METHODOLOGIES FOR BASIC SOIL ANALYSES

A Methodology for Defining and Assessing Soils In the Raritan River Basin

Upper Raritan Watershed Association, for the
Raritan Basin Watershed Management Project

May 2000

METHODOLOGY FOR DEFINING AND ASSESSING SOILS
TABLE OF CONTENTS

EXECUTIVE SUMMARY

This document outlines the methods that will be employed in the undertaking of several basic soil analyses for inclusion in the characterization and assessment of the Raritan Basin. These soil studies include *suitability of soils for agriculture*; *suitability of soils for development*; and *susceptibility of soils to erosion*.

The methods by which the soils will be analyzed and the systems by which they are stratified have been taken directly from those derived by USDA - Natural Resources Conservation Service (*NRCS*) soil scientists. These analyses provide stand-alone results but, for the most part, give little insight into their meaning with respect to the state of the Basin. A better understanding of the meaning of soil properties will be gained from interpretive investigations conducted with the use of additional geographic information. The maps that result from the synthesis of soil properties and contextual information such as land use/land cover and proximal water bodies will vividly illustrate the current state of development in the Raritan Basin with respect to suitability for those uses.

The following soil analyses will be conducted, resulting in associated maps and quantitative summaries:

- Suitability of Soils for Agriculture
  - Map: Nonirrigated agricultural suitability of soils in the Raritan Basin prior to development.
    - Summary: Acreage by capability subclass per HUC14 unit, aggregated to HUC11 unit.
  - Map: Nonirrigated agricultural suitability of soils in the Raritan Basin vis-à-vis current land use.
    - Summary: Acreage of remaining potentially agriculture-suited soils by capability subclass per HUC14 unit, aggregated to HUC11 unit.

- Suitability of Soils for Development
  - Map: Composite analysis of suitability ratings for the following elements of community development and infrastructure:
    - Septic tank absorption fields
    - Foundations for dwellings with basements
    - Foundations for dwellings without basements
    - Foundations for small commercial buildings
    - Local roads and streets
    - Lawns, landscaping, and golf fairways

- Susceptibility of Soils To Erosion
  - Map: Soil erodibility in each of the constituent watershed management areas.
    - Summary: Acreage by erodibility class per HUC14 unit, aggregated to HUC11 unit.

ACKNOWLEDGEMENTS

Primary Author:
Caroline R. Phillipuk, GIS Specialist, Upper Raritan Watershed Association

Contributing Author:
David Peifer, Executive Director, Upper Raritan Watershed Association

An extended “thank you” to the Raritan Basin Watershed Management Project Characterization Committee and Project Team for all of their comments, hard work and suggestions. Project Team members include:

- New Jersey Department of Environmental Protection
- New Jersey Water Supply Authority
- North Jersey Resource Conservation and Development Council
- Rutgers Center for Environmental Communication
- South Branch Watershed Association
- Stony Brook-Millstone Watershed Association
- United States Department of Agriculture – Natural Resources Conservation Service
- United States Geological Survey
- Upper Raritan Watershed Association

1.0 INTRODUCTION

An understanding of soil is crucial to the development of an understanding of watershed character. Such an understanding is vital to the management, preservation, and restoration of watershed health.

Soils cover virtually the entire landscape, and are intimately connected with both the surface and ground water that flows through a watershed. They form a "mediating layer" between the non-living mineral world, the atmosphere, water, and the living community on the surface of the land. Although it is a vital ecological element in its own right, soil also supports and facilitates many of the physical, chemical, and biological processes related to the quality and quantity of water within a watershed. These in turn support plant and animal communities, as well as human activities.

Soil is defined as "the uppermost part of the earth's surface, which has been modified by physical, chemical and biological processes over time. It is a complex and dynamic mixture of solid and dissolved mineral matter, living and dead organic matter, water and air."[1] This definition is far more complex and thought provoking than the common understanding of soils among the general population.

Most people regard this complex system as "dirt" and, depending upon their interests, have an incomplete though sometimes detailed knowledge of some aspects of soil. For example, a miner interested in hard rock minerals thinks of soil as a nuisance through which he must dig to reach his goal. The engineer is concerned with the ability of the soil on a site to support proposed construction. The farmer views the soil as primarily a habitat for plants. It is an indispensable element of his economic activity. Even home gardeners have an understanding of soils, preferring an easily worked loam to a hard clay soil.[2] A complete understanding of soil, however, is rarely found outside of the discipline of soil science.

