PRINCIPLES OF SOIL SCIENCE EXERCISE MANUAL

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Licensing

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1.1: Determining Soil Physical Properties

Learning Objectives

Upon completion of this exercise you should be able to:

- determine Munsell color of dry and moist soil samples
- identify soil structure using the Field book for describing and sampling soils
- classify soil texture using the "Feel Method"

Purpose:

The purpose of this exercise is to familiarize you with basic soil physical properties (color, structure, and texture) of soil samples.

Background:

For this exercise we will be describing basic soil properties (color, texture, and structure) in discreet hand samples. Soil color has little bearing on the function or use of soils, but provides information about soil properties and conditions. Color is most influenced by organic matter content, water content, and oxidation state. Also, soil color is the most obvious feature of a soil and one of the easiest properties to measure. We will determine soil color using a Munsell Color Chart. When using the chart to determine a soil color, soil is compared to a small color chip that is described by **hue** (red/yellowness), **value** (light/dark), and **chroma** (intensity of brightness) in that order. Soil color should always be determined when the soil is slightly moist.

- Example:

Soil structure refers to the arrangement of primary soil particles into groupings called aggregates or **peds**. Structure greatly influences water movement, heat transfer, aeration, and porosity in soils. Structure is characterized in terms of the shape (or type), size, and distinctness of the peds. There are four basic structural shapes, some of which are subdivided: spheroidal (granular or crumb), plate-like, blocky (angular or subangular), and prism-like (columnar or prismatic). Size includes fine, medium, or coarse, while distinctness is described as strong, moderate, or weak.

Soil texture describes the size of soil particles within the **fine earth fraction**, that portion excluding gravels, cobbles and boulders. Thus, soil texture is a combination of the sand, silt, and clay fractions. There are three basic soil textural classes: sandy soils, clayey soils, and loamy soils; loams are combinations of sands, silts, and clays in nearly equal portions. The basic textural classes can be subdivided and from coarsest to finest texture are: sand, loamy sand, sandy loam, loam, silt loam, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay and clay. Texture can be further subdivided into fine and coarse factions (i.e. fine sandy loam etc.). For this exercise we will classify soil texture using the "Feel" method (see Box 4.1, page 103 in Brady and Weil) and later in the semester we will use other laboratory techniques.

Equipment required:

- Munsell Color Chart
- Water spray bottle
- Paper towels
- Soil samples
- Field Book for Describing and Sampling Soils (Ver. 3.0)
- Water squirt bottle
- Mud bucket

Exercises:

1. Using the Munsell Color Chart classify DRY soil color for the following samples

    A.

    B.

    C.

D.

E.

2. Using the Munsell Color Chart classify MOIST soil color for the following samples:

A.

B.

C.

D.

E.

3. Visually inspect the soil samples to determine structure (include Type, Grade, and Size):

A.

B.

C.

D.

E.

4. Use the “Feel” method to determine texture for the following samples:

A.

B.

C.

D.

E.

1.2: Soil Profile Descriptions

Learning Objectives

Upon completion of this exercise you should be able to:

- identify master and subordinate horizons
- determine physical properties of soil horizons
- complete a detailed description of the soil profile

Purpose:

The purpose of this exercise is to familiarize you soil profiles, soil Master and subordinate horizons, and how soil properties vary with depth in a soil profile.

Background:

From Brady and Weil, The Nature and Properties of Soils, 14th Edition

Soil Taxonomy is a hierarchical system developed in the United States to group/classify soils. This system is a based on a set of properties that can be objectively identified in the field and measured in the laboratory. Examples of properties used in Soil Taxonomy include moisture and temperature patterns throughout the year, color, texture, horizons, pH, organic matter content, etc. The combination of various properties is used to define **diagnostic soil horizons** and the presence or absence of diagnostic horizons is used to classify the soil. There are eight diagnostic surface horizons, termed **epipedons**, and nineteen diagnostic subsurface horizons. There are six classes within Soil Taxonomy: order, suborder, great group, subgroup, family, and series (from broadest to most specific).

A **soil profile** is a vertical section of soil exposing several layers or **horizons**. Profiles can be measured and sampled as exposed faces (i.e. road cuts, streams banks, etc.) or from soil cores. **Soil horizons** are layers or zones of soils paralleling the surface, with distinct properties and characteristics from soils above or below. The uppermost soil horizons are generally the most weathered soils, while the lowest horizons are typically the least weathered and are most similar to the soil's **parent material**. Soils can exhibit a range of master horizons including: O, A, E, B, C, and R. O horizons are surface organic horizons and are not always present, A horizons are surface mineral horizons and are common in all profiles, E horizons are subsurface horizons dominated by **eluviation** or leaching and are not very common, B horizons are subsurface horizons dominated by **illuviation** or accumulation and require some degree of weathering of the profile to be present, C horizons are subsurface horizons with minimal weathering and resemble the parent material, and the R horizon is bedrock or unweathered parent material found at the base of the profile. Special characteristics distinct to a master horizon may also be indicated with the designation of a lowercase letter immediately following the capital letter that indicates the master horizon (i.e., Ap indicates the "A" master horizon has been modified by plowing). These subordinate distinctions include special physical properties and/or the accumulation of material such as clays or salts. There are currently 30 possible subordinate classifications.

Equipment required:

- Munsell Soil Color Chart
- Soil cores
- Weak acid
- Field Book for Describing and Sampling Soils (Version 3.0)
- Mud bucket
- Colored pencils
- Soil core racks
- Horizon markers
- Water spray bottle
- Tape measure
- Paper towels

Core: __________

Complete a core profile description, identifying and describing master, transitional, and subordinate horizons. Provide a sketch of the soil profile using colored pencils – in addition to coloring, include horizon boundaries and structure in your drawing.

SOIL PROFILE (color, texture, structure)	HORIZON	DESCRIPTION

1.3: Introduction to Online Soil Data

Learning Objectives

Upon completion of this exercise you should be able to:

- navigate the Web Soil Survey
- utilize Google Earth
- determine landscape and soil properties
- link soil properties to geomorphic processes
- complete NRCS pedon description form

Purpose:

The purpose of this exercise is for you to gain familiarity with a variety of online soil data sources and explore the area we will visit on the class field trip.

Exercise:

Navigate to the Web Soil Survey available at: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Start the Web Soil Survey by clicking the on the green "Start WSS" button. Under the "Area of Interest" area select "Import" and select "Create AOI from shapefile". Download the three files from D2L and select them for import.

You should now have a rectangular box located over the area we will visit for our class field trip.

1. What county is our field trip located in?

2. What is the total area in acres for your Area of Interest?

3. What is the version and date of the Tabular and Spatial data?

4. Click on the Identify button (the blue button with a lower case "i") and click anywhere inside the Area of Interest. What is the range of dates photographed for the aerial photography?

5. Click on the Measure Distance button (the button with a ruler). What is the height and width of the Area of Interest in feet and meters?

6. Select the "Soil Map" tab near the top left of the page to see all the soils within your AOI. Soil units are delineated with thin orange lines and labeled with small orange letters that correspond to the table at the left of the screen. Which three soil series (i.e., Map Unit Name) occupy the greatest land area in the AOI? Include map unit symbol and name, Acres in AOI, and percent of AOI.

7. In the table on the left side of the screen, click on the map unit name for each of the three soils that occupy the greatest area to complete the table below.

Map unit name			
Landform			
Landform position			
Parent material			
Slope			
Drainage class			
Depth to water table			
Flooding frequency			
Ponding frequency			

8. Now click on the "Soil Data Explorer" tab near the top of the page. Under the "Suitabilities and Limitations for Use" tab expand the "Land Classifications" section and click "View Rating" for Soil Taxonomy Classification. What is the soil taxonomy for each of the three soils (listed under the "Rating" heading)?

9. Click on the "Soil Properties and Qualities" tab and browse through chemical, physical, and qualities properties to complete the table below. If given the option, select surface layer.

Map unit name			
pH (surface layer)			
Organic Matter (surface layer)			
Surface texture			
Depth to any soil restrictive layer			

Now you will utilize Google Earth to examine soils and topographic data. You must have Google Earth installed on your computer, which you can download for free at: www.google.com/earth

To import the SoilWeb Earth file created by the California Soil Resource Lab navigate to: http://casoilresource.lawr.ucdavis.edu/soilweb/ and click on the "SoilWeb Earth" link. You can save the file to your computer and open it with Google Earth, or you can select "Open with", click on the browse button, and select Google Earth. Click Ok and "SoilWeb" should appear in your "Temporary Places" in the Places panel. You can turn the layer off and on by clicking on the white box next to the name in the Places panel.

To import topographic maps, visit the following website: http://www.earthpoint.us/TopoMap.aspx and follow similar steps to open the file in Google Earth. It should add the "Earth Point Topo Maps" layer to the Places panel and automatically load the topographic maps. You can turn the layer off and on by clicking on the white box next to the name in the Places panel.

Download and open the Kettlemorainesoils.kmz file from D2L to load the locations of the four sites we will visit on our fieldtrip.

10. Using the SoilWeb Earth file, determine the dominant soil series, percentage of map unit, and depth of a typical profile for each site by clicking anywhere next to the site marker and reading from the pop-up box.

	Dominant Soil Series	**% of Map Unit**	**Depth of a Typical Profile**
Site 1			
Site 2			
Site 3			
Site 4			

11. Click on the soil name at the top of the pop-up box to open a website with detailed information about the map unit. Determine the geomorphic position of the dominant soil series for each site.

Site 1: ____

Site 2: ____

Site 3: ____

Site 4: ____

Go back to Google Earth and click on the soil series name (in small blue letters) immediately above the soil profile in the pop-up box for the dominant soil series at each site to open a website with detailed information about the soil series. Scroll down to the graphs; you can click anywhere on any graph (not the titles) to open a pop-up window with soils data by horizon.

12. Which site and soil series has the highest organic matter content, and what is the organic matter content for the surface horizon of that soil?

13. How does clay content change from the A horizon to the B horizon in each soil?

14. Using the Earth Point Topo Maps file, determine the approximate elevation of each site. Tip: contour lines have a 10 foot interval.

Site 1: ________________________

Site 2: ________________________

Site 3: ________________________

Site 4: ________________________

15. What type of landform/land cover is mapped on the topographic map at site 4?

16. Navigate to the following website: https://soilseries.sc.egov.usda.gov/osdlist.aspx and search for each of the three soils using only the first name (i.e., Fox, Casco, Wallkill). Click on View Extent Map and View Description to complete the following:

Map unit name / Soil series: ____

States the soil is located in:____

Typical Pedon: ____

Horizon	**Depth range (cm)**	**Moist Color**	**Texture**	**Structure (grade, size, type)**	**Consistence (friable, loose, etc.)**

17. Navigate to the following website: https://soilseries.sc.egov.usda.gov/osdlist.aspx and search for each of the three soils using only the first name (i.e., Fox, Casco, Wallkill). Click on View Extent Map and View Description to complete the following:

Map unit name / Soil series: ____

States the soil is located in:____

Typical Pedon: ____

Horizon	Depth range (cm)	Moist Color	Texture	Structure (grade, size, type)	Consistence (friable, loose, etc.)

