SOIL

DEFINITION: The collection of natural bodies on the earth's surface, in places modified or even made by man, of earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors. The upper limit of soil is air or shallow water. The lower limit of soil is normally the lower limit of biologic activity which is approximately the common rooting depth of native perennial plants. This definition focuses on soils ability to support plants because it is considered the most important function of soil by the people of the world.

SOIL COMPONENTS: The average surface mineral soil horizon (topsoil) contains more than just mineral matter. Equally important for a soils ability to support plants are three other major components. The major soil components and their average percentages are:

1. Mineral Matter (small rock fragments less than 2mm dia.) - Approximately 45% .
2. Air (air filled pores) - 20 to 30%
3. Water (water filled pores) - 20 to 30%
4. Organic Matter (includes living organisms) - 5%

It is important to understand that soil is not just a random assortment of mineral particles. A healthy soil is actually a dynamic material that is constantly under going change and which also contains millions of living organisms, air and water. If any of these components are lacking or out of balance it has a profound effect upon what, if any, plant life can grow on or in the soil.

Soil Air - Air in the soil is as important to plants as air in the atmosphere is to people. That is because plant roots and soil micro-organisms need to breath. If a soil is compressed so that no pore space exists, plants could not survive because the roots would not have room to grow and they would not have enough air to breathe. It would also be very hard for plant roots to penetrate the hard soil or for microbes to find a place to live or get air to breathe.

Soil Water - Water is essential for all living organisms, as we all know. Not only does soil water satisfy living organisms need for water but it serves several other functions. It is the primary means by which nutrients are removed from the soil and transported to plants. Soil water can act as a solvent, dissolving certain nutrients, making them available to be taken up by plants. It also is responsible for moving materials into and out of soil horizons, resulting in the development of distinct soil profiles. Without soil moisture, micro-organisms could not breakdown organic matter and return the nutrients for recycling. It is also one of the primary agents for breaking down rocks into soil particles.

Soil Organic Matter - Soil organic matter influences the physical and chemical properties of soil far out of proportion to the small quantities present in a soil. It acts like a "magnet" to hold on to nutrients so they are available to be used by plants (clay does also but no where to the extent that organic matter does). Organic matter is the most important factor in causing soil particles to clump together into structural units. The result is that the soil will have a lot of pore space, between the structural units, which is very desirable in helping to aerate the soil. It also acts like a sponge to hold water, even from the atmosphere, where it is stored for later use by plants. And, finally, organic matter is a primary source of food for soil micro-organisms.

Soil Organisms - There are two general categories of soil organisms, Macro or large and Micro or small organisms:

1. Macro-organisms - Macro-organisms include such things as ground hogs, moles and earth worms. The most important macro-organism is the earth worm. They pass up to 15 tons of soil through their bodies/acre/year. They are beneficial in that they aerate the soil with their channels and they mix the soil.

2. Micro-organisms - Micro-organisms include both plants and animals, some of which are very small. Examples of micro-animals are Nematodes, small worm like creatures, and protozoa which are the most common soil micro-animal. They generally live on other soil organisms. Some examples of soil micro-plants are algae, yeasts, molds mushrooms and bacteria, the most numerous of the micro-plants. A single gram of soil can contain up to 3 Billion bacteria! Soil micro-organisms can:

a. cause plant diseases

b. eat plant roots (micro-animals)

c. compete with plants for soil nutrients

d. use up oxygen in a soil that has little oxygen (usually a wet soil) so it is not available for plants.

e. cause some soil nutrients, such as sulfur or nitrogen to be changed in form so it will be lost as a gas.

f. cause some soil nutrients such as iron or manganese to reach toxic levels.

g. produce anti-bodies that kill other soil organisms

h. some fungi form a relationship with plant roots (called a micorrhizae) which helps both the plant and fungi to survive. In a few instances, the relationship is so important that neither can survive without the other.

SOIL FORMATION: There are five primary factors which influence soil formation. They are:

1. Climate - Temperature (freezing, thawing and high temperatures) and rainfall (erosion and leaching) are the main climatic factors that influence soil formation.

