U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
GREEN MOUNTAIN NATIONAL FOREST

SOIL ASSESSMENT
Revision 1

September 2003

Prepared by
Tetra Tech EM Inc.
175 N. Corporate Drive
Brookfield, Wisconsin 53045
Contract No. 53-56A1-02-01628
Task Order No. 1

U.S. Forest Service Project Officers
Melissa Reichert and Nancy Burt
Green Mountain and Finger Lakes National Forests
Rutland, Vermont

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ACRONYMS AND ABBREVIATIONS

AMP	Accepted Management Practice
BMP	Best Management Practice
CFR	Code of Federal Regulations
ELT	Ecological Land Type
ELTP	Ecological Land Type Phase
FSH	Forest Service Handbook
FSM	Forest Service Manual
GMNF	Green Mountain National Forest
LTA	Land Type Association
NCSS	National Cooperative Soil Survey
NEFES	USFS - Northeastern Forest Experiment Station
NEPA	National Environmental Policy Act
NFMA	National Forest Management Act
NFS	National Forest System
NHFEU	National Hierarchical Framework of Ecological Units
NRCS	U.S. Department of Agriculture – Natural Resources Conservation Service
RPA	Resources Planning Act
S&Gs	Standards and Guidelines
SQS	Soil Quality Standard
STATSGO	State Soil Survey Geographic Data Base
SSURGO	Soil Survey Geographic Data Base
TEU	Terrestrial Ecological Unit
TEUI	Terrestrial Ecological Unit Inventory
USDA	United States Department of Agriculture
USFS	U.S. Department of Agriculture – Forest Service

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ABSTRACT

The U.S. Department of Agriculture, Forest Service has tasked Tetra Tech EM Inc. to provide an assessment of the condition of soils and the status of soil information for the Green Mountain National Forest (GMNF). This assessment is needed for revision of the National Forest Land and Resource Management Plan (also known as the "Forest Plan").

This soil assessment provides information for the Forest Plan revision. It includes an overview of the legal and administrative framework guiding soil management on National Forest System lands, effects of major disturbances, availability of soils information, and the kinds of soils that occupy the GMNF, as well as a discussion of the major soil-related issues to be addressed in the Forest Plan revision.

This soil assessment includes the following major recommendations:

- Update standards and guidelines for soil management to incorporate the latest agency direction and scientific knowledge.
- Develop soil quality standards and incorporate them into the updated standards and guidelines.
- Develop and implement an ecological monitoring strategy.
- Work with research organizations to further identify soil parameters that influence the effects of acid deposition.
- Develop soil information to the level of intensity needed for land and resource management decisions.
- Identify and improve all areas where soil quality has been impaired.

This soil assessment further recommends that the Forest Plan revision include direction to achieve those recommendations that cannot be achieved in time to be incorporated into the Forest Plan revision.

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EXECUTIVE SUMMARY

This assessment of soil conditions and available information for the Green Mountain National Forest (GMNF) provides information needed for revision of the National Forest Land and Resource Management Plan (Forest Plan). The assessment provides a historic context for soil conditions and establishes information to enable the Forest Service (USFS) to effectively respond to emerging issues and close information gaps. This Executive Summary provides an overview of the contents of the soil assessment for GMNF; it is focused on information that is most relevant to future management direction.

Historic information and current soils data provide a foundation for future management of the soils of the GMNF. This assessment outlines the legal and administrative framework (Section 2) for soil management, from the 1897 Organic Act that established the National Forest System, to contemporary laws, regulations, and directives that require the Forest Plan and establish goals and standards for resource management. This legal and administrative framework is the foundation of soil management goals (Section 3) that are included in the existing Forest Plan.

Managing soils, like managing habitats, requires knowledge of past "disturbances," current conditions, and the structure and composition of the resource. This information about the soils of the GMNF is summarized in Sections 4 through 6 of the assessment. Actions toward soil management goals, issues and concerns that affect future management, assessment conclusions, and information needs are summarized below. They are discussed in more detail in Sections 7 through 10 of the assessment.

ACTIONS TOWARD GOALS

Current actions toward soil management goals include the following:

- Application of Standards & Guidelines (S&Gs)-- Potential impacts of each planned project are assessed, and Forest Plan S&Gs are applied to minimize or eliminate the impacts. Mitigation measures are recorded in decision memoranda and notices.

- Monitoring-- The GMNF monitors the application and effectiveness of S&Gs, and cooperates with other organizations in long-term studies toward development of monitoring tools, such as acid sensitivity maps and/or till source models.

- Soil Resource improvement-- The GMNF, with help from partners, implements 10 to 12 projects per year to control erosion and improve soil quality on degraded areas.

KEY ISSUES AND CONCERNS

Key issues and concerns that affect future management action and revision of the Forest Plan are identified in the assessment and are briefly summarized in the following paragraphs.

Maintaining long-term soil productivity: Long-term soil productivity is the largest issue and concern, and most interrelated with the other issues and concerns. Soil impacts that can affect productivity include (1) physical impacts such as erosion and compaction, and (2) chemical impacts such as acidification and nutrient depletion.

- Physical Impacts: Monitoring indicates that the physical impacts are mitigated to large degree by application of S&Gs. Updating the S&Gs, developing and applying Soil Quality Standards (SQS), and continuing monitoring will ensure that forest management activities will not result in physical impacts that reduce soil quality and productivity.

- Chemical Impacts: Nutrients can potentially be depleted by acid deposition and, to a much lesser extent, timber harvesting.

    1. *Acid Deposition:* The most complex aspect of the long-term soil productivity maintenance issue involves assessing and mitigating the effects of acid deposition. Studies of these effects since the 1970s cumulatively indicate that acid deposition may reduce soil quality and soil productivity on sensitive sites. However, conclusive evidence that soil productivity has thus far been affected by acid deposition is lacking.

       Soil acidification from acid deposition also has secondary effects, which have negative implications for both terrestrial and aquatic ecosystems.

    2. *Timber Harvesting:* Nutrient losses from GMNF soils due to timber harvesting can reasonably be expected to be small due to low-intensity harvest operations, small selective acreage of impacted land, and application of S&Gs.

Update Forest Plan direction for protection and enhancement of soils: The current soil quality S&Gs do not fully reflect the latest management direction and scientific knowledge. Recommendations for updating the S&Gs are provided in the assessment.

Identify and improve areas where soil quality is impaired: The Soil Improvement Needs inventory should be completed and maintained so that improvement projects can be effectively directed toward the highest priority areas.

Further Develop and Improve the Terrestrial Ecological Classification and Inventory System: The Terrestrial Ecological Classification and Inventory system needs to be updated to (1) incorporate current concepts, link Land Type Associations (LTAs) to Ecological Land Types (ELTs), and improve vegetative predictability; and (2) identify, prioritize, and fulfill Ecological Land Type Phase (ELTP) mapping needs for project and intensive use areas.

- Update the ELTs, and link ELTs to LTAs: The GMNF ELTs and LTAs do not link well together because they were developed during different decades, and exist at different levels in the evolution of the science of ecological land classification. It is suggested that the Forest Plan revision should provide direction for updating the ELTs, and ensuring their hierarchical integration with the LTAs and ELTPs.

- Identify, prioritize, and fulfill ELTP mapping needs*:* The Forest Plan revision should include direction for identifying and prioritizing ELTP needs, and for developing and mapping ELTPs, where needed.

Emerging Issues: The following issues may soon become important to the GMNF, and should be addressed in the Forest Plan revision:

- Terrestrial large woody debris
- Carbon sequestration
- Soil floral and faunal communities
- Protection of uncommon landform/geologic/soil types
- Protection of example sites of representative ecological types from anthropogenic disturbances

Future Monitoring and Research Needs: The following future monitoring and research efforts would help ensure maintenance of long-term soil productivity, as well as address the other issues and concerns:

- Develop SQSs and incorporate them into updated S&Gs.
- Develop an ecological monitoring strategy that incorporates the S&Gs (including the SQSs).
- Continue involvement in the cooperative long-term soil monitoring study.
- Update the ELTs so that they more accurately reflect vegetative potential, and conform to the boundaries of the LTAs.
- Improve identification of acid deposition-sensitive areas and sites.
- Identify better ways to define and measure soil productivity.

CONCLUSIONS AND CRITICAL INFORMATION NEEDS

Conclusions of the assessment include the following:

- The general health of the soils of the GMNF today is good. Exceptions include small areas consisting primarily of landslides, eroding stream banks, old gravel pits or borrow areas, minor skid trails, dispersed campsites, and areas frequently used (illegally) by all-terrain vehicles.

- The USFS is generally capable of addressing the key issues and concerns over the next several years. The rate at which the goals and recommendations are achieved will be highly dependent on future funding levels.

Revision of the GMNF Forest Plan provides an opportunity for the USFS to focus on the following critical information needs:

- Establish SQSs to provide a basis to monitor changes in soil properties of the LTAs, ELTs, and ELTPs that are identified on the GMNF.

- Map ELTPs on all parts of the GMNF where intensive management is planned.

- Evaluate ELT mapping to ensure it reflects current concepts and meshes with the LTA mapping.

- Obtain more definitive information on the chemical aspects of soil productivity, including calcium dynamics, buffering capacity, and effects of acid deposition. This work is ongoing through USFS Research and GMNF work with the Vermont Monitoring Cooperative. The USFS should continue to conduct monitoring and research throughout the next 10 to 15 years to address these information needs.

- Adopt an ecological monitoring strategy that incorporates SQSs and is flexible enough to incorporate new information as it becomes available

1.0 INTRODUCTION

The U.S. Department of Agriculture (USDA), Forest Service (USFS) has tasked Tetra Tech EM Inc. to provide an assessment of the condition of soils and the status of soil information for the Green Mountain National Forest (GMNF) in Vermont. This assessment is needed for revision of the National Forest Land and Resource Management Plan (also known as the "Forest Plan").

This introduction provides an overview of the terms soil quality, health, and function and discusses the uses for this soil assessment. In addition to this introduction, the soil assessment discusses the following:

- Legal and administrative framework for managing the National Forest System (NFS) (Section 2.0)
- Soil management goals for the GMNF (Section 3.0)
- Major disturbances and the soil reference condition for the GMNF (Section 4.0)
- Soil reference information for the GMNF (Section 5.0)
- An overview of the soils and physical setting of the GMNF (Section 6.0)
- Actions toward the soil management goals for the GMNF (Section 7.0)
- Issues and concerns that should be addressed in the Forest Plan revision (Section 8.0)
- Conclusions (Section 9.0)
- Critical additional information needs (Section 10.0)

A glossary of terms used in the soil assessment is also provided in Section 11.0. References used to prepare this document are presented in Section 12.0.

1.1 SOIL QUALITY, HEALTH, AND FUNCTION

Soil is a fundamental ecosystem component and a foundation of sustaining healthy forests. The objective of soil management is to maintain soil quality and health, and thereby sustain soil function and productive potential.

Soil Quality is defined as the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain or enhance water and air quality, and support human health and habitation (USDA undated [a]).

- *Inherent soil quality* is that aspect of soil quality relating to a soil's natural composition and properties as influenced by the factors and processes of soil formation. Inherent soil quality varies among different kinds of soil.

- *Dynamic soil quality* relates to soil properties that may change as a result of soil use and management.

Soil Health is a term that can be used interchangeably with *dynamic soil quality.*

Soil Function *is maintained by preserving soil health. The basic functions of soil are the following:*

- Sustaining biological activity, diversity, and productivity
- Regulating and partitioning water and solute flow
- Filtering, buffering, degrading, and detoxifying potential pollutants
- Storing and cycling nutrients
- Providing physical support for terrestrial organisms, including humans; and for structures, including buildings, roads and trails (USDA undated [a]).

1.2 PURPOSE AND USE OF THIS ASSESSMENT

The assessment will be used for the following:

- Share general information with the public regarding the conditions and effects of management practices on the soil resources of the GMNF

- Assess the general health and productivity of the GMNF soils

- Identify opportunities to restore, protect, and enhance soil conditions

- Share with the public the most critical soil resource issues identified

- Identify ways to improve monitoring and evaluation of soil resource conditions

- Identify soil information gaps and needs

- Identify problems and issues that are outside the scope of forest planning

2.0 LEGAL AND ADMINISTRATIVE FRAMEWORK

The framework for managing the NFS is established in laws and regulations, and by the USFS directive system, which are summarized below.

2.1 LAWS AND REGULATIONS

The most significant federal laws and regulations that include provisions to protect soil resources on NFS lands are as follows:

- **The Organic Administration Act of 1897** established NFS reserves to improve and protect forests within the boundaries and to secure favorable conditions of water flows. By implication, this Act requires protecting and maintaining the soil resource quality.

