.2	0.1	-
750	9.1	4.2	2.6	1.8	1.3	1	0.7	0.6	0.4	0.3
1,000	12.4	5.9	3.7	2.6	2	1.5	1.2	1	0.7	0.7
1,250	15.6	7.5	4.8	3.4	2.6	2	1.7	1.4	1.2	1
1,500	18.9	9.1	5.9	4.2	3.3	2.6	2.1	1.8	1.5	1.3
1,750	22.1	10.7	6.9	5	3.9	3.1	2.6	2.2	1.9	1.6
2,000	25.4	12.4	8	5.9	4.5	3.7	3.1	2.6	2.2	2
2,250	28.6	14	9.1	6.7	5.2	4.2	3.5	3	2.6	2.3
2,500	31.9	15.6	10.2	7.5	5.9	4.8	4	4	3	2.6

accelerates development of the scum/sludge layers. Flushing of non-biodegradable products (flushable wipes) down the toilet leads to clogging of components. Overuse of caustic cleansers and antibiotics (or even chemotherapy medications) can affect the bacterial content of the septic tank. VDH does not recommend the use of any additives in the septic tank.

When the owner applies for a repair permit, they will be instructed to pump the tank and uncover the inlet and outlet of the septic tank. If the evaluator is present at the time the tank is pumped, he/she should observe what happens as the tank is emptied. Or, ask the septic pumper for their input and observations. Look into the septic tank, but DO NOT ENTER the septic tank. Dangerous methane gas and the risk of injury are present. Does the liquid level appear normal? A proper liquid level should be below the outlet tee.


Figure: 7-7. A "mouse" may be used to locate the septic tank. It can be flushed down the toilet and traced. *(Photo by Tom Saxton)*

Observe any leaks or trickling sounds. If the septic tank is not watertight, surface water will cause the tank to fill quicker and trigger back ups or hydraulic overload of the entire system. Are the tee's in place? If the inlet tee has deteriorated or fallen off, the sewer line cannot baffle properly and may also result in back ups into the house. If the outlet tee has fallen off, solids may flow to the distribution box. Does water run into the tank from the outlet tee or the inlet tee? If it's running in from the outlet, there is a chance a component further down the system is not functioning properly or that the system is saturated and therefore, draining poorly. If water does not enter the tank, then the sewer line is compromised. What color is the water – clear water running back into the tank may be a sign that surface water is infiltrating the system. If water is coming from the inlet, then a plumbing fixture may be leaking, especially if no one is in the house to run appliances or faucets. *(Adapted from Beth Manghi, 2009)*

Pump Chamber


Figure: 7-8. Investigating a leaky pump chamber. *(Photo by Ruby Shipman, EHS)*

The pump chamber is another component vulnerable to surface water intrusion. Check the pump chamber for signs of leakage. Listen for any trickling sounds while the pump is off. Use a flashlight to scan the sides of the walls for leaks or abnormal liquid levels. Check the outlet where the force main leaves the pump chamber – is it sealed properly? Many tanks are mid-seam tanks. These often leak and allow groundwater into the pump chamber after the pump has emptied the tank below the mid-seam. Measure the depth of the water in the chamber. Be certain there is no inside water use. Go to lunch, then return and measure again. If the water level has risen, then the tank is leaking. One inch of water in a 1000-gallon tank is approximately 20 gallons of water. If the water level in the tank rises one inch in an hour, this equals approximately 480 gallons in 24 hours leaking into the tank. This is more water than the design capacity of a 3-bedroom residence.

Is the pump functioning? Is it running too often because of a malfunction or excessive water use? Check the dosing volumes, which are based on the prescribed estimated daily flow, to ensure they are correct or recommend adjusting the pump floats as needed. *(Adapted from Beth Manghi, 2009)*

Conveyance Line / Force Main

Have the conveyance line and/or force main been damaged, crushed or clogged? Clogged

Figure: 7-9. Orangeburg pipe (also known as "fiber" pipe was constructed of paper and tar rolled into a pipe) on the left and terracotta pipe on the right should be replaced with sch 40 plastic pipe. *(Photo by Tom Saxton)*

lines can be snaked by a contractor. Old systems, prior to the early 1970s may have solid pipes constructed of orangeburg, cast iron or terracotta. These are susceptible to failure and should be replaced with current materials. Remember, the regulations are the *minimum* requirement. At times, it is prudent to use better than the minimum required materials, especially in high traffic areas.