2. Aspect - Aspect, which can also be called position in the landscape, is an important soil forming factor. If a soil is on top of a hill, it will be much drier as compared to being at the bottom of a hill, in a depression. Soil temperature will also vary from a south facing slope as compared to a north facing slope. Soil on a steep side slope may erode easily whereas a soil in a low area may accumulate soil material eroded from above.

3. Vegetation - Soil formation is influenced by the type of vegetation growing on it. Some vegetation is much more acidic than others (hemlock needles are much more acidic than hardwood leaves). Some vegetation has deep roots while other plants may have shallow roots. There is even a difference in the nutrients or chemicals found in various plants and the type of micro-organisms associated with them.

4. Time - Soil takes a long time to develop. Estimates are that it takes about 100 years to develop one inch of top soil. In addition, after soil material initially forms, the combination of aspect, slope and vegetation act upon it to create a unique set of characteristics that distinguish the soil from other soils. The longer a soil has to develop, the deeper the soil is and the more well developed it is. In Maine, we have young (geologically speaking) soils because it has only been 10,000 - 12,000 years since the last glacier left. In tropical areas, soils have been developing for millions of years, in comparison.

5. Parent Material - The mineral and organic matter from which a soil is developed, over time and under the influence of climate, aspect and vegetation is called the parent material. In some places, such as the tropics, parent material is simply decomposed bedrock which has weathered in place. In Maine however, our parent materials are usually not weathered in place bedrock but soil material which has been transported by water or glaciers, from one location to another. Some times, we can find more than one parent material in one location as a result of the advance and retreat of glaciers, glacial lakes forming and draining and the advance and retreat of the ocean. There are six general categories of soil parent material found in Maine. They are:

a. *Organic* - Some soils are made up mostly of organic matter, with little or no mineral components. These are soils that usually develop in wet conditions, such as swamps, bogs or marshes, but can also occur in cold areas like mountains or off the coast. Normally, leaves, twigs or grasses decompose fairly rapidly when they fall on the soil surface. If, however, the soil is wet or cold, micro-organisms responsible for decomposing the organic matter are slowed so that the organic matter builds up. After a while the mineral soil is buried beneath a deep layer of organic matter and you have an organic soil. In general, after you build up 16 inches or more of organic matter on the mineral soil surface, the soil is considered to be an organic soil.

b. *Glacial Till* - Our most common type of soil is called glacial till. It is soil material that was moved from one place to another directly by a glacier. It may have been pushed by the glacier like a bulldozer or dropped out underneath the glacier as it melts (all glaciers are made up of very dirty water which has a lot of soil material in it). The soil material deposited by a glacier is unsorted, meaning that it has a random mixture of sand, silt, clay and rocks. All of the other mineral soil parent materials have been water sorted, to some extent (meaning that they are generally lacking at least one of the sand, silt, clay or rock components found in glacial till). There are two general categories of glacial till; *basal till*, deposited beneath glaciers and *ablation till*, pushed by glaciers. Because basal till material was deposited beneath glaciers it experienced extreme compaction and is therefore very dense below the top 1 to 2 feet of weathered topsoil. It has what we call a "hardpan" and can be very hard to dig a hole in. Ablation till on the other hand is loose and easy to dig because it did not have the enormous weight of a glacier on it. The rocks found in glacial till are generally angular and not rounded. This is because of the scraping and grinding action of the glaciers as they moved over the land.

c. *Outwash or Stratified Drift* - This is the soil material that is found where sand and gravel pits are dug. It is the coarsest of our soil parent materials and generally lacks all but maybe a trace of silt or clay in most subsoil horizons. They do however, often have a topsoil horizon which formd from fine soil particles that were probably wind blown over the gravel after the glacial stream dried up but before vegetation covered surrounding areas. These soils were deposited by glacial melt water streams and rivers and they are therefore water sorted. As the earth warmed, at the end of the last ice age, glaciers started to melt rapidly. The streams and rivers that formed by the melting glaciers carried the dirty melt water away from the glaciers. Heavy particles, such as sand and gravel, were able to drop out of the flowing water while lighter particles, such as silt and clay, were carried downstream. After many years, the sand and gravel would build up to form the soils that are now our gravel pits. If you look at the excavated side of a gravel pit you will usually see layers of sand and gravel (stratification). These layers formed due to variations in the speed of the melting water. In cooler times, the glacier melted more slowly so the stream or river flow was slower and therefore only smaller sand particles could be carried. At warmer times (middle of the summer), glaciers melted faster so the stream or river flowed faster and could therefore carry larger soil and gravel particles. Because of the constant water flow, the rocks are generally rounded. After the glaciers completely melted, the streams and rivers dried up and soil was able to form which today supports tree and other plant growth.