- **The Multiple-Use Sustained Yield Act of 1960** states that management of the national forests must provide "sustained yields in perpetuity without impairment of the productivity of the land."

- **The National Environmental Policy Act of 1969 (NEPA)** requires federal agencies to assess the environmental effects of their actions. NEPA therefore requires the Forest Service to assess the impacts of planned land and resource management activities.

- **The Federal Water Pollution Control Act (also known as the "Clean Water Act" [1956, and as subsequently amended])** provides for measures to prevent, reduce, and eliminate water pollution. Because soil erosion is a source of water pollution, this Act requires management of soils to prevent or minimize erosion, including implementation of Best Management Practices (BMP).

- **The Forest and Rangelands Renewable Resources Planning Act of 1974 (RPA)** requires an assessment of the present and potential productivity of the land. Regulations are to specify land management planning guidelines to ensure that timber will be harvested from NFS land only where soil, slope, or other watershed conditions will not be irreversibly damaged.

- **The National Forest Management Act of 1976 (NFMA)** amended the RPA. The NFMA strengthens RPA requirements pertaining to suitability and compatibility of land areas, maintenance of productivity, the need to protect and improve the quality of soil and water resources, and the need to avoid permanent impairment of productive capability of the land.

- **Title 36 Code of Federal Regulations (CFR) Part 219, NFS Land and Resource Management Planning Rules (1982) and proposed Rules (2000 and 2002)** establishes requirements for integrating all of the above mandates into National Forest Land and Resource Management Plans. Requirements to "protect and conserve soil and water resources, and not allow significant or permanent impairment of the productivity of the land" are emphasized throughout both the 1982 and proposed revised rules.

2.2 U.S. FOREST SERVICE DIRECTIVES SYSTEM

The Forest Service Directives System includes the Forest Service Manual (FSM), which provides policy direction, and the Forest Service Handbook (FSH), which provides procedural direction. The FSM and FSH titles and chapters that most affect soil management are as follows:

- **FSM Title 2500** provides overall policy guidance for managing watershed and air resources throughout the NFS, consistent with all applicable laws, regulations, rules, and executive orders.
- **FSM Chapter 2550** provides overall policy guidance for managing soil resources of the national forests, consistent with all applicable laws, regulations, rules, and executive orders.
- **FSH 2509.18** provides procedural directions for a comprehensive approach to incorporating soil information into land management decisions through soil resource inventory, soil management support services, soil quality monitoring, soil interpretation, and soil information training.
- **FSH 2509.18 Chapter 2 - Region 9 Interim Directive R9 RO 2509.18-2002-1** provides regional guidelines for soil quality monitoring, establishes regional soil quality standards (SQS), and directs Forest Supervisors to "propose revised standards as needed based on ecological unit characteristics."
- **FSM Chapter 2060** provides overall policy guidance for ecological classification and mapping.
- **FSH 2090.11** provides procedural guidance for ecological classification and mapping, of which soils are a primary component.

So far as can be determined within the scope of this document, all laws, regulations, rules, and policy requirements are currently being met by the Forest Service in management of the GMNF. However, opportunities exist to enhance demonstration of compliance with requirements relating to maintaining soil quality and long-term productivity through adoption of SQSs, and their incorporation into updated Standards & Guidelines (S&Gs).

3.0 SOIL MANAGEMENT GOALS

One goal in the 1986 GMNF Plan (USFS 1986) directly addresses the soil resources. It is stated as follows:

> "Stabilize and enrich the soils on the GMNF by fixing sources of erosion, preventing future problems from occurring and protecting the nutrients which cycle through the Forest ecosystem."

Several additional goals in the Forest Plan imply good soil management, because their achievement would depend in part on maintenance of soil quality. Examples include, but are not limited to, the following:

- "Nurture and protect the complex, interrelated, natural systems which are part of the GMNF and affected by its management. Recognize the many interrelationships and interactions between resources and uses when making decisions which could be detrimental to the ecosystem as a whole."
- "Manage watersheds in order to protect municipal water supplies, provide adequate flood control, ensure high water quality, sufficient quantity, and benefit important fish and wildlife habitats."
- "Maintain adequate quality, amount and distribution of habitats to support viable populations of all existing native and desired non-native vertebrate species on the National Forest."
- "Maintain and protect all wetland areas."
- "Provide a well distributed variety of vegetative conditions and types on the GMNF in order to enhance diversity, meet the habitat needs of wildlife and to provide wood products and recreational opportunities for people."

Progress toward meeting the goals in the 1986 Forest Plan is assessed in the report titled Implementing the GMNF Forest Plan a 15 Year Retrospective (USFS 2002b).

All of the goals that address or implicate soil resources were achieved to a significant degree. However, they are generally stated as goals that merit repeated or continuing achievement year after year, rather than on a one-time basis.

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4.0 MAJOR DISTURBANCES AND REFERENCE CONDITION

Disturbances are important processes in the forest environment. The natural world is full of significant disturbances, including, but not limited to, fire, wind and ice storms; downslope movement; disease; insect and fungal attack; and flooding (Klyza and Trombulak 1999). Anthropogenic (human-caused) disturbances include land clearing for crops, livestock grazing, road and trail construction, forest burning, and silvicultural practices such as timber harvest, prescribed burning, timber stand improvement, and tree planting. Other disturbances, such as acid deposition and climate change, may have both natural and anthropogenic causes. Human activities often influence the effects of some natural disturbances.

Disturbance regimes vary over time as a result of different natural and human influences. In and around the area that is now the GMNF, variations over the past 2,000 years have been primarily attributable to human influences. Disturbances that have affected this area over three time periods are discussed, focusing on those disturbances that have affected soil quality. The reference condition to which discussion of dynamic conditions can be based is also established.

4.1 2,000 YEARS TO 300 YEARS BEFORE PRESENT

From 2,000 years to 300 years before present, the human population was relatively sparse. The Native Americans' use of the land was dispersed and resulted in few permanent changes in ecological processes (Thompson and Sorenson 2000). In general, they lived and farmed in the valleys, and used the mountains for hunting. We can assume that natural disturbances had relatively minor impacts on soil quality. Infrequent windstorms likely toppled some trees, primarily on shallow soils, which probably resulted in enhancing soil building processes. Fires tended to be restricted to small patchy areas with warmer aspect and thin soils, particularly on west-facing escarpments along the Champlain Valley-Green Mountain boundary (Mann and others 1994). Overall, however, fires were a minor player in the ecology of Vermont's forests because of the moist climate (Thompson and Sorenson 2000). Small landslides probably occurred on some of the steeper slopes, where shallow, wet soils prevailed. The result would have been a reduction of soil quality at the sites from where the soil was removed, but an improvement in soil quality at the downslope sites where the soil materials were deposited. Floods were probably relatively infrequent and their severity limited as a result of the forested watersheds with optimum soil hydrologic quality.

4.2 300 YEARS BEFORE PRESENT TO 1986

Between 1760 and the early 1800s, European settlers arrived in great numbers. They cleared forests, planted crops, grazed livestock, and built roads. These activities were imposed on the landscape with little understanding of, or little concern for, land capability or soil quality effects. The colonists' reliance on monoculture and livestock grazing led to erosion and soils exhaustion. This meant that after a number of years, colonial farmers abandoned their farms and moved on to fresh, fertile land, necessitating the clearing of yet more forestland (Klyza and Tromulak 1999). By the 1850s, most of Vermont had been cleared for agriculture, and sheep were abundant (Thompson 2002; Vermont Agency of Natural Resources undated).

Deforestation and conversion of land use to grazing was accompanied by loss of soil cover to the erosive energy of rainfall and increased soil compaction. This change in land use that occurred during the colonial period generally results in decreased infiltration of rainfall, increased overland flow and soil erosion (Lull and Reinhart 1972; Dunne and Leopold 1978). Severe floods during the 1920s impacted the economy of Vermont and provided impetus for establishment of the GMNF (Klyza and Trombulak 1999; USFS 1997). Evidence also exists that land use practices associated with logging operations may have contributed to increased occurrence and severity of fires during the late 1800s and early 1900s, especially in high-elevation conifer stands (Richburg and Patterson 2000).

During the 1930s, soil conservation practices began to be applied, forests were becoming re-established, and the long process of restoring soil quality was begun.

4.3 1986 TO THE PRESENT

Presently, natural disturbances are again having relatively minor effects on soil resources. Forest cover has been re-established, and much, but by no means all, of the pre-settlement soil quality and function has been restored. Human disturbances, although far less severe than in the 1800s, do exist in localized areas of the GMNF. Some of the more common current human disturbances are road and trail construction, ski areas, logging, and other silvicultural practices. Adverse impacts of these and other activities are mitigated by careful planning, attention to land capability, soil conservation techniques, and application of Acceptable Management Practices (AMP) (Vermont Agency of Natural Resources 1987).

Acid deposition is an anthropogenic disturbance caused by air pollution. Soil characteristics both influence the effect of, and are influenced by, acid deposition. In general, fine- to medium-textured deep soils with a high nutrient-holding capacity and high base content can buffer acidity from acid deposition to a much larger degree than shallower, sandy or gravelly, more nutrient-poor soils.

Over time, however, it is likely that acid deposition can reduce the buffering capacity of soils. Visible evidence of stressed vegetation (primarily red spruce) at higher elevations in the Green Mountains has been attributed to acid deposition. This condition is thought to be attributable to a high incidence of acid foggy conditions, as well as shallow, nutrient-poor soils at these locations. The effect of acid deposition is a subject of scientific inquiry at this time and is an important component of a forest planning issue.

4.4 REFERENCE CONDITION

As discussed in Sections 4.2 and 4.3, the general condition of the soils of the area that is now the GMNF has changed significantly over the past 300 years. It is useful to cite the condition of the land at the time of arrival of the first European settlers as a reference by which to discuss the changes. Although no actual data are available regarding the condition of the soils during the 1750s, the following may be assumed: (1) soils were for the most part undisturbed, and soil forming processes were proceeding normally; (2) No perceptible difference was identifiable between inherent and dynamic soil quality, so soils were healthy and functioning according to their inherent potential; (3) rainwater and snowmelt were readily absorbed into the soil and released gradually to maintain streamflow and lake and groundwater levels and support plant and animal life; and (4) soils were more fertile than today. Chemically, soils were likely less acidic and contained more base cations.

For purposes of this discussion, the reference condition may be defined as a benchmark, standard, or norm upon which to base discussion of dynamic conditions. The reference condition is not the same as the desired future condition. It would not be realistic to expect that soils could be returned to pre-settlement conditions in the foreseeable future.

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5.0 SOIL RESOURCE INFORMATION

Geographic soil information for the GMNF is available in terrestrial ecological unit inventories (TEUI) conducted by the USFS, and in general soil maps and soil surveys produced under the leadership of the USDA, Natural Resources Conservation Service (NRCS).

5.1 TERRESTRIAL ECOLOGICAL UNIT INVENTORIES

TEUIs consist of maps of Terrestrial Ecological Units (TEU), together with associated descriptive and interpretive data and information. TEUs are units of land that share features of climate, geology, topography, soils, and natural communities. They integrate knowledge of ecological processes and provide predictions of ecological potential. TEUs are defined and mapped at different scales in conformance with the National Hierarchical Framework of Ecological Units (NHFEU) (USFS 1993; Cleland and others 1997). The terrestrial scales of the NHFEU are illustrated in Table 1.