As landowners, policy makers, and citizens, we all have some impact on the structure, condition, and overall state of health of the soil in our watershed. We may take actions that affect the soil on a site, preclude future options, and export problems to other sites located downstream. Conversely, we may also act to preserve the soils, enhance their functions and values, and return the character of the watershed toward its former, natural condition. Therefore the objectives of watershed management imply prevention of future problems from the unwise use of soils as well as the preservation of desirable characteristics of the soils and restoration of previously damaged soil.

New Jersey has the benefit of detailed information about soil provided by the U.S. Department of Agriculture's Natural Resources Conservation Service. This information includes characterization of soils, spatial mapping, textual information and detailed data about many of the properties of soils. This voluminous collection of data has been developed over an extended period of time for a variety of users who range from land planners to farmers, engineers and homeowners. These data, however, have not been compiled or organized to facilitate watershed protection and management.

It is the goal of this methodology to synthesize some limited segment of these data to provide information relevant to the purposes of watershed characterization and assessment and to provide the basis for the development of a management plan for the entire Raritan River basin.

Three general areas have been selected for analysis and presentation. These include *suitability of soil for agriculture*, *suitability of soil for development*, and *susceptibility of soil to erosion*.

This is not an exhaustive treatment of the entire universe of knowledge concerning soil. We anticipate that these analyses will provide a basis for the development of a more complete understanding of the roles played by soil under natural conditions and under the influence of widespread human manipulation in the Basin.

2.0 SUITABILITY OF SOILS FOR AGRICULTURE

Methodology

The USDA-Natural Resources Conservation Service developed a method to generally describe the suitability of soil varieties for field crops and pasture. This method, known as *capability grouping*, addresses the principal concerns in managing soils for agriculture: **maintaining fertility**; **controlling erosion**; **providing drainage;** and **improving tilth**.[3] This grouping results in stratification of the soils according to "**limitations that may impede their use for field crops**; **the risk of damage when so used**; and **the ways in which they respond to intervention**."[4] The soils of the Raritan Basin will be mapped and assessed for nonirrigated agricultural use according to this method.

The capability grouping system, applied separately with respect to irrigated and nonirrigated agriculture, provides a two-tier description of each soil. The *capability class* is the most general of the two descriptors. It consists of numerals 1-8 that indicate "progressively greater limitations and narrower choices for use."[5]

The secondary rating, *capability subclass* is applied to groups of soils within the same capability class. A lowercase letter *e*, *w*, *s*, or *c* is appended to a class numeral to describe the main limitation of a particular soil. The subclass letter *e* indicates risk of *erosion* unless recommended management techniques are employed. The letter *w* indicates that wetness may limit or preclude certain agricultural activities except where artificial drainage is viable. The letter *s* is used to indicate that the agricultural use of a soil is limited by excessive stoniness, droughtiness, or shallow depth to rock. The letter *c* is used to indicate that climate (cold temperatures or aridness) is the primary limiting factor of a soil. This subclass is not used in New Jersey.

A complete listing and description of the capability classes and subclasses may be found in Appendix A.

GIS Implementation

The Raritan Basin Watershed Management project team will employ the capability grouping system in order to map agricultural suitability ratings throughout the constituent watershed management areas. This analysis will focus on *nonirrigated* agricultural use of soils due to the climate, physical geography, and prevalent farming methods of the region.

One 11"x17" basin-wide map of the nonirrigated agricultural suitability of soils, without regard to present land use, will be included in order to illustrate agricultural suitability prior to development. A quantitative study will be performed in order to summarize the acreage of capability subclasses per HUC14 unit.

Three 8.5"x11" maps of the constituent watershed management areas that illustrate present land cover vis-à-vis agricultural suitability will also be included. Capability groupings are based upon the properties of undisturbed soil. It can be assumed that some land uses in the Raritan Basin have robbed the soil of many or all of the properties for which they gained their capability grouping. The 1995 land use/land cover data will be used to discount areas where present land cover (urban, built-up, barren, or altered) precludes agriculture. A quantitative study will be performed in order to summarize the remaining potentially agriculture-suited acreage by capability subclasses per HUC14 unit.