d. *Lacustrine Sediments* - These soils are also known as lake bottom sediments because they formed at the bottom of a lake. During the time that glaciers were melting and forming all of those streams and rivers, glacial lakes were also forming. Lots of times the streams and rivers were blocked by other glaciers as they flowed away from their glacier of origin. When that happened, a glacial lake would form which would last until the glacier dam melted. These glacial lakes were fed by muddy streams and rivers which had already dropped most of their sand and gravel onto the stream bottom. What was left in the water as it entered the lake was very fine sand, silt and clay, with no rocks. Water moves through a lake slowly, depending upon the lake size and amount of water entering the lake. As a result, soil particles which could not drop out of the fast moving stream or river could now drop out to the lake bottom. Generally, very fine sand and silt were the soil particles which dropped out but sometimes clay would also settle out, if the lake water was moving very slowly or was stagnant. You will often find layering of soil in these lake sediments for the same reason you do with the stratified drift; fluctuating speeds of water, flowing through the lake. When the glacier was melting rapidly and large volumes of water were entering the lake, water moved through the lake more quickly, only allowing the very fine sand to drop out. When the glacier was melting slowly, water entered and left the lake slowly, allowing the silt and some clay to drop out of suspension. After the ice dam melted, the soil would dry up and become vegetated. We can still tell how that soil formed, however, by digging a hole and looking at the soil features.

e. *Marine Sediments* - Our finest textured soils are called marine sediments because they formed beneath the ocean. You can see modern day marine sediments being formed by visiting the ocean where mud flats occur. They are made up of clay with very little silt and no sand or rocks. Going back to the melting glaciers, remember how the sand and gravel dropped onto the stream or river bottom and the very fine sand and some of the silt dropped onto the lake bottom? All that was left in suspension, as the melt water left the lake, was clay and the finer silt particles. Clay and the smallest silt particles are microscopic in size and can take up to six months to settle out of calm water. Since the ocean is the last place water can drain to, it must stay there until it is recycled by evaporating and being redeposited to the land as precipitation. Eventually, even the clay particles will drop out, forming mud flats. Marine sediments can be found a long way from the present location of the coast because the ocean was once much higher that it is today. In fact, it was once found up to 300 feet above it's present location. That was primarily due to the tremendous weight of the glaciers pressing down the land, allowing the ocean to move inland, up to the Bangor area. As the glaciers melted, the land rebounded, moving the ocean back to where it is today.

f. *Alluvial Soils* - Alluvial soils are formed from soil materials which were recently deposited by moving water. They are found in such areas as flood plains or beaches and vary in texture from sand to silt, depending on the speed of water from which they were deposited. Alluvial soils can be distinguished from other soils by the lack of any profile development (no distinct soil horizons). This is because soil material is deposited so frequently that it does not have enough time for soil horizons to develop. There may however, be layers with different soil textures or colors in the soil profile. Layering is due to varying speeds of water depositing the soil particles. Slow moving water will result in finer soil particles being deposited while faster water will only allow the larger soil particles to drop out of suspension. Varying colors are due to the source soil material. If top soil eroded upstream, it will have a dark brown color when deposited. If it is a subsoil which eroded, the deposit will have a much lighter color.

SOIL PROFILE: A soil profile is a vertical cross-section of the soil through all of its horizons and extending to the unweathered parent material. Simply put, it is all of the soil layers down to the soil material from which the soil developed. Soil horizons are layers of soil, approximately parallel to the soil surface, that have distinct characteristics as a result of the soil forming process. There are six primary soil horizons:

1. <u>"O" Horizon</u> - The "O" horizon is an organic matter accumulation from dead plants and animals. It is sometimes referred to as "litter", "duff" or "humus". Organic soil horizons are found above the mineral soil, unless some form of soil disturbance has occurred. They are commonly found in forested areas but not in grasslands or plowed fields.

