Educating Resource Technicians to the New Concept

of

Ecological Classification Systems

by

Lori J. Schmidt

Report in Partial Fulfillment of the Requirements for the Master's of Forestry Degree

Faculty of Forestry and the Forest Environment
Lakehead University

March 2001

Co-Major Advisor **Co-Major Advisor**

0-612-70803-9

Educating Resource Technicians to the New Concept of Ecological Classification Systems

By

Lori J. Schmidt

Abstract

Schmidt, Lori J. 2000. Educating Resource Technicians to the New Concept of Ecological Classification Systems. 68 pp. Advisor: Dr. Ed Setliff, Faculty of Forestry, Lakehead University, Thunder Bay, Ontario

Key Words: Ecological classification systems, Minnesota Department of Natural Resources, Resource technicians

The topics of Ecosystem Management (EM) and Ecological Classification Systems (ECS) are appearing more frequently in forest management literature. These systems facilitate our understanding, not only of forests from a tree standpoint, but also by the associations of shrubs, plants, soils, climatic and geological influences considered when describing a forest community for which a stand of trees is a component. This paper specifically describes the ECS commonly used by the Minnesota Department of Natural Resources (MN DNR) as well as the U.S. Forest Service.

Terminology associated with the description of ecological units is listed and field techniques used by entry-level resource technicians are provided to help understand and utilize the ECS.

Table of Contents

List of Tables

List of Figures

Introduction

Forest managers and silviculturalists traditionally recognize a link between forest species representation and soil composition. Many silvicultural texts, manuals and field guides are based upon forest research that resulted in an organized classification of forest ecosystems. A rationale for this type of organization can be found in The Field Guide to Forest Ecosystem Classification (Jones *et al.* 1983). This manual states that,

> *"Forest Ecosystems are the stands that the forest manager deals with during the planning, harvesting and regeneration, release and tending stage of management. If management knowledge and experience are to be organized, communicated and used effectively, a practical, clear system for classifying these stands (ecosystems) is needed to ensure that each manager know what the others are talking or writing about.... Forest stands are more than just trees in the canopy. The lower vegetation and the soil and other physical site features all play an profound part in determining how a forest stand grows and regenerates. To appreciate the stand as an ecosystem, then, the forest manager must consider more than just the forest cover type and must use a classification on more features than just the trees."*

This paper presents an overview of the historical development of an Ecological Classification System (ECS) within the United States for federal land managers and later modified for use in Minnesota by the Department of Natural Resources (DNR). Several papers and manuals are reviewed to demonstrate the complexity of designing a uniform system that defines an ecosystem.

If one had to describe the ultimate goal of the ECS, it is to provide a common ground of communication between the various disciplines within the Natural Resource Management field. Typically, natural resource disciplines from various fields were only familiar with their own area of expertise. Wildlife biologists studied plants from the aspect of habitat; foresters examined plants from the aspect of dominant covertypes for harvest; plant ecologists looked for rare or endangered plants. However, if there's one overwhelming theme in nature it is that everything is connected. Action directed to one aspect of an environment may be impacting another component of the ecological system. Resource managers are continually challenged with the mission of managing a resource for all interested parties, while maintaining a healthy ecosystem. How does a resource manager make the best decision possible to meet the management objectives and maintain the natural community that is more likely to be productive, healthy and resistant to disease? According to the Minnesota DNR, the best method is through an ECS management policy.

ECS incorporates a wide-array of information including nutrient cycling, hydrology, history, disturbance regime, as well as the usual vegetative and soil data. This system intends to improve a manager's ability to conduct sustainable resource management and to improve communication among the disciplines. An ECS classification within Minnesota may represent resources at a province level with a scale of 1:30,000,000 down to the site level, which may be represented at a 1:24,000 scale or smaller if the need arises.

If the ultimate goal of the ECS is to provide a common ground of communication, then the ultimate goal of this report is to interpret the terminology associated with ECS to the resource technicians working or entering the field. To accomplish this goal, this paper describes ECS terminology and demonstrates examples of field implementation. This paper is designed to facilitate an individual with a resource-based background into a common system where all users can appreciate the forest.

Literature Review

Quantitative Relationships among Vegetation and Soil Classifications

A true and balanced understanding of the past is critical to understanding the present and the requirements necessary for a successful future. Therefore, The first paper reviewed is that of Grigal and Arneman (1970) which provides a good reference to the early developmental stages of an ECS and the effectiveness of various data sets. As this paper demonstrates, ecological systems are not always easy to define.