Data Requirements

1. Raritan Watershed Soils;
   USDA – Natural Resources Conservation Service, 1999.

2. Land use/land cover - WMAs 8, 9, and 10;
   NJDEP – Bureau of Geographic Information and Analysis, 2000.

3. Basins from GIS Resource Data Series I;
   USGS and NJDEP – Bureau of Geographic Information and Analysis, 1996.

4. Statmuir component table, *comp*;
   USDA – Natural Resources Conservation Service, 2000.

3.0 SUITABILITY OF SOILS FOR DEVELOPMENT

Methodology

The USDA – Natural Resources Conservation Service has generally evaluated soils for the most common uses in community development. These evaluations consist of the *severity* and *kind of limitations* inherent in each mapping unit with respect to several possible land uses. The soils of the Raritan Basin will be mapped and assessed for six of the twenty-six community development applications that have been considered by *NRCS*.

The town and country planning soil interpretations identify one or more of the most limiting factors of a soil for a given use. Common limiting factors include (but are not limited to) shallow depth to seasonal high water table; shallow depth to bedrock; slope; etc. Ratings of *slight*, *moderate*, and *severe* are applied to describe the degree of such limitations. (The more severe rating is applied to map units wherein more than one limitation has been found). These simple terms infer the following about the degree of difficulties that may be encountered when attempting to develop on various soils.

- *Slight.* This rating is given to soils that have properties favorable for the use. This degree of limitation is minor and can be overcome easily. Good performance and low maintenance can be expected.

- *Moderate.* This rating is given to soils that have properties moderately favorable for the use. This degree of limitation can be overcome or modified by special planning, design, or maintenance. The expected performance of the structure or other planned use is somewhat less desirable than for soils rated *slight*.

- *Severe.* This rating is given to soils that have one or more properties unfavorable for the rated use. This degree of limitation generally requires major soil reclamation, special design, or intensive maintenance. Reducing or removing the soil feature that limits use can improve some soil varieties. In most situations, it is difficult and costly to alter the soil or to design a structure so as to compensate for a severe degree of limitation.[6]

A complete listing of community development elements, the limiting factors of soils with respect to community development, and assumptions made about selected land uses may be found in Appendices B, C, and D respectively.

<u>GIS Implementation</u>

The Raritan Basin Watershed Management project team will employ the land use-related soil interpretations devised by *NRCS* in order to map development suitability ratings throughout the constituent watershed management areas. The broad scope and cursory nature of this characterization does not necessitate analysis of each of the twenty-six land uses and infrastructure elements for which soil properties have been examined. This analysis will, therefore, include suitability ratings for the following pertinent elements of development:

- Septic tank absorption fields
- Foundations for dwellings with basements
- Foundations for dwellings without basements
- Foundations for small commercial buildings
- Local roads and streets
- Lawns, landscaping, and golf fairways[7]

A composite analysis will be developed to circumvent the proliferation of nearly meaningless maps that would result if displays were created for each parameter. This type of analysis will work in the following manner. Numerical values will be substituted for the suitability ratings *slight*, *moderate*, and *severe* for each developmental element. Higher numbers will be used to indicate greater severity of soil-based limitations. This will result in six suitability layers. The six preliminary maps will, then, be added together to give one composite view. Areas that are least suited to any or all of the chosen community development elements will have higher numerical values. The final composite may then be compared to current land use in order to identify areas where generally unsuited land uses exist. The results of such a comparison will be quantified by HUC14 and aggregated to HUC11.

Data Requirements

1. Raritan Watershed Soils;
   USDA – Natural Resources Conservation Service, 1999.

2. 1995 Land use/land cover – WMAs 8, 9, and 10;
   NJDEP – Bureau of Geographic Information and Analysis, 2000.

3. Statmuir component table, *interp*;
   USDA – Natural Resources Conservation Service, 2000.

4.0 SUSCEPTIBILITY OF SOILS TO EROSION

Methodology

The USDA-Natural Resources Conservation Service has devised a method by which to generally describe the susceptibility of various soils to erosion. This method consists of a series of calculations that determine the erodibility of land as a function of **land cover** and **amount of rainfall**. The soils of the Raritan Basin will be mapped and assessed according to this method.