2. "A" Horizon - The "A" horizon is a mineral soil horizon which has quite a bit of organic matter in it so that it appears dark brown to black in color. It is usually found at the soil surface or just beneath of the "O" horizon. In forested areas of Maine, the "A" horizon is usually absent , except for those soils which are wet much of the year. In cultivated or field areas of Maine, there is generally an "A" horizon which is called an "Ap" horizon. An "Ap" horizon indicates that there is an "A" horizon which has been plowed. These horizons are typically 8 - 12 inches deep, the depth of the average plow. "Ap" horizons do not only include what used to be the "O" and "A" horizons but can also include other horizons which are mixed in by the plowing process. In extreme cases where a lot of erosion has taken place, the "Ap" horizon may extend down into the parent material, eliminating all of the other horizons.

3. "E" Horizon - The "E" horizon is a soil horizon which has undergone intense leaching. It is generally only found in forested areas, particularly softwood forested areas. This is because of the leaching process. In forests, there is an organic layer ("O" horizon) which rests upon the mineral soil below. When it rains or the snow melts, water infiltrates through the organic matter to the mineral soil. As the water passes through the organic matter, it becomes acidified and acts as a bleaching agent to the soil horizon directly below it. This is the "E" horizon. It typically appears white or gray due to the bleaching action and varies in thickness but is usually only an inch or two thick. In wet sandy soils however, where there is a thick "O" horizon, the "E" horizon can be as much as 1 1/2 feet thick. It is not generally found in field or plowed areas because of the mixing action of the plowing. It is also not often found in wet soils, except for sands which can still leach even when wet.

4. "B" Horizon - The "B" horizon is found below the "O", "A" or "E" horizons but above the unweathered parent material. In Maine, it is often seen as the horizon where the leached material from above was deposited. It will often appear as a yellowish, reddish or even black color (depending on whether the leached material was mostly iron or organic matter). In wetter soils, where there is a lack of oxygen to "rust" the iron in the soil orthe iron has been leached out of the soil, colors of the "B" horizon are not as bright. An exception is the wet sandy soils where much organic matter may leach into the "B" horizon from above, beside and even beneath it, giving it a black or very dark red color. In most wet non-sandy soils the "B" horizon won't show signs of accumulating iron or organic matter but do show signs of weathering such as having soil structure, root penetration, worm channels etc. The same is true for our drier, finer textured soils (clays and silts). They are too fine for much leaching but do show signs of weathering.

5. "C" Horizon - This is the horizon which is used to indicate the unweathered parent material, though it may be a different parent material from the one which the soil above developed. This is because it is possible to have more than one parent material deposited in one location, over time. The important thing to remember about the "C" horizon is that it has not undergone the soil forming process, as the soil above have. It does not have any accumulation or leaching, does not have any developed soil structure, no roots or worm holes. Basically, it still resembles the soil material as it was originally deposited.

6. "R" horizon - The "R" horizon is used to indicate bedrock. It may or may not be the bedrock from which the soil above developed. In Maine, it is usually not the bedrock from which the soil immediately above developed. This is because of the fact that most of our soil material was moved around by glaciers or water from melting glaciers.

SOIL PROPERTIES: There are five primary soil properties which are important to understand and which greatly influence how a soil may be used for many purposes:

1. Soil Texture - The mineral component of soil is made up of various combinations of three soil separates: sand, which is the largest of the particles and is from 0.05mm - 2.0mm in diameter; silt, which is intermediate in size and is from 0.002mm - 0.05mm in diameter; and clay, which is the smallest of the soil separates or particles and is less than 0.002mm in diameter. Any particle over 2 millimeters in diameter is considered a rock fragment. Soil texture is determined by the amount of any one or all of the soil separates present in a soil. Soil scientists use what is called a textural triangle to make such determinations. Though a lab is needed to do precise textural determinations, most practicing professionals rub a small soil sample between the thumb and fore finger to make determinations in the field. A flow chart has been created by educators to help the non-professionals make the same kind of field determinations that professionals do. It works quite well.