The purpose of this paper related to the classification of forest stands based on pre-determined criteria and resulted in a comparative analysis of the effectiveness of each criteria as a tool to classify like forest stands. Previous analysis revealed good correlation between vegetation and soils at the Forest Biome level; but when an analysis is conducted at the smaller, more-detailed covertypes, the correlations are less certain.

There are four important pieces of literature that provides the foundation for the ECS. These are summarized as follows:

1. Vegetative responses to environmental change are generally quicker than soil responses. Depending on the disturbance regime, there needs to be significant time allowed to determine a correlation. The amount of time necessary is dependent upon the system.
2. The effect of a microclimate needs to be considered; slope-aspect, topography; all of these factors can affect and override soil/vegetative correlation's.

3. Relative properties must be used. Be cautious of covertypes with a broad-range of tolerances.
4. Using the correct scale is critical. Avoid broadening the scale for one classification, then narrowing the scale for another, comparative analysis requires comparing like scales.

The authors chose to study select Minnesota forest sites while paying attention to the four above-mentioned factors. The study area included the Arrowhead Region of Minnesota near Grand Marais. This region includes Northeastern St. Louis County, Lake County and Cook County. This area is considered to be very similar in microclimate with good soil diversity.

Site selection was chosen with an emphasis on minimizing variability. Forty sites were chosen with the following criteria: Minimum soil depth, 45 cm; no major slope (>10%); edaphic conditions, those determined by soil and not climate; continuous covertypes, pure stands if possible; and lack of disturbance for at least 40 years.

The sampling procedure tended to favor the rarer species such as *Pinus strobus*, *Pinus resinosa* and *Pinus banksiana* since the criteria tend to be better represented by *Pinus* than other genera in the region. *Abies balsamea* was under represented due to the large spread infestation of Spruce-Budworm that affected the 40-year disturbance regime.

Three criteria were used to classify stands, an environmental component, vegetative component and a soil component. These criteria are detailed on the following page:

– Environmental Component

Gradients of heat, moisture and nutrients on a scale of 1 being the least and 5 being the most. Heat was affected by latitude; slope and aspect; nighttime temperature classes. Southwestern slopes were generally rated as a 5 while Northeastern slopes were rated as a 1.

- Moisture

  Determined by laboratory soil characteristics. Local topography and climatic data with the characteristics of moisture were heavily weighed toward the soil influence due to homogeneous potential of topography and climate throughout the study area.

- Nutrient Gradient

  This factor can reference productivity and is influenced by plant uptake variations, mycorrhizae, nutrient cycling and the heat and moisture factors, which affect decomposition.

- Vegetative Component

The sampling criteria used in this study included ten sampling points for each stand included in the study. The herbaceous ground cover was recorded on a 10 m^2 circular plot; shrubs were measured on a 100 m^2 circular plot; trees were recorded on a 250 m^2 square meter circular plot. At three of the 10 sampling points, diameters were recorded for all shrubs and trees within the respective plots.

– Soil Component

Soil characteristics were assigned from a 1.25-meter deep soil pit at the center of each sampled stand. Soil profiles were described using the U.S. Department of Agriculture standard terminology (Soil Survey Staff, 1951). Horizon samples were sent for lab analysis to determine particle size, moisture characteristics, organic carbon and exchangeable cations. Soil with high base exchange capacity were believed to retain more nutrients with less leaching.

Table I denotes the forty stands identified for this study with categories of stand identification number, dendrogram code, cover type description and soils. The category referred as the dendrogram code shows the results of an assessment of overstory basal area data, frequency of species occurrence, soil properties and the three environmental gradients previously discussed in this paper. Euclidean distance (straight-line distance between two points) was used to determine a relationship between stands soils, frequency of species and environmental gradients. The basal area data was calculated using Product Moment Correlation, reflecting the degree of linear relationship between two variables. It ranges from +1 to -1. A correlation of +1 means that there is a perfect positive linear relationship between variables.