The *highly erodible land* classification system was previously employed by few states.[8] Two preliminary erodibility ratings, *subjectivity to erosion by wind* and *subjectivity to erosion by water*, are reached for each map unit by calculations that involve rainfall and land cover factors. The more limiting rating of the two is used to determine whether or not the map unit meets the criteria that distinguish highly erodible lands from those that are not highly erodible.

One of the following descriptors is given to each map unit for which the preliminary calculations have been performed.

- *Highly Erodible Land* (Arabic numeral 1) soils that meet the criteria for highly erodible lands.
- *Potentially Highly Erodible* (Arabic numeral 2) mapping units in which the properties of both highly erodible and *not* highly erodible soils exist.
- *Not Highly Erodible* (Arabic numeral 3) soil map units that do not meet the criteria for highly erodible land[9]

GIS Implementation

The Raritan Basin Watershed Management project team will employ the highly erodible land classification system in order to map the potential for soil erosion throughout the constituent watershed management areas. It should be noted that most of the erodibility ratings are based on calculations of the preliminary rating, *subjectivity of soil to erosion by water*. The *subjectivity of soil to erosion by wind* rating is generally inapplicable due to the climate and physical geography of the region.

Our initial recommendation is to include simple maps of soil erodibility and descriptive quantitative analyses for each HUC14, aggregated to HUC11. Additional, more complex geographic analyses may be possible if data availability and expertise allow.

Data Requirements

1. Raritan Watershed Soils;
   USDA – Natural Resources Conservation Service, 1999.

2. Statmuir component table, *helclass*;
   USDA – Natural Resources Conservation Service, 2000.

5.0 GLOSSARY OF TERMS

HUC11 – watersheds of New Jersey coded to 11-digit hydrologic unit codes.

HUC14 – watersheds of New Jersey coded to 14-digit hydrologic unit codes.

Tilth – the condition of soil, especially the soil structure, as related to the growth of plants. Good *tilth* is associated with high non-capillary porosity and stable structure.

6.0 LIST OF REFERENCES

Brady, Nyle C., Harry O. Buckman. Nature and Properties of Soils; Macmillan Company, New York, 1967.

Cutter, Susan L., et al. Exploitation, Conservation, Preservation: A Geographic Perspective on Natural Resource Use; John Wiley and Sons, Inc., New York, 1991, p. 121.

"Data Use Information." Soil Survey Geographic (SSURGO) Database; United States Dept. Of Agriculture – Natural Resources Conservation Service, 1995.

Fletcher, Sylvester J. Soil Survey Of Warren County, New Jersey; United States Dept. of Agriculture – Soil Conservation Service, 1979.

Kirkham, Wendell C. Soil Survey Of Somerset County, New Jersey; United States Dept. Of Agriculture – Soil Conservation Service, 1976.

Smith, Chris. Soil Scientist,
United States Dept. of Agriculture - Natural Resources Conservation Service.
Electronic mail correspondence of January 13, 2000.

Soil Survey Staff. National Soil Survey Handbook, Title 430–VI; United States Dept. Of Agriculture – Natural Resources Conservation Service; Washington, DC. US Government Printing Office, November 1996.

Vasilas, Lenore Matula and Keenan, Scott C. Soil Survey of Cape May County, New Jersey; United States Dept. of Agriculture – Natural Resources Conservation Service, 2000.

Appendix A: Agricultural Capability Grouping

Class I. **Soils having few limitations that restrict their use.**

No subclasses.

Class II. **Soils having moderate limitations that reduce the choice of plants or that require moderate conservation practices.**

Subclass IIe.	Soils subject to moderate erosion unless protected.
Subclass IIw.	Soils moderately limited by excess water.
Subclass IIs.	Soils moderately limited by droughtiness.

Class III. Soils having severe limitations that reduce the choice of plants, that require special conservation practices, or both.

Subclass IIIe.	Soils subject to severe erosion if they are cultivated and not protected.
Subclass IIIw.	Soils severely limited by excess water.
Subclass IIIs.	Soils that are severely limited by droughtiness.

