Exercise Objectives:
- Provide you with the background information needed to describe soils and name horizons in the field.
- Provide you with a hands-on exercise to describe a soil and name its horizons

Introduction
An important skill in learning about soils is to be able to describe their properties in the field and use these properties to recognize and interpret processes of soil formation. The transformation of parent material into soil is brought about through interactive physical, biological, and chemical processes as considered by the soil forming factors (climoprt: climate, parent material, relief, organisms and time). This results in the organization of soil into distinctive layers, or **horizons**. The differentiation of soil into horizons is a hallmark of soil formation. The kinds of properties and horizons that develop in soils depend on the nature, intensity and duration of these processes, which are in turn governed by climate, geology, living organisms and landscape topographic factors.

For practical reasons, soils are typically studied in the field in relatively small excavations that expose soil profiles. **Soil profiles** are two-dimensional vertical cuts down through the soil that include all the horizons. It is important to keep in mind that even though soils are observed in these small exposures, the goal is to make enough observations to extrapolate findings to soil distribution on the landscape.

Soil profile description involves two distinct steps: 1) description of soil properties and 2) interpretation of those properties by naming horizons. Key properties characterizing soil that can be observed and measured in the field constitute **soil morphology**. These include properties such as **color**, **texture**, **structure**, **consistence**, **coatings**, **pores**, **pH**, and others. When horizons having the same morphology are identified, horizon depths (thicknesses) and boundary conditions are recorded in the description. Soil morphological properties provide the basic data for subsequent horizon interpretation, so it is important to be as accurate as possible when describing morphology. In other words, soil morphology makes up the most objective information about the soil that can be obtained, while naming soil horizons is more subjective. The morphology of a soil should be described similarly by different observers, but interpretations of that basic data commonly vary. While it is important to make this basic distinction between morphology and horizon names, it is also important to realize that horizons are identified by specific combinations of morphological criteria.

Because a soil description involves determining a number of properties for several horizons, description forms or worksheets are usually used to systematically organize and record information about the soil. An example of a **soil description form** is found at the end of this handout. In addition to the soil information itself, description forms also provide guidelines for recording location and environmental information about the soil and site.

A summary of important morphological properties is given in the following paragraphs, followed by a guide for naming soil horizons. For more detailed information about description, genesis, and significance of these properties, references listed at the end of this document should be consulted. Emphasis in this document is on **color**, **texture**, and **structure**, which are the most important morphological properties. The order of presentation for soil morphology roughly follows that on the soil description sheet provided.

**Soil Morphological Properties**

**Color**
Color is usually the first property that attracts attention in observing soil. Color can provide valuable clues about processes that are or have been operating in the soil (Bigham and Cioclosz, 1993). For example, the **darker the topsoil color the more organic matter** it usually contains, a critical soil component for fertility and tilth. A practical application of this relationship is for pesticide recommendations, which vary with soil organic matter content. **Grey colors and mixed colors in subsurface horizons are often indicative of seasonally wet conditions** when the water table is high. In some regions, **degree of redness in subsurface...**
horizons can be correlated with soil age and landscape stability, which has practical applications in geotechnical engineering.

Soil color is measured with the Munsell Soil Color Charts, which allow fairly precise observation of the three color attributes. The soil color book, which is made up of these charts, only contains those colors commonly found in soils, which represents only part of the entire visible spectrum. The first color attribute, hue, refers to the dominant spectral color, or wavelength of light. Each page in the color book represents a different hue, with the hue symbol written on the upper right side of each page. The color book begins with the red hues (10R), followed by yellow-red hues (2.5YR, 5YR, 7.5YR, and 10YR-each progressively less red and more yellow), and ends with the yellow hues (2.5Y and 5Y). Other special pages, for example for soils redder than 10R found in the tropics, or the color chart for wetland soils, are also available. Value refers to the darkness or lightness of the color, on a scale from 2 (dark) to 8 (light) for soils [the total scale is from absolute black (0) to absolute white (10)]. Chroma refers to the relative strength or purity of the spectral color, ranging from 0 (neutral grey) to 10 (bright saturated color). (Note: If the chroma is zero, there actually is no hue and the letter N is used instead). Each page of the color book (representing each hue) is set up as a matrix or grid filled with color chips, with value on the y-axis (dark to light from bottom to top), and chroma on the x-axis (dull to bright from left to right). The conventional notation for recording color is to write the hue and then the value and chroma as in the following example:

\[
\begin{align*}
\text{Hue} & \quad 10YR 5/4 \\
\text{Value (numerator)} & \\
\text{Chroma (denominator)} &
\end{align*}
\]

In writing a formal soil description, the color name associated with each color chip is added (e.g., yellowish brown for 10YR 5/4). Refer to the color book for details on how the Munsell color system works.