18. Navigate to the following website: https://soilseries.sc.egov.usda.gov/osdlist.aspx and search for each of the three soils using only the first name (i.e., Fox, Casco, Wallkill). Click on View Extent Map and View Description to complete the following:

Map unit name / Soil series: ____

States the soil is located in:____

Typical Pedon: ____

Horizon	Depth range (cm)	Moist Color	Texture	Structure (grade, size, type)	Consistence (friable, loose, etc.)

1.4: Soil Field Methods

Learning Outcomes:

Upon completion of this exercise you should be able to:

- identify master and subordinate horizons in a field setting
- determine soil physical properties of each horizon in the field
- complete detailed site and profile descriptions

Purpose:

The purpose of this exercise is to provide you with hands-on experience in the field collecting soil profiles by bucket augering and describing site geomorphology and soil profiles.

Background:

Fieldwork is an integral part of any soil laboratory exercise since soils must first be collected before they can be analyzed. It is extremely important to ensure that samples are collected as carefully and precisely as possible to reduce errors and eliminate opportunities for sample contamination. It is also important to add a geographic and geomorphic context to your sampling procedures, as they are intimately linked to soil forming factors. Therefore, sample collection is but one component of the fieldwork procedures.

Soil samples can be collected from a variety of environments using various methods to expose the soil. One common, and often preferred method, is sampling of road cuts since the work of exposing a clean face for sampling has mostly been done for you. Digging a large pit, either by hand or with backhoe, is also common but is either very labor intensive or expensive. The third common method of soil sample collection is by collection through coring. Coring allows you to collect samples for the entire soil profile (or as deep as you can core) without having to expose a face for sampling. All three methods have advantages and disadvantages that you will experience during this exercise.

Typical Field Equipment:

- Sturdy boots
- Bandana
- Water
- Shovel
- Field clothes
- Camera
- Pencil
- Gloves
- Pocket knife
- Notebook
- Hat
- Pocket tool (i.e. Leatherman)
- Sample containers
- Trowel
- GPS
- Flagging
- Soil survey
- Bucket auger
- Compass
- Field Book for Describing and Sampling Soils (Version 3.0)
- Topographic maps
- Profile tray
- Abney level
- Munsell Color Chart
- Tape measure

- Acid bottle

Exercise:

In groups of four you will incrementally collect a soil profile using a bucket auger. Lay samples out in a PVC tray to make a continuous profile. Once a four-foot-long profile has been collected, complete a detailed profile description. You must also complete a detailed site description.

Use the Field Book for Describing and Sampling Soils (Version 3.0) for an example of how to complete the site and profile description forms and to look-up appropriate codes for the various sections.

Site Description

Site ID:	Describer(s):	
Date:	Current Weather:	
Series/Map Unit Name:		Map Unit Symbol:
Taxonomy:		
County & State:	Lat-Long:	Elevation:
Avg Annual Temp:	Max Temp & Month:	Min Temp & Month:
Avg Annual Precip:	Avg Annual Snow:	Effective Precip
Slope Aspect:	Slope Gradient:	
Slope Complexity:	Slope Shape:	
Hillslope Profile Position:	Geomorph Comp:	
Land Cover:	Parent Material:	
Landscape/Landform:	Soil Moisture Status:	
Micro features:	Another Features:	
Misc.Notes/Sketch:		

Profile Description ID:

	Horizon	Moist Color	Depth (cm)	Structure (grade/size/type)	Roots and Pores (Quant./size/location)	Rock and Other Fragments (kind/size/%vol./roundness)
1						
2						
3						
4						
5						
6						

	Horizon	Boundary (Distinctness)	Consistence	Texture	Misc.Notes (e.g., redox features, concentrations, etc.)
1					
2					
3					
4					
5					
6					

1.5: Sample Preparation and Gravimetric Water Content

Purpose:

The purpose of this exercise is to learn proper laboratory techniques to prepare a soil sample for laboratory analysis and measure gravimetric water content.

Learning Outcomes:

Upon completion of this exercise you should be able to:

- prepare a sample for soil moisture analysis
- calculate soil moisture content using the gravimetric method
- measure infiltration rates of different soils in the lab

Background:

From Brady and Weil, The Nature and Properties of Soils, 13th Ed. Water is vital to the ecological functioning of soils. The presence of water in soils is essential to support plants and soil organisms. **Soil moisture regime**, a result of climate, is a major determinant of ecosystem productivity. Also, soil water contains many dissolved constituents that can greatly impact local and regional water resources.

Water causes soil particles to swell and shrink, to adhere to each other, and to form **structural aggregates**. Water is involved in most chemical reactions that release or bind nutrients, create acids, and dissolve minerals. In addition, soil moisture affects micronutrient availability, soil temperature, and engineering properties of soils such as compaction, consistency limits and stability. Soil moisture also affects the performance of septic systems, drain fields and contaminant leach fields.

It is important to keep in mind how soil samples are collected and stored before laboratory analysis. You can imagine a soil sample collected and stored in a cardboard box in your car will have a much different soil moisture content compared to a sample collected in an air tight container and stored in a refrigerator. Core tubes, sealable jars, and Ziploc baggies are usually the preferred vessels for soil collection because they minimize exposure to elements such as heat and prevent moisture from entering or leaving the sample. Samples should be kept on ice in a cooler or in a refrigerator until lab work is ready to begin in order to yield the most accurate results possible. Try to minimize time between sample collection and analysis for best results.

Equipment Required

- Convection oven
- Containers w/lid
- Sharpie
- Insulated oven mitt
- Tweezers
- Soil spatula
- Top load balance
- Soil samples
- Calculator
- Specimen cups and lids
- Mortar and pestle
- #10 sieve and sieve pan
- Masking tape

Exercise:

1. Heat VWR convection oven to 80^{o}C (~175^{o}F).
2. Thoroughly wash three containers and lids with soap and hot water.
3. With masking tape and a Sharpie label each container with your initials and sample # (DO NOT WRITE DIRECTLY ON THE CONTAINER!) and place containers in oven upside down for 3-4 hours to allow to thoroughly dry.
4. Remove containers from oven to allow to cool and turn on balance, tare balance (zero the balance), and allow balance to stabilize at 0.0 g (may require repeated taring)
5. Place container on tared balance, allow reading to stabilize, and record container weight (including unit of measurement).

6. Prepare samples by breaking up peds into smallest aggregates possible and picking out as many roots and rootlets as possible using tweezers.
7. Add approximately 300 g of prepared soil sample into container.
8. Place container with soil sample on same tared balance, allow reading to stabilize, and record container + wet soil weight.
9. Place container with soil sample into oven at 80oC and allow sample to dry for at least 48 hours, longer is fine.
10. After 48 or more hours, remove container with soil sample from oven and place on tared balance. Record container + dry soil weight.
11. Compute the following calculations:

	<u>**SAMPLE 1**</u>	<u>**SAMPLE 2**</u>	<u>**SAMPLE 3**</u>
A. Container Weight			
B. Container Weight + wet soil sample			
C. Container weight + dry soil sample			
D. Wet sample weight (B – A)			
E. Dry soil weight (C – A)			
F. Moisture weight (D – E)			
G. Soil Moisture (%) = 100 x (F)/(E)			

Example:	<u>***SAMPLE***</u>
A. Container weight	*115.27 g*
B. Container weight + wet soil sample	*177.57 g*
C. Container weight + dry soil sample	*168.10 g*
D. Wet sample weight (B – A)	*62.30 g*
E. Dry soil weight (C – A)	*52.83 g*
F. Moisture weight (D – E)	*9.47 g*
G. Soil Moisture (%) = 100 x (F)/(E)	***17.93%***

12. After you have weighed and recorded container + dry soil sample, dump contents of sample 1 container into a #10 sieve with sieve pan underneath and gently shake. Remove any rocks or other non-soil debris that does not pass through the sieve and put into a mud bucket.
13. Dump the soil that does not pass through the sieve into a mortar and grind with pestle.
14. Dump contents of mortar into #10 sieve with sieve pan underneath and gently shake. Remove any rock or other non-soil debris that does not pass through the sieve and put into a mud bucket.
15. Repeat steps 13 and 14 until all soil passes through the #10 sieve and all rocks and other non-soil debris are removed.
16. Dump contents of sieve pan (i.e., soil sample that passed through the sieve) back into the container and put a lid on it.
17. Repeat steps 12 – 16 for your other samples. You do not need to thoroughly clean the sieve, sieve pan, mortar, or pestle between samples; just wipe them out with a dry towel.
18. Clean mortar, pestle, #10 sieve, sieve pan, and any other equipment using soap, water, and a sponge. When cleaning the sieve, make sure there is no material trapped within the sieve screen – if material is trapped, remove by gently pushing through from the bottom using your fingernail, a pencil, or other pointed object – BE VERY CAREFUL NOT TO DAMAGE THE SIEVE SCREEN!

1.6: Particle Size Analysis: The Hydrometer Method

Purpose:

The purpose of this exercise is to introduce you to one of the most common laboratory techniques for determining soil particle size distribution and soil textural class.

