Appendix B:
Soil Assessment

B.1. Introduction

This appendix provides additional guidance on assessing soils for the following practices: **Conservation Landscapes, Rain Gardens, Infiltration Trenches, and Permeable Hardscapes.** As mentioned in the respective chapters, practices that depend on stormwater infiltrating into the ground must be located and designed according the characteristics of the underlying soil. Several factors determine the soil suitability at a particular site. This appendix describes how to test on-site soils for:

- Texture
- Infiltration rate (percolation test)
- Depth to groundwater

While this appendix gives basic guidance on soil assessment techniques, it is not comprehensive. For further assistance, the local Soil Conservation District or Extension Service office may provide more guidance or a referral to a good resource.

B.2. Soil Texture

Not all soils allow water to percolate through them easily. In general, soils with a lot of sand tend to allow water to flow through them easily, while soils with high clay content do not allow water to pass through as well. The average particle sizes of sand, silt, and clay decrease in that order, and the spaces between the particles also decreases. Smaller pore spaces between the particles make it more difficult for water to infiltrate through them. In addition to particle size, compaction is another factor that can reduce the size of pore spaces. Urban soils, especially those around buildings, can be quite hard due to compaction from grading equipment, mowers, cars, and even foot traffic. To determine the soil suitability for a Rain Garden, Infiltration Practice, or Permeable Hardscape, follow the processes below.

Note: Remember to call Miss Utility (1-800-257-7777 or 811 in Maryland) at least 48 hours before digging to mark underground utilities. **Always call before digging!**

Take Soil Sample To take a soil sample, first dig a test hole down to approximately the *bottom* level of the practice that will be installed. (***Example:*** If installing a 2-foot deep Rain Garden with 6 inches of ponding, dig to 2 ½ feet deep.) The hole should be wide enough to remove dirt as the hole is dug and wide enough to get a hand trowel to the bottom to take the soil sample. Once the hole is deep enough, use a hand trowel to scoop out a handful of dirt from the lowest part of the test hole and put it into a bucket or other container. (To look at the soils *below* the depth of the practice, either dig the test hole even deeper or use a soil auger to pull out a deeper sample.) For large practices, take samples at a few locations, since the soil can change from location to location. Collect one sample per every 100 square feet.

Compaction While digging the test hole(s), take note of how hard it is to dig through and loosen the soil. If the soil takes a lot of effort to break up and remove, it is likely excessively compacted and will need to be tilled well if a Rain Garden or Infiltration Practice is to be installed there. Of course, this is a low-cost, low-tech method of testing soil compaction. There are also quantifiable ways (not discussed here) to test soil compaction with instruments such as a penetrometer.

Handle the Sample Next, have a container of water and a ruler available to conduct the following soil texture tests on the sample (see **Figure B.1**):

Ball Test - Take about 1 tablespoon of the soil sample and knead it together by hand, wetting it gradually. If the soil will not form a cohesive ball it is a sandy soil. If the soil forms a ball, conduct the feel test and ribbon test.

Feel Test - Squeeze and knead the soil in a ball. The sandiest soils will feel gritty and emit a grinding sound while it is squeezed and kneaded. The least sandy soils will be smooth and silky, with no grinding sound.

Ribbon Test - Finally, placing the soil between the forefinger and thumb, use the thumb to gently push the soil and try to form the soil into a ribbon. Soils with higher clay content will form longer ribbons.

Figure B.1. *Shown from left to right: Ball test, feel test, and ribbon test*

The flow chart shown in **Figure B.2** provides a schematic for these tests and gives more detail. The soils represented in the blue-shaded area are not likely to infiltrate well. However, performing an infiltration test (described in the next section) will help further clarify how suitable the site is for different stormwater practices.