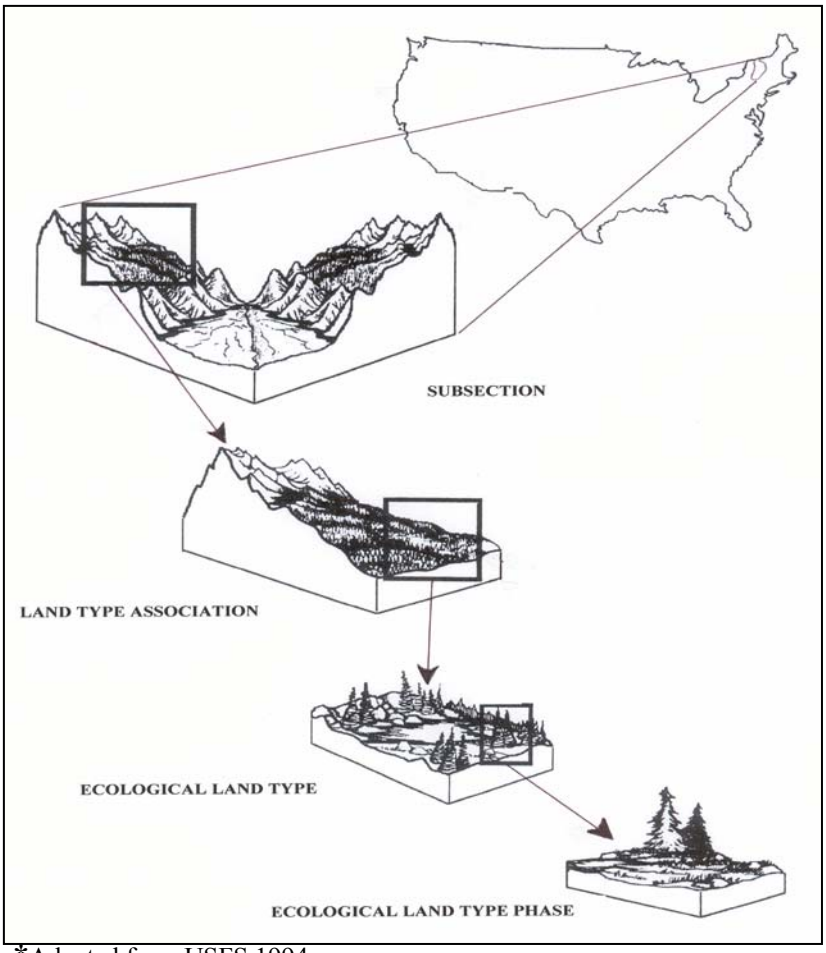
TABLE 1
NATIONAL HIERARCHICAL FRAMEWORK OF TERRESTRIAL ECOLOGICAL UNITS*

Scale or Hierarchical Level	Primary Differentiating Criteria	Purpose, Objectives, General Use	General Size Range
Ecoregion Domain Division Province	Regional climate, geology, and landform patterns	Strategic Planning and Assessment at National and International scales; Context for lower hierarchical levels	1,000,000s to 10,000s of square miles
Subregion Section Subsection	Subregional climate, geology, landform patterns, and natural community formations	Strategic state-wide, multi-agency analysis and assessment; Context for lower hierarchical levels	1,000s to 100s of square miles
Land Type Association (LTA)	Area geology, landform, and climate; soil associations and natural community patterns	Forest or area-wide assessment and planning, watershed assessment; Context for lower hierarchical levels	1,000s to 100s of acres
Ecological Land Type (ELT)	Semi-local geology, landform, and climate; soils and natural communities	Management Area planning, analysis, and monitoring; Context for ELTPs	100s of acres
Ecological Land Type Phase (ELTP)	Local landform, soils, and geology; micro-climate, and natural communities	Project planning, analysis, and monitoring	100s to less than 10 acres

*Adapted from USFS 1993.

The scales most significant to management of the GMNF are Subsection, Land Type Association (LTA), Ecological Land Type (ELT), and Ecological Land Type Phase (ELTP). These scales are illustrated schematically in Figure 1.

FIGURE 1
TERRESTRIAL ECOLOGICAL UNIT
HIERARCHICAL SCALE RELATIONSHIPS*



*Adapted from USFS 1994

5.1.1 Subsections

Subsections are subdivisions of sections, which in turn are subdivisions of ecoregions. The GMNF occupies parts of three subsections, which are parts of the Green, Taconic, and Berkshire Mountains Section, which is in turn a subdivision of the Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow ecological province (USFS 1994). The subsections that lie partially within the GMNF

are the Northern Green Mountains, Southern Green Mountains, and Taconic Mountains (USFS 1995). In the GMNF, the subsections are, with minor exceptions, synonymous with the Biophysical Regions of Vermont (Thompson and Sorenson 2000). The primary exception is that the Vermont Valley Biophysical Region is included in the Taconic Mountains Subsection. Subsections are useful for providing a brief ecological overview of the entire GMNF and a framework from which to subdivide the forest into smaller ecological units. They also help forest resource managers to address broad-scale biodiversity issues. Subsection map polygons are generally hundreds to thousands of square miles in size.

5.1.2 Land Type Associations

LTAs for the GMNF are described in a report, "Draft Preliminary Landtype Associations-Biophysical Features Green Mountain National Forest" (USFS 1999). LTAs, ideally, are both subdivisions of subsections and aggregations of ELTs. Because LTAs and ELTs were developed independently on the GMNF, however, they are not hierarchically integrated at this time. This lack of integration is part of the management concern discussed in Section 8.4. LTA classification is based on an integration of factors of geology, geomorphology, potential natural community, climate, and soils. The most important factors at the LTA scale are geology and geomorphology. Geology includes bedrock type and composition, and surficial deposits. Geomorphology (or landform) includes the overall shape of the land and position on the landscape. Climate, within the broader climatic scales defined in subsections and higher categories, is strongly influenced by landform. Geology, geomorphology, and climate exert strong influences over the kinds of soils and potential natural communities that exist in an LTA.

LTAs provide a framework for evaluating ecological potentials and biodiversity on a forest-wide basis at a finer scale than subsections. The scale is generally appropriate for forest-wide resource management planning. LTA map polygons generally range from hundreds to thousands of acres in size. Figures 2 and 3, respectively, display maps of the LTAs of the northern and southern sections of the GMNF. Table 2 displays a legend of the LTAs mapped in the GMNF.

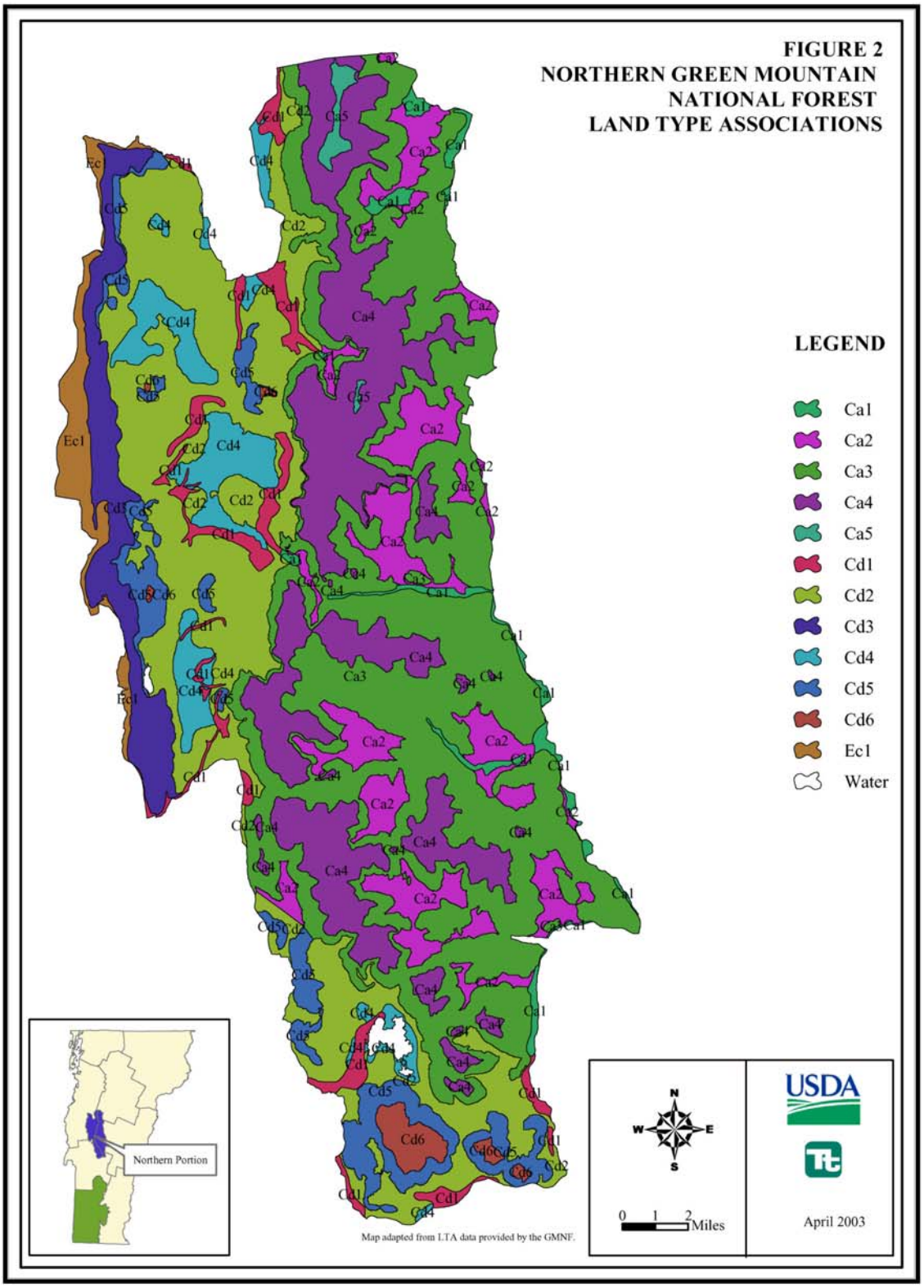


FIGURE 2
NORTHERN GREEN MOUNTAIN
NATIONAL FOREST
LAND TYPE ASSOCIATIONS
LEGEND
Ca1
Ca2
Ca3
Ca4
Ca5
Cd1
Cd2
Cd3
Cd4
Cd5
Cd6
Ec1
Water
Northern Portion
Map adapted from LTA data provided by the GMNF.
N
W
E
S
0 1 2 Miles
USDA
April 2003

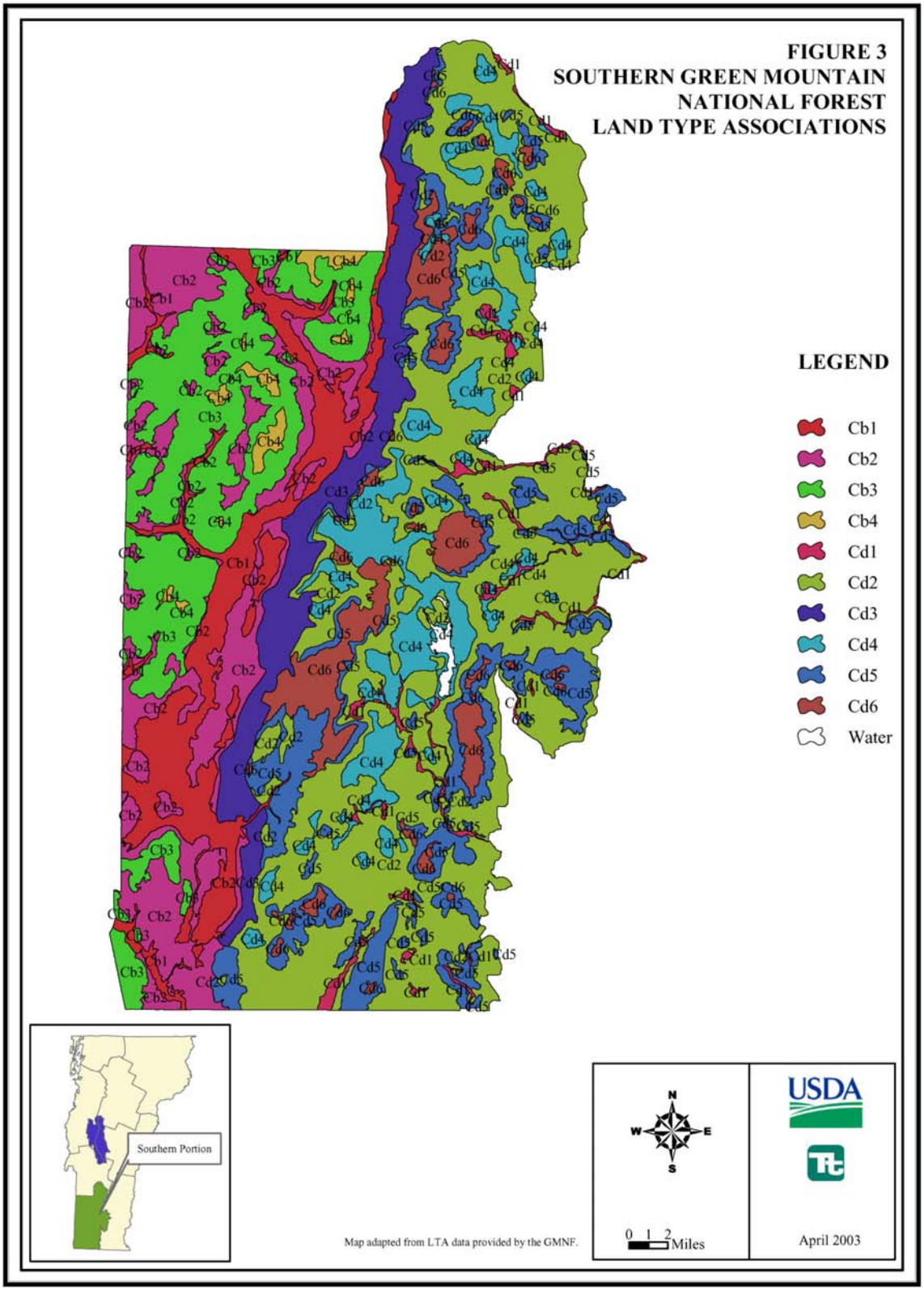


FIGURE 3
SOUTHERN GREEN MOUNTAIN
NATIONAL FOREST
LAND TYPE ASSOCIATIONS
LEGEND
Cb1
Cb2
Cb3
Cb4
Cd1
Cd2
Cd3
Cd4
Cd5
Cd6
Water
Southern Portion
Map adapted from LTA data provided by the GMNF.
N
W
E
S
0 1 2 Miles
USDA
April 2003