Figure: 7-10. Somehow, this crushed conveyance line lasted 20 years. While the regulations allow this grade of pipe, sch 40 is recommended. *(Photo by Tom Saxton)*

Figure: 7-11. Old cast iron and orangeburg have degraded. *(Photo by Tom Saxton)*

Distribution Box

The distribution box is akin to the central nervous system of the septic system. The distribution box controls much of the functionality of the trenches. The distribution box is the most valuable component to have uncovered prior to evaluating a failed system. If the distribution box is not correctly leveled for even distribution, some trenches may receive a greater proportion of the flow. This may result in hydraulic overloading of that trench. Is the distribution box is in good condition? The effluent may have dissolved older boxes (see figure 7-15). Use a tile probe to inspect the integrity of the bottom of the box. Sewage is corrosive and will accelerate the deterioration of the concrete. Is water flowing into the box when water isn't being used? If so, a toilet may be stuck. Plastic distribution boxes are prone to being crushed or cracked (figure 7-31).

If the distribution box is full of water or will not take water, then a problem may exist further down the system at the header lines or the trenches. Adding water to the distribution box will enable a visual inspection of equal distribution as well as determining the ability of the remainder of the system to accept water. *(Adapted from Beth Manghi, 2009)*

Trenches

Figure: 7-12. A flooded distribution box indicates that something beyond the box has failed. This could be crushed or root-invaded headers or hydraulically overloaded trenches. *(Photo by Tom Saxton)*

Several factors affect whether or not the trenches will function properly – hydraulic load, soils, topography, etc. Areas of grass or vegetation that are more lush and/or greener can often identify the drainfield area. The trenches oftenmay be sunken and linear. Boring a hole or probing with a tile probe in the drainfield may provide indications of how the trenches are functioning. If the gravel is clean and dry, effluent may not be reaching the trenches, or the trenches and soil are draining properly. If the gravel is black and saturated, the drainfield may no longer be functional. The black substance (biological mat) may be clogging the lines and or soil pores and fractures. The biological mat (biome) is a thick, black, jelly-like substance that forms at the gravel-soil interface in the trenches. It is composed of microorganisms and their by-products. High organic loads, i.e. the solids added to the system by using a garbage disposal or high volumes of grease accelerate the development of the biomat. Protective gloves and sanitizer should be used due to the presence of pathogens.

Boring a hole around the perimeter of the drainfield or between the trenches will indicate the installation depth soil characteristics. Document the depth to redoximorphic features, texture changes, and/or possible zones of reduced permeability.

Figure: 7-13. This large maple was planted in the middle of the drainfield. Eventually, the drainfield ceased to function. The upper portion of the drainfield is also higher than the floor level of the lowest plumbing fixture on the lower floor. This caused back ups during heavy precipitation events. *(Photo by Tom Saxton)*

Prior to the 1982 *Sewage Handling and Disposal Regulations*, septic system design focused on disposal, not treatment. Often, trenches were installed into the water table, bedrock or shrink-swell soils, and remained saturated for long periods of time. Observe the topographic position of the drainfield. Is the landscape position one that collects or disperses water? A lateral groundwater movement interceptor (LGMI) may be an appropriate addition to divert surface water from the drainfield. Downspouts from roof drains may also adversely affect the drainfield area. If this system is not installed on contour, uneven hydraulic loading may cause a failure. Installation of a pump may extend the life of the system or prevent backup into the residence. Is there hydrophilic vegetation within 50 feet of the drainfield? Any woody vegetation may invade the system over time, but water-loving vegetation should be removed to 50 feet or greater from the onsite sewage disposal system. *(Adapted from Beth Manghi, 2009)*

Concrete and clay tile pipe was used prior to approximately 1970. Concrete pipe often dissolves and only leaves a "shadow" of itself.