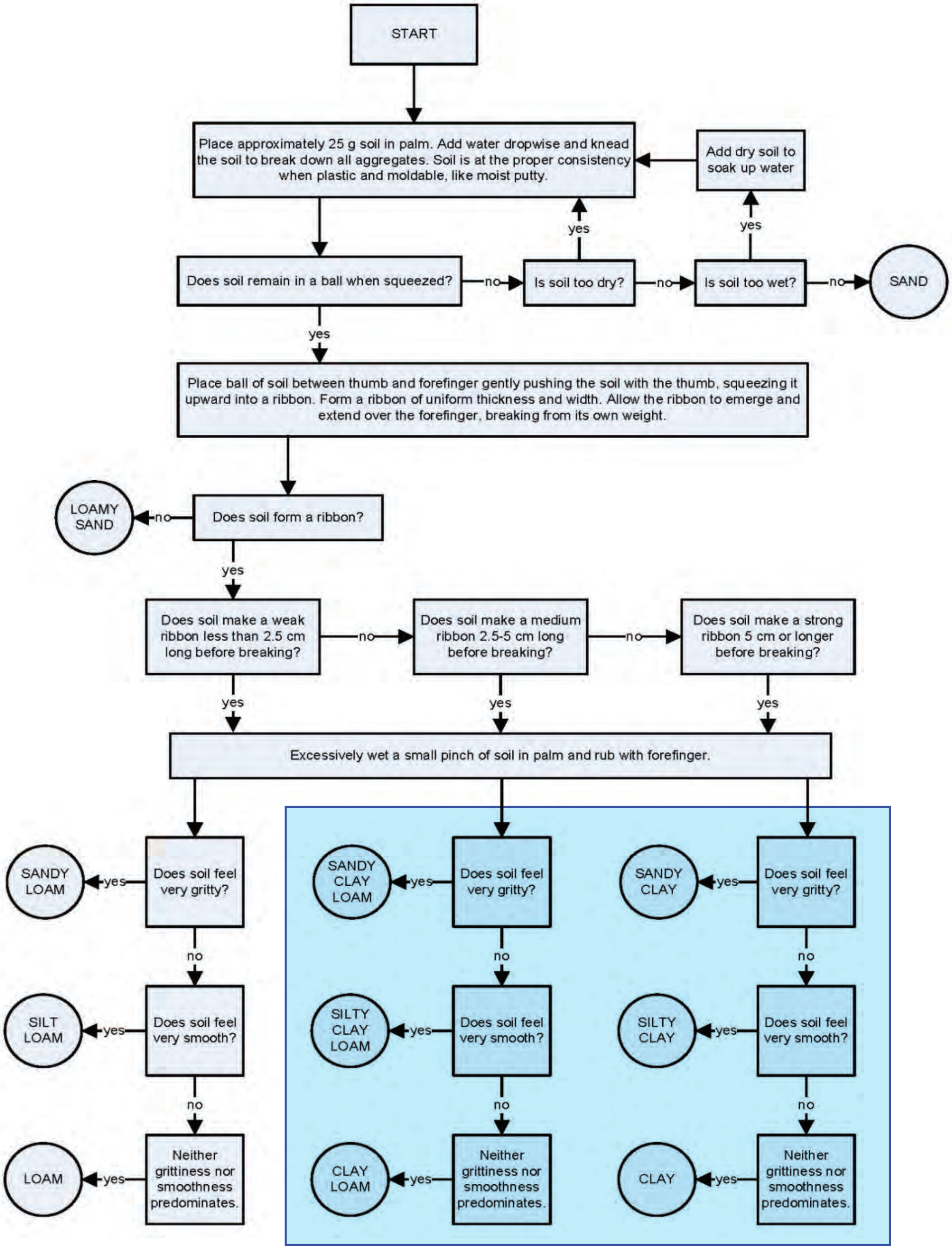
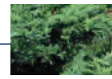


Figure B.2: *Flow chart to decipher soil texture type*

(Source: United States Department of Agriculture, National Resources Conservation Service)



B.3. Infiltration Rates

A basic infiltration test, sometimes called a percolation or "perc" test, is relatively easy to perform as long as the tester has adequate time for observation. In its simplest form, one simply digs a hole, fills it with water, waits until the next day and fills it again, then observes how long it takes for the water to soak completely into the ground. A little care and a few measurements will provide confidence in a relatively accurate infiltration rate.

In the references listed in **Section B.5**, soils are often assigned to one of four hydrologic soil groups (HSG). These groupings provide information about runoff and infiltration characteristics.