Class IV. **Soils having very severe limitations that reduce the choice of plants, that require very careful management, or both.**

Subclass IVe.	Soils subject to very severe erosion if they are cultivated and not protected.
Subclass IVw.	Soils very severely limited by excess wetness.
Subclass IVs.	Soils very severely limited by droughtiness.

Class V. **Soils subject to little or no erosion but having other limitations, impractical to remove, that limit their use largely to pasture, woodland, or wildlife habitat.**

Subclass Vw.	Soils too wet for cultivation; drainage generally not feasible.

Class VI. **Soils having severe limitations that make them generally unsuited to cultivation and that limit their use largely to pasture, woodland, or wildlife habitat.**

Subclass VIe.	Soils severely limited, mainly by risk of erosion, unless protective cover is maintained.
Subclass VIw.	Soils severely limited by excess water; generally unsuitable for cultivation.

Subclass VIs. Soils generally unsuitable for cultivation and limited for other uses by their low available water capacity, stoniness, or other characteristics.

Class VII. Soils having very severe limitations that make them unsuited to cultivation and that restrict their use largely to grazing, woodland, or wildlife habitat.

Subclass VIIe. Soils very severely limited, mainly by risk of erosion unless protective cover is maintained.

Subclass VIIs. Soils very severely limited by low available water capacity, stones, or other soils features.

Class VIII. Soils having severe limitations that preclude their use for commercial plant production and restrict their open-space uses to recreation, wildlife habitat, water supply, or esthetic purposes.

Subclass VIIIs. Soils very severely limited by coarse fragments, rock outcrops, and shallowness.

Reprinted from:

Jablonski, C.F. Soil Survey Of Mercer County, New Jersey, p. 52;
United States Dept. Of Agriculture – Soil Conservation Service, 1972.

Kirkham, Wendell C. Soil Survey Of Somerset County, New Jersey, pp. 51-53;
United States Dept. Of Agriculture – Soil Conservation Service, 1976.

Appendix B: Interpretive Group Codes (Development Suitability)

The following community development elements are reprinted from:

“Data Use Information.” Soil Survey Geographic (SSURGO) Database, p. B5;
United States Dept. Of Agriculture – Natural Resources Conservation Service, 1995.

Grpcode 1 – septic tank absorption fields*
Grpcode 2 – sewage lagoons
Grpcode 3 – trench sanitary landfill
Grpcode 4 – area sanitary landfill
Grpcode 5 – daily cover for landfill
Grpcode 6 – shallow excavations
Grpcode 7 – foundations for dwellings without basements*
Grpcode 8 – foundations for dwellings with basements*
Grpcode 9 – foundations for small commercial buildings*
Grpcode 10 – local roads and streets*
Grpcode 11 – lawns, landscaping, and golf fairways*
Grpcode 12 – roadfill
Grpcode 13 – sand
Grpcode 14 – gravel
Grpcode 15 – topsoil
Grpcode 16 – pond reservoir area
Grpcode 17 – embankments, dikes, and levees
Grpcode 18 – aquifer-fed excavated ponds
Grpcode 19 – drainage
Grpcode 20 – irrigation
Grpcode 21 – terraces and diversions
Grpcode 22 – grassed waterways
Grpcode 23 – camp areas
Grpcode 24 – picnic areas
Grpcode 25 – playgrounds
Grpcode 26 – paths and trails

***These elements will be incorporated into the study of the suitability of Raritan Basin soils for development.**

Appendix C: Soil Limitations For Development Suitability

The following restrictions are reprinted from:

"Data Use Information." Soil Survey Geographic (SSURGO) Database, pp. B39-B40; United States Dept. Of Agriculture – Natural Resources Conservation Service, 1995.