Chamber systems are susceptible to being crushed or may fill in with soil during hydraulic overload from leaking toilets, etc. Chamber systems are more sensitive to abuse than aggregate systems. Without a backhoe or camera

Figure: 7-14. This chamber system could be easily damaged during filling and grading. *(Photo by Tom Saxton)* autopsy, it may be nearly impossible to determine whether a chamber system has been damaged.

Figure: 7-15. Infrequent septic tank pumping has promoted sludge accumulation in this pipe. *(Photo by Sarah Lewis, EHS)*

Figure: 7-16. Dissolved distribution box. *(Photo by Tom Saxton)*

Figure: 7-18. Alternative treatment systems are not immune to problems. In this case, an automotive repair shop's system was compromised by mechanics hand cleaner. *(Photo by Tom Saxton)*

Figure: 7-17. Construction of swimming pools commonly damages a system. In this case, the trench is at the top of the cut bank. Effluent is erupting from the slope. *(Photo by Gary Gilliam, EH Supervisor)*

Figure: 7-19. A baffle should be installed to prevent "short-circuiting" preferential flow to one trench. A 90-degree elbow on the inlet may solve this problem. *(Photo by Tom Saxton)*

Figure: 7-20. This chamber system was apparently crushed when the trenches were filled.
(Photo by Todd Fowler, EH Supervisor)

Figure: 7-21. This chamber system is crushed and subsequently filled with soil material. *(Photo by Sarah Lewis, EHS)*

Figure: 7-22. The louvers in the chamber sidewalls allowed liquefied soil to slowly migrate into the void beneath the chamber. *(Photo by Sarah Lewis, EHS)*

Figure: 7-23. Pine tree roots (top), not normally considered hydrophilic, have invaded and filled up the distribution box (middle). Maple tree roots have inundated the drainfield trenches (bottom). *(Photos by Tom Saxton)*

Figure: 7-24. This force main, one of 11, was found to have a linear crack. The difficulty in this case was that all 11 were installed in an easement leading to offsite drainfields. Therefore, 11 homes owned the easement. Who was responsible? Sewage was flowing on the ground. But there was no one to hold responsible in order to repair the failed force main. Ultimately, the original contractors volunteered at their own expense. Offsite systems present unique problems for the evaluator. *(Photos by Tom Saxton)*

Due to the air space in a chamber, effluent only "wicks" up the sidewalls of the trench.

Figure: 7-25. The type system may be determined by the patterns in the grass. *(Photos by Tom Saxton)*

Aggregate Trenches "wick" water across the entire trench.

Figure: 7-26. Aggregate trench surfacing patterns. *(Photos by Tom Saxton & Gary Gilliam)*

The trench below has undergone anaerobic conditions.

The trench above was invaded by tree roots.