Table I. Summary of stand data for forty research sites in northeastern Minnesota (Grigal 1970)

Stand	Dendrogram* code	Cover type†	Soil at great group level: American‡	Soil at great group level: Canadian§	Surface soil texture
1	BF	Balsam fir – white spruce – paper birch	Dystrochrept	Dystric Brunisol	Sandy loam
2	JP	Jack pine	Dystrochrept	Dystric Brunisol	Loam
3	AsB	Aspen	Fragiochrept	Dystric Brunisol	Sandy loam
4	BF	White spruce – balsam fir – aspen	Ochraqualf	Eluviated Gleysol	Clay loam
5	BF	Northern white cedar	Hapludalf	Gray Brown Luvisol	Clay loam
6	BF	White spruce – balsam fir	Ochraqualf	Eluviated Gleysol	Loam
7	AsB	Aspen	Ochraqualf	Eluviated Gleysol	Clay
8	RP	Red pine	Fragiochrept	Dystric Brunisol	Loam
9	JP	Jack pine	Udipsamment	Regosol	Loamy sand
10	NoH	Northern red oak – basswood	Dystrochrept	Dystric Brunisol	·Loam
11	JP	Jack pine	Haplorthod	Humo-Ferric Podzol	Loam
12	BF	Balsam fir	Haplorthod	Humo-Ferric Podzol	Sandy loam
13	JP	Jack pine	Haplorthod	Humo-Ferric Podzol	Silt loam
14	AsB	Paper birch	Dystrochrept	Dystric Brunisol	Loam
15	JP	Jack pine	Dystrochrept	Dystric Brunisol	Sandy loam
16	WP	White pine	Haplorthod	Humo-Ferric Podzol	Loam
17	AsB	Aspen	Haplorthod	Humo-Ferric Podzol	Loam
18	AsB	Aspen	Haplorthod	Humo-Ferric Podzol	Loam
19	WP	White pine	Haplorthod	Humo-Ferric Podzol	Loam
20	AsB	Aspen – paper birch	Haplorthod	Humo-Ferric Podzol	Sandy loam
21	AsB	Aspen – paper birch	Dystrochrept	Dystric Brunisol	Loam
22	JP	Jack pine	Udipsamment	Dystric Brunisol	Sandy loam
23	AsB	Aspen	Ochraqualf	Eluviated Gleysol	Clay
24	JP	Jack pine – black spruce	Udipsamment	Regosol	Sandy loam
25	AsB	Aspen	Haplorthod	Humo-Ferric Podzol	Sandy loam
26	JP	Jack pine	Udipsamment	Regosol	Loamy sand
27	AsB	Aspen	Dystrochrept	Dystric Brunisol	Loam
28	AsB	Aspen	Haplorthod	Humo-Ferric Podzol	Sandy loam
29	JP	Jack pine – black spruce	Haplorthod	Humo-Ferric Podzol	Loam
30	JP	Jack pine – aspen	Haplorthod	Humo-Ferric Podzol	Silt loam
31	AsB	Aspen	Haplorthod	Humo-Ferric Podzol	Sandy loam
32	WP	White pine	Haplorthod	Humo-Ferric Podzol	Sandy loam
33	NoH	Sugar maple	Haplorthod	Humo-Ferric Podzol	Loam
34	AsB	Aspen	Hapludalf	Gray Brown Luvisol	Clay loam
35	NoH	Sugar maple	Haplorthod	Humo-Ferric Podzol	Loam
36	AsB	Aspen	Haplorthod	Humo-Ferric Podzol	Sandy loam
37	AsB	Aspen – paper birch	Haplorthod	Humo-Ferric Podzol	Sandy loam
38	NoH	Sugar maple – basswood	Eutrochrept	Eutric Brunisol	Sandy loam
39	AsB	Aspen	Ochraqualf	Eluviated Gleysol	Loam
40	RP	Red pine	Udipsamment	Dystric Brunisol	Sandy loam

After analysis of stand classifications initiated by this project, the authors suggest that stands must be homogeneous not just in overstory, but in soils and environmental conditions in order to estimate a similar response to management techniques. The most likely reflection of a homogeneous stand is the frequency of species occurrence within a stand. If understory plant species occur in high frequency with similar frequency of overstory tree cover, the more representative of homogeneous stands. Grigal and Arneman (1970) stated " Management plans which are based on overstory composition (alone) may easily fail."

Modeling Forest Succession Among Ecological Land Units

Ecological Classification Systems (ECS) attempt to identify landtypes based on vegetative species composition, forest productivity, soils and physiographic characteristics, therefore their use in modeling forest succession can be very effective according to, Pastor and Host (1998). Both authors are research scientists at the Natural Resource Research Institute at the University of Minnesota-Duluth campus. According to their introduction, they see ECS as allowing us to understand how different parts of a landscape respond to management. The composition and structural data of an ecosystem are gathered when developing and validating an ECS (Host et al. 1993), therefore, the data is in place to model the ecological processes from the structural data set. While the modeling process is more extensive and a separate component from ECS development, it can provide Natural Resource managers with an opportunity to better manage landtypes by providing a broader understanding of the ecological processes which drive the system.