Learning Outcomes:

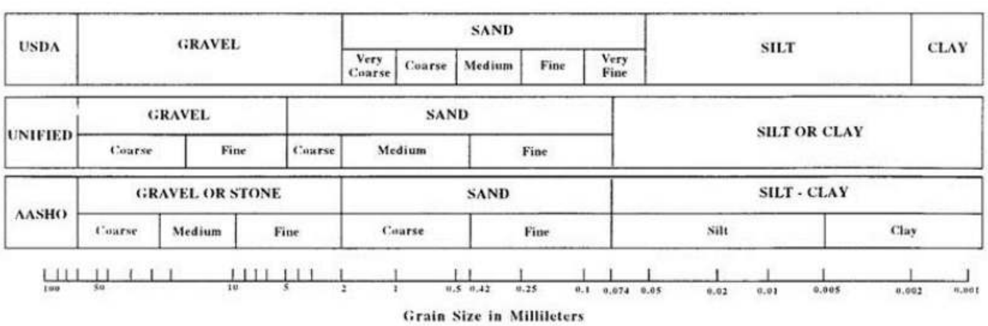
Upon completion of this exercise you should be able to:

- determine the percent sand, silt, and clay of a soil sample using the hydrometer method
- classify soil textural class

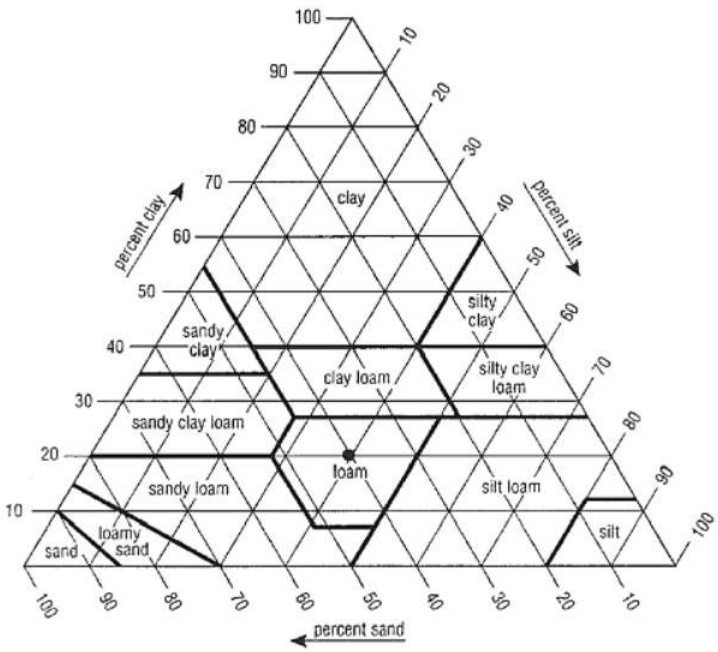
Background:

The hydrometer method is one commonly used method to accurately determine particle size distribution in a soil sample. As the name implies, a hydrometer is used; a hydrometer is an instrument used to measure the specific gravity of a fluid. The basis for this test is Stoke's Law for falling spheres in a viscous fluid in which the terminal velocity of fall depends on the grain diameter and the densities of the grains in suspension and of the fluid. The grain diameter thus can be calculated from knowledge of the distance and time of fall. The hydrometer also determines the specific gravity (or density) of the suspension, and this enables the percentage of particles of a certain equivalent particle diameter to be calculated.

The hydrometer method is useful only for measuring particles with a grain diameter of 2 mm or less (sands, silts, and clays). Based on Stoke's Law, it is known that sand size particles (0.05 mm to 2 mm) fall from suspension rapidly. Smaller silt sized particles (0.002 mm to 0.05 mm) remain in suspension longer, but eventually fall from suspension. Clay sized particles (less than 0.002 mm) are small enough to remain in suspension indefinitely. Therefore, two hydrometer readings are necessary to determine particle size distribution. The first reading gives a measure of the percent of silt and clay in suspension. The second reading gives a measure of the percent of clay in suspension. By subtracting the second reading from the first, percent silt can quickly be determined. Also, by knowing that the sample must add to 100%, the percent sand can also quickly be determined. Calculations for this method are provided below.



Once percent sand, silt, and clay are known for a sample, the soil can be classified by textural class using the textural triangle.



Equipment required:

- Soil spatula
- 100 mL graduated cylinder
- Top load balance
- R-O water bottle
- Sharpie marker
- Weighing paper
- Cylinder plunger
- Calculator
- 250 mL Erlenmeyer flask (3)
- 1000 mL graduated cylinders
- Fahrenheit thermometer
- Buoyoucose Hydrometer calibrated to 68 F
- Soil samples
- Electronic mixer and mixer cups
- 5% Calgon solution- (Sodium hexametaphosphate- $Na_6(PO_3)_6$) is created by mixing 50 grams of Calgon powder into 1 liter (1000 mL) distilled water. I'll try to always restock- but now you have the recipe just in case!

Exercise:

1. Place 50 grams of your dried, ground, and sieved soil sample in a 250 mL Erlenmeyer flask. Add 100 mL of 5% Calgon solution to the sample, cap flask, and swirl until solution and soil are well mixed (several minutes). Let the mixture sit over night (a minimum of 12 hours) to allow the solution to effectively disperse the soil separates (sand, silt, clay).
2. Transfer soil-Calgon mixture from flask to electric mixer cup. Use a water bottle to completely rinse **all material** from the flask into the mixing cup. Fill the mixing cup with water to about 3 inches from the top. Attach cup to mixer and stir for 3 minutes.
3. Slowly remove and lower the mixing cup so that the mixer propeller is just above water level. Use a water bottle to rinse all of the soil mixture remaining on the mixing rod and propeller into the cup.
4. Empty mixing cup of soil, Calgon, and water into 1000 mL graduated cylinder. Completely wash remaining residue out of the mixing cup with a water bottle into the graduated cylinder and continue filling graduated cylinder to 1000 mL mark. All soil material should be below the 1000 mL mark
5. Insert the plunger into the graduated cylinder and gently mix the soil until a uniform suspension is obtained (at least 30 seconds). Make sure that a clock with a second hand is readily visible and that a clean hydrometer is on hand.

NOTE You must carefully rinse ALL of your sample from the cup into the graduated cylinder. If you lose any sample at any step in this process you must restart, methods are based on having exactly 50 g of soil sample in graduated cylinder.

6. As soon as you remove the plunger, check the exact time, record/remember it, quickly rinse the plunger into the graduated cylinder using as little water as possible, and gently insert the hydrometer into the suspension. After 40 seconds has elapsed from the time the plunger was removed, read and record the **40-second hydrometer reading.**
7. Remove the hydrometer, rinse it clean, wipe dry, and put it back in its protective case.
8. To correct for temperature effects and density of the dispersion agent, mix 100 mL of 5% Calgon and 880 mL of distilled water in a clean 1000 mL graduated cylinder and allow it to sit for two hours. (NOTE: 100 mL + 880 mL = 980 mL… the missing 20 mL accounts for the approximate volume occupied by 50 grams of soil).
9. After 2 hours have elapsed, take another hydrometer reading from soil solution and record the **2-hour hydrometer reading.** Remove and clean hydrometer.
10. Place clean hydrometer into water-Calgon solution and record **blank hydrometer reading.** This allows for hydrometer calibration to account for temperature differences.
11. Place thermometer into water-Calgon solution and read temperature. If temperature is above 68◦ F, add 0.2 units to the blank hydrometer reading for EACH degree above 68◦ . If the temperature is below 68 ◦F, subtract 0.2 units from the blank hydrometer reading for EACH degree below 68 ◦F. Record this as the **corrected hydrometer reading.**
NOTE If you are using a Celsius thermometer, for readings above 20◦ C, add 0.36 units. If temperature is below 20◦C, subtract 0.36 units.
12. Subtract corrected blank hydrometer reading from 40-second and 2-hour hydrometer readings to calculate calibrated 40-second and 2-hour readings.
13. Calculate the percentages of sand, silt and clay in soil sample using the following equations: % Clay = (calibrated 2-hour reading) x (100/sample weight) % Silt = (calibrated 40-second reading) x (100/sample weight)-(%clay) % Sand = 100 – (%silt + % clay)

Example:

40 second reading = 37 g

2 hour reading = 16 g

Blank hydrometer reading = 4 g

Temperature = 74 o F

Corrected hydrometer reading = 5.2 g = (4 g + 1.2 g temperature correction)

Calibrated 40 second reading = 31.8 g = (37 g – 5.2 g)

Calibrated 2 hour reading = 10.8 g = (16 g – 5.2 g)

% clay: 10.8 g x (100/50g) = 21.6 % clay

% silt: (31.8g x 100/50g) -21.6 = 42 % silt

% sand: 100 – (42 + 21.6) = 36.4 % sand

Textural class = loam

	Sample 1	Sample 2	Sample 3
40 second reading:			
2 hour reading:			
Blank reading:			
Temperature:			
Corrected Hydrometer:			
Calibrated 40-sec:			
Calibrated 2-hour:			
% clay:			

% silt:			
% sand:			
Textural class:			

**** You must turn in a sheet that shows all the work for your calculations. ****

1.7: pH and Electrical Conductivity

Purpose:

The purpose of this exercise is to introduce students to a variety of laboratory techniques to measure soil pH and electrical conductivity.

Learning Outcomes

– Upon completion of this exercise you should be able to:

- determine soil pH using hydrion paper and a meter
- measure electrical conductivity using an EC meter

Part 1. Soil pH

Background:

From Brady and Weil, The Nature and Properties of Soils, 13 th Ed. The degree of soil acidity or alkalinity, expressed as soil pH, is a master variable that affects a wide range of soil properties. Soil pH greatly influences the availability for plant roots to take up nutrients and toxins. Soil pH also affects soil microbial activity and influences what plant species can grow at a particular site. Soil pH affects the mobility of many pollutants in soil by influencing the rate of biochemical breakdown, solubility, and adsorption to colloids. Acids can build-up to such high concentrations in soils, typically associated with mine tailings, that the acid itself is considered a pollutant. Soil pH also influences soil structure by dispersing or stabilizing clays. At low pH fungi dominate, fungi cause soils to form large soil aggregates. At high pH clays are dispersed and the soil has little or no structure. Remember that structure in part controls the movement of air and water into and through the soil profile.

Soil pH is measured in pH units. Soil pH is defined as the negative logarithm of the hydrogen ion concentration. The pH scale ranges from 0 to 14 with pH 7 as the neutral point. As the amount of hydrogen ions in the soil increases, the soil pH decreases thus becoming more acidic. From pH 7 to 0 the soil is increasingly more acidic and from pH 7 to 14 the soil is increasingly more alkaline or basic. A change of 1 pH unit is actually a factor of 10; for example, pH 4 is ten times more acidic than pH 5 and 100 times more acidic than pH 6.

Descriptive terms commonly associated with certain ranges in soil pH are:

- Extremely acid: < than 4.5; lemon=2.5; vinegar=3.0; stomach acid=2.0; soda=2–4
- Very strongly acid: 4.5–5.0; beer=4.5–5.0; tomatoes=4.5
- Strongly acid: 5.1–5.5; carrots=5.0; asparagus=5.5; boric acid=5.2; cabbage=5.3
- Moderately acid: 5.6–6.0; potatoes=5.6
- Slightly acid: 6.1–6.5; salmon=6.2; cow's milk=6.5
- Neutral: 6.6–7.3; saliva=6.6–7.3; blood=7.3; shrimp=7.0
- Slightly alkaline: 7.4–7.8; eggs=7.6–7.8
- Moderately alkaline: 7.9–8.4; sea water=8.2; sodium bicarbonate=8.4
- Strongly alkaline: 8.5–9.0; borax=9.0
- Very strongly alkaline: > than 9.1; milk of magnesia=10.5, ammonia=11.1; lime=12 From: College of Environmental Science and Forestry Syracuse University, Syracuse, N.Y.