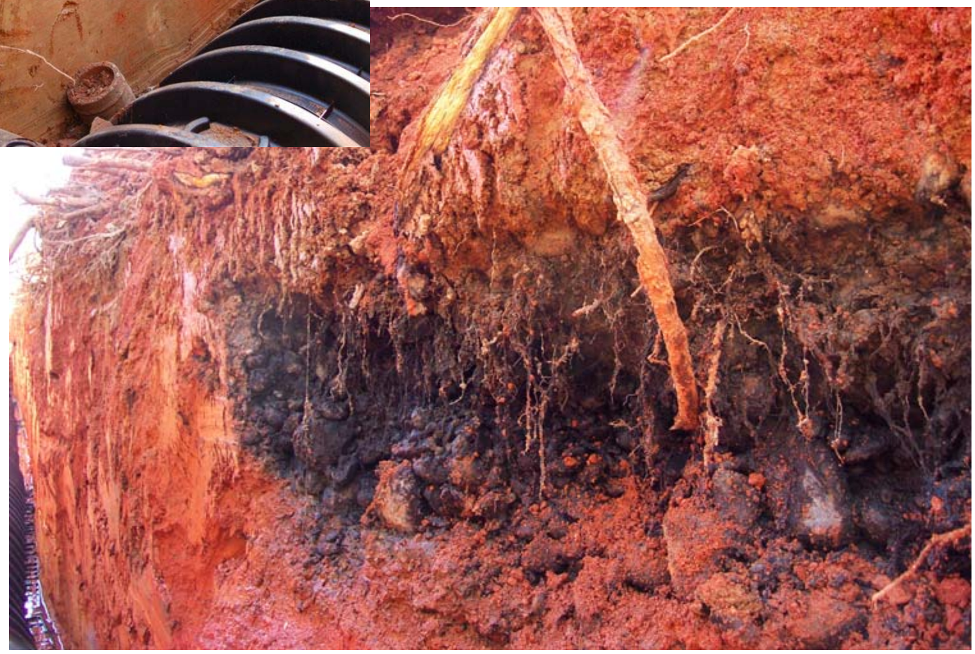


Figure: 7-27. Roots (above) and anaerobic conditions (below) due to poor septic tank maintenance and a perched water table have shortened the lifespan of these drainfields. *(Photos by Tom Saxton)*

Figure: 7-28. What's wrong with this picture? Lack of equal distribution; the distribution box needs adjustment. Some trenches are receiving more effluent than others. This may shorten the lifespan of this drainfield. The drainfield also appears to be failing over some of the trenches as evidenced by the dead spots where flooding effluent has killed the grass. The distribution box is leaking as well. *(Photo by Loudon County EH)*

Solutions

The cause of failure has now been determined, what's next? A phased approach may be prudent, especially if there is limited space and financial resources. The customer is not served well if the entire drainfield is replaced when only the conveyance line needed to be unclogged. Financially, it may be a better fix for the owner to take steps to replace components and then replace the drainfield at a later time. Especially, when there is limited space. Failure may come from multiple sources; fixing one component may enable another to work properly. Be clear with the owner about the steps in the process. If the first step does not resolve the problem, move to the next but document, document, document.

12 VAC 5-610-280. Issuance of the construction permit.

C. Exception.

2. When issuing a construction permit for **repair** of an existing failing sewage disposal system for an occupied structure with indoor plumbing, the criteria contained in Parts IV and V of this chapter shall be complied with to the *greatest extent possible.* However, *it is not necessary to substantially comply* with all of the requirements in those parts of this chapter with the exception of the set back distances for shellfish waters or drinking water wells, unless the system is already closer in which case *the corrected system shall not be closer than the existing system*. Furthermore, when it can be documented that compliance with those parts creates an economic hardship, the district health director or the district environmental health manager may waive the requirements for pre-treating the effluent *(see HB 930 section)*. All corrections must be of such a nature that they can reasonably be expected to reduce the risk to public health caused by the malfunctioning systems.

The decisions for the repair solution should come from the owner. Provide the client with all the options so they may make an informed decision. Keep public health rationale and significance in mind while assessing the system and explaining what is required to the owner. Many homeowners are not aware of the legal liability of sewage on the ground surface. They may be shocked when they receive the *Notice of Alleged Violation* letter. It may serve the evaluator to warn the client in advance that they will receive this letter. This is one of the most difficult parts of the task. The client asks for your help and now you (public sector) are required to send them a threatening letter. If there is sewage on the surface of the ground, the owner must spread lime over the affected areas to neutralize pathogens and reduce the public health hazard. *(Adapted from Beth Manghi, 2009)*

Figure: 7-29. Jetting the lines may help remove solids from pipes thereby extending the life of the system. *(Photo by Tom Saxton)*

There are many technologies available to the owner. Some do not require permits. For example, terra lifting, jetting, and using a camera to inspect the system do not require a permit. But all these may be helpful.