TABLE 2

LAND TYPE ASSOCIATION LEGEND*

Subsection	LTA Identifier	LTA Name
Northern Green Mountain	Ca1	Valley Bottoms/Flood Plain Hardwoods
	Ca2	Small Hills and Footslopes of Mountains/Northern Hardwoods
	Ca3	Mountain Slopes/Northern Hardwoods
	Ca4	Upper Mountain Slopes/Montane Spruce-fir
	Ca5	Alpine/Krummholz-tundra
Southern Green Mountain	Cd1	Valley Bottoms/Floodplain Hardwoods
	Cd2	Low Mountains and Hills/Northern Hardwoods
	Cd3	Vermont Escarpment/Mixed Conifer-transition Hardwoods
	Cd4	Precambrian Plateau/Mixed Conifer-northern Hardwoods
	Cd5	Mountain Slopes/Northern Hardwoods
	Cd6	Upper Mountain Slopes and Mountain Tops/Subalpine Spruce-fir
Taconic Mountain	Cb1	Valley Bottoms/Flood Plain Hardwoods
	Cb2	Small Hills and Footslopes of Mountains/Transition Hardwoods
	Cb3	Mountain Slopes/Northern Hardwoods
	Cb4	Upper Mountain Slopes and Mountain Tops/Subalpine Spruce-fir

Notes:

Adapted from USFS 1999

*The LTA that appears in Figure 2 as EC1 is in the Champlain Valley. It has not been analyzed nor further identified due to very low GMNF acreage (USFS 2003b).

5.1.3 Ecological Land Types

ELTs were mapped in the 1970s and 1980s, and represent the first attempt at TEUIs on the GMNF. The current ELTs, which should be considered preliminary, have been mapped across the entire GMNF except the Taconic Mountains. The Ecological Land Type Report-Manchester Ranger District (USFS 1988) covers the southern part of the GMNF. It contains ELT descriptions and a comprehensive set of management interpretations. The ELT report for the Rochester and Middlebury Ranger Districts (USFS undated [a]) covers the northern part of the GMNF. It is a much shorter report, containing basic ELT descriptions and brief silvicultural interpretations.

ELT classification is based on a combination of factors of geology, geomorphology, potential natural community, soils, and climate. Generally, surface geology and soils play a larger role than at the LTA scale. Bedrock geology, having been defined at the LTA scale, is not as diagnostic at the ELT scale, except where it varies widely within an LTA, or occurs very near the surface. Geomorphology is still extremely important. Geomorphology at the ELT scale may be considered in the context of a mountainside slope, for example, rather than a complex of slopes as at the LTA level. Soil characteristics depend largely on near-surface geology, landscape position, and land use or vegetative history. Climate, having been defined at higher levels, is an important criterion if significant local variations exist. The potential natural community is important at this scale, and depends on a combination of geology, geomorphology, soils, and climate.

Individual ELT map polygons are generally hundreds of acres in size. ELTs provide ecological and land capability information at an appropriate scale for Management Area planning.

The need to update the GMNF ELTs, and hierarchically integrate them with LTAs, is discussed in Sections 8.4 and 8.6.

5.1.4 Ecological Land Type Phases

ELTPs are TEUs mapped at a finer scale than ELTs. ELTPs have been mapped on about 18,000 acres within the GMNF, including the following acreage and areas: about 10,000 acres in the southern Green Mountains (Manchester Ranger District, Hapgood Pond and Greendale areas); about 5,000 acres in the northern Green Mountains (Middlebury Ranger District and Abby Pond area); and about 3,000 acres on recently acquired lands in the Taconic Mountains. The most recent ELTP mapping and current emphasis is in the Taconic Mountains. The ELTP legend for the Taconic Mountains consists largely of the Natural Communities of Vermont as described in Thompson and Sorenson (2000).

ELTPs, like TEUs at the coarser scales, are based on an integration of factors of geology, geomorphology, soils, climate, and potential natural community. Soil characteristics important to forest resource management and potential natural community prediction, become dominant criteria at this scale. Surficial geology and geomorphology are also very important, as they strongly influence soil characterisitics. Geomorphology at this scale is defined primarily in terms of landscape position, land shape, slope gradient, and aspect. Micro-climate is influenced by geomorphology, and exerts a strong influence on

soils and potential natural community. Vegetative composition is a valuable indicator, especially in relatively undisturbed areas.

ELTP map polygons range in size from less than ten to a few hundred acres. This scale of mapping is most useful for site-specific project planning and resource protection. Over the long term, the GMNF expects to have ELTP mapping of all areas where a need for this level of information is identified. Some examples of such areas are listed in Section 9.2.5.

5.2 GENERAL SOIL MAPS AND SOIL SURVEYS

General soil maps are compiled, and soil surveys are conducted, as part of the National Cooperative Soil Survey (NCSS) program under the leadership of the NRCS.

5.2.1 General Soil Maps

General soil maps, also known as soil association maps, have been compiled throughout the United States by the NRCS. These maps and associated data comprise the State Soil Geographic Database (STATSGO). The general soil map for Vermont is currently being updated. A draft copy of the portion of the updated map covering the GMNF, courtesy of the NRCS, is displayed as Figure 4.

5.2.2 Soil Surveys

USDA cooperative soil surveys have been completed across nearly all of the GMNF. They were conducted on a county-by-county basis, and are a part of the NRCS Soil Survey Geographic Data Base (SSURGO). The soil surveys covering the GMNF are summarized in Table 3.

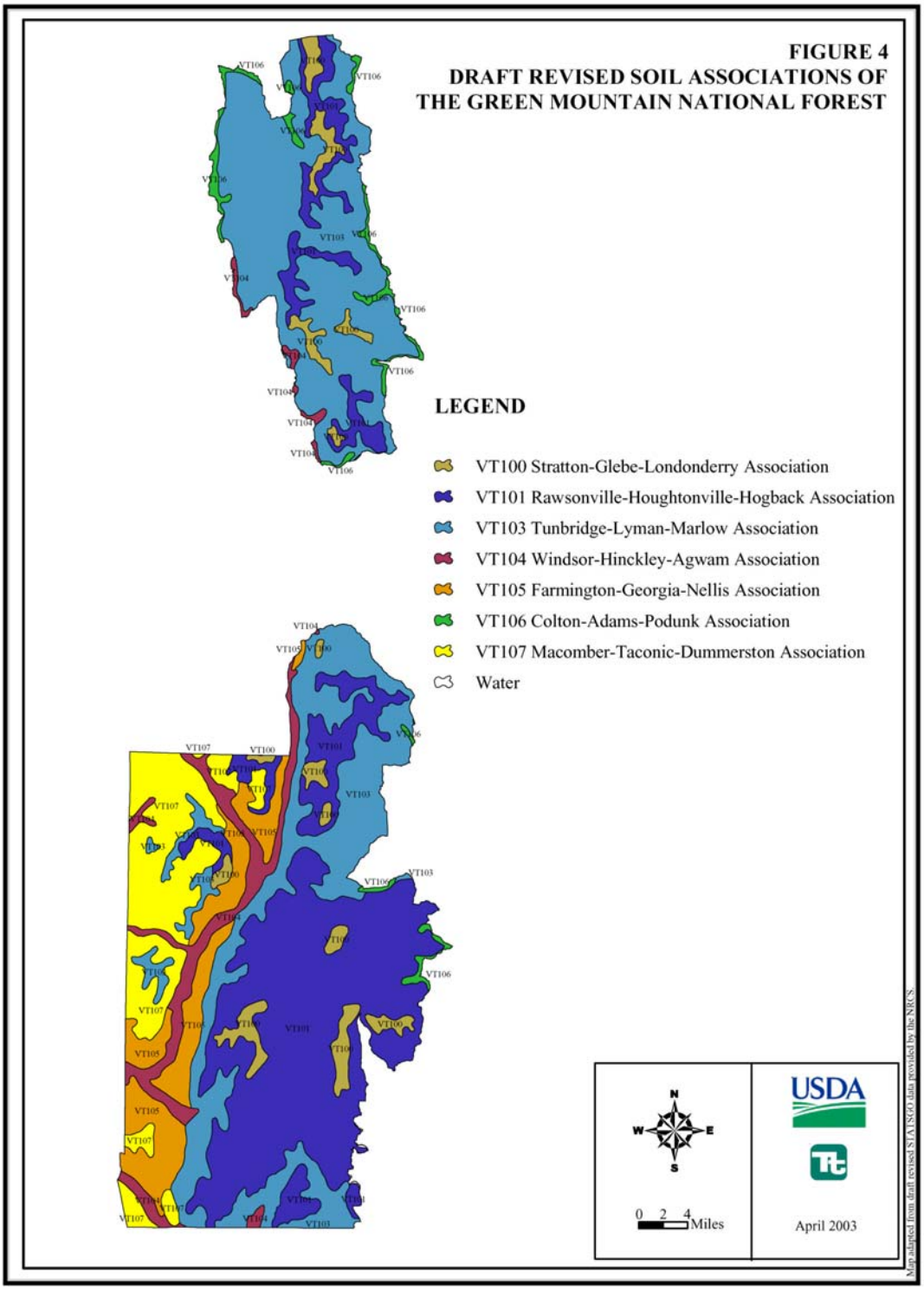


FIGURE 4
DRAFT REVISED SOIL ASSOCIATIONS OF
THE GREEN MOUNTAIN NATIONAL FOREST
LEGEND
VT100 Stratton-Glebe-Londonderry Association
VT101 Rawsonville-Houghtonville-Hogback Association
VT103 Tunbridge-Lyman-Marlow Association
VT104 Windsor-Hinckley-Agwam Association
VT105 Farmington-Georgia-Nellis Association
VT106 Colton-Adams-Podunk Association
VT107 Macomber-Taconic-Dummerston Association
Water
N
W
E
S
0 2 4 Miles
USDA
April 2003
Map adapted from draft revised STATSGO data provided by the NRCS

TABLE 3

COOPERATIVE SOIL SURVEYS OF THE GREEN MOUNTAIN NATIONAL FOREST

Soil Survey Area	GMNF Acres	Date Fieldwork Completed	Publication Date	Map Publication Scale	Status
Addison County	90,614	1960's	1971	1:15,840	Out of date – very limited number of copies available
Windham County	35,352	1982	1987	1:20,000	Current – publication available
Rutland County	79,180	1984	1998	1:20,000	Current – publication available
Bennington County	149,888	1987	Undetermined	1:24,000	Current -- awaiting publication
Washington County	7,289	1990	Undetermined	1:24,000	Current -- awaiting publication
Windsor County	22,512	1998	Undetermined	1:24,000	Current -- awaiting publication
Essex County	1,660	Not completed	Undetermined	1:24,000	Incomplete

Notes:

Sources: USDA undated (b); USDA 2003; USFS 2003a

Copies of published soil surveys and unpublished data are available from the NRCS

5.3 USE OF SOILS INFORMATION IN FOREST PLAN REVISION

As previously noted, the TEUI integrates several ecological factors to divide the landscape into ecologically significant units. With regard to soils, the TEUI emphasis is on integrating those soil attributes that most significantly affect ecological processes. While soil surveys also seek to divide the landscape into units of relatively uniform land capability, they have tended to place less emphasis on integration of multiple ecological factors and more emphasis on soil taxonomic classification. Soil associations and detailed soil surveys compliment the TEUIs by providing more in-depth information about the soil components of the ecological units. LTAs and ELTs provide ecological and land capability information appropriate for stratifying land for the Forest Plan revision. ELTs and ELTPs provide ecological and land capability information at scales appropriate for planning resource management projects to implement the Forest Plan revision. Soil associations and detailed soil surveys can be used as needed to supplement the soil information in the TEUIs. A combination of this information also can be used to identify needs for further information and research.

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6.0 OVERVIEW OF SOILS

The soils over almost all of the GMNF developed in Wisconsin-age glacial till of sandy loam to loam texture. Two principal types of glacial till are ablation till, which is relatively loose and permeable, and basal till, which is compact and dense. Generally, soils formed in ablation till are permeable and well-drained, while soils formed in basal till are less well-drained and tend to have seasonally high water tables. Relatively minor portions of the GMNF, primarily in the valleys and along streams, have soils formed in sandy to gravelly glacial outwash and alluvial materials. Still smaller portions of the GMNF have soils made up of clayey, silty, or organic materials. These minor areas are located in old lake beds, some depressions, and flood plains. This section describes the draft soil associations for GMNF and provides a comparison to those of the larger landscape.