Equipment required:

- Soil samples
- Hydrion paper (wide-range and narrow-range)
- pH meters (3)
- pH meter buffer solutions
- 50 mL beakers
- Stirring rod
- Deionized water bottle
- Small graduated cylinder
- Balance
- Mud bucket

- Paper towels

Exercise:

You will measure pH for your samples using two types of hydrion paper and a low-cost penstyle pH meter. You need 20 g each from the three soil samples you dried, ground, and sieved in the sample preparation exercise.

Hydrion paper

1. Add 20 g of dried and ground soil sample to a 50 mL beaker.
2. Add 20 mL of water to create a soil solution.
3. Use a stirring rod to thoroughly mix the sample for at least 5 minutes.
4. Use the stirring rod to drip a small amount of soil solution onto wide-range hydrion paper (i.e., 0 – 13 pH).
5. Hydrion paper will change color – compare to color chart on the case to determine pH.
6. Record wide-range hydrion paper pH.
7. Narrow-range hydrion paper provides a more accurate pH measure, so re-test your sample using the appropriate narrow-range paper (i.e., 0 – 6 pH or 5 – 9 pH).
8. Record the pH of the narrow-range hydrion paper.

pH meter (eco Testr pH2)

1. Before using the pH meter to test soil pH, the meter must be calibrated using three pH buffer solutions (pH 4, 7, and 10).
2. To calibrate, pour about 1 inch of each buffer solution into 50 mL beakers.
3. Turn on the pH meter.
4. Dip the sensor into the calibration solution starting with pH 7 buffer solution, stir gently, and wait for the reading to stabilize. Press the "cal" button, then press the "hold/ent" button. If calibrated correctly, the display with read "Ent". Rinse the sensor clean with water.
5. Repeat step 4 to calibrate with the pH 4 buffer solution then the pH 10 buffer solution.
6. Rinse the pH meter electrodes with water before using each buffer solution and upon completing calibration procedures. Used buffer solution can be dumped down the sink drain.
7. Submerse calibrated pH meter into the soil solution and gently stir with pH meter for about 1 minute.
8. Allow the reading to stabilize and record soil pH.
9. Rinse and clean the pH meter with water, replace cap, and store.

Part 2. Electrical Conductivity

Background:

From Brady and Weil, The Nature and Properties of Soils, 13 th Ed. Salt-affected soils, particularly common in semi-arid and arid regions under irrigation, limit plant growth and reduce agricultural productivity. Salts are detrimental to plant growth for two primary reasons: 1) salts lower the osmotic potential of soil water so roots have a harder time extracting water from the soils, and 2) several salt ions are toxic to plants or nutrient exchange sites are blocked by salt ions. Salts, primarily chlorides and sulfates of calcium, magnesium, sodium, and potassium, typically accumulate in soils in regions where the precipitation: evaporation ratio is less than 1 – water evaporates but salts remain in the soil. Keep in mind that **salinity** refers to all salts while **sodicity** refers specifically to sodium. Salt accumulation is not typically a problem in humid regions because sufficient precipitation flushes salts from the soil.

Salinity is commonly estimated by measuring soil electrical conductivity (EC) or total dissolved solids concentration (TDS). Pure water is a poor conductor of electricity, but as salts are added the ability to conduct an electrical charge increases. So, measuring EC of a soil solution gives an indirect measurement of a soil's salt content. Electrical conductivity is also influenced by soil texture, with coarser-grained soils typically having lower EC values than silt- and clay-rich soils. The most common method for measuring EC, and the method used in this exercise, is the saturation paste extract method. A soil sample is saturated with deionized water and mixed to the consistency of a paste – the deionized water dissolves the salts from the soil, which can then be measured with an EC meter. Measuring TDS is a more complex process in which a soil sample is saturated with deionized water to dissolve all the salts from the soil, the water is then extracted into a beaker, weighed, completely evaporated, and the weight of the remaining residue is weighed to determine TDS. TDS concentration and EC are directly related, so some EC meters also provide information on TDS concentration.

Class of salt-affected soils:

- Saline: EC > 4 ds/m but have an Exchangeable Sodium Percentage (ESP) < 15 (i.e. lots of salts, but most salts are not sodium)
- Saline-Sodic – EC > 4 ds/m and ESP > 15 (i.e. high levels of salts, with a high proportion of sodium)
- Sodic – EC < 4 ds/m and ESP >15 (i.e. low level of salts, but relatively high levels of sodium)

Equipment required:

- Soil samples
- EC meters (low and high)
- EC calibration solution
- 50 mL beakers
- Stirring rod
- Deionized water bottle
- Top load balance
- Mud bucket
- Paper towels

Exercise:

25 g of soil sample must be prepared following Exercise 5 methods (pick roots, dry, grind, and sieve) before proceeding.

1. Add 20 grams of soil sample to 50 mL beaker.
2. Add R-O water to soil sample until you form a gooey paste (a consistency between pudding and a milkshake). If you make it too runny, you can add more soil.
3. Use a stirring rod to stir the mixture for at least 10 minutes. Cover/seal the sample and allow sample to sit for 24 hours.
4. Before using the EC meters to test soil EC, the meters must be calibrated using a single EC buffer solution.
5. To calibrate, pour about 1 inch of buffer solution into a 50 mL beaker.
6. Turn on the meter, dip the sensor into the calibration solution, and wait for the value to stabilize. Press the “cal” button. Press “hold/ent” until the blinking value matches the value of the calibration standard. Release the “hold/ent” button to accept the calibration value. If calibrated correctly, the display will read “Ent”.
7. Rinse the EC meter electrodes with R-O water upon completing calibration procedures. *Used buffer solution can be dumped down the sink drain.*
8. After 24 hours has elapsed since the sample was prepared, thoroughly mix the sample, submerse calibrated EC meter into solution and gently stir mixture with EC meter for about 1 minute.
9. Allow reading to stabilize and record soil electrical conductivity.
10. Rinse and clean EC meter in R-O water, replace cap, and store.
11. Steps 4 through 10 must be completed for both the eco Testr EC low and EC high meters.

Sample	EC low meter	EC high meter
1		
2		
3		

1.8: Soil Organic Matter Content: Loss-On-Ignition

Purpose:

The purpose of this exercise is for you learn proper laboratory techniques to measure organic matter content and aggregate stability and become familiar with how they are related.

Learning Outcomes:

Upon completion of this exercise you should be able to:

- determine organic matter content of a soil sample using the loss-on-ignition method
- understand how soil organic matter content affects soil stability and erosion

Background:

From Brady and Weil, The Nature and Properties of Soils, 13 th Ed. Soil organic matter consists of a wide range of organic substances including living organisms such as bacteria and fungi, organism remains such as partially decayed plant material and soil organisms, and organic compounds formed by metabolic processes. Organic matter comprises only a small portion of a typical soil (~1 to 7% in surface horizons and much less for subsurface horizons).

Organic matter binds mineral particles, giving soils a **granular structure**, keeping the soil loose and aerated. Organic matter also increases the **water holding capacity** of soils and water availability to plants. As organic matter decays it releases essential nutrients to the soil that is taken up by plants. Also, organic matter is the primary source of carbon and energy for soil organisms.

As organic matter continues to break down and accumulate within the soil, **humus** forms. Humus is the **colloidal fraction** of soil organic matter. This gives fertile soils the distinct dark brown to black color. Humus has a surface charge that attracts and binds nutrients ions and water molecules, increasing soil fertility. It is also one of two sources of **cation exchange capacity (CEC)** in the soil (clay is the other major source). CEC represents the sites in the soil that can hold positively charged nutrients like calcium (Ca^{++}), magnesium (Mg^{+}) and potassium (K^{+}). If CEC is increased, the soil can hold more nutrients and release them for plant growth. To increase CEC, you must increase soil organic matter content.

Equipment required:

- Soil samples
- Convection oven
- Insulated gloves
- Soil spatula
- Top load balance
- Mortar and pestle
- Crucibles
- Sharpie marker
- Weighing paper
- Tray (2)
- Tongs
- Muffle
- Furnace
- Tweezers
- Muffle furnace map (2)
- Calculator

Exercise:

1. Use the soil samples you dried, ground, and sieved in the sample preparation exercise.
2. Clean and dry crucibles following cleaning methods outlined in sample preparation exercise.
3. Label crucibles and weigh on balance, record crucible weight (C1).
4. Thoroughly pick **ALL** roots from soil samples.
5. Place soil samples in clean, labeled crucibles and weigh on same balance, record crucible + sample weight (C2).

6. Record sample locations on “muffle furnace map” and place crucibles on the map.
   ****NOTE** DO NOT PLACE ANYTHING SUCH AS COOKIE SHEETS, PAPER, OR ANYTHING OTHER THAN THE CRUCIBLES CONTAINING SOIL SAMPLE IN MUFFLE FURNACE!!!**
7. The following muffle furnace program is necessary to remove organic matter from soil samples: 1) Ramp muffle furnace to 550o C in 1 hour (a rate of ~9.15oC/min); 2) soak samples in muffle furnace at 550oC for 2 hours; 3) allow samples to cool for 4 hours or more
   ****NOTE** Muffle furnace should already be programmed. Begin heating by turning muffle furnace on and holding the “Run” button for three seconds. If program needs to be entered, either get help from the instructor or follow instructions beginning on pg 11 of the muffle furnace manual (All manuals are in the bottom drawer to the left of the sink).**
8. Allow samples to cool in muffle furnace until sufficiently cool to handle with gloves, place in convection oven if still too hot to place on scale.
9. Weigh crucible + no OM sample on balance, record crucible + no OM sample weight (C3).
10. Calculate the percent organic matter by weight using the following formula:

    % Organic Matter = [(C2 – C3) / (C2 – C1)] x 100

	Sample 1	**Sample 2**	**Sample 3**
C1 (Crucible Weight)			
C2 (Crucible + sample weight)			
C3 (Crucible + no OM sample weight)			
% Organic Matter			

1.9: Bulk Density, Particle Density, and Porosity

Purpose:

Upon completion of this laboratory exercise students should be able to directly measure bulk density and particle density using the graduated cylinder method for coarse textured, non-aggregated soil samples. Students will also learn to calculate soil porosity.

Learning Outcomes:

Upon completion of this exercise you should be able to:

- directly measure bulk density and particle density using the graduated cylinder method for coarse textured, non-aggregated soil samples
- determine bulk density of a soil core, accounting for compaction during collection
- calculate soil porosity

Background:

From Brady and Weil, The Nature and Properties of Soils, 13 th Ed. Soils are composed of a combination of solids (soil particles), liquids (soil water), and gases (soil atmosphere). The liquid and gas portions are essential for plant growth and are found in the pore spaces among the soil solids. Bulk density is a measure of the mass of a soil per given volume (i.e. g/cm3), including solids and pore spaces. **Bulk density** is a commonly measured soil property by agriculturalists and engineers. High bulk density soils are soils with little pore space, so water infiltration is reduced, root penetration is inhibited, and aeration is restricted – reducing agricultural productivity. Low bulk density soils are easily compacted and may settle considerably to the detriment of roads, sidewalks, and building foundations.