2. Soil Structure - Simply put, the term structure refers to the combining of soil separates (particles) into units or groups. This process is quite important in a soil as it has a direct impact on the amount and type of pores in a soil. It is better to have many small units than to have a few large ones because it results in many more pores between the units. Soil structural units are referred to by the shape they take. The four main soil structural units are: *platy*, where soil particles form into thin horizontal plate like structures; *prismlike*, where the soil structural units form into prismlike shapes; *blocklike*, where soil structural units form into cube like shapes and *spheroidal*, where soil structural units form that are rounded. Generally, spheroidal structure is the most desirable for plant growth and drainage as it represents many small units commonly found in rich topsoil (organic matter encourages spheroidal structure formation). Block like structural units are usually larger than spheroidal units and are typically found in soils with insufficient organic matter. Both prismlike and platelike structural units are usually found in subsoils, which have not weathered greatly and are indicative of a hardpan or restrictive layer. They can also be very large in size, resulting in few pores for air or water movement. Often, a soil will have a combination of structural units, sometimes in the same soil horizon. It is also possible to have a soil with no structure, such as sand which is single grain and some wet clays which are called massive (one large mass of soil with no smaller structural units).

3. Soil Consistence - This term refers to the firmness of a soil. If you dig a hole in the ground and use a soil probe to remove a sample of soil from the profile, resistance is generally referred to by how much pressure must be exerted to crush the soil sample. It can also refer to resistance "in place" which means how much pressure must be exerted to penetrate the side wall of a soil pit with a soil probe (usually a knife or screwdriver). The most commonly used soil consistence terms are; loose, friable (very little resistance to penetration or crushing), firm and very firm. Sands and gravels are usually loose; topsoil is usually friable and hardpans or clay pans are usually firm or very firm.

4. Soil Depth - The depth of soil above bedrock is very important, especially if you want to dig a deep hole for any reason (excavate a building foundation for example). A shallow soil is one that is less than 20 inches deep. A very deep soil is one that is over 60 inches deep. In-between are moderately deep and deep soils.

5. Soil Drainage - This term refers to how far below the soil surface it is to the water table and how fast the soil drains when it rains or snow melts. Sandy soils, with a deep water table are considered well or excessively drained (they may be droughty to plant growth). On the other hand, clay soils in a low lying area are often considered poorly drained because they are wet much of the time. The term water table is use to describe either the "apparent" or "perched water table". An apparent water table is one that is permanent though it might fluctuate up or down some in the soil. A perched water table however, is the more common type found in Maine soils. It is present only during the wetter times of year (spring or fall) and usually is gone during the summer months. It forms by water infiltrating the soil, after a rainfall or snow melt, and then "perching" above a hardpan which it can not penetrate. Soil scientists can tell if a perched water table is present in a soil at some time, even if it is dry at the time of examination by observing the soil color. Soils which are almost always dry usually have bright colors, such as yellows or reds or browns. Soils which are almost always wet are usually dull in color, such as gray, green or blue. Soils which have a perched water table usually have a combination of colors, commonly referred to as mottling. They can be grayish with reddish spots or brown with gray spots. Generally, the grayer the soil is the longer it is wet. We can only tell if a soil has a water table during certain times of year, however. This is because of complex biological and chemical processes that occur in the soil. If the soil has a water table, when the soil temperature is above 41 degrees F, micro-organisms are active and will be breaking down organic matter in the soil. These organisms need oxygen to breath, just like we do, which they can get from soil air and even from soil water. After about a week though, if the soil is saturated and the soil water is stagnant, the micro-organisms use up all of the air in the soil water. When this happens, other soil micro-organisms start breaking down the organic matter, ones that don't need free air. They are called anaerobic micro-organisms and they get their oxygen from oxidized minerals in the soil (such as rusted iron, or manganese). The rusted iron or manganese in soil is usually strongly attached to soil particles and does not move when water moves through the soil. When the oxygen is removed from them however, they can move very easily. In a soil where there is a temporary water table, for a short time, there will be a few gray spots in the general reddish, yellowish or brownish soil colors where small amounts of iron or manganese lost their oxygen and nearby, a few brighter red or yellow spots where the iron or manganese moved to before the water table dropped enough for air to once again oxidize the iron or manganese. In soils which have a water table present for a longer time, there will be more gray colors with some red or yellow spots. In those soils, the iron or manganese may have leached completely out of the soil