6.1 BRIEF DESCRIPTIONS OF REVISED DRAFT SOIL ASSOCIATIONS

The revised draft soil associations that occur within the GMNF are described in numerical order (USDA 2002). Those associations that comprise major portions of the GMNF are described in greater detail than those that comprise only minor portions.

6.1.1 VT100 - Stratton-Glebe-Londonderry Association

FIGURE 5
STRATTON SOIL SAMPLING SITE

Soils of the Stratton-Glebe-Londonderry association occur on the highest elevations of the Northern and Southern Green Mountain Subsections. A small acreage also occurs in the northern part of the Taconic Mountain Subsection. These soils tend to be cold and wet. They are generally shallow (less than 2 feet) to bedrock. The Stratton and Glebe soils tend to have a subsurface, spodic horizon that is high in organic matter and has a “greasy” or “smeary” consistency. These soils are very susceptible to compaction and not favorably suited to location of roads and other facilities. They support Montane spruce-fir and Alpine/Krummholz-tundra plant communities. These soils are

thought to be the most vulnerable, of any on the GMNF, to effects of acid deposition because of their high elevation where there is high incidence of fog, their low base saturation, and shallow depth to bedrock. In Soil Taxonomy, these soils are classified as Humicryods and Cryorthents. They have a Cryic temperature regime, which means that their mean annual soil temperature is between 32 and 47 degrees Farenheit (USDA 1999). This soil association is associated with LTAs Ca4 and Ca5 in the Northern Green Mountain Subsection and LTA Cd6 in the Southern Green Mountain Subsection. A small amount occurs in the northern part of the Taconic Mountain Subsection. Figure 5 shows a Stratton soil sampling site.

6.1.2 VT101 - Rawsonville-Houghtonville-Hogback Association

Soils of the Rawsonville-Houghtonville-Hogback Association dominate the high plateaus and some of the steep upper slopes of the Southern Green Mountain Subsection. They occur to a smaller extent in the Northern Green Mountain Subsection and in the northern part of the Taconic Mountain Subsection. They occur almost exclusively at elevations above 2,000 feet. These soils have a subsurface spodic horizon that contains a large amount of organic matter and tends to have a slippery or "smeary" consistency. This causes the soils to be slippery when wet and somewhat limits their use for roads, trails, and heavy equipment traffic. Depth to schist or gneiss bedrock tends to range from about 10 inches to more than 60 inches. There are interspersed wetlands, particularly on the plateau in the Southern Green Mountain Subsection. These soils support a mixture of various extents of northern hardwoods and spruce-fir forest communities. Overall forest productivity is not high. These soils are susceptible to damage from erosion and compaction. Motorized use and management activities on these soils require careful attention to AMPs. Location of logging roads, log landings, and any other facilities tends to be particularly critical. In Soil Taxonomy, these soils are classified as Humods, with a Frigid temperature regime. In the Southern Green Mountain Subsection, this association is associated with LTA Cd4, and to a lesser degree, with LTA Cd3. Figure 6 shows a Houghtonville soil sampling site.

FIGURE 6

HOUGHTONVILLE SOIL SAMPLING SITE

6.1.3 VT103 - Tunbridge-Lyman-Marlow Association

Soils of the Tunbridge-Lyman-Marlow Association occur on mountain slopes throughout the Northern Green Mountain and part of the Southern Green Mountain Subsections. Tunbridge and Lyman soils formed in ablation till and are well-drained, while the Marlow soil formed in basal till and is moderately well-drained. These soils have a subsurface spodic horizon that contains less organic matter and lacks the slippery, "smeary" consistency typified by the soils of Soil Associations VT100 and VT101. Depth to schist or gneiss bedrock ranges from about 20 to more than 60 inches. These soils are moderately productive and suitable for northern hardwoods silviculture, but require careful attention to appropriate erosion controls including implementation of AMPs. Seasonal equipment operating restrictions to reduce the compaction hazard are needed on soils with basal till substrate, such as Marlow. In Soil Taxonomy, these soils are classified as Haplorthods with a Frigid temperature regime. This soil association is associated with LTAs Ca2 and Ca3 in the Northern Green Mountain Subsection, and LTA Cd2 in the Southern Green Mountain Subsection. Association with other LTAs is less well defined. A small acreage occurs in the Taconic Mountain Subsection.

6.1.4 VT104 - Windsor-Hinckley-Agawam Association

Soils of the Windsor-Hinckley-Agawam Association occur in the level to nearly level terraces and flood plains of the Vermont Valley. They are dominantly composed of relatively young fluvial, sandy sediments, with some gravel. Most of this soil association is in private ownership and is used for agriculture. In Soil Taxonomy, these soils are classified as Inceptisols, with a Mesic temperature regime. This soil association is most closely associated with LTA Cb1 in the Taconic Mountain Subsection.

6.1.5 VT105 - Farmington-Georgia-Nellis Association

Soils of the Farmington-Georgia-Nellis Association occur on the lower slopes adjacent to the Vermont Valley. They overlie limestone, and have a relatively high base content. In Soil Taxonomy, they are classified as Eutrudepts, with a Mesic soil temperature regime. These soils support mesic dry transitional hardwoods and some softwood communities, primarily hemlock. They tend to be more productive and less erosive than soils on the higher, steeper mountain slopes. This soil association appears to be associated with the lower portion of LTA Cb2 in the Taconic Mountain Subsection.

6.1.6 VT106 - Colton-Adams-Podunk Association

Soils of the Colton-Adams-Podunk Association occur on stream terraces, outwash areas, and flood plains in valleys in the Northern and Southern Green Mountain Subsections. Soil drainage ranges from moderately well to excessively drained. These soils can be expected to support natural forest communities such as Hemlock-Northern Hardwoods and Oak-Pine-Northern Hardwoods. Productivity ranges from low to high. Erosion and compaction hazards are generally less severe than at higher elevations, but are severe in some places. These soils are quite variable. In Soil Taxonomy, they have a variety of classifications, ranging from Fluventic Dystrudepts to Typic Haplorthods. They typically have a Frigid temperature regime. This soil association is most closely associated with LTA Ca1 in the Northern Green Mountain Subsection and LTA Cd1 in the Southern Green Mountain Subsection.

6.1.7 VT107 - Macomber-Taconic-Dummerston Association

Soils of the Macomber-Taconic-Dummerston Association occur extensively in the northern part of the Taconic Mountains Subsection. They are generally well-drained to somewhat excessively drained soils that formed in loamy glacial till. Depth to slate bedrock ranges from about 10 to more than 60 inches. These soils are less sandy and lack the spodic horizons that typify the soils of the Green Mountains. They support relatively productive northern hardwoods communities. They are suitable for northern hardwoods silviculture, but like all soils on mountain slopes, require careful attention to AMPs. In Soil Taxonomy, these soils are classified as Dystrudepts with Frigid temperature regimes. This soil association appears to be associated with LTA Cb3 in the Taconic Mountain Subsection.

6.2 COMPARISON TO SOILS OF THE LARGER LANDSCAPE

In the GMNF and other mountainous areas of New England, the soils are dominantly Spodosols with a Frigid temperature regime at all except at the highest elevations, which have a Cryic temperature regime. Outside the GMNF, at lower elevations in New England and New York, the soils tend to be warmer (Mesic temperature regime); they usually occur on flatter landscapes, and are therefore less erosive than in the GMNF. The entire New England area is dominated by Spodosols, but at lower elevations there tends to be a larger component of other soil orders, primarily Inceptisols. Inceptisols dominate the Northern Glaciated Allegheny Plateau Section in Southern New York, and are common in the lower elevations of the Taconic Mountains and the major valleys (USFS 1994, 1995).

In the Champlain, Hudson, Vermont, and Connecticut valleys, the soils also tend to be more fertile and less erosive than in the GMNF.

Some scientists have observed that GMNF soils appear to support richer plant communities than occur in other parts of Northern New England (USFS 2003e, 2003f). However, documented scientific evidence that soils are actually higher in base nutrients is lacking. Bailey (USFS 2003g) suggests that the soils of the GMNF may be more variable than in other areas of New England, with very high base saturation soils in limited areas, and very base-poor soils in other parts of the GMNF.

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7.0 ACTIONS TOWARD GOALS

The USFS is working in the following areas toward the goals for managing the soil resources on the GMNF:

- Application of S&Gs
- Monitoring effects of resource management activities and acid deposition
- Improving sites where soils are degraded (Soil Resource Improvement)

These three areas are discussed in the following subsections.

7.1 APPLICATION OF STANDARDS AND GUIDELINES

Potential impacts of each planned project are assessed, and Forest Plan S&Gs are applied to minimize or eliminate the impacts. Mitigation measures are recorded in decision memoranda and notices. Common mitigation measures include the following:

- Allow tree harvest and skidding only in winter when soils are frozen or covered with a thick, protective snow cover
- Special erosion control measures such as hay bales or sediment screens to control erosion
- Special seeding and mulching requirements to control erosion
- Avoidance of soil disturbance in wetlands and vernal pools
- Exclusion of very steep (more than 45-50 percent gradient) slopes from timber sale areas

Projects are monitored to ensure that S&Gs are applied properly and that they are effective (USFS 2002b).

7.2 MONITORING

Most monitoring is directed toward resource management projects to ensure application and effectiveness of S&Gs. Of equal importance, however, is GMNF participation in cooperative projects involving long-term monitoring, and development of monitoring tools such as an acid sensitivity map and a till source model.

7.2.1 Project Monitoring

The GMNF monitors resource management projects and activities to ensure that S&Gs are applied and effective. Projects monitored include, but are not limited to, timber sales, use and expansion of downhill ski areas, recreation trails for hiking, snowmobiles, off-road vehicles, and cross-country skiing. While evaluating the application and effectiveness of S&Gs, monitoring identifies any further needs for protection measures and corrective actions, which are implemented as needed. Project monitoring results are documented in GMNF annual monitoring and evaluation reports, and summarized in other GMNF reports, such as the following:

- Soil, Water and Fish Monitoring on Timber Sales on the Green Mountain National Forest 1992-1999 (USFS Undated [b]).
- Implementing the Green Mountain National Forest Land and Resource Management Plan a 15 Year Retrospective (USFS 2002b)

The most important results of project monitoring of the 1986 Forest Plan are the following:

- S&Gs for protection of the soil, water, and riparian area resources on timber sales were implemented and effective in protecting these resources most of the time. More specifically, from 1992-1999, two thirds of the S&Gs were implemented 100 percent of the time, and the remaining one-third were implemented 76-87 percent of the time. Compliance with S&Gs has improved from 1992 to the present. Implemented S&Gs were effective in protecting the soil and water resources, except when localized and heavy rainfall events occurred (10, 25, or 100+ year storms) (USFS undated).
- Illegal ATV use on the forest has resulted in erosion and severe compaction on heavily used trails.
- Some roads and trails in riparian areas, and a limited number of road maintenance practices, cause erosion and sedimentation.
- Erosion on hiking, snowmobile, and cross-country ski trails is limited. Erosion problems are associated with steep or wet areas, streams, or highly erosive soils at high elevations.

Based on project monitoring results compiled over the past decade, the GMNF should consider revising some existing S&Gs, and adding new S&Gs to better protect and improve the soil resources. Recommendations for changes to S&Gs are recorded in the report, "Implementing the Green Mountain National Forest Land and Resource Management Plan – A 15 year Retrospective (USFS 2002b). Some changes recommended in the Retrospective are the following:

- Define the desired condition for stream, pond, and wetlands riparian areas
- Have the S&Gs coincide with the Vermont AMPs for timber harvest
- Incorporate S&Gs for snowmobile trails to provide optimal soil resource protection
- Add S&Gs for dead, dying, and down woody debris, since woody debris is an important contributor to soil structure, nutrient levels, and biological processes

7.2.2 Long-term Monitoring

The GMNF is cooperating with the Vermont Monitoring Cooperative in a Long-Term Soil Productivity Monitoring Study that began in 2001. The study has a 200-year time frame and two study sites are located on the GMNF. The study focuses on long-term impacts of air pollution on forest soil quality, including loss of available nutrients, especially calcium and magnesium dissolution and leaching. The study also includes evaluating changes in carbon and nitrogen pools due to nitrogen saturation and effects of climate change. The overall goal is to detect changes in soils due to human-caused impacts. Initial study results are not yet available.

Additional studies planned in association with the long-term monitoring sites include weathering rates of soils, status of mercury accumulation in soils, calcium transformations over time, rooting depth and density, and carbon flux. NRCS soil scientists are working with the Soil Science Society of America to establish forest soil reference samples. Other cooperators in this study include the Northeast Forest Experiment Station, NRCS, University of Vermont, and Vermont Department of Forests, Parks, and Recreation (Vermont Monitoring Cooperative 2002).