Jetting, while using the septic tank pump truck, is a method by which a high-pressure hose is inserted into the pipe (header, conveyance, drain tile, etc.). Water sprays out of the hose backwards acting much as "rocket" thrust. This thrust helps to draw the hose through the lines while the pump truck sucks up dislodged solids. This process may help remove small roots as well.

Figure: 7-30. "Jetting" *(Photo by Tom Saxton)*

Terralift© (GMP 80) is a method of attempting to revitalize an old system. There are no current research statistics for the success rate. The machine forces a probe into the soil near the drainfield trenches. A burst of high-pressure air along with fine Styrofoam pellets (#10 beads) is shot into the ground. The concept is that the air separates the soil, causing fractures. The pellets enter the fractures to hold them open so that effluent may leave the previously sealed trenches.

Figure: 7-31. Terralift© machine in operation above, pellets below. The machine delivers approximately 300psi at one instant. The ground virtually "jumps" up when the air is released. *(Photo by Tom Saxton)*

Ksat devices such as the Amoozemeter©, Johsonmeter© or Aardvark© may be useful for permeability determinations (see Chapter 5). A reduced permeability layer may perch water. Mounding of the effluent may occur in this instance. It may be prudent to minimize this by increasing the center to center spacing and possibly "butterflying" the trenches (see Chapter 6). Enhanced flow will also reduce the concentration of effluent over a given spot. Manifold distribution will do this even more effectively. Understanding the permeability may lead to a better design.

GMP 122 is a procedure that allows the homeowner to attempt the remediation of their old system using a treatment device. Often, this is accompanied by treatment with "digesting" compounds that are intended to oxidize the biomat and sludge that is sealing the soil surface. There is paperwork associated with this system. It requires an application and a conditional permit is recorded on the landowner's deed. The health department does not endorse or discourage this type system. It is considered a voluntary upgrade.

Conditional permits may allow the evaluator freedom to navigate within the regulations when there is limited space and small occupancy. There may be only two people living in a three-bedroom home. Limiting occupancy to two persons frees the evaluator when there is limited space for a new system.

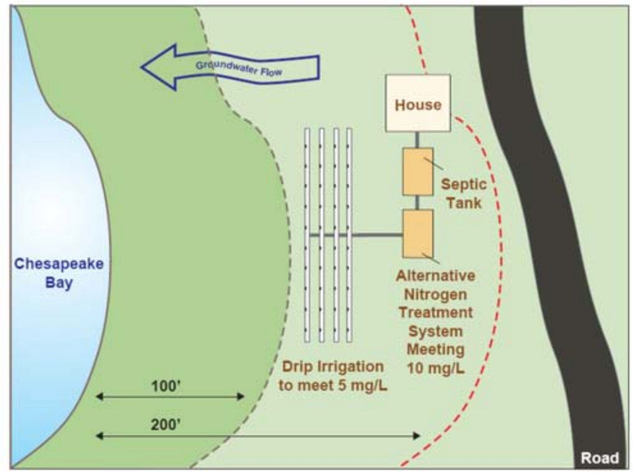


Figure: 7-32. "Butterflying" and manifold distribution will lessen the negative effect to the groundwater as well as surface waters. *(EPA, November 2012)*

HB 930 (GMP 128) is another aide, albeit complex. In this case, the owner records a waiver of treatment onto their deed. The language in this waiver also frees the evaluator from the responsibility of "owning" the system, which may be a relief in many tenuous repair scenarios.

The 2004 General Assembly passed House Bill 930 (Acts of Assembly, Chapter 916, 2004), which amends § 32.1-164.1:1 of the *Code of Virginia* by adding the following subsection:

B. Further, whenever any onsite sewage system is failing and the Board's regulations for repairing such failing system impose (i) a requirement for treatment beyond the level of treatment provided by the existing onsite sewage system when operating properly or (ii) a new requirement for pressure dosing, the owner may request a waiver from such requirements. The Commissioner shall grant any request for such waiver, unless he finds that the failing system was installed illegally without a permit. Any such waivers shall be recorded in the land records of the clerk of the circuit court in the jurisdiction in which the property on which the relevant onsite sewage system is located. Except between a husband and a wife, waivers granted hereunder shall not be transferable and shall be null and void upon transfer or sale of the property on which the onsite sewage system is located. Additional treatment or pressure dosing requirements shall be imposed in such instances when the property is transferred or sold.