Distilled from USDA/NRCS TR-55 documentation:

Soils in the U.S. are classified in four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D), conveying information about their infiltration rates when thoroughly wet.

Group A
- Low runoff potential, high infiltration rates, well- or excessively drained soils

Group B
- Moderate infiltration rates, moderately well- to well-drained soils

Group C
- Low infiltration rates, typically having a layer that impedes downward movement of water

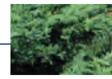
Group D
- High runoff potential, very low infiltration rates, typically clay soils, often with permanently high water table or impermeable clay layer near the surface

Dual classifications: Soils that, due to high water table, have a drainage problem. Once these soils are effectively drained, the group changes.

The essential steps and tools needed to conduct an infiltration test are as follows:

Do not conduct the infiltration test during a period when the forecast calls for rain. However, it is beneficial to conduct the test after a rainfall since saturated soils will provide more accurate infiltration rate measurements. To avoid digging another hole, use the same test hole used for the soil sample.

Tools Needed:
- Shovel or post hole digger
- Tape measure or measuring stick
- Watch or clock
- Garden hose or other water source
- Pencil and paper for taking notes
- Section of 4-inch diameter PVC or metal pipe, at least as long as the hole is deep
- Digging bar (optional)
- Enough gravel to cover the bottom surface of the hole to 2-inch depth (optional)



Procedure:

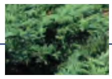
1. Dig a hole to at least the depth of the intended practice and ideally at least 1 foot in diameter.
2. Fill this hole with water, and let it sit overnight.
3. Tap a section of vertical PVC pipe securely into the soil at the bottom of the hole so that the water only infiltrates through the bottom of the hole. Add about 2 inches of gravel into the bottom of the pipe so that any clay particles do not form a seal along the bottom of the hole. The pipe will prevent water from infiltrating sideways, which could falsely increase the infiltration rate results.
4. Fill the pipe with water a few inches short of the top and measure the height difference between the water surface and the top of the pipe.
5. Mark the measurement and time. An example is shown in **Table B.1**.
6. Approximately once per hour, measure the depth from the top of the pipe to the surface of the water, until the water has completely infiltrated, or the test must be abandoned for other reasons. At each measurement, write down the depth and the time.
7. After completing the test measurement, calculate the infiltration rate for each time period: mark the difference in depth and the amount of time that has passed, and then divide the depth by the amount of time. After calculating the infiltration rate for each time period, divide the total change in depth by the total amount of time taken for the test.

Table B.1. Example of Infiltration Test Record

A	B	C	D	E
Depth (inches)	Time	Difference in depth (inches)	Time elapsed (hours)	Infiltration rate (Column C/D)
3.5	8:30 AM	-	-	-
4.7	9:30 AM	1.2	1	1.2 inches/hour
5.5	10:30 AM	0.8	1	0.8 inches/hour
6.8	11:45 AM	1.3	1.25	1.04 inches/hour
7.6	1:30 PM	0.8	1.75	0.46 inches/hour
8.9	2:30 PM	1.3	1	1.3 inches/hour
9.8	3:30PM	0.9	1	0.9 inches/hour
10.6	4:15 PM	0.8	0.75	1.07 inches/hour
11.8	5:30 PM	1.2	1.25	0.96 inches/hour
			Average rate	**0.92 inches/hour**

The hypothetical test shown in **Table B.1** shows an average infiltration rate of approximately 0.92 inches per hour. See calculation below.

11.8 inches – 3.5 inches = 8.3 inches
5:30 PM – 8:30 AM = 9 hours
8.3 inches / 9 hours = 0.92 inches per hour



Notice that the infiltration rate can vary over time – this is not unusual. If the infiltration rate changes *significantly* over time, one of the following conditions may have caused this:

- The water was infiltrating through the sidewalls quickly into a layer of soil with higher infiltration. There are layers of different soil types at different depths. The bottom of the layer with the higher infiltration is probably at roughly the depth where the rate slowed considerably. This is not necessarily a problem.
- The soil was not completely saturated when the test started. Initially, the water was soaking into unsaturated soil, and once the soil became saturated, the rate slowed.
- If the infiltration starts slow, then speeds up, this may be a surface tension issue. If time permits, while there is still water in the hole, add more water and see if the rate stays somewhat steady. If so, it is probable that a layer of air was "blocking" the water, but once the water settled past that level, the rate increased.