When determining soil color, the basic task is to match the soil color as closely as possible to one of the color chips in the book. Determination of soil color in full sunlight is preferable, other conditions should be noted. Because soil color varies by moisture content, measurement in a complete soil description is usually done in the moist and dry (if possible) state, not in between. If the soil is partly dry, it is necessary to spray water on a sample to determine the moist color. It is conventional to determine the color of the first horizon on a crushed sample, but on the face of a broken fragment for subsequent horizons. The color chips are fragile, so avoid touching or getting soil, water, etc. on them.

Redoximorphic Features (also known as mottles and gley colors)
Redoximorphic ("redox" for short) features refer to special soil colors caused by wet conditions, in which anaerobic conditions (lack of oxygen) occur in the soil for significant periods. Such redox features constitute a state of variable soil color brought about mainly by the reduction and oxidation of iron and manganese. When soil becomes excessively wet and low in oxygen, iron is reduced from Fe\(^{3+}\) to Fe\(^{2+}\) and manganese from Mn\(^{3+}\) or Mn\(^{4+}\) to Mn\(^{2+}\), and these reduced forms are mobile. These reduced, mobilized cations then diffuse towards more aerobic zones (e.g., more oxygen-rich macropores), where they reoxidize into brighter-colored Fe and Mn oxides and hydroxides. Such a soil has a characteristic "splotchy" or variegated (mottled) color with zones of grey and brighter reds or other colors. The grey zones are called redox depletions because the reduced Fe and Mn has moved away, and the brightly-colored zones are called redox concentrations because Fe (commonly red color) or Mn (commonly black in color) has accumulated there as oxides. In describing redox features, the color, abundance, and color contrast between redox features are recorded for each horizon in which they occur. The zone in which Fe and Mn has become reduced or depleted takes on what is known as a "gley" color, in which chroma is low (<2) and value is typically ≥4. This is a dull grey color, or in cases in which significant amounts of reduced Fe or Mn are still present, the soil color may be various shades of blue or green (see gley color chart). If the soil is entirely anaerobic, the soil may become completely gleyed, without any bright-colored redox concentrations. For further information on wetland soil morphology, the reference by Vepraskas (1992) is recommended.
Texture

Texture generally refers to the size distribution of mineral particles in soil. Being able to estimate texture is important because of the major influence this variable has on many facets of ecosystems, as well as land use such as agriculture and engineering. For example, particle-size greatly affects water infiltration and movement, water availability for plants, aeration, fertility, root growth, and resistance to physical stress.

Specifically, texture consists of the proportions (by weight) of three particle-size classes: sand, silt, and clay. These are defined by size as follows:

- **sand** = mineral particles 0.05 to 2mm diameter
- **silt** = mineral particles 0.002 to 0.05mm diameter
- **clay** = mineral particles <0.002mm (<2um) diameter

The proportions of sand, silt, and clay are expressed as percentages and always add up to 100%.

Sand, silt, and clay can be distinguished in the field by tactile properties such as grittiness, smoothness, stickiness, and plasticity. You will learn the "feel" method for estimating soil texture in lab. To facilitate texture description, the various proportions of sand, silt, and clay are grouped into 12 classes (classes based on similar physical behavior) using a graph called the textural triangle (see example below). Soil textures that contain behaviorly equal amounts of sand, silt, and clay are grouped into the class of "loam." The texture triangle reflects the greater influence clay has on soil behavior relative to sand or silt. Other texture classes in which either sand, silt, or clay dominate are named using that term alone or in combination with loam, depending on the relative amounts. For example, a soil with 40% sand, 30% silt, and 30% clay plotted on the triangle falls into the class "clay loam."