7.2.3 Development of Monitoring Tools

The GMNF is cooperating in the development of an acid sensitivity map, and a till source model.

Acid Sensitivity Map Development: The GMNF is cooperating with the Vermont Monitoring Cooperative, University of Vermont, the USFS-Northeastern Forest Experiment Station (NEFES), and several others, in the forest sensitivity mapping project commissioned by the New England Governors' and Eastern Canadian Premiers' acid rain task group. The objective is to develop maps displaying site sensitivity to acid deposition. The GMNF provided data for this project. Key components include geology, geomorphology, soil attributes, vegetation, and acid deposition history. Three tree harvest

scenarios are also being modeled. The maps will cover all of New England and the southeastern Canadian Provinces, and should be available in fall 2003.

Till Source Model: The till source model is being developed in Vermont as a component of the acid sensitivity mapping project. The till source model is a computerized method devised to estimate glacier travel direction, estimate the kinds and amounts of minerals transported to a selected location, and translate the information into a map useful for inferring acid sensitivity (Bailey 2000). It is an extension of a similar effort on the White Mountain National Forest in New Hampshire. The GMNF is cooperating in development of the till source model in Vermont.

7.3 SOIL RESOURCE IMPROVEMENT

The GMNF, with help from partners, implements 10 to 12 projects per year to control erosion and improve soil quality on degraded areas. Common projects include the following:

- Revegetation of landslides along streams, generally less than 1 acre in size. These slides are eroding and contributing sediment to streams, and are not the result of GMNF management activities
- Installation of water bars, culverts, and ditches to control erosion on roads and trails
- Erosion control and revegetation of gravel pits
- Closure and revegetation of overused, compacted, erosion-prone dispersed campsites
- Removal of old, collapsing bridges and culverts to prevent potential stream channel blockages and associated erosion

Most improvement projects are effective in correcting the source of the erosion, compaction, or soil instability. Roads, trails, and riparian areas are probably the largest forest-wide source of erosion and sediment delivery to streams. Funding for projects to correct erosion and sedimentation problems on GMNF roads and trails has increased by 100-200 percent since the mid-1990s.

Two soil resource improvement projects are illustrated in Figures 7 and 8.

FIGURE 7

REVEGETATION OF A CLOSED ROAD

FIGURE 8

REVEGETATION OF A LANDSLIDE AREA

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8.0 KEY ISSUES AND CONCERNS

The Forest Plan revision is an opportunity to provide new guidance to address issues and concerns. This section describes the following issues and concerns for soil resource management.

- Maintaining long-term soil productivity
  - Physical impacts to soil productivity
  - Chemical impacts to soil productivity
    - Role of acid deposition
    - Role of timber harvesting
- Update Forest Plan direction for protection and enhancement of soils
- Identify and improve areas where soil quality is impaired
- Further develop and improve the Terrestrial Ecological Classification and Inventory system
  - Update ELTs so they they link properly with LTAs, and more reliably predict vegetation
  - Identify, prioritize, and fulfill ELTP mapping needs
- Emerging issues related to soils
  - Role of terrestrial large woody debris
  - Role of carbon sequestration
  - Importance of soil floral and faunal communities
  - Need to protect uncommon landform/geologic/soil types
  - Need to preserve representative examples of ecological types

8.1 MAINTAINING LONG-TERM SOIL PRODUCTIVITY

The USFS and the public are concerned about maintaining long-term soil productivity of NFS lands. Soil productivity is defined as the inherent capacity of a soil to support the growth of specified plants, plant communities, or a sequence of plant communities (USFS 1991). Different soils vary in their inherent productivity. An objective of management is to maintain soil productivity at or near the inherent level for each particular kind of soil. Soil productivity is closely linked to soil quality. Maintaining soil quality will maintain soil productivity.

Soil impacts that can affect productivity include physical impacts such as erosion and compaction, and chemical impacts such as nutrient depletion and acidification. Erosion removes surface layers that contain the largest amount of organic matter, microorganisms, and available plant nutrients, and have the greatest capacity for absorbing water from rainfall and snowmelt. Compaction reduces the soil's pore space, which in turn reduces capacity to absorb and store water. Reduced pore space may also affect soil aeration, which is important for soil microorganisms and plant growth. Compaction can also make it physically more difficult for plant roots to grow.

8.1.1 Physical Impacts that Affect Soil Productivity

Soils are potentially exposed to erosion when the vegetative cover is removed and the surface organic layer is disturbed. Soil can be compacted by vehicular traffic or by repeated, concentrated foot traffic by animals or humans. Compaction impacts are often aggravated by high moisture conditions. Forest use and management activities that have potential to expose soils to erosion and compaction include timber sales, ski area operations and expansion, and recreation trails. The major areas of concern with regard to timber sales are log landings, skid trails, and haul roads. S&Gs require all of these facilities to be properly located, protected from erosion, and rehabilitated when the sale is closed. Ski area operators are required to follow Ski Trail Maintenance, Development, and Rehabilitation Guidelines for each major ski area (USFS 1986). S&Gs also require protection of soils along recreation trails.

The potential physical impacts were addressed by the soil and water S&Gs in the 1986 Forest Plan. Monitoring of management activities implementing the Forest Plan indicated that, with few exceptions, S&Gs for protection of soil and water resources were implemented consistently and were effective – however, they should be updated to reflect current science and management direction (USFS 2002a). Development and application of new SQSs and continued monitoring of the S&Gs in the revised Forest Plan will ensure that forest management activities will not result in physical impacts that reduce soil quality and productivity.

8.1.2 Chemical Impacts to Soil Productivity – Nutrient Depletion

The status of soil nutrients in the forest landscape of New England is a central issue. Acid deposition, forest harvest, land use history, and soil characteristics all affect the outcome. It is a complex cumulative effects problem (USFS 2001b). Since the early 1970s, researchers have tried to quantify nutrient removals from eastern North American forest soils and assess their effects (Federer and others 1989).

According to research, there is increasing concern that exchangeable base cation reserves in forest soils are being depleted over large parts of eastern North America due to a combination of acid deposition and tree harvesting (Watmough and Dillon 2002). The base cations most likely to be removed include calcium, magnesium and potassium (Driscoll and others 2001; Federer and others 1989). Most studies indicate that calcium is of greatest concern because of its importance to tree growth, its capacity to buffer effects of acid precipitation, and its important role as a component of surface waters (DeHays and others 1999; Federer and others 1989; USFS 2001b). Some leaching is induced by soil disturbances caused by intensive timber harvesting operations, but the total amount is thought to be minor compared to the amount lost through dissolution and leaching induced by acid deposition. The chemical impacts of acid deposition and timber harvesting are further discussed below.

Acid Deposition: It is well documented that anthropogenic changes in precipitation chemistry, including acidity, have occurred over the past several decades in North America (DeHays and others 1999). Acid deposition is complex, but the main constituents of concern are acidic sulfates and nitrates, with smaller amounts of heavy metals such as mercury and lead. Nitrates and sulfates are essential plant nutrients; however, in excessive amounts they disrupt the nutrient balance and can increase soil acidity. Despite a downward trend in sulfate concentrations due to reductions in sulfur dioxide emissions since the 1980s, there has been no appreciable decrease in the acidity of precipitation, especially in the northeastern U.S., where cloud water pH as low as 2.1 was recorded (DeHays and others 1999). The pH of precipitation at Hubbard Brook Experimental Forest in the White Mountains of New Hampshire rose steadily from about 4.1 in the early 1960s to about 4.3 to 4.4 in the mid-1990s (USFS 2003c). Nitrate emissions have remained fairly constant (Lovett and others 2000; Watmough and Dillon 2002), but are expected to increase throughout much of the eastern United States during the next two decades (Galloway and others 1995).

Potential consequences of acid deposition include accelerated leaching of base cations and subsequent acidification of soils (Johnson and others 1985). Studies over the past 30 years indicate that acid deposition disrupts the calcium cycle in forests (DeHays and others 1999), and contributes to a decrease in base-cation concentrations in forest soils (Lawrence 2000). Current rates of cation depletion in the northeastern U.S. are probably the result of acid deposition. Watershed analyses throughout the Appalachians suggest that calcium is the nutrient most likely to be depleted by acid deposition-induced leaching and intensive harvesting removals (Federer and others 1989). Calcium is essential to plant growth and is an excellent cation to buffer acidity.

Some studies indicate that acid deposition has contributed to the documented decline of montane red spruce in the northeastern U.S. over the past 40 years (DeHays and others 1999). However, other studies have reached different conclusions. In an analysis of 60 years of management and natural disturbances at the Bartlett Experimental Forest in the White Mountains of New Hampshire, it is reported that red spruce declines at the highest elevations, and increases in the next highest, apparently reflecting a pattern of wind damage rather than acid deposition-induced spruce decline (Fay 1995; Smith and Leak 1994). Other studies in New Hampshire (Huntington and others 1990), and the Adirondacks of New York (Johnson and others 1994) support the conclusion that high elevation spruce decline was not definitively tied to acid deposition. Still other studies suggest that high-elevation spruce decline may be caused by direct contact with acid precipitation, rather than through the soil.

Linking forest vegetation responses to soil chemical changes resulting from acid deposition has proven difficult. A 1998 study in the White Mountains of New Hampshire concluded that "forest growth in terms of aboveground tree biomass has not diminished significantly as a result of recent environmental effects." The same study cautioned that this statement did not necessarily mean that forest health was not impacted (Nuengsigkapian 1988). Fay (1995), citing 27 different research studies in the Northeast, concluded there was no firm evidence of growth decline from changes in soil nutrients.

Recent research on the Allegheny Plateau points toward deficiency of magnesium and possibly calcium as a factor in sugar maple decline (USFS 2000). Another recent theory suggests that calcium may occur in forest ecosystems in larger quantities than commonly thought. This theory suggests that as trees grow they accumulate calcium in amounts greater than they can use, and store it as calcium oxalate, a crystal-like or mineral-like entity that is nearly insoluble, and therefore undetectable with normal extraction methods. In the presence of increased acidity, caused either by harvesting trees or acid deposition, calcium oxalate becomes soluble and available to plants (USFS 2002a). A suggested priority research need is to better define the pools of calcium oxalate in the soil environment.

In summary, conclusive evidence that soil productivity has thus far been affected by acid deposition is lacking. However, this does not mean there is no reason for concern. There is potential to reduce soil quality and soil productivity on sensitive sites from soil nutrient cation removal induced by acid deposition. Sensitive sites are generally soils with an inherently low buffering capacity. These sites generally are associated with coarse (sand) textures, low inherent base content, low organic matter, and shallow depth to bedrock. Deeper, finer-textured soils tend to have more capacity to store the base

cations that buffer acidity. Also, soils developed from basic parent materials have inherently more buffering capacity than soils developed from acidic parent materials.

There are also secondary effects of soil acidification from acid deposition. Soil water will become more acidic when calcium is depleted. Increased soil acidity causes organic aluminum in the soil to be changed to an inorganic form that can interfere with root function and has toxic effects on aquatic life. Several studies have shown a depletion of calcium and significant increases in levels of toxic inorganic aluminum in New England surface waters (Lawrence 2000).

Another secondary effect is an increase in plant susceptibility to freezing injury and a range of other stresses from the depletion of calcium from plant cell membranes. However, this effect may be due more to the plants direct contact with acid deposition than depletion of calcium from the soil (DeHays and others 1999).

Harvesting: Many studies have indicated that large amounts of calcium are stored in wood, and therefore removed from the forest ecosystem when trees are harvested. Most studies of harvesting impacts have focused on intensive harvesting practices such as whole tree harvesting, which comprises a very small portion of the total harvesting on the GMNF. During the period 1987 to 2002, commercial timber harvesting occurred on a total of 762 acres annually, or about 0.2 percent of the total GMNF land. The 762 acres of annual harvest included 143 acres clear-cut, 249 acres shelterwood cut, and 370 acres selection cut (USFS 2003d). Nutrient losses from GMNF soils due to timber harvesting can reasonably be expected to be small due to the following:

- Low-intensity harvest operations, including very little whole tree harvesting, limited clear-cutting, and relatively large quantities of wood left in the forest
- Small, selective acreage of land impacted
- Soil losses are minimized through the application of S&Gs, and in most cases, winter logging

The Forest Service will carefully consider the adoption of additional S&Gs to further ensure that any nutrient loss from harvesting is minimized. A possible example is a requirement to leave specified quantities of large woody debris.