If the test results seem suspicious or the average rate is very close to the minimum infiltration rate required, it is wise to test again.

Interpreting Results Interpreting the results of the infiltration and soil texture tests depends on the type of practice to be installed. Rain Garden designs can be adjusted to work in soils with low infiltration rates, whereas Infiltration Trenches, Dry Wells, and Permeable Hardscapes must have a minimum infiltration rate of 1 inch per hour. **Table B.2** shows the design options available for these practices based on infiltration rate and soil texture.

Table B.2. Design Options Based on Infiltration Rate & Soil Texture

Practice	Infiltration Rate	Design Options
Rain Garden		
	<½ inch per hour	Replace existing soil with a soil mix and use an underdrain
	½ – 1 inch per hour	Replace existing soil with soil mix
	>1 inch per hour	Use existing soil (as long as soil texture is not in a clay category) Compost amendments recommended
Infiltration Trench, Dry Well, and Permeable Hardscape		
	<1 inch per hour	Do not install practice in this location
	1 – 2 inches per hour	Acceptable to install practice here (as long as soil texture is not in a clay category)
	>2 inches per hour	Acceptable to install practice here

If infiltration rates are too low or soils have too much clay to use the type of practice initially proposed, consider using a different stormwater management practice in that location, such as Rainwater Harvesting or Conservation Landscapes.

B.4. Depth to Groundwater

The location of the groundwater table is another consideration for any practice that infiltrates water. When the groundwater rises up near the bottom of a stormwater practice, there is a danger that the surface runoff can contaminate the groundwater. Also, the practice will not drain properly if the groundwater rises up high enough to start filling the practice.

Stormwater practices that rely on infiltration should be designed with at least a 2-foot vertical separation from the seasonally high water table. Groundwater rises and falls throughout the year, so the bottom of the practice should be at least 2 feet above the highest elevation to which the groundwater rises.

Check Data Available Online databases and web tools (described in **Section B.5**) are available to look up the high groundwater levels for the area where the practice will be located. As a first step, use one of these websites to see if the recorded high groundwater level in the area is close to the minimum depth needed. If the seasonally high groundwater level reported suggests that there may be less than 2 feet of space between the bottom of the practice and the water table, visual inspection is recommended.

The test hole used for the previous tests should provide some clues. If the soil in the bottom of the hole was noticeably wet upon initial excavation, but the soil above it was dry, there is likely high groundwater in that location. If the bottom of the hole was not wet, look for the following signs that the soil is periodically saturated with water.

Gleying and Mottling When soil is saturated for a long period, it often turns a bluish-grey color (gleying), with red spots or stripes (i.e. mottles). A mottled soil has streaks or spots of reddish or reddish-brown color. This is caused by iron leaching out of the soil when it is wet and rusting when it is exposed to oxygen during the dry period. These conditions indicate the high groundwater level.

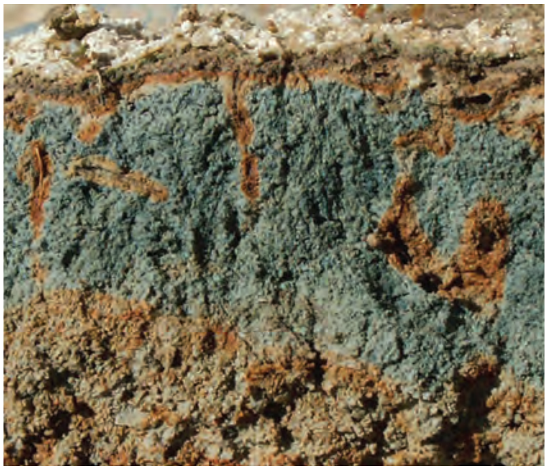


Figure B.3: *Soil with gleying and mottling due to high groundwater*
(Source: http://soilscienceaustralia.com.au/)

Smell Soils that are wet for a long time begin to have a sulfur or rotten egg smell. If this smell is present when excavating the test hole, it almost certainly indicates the groundwater level has been reached.