Note that mineral particles larger than sand, such as gravel, boulders, etc., are not strictly part of texture, which only includes the "fine-earth" (<2mm) fraction of the mineral soil. Larger particles, referred to collectively as "rock fragments," are usually determined separately in the field by the percent volume they occupy in the soil. When significant amounts of rock fragments are present in the soil (>15% by volume), adjectives such as "gravelly" are written in front of the texture name (e.g., "gravelly loam").
Structure
Whereas texture concerns individual mineral particles in soil, structure refers to how those particles and other materials are clustered or aggregated into larger units. Structure is analogous to a house, an organized entity composed of solid particles (mineral particles and organic matter) as building blocks, with the space (pores) between solid particles filled with air or water. Like texture, soil structure is significant with regard to plant growth requirements and many land use considerations. Soil aggregation results from complex physical, chemical, and biological processes and interactions. Among the important mechanisms of aggregation (i.e., the nails and "glue" holding the house together) are electrochemical interactions of clay, humus, cations, and water, cementing agents such as Fe and Al oxides, silica, and calcium carbonate, and biological materials such as root exudates, fungal hyphae, and microbial products that act as binding agents. Other references should be consulted for information about soil structure genesis and aggregate stability [e.g., see Brady and Weil (2002) for basic information and Hillel (1998) for a more in-depth treatment].

Two basic conditions exist with regard to soil structure, namely, whether or not the soil contains a pattern of aggregates of certain shape and size. Some soils, or more likely, horizons within a soil, are not aggregated at all. Unaggregated soils, such as sands or gravels consisting of loose, individual particles lacking cohesion, are described as "single grain." A soil condition in which irregular masses occur without soil-formed, patterned aggregation is called "massive." Material below the zone of active soil formation (i.e., in the C horizon) is usually massive, as is topsoil whose structure has been destroyed by excessive tillage and compaction. Parent materials commonly possess geologic or sedimentary structure, which should be described separately from pedogenic structure.

Soil-formed horizons commonly have an aggregated structure in which certain patterns of aggregate size and shape are evident. An individual aggregate is called a ped. Peds separate along planes of weakness with characteristic pores shapes in between. The degree to which aggregates are evident is described by the property of structure known as grade, which may be weak, moderate, or strong. It should be noted that in many cases, structure is compound. That is, larger peds may contain smaller peds of the same or different shape within them. Types of structure, described in the attached figure, include granular, platy, blocky (subangular or angular blocky), prismatic, and columnar. A brief summary of each structure type (shape), and common associations of each type with certain horizons, are presented here:

*Granular*-peds are approximately spheroidal, with non-accomodating faces. Ped size varies but granules commonly have the size and look of "grape nuts." Very porous granular structure is sometimes known as "crumb structure." Granular structure is formed where there is abundant organic matter and biological activity, so it is commonly found in A horizons. Stable granular structure with plenty of organic matter is usually favorable for plant growth because of macropores between and within peds providing for a good seed bed, and easy passage of water, air, and roots. Such a condition is associate with good "tilth."

*Platy*-peds are thin, flat, and horizontally layered. Genesis is not well understood, but platy structure commonly occurs in E horizons, light-colored eluviated horizons that underlie some A horizons, for example in certain forested soils (including soils under deciduous forest in Iowa).

*Blocky*-peds are polyhedral in shape and approximately the same size in all dimensions. Ped faces accomodate each other, fitting together like puzzle pieces with intervening planar pores. Blocky structure forms mainly by repeated shrinking and swelling of clay as it dries and wets. In *subangular blocky* structure, both rounded and flat ped faces occur, and edges are mostly rounded. In contrast, faces in *angular blocky* structure are mostly flat and edges have sharp angles. Increasing angularity is correlated with greater clay content (more pronounced shrinking and swelling). Blocky structure occurs in several kinds of horizons but is most prevalent in B horizons.

*Prismatic*-peds are vertically oriented, pillar-shaped, with accomodation between adjoining faces. Most common in clayey soils with strong shrinking and swelling, such as Vertisols and older soils with well-developed horizons of clay accumulation.
Columnar-peds are also long in the vertical dimension, as in prismatic structure, but with a rounded, cap-like top. Most common in clayey natric (Btn) horizons which are high in exchangeable sodium. The rounded top may be produced by upward swelling of the peds and/or by dispersion of clay as the sodic soil is wetted from above.