Particle density is a measure of the mass of soil solids per given volume (g/cm3); however, pore space is not included as it is with bulk density. Particle density is similar to the specific gravity of a solid and is not impacted by land use. Particle density is approximated as 2.65 g/cm3 , although this number may vary considerably if the soil sample has a high concentration of organic matter, which would lower particle density, or high-density minerals such as magnetite, garnet, hornblende, etc.

Porosity, the percent by volume of a soil sample not occupied by solids, is directly related to bulk density and particle density. If particle density remains constant, as bulk density increases porosity decreases.

Equipment required:

- 2 sandy soil samples – one coarse and one fine
- Top load balance
- Soil spatula
- 100 mL graduated cylinder
- 50 mL beaker (2)
- Water bottle
- Calculator
- Paper towels
- Mud bucket

Exercise:

1. Add slightly more than 50 mL of the two soil samples to 50 mL beakers.
2. Clean and thoroughly dry a 100 mL graduated cylinder. Weigh and record weight (A).
3. Slowly add Soil Sample #1 to pre-weighed graduated cylinder to the 10 mL line. Compact the soil by dropping onto a padded surface like a book, notebook, etc. at least ten times from a height of about 2-3 inches.
4. Repeat this process in ten mL intervals until you reach the 50 mL mark.
5. Use a soil spatula to level the top of the sample in the graduated cylinder and add soil with the spatula until the top of the soil sample is exactly even with the 50 mL line – this is the bulk volume of compacted soil (B) (1 mL = 1 cm3).
6. Weigh and record graduated cylinder plus compact soil weight (C).
7. Return any soil sample remaining in beaker to sample storage container and dry clean beaker.
8. Return 50 mL sample in graduated cylinder to 50 mL beaker. Remove all of sample within graduated cylinder.
9. Now add exactly 50 mL of water to the graduated cylinder, record volume (E).

10. Slowly pour approximately 25 mL of soil sample from beaker into water in the graduated cylinder. Gently stir soil/water mixture to remove any air bubbles. Add the second 25 mL of soil sample and stir again to remove air bubbles.
   NOTE Make sure that you remove all soil sample from the beaker. Also, ensure that no soil sample is stuck to the sides of the graduated cylinder above the water line.
11. Record the new volume (F)
12. Repeat process for Soil Sample #2.
13. Calculate bulk density, particle density, and porosity using the following formulas:

	SAMPLE 1	SAMPLE 2
A. Weight of 1st graduated cylinder		
B. Bulk volume of compacted soil	50 mL	50 mL
C. Weight of 1st cylinder plus compacted soil		
D. Weight of soil sample (C – A)		
E. Volume of water in 2nd cylinder	50 mL	50 mL
F. Volume of soil and water in 2nd cylinder		
G. Volume of soil (F – E)		
H. Bulk density (g/cm3) (D/B)		
I. Particle density (g/cm3) (D/G)		
J. Soil porosity (%) (100 – (H/I x 100))		

EXAMPLE	
	SAMPLE
A. Weight of 1st graduated cylinder	*138.4 g*
B. Bulk volume of compacted soil	*50 cm^3*
C. Weight of 1st cylinder plus compacted soil	*223.90 g*
D. Weight of soil sample (C – A)	*85.43 g*
E. Volume of water in 2nd cylinder	*50 cm^3*
F. Volume of soil and water in 2nd cylinder	*83 cm^3*
G. Volume of soil (F – E)	*33 cm^3*
H. Bulk density (g/cm3) (D/B)	*1.66 g/cm^3*
I. Particle density (g/cm3) (D/G)	*2.52 g/cm^3*
J. Soil porosity (%) (100 – (H/I x 100))	*34.13%*

1.10: Environmental Magnetic Susceptibility

Purpose:

The purpose of this exercise is to introduce you to how magnetic signals are derived and preserved in the natural environment and what they tell about soil development, and learn techniques to measure soil magnetic susceptibility, from soil cores in particular.

Learning Outcomes:

Upon completion of this exercise you should be able to:

- operate a Bartington MS2-C sensor to measure magnetic susceptibility of a soil core
- use Excel to create a magnetic susceptibility graph
- interpret a magnetic susceptibility graph

Background:

All material has a magnetic signal; this magnetic signal is a result of the spin of electrons, both around their axis and around the nucleus, within atoms. The degree of magnetism is controlled by the types and concentrations of atoms within a mineral structure and the arrangement of that structure. In soils, the magnetic signal is imparted by the soil's parent material, which contains primary minerals, and by pedogenic weathering, which forms secondary minerals that produce magnetic enhancement.

Magnetic susceptibility is simply the measure of a material's (i.e. soil's) ability to become magnetized and is generally controlled by the iron-bearing minerals in a sample. Magnetic susceptibility is one measure for determining the mineralogy and geochemistry of samples, providing insight into provenance and environmental conditions during mineral formation. The Bartington MS2C core scanning sensor works by 1) creating a magnetic field, 2) detecting the magnetism of the sample, and then 3) creating a ratio between the two – magnetic susceptibility. This magnetic susceptibility value is on a volume basis, and thus, is referred to as volume susceptibility (κ), in contrast to mass-specific susceptibility, in which measurements from dried samples are adjusted for weight by volume.

Magnetic susceptibility offers a wide array of scientists a simple, inexpensive, and convenient tool for environmental research. There are several reasons, or advantages, for measuring magnetic susceptibility. The first, and most obvious, is that it is easy to use and fairly inexpensive; besides the initial purchase of equipment, there is virtually no expense since chemicals or other agents are not used. This method is also fast, non-toxic, and nondestructive to samples. Several hundred soil samples can easily be measured in a day, and, since no additional chemicals are used, samples can be reused for further study, such as x-ray diffraction, particle size analysis, and stable isotope analysis. Equipment is small, lightweight, and easily portable, so measurements can be made in the field or in a laboratory environment. In addition, due to its low cost, magnetic susceptibility is often coupled with additional environmental properties like stable carbon isotope, radioisotope, chemical, and microfossil analysis.

Partly due to its ease of operation and inexpensive nature and partly because of the ubiquity of a magnetic signal in the natural environment, magnetic susceptibility has wide-ranging applications in nearly every field of science. Here is a short list of some fields that commonly use magnetic susceptibility and associated applications:

Geology: field mapping, identifying rock type, identifying erratics, identifying minerals

Soils: field mapping, identifying provenance, identifying buried soils, highlighting slope processes, mapping patterns of sediment accumulation

Archaeology: locating occupation sites, identifying hearths, building materials, and foundations

Hydrology: tracing bedload movement, identifying sediment and pollution sources

The MS2C sensor is designed to make volume susceptibility measurements from soil cores collected in **diamagnetic** clear-plastic liners. The soil core is simply placed on the holding rack and incrementally slid through the MS2C sensor at intervals of 20 – 50 mm. Magnetic susceptibility readings are influenced by surrounding material up to one sensor diameter away, so a 72 mm diameter sensor actually measures a 144 mm section; thus, an individual measurement can be thought of as a 3-point moving average with one center position and two end points. As a result, the susceptibility signal degrades towards the end of the core, so measurements should not be taken within ½ core sensor diameter from soil core ends (i.e. with a 72 mm sensor measurements should not be taken within 36 mm of either end of the soil core). As discussed above, magnetic susceptibility in soils results from parent materials and pedogenic weathering; consequently, magnetic susceptibility measurements taken throughout a soil can reveal changes in parent material and environmental conditions, such as climate change. For example, deposited and reworked loess generally has a reduced magnetic susceptibility signal compared to underlying residuum while limestone bedrock has virtually no signal (Fig. 1).

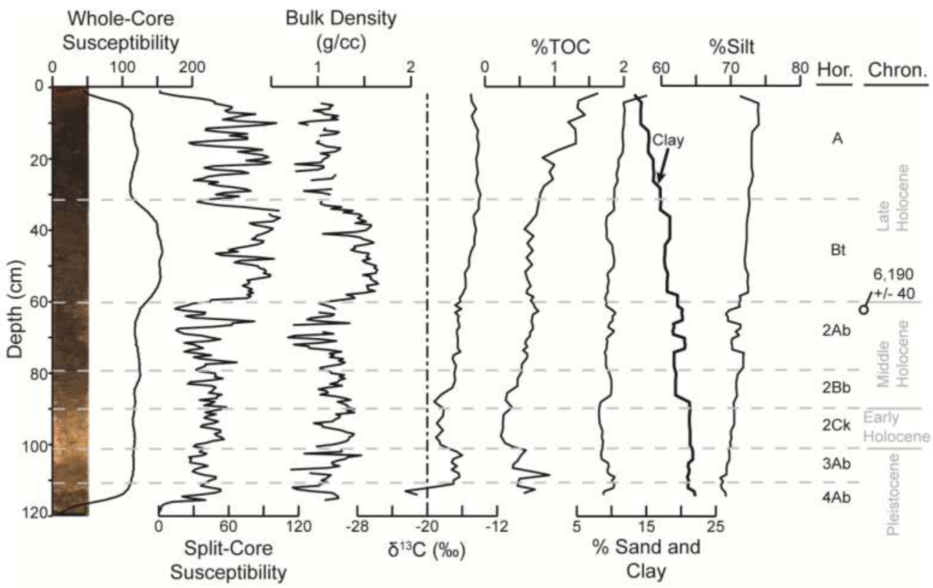


Figure 1. Magnetic susceptibility and other data for a soil core (Bowen and Johnson, 2015).