Interpreting Results If the investigation into groundwater level at the proposed site suggests that the groundwater levels may be too high for the particular practice, several options are available: (1) design the practice to be shallower and broader (as practical) to give more vertical separation from the groundwater while still treating the same volume of runoff or (2) choose a different type of practice for the site.

B.5. Web-based Tools

Performing location-specific, on-site tests like the ones described in the previous sections is the best way to determine the soil texture, infiltration rates, and seasonally high groundwater levels at the specific location of the proposed stormwater practice. However, broader-scale tools are also available to determine soil characteristics within a general area. Three such tools are described below.

- The USDA's national *Web Soil Survey* provides soil type, expected infiltration rates, approximate depth to water table, and much more information.

- Maryland's Environmental Resource and Land Information Network (*MERLIN*) is a user-friendly mapping tool that contains information on all kinds of natural resources in Maryland. **Figure B.4** shows a screenshot of MERLIN with the soil data layer selected and shown. Clicking on an area of the map with this data layer on will show a variety of data, including the high groundwater level (in red box).
- Users of *Google Earth or Google Earth Pro* (both free programs) can add the *SoilWeb plugin* which also offers a very fast and user-friendly portal to most of the same data, with the exception of depth to groundwater. Visit Appendix A: Site Assessment for more information about the utility of Google Earth. **Figures B.5** and **B.6** show examples of the interface and output of SoilWeb.

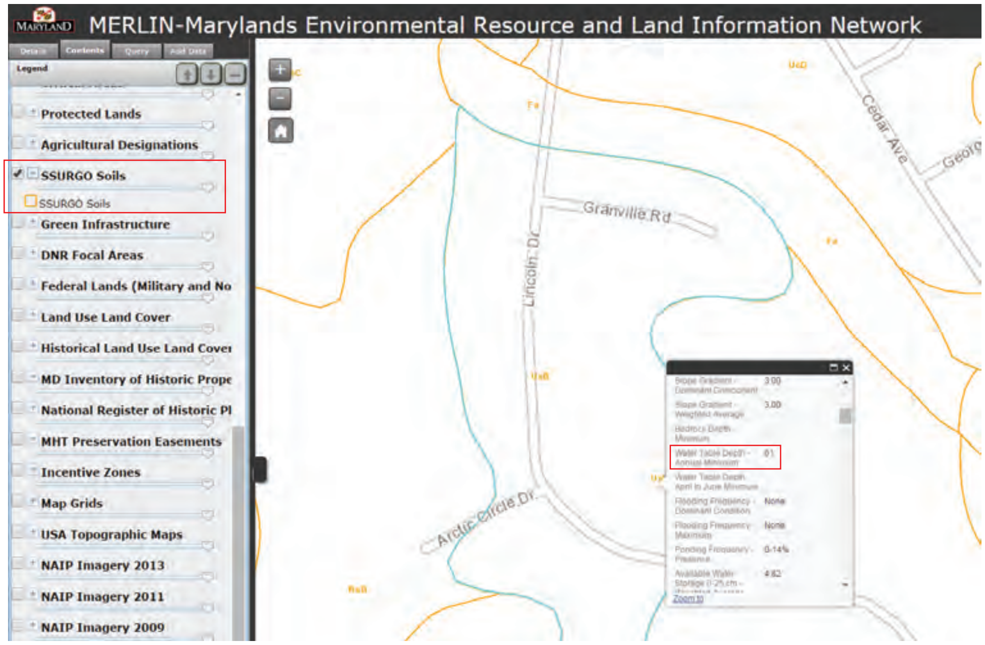


Figure B.4: *Screenshot of web-based tool, MERLIN, showing soil data and groundwater level*

(Source: MD Department of Natural Resources)