When developing and implementing the use of ECS, it is important to interpret the specific landtypes based on the objectives desired by the Resource Manager. The following authors identified sample objectives as:

- Assessments of Forest Succession (Host *et al.* 1987)
- Response to Silvicultural Treatments, Productivity (Host *et al.* 1988)
- Species Diversity (Host and Pregitzer 1991)
- Game and Non-game habitat (Johnson *et al.* 1991)

To fulfill these objectives, detailed data concerning the ecosystem composition, structure and function must be acquired. In addition to this field data, field-based and computer modeling are necessary to comprehend the often-complex ecosystem processes.

One of the ecosystem processes of a forest stand is succession. The authors designed a study using a Gap Model to simulate successional patterns based on the historic pattern of vegetative species and the soil nutrient availability. The soil and vegetation data to run the model was gathered on a project designed by the authors.

The study area included two specific landtypes. The first represented an area of relatively level glacial till composed of sandy-loam in the A-horizon and clay present in the lower horizons. The second study area consisted of sand dunes that had varying horizon depths to the water table. Within each type, study sites were identified based on the depth of water table and three phases of physiographic characteristic representing Xeric, Mesic and Hydric sites.

The study included five sample plots within the three physiographic phases of each of the two sites. Overstory data was gathered by use of variable plot cruise with a 10-factor prism. D.B.H. and species data were recorded on each plot. Three trees on each plot were measured for height and age to provide site index and productivity data.

Three soil cores were taken at each of the thirty plots to a depth of 50 cm and soil carbon and nitrogen was determined from soil samples. Four additional soil cores were gathered between plots to provide a representation of the soil variability within the stands. Bulk density was determined as a function of soil carbon based on field techniques published by Grigal (1980).

The vegetation and soils data were used as model input parameters to simulate changes in soil and forest composition over time. Mean precipitation and temperature were entered into the model and were based on 30-year regional datasets.

This study indicated a variance between types and physiographic phases as indicated by the ECS designations and was supported by the successional outputs of the model. There appeared to be a distinct trend in soil carbon based on physiographic phases. Soil carbon values were generally higher on Hydric sites in the Sandy/Loam sites and Mesic sites in the sand dune sites. Nitrogen was far more variable than carbon levels and no-patterns were documented. The authors suggest that the release of nutrients is far more indicative of the ratio of carbon to nitrogen rather than the amount of carbon or nitrogen present.

The discussion of the article sees the use of ECS's as a tool that can distinguish functional processes as well as composition variables of both soil and vegetation. The use of models in combination with ECS's can allow for more in-depth management decisions based on the predictive nature of computer modeling. The benefit of modeling is that Silvicultural practices and other forest management decisions can be tested easily by executing model simulations, but data needs to be gathered to make the model functional. Typical forest management data often neglects the detailed soil testing which is believed to have a significant impact on forest productivity. The development of effective ecological field guides will undoubtedly include the necessary detailed soil information, as ECS's become more commonplace.

Standardized National Vegetation Classification System Manual

In an effort to create a standardized vegetation classification system, the U.S. Geological Survey (USGS) Division contracted with The Nature Conservancy and Environmental Systems Research Institute (GIS specialists) to develop a standardized classification system for terrestrial vegetation throughout the United States. The project goals were to improve resource management and stewardship by increasing data sharing among federal land agencies as well as standardizing the data collected. The USGS project summary states that standardized data will "...provide a structure for framing and answering critical scientific questions about vegetation types and their relationship to environmental processes across the landscape."

What are these scientific questions? The vegetative manual developed by The Nature Conservancy (Grossman 1994) suggests a standardized system will provide answers to the following questions:

1. What are the origins and geographic distribution of vegetation?
2. What is the relationship between ecological units across the landscape?
3. What is the relative importance of individual vegetative types?
4. What is the species composition and variability in ecological units?

The answers to these questions will enable a manager to better understand a resource and lead to better management decisions. To develop a system comprehensive enough to be effective, the system needed to be based on the concept that all resources are part of a larger ecological unit and therefore, should have documented standards, across a large geographic area. The actual classification, field methods and accuracy assessment techniques must be uniform across a variety of ecological systems, even though the comparisons will likely stay within an Ecological Classification grouped by common attributes (Kent and Coker 1992).

In a forest, standard practice generally considers the classified unit as a forest stand, which has common vegetative understory, soils and tree covertypes. This may include a separation of stand age, density, genetic clones and historical trend data. Accompanying data may include soils, hydrology and topography as well as any other key environmental attributes.