The owner of the relevant property shall disclose, in writing, to any and all potential purchasers or mortgage holders that any operating permit for the onsite sewage system that has been granted a waiver authorized by this subsection shall be null and void at the time of transfer or sale of the property and that the Board's regulatory requirements for additional treatment or pressure dosing shall be required before an operating permit may be reinstated. (GMP #128)

A qualified owner may request a waiver and the waiver must be granted unless the Commissioner finds "that the failing system was installed illegally without a permit." The waiver is transferable only between a husband and a wife. Any other transfer of the property voids the waiver and the current operating permit for the system, even if that system is not failing at the time of the transfer. To obtain a new operating permit, the new owner must comply with the *Regulations* that were waived as well as any subsequent requirements that may have been imposed since the waiver was granted. Any owner who receives a waiver must record the Waiver in the land records of the circuit court and disclose the waiver in writing to any potential purchaser or mortgage holder.

Section 280.C.2 of the *Regulations* provides that the district health director or environmental health manager may, in cases of economic hardship, waive the requirement for secondary treatment for repairs. Effective immediately, this policy shall be used to implement § 280.C.2 of the *Regulations*. *(GMP #128)*

In other words, the regulatory passages shown in the yellow boxes no longer apply and GMP #128 is used to make decisions considering the waiver of treatment.

The following is taken form GMP #128: *This policy shall not be construed as imposing any obligation on VDH to provide consulting services, to minimize or maximize an owner's financial liability, or to guarantee that any system designed and permitted by VDH will function for any specified period of time. All stakeholders must understand that any system designed with a waiver under § 32.1-164.1:1.B does not comply with the Regulations for new construction nor does it meet the industry's current expectations for system designs.*

Figure: 7-33. Root mass in a sewer line (left). Camera equipment that photographed this root mass (right).
(Trent Warner, PE)

Figure: 7-34. Crushed plastic distribution boxes. *(Photo by Tom Saxton)*

Figure: 7-35. Performing Ksats can be made comfortable. *(Photo by Tom Saxton)*

Figure: 7-36. Floating pump chamber. *(Photo by Sarah Lewis, EHS)*

Bad Solutions

Some things are not good solutions. The owner will invariably ask; why can't I just add a few lines to the old system? Once the evaluator decides to dig up or add trenches, he/she has taken ownership of the soil conditions at the site. Simply scraping out the old gravel and pipe and putting in new pipe and gravel because the old system "worked" is insufficient. Adding two trenches to an existing set of four failing trenches will not solve the problem for long. Should the evaluator be tempted to do this, they must perform a normal site evaluation and permeability estimate at that depth. They are responsible for insuring vertical standoffs as well. This may be the only solution and certainly, it is reasonable to think that if the old system worked for 45 years at this site, the new one should also. But, we are not allowed to guess like they did in 1965. The designer must justify the decision with data. The old system may act somewhat as a permeability assessment if the designer is certain there are no other variables involved, such as straight-pipes. Remember, grey-water was not considered sewage until the mid 1960s. Therefore, any system being repaired from that time period has a high likelihood of having a grey-water straight pipe. There are many ingenious "fixes" one may encounter that enabled these old systems to function for as long as they have. One must be careful not to assume that the old system was the only discharge source and that it functioned at today's standards.