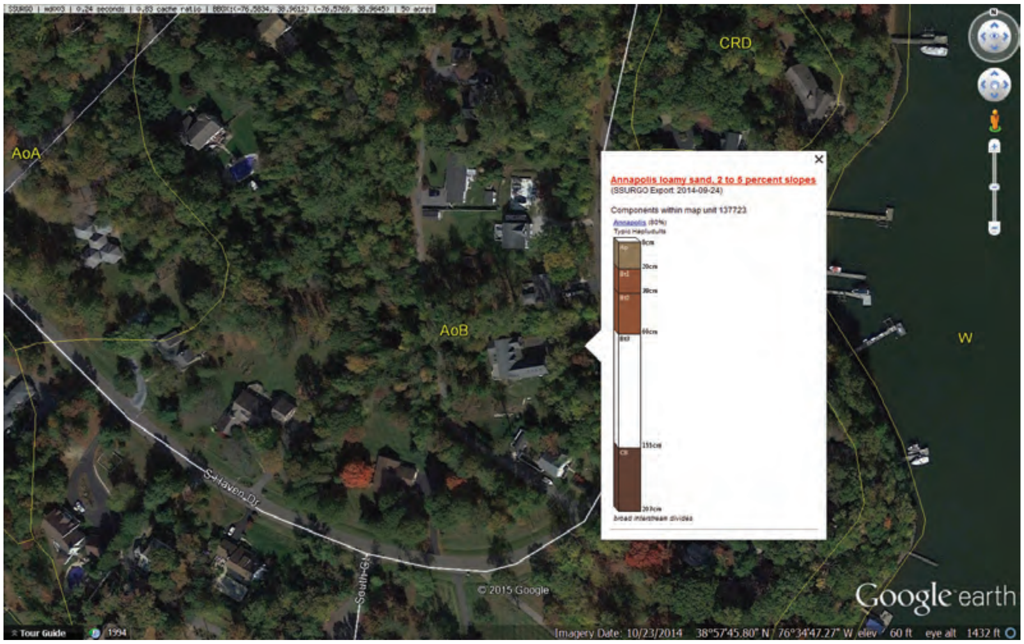
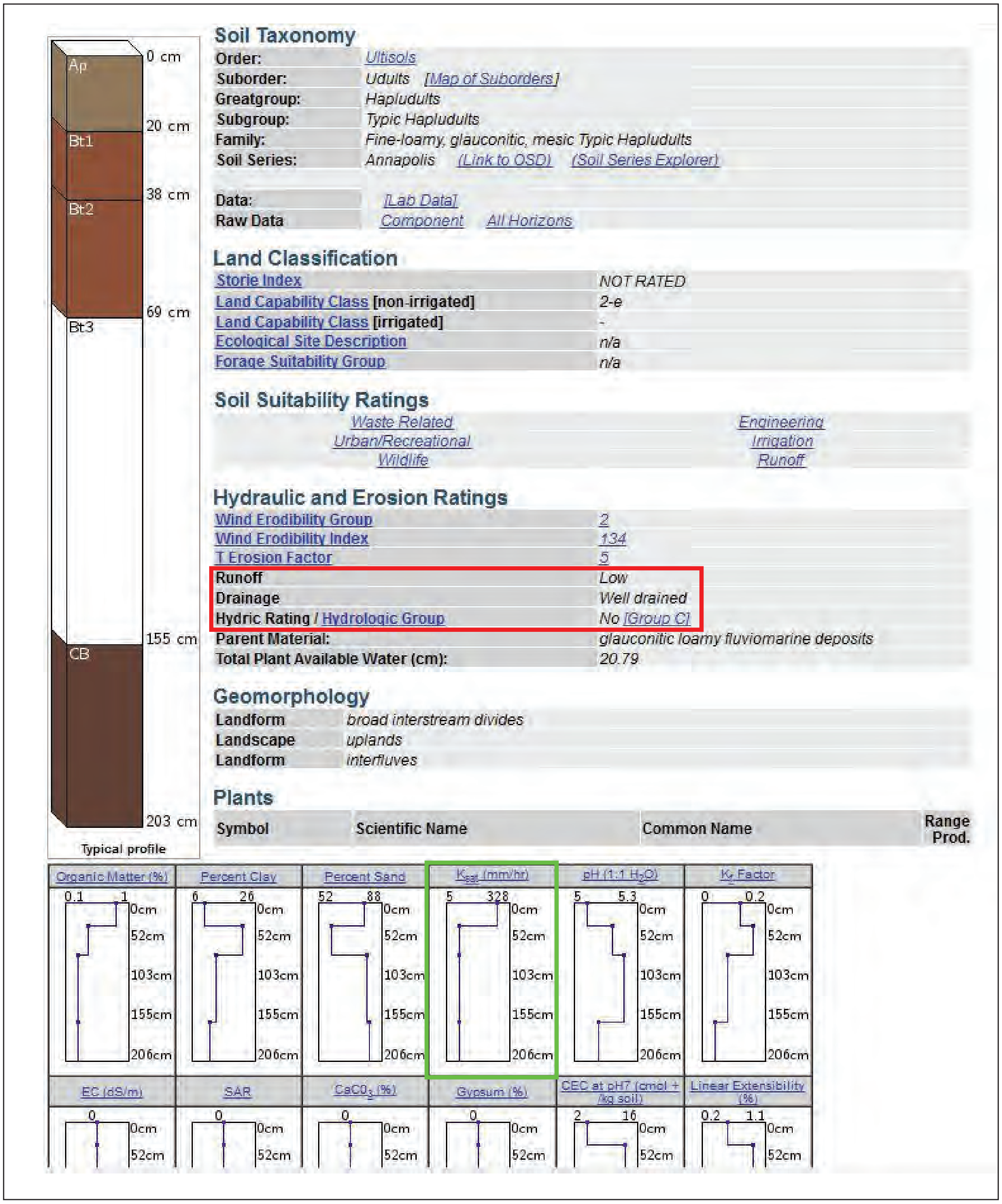