This manual discusses the traditional historical view within the United States as showing disinterest in classification. The author references several sources including Gleason (1917,1926), Whittaker (1956,1962) and Curtis (1959), all which hold a view that vegetative units could not be defined due to the idea that "...species respond individually to environmental gradients." This viewpoint is identified in the manual as "individualistic dissent." Those who counteract this viewpoint give the following rationale supporting their dissent.

– Familiar species tend to re-occur and are generally correlated with their environment. The tendency is to see the highest correlation within certain landscapes, but the overall goal of classification is to determine similarities and dissimilarities across the entire landscape...

There are several vegetative classification systems, but three are more generally used by Howard and Mitchell, (1985) as follows: physiognomic – the structure and life forms of the dominant species, floristic – characterize the individual species; generally use the term "indicator species" as an association of a community, and ecosystem classifications – relationship between vegetation and the soils as a reflection of site characteristics.

As stated earlier, the USGS contracted with The Nature Conservancy to develop a standardized system that would be ecosystem-based and applicable throughout the entire United States by all Federal Land management agencies. The Conservancy established units for the new standardized system from land areas that were already part of the Natural Heritage program. These areas had four-represented regions in the United States, namely, *West, Midwest, East and Southeast* and each region had a complete vegetation assessment. The Nature Conservancy methodology used a standard set of over 100 attributes to assist in the determination of an area's Ecosystem classification. While not all attributes were available for all areas, a minimum set of data included vegetation, key environmental factors, dynamic processes, landscape relations, community variability and management needs.

The National Vegetation Classification system has seven levels. These are the system, physiognomic class, physiognomic subclass, formation group, formation, alliance and community levels. The system level determination is relatively simple in assessing whether a community is terrestrial, Aquatic or Sub-terranean. To determine the state of the vegetative community as it relates to management practices, requires a more detailed look at the remaining six levels of classification such as the physiognomic class and subclass as well as the formation, associations and community elements.

The physiognomic class, level two in the system, is based on the structure of the vegetation as the forest, shrubland, grasslands or herbaceous cover. Once the physiognomic class is determined, a further subclass, level three, will identify a unit based on the dominant covertype, for example: evergreen forest type would be a physiognomic class and subclass determination.

The formation group is the fourth level in the National Vegetation Classification system and is based on a combination of climate, leaf morphology and phenology data. To further break down the aspect of climate a fifth level termed the formation level determined specific attributes as elevation, aspect, hydrologic physiographic classification, and structural factors such as crown shape and closure which may impact the microclimate of a stand.

A vegetative alliance is similar to the term covertype and represents the sixth layer in the National Vegetation Classification system. Generally, the association references a species from the upper canopy. For instance, a *Pinus banksiana* type would be used to describe an association or alliance of vegetation that is common in a *Pinus banksiana* dominant stand as would species of V*accinium*.

The community element is the most detailed level of the classification system. This is generally where the individual species is represented at any stratum. The term community element and plant association can be used synonymously representing the ground cover associations.

A classification system is only as good as the data gathered. Confidence level ratings are assigned to each classification to indicate the amount and type of information available. The confidence ratings are as follows:

1. Strong- based on quantitative analysis of verifiable data
2. Moderate – based on qualitative assessment of published field data or data with a limited number of samples
3. Weak- classification is based on anecdotal information

The true benefit of an ecosystem classification system for the federal resource management agencies in the United States is the chance to create a better understanding of the resources as well as share data throughout the public land system. The hierarchy organization of this standardized classification will allow for applications at multiple scales. The system can be replicated in any geographic area and is based on standard field and data analysis protocol. The future resource technicians entering the natural resource field would be well suited at learning the organization of this standardized system.

Identification, Description and Ecology of Forested, Native Plant Communities

A manual assisting field foresters, wildlife specialist and ecologists working within the Minnesota DNR is available from the Minnesota DNR. John Almendinger, a plant ecologist, and Dan Hanson, a DNR soil specialist, worked collaboratively to produce a field based manual to be used in conjunction with a one-page field key to assist in assigning a forest stand to a vegetative community. Their first efforts focused on the Northern Minnesota Drift and Lake Plain section in the Minnesota ECS, which encompasses their field office near Grand Rapids, Minnesota. With further data acquisition, the possibility exists for a manual for each ecological section classified within Minnesota.

The Minnesota DNR participates in National Hiearchial Framework of Ecological units (adopted by the US Forest Service) which has eight levels. The first level is the Domain, which are the largest map units, with a 1:30,000,000 scale. The domain level is largely based on climatic data, more specifically, weather patterns, precipitation and to some extent, latitude. There are four major domains identified across the globe. These are the Polar, Humid Temperate, Humid Tropical, and Dry.