Figure: 7-37. Another common solution is to cover the failed area with soil. As you can see from this photo, that is doomed to failure. The effluent is just wicked up into the fill material. *(Photo by Gary Gillian)*

Figure: 7-38. Bad solutions will continue to haunt the homeowner. *(water.me.vccs.edu)*

A three-bedroom house with a 720-gallon septic tank will need a new tank of larger capacity. If the old tank is in good condition, installing the second in series will act as an additional filter/baffle to the system. The owner may be upset that they need this tank. The evaluator will be tempted to overlook this requirement. However, there is much greater water use in today's age. Many of the old tanks were only connected to the toilet; the rest of the discharge was straight-piped. The designer must follow current regulatory standards, which are only minimum standards.

The owner will question the evaluator about the size of the new system and why it is so much larger than the old. Again, there may be a temptation not to follow current design standards. But the owner should be easily convinced that the reason for the new system is the failure of the old. Most people understand today's requirements once they have been explained.

Along the shore, sea level is rising. This may be a consideration for a repair if contamination of the Chesapeake Bay and or the Atlantic Ocean is of concern. The evaluator should take into account all available information, including potential future changes.

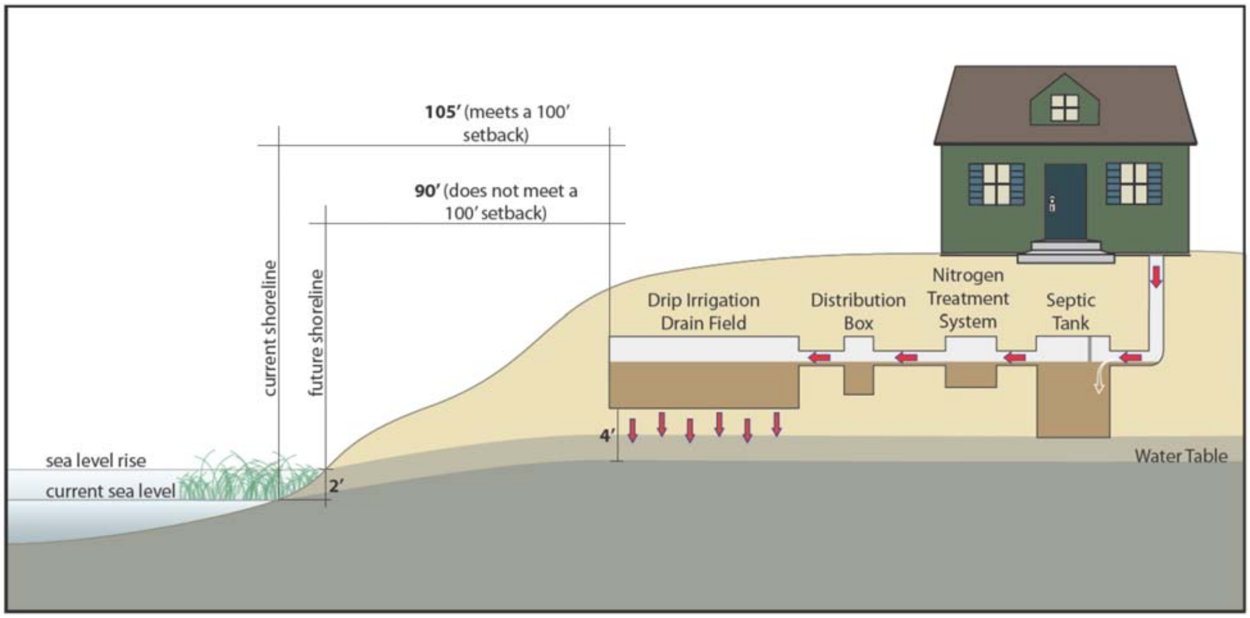


Figure: 7-39. Rising sea level will affect setbacks to shellfish waters. Water tables will subsequently rise as well. So, when in doubt, be conservative about designs. *(EPA, November 2012)*

Figure: 7-40. Rising sea levels and "King" tides (highest astronomical tide of the year) must be considered when designing a repair system. In the past, these things were not a concern. *(EPA, November 2012)*

Table: 7-3. Failure scenarios with possible causes of the problem and suggested solutions. Boldfaced items are the surficial (obvious) malfunction. Italicized items are the defining points. *(Adapted from Beth Manghi, 2009)*