Types of aggregated structure
(Soil Survey Staff, 1975):

Coatings
Fine material may move through soil pores suspended in water. When the water is withdrawn into peds or evaporates, that suspended material is deposited along the pores on the surfaces of peds and particles. Over time, the deposits can become thick enough to be visible as coatings. Potentially mobile materials in soil that commonly form coatings include clay, iron, silica, manganese, calcium carbonate or more soluble salts, and organic matter. When describing coatings, the type of material, thickness, and location are noted. Microscopic study of coatings may be warranted.

Clay coatings are especially prevalent in many regions of the world, including here in Iowa. It may take thousands of years of soil formation for clay coatings to become visible, so the presence of these
Coatings in horizons of clay accumulation is usually indicative of a land surface that has been stable for a significant length of time.

**Concentrations**
Mobile materials may also be concentrated into secondary masses in soils. For example, sufficient iron or manganese may build-up from reduction-oxidation processes such that concretions and nodules form. Concretions form as material periodically accretes around a nucleus of material, so the mass becomes concentrically banded. Nodules are secondary masses without internal structure. Calcium carbonate and silica also produce secondary masses in some soils.

**Pores**
The "holes" in soil architecture, called pores or voids, are commonly overlooked in soil description but are clearly as important as the solid space they lie between. They conduct water, air, and suspended or dissolved solids through soil and are the passages through which roots grow. Pores are created by both physical and biological processes. In a complete soil description, observations of pore shape, size, location, number per unit soil volume, and orientation are made. Depending on the purpose, microscopic study may be helpful.

**Roots**
Whether or not roots should be considered part of soil morphology is open to question. Nevertheless, roots are a key biological measure of soil as a medium for plant growth. In a complete soil description, the size, location, and number of roots in a unit volume of soil are measured. It is especially important to note whether there are any restrictions to rooting. A clayey soil with prismatic structure may only allow rooting along the vertically oriented planar pores, thus greatly restricting plants' ability to extract water or nutrients. Stresses in such situations may cause root deformation. Some horizons, such as fragipans or more permanently cemented horizons, may completely shut out roots altogether. In encountering these restrictive horizons, roots commonly abruptly change direction from vertical to horizontal.

**Carbonate and other salts**
Carbonate (especially calcium carbonate, CaCO₃) is commonly found in soils of arid and semiarid lands, where precipitation is insufficient to leach or wash the soil of carbonate or more soluble salts. Carbonate can also accumulate in humid regions around topographic depressions with high groundwater tables. In these settings, carbonate-charged groundwater rises by capillary action to the surface and evaporates, leaving the carbonate behind to precipitate at or near the soil surface.

Carbonate is detected in the field by adding a few drops of one molar HCl on the soil. Presence of carbonate is confirmed if bubbling (effervescence) occurs (from release of CO₂). The level of carbonate present is correlated with the degree of effervescence detected, which can range from audible but not visible, to slightly visible, to obvious foaming. Carbonate is also commonly visible in soil as a white precipitate, which can take various forms such as filaments, coatings, soft or hard masses, and laminae.

Other salts may accumulate in soil such as gypsum, sodium salts, etc. Each of these has chemical and morphological traits that can be differentiated in the field.

**Soil pH**
An important chemical property of soils that can be measured in the field is pH, also called soil "reaction." Soil pH, as an indicator of acidity or alkalinity, provides important practical information about fertility and other soil properties needed to understand ecosystems, as well as land use suitability and hazards. Soil pH can range from as acid as 2 to as alkaline as 10, with most soils between pH 4 and 8.
The nature of the boundary between soil horizons is also noted in field descriptions of soils. The distinctness of boundary refers to the distance of transition from one horizon to another. Boundaries may range in distinctness from abrupt to gradual. The topography of the boundary between horizons, be it smooth, wavy, or irregular, is also described.

**Naming Soil Horizons**

**Master Horizons**

O - Horizon dominated by organic matter.

A - Mineral horizon with some organic matter accumulation.

E - Mineral horizon formed by eluviation (loss by leaching) of clay, iron, and/or aluminum. Horizon relatively light colored.