The Humid Temperate domain covers most of the eastern United States and is affected by both tropical and polar jet streams (Fig. 1). This area is also defined as having distinct seasonal fluctuations of precipitation and temperature which determine a winter season and create vegetative differences. Vegetative communities such as prairie, broadleaf deciduous and evergreen conifer forests exist in this domain, but these fluctuations are identified at the smaller divisional level rather than the domain level.

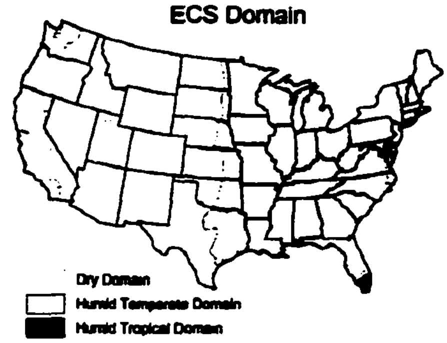

Figure 1: Domain level of Minnesota's Ecological Classification System (Interagency Information Cooperative Website).

The second level is called the division level and is based on similar regional characteristics such as similar characteristics such as regional climate, precipitation, winter temperature and vegetation (Fig. 2). There are three divisions in Minnesota and map scales can range from 1:30,000,000 to 1: 7,500,000.

1. Warm continental- Laurentian Mixed Forest
2. Hot continental –Eastern Broadleaf Forest
3. Prairie division –Prairie Parkland

Figure 2. Three divisions of Minnesota's Ecological Classification System (Minnesota DNR – Website)

The third level is where divisions are subdivided into provinces where map scales range from 1:15,000,000 to 1:5,000,000. These subdivisions are based on vegetation responses to the climatic subzones of moisture and temperature at the division level. A pre-European settlement map, Figure 3, depicts native vegetative boundaries used as a basis for delineating provinces in Minnesota, note the similarities to the divisional boundaries. Because Minnesota doesn't separate between the division and the provinces, they are considered the same.

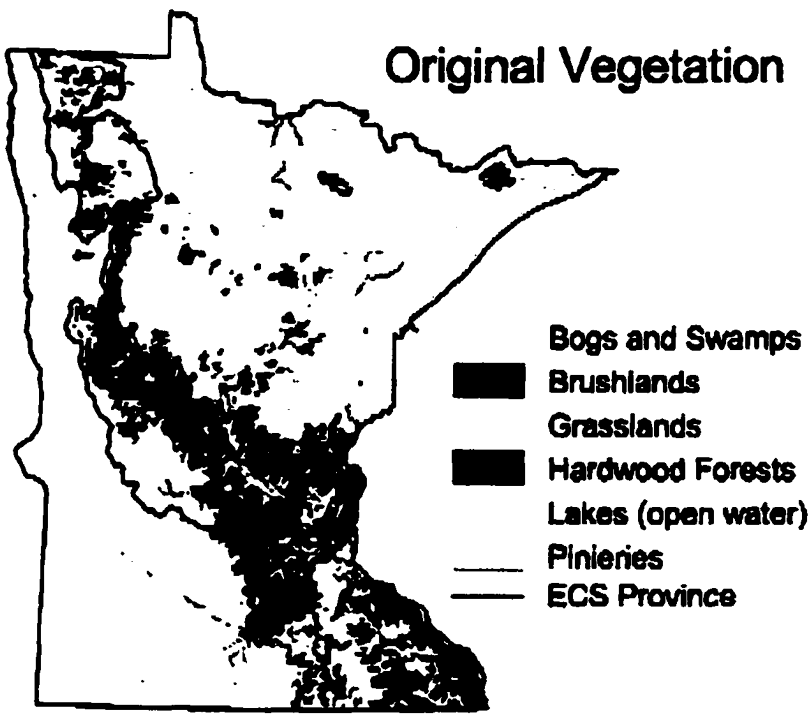

Figure 3. Original vegetative map depicting the ECS Province boundary

The fourth level is called the Section level that identifies the geological features, glacial sediments and distribution of plant communities as attributes at this level. Map scales in the section level range from 1: 750,000 to 1: 3,500,000. Minnesota has 10 sections throughout the state, Figure 4.