8.2 UPDATE FOREST PLAN DIRECTION FOR PROTECTION AND ENHANCEMENT OF SOILS

There is a management concern that current soil quality S&Gs do not fully reflect the latest management direction and scientific knowledge. For example, the current S&Gs do not include current USFS direction for maintaining long-term soil productivity, nor current guidelines for erosion and sediment control on new snowmobile trails (USFS 2002b). To resolve this management concern, emphasis on the following items is suggested:

- Update S&Gs for the Forest Plan Revision to reflect recommendations from the 15-year retrospective, and the most current scientific knowledge in the area of forest soil management
- Develop SQSs as described in Section 8.6, and incorporate them into the updated S&Gs
- Apply current and future research and monitoring results relating to soil quality and productivity

8.3 IDENTIFY AND IMPROVE AREAS WHERE SOIL QUALITY IS IMPAIRED

Current progress in this area is discussed in Section 7.3. Approximately one-third of the GMNF has been inventoried for soil improvement needs. The remainder of the GMNF needs to be comprehensively inventoried, although the most severe problems are known. Annual priorities are set based on severity of all known erosion/sedimentation problems and available funding. Most projects are accomplished with help from partners. Currently, 10 to 12 projects to control erosion and improve soil quality are accomplished annually on the GMNF. This rate is all that current funding permits, and is not sufficient to address all soil improvement needs within the next 10 to 15 years. There is a management concern that the inventory should be completed and kept updated so that improvement projects can be effectively directed toward the highest priority areas. Keeping the inventory updated is particularly important with regard to newly acquired lands. It is suggested that inventory of the remaining lands be accelerated, and improvement needs prioritized so that those areas with the greatest need can be addressed as early as possible.

8.4 FURTHER DEVELOP AND IMPROVE THE TERRESTRIAL ECOLOGICAL CLASSIFICATION AND INVENTORY SYSTEM

The TEUI system needs to be updated to link LTAs to ELTs, and to improve vegetative predictability. ELTP development and mapping is needed for project and intensive use areas.

8.4.1 Update ELTs, and Link to LTAs

The GMNF ELTs were developed during the 1970s and 1980s by integrating factors of soils, geology, landforms, and vegetation in a rather subjective manner. LTAs were provisionally developed in a more analytical fashion during the 1990s. Since the LTAs and ELTs were developed independently, by different people, and at different times they do not fit well together. Observations by forest ecologists, as well as at least one research study, indicate that the ELTs as currently developed fail to adequately integrate some factors, such as differences in soil fertility, mineralogy, acidity, microtopography, and past disturbances, which would explain or indicate variations in vegetative potential (USFS 2003e; Bove 1997). The ELTs serve an essential function of dividing the land into areas of relatively uniform land capability for prescribing management practices, including S&Gs. However, updating could significantly improve their predictive value and function.

Updating the ELTs would be a long-term process, and would involve specialists and researchers from multiple natural resources disciplines. It is suggested that direction for updating the ELTs, and insuring their hierarchical integration with the ELTPs below, and LTAs above, be included in the Forest Plan revision.

8.4.2 Identify, Prioritize, and Fulfill ELTP Mapping Needs

ELTPs provide a level of ecological and land capability information normally appropriate for project-level planning and intensive use areas. The inherent spatial variability of the soils of the GMNF tends to emphasize the importance of using site-specific data to evaluate project level questions (USFS 2003g).

Some examples of areas where ELTP mapping might be needed include the following:

- Timber harvest areas
- Intensive recreational use areas
- Research and baseline monitoring areas

- Study areas to evaluate acid deposition sensitivity and effects

- Assess and evaluate some wildlife management goals

It is suggested that the Forest Plan revision include direction for identifying and prioritizing ELTP needs, and for developing and mapping ELTPs where needed.

8.5 EMERGING ISSUES

Several emerging issues may soon become important to the GMNF, and should be addressed in the Forest Plan revision. These include:

- Terrestrial large woody debris
- Carbon sequestration
- Soil floral and faunal communities
- Protection of uncommon landform/geologic/soil types
- Protection of example sites of representative ecological types from anthropogenic disturbances

8.5.1 Terrestrial Large Woody Debris

Large woody debris, or downed dead wood, is important for its role in carbon and nutrient cycling, carbon sequestration, plant reproduction, wildlife habitat, and wildfire behavior (USFS 2001a). It may also be significant because of the relatively large amounts of calcium stored in wood. The following sequence of actions is suggested:

- Conduct a literature review to assemble data and information on desired amounts, types, sites, and occurance of large woody debris

- Establish goals and objectives for large woody debris
- Consider adopting S&Gs for large woody debris to be left in timber sales. S&Gs should include guidance on what kinds, amounts, and size ranges of large woody debris should be left on what sites

8.5.2 Carbon Sequestration

The United States 1993 Climate Change Action Plan called upon the forestry sector to sequester an additional 10 million metric tons of carbon per year by 2000 (Heath and Joyce 1997). Carbon sequestration is important because of the role of carbon in the formation of carbon dioxide (CO_2) and other greenhouse gases. Forestlands can store large amounts of carbon for long periods of time (Heath, Smith, and Birdsey 2002). The soil in U.S. forests contains about 60 percent of the total forest ecosystem carbon (Heath and others 2002). Forests have the potential to increase carbon in soils for a long time, and may be the best available option for storing carbon in terrestrial ecosystems (Heath, Smith, and Birdsey 2002). The GMNF may need to consider adopting guidelines for optimizing carbon sequestration in forest soils.

8.5.3 Soil Floral and Faunal Communities

Soil is by far the most biologically diverse part of any terrestrial ecosystem. The soil is home to thousands of types of microorganisms, and to many larger species, such as worms, ants, burrowing rodents, and plants. The exceedingly diverse soil biota is extremely important to nutrient cycling and other ecosystem functions. The importance of managing soil floral and faunal communities may become an important issue.

8.5.4 Protection of Uncommon Landform/Geologic/Soil Types

It may be important to preserve examples of uncommon types of landforms, geologic types, and/or soil types that exist in the GMNF for scientific, research, or monitoring purposes; examples might include eskers or kame terraces and their associated soils. The need to evaluate this may become an issue or a management concern.

8.5.5 Protection of Example Sites of Representative Ecological Types from Anthropogenic Disturbances

It may be useful to exclude management activities from selected sites with important representative ecological types, such as ELTPs, in order to allow soil and other ecological processes to proceed unhindered. This could also provide a basis for monitoring changes attributable to management activities.

8.6 FUTURE MONITORING AND RESEARCH NEEDS

The GMNF conducts monitoring, but does not conduct research. The GMNF does cooperate with other organizations, such as the NEFES, universities, and the Vermont Monitoring Cooperative, in some monitoring efforts, and in research to support GMNF monitoring efforts.

Future monitoring and research efforts, as suggested in the following sections would help ensure maintenance of long-term soil productivity, and address the other issues and concerns discussed earlier in Section 8.0.

8.6.1 Develop SQSs

FSH 2509.18 Chapter 2 - Region 9 Interim Directive R9 RO 2509.18-2002-1 (USFS 2002c) provides Regional SQSs and suggests that National Forests develop more specific SQSs based on local ecological unit characteristics. SQSs provide benchmark numerical values to monitor in order to detect change. It is suggested that SQSs be developed for (1) LTAs to apply at the Forest Plan level; (2) ELTs to apply at the Management Area level; and (3) ELTPs to apply at the Project level. The SQSs should become a part of the Forest Plan S&Gs. SQSs are identified in Section 10.0 as a critical information need.

8.6.2 Develop An Ecological Monitoring Strategy that Incorporates the S&Gs, Including the SQSs

An ecological monitoring strategy is a framework to guide and coordinate monitoring across all resource areas. Its basic purpose is to ensure that monitoring needs are identified and met. It should include all levels of monitoring from simple systematic observation of projects to ensure application and effectiveness of S&Gs, to complex long-term monitoring projects involving research. The ecological monitoring strategy should include procedures to monitor indicators of forest health, evaluate the S&Gs on a continuing basis, identify research needs, monitor the effectiveness of soil improvement projects, and immediately correct operational problems that are found to cause soil degradation. An ecological monitoring strategy is identified in Section 10.0 as a critical information need.

8.6.3 Continue Involvement in the Cooperative Long-term Soil Monitoring Study

The cooperative long-term soil monitoring study is expected to continue to provide valuable data that can be used to establish and periodically update the SQSs and monitoring strategy. The GMNF should continue its involvement in this effort.

8.6.4 Update the ELTs so That They More Accurately Reflect Vegetative Potential, and Nest Within the LTAs

This is also recognized as a management issue and concern, and is discussed in Section 8.4.1. The GMNF capability with regard to this issue is discussed in Section 9.2.

8.6.5 Improve Identification of Acid Deposition-Sensitive Areas and Sites

The regional acid sensitivity map and the till source model, both described in Section 7.2, are significant ongoing coordinated efforts toward resolution of this need. It is suggested that the GMNF maintain involvement in this effort.

8.6.6 Identify Better Ways to Define and Measure Soil Productivity

This is a research challenge that includes finding more accurate ways of measuring soil nutrient content and assessing soil nutrient implications to productivity. This research need includes identifying key threshold values of major nutrients, and learning more about the occurrence and significance of calcium oxalate in the soil environment. This research would attempt to determine what changes in soil chemical properties actually affect soil productivity. A component of this research might be to further identify and quantify soil parameters that affect site sensitivity to acid deposition.

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9.0 CONCLUSIONS

This section presents conclusions regarding the overall existing soil condition, and the GMNF's capability to address key issues and concerns.

9.1 OVERALL EXISTING SOIL CONDITION

The general health of the soils of the GMNF today is good; the only exceptions are occasional small areas where erosion, compaction, or other types of soil degradation are judged to be excessive. Unhealthy areas can be caused by natural or anthropogenic disturbances. They commonly consist of landslides, eroding stream banks, old gravel pits or borrow areas, minor skid trails used for tree harvest, dispersed campsites, and areas frequently used by all-terrain vehicles (illegally). These areas are progressively being located, inventoried, and restored to the extent possible. Lands dedicated to specific long-term uses such as developed campsites, roads, trails, parking lots, buildings, and log landings are not included in areas categorized as unhealthy.

The general health and condition of soils surrounding the GMNF varies because land uses are more variable and generally more intensive than found on the GMNF, and there are multiple landowners with many different management scenarios. In general, the land surrounding the GMNF is used for forestry, agriculture, downhill ski areas and other forms of outdoor recreation, and housing developments. On a portion of the forestland, where use and management is not intensive, soil quality is comparable to that on the GMNF. Overall, however, soil health cannot be expected to be as high on the lands surrounding the GMNF because of the reasons stated above.

9.2 CAPABILITY TO ADDRESS KEY ISSUES AND CONCERNS

The USFS's capability to address the key issues and concerns described in Section 8.0 is assessed in the following sections. The rate at which these goals and recommendations are achieved will be highly dependent on future funding levels.

9.2.1 Maintaining Long-Term Soil Productivity

Maintaining long-term soil productivity is the dominant issue, and is discussed in Section 8.1. The GMNF's capability to address this issue is dependent on its capability to address the other related issues, and some of the monitoring and research needs.

9.2.2 Update Forest Plan Direction for Protection and Enhancement of Soils

This management concern is discussed in Section 8.2. It includes developing SQSs, updating the S&Gs, incorporating the SQSs into the updated S&Gs, and applying current and future research and monitoring results relating to soil quality and productivity.

Develop SQSs: This issue is also discussed in Section 8.6.1 as a future monitoring and research need. The Regional SQSs (USFS 2002c) provides an umbrella under which Forest SQSs can be developed. It is suggested that GMNF staff develop LTA-specific SQSs for the Forest Plan revision. This development can lead to ELT-specific, and finally ELTP-specific, SQSs to be applied to projects. Initially, the SQSs should be based on what is currently known about the capabilities of the soils and ecological units that occur on the GMNF. The GMNF is capable of developing initial SQSs for the Forest Plan revision, and periodically updating them as knowledge is gained through monitoring, evaluation, and research.

Update S&Gs: The GMNF has already identified needs and opportunities to update S&Gs for soil enhancement and protection, as discussed in the 15-year Retrospective (USFS 2002b). The GMNF is capable of updating the S&Gs, and incorporating SQSs.

Applying current and future monitoring results: The GMNF can incorporate current research and monitoring results, as well as direction to incorporate future results, into the Forest Plan revision.

9.2.3 Identify and Improve Areas Where Soil Quality has been Impaired

This management concern is discussed in Section 8.3. Currently, with available funding and help from partners, the GMNF accomplishes 10 to 12 improvement projects annually. This rate is not sufficient to improve all areas within 10 to 15 years. The GMNF should be capable of completing a soil improvement needs inventory within 5 years, and then keeping it updated. A completed inventory and prioritized documentation of needs may provide a basis to increase funding and capability to accomplish the needed improvements within a shorter time period.