Figure B.5: *Screenshot of Google Earth's SoilWeb tool showing soil type delineations and a vertical soil type profile for the selected subarea*

(Source: Google)



Soil Taxonomy

Order:	Ultisols
Suborder:	Udults [Map of Suborders]
Greatgroup:	Hapludults
Subgroup:	Typic Hapludults
Family:	Fine-loamy, glauconitic, mesic Typic Hapludults
Soil Series:	Annapolis (Link to OSD) (Soil Series Explorer)
Data:	[Lab Data]
Raw Data	Component All Horizons

Land Classification

Storie Index	NOT RATED
Land Capability Class [non-irrigated]	2-e
Land Capability Class [irrigated]	-
Ecological Site Description	n/a
Forage Suitability Group	n/a

Soil Suitability Ratings

Waste Related	Engineering
Urban/Recreational	Irrigation
Wildlife	Runoff

Hydraulic and Erosion Ratings

Wind Erodibility Group	2
Wind Erodibility Index	134
T Erosion Factor	5
Runoff	Low
Drainage	Well drained
Hydric Rating / Hydrologic Group	No [Group C]
Parent Material:	glauconitic loamy fluviomarine deposits
Total Plant Available Water (cm):	20.79

Geomorphology

Landform	broad interstream divides
Landscape	uplands
Landform	interfluves

Plants

Symbol	Scientific Name	Common Name	Range Prod.

Figure B.6: *Report from Google Earth's SoilWeb tool, showing results for the "Annapolis" soil type. Runoff/drainage characteristics and soil type are highlighted in red box. The infiltration rate profile graph is shown in the green box. This depicts a fast infiltration rate to a depth of approximately 1½ feet and very slow infiltration at greater depths.*
(Source: Google)

B.7. References & Resources

Association of Professional Landscape Designers Guide to Sustainable Soils
http://apld.org/_media/Sustainability/Sustainable%20Soils%20Brochure%20-%205-1-12.pdf

Building Soil – Resource Efficient Natural Landscaping
http://www.buildingsoil.org/tools/Landscaping_Guide.pdf

Google Earth *SoilWeb* plugin
http://www.gelib.com/soilweb.htm

Maryland's Environmental Resource and Land Information Network
http://geodata.md.gov/imaptemplate/?appid=a8ec7e2ff4c34a31bc1e9411ed8e7a7e

USDA Natural Resource Conservation Service *Web Soil Survey*
http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

United States Department of Agriculture (1986). Urban Hydrology for Small Watersheds (PDF). Technical Release 55 (TR-55) (Second Edition). Natural Resources Conservation Service, Conservation Engineering Division.
http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf

Anne Arundel County GIS Mapping
http://gis-world2.aacounty.org/silverlightviewer/?Viewer=WERS