Restct 1 – area reclaim
Restct 2 – cemented pan
Restct 3 – complex slope
Restct 4 – compressible
Restct 5 – corrosive
Restct 6 – cutbanks cave
Restct 7 – deep to water
Restct 8 – depth to rock
Restct 9 – droughty
Restct 10 – dusty
Restct 11 – erodes easily
Restct 12 – excess sodium
Restct 13 – excess humus
Restct 14 – excess lime
Restct 15 – excess salt
Restct 16 – fast intake
Restct 17 – favorable
Restct 18 – flooding
Restct 19 – frost action
Restct 20 – hard to pack
Restct 21 – large stones
Restct 22 – low strength
Restct 23 – no water
Restct 24 – not needed
Restct 25 – seepage
Restct 26 – percs slowly
Restct 27 – piping
Restct 28 – poor outlets
Restct 30 – rooting depth
Restct 31 – shrink-swell
Restct 32 – slope
Restct 33 – slow intake
Restct 34 – slow refill
Restct 35 – small stones
Restct 36 – thin layer
Restct 37 – too clayey
Restct 38 – too sandy
Restct 39 – unstable fill
Restct 40 – wetness
Restct 41 – excess fines
Restct 42 – soil blowing
Restct 43 – permafrost
Restct 44 – pitting
Restct 45 – salty water
Restct 46 – subsides
Restct 47 – too acid
Restct 48 – ponding
Restct 49 – excess sulfur
Restct 50 – poor filter
Restct 51 – dense layer
Restct 52 – fragile
Restct 53 – slippage
Restct 54 – variable
Restct 55 – excess gypsum
Restct 56 – too arid

Appendix D: Building Site Development And Sanitary Facilities

Dwellings and small commercial buildings. Ratings are intended for structures built on shallow foundations on undisturbed soil. The load limit is the same as that for single-family dwellings no higher than three stories. Ratings are made for small commercial buildings without basements, for dwellings with basements, and for dwellings without basements. The ratings are based on soil properties, site features, and observed performance of the soils. A high water table, flooding, shrinking and swelling, and organic layers can cause the movement of footings. Depth to a high water table, depth to bedrock, large stones, and flooding affect the ease of excavation and construction. Landscaping and grading that require cuts and fills of more than 5 or 6 feet are not considered.

Local roads and streets. Ratings are based on the assumption that roads and streets have an all-weather surface and carry automobile and light truck traffic all year. They have a sub grade of cut or fill soil material; a base of gravel, crushed rock, or stabilized soil material; and a flexible or rigid surface. Cuts and fills are generally limited to less than 6 feet. The ratings are based on soil properties, site features, and observed performance of the soils. Depth to bedrock, depth to high water table, flooding, large stones, and slope affect the ease of excavating and grading. Soil strength (as inferred from the engineering classification of the soil), shrink-swell potential, frost action potential, and depth to a high water table affect the traffic-supporting capacity.

Lawns, landscaping, and golf fairways. Ratings are based on those soils on which turf and ornamental trees and shrubs can be established and maintained. The ratings are based on soil properties, site features, and observed performance of the soils. Soil reaction, depth to a high water table, depth to bedrock, and the available water capacity in the upper 40 inches affect plant growth. Flooding, wetness, slope, stoniness, and the amount of sand, clay, or organic matter in the surface layer affect trafficability after vegetation is established. Soil tests are essential to determine liming and fertilizer needs. Help in making soil tests or in deciding what soil additive, if any, should be used can be obtained from the local office of the Cooperative Extension Service.

***Septic tank absorption fields*. Ratings are for areas in which effluent from a septic tank is distributed into the soil through subsurface tiles or perforated pipe. Only that part of the soil between depths of 24 and 72 inches is evaluated. The ratings are based on soil properties, site features, and observed performance of the soils. Permeability, depth to a high water table, depth to bedrock, and flooding affect absorption of the effluent. Large stones and bedrock interfere with installation. Unsatisfactory performance of septic tank absorption fields, including excessively slow absorption of effluent, surfacing of effluent, and hillside seepage, can affect public health. Ground water can be polluted if highly permeable sand and gravel or fractured bedrock is less than 4 feet below the base of the absorption field, if slope is excessive, or if the water table is near the surface. There must be unsaturated soil material beneath the absorption field to filter the effluent effectively. Many local ordinances require that this material be of a certain thickness.

Reprinted from:
Vasilas, Lenore Matula and Keenan, Scott C. Soil Survey of Cape May County, New Jersey; United States Dept. of Agriculture – Natural Resources Conservation Service, 2000

---

[1] Cutter, 1991
[2] Brady, 1967
[3] Kirkham, 1976 and Vasilas, 2000
[4] Kirkham, 1976
[5] Kirkham, 1976
[6] Soil Survey Staff, 1996
[7] USDA – NRCS, 1995
[8] Smith, 2000
[9] USDA – NRCS, 1995