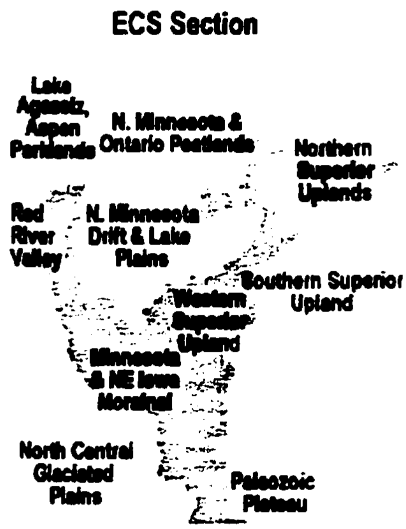

Figure 4. Ten Sections of Minnesota's Ecological Classification System (Minnesota DNR Website)

Resource data used to determine the section boundaries included a general mapping of soils within the state, Figure 5, as well as the influence of drainage basins, Figure 6.

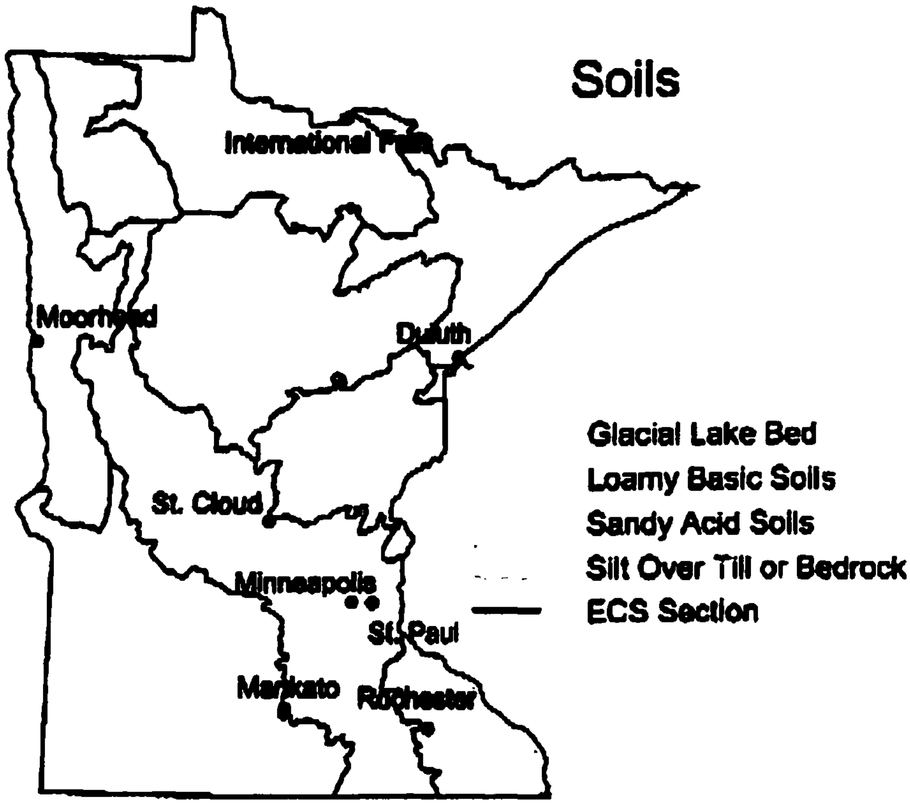

Figure 5. General map of soil associations used to determine Minnesota ECS sections