profile. It is important to understand however, that this process won't occur if the soil temperature falls to below 41 degrees F, considered biologic zero. Therefore, a water table which is present from November to April will not alter soil colors and will therefore not leave any indicator of its presence behind.

6. Soil pH - Soil pH is the degree of acidity or alkalinity of a soil, measured on a scale of 1 - 14 where 7 is neutral, less than 7 is acidic and greater than 7 is basic or alkaline. In general, soils which receive more rainfall than evaporates or transpires (soils which experience leaching) are acidic. Soils where evapo-transpiration exceeds precipitation are generally alkaline. Because we have about 40 inches of precipitation each year in Maine and only about 20 inches of evapo-transpiration, our soils are usually acidic, unless they have been limed. This is paticularly true of our soils which form under softwood trees because rain water moving through the layer of needles on the forest floor becomes acidic and is more effective at leaching. Soils which are strongly acid or alkaline can be toxic to plants and soil micro-organisms. Therefore, soils should be managed so that they are nearly neutral in pH for optimum plant growth.

7. Cation Exchange Capacity - Very small soil particles, including organic matter particles, generally have negative charges on their edges and flat surfaces. They act like magnets to attract positively charged ions in the soil solution such as calcium, sodium, ammonia and potasium. This is one of the most important soil properties in that it affects soil fertility for plant growth and a soils ability to treat contaminated water moving through it. It also relates to soil pH. Soils which do not have a lot of positively charged ions attached to them are acidic and soils with high amounts of those positively charged ion are alkaline. Acidic soils very strongly hold onto positively charged ions so that they are not available to plants as nutrients. Soils which are neutral in pH have enough positively charged ions to supply plants for growth but not so many that they can be toxic to the plants. Ideally, soils will have a good mixture of positively charged ions and not be overloaded with one particular type.

A soils ability to hold onto positively charged ions is referred to as Cation Exchange Capacity. It is directly related to soil texture and organic matter content. This is because very small particles such as silt, clay and decomposed organic matter (humus) have a much greater surface area with negative charges than larger particles such as sand. For example, the surface area of one gram of clay is at least 1000 times that of a coarse sand. Soil organic matter has the greatest cation exchange capacity of any soil particle, often being many times that of clay or silt.

SOIL MAPS: Soil maps are maps which show the different kinds of soils present in an area. They are like forest type maps except that they show boundaries which are hidden underground. There are over 100 different kinds of soils, called soil series, recognized in Maine. Soil series differ by such factors as slope, parent material, texture, depth, PH, and drainage class. Many useful charts and tables have been developed for each of the soil series describing soil properties and the soils suitability for many purposes. These are often compiled into what is called a" published soil survey" which is a document that is made after all of the soils an area (such as a County) are mapped. They are available at local Soil and Water Conservation District Offices. For the counties which do not yet have a published soil survey, soil maps are still available for at least the developed areas. This is because soil scientists have either made soil maps in the past or are presently mapping there now.

It is important to understand that these County soil maps are only general in nature, due to the level of detail they show. It would be very time consuming and expensive to make maps which show very small differences in soils, over such a large area. Therefore, the maps only indicate significant soil differences which are large enough to show up at the scale of mapping. For developed areas, county soil maps show different kinds of soils only if they are at least 3 to 6 acres in size. For undeveloped areas, such as large tracts of woodland, county soil maps may not show different kinds of soils unless they are 20 to 60 acres in size. Sometimes, professional soil scientists are hired to make soil maps which show much smaller differences, for subdivisions or other intensive land uses but these are much more time consuming and costly than the more general published soil surveys. These soil maps can show differences in soil types for areas as small as 1/8 acre.