Equipment required:

- USB drive (supplied by student)
- Computer with Excel & internet access
- Bartington MS2C core logging system
- Soil cores

Exercise:

****NOTE** Before you begin, remove iPods (turn off also), cell phones (turn off also), keys, and any other metallic or electronic material on you (piercings are fine). Also, make sure no metallic material is on the table that the sensor and rack are sitting on.**

1. First, turn on the Bartington meter by turning the left-most knob to "SI", make sure the right-most knob is set to "1". Flip the silver toggle switch to the right to zero the sensor – every few seconds you should here a "beep" and the meter will quickly flash "00:0.0". **Allow sensor to zero for a minimum of ten minutes.**
2. If not on, turn on the computer and open the "304-MagSus_blank" Excel file.
3. Save the 304-MagSus_blank Excel file as FirstnameLastname_MagSus. Notice on the Excel file that there are two worksheet tabs named Soil Core 1 and Soil Core 2 (see bottom left of Excel) – you need to analyze both soil cores. Within this file Depth and Tape Position values are already entered. Tape position is only used as a guide to position the bottom end of the core (i.e., the end with the black cap); you will not use tape position to make your graphs.
4. After 10 minutes or more has elapsed, flip the silver toggle switch to the center position.
5. Place the first core on the core rack and slide the end with the red cap through the sensor until the end of the black cap is aligned exactly at 122 cm.
6. Take your first reading by pressing the "M" button. After the first reading appears, enter this value into the Excel spreadsheet in the "Mag Sus" column, advance the core 2 cm, and press "Measure" again. Repeat until the end of the black cap is aligned with the middle of the sensor. There is a piece of blue tape near the left end of the rack designating the 2 cm and 0 cm positions for your final two readings.
7. Repeat steps 5 & 6 for the second soil core.
8. Once both cores have been analyzed and saved, you need to create graphs of magnetic susceptibility variability by depth, as demonstrated in class. *You should only create one file with two worksheets that include data and graphs.* **There is an example graph on the desktop of the Magnetic Susceptibility computer – MarkBowen_MagSusExample.**

1. Create an X-Y scatterplot with magnetic susceptibility on the x-axis and depth on the y-axis (see graph examples in Fig. 1 above).
2. On each graph, you need to add horizontal lines across the graph denoting where you think horizon boundaries are located and label the horizons (see graph examples in Fig. 1 above).

9. Save your Excel file as “FirstnameLastname_MagSus” and upload to D2L dropbox.

CHAPTER OVERVIEW

2: Take-Home Exercise

2.1: Soil Physical Properties
2.2: The Soil Profile
2.3: Soil Taxonomy
2.4: Soil Forming Factors
2.5: Soil Orders
2.6: Soil Water
2.7: Soils and the Hydrologic Cycle
2.8: Soil Aeration and Temperature
2.9: Soil Chemistry
2.10: Soil Organic Matter
2.11: Soil Organisms
2.12: Soil Nutrients
2.13: Soils and Paleoenvironmental Reconstructions
2.14: Soil and Water Conservation

2.1: Soil Physical Properties

1. Use the soil textural triangle to determine the textural class of the following soil samples:
   a. % Sand = 40, % Silt = 30, % Clay = 30 ________________________________
   b. % Sand = 10, % Silt = 55, % Clay = 35 ________________________________
   c. % Sand = 50, % Silt = 25, % Clay = 25 ________________________________
   d. % Sand = 25, % Silt = 30, % Clay = 45 ________________________________
   e. % Sand = 37, % Silt = 40, % Clay = 23 ________________________________
2. What affect does organic matter have on soil color?

3. What are redoximorphic features? What does gley mean?

4. Why is soil texture important?

5. What is the equation for Stoke's Law? Define all the variables and explain how this equation is useful for determining soil texture.

6. Assume you plan on purchasing a farm (either Farm A or B) after graduation. Farm A is dominated by sandy loams and loamy sands, while Farm B is dominated by clay loams and clays. List the potential advantages and disadvantages of each farm.

7. Give five examples of "insight into other soil properties" that are derived from soil color.

8. What are three main factors that influence soil color?

9. What are three biological processes that influence soil structure?

10. List eight different types of soil structure.

2.2: The Soil Profile

1. What is regolith and what are its two possible origins?

2. What is a residual soil and how does it form?

3. What are the three zones of a weathering profile and in which zone(s) do you find the soil profile?

4. Rank the following in order from shallowest (1) to deepest (4):

   Weathering profile: ______________

   Solum: ______________

   Regolith: ______________

   Soil profile: ______________

5. Define the following:

   Soil profile –

   Pedon –

   Polypedon –

   Soil map unit –

6. Write the symbol that applies to the master, transitional, or subordinate horizon below:

   a. zone of maximum leaching/eluviation __________

   b. subsoil zone with accumulation of silicate clays __________

   c. surface layer disturbed by plowing __________

   d. unconsolidated material underlying the solum __________

   e. subsoil layer that is weakly developed __________

   f. bedrock __________

g. surface layer of highly decomposed organic matter

h. intermixed zone of eluviation and illuviation, with illuviation dominating

7. What is a lithologic discontinuity and how is it denoted within a soil profile?

8. What is a paleosol and how is it denoted within a soil profile?

2.3: Soil Taxonomy

1. Define the following diagnostic surface horizons:
   a. Mollic
   b. Umbric
   c. Ochric
   d. Histic
   e. Melanic
2. Define the following diagnostic subsurface horizons:
   a. Argillic
   b. Natric
   c. Spodic
   d. Albic
   e. Cambic
3. Define the following soil moisture regimes and list a state or portion of a state in the U.S. you are likely to find that regime:
   a. Aquic
   b. Udic
   c. Ustic
   d. Aridic
   e. Xeric
4. Define the following soil temperature regimes and list a state or portion of a state in the U.S. you are likely to find that regime:
   a. Hyperthermic
   b. Thermic
   c. Mesic
   d. Frigid
   e. Cryic

5. For the following soil taxonomic classification, identify which element in the classification belongs to each level of Soil Taxonomy and what it tells you about that soil: **Loamy, mixed, superactive, mesic, Typic Palefluvent**
(Example: Fine, smectitic, active, thermic, Vermic Argiaquoll – oll indicates Mollisol soil order; aqu indicates it is the wet suborder; Argi indicates it is in the great group with an argillic horizon, Vermic indicates it is the subgroup with intense earthworm activity, etc.)

a. Order:____

b. Suborder:____

c. Great Group:____

d. Subgroup:____

e. Family:____

2.4: Soil Forming Factors

1. List and briefly describe the five factors of soil formation.

2. List five different types of parent materials and the process(es) that formed/transported/deposited the parent material.

3. Compare and contrast two types of parent materials (geomorphic processes, spatial distribution, timing, dominant properties, etc.).

4. What are the two principal climatic variables influencing soil formation, and how do changes in these variables influence soil formation?

5. Compare and contrast the role of grassland vegetation versus trees in soil formation.

6. How do animals influence soil formation?

7. How does topography influence soil formation?

8. Describe a catena.

9. How do soils change over time?

10. List and briefly describe the four basic processes of soil formation.

2.5: Soil Orders

1. Classification into a soil order is primarily based on what?

2. Which soil order is the most highly weathered? Least weathered?

3. What soil order are you likely to find in wet regions with thermic soil temperatures?

4. What soil order are you likely to find in moist to dry regions with mesic soil temperatures?

5. Which two soil orders are defined directly in relation to climate?

6. Briefly describe each soil order. Include in your description major characteristics and diagnostic features, and locations in the U.S. you are likely to find that order.

   a. Entisol

   b. Inceptisol

   c. Alfisol

   d. Mollisol

   e. Ultisol

   f. Aridisol

   g. Vertisol

   h. Oxisol

   i. Andisol

   j. Spodosol

   k. Histosol

   l. Gelisol

2.6: Soil Water

1. Why is water polarity important?

2. Draw a diagram that illustrates water hydrogen bonding.

3. What two factors allow water to flow by capillarity, and what controls the height of capillary rise?

4. List and describe the three forces that affect the energy level of soil water.

5. List and describe four factors that influence hydraulic conductivity.

6. What values do you need to know to calculate the saturated flow rate within a soil?

7. Explain the difference between infiltration and percolation.

8. What is the term for the difference between the field capacity and wilting coefficient?

9. What are the three ways that water moves through a soil?

10. Explain the gravimetric method for measuring soil water content.

2.7: Soils and the Hydrologic Cycle

1. Describe the role of soil in the hydrologic cycle.

2. What is a watershed and what are three potential routes for water falling in a watershed?

3. Write the water balance equation and define all the variables in the equation.

4. What is meant by antecedent condition and why is it important?

5. List five factors that affect infiltration.

6. If a pan evaporation study indicates that 0.8 cm of water is lost per day, what would the potential evapotranspiration rate equal? (Show your work and include units)

7. Define the following:

   a. Vadose zone –

   b. Capillary fringe –

   c. Aquiclude –

   d. Water table –

   e. Unconfined aquifer –

   f. Confined aquifer –

8. Even though the city of Oshkosh has a shallow depth to the water table, there is low susceptibility for groundwater contamination. Why?

9. What are three factors you should consider when installing a septic tank?

10. What are three things you can do to decrease runoff and increase infiltration rates in agricultural and/or urban areas?

2.8: Soil Aeration and Temperature

1. In what four ways can you describe soil aeration?

2. Oxygen availability in soils is regulated by what three principal factors?

3. Describe the two ways in which gases are exchanged between the soil and the atmosphere.

4. How does the gaseous composition of soil compare to the atmosphere?

5. What is redox potential and why is it important?

6. Briefly describe the different types of redoximorphic features found in soils.

7. Describe three natural processes that are affected by soil temperature.

8. Explain how a wildfire can result in a mudslide.

9. How does soil water content influence soil temperature?

10. How does soil temperature vary with time and depth?

2.9: Soil Chemistry

1. pH is the balance between what two ions? How are the concentrations of these two ions related?

2. What are the four different pools of soil acidity?

3. Describe three processes that cause soil acidity and three processes that cause alkalinity.

4. What is the difference between acid saturation and base saturation?

5. How does rainfall affect soil pH?

6. What does soil buffering refer to?

7. How does acid rain influence soil pH?

8. How do salt-affected soils develop? Where are you most likely to find salt-affected soils?

9. Describe the four different ways to measure and report soil salinity/sodicity.

10. Describe the three different classes of salt-affected soils.

2.10: Soil Organic Matter

1. List five reasons soil organic matter is important.

2. Explain the role of soil in the global carbon cycle.

3. Which soil order contains the greatest amount of carbon? What two factors account for the fact that the soil order contains the greatest amount of carbon?

4. How does organic matter influence soil physical properties?

5. How does organic matter influence soil chemical properties?

6. Explain the difference between the active and passive pools of soil organic matter.

7. List five factors that promote gains in soil organic matter content and five factors that promote losses in soil organic matter content.

8. How does climate influence soil organic matter content?

9. Which generally has a higher soil organic matter content, grassland or forests? Why?

10. How does soil organic matter content of agricultural soils compare to soils with natural vegetation? Why?

2.11: Soil Organisms

1. There are five different size classes of soil organisms, list each class and provide each example of an organism within that size class.