B - Mineral horizon that has lost all or most geologic structure (including fine stratification of sediments) and contains evidence for one or more of the following soil-forming processes:

1) illuviation (accumulation by translocation) of clay, iron, aluminum, humus, carbonates, gypsum, or other salts.
2) residual accumulation of clay or Fe/Al oxides by in place weathering.
3) soil-forming processes such as leaching of carbonates, or development of structure and/or color.

C - Relatively unweathered, unconsolidated mineral material or soft bedrock.

R - Hard bedrock.

**Common Transitional Horizons**

AB - A horizon transitional to B; BA - B horizon transitional to A.

EB - E horizon transitional to B; BE - B horizon transitional to E.

E/B - E horizon “tonguing” into B (mostly E); B/E - E “tonguing” into B (mostly B)

BC - B horizon transitional to C; CB - C horizon transitional to B.

AC - Transition zone between A and C horizons.

**Sub-horizon Symbols**

a-decomposed organic matter (humus)  o-residual Al and/or Fe oxide accumulation

b-buried horizon  p-plowing or other disturbance

c-concretions or nodules  q-silica accumulation

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**Range of soil pH (Jenny, 1980):**

<table>
<thead>
<tr>
<th>pH</th>
<th>Acid</th>
<th>Neutral</th>
<th>Alkaline</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Lemon Juice Acid Sulfate Soils</td>
<td>Leached soils</td>
<td>Many fertile soils</td>
</tr>
<tr>
<td>4</td>
<td>Pure Water</td>
<td>Calcareous soils</td>
<td>Soap Sodic soils</td>
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<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
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<td>10</td>
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</tbody>
</table>

**Boundary**

The nature of the boundary between soil horizons is also noted in field descriptions of soils. The distinctness of boundary refers to the distance of transition from one horizon to another. Boundaries may range in distinctness from abrupt to gradual. The topography of the boundary between horizons, be it smooth, wavy, or irregular, is also described.
Some Guidelines for Naming Horizons

1. Subhorizon symbols are suffixes for master and transitional horizons. More than one subhorizon symbol can be used (e.g., Btg). An important rule is that B horizons always have a subhorizon symbol. If used, "t" usually precedes other subhorizon symbols in B horizons. "w" is used alone with a B horizon and only if no other subhorizon symbol fits.

2. Arabic numeral suffixes are used to subdivide horizons with the same letter designations. For example, the horizon sequence A1-A2-Bt1-Bt2-Btg-C.

3. Arabic numeral prefixes are used to indicate changes in soil parent materials (lithologic discontinuities). The uppermost mineral parent material is understood to be 1, but not numbered. The rest are numbered 2, 3,... in sequence. For example, the horizon sequence A1-A2-Btl-2Bt2-2Btg-2C, for a soil with two parent materials.

4. Primes are used on the lower of two horizons having the same letter designations but separated by a different horizon. For example, the horizon sequence A-E-Bt-E'-Btx-C. A double prime is used on the lowest of three separated horizons having the same letter designation.

Action Items

- We will describe soil characteristics and name horizons in several soil pits located at Reactor Woods part of the ISU Applied Sciences Complex.
- Each team will fill out one form for two pits that they describe – this information will be used in other exercises during the course.
- Further exploration of soils will be done at this site in the coming weeks.
- Following these exercises each person will be held responsible for understanding the Soil Landscape Model for Central Iowa that has been provided to you in previous labs.
- Later in the semester this site will also be used for a major term project.
- It is therefore important to clearly understand the differences in soils found at the site.
Comparison of Current Soil Horizon Naming System with Previous System (found in older soil survey reports, etc.)

CHANGES IN MASTER HORIZON DESIGNATIONS

2. Capital letters, lowercase letters, and Arabic numerals are used to form the horizon designators.
   a. Capital letters are used to designate master horizons. This convention is unchanged.
   b. Lowercase letters are used as suffixes to indicate specific characteristics of the master horizon. This convention is unchanged.
   c. Arabic numerals are used as suffixes to indicate vertical subdivisions within a horizon and as prefixes to indicate discontinuities. This is a change. Previously, Arabic numerals were used as suffixes to indicate a kind of O, A, or B horizon and indicate vertical subdivisions of a horizon, and Roman numerals were used as prefixes to indicate discontinuities.