Conditions	Possible Source	Recommended Action
Effluent backing into house *Septic Tank not full* Pump Chamber not full (if applicable) Distribution Box is dry (no water) Trenches are dry	Building Sewer Crushed or broken component	Unclog building sewer
Effluent backing into house Septic tank is full *Distribution Box is dry* Trenches are dry	Septic Tank Pump Chamber Outlet Tee Conveyance Line Force Main (if applicable) Crushed or broken component	Pump Septic Tank Check Septic tank for water-tightness Check Pump Chamber for water-tightness Replace Pump/Floats Check dosing volumes for Pump Replace inlet/outlet Tees Unclog Conveyance Line Replace Conveyance Line Redirect downspouts (gutters) Repair leaking fixtures Adjust water use behaviors
Effluent backing into house Septic Tank is full Pump Chamber is full Distribution Box is full *Trenches are dry*	Header Lines Crushed or broken component Trenches	Check condition of Distribution Box Level Distribution Box Check condition of Header Lines (camera) Unclog Header Lines Drainfield may be compromised by roots; replace drainfield/pull roots out Chambers may have collapsed; replace drainfield Chambers may be inundated with soil; replace drainfield
Effluent backing into house Septic Tank is full Pump Chamber is full Distribution Box is full *Trenches are saturated*	Septic Tank Pump Chamber Distribution Box Header Lines Trenches Surface water/water table Crushed or broken component Water Table Sump pump discharge	Check Septic tank for water-tightness Check Pump Chamber for water-tightness Replace Pump/Floats Check dosing volumes for Pump Redirect downspouts (gutters) Repair leaking fixtures Adjust water use behaviors Install LGMI Replace Drainfield (consider age)
Wet spot over Septic Tank *Distribution Box is dry* Trenches are dry	Septic Tank Tees Pump Chamber Conveyance Line Surface water/water table Crushed or broken component Sump pump discharge	Pump Septic Tank Check Septic tank for water-tightness Replace Tees Check Pump Chamber for water-tightness Replace Pump/Floats Check Dosing volumes Unclog Conveyance line Replace Conveyance Line Replace Force Main
Wet spot over Distribution Box Distribution Box is full *Trenches are dry*	Distribution Box Header Lines Trenches Crushed or broken component	Check condition of Distribution Box Level Distribution Box Check condition of Header Lines Unclog Header Lines Drainfield may be compromised by roots; replace drainfield/pull roots out Chambers may have collapsed; replace drainfield Chambers may be inundated with soil; replace drainfield

Wet spot over saturated Trenches Distribution Box is full Septic Tank is full Pump Chamber is full	Pump Chamber Surface water/water table Water use volume Trenches Downspouts Sump pump discharge	Check Pump Chamber for water-tightness Replace Pump/Floats Check Dosing volumes Redirect downspouts (gutters) Repair leaking fixtures Adjust water use behaviors Install LGMI Replace Drainfield Chambers may have collapsed; replace drainfield Chambers may be inundated with soil; replace drainfield
Wet spot over saturated Trenches *Distribution Box is dry* Septic Tank is at normal level Pump Chamber is at normal level	*Pump System* Pump Chamber Water use volume Surface water/water table Slow percolation rates Landscape Position	Check Pump Chamber for water-tightness Replace Pump/Floats Check Dosing volumes Install LGMI Chambers may have collapsed; replace drainfield Chambers may be inundated with soil; replace drainfield Replace Drainfield
	Gravity System Conveyance Line Surface water/water table Slow percolation rates Landscape Position	Unclog/replace Conveyance Line Install LGMI Chambers may have collapsed; replace drainfield Chambers may be inundated with soil; replace drainfield Replace Drainfield
Pump is running often / excessively	Pump Chamber Pump Floats Surface water/water table Leaking fixture Excessive water use behaviors	Check Pump Chamber for water-tightness Replace Pump/Floats Repair leaking fixtures Adjust water use behaviors

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