9.2.4 Further Develop and Improve the Terrestrial Ecological Classification and Inventory System

There are 2 parts to this issue. One part is the need to update and link ELTs to LTAs. The other is to identify, prioritize, and fulfill ELTP mapping needs.

Update and link ELTs to LTAs: This issue is discussed in Section 8.4.1. It is also recognized in Section 8.6.4 as a future monitoring and research need. The GMNF has ecological, soils, and other resource expertise, and has access to research partners, that can initiate this effort. It is a long-term, iterative process. The GMNF is capable of beginning this task, and setting a course for its accomplishment.

Identify, prioritize, and fulfill ELTP mapping needs: This issue is discussed in Section 8.4.2. The GMNF's long-term goal is to have ELTP mapping completed in all areas where the need is identified. Some examples of ELTP mapping needs are presented in Section 8.4.2. At the current level of funding, the GMNF is capable of meeting about 10 percent of this goal over the next 10 to 15 years.

9.2.5 Emerging issues

The GMNF is capable of addressing the five emerging issues discussed in Section 8.5.

9.2.6 Develop and Implement an Ecological Monitoring Strategy that Incorporates the S&Gs, Including the SQSs

This is a future monitoring and research need discussed in Section 8.6.2. An ecological monitoring strategy should include all levels of monitoring from simple systematic observation of projects to ensure application and effectiveness of S&Gs, to complex long-term monitoring projects involving research. Many of the pieces are already in place. GMNF staff can build on existing monitoring efforts to develop a more comprehensive ecological monitoring strategy. The existing cooperative long-term soil productivity study is an important component. Monitoring presents many opportunities for partnerships. A comprehensive ecological monitoring strategy should be dynamic and subject to periodic updating. A monitoring objective should be to validate and refine SQSs. Another monitoring objective might be to

validate and refine the acid sensitivity map. It is within the capability of the GMNF to develop an ecological monitoring strategy.

10.0 CRITICAL INFORMATION NEEDS

The Forest Plan revision should include direction to address the following critical needs:

- SQSs are needed to provide a basis to monitor changes in soil properties, the LTAs, ELTs, and ELTPs that are mapped on the GMNF. SQSs should be developed within the next 5 years.

- ELTP mapping is needed on all parts of the GMNF where intensive management is planned. ELTP development should include sufficient analysis to provide data to develop SQSs and management interpretations. Work on this need is expected to continue at a low rate due to funding limitations. However, ELTP mapping in the Taconic Mountains and Lye Brook Wilderness (a focus area for monitoring effects of acid deposition) is expected to be completed within 5 years.

- There is a need to evaluate ELT mapping to ensure it reflects current concepts and meshes with the LTA mapping. ELT descriptions and interpretations need to be evaluated to ensure they are current and provide sufficient information to develop SQSs. This goal is expected to be accomplished within the next 5 years

- More definitive information is needed on the chemical aspects of soil productivity, including calcium dynamics, buffering capacity, and effects of acid deposition. This work is ongoing through USFS Research and GMNF work with the Vermont Monitoring Cooperative. The USFS will continue to conduct monitoring and research throughout the next 10 to 15 years to address these information needs.

- Finally, an ecological monitoring strategy is needed that incorporates SQSs, and is flexible enough to incorporate new information as it becomes available. A successful monitoring strategy should:

  - Ensure implementation of SQSs and S&Gs

  - Ensure effectiveness of SQSs and S&Gs

  - Assess validity and accuracy of ecological unit mapping

  - Include provisions for cooperative monitoring efforts to assess long-term effects of broad-scale phenomena, such as acid deposition

  The ecological monitoring strategy should be developed within the next 5 years.

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11.0 GLOSSARY

This glossary presents definitions of terms used in the text, and also of some terms imbedded in the glossary that might not be readily understood by the reader. References used to prepare these definitions are included in Section 12.0.

Ablation till. A general term for loose, relatively permeable material, either contained within or accumulated on the surface of a glacier deposited during the downwasting of nearly static glacial ice (Soil Science Society of America [SSSA] 1997). Relatively loose, permeable glacial till.

Acceptable Management Practice (AMP). The proper method for the control and dispersal of water collecting on logging roads, skid trails, and log landings to minimize erosion and reduce sediment and temperature changes in streams (Vermont Agency of Natural Resources 1987).

Alluvial. Pertaining to processes or materials associated with transportation or deposition by running water (SSSA 1997).

Aquods. Spodosols that are saturated with water for periods long enough to limit their use for most crops other than pasture or woodland unless they are artificially drained. (a suborder in the U.S. system of soil taxonomy) (SSSA 1997).

Basal till. Unconsolidated material deposited and compacted beneath a glacier and having a relatively high bulk density (SSSA 1997).

Base cations. Positively charged ions of base elements. Basic nutrient elements in soils, especially, but not exclusively calcium and magnesium.

BMPs. Methods, measures, or practices selected by an agency to meet its nonpoint source control needs. BMPs include but are not limited to structural and nonstructural controls and operation and maintenance procedures. BMPs can be applied before, during, and after pollution-producing activities to reduce or eliminate the introduction of pollutants into receiving waters (40 CFR 130).

Clastic. Noting or pertaining to rock or rocks composed of fragments or particles of older rocks or previously existing solid matter; fragmental (Random House 1966).

Cryic. A soil temperature regime that has mean annual soil temperatures of >0° C but <8° C, >5° C difference between mean summer and mean winter soil temperatures at 50 cm, and cold summer temperatures (SSSA 1997).

Cryods. Spodosols that have a cryic or pergelic soil temperature regime (A suborder in the U.S. system of soil taxonomy) (SSSA 1997).

Cryorthents. Orthents that have a cryic temperature regime (USDA 1999).

Dystrudepts. Acid Udepts (USDA 1999).

Ecological Land Type (ELT). A specific scale of TEU. A subdivision of a LTA. An aggregation of (ELTPs). Individual ELTs are generally hundreds of acres in size.

Ecological Land Type Phase (ELTP). A specific scale of TEU. A subdivision of an ELT. Individual ELTPs range in size from less than 10 to a few hundred acres.

Entisols. Mineral soils that have no distinct subsurface diagnostic horizons within 1 meter of the soil surface (an order in the U.S. system of soil taxonomy) (SSSA 1997).

Eutrudepts. Base-rich Udepts of humid regions (USDA 1999).

Excessively drained. A soil drainage class in which water is removed very rapidly, and occurrence of internal free water is very rare or very deep (USDA 1993).

Fluvial. (1) Pertaining to streams, (2) growing or living in streams or ponds, or (3) produced by river action, as a fluvial plain (U.S. Geological Survey 1978).

Fluventic Dystrudepts. Dystrudepts on flood plains developed in recent alluvium (USDA 1999).

Fragipan. A natural subsurface horizon with very low organic matter, high bulk density and/or high mechanical strength relative to overlying and underlying horizons; has hard or very hard consistence (seemingly cemented) when dry, but showing a moderate to weak brittleness when moist. The layer typically is slowly or very slowly permeable to water, is considered to be root restricting, and usually has few to many bleached, roughly vertical planes which are faces of coarse or very coarse polyhedrons or prisms (SSSA 1997).

Frigid. A soil temperature regime that has mean annual soil temperatures of >0° C but <8° C, >5° C difference between mean summer and mean winter soil temperatures at 50 cm below the surface, and warm summer temperatures (SSSA 1997).

Glacial Till. See Till.

Haplorthods. Orthods that: (1) do not have less than 0.10 percent iron (by ammonium oxalate) in 75 percent or more of the spodic horizon; (2) lack a placic horizon; (3) do not have a fragipan with its upper boundary within 100 centimeters of the surface; and (4) lack a cemented soil layer within 100 centimeters of the soil surface (USDA 1999).

Humicryods. Cryods that have a high content of organic carbon in the upper part of the spodic horizon; they commonly occur at high elevations or high latitudes (USDA 1993).

Humods. Spodosols that have accumulated organic carbon and aluminum, but not iron, in the upper part of the spodic horizon. Humods are rarely saturated with water or do not have characteristics associated with wetness (a suborder in the U.S. system of soil taxonomy) (SSSA 1997).

Inceptisols. Mineral soils that have one or more pedogenic horizons in which mineral materials other than carbonates or amorphous silica have been altered or removed but not accumulated to a significant degree. Water is available to plants more than half of the year or more than 90 consecutive days during a warm season (an order in the U.S. system of soil taxonomy) (SSSA 1997).

Land Type Association (LTA) (also Landtype Association). A specific scale of TEU. A subdivision of a Subsection. An aggregation of ELTs. Individual LTAs generally range in size from hundreds to thousands of acres.

Mesic. A soil temperature regime that has mean annual soil temperatures of 8° C or more but less than 15° C, and more than 5° C difference between mean summer and mean winter soil temperatures at 50 centimeters below the surface (SSSA 1997).

Moderately well drained. A natural soil drainage class in which water is removed from the soil somewhat slowly during some periods of the year. Internal free water occurrence commonly is moderately deep and transitory though permanent. The soils are wet for only a short time within the rooting depth during the growing season, but long enough that most mesophytic crops are affected. They commonly have a moderately low or lower saturated hydraulic conductivity in a layer within the upper 1 meter (USDA 1993).

Orthents. Entisols that have either textures of very fine sand or finer in the fine earth fraction, or textures of loamy fine sand or coarser and a coarse fragment content of 35 percent or more and that have an organic carbon content that decreases regularly with depth. Orthents are not saturated with water for periods long enough to limit their use for most crops (a suborder in the U.S. system of soil taxonomy) (SSSA 1997).

Orthods. Spodosols that have less than six times as much free iron (elemental) than organic carbon in the spodic horizon but the ratio of iron to carbon is 0.2 or more. Orthods are not saturated with water for periods long enough to limit their use for most crops (a suborder in the U.S. system of soil taxonomy) (SSSA 1997).

Outwash. Stratified detritus (chiefly sand and gravel) removed or "washed out" from a glacier by melt-water streams and deposited in front of or beyond the end moraine or the margin of an active glacier. The coarser material is deposited nearer to the ice (SSSA 1997).

Placic horizon. A black to dark reddish mineral soil horizon that is usually thin but that may range from 1 mm to 25 millimeters in thickness. The placic horizon is commonly cemented with iron and is slowly permeable or impenetrable to water and roots (SSSA 1997).

Soil Taxonomy: U.S. Department of Agriculture soil classification system (SSSA 1997).

Somewhat excessively drained. A soil drainage class in which water is removed from the soil rapidly. Internal free water occurrence commonly is very rare or very deep. The soils are commonly coarse-textured and have high saturated hydraulic conductivity or are very shallow (USDA 1993).

Spodic horizon. A mineral soil horizon that is characterized by the illuvial accumulation of amorphous materials composed of aluminum and organic carbon with or without iron. The spodic horizon has a certain minimum thickness, and a minimum quantity of extractable carbon plus iron plus aluminum in relation to its content of clay (SSSA 1997).

Spodosols. Mineral soils that have a spodic horizon or a placic horizon that overlies a fragipan (an order in the U.S. system of soil taxonomy) (SSSA 1997).

Subsection. A specific scale of TEU within the NHFEU. A subdivision of a Section. An aggregation of LTAs. An individual subsection generally ranges in size from hundreds to thousands of square miles.

Terrestrial Ecological Unit (TEU). A mapped unit of land with relatively uniform properties or patterns of soils, geology, landforms, climate, and potential natural vegetation, with relatively uniform productive capacity and response to management actions. TEUs are defined at different scales in conformance with the NHFEU.

Terrestrial Ecological Unit Inventory (TEUI). A map of TEUs with descriptive and interpretive information.

Till. Unsorted and unstratified earth material, deposited by glacial ice, which consists of a mixture of clay, silt, sand, gravel, stones, and boulders in any proportion (SSSA 1997).

Typic Haplorthods. A subgroup representing the central concept of Haplorthods.

Udalfs. Alfisols that have a udic soil moisture regime and mesic or warmer soil temperature regimes. Udalfs generally have brownish colors throughout, and are not saturated with water for periods long enough to limit their use for most crops (a suborder in the U.S. system of soil taxonomy) (SSSA 1997).

Udic. A soil moisture regime that is neither dry for as long as 90 cumulative days nor for as long as 60 consecutive days in the 90 days following the summer solstice at periods when the soil temperature at 50 cm below the surface is above 5°C (SSSA 1997).

Udepts. Inceptisols that have a udic moisture regime (USDA 1999).

Well drained. A natural soil drainage class in which water is removed from the soil readily but not rapidly. Internal free water occurrence commonly is deep or very deep; annual duration is not specified. Water is available to plants throughout most of the growing season in humid regions. Wetness does not inhibit growth of roots for significant periods during most growing seasons (USDA 1993).

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