2. What are the most common/abundant types of organisms found within soil?

3. Explain how functional and species diversity differ and why that is important to soil.

4. What is meant by the term ecosystem engineer? Provide at least four examples of ecosystem engineers.

5. What are four controls on the amount and diversity of soil organisms?

6. What are the three types of earthworms and where in the soil will you find each type?

7. How do ants influence soils?

8. Explain the role of mycorrhizae within soils.

9. What are actinomycetes? What are their roles in soils?

10. List four benefits of soil organisms.

2.12: Soil Nutrients

1. What are the five processes in the nitrogen cycle?

2. What are the two principle forms of nitrogen used by plants?

3. What environmental problems are associated with excess nitrogen?

4. What are the primary natural sources of sulfur?

5. List three major sources of gains and three losses of available sulfur in soils.

6. Why is phosphorus often limited in soils?

7. What environmental problems are associated with phosphorus?

8. What are the benefits of potassium to plants?

9. What problems are associated with potassium in soils?

10. List the pools of calcium within soils.

2.13: Soils and Paleoenvironmental Reconstructions

1. What is a paleosol?

2. Describe these four types of paleosols:

a. relict paleosol

b. buried paleosol

c. isolated paleosol

d. exhumed paleosol

3. What are two main problems that arise when trying to recognize a paleosol?

4. What are three main features used to differentiate paleosols from sediment?

5. How are pedogenesis and diagenesis different? Provide examples of each process.

6. Stratigraphically, what are three things paleosols can be used for?

7. What was the climate like during deposition of loess units compared to intercalated paleosols on the Great Plains and Chinese Loess Plateau?

8. What are three techniques to provide age control of soils/sediment and what are the age ranges of each technique?

9. What is magnetic susceptibility and how is it useful for paleoenvironmental reconstructions?

10. What is $\delta^{13}C$ and how is it useful for paleoenvironmental reconstructions?

2.14: Soil and Water Conservation

1. According to your reading, world soils are now managed to provide what four functions?

2. What are the two main agents that erode soil and what percentage of area worldwide is affected by each?

3. Describe the two main types of soil erosion.

4. What are the different forms of water erosion?

5. What are the five main drivers of wind erosion in arid and semi-arid regions?

6. What are three on-site and three off-site problems with soil erosion?

7. What are the three leading causes of accelerated soil erosion and what percentage is attributed to each?

8. Where are the six main “hot spots of soil erosion” in the world?

9. When, why, and how did soil conservation begin in the United States?

10. What is the Conservation Reserve Program and how does it help soil conservation?

CHAPTER OVERVIEW

3: Final Project

3.1: Soil Profile Descriptions Assignment

3.1: Soil Profile Descriptions Assignment

100 Points

Purpose:

The purpose of the assignment is for you to apply concepts of soil development learned in class to compare soil variability across the landscape.

Learning Outcomes:

Upon completion of this exercise you should be able to:

- complete a site description
- complete a soil profile description
- acquire and interpret online soil data
- link soil profile characteristics to soil forming factors

Background:

From the NRCS Soil Survey Manual, Chapter Five Soil profile descriptions are basic data in all soil surveys. They provide a major part of the information required for correlation and classification of the soils of an area. They are essential for interpreting soils and for coordinating interpretations across State and regional boundaries. The soil descriptions and the soil map are the parts of a published survey having the longest useful life.

Field descriptions of soil profiles range from partial descriptions of material removed by a spade or by an auger to complete descriptions of pedons seen in three dimensions from intersecting pits as horizontal layers are removed sequentially from the surface downward. Most field descriptions of soil profiles are the former, so care in making them is essential. Field descriptions should include:

- Observed external attributes of the area, such as landform and characteristics of slope;
- Inferred attributes of the area, such as parent material and soil-water states;
- Observed internal properties of the profile, such as horizon thickness, color, texture, structure, and consistence;
- Inferred attributes of the profile, such as horizon designations and parent material;
- Inferred soil drainage class;
- Classification of the profile in the lowest feasible category;
- Location of the site relative to geographic markers and in terms of landscape position;
- Plant cover or use of the site;
- Date, time of day, and weather conditions;
- Name of the describer

Exercise:

You will complete detailed site and profile descriptions for four locations. The four sites must either encompass a lithosequence, toposequence, climosequence, biosequence, or chronosequence. The four sites must also encompass at least three different mapped soil series (i.e., map units) in the Web Soil Survey. All equipment necessary to complete site and soil profile descriptions (i.e., trowel, bucket auger, GPS, Munsell color book, Abney level, etc.) will be available on a first come first served basis.

For each site you must:

1. Collect latitude-longitude with a GPS
2. Collect a 3 to 4-foot-long soil profile using a bucket auger, shovel, or any other means
3. Complete a Site Description form (Appendix 1)
4. Complete a Profile Description form (Appendix 2)
5. Complete an Official Series Description form (Appendix 3)
6. Complete a Soil Taxonomy form (Appendix 4)
7. Take a "selfie" that provides a view of the landscape of your site (you or the field equipment must be visible in the picture) (Figures 1 – 4)
8. Take a picture of your profile in the field in the PVC soil profile tray with horizons marked (Figures 5 – 8)

9. Generate a soil map using the Web Soil Survey (Figure 9). If all your sites are in close proximity, you can create one soil map, but if they are spread out you need to create multiple soil maps (and label them Figure 9a, Figure 9b, etc.)
10. Generate a topographic map using the Web Soil Survey, Google Earth, or any other mapping software (Figure 10). If all your sites are in close proximity, you can create one topographic map, but if they are spread out you need to create multiple topographic maps (and label them Figure 10a, Figure 10b, etc.).

You must write a 4,000 – 5,000 word report describing:

A. the type of soil sequence you examined (i.e., litho, topo, chrono, bio, or climo),

B. the soil forming factors for each site,

C. the soil profile for each site, with a comparison of soil profiles among all four sites,

D. how your soil profile descriptions compared to and contrasted with the Official Series Description for each site, with an assessment of why they were different or similar, and E. how changes in the five soil forming factors resulted in differences among your four soil profiles, with a focus on how variability of the soil forming factor being examined (the one selected in A above) was the primary driver of those differences.

The first page of the report should be a title page that includes your name, GEOG 304, semester and year, and "Soil Profile Descriptions of a **_________** sequence in *County, State"* at the top of the page with an overview map showing the location of all soil profile description locations. This should be followed on the next page by the report text. The report should have a References Cited page (examples of how to format references are below).

All figures should be placed after the report text. All figures should be formatted to be approximately 4" tall x 5" wide and two figures should be on each page. Each figure should include a caption describing it (e.g., Figure 1. Landscape view of site 1).

All appendices should follow the figures and the pages should be oriented landscape. To do this in Word, at the end of the last figure caption from the "Layout" menu select "Breaks" and then "Section Breaks" "Next Page". A new page should be added to the end. Now from the "Layout" menu change the orientation of the page to landscape. Copy your tables from Excel and Paste them into Word using "Paste Special..." "Formatted Text (RTF)". Each table should be on a separate page and include a caption describing it (e.g., Appendix 1.1. Site description for site 1).

Format:

Times New Roman, size 12 font, double-spaced narrative and single-spaced tables, 1" margins with your last name and page numbers in the footer on all pages except the title page.

Submit:

Submit an electronic copy of a single Word (preferred) or PDF file through the D2L Soil Profile Descriptions dropbox before 1:20 pm on the last Tuesday of the semester

The project will require a significant time commitment and must be completed regardless of the weather, soil conditions, or snowfall – DO NOT PROCRASTINATE!

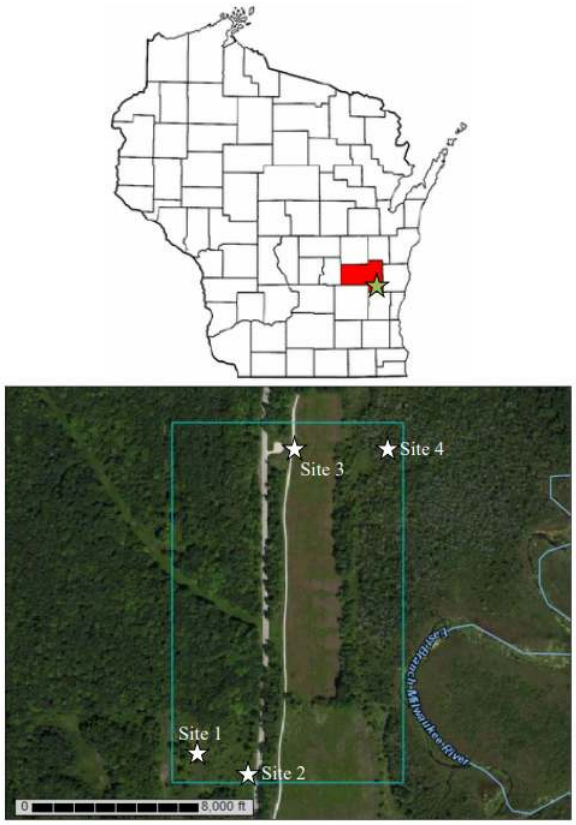
EXAMPLE

Mark Bowen

GEOG 304

Fall 2015

Soil Profile Descriptions of a Toposequence in the Kettle Moraine State Forest, Fond Du Lac County



Introduction

- Specifically state the type of soil sequence you examined (i.e., litho, topo, chrono, bio, or climo-sequence)
- Describe the geographic location of where your sites are located (e.g., In the Kettle Moraine State Forest near Dundee, WI)
- Provide a rationale for why you selected your sites specifically describing how those sites allowed you to investigate the type of sequence examined

Soil Forming Factors

Climate

- Temperature: mean annual, maximum monthly, minimum monthly; seasonal distribution (must include reference)
- Precipitation: average annual precipitation and average annual snowfall; seasonal distribution (must include reference)

If sites are all in close proximity, you can describe the temperature and precipitation for all four sites at once. If sites are in more than one county, then you need to describe them separately.

- Effective precipitation: for each site you must describe effective precipitation is higher or lower due to it generating run-off or receiving run-on based on landscape position (based on field description)

Organisms

- Ecoregion: Levels I through IV (must include reference) - If sites are all in close proximity, you can describe ecoregions for all four sites at once. If sites are in more than one ecoregion, then you need to describe each ecoregion separately.
- Dominant vegetation surrounding the site (based on field description) – describe each site separately
- Actual vegetation at your site (based on field description) – describe each site separately
- Anthropogenic features (based on field description) – describe each site separately

Relief

- Landform and landscape (based on field description) - If sites are all in close proximity, you can describe landforms and landscape for all four sites at once. If sites are in more than one landscape, then you need to describe each landform and landscape separately.