3. The symbols used for many horizon characteristics have been changed. The comparison of symbols used to designate master horizons and subordinate distinctions within master horizons can be only approximate. Some designations for master horizons in the old system can best be equated with a combination of master horizon symbol and subordinate symbol in the new system.
   a. Master horizons

<table>
<thead>
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<th>Old</th>
<th>New</th>
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<tbody>
<tr>
<td>O</td>
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<tr>
<td>O1</td>
<td>Oi, Oe</td>
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<tr>
<td>O2</td>
<td>Oe, Oe</td>
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<tr>
<td>A</td>
<td>A</td>
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<td>A1</td>
<td>A</td>
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<td>A2</td>
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<td>A3</td>
<td>AB or EB</td>
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<td>AB</td>
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<td>A&amp;B</td>
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<td>B1</td>
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4. Primes are used in both the old and new systems, but the conventions for using them are different. In the old system primes were used to identify the lower sequence of a soil having two sequences, although not for a buried soil. In the new system it may be appropriate to give the same designation to two or more horizons in a pedon if the horizons are separated by a horizon of a different kind. The prime is used on the lower of the two horizons having identical letter designations. If three horizons have identical designations a double prime is used on the lowest.
References on Soil Morphology and Soil Profile Description


Note: this document was prepared by Jon Sandor in 1994 (updated August, 2004)(slightly modified by Dick Schultz, 2006), at Iowa State University for use in the following courses: Soil Genesis and Landscape Relationships (Agronomy 473), Field Experience in Soil Description and Interpretation (Agronomy 370), and Forest Ecology and Soils (Natural Resource and Ecology Management 301).
KEY TO SOIL TEXTURE BY FEEL

[Adapted from flow chart by Steve Thien, 1979, source unknown.]

Begin at the place marked "Start" and follow the flow chart by answering the questions, until you identify the soil sample.

START

Place approximately 2 teaspoons of soil in your palm. Add water by drops and knead the soil until it is moldable and feels like moist putty.

Add dry soil to soak up water.

Add drops to make wetter.

Does soil remain in a ball when squeezed?

YES NO

Is soil too dry? NO

Is soil too wet? NO

SAND

Place ball of soil between thumb and forefinger. Gently push the soil with thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over forefinger, until it breaks from its own weight. Does soil form a ribbon?

NO YES

LOAMY SAND

Wet a small pinch of soil in palm until it is very wet. Rub soil around with your finger.

Does soil make a weak ribbon <1" long before it breaks?

YES

HI

SANDY LOAM

Does soil feel very gritty?

YES NO

SANDY CLAY LOAM

Does soil feel very gritty?

YES NO

SANDY CLAY

Does soil make a medium ribbon 1-2" long before it breaks?

YES

SANDY CLAY

Does soil make a strong ribbon >2" or longer before it breaks?

YES

SANDY CLAY

Does soil feel very gritty?

YES NO

CLAY LOAM

Is soil really neither gritty nor smooth?

YES NO

CLAY

Is soil really neither gritty nor smooth?

YES NO

CLAY

SILTY LOAM

Does soil feel very smooth?

YES

LO

SILTY CLAY LOAM

Does soil feel very smooth?

YES

SILTY CLAY LOAM

Does soil feel very smooth?

YES

SILTY CLAY

SILTY LOAM

Does soil feel very smooth?

YES

WOW! The Wonders Of Wetlands Environmental Concern Inc., P.O.Box P, St. Michaels, Maryland 21663
<table>
<thead>
<tr>
<th>Soil</th>
<th>Date</th>
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<tr>
<td>Location</td>
<td>Description by</td>
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<td>Drainage Class</td>
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<td>Slope</td>
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<td>Landform</td>
<td>Erosion</td>
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<td>Vegetative Cover</td>
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**Classification**

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Main Color(s)</th>
<th>Redox Features</th>
<th>Clay Coatings</th>
<th>Texture</th>
<th>Structure</th>
<th>Consistency</th>
<th>pH</th>
<th>Boundary to Horizon Below</th>
<th>Remarks (gravel, carbonate, roots, pores, concretions, etc.)</th>
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**Soil Profile Description Form**
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