- Slope aspect, gradient, complexity, shape, and position (based on field description) – describe each site separately
- Microrelief (based on field description) – describe each site separately

Parent Material

- Regional geology (must include reference) - If sites are all in close proximity, you can describe regional geology for all four sites at once. If sites are spread out, then you need to describe geology for each site separately.
- As described in Web Soil Survey or Official Series Description – describe each site separately
- As you determine in the field – describe each site separately

Time

- estimate the time based on when glaciers retreated (must include reference) - If sites are all in close proximity, you can describe time for all four sites at once. If sites are spread out, then you need to describe time for each site separately.
- note if any natural or human cause disturbances have reset soil formation (e.g., floods, construction) – describe each site sepately

Soil Profile Descriptions

- Site 1 – interpret Appendix 2.1 – don't just report the data, but describe what the data mean
- Site 2
- Site 3
- Site 4
- Compare and contrast profiles among the four sites; explain how and why profiles differed

Comparisons to Official Series Descriptions

- Site 1 - describe any meaningful differences or similarities between your profile description and the Official Series Description (i.e., compare and contrast Appendix 2.1 and Appendix 3.1) with an assessment of why they were different or similar
- Site 2
- Site 3
- Site 4

Summary

- a description of how changes in ClORPT resulted in differences in soil profiles among your four sites
  - ideally four of the five factors will be the same or very similar for all sites and only one varied considerably among sites
  - focus on how variability of the soil forming factor being examined in your soil sequence was the primary driver of those differences in the soil profiles

References

Appendices

Appendix 1 – Site Description tables

Appendix 1.1 – Site 1

Appendix 1.2 – Site 2

Appendix 1.3 – Site 3

Appendix 1.4 – Site 4

Appendix 2 – Profile Description tables

Appendix 2.1 – Site 1

Appendix 2.2 – Site 2

Appendix 2.3 – Site 3 Appendix 2.4 – Site 4

Appendix 3 – Official Series Description tables

Appendix 3.1 – Site 1

Appendix 3.2 – Site 2

Appendix 3.3 – Site 3

Appendix 3.4 – Site 4

Appendix 4 – Soil Taxonomy Descriptions

Appendix 4.1 – Site 1

Appendix 4.2 – Site 2

Appendix 4.3 – Site 3

Appendix 4.4 – Site 4

Table 1. Site 1 Site Description

Site ID: Site 1	**Describer(s):** Mark Bowen	
Date: 9/14/2017	**Current Weather:** clear and warm	
Series/Map Unit Name: Casco-Rodman loams, 12 to 30 percent slopes		**Map Unit Symbol:** CpE
Taxonomy: Fine-loamy over sandy or sandy-skeletal, mixed, superactive, mesic Inceptic Hapludalfs		
County & State: Fond Du Lac, WI	**Lat-Long:** 43.632689, - 88.190793	**Elevation:** 1,099 ft
Avg. Annual Temp: 45° F	**Max Temp & Month:** 80°F; July	**Min Temp & Month:** 25°F; January
Avg. Annual Precip: 30" rain	**Avg. Annual Snow:** 36"	**Effective Precip:** less due to runoff
Slope Aspect: ~100° (ESE)	**Slope Gradient:** 24%	
Slope Complexity: simples	**Slope Shape:** linear/linear	
Hillslope Profile Position: back slope	**Geomorph Comp:** nose slope	
Land Cover: forested with grasses	**Parent Material:** loamy glaciofluvial deposits over sandy and gravelly outwash	
Landscape/Landform: outwash plain/moraine	**Soil Moisture Status:** moist but nor water; water table was not encountered	
Microfeatures: N/A	**Anthro Features:** road cut for logging immediately adjacent to site	
Misc. Notes/Sketch: A path for a logging road has been bulldozed into the slope immediately adjacent to the site I augured. A rocky ~2 ft tall profile has been exposed along the road. Horizons are visible but profile is shallow and rocky.		

Table 2. Site 1 Profile Description

	Horizon	Depth (cm)	Moist Color	Structure (grade/size/type)	Roots and Pores (Quant./size/location)	Rock and Other Fragments (kind/size/%vol./roundness)
1	A	0 - 18	10YR 4/3	moderate, medium granular	common fine	mixed rocks/coarse gravel/rounded
2	B1	18 - 28	10YR 6/4	weak, medium subangular blocky	common fine	mixed rocks/coarse gravel/rounded

3	B2	28 - 40	7.5YR 5/4	weak, medium subangular blocky	common fine	mixed rocks/cobbles/rounded
4	C	40 - 84	10YR 6/3	weak, medium subangular blocky	common fine	mixed rocks/cobbles/rounded

	Horizon	Boundary	Efferv. Class	Texture	Misc. Notes (e.g., consistence, redox features, concentrations, etc.)
1	A	smooth abrupt	NE	silty loam	friable
2	B1	smooth clear	NE	sandy clay loam	friable
3	B2	wavy clear	NE	sandy clay loam	firm
4	C	N/A	NE	sandy clay loam	friable; very rocky layer cannot go any deeper because of rocks

Table 3. Site 1 Official Series Description for Casco soil series

Series: Casco	**States soil series located in:** Wisconsin, Illinois, Indiana, and Ohio
Taxonomic class: fine-loamy over sandy or sandy-skeletal, mixed, superactive, mesic, Inceptic Hapludalfs	
Typical pedon: Casco loam on a convex southwest-facing 5 percent slope under alfalfa-brome at an elevation of 324 meters (1,054 feet)	
Type Location: Sheboygan County, Wisconsin about 9 miles southwest of Plymouth	
Geographic setting - landform: outwash plains, outwash terraces, eskers, kames, and moraines	
Geographic setting - parent material: thin layer of loamy alluvium underlain by calcareous stratified sandy outwash	
Mean annual precipitation (mm and in): 71-102 cm; 28-40 in	**Mean annual temperature (C and F):** 7.8-13.9 C; 46-57 F
Draina ge: somewhat excessively drained	**Runoff potential:** slow to rapid
Saturated hydraulic conductivity and permeability: moderately high to high and moderate to very rapid	
Use and Vegetation: most of the less sloping areas are used for cropland; corn, small grains, and hay are the principle crops; some areas are used for woodland and some for pasture. Native vegetation is mixed hardwood forest.	

Horizon	Depth Range (cm)	Moist Color	Texture	Structure (grade, size, type)	Consistence (friable, firm, loose, etc.)	Boundary

Ap	0-20	10YR 4/2	loam	weak, medium, subangular blocky	friable	abrupt smooth
Bt1	20-33	7.5YR 4/4	clay loam	moderate, medium, subangular blocky	firm	clear smooth
Bt2	33-43	7.5YR 4/4	sandy clay loam	moderate, medium, subangular blocky	firm	abrupt wavy
2C	43-152	10YR 5/3	stratified gravelly coarse sand, very gravelly coarse sand, and extremely gravelly coarse sand	single grain	loose	

Figure 1. Site 1 “selfie”

Figure 2. Site 1 Soil Profile

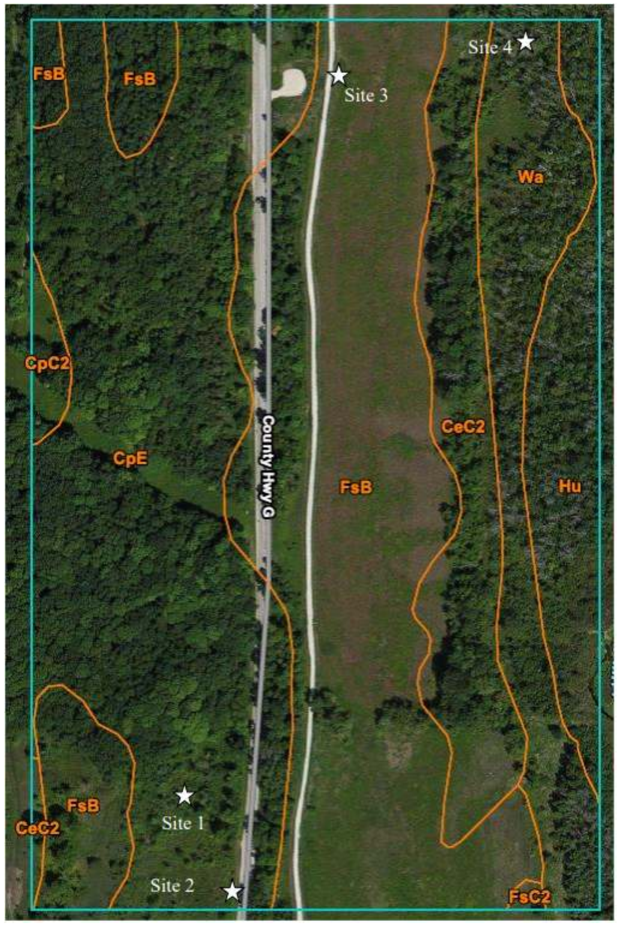


Figure 3. Soil map of site locations (Web Soil Survey, 2015).

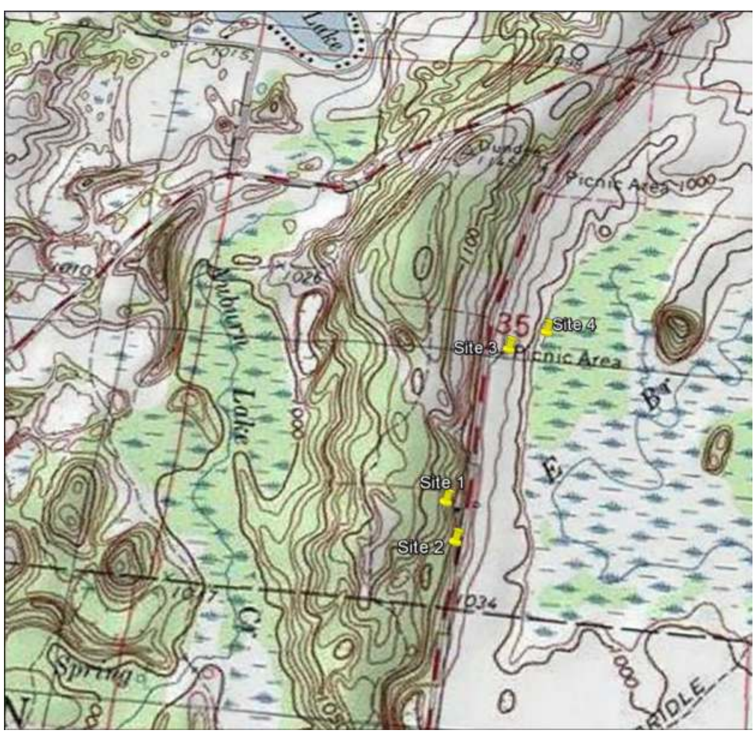


Figure 4. Topographic map of site locations (Google Earth, 2015)

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1.1: Determining Soil Physical Properties

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soil organisms

2.11: Soil Organisms

Glossary

Sample Word 1 | Sample Definition 1

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