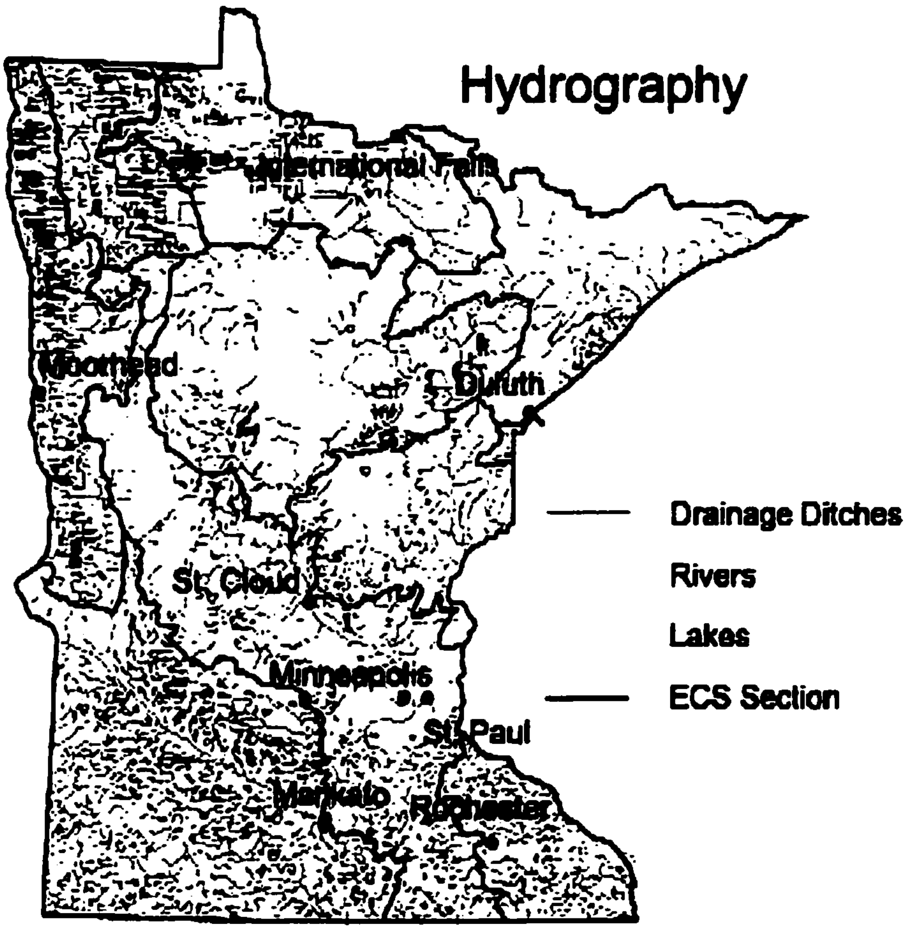

Figure 6. Hydrological drainage basins used to determine Minnesota ECS sections

The fifth level, called the subsection level, is based on a more narrow description of the glacial deposits, climate, and topography and in some cases, dominant tree covertypes, Figure 7. There are 24 subsections identified in Minnesota with details of these subsection found in Appendix 14. Map scale for subsection designations ranges from 1:3,500,000 to 1:250,000 with a polygon size of 10's to low 1,000's of square miles.

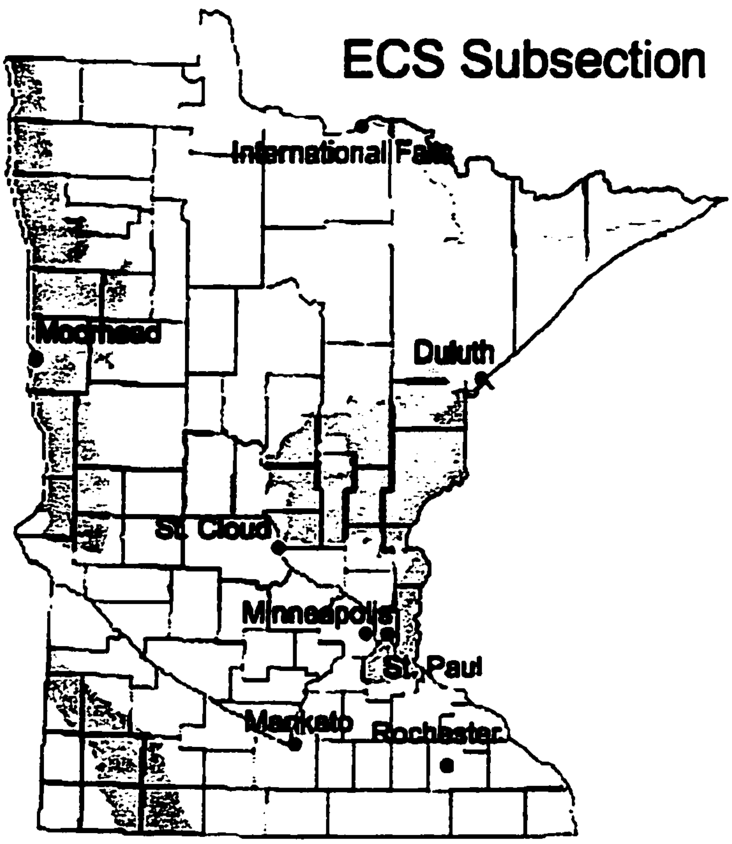

Figure 7. Twenty-four Sub-Sections of Minnesota's ECS
(Interagency Information Cooperative Website)

Influences at the subsection level relate to the geological history of the region, topography and native vegetation maps. Surface geology of the state, Figure 8 and elevation changes throughout the state, Figure 9 are significant factors to determining the Subsection boundaries, but native vegetation maps, Figure 10 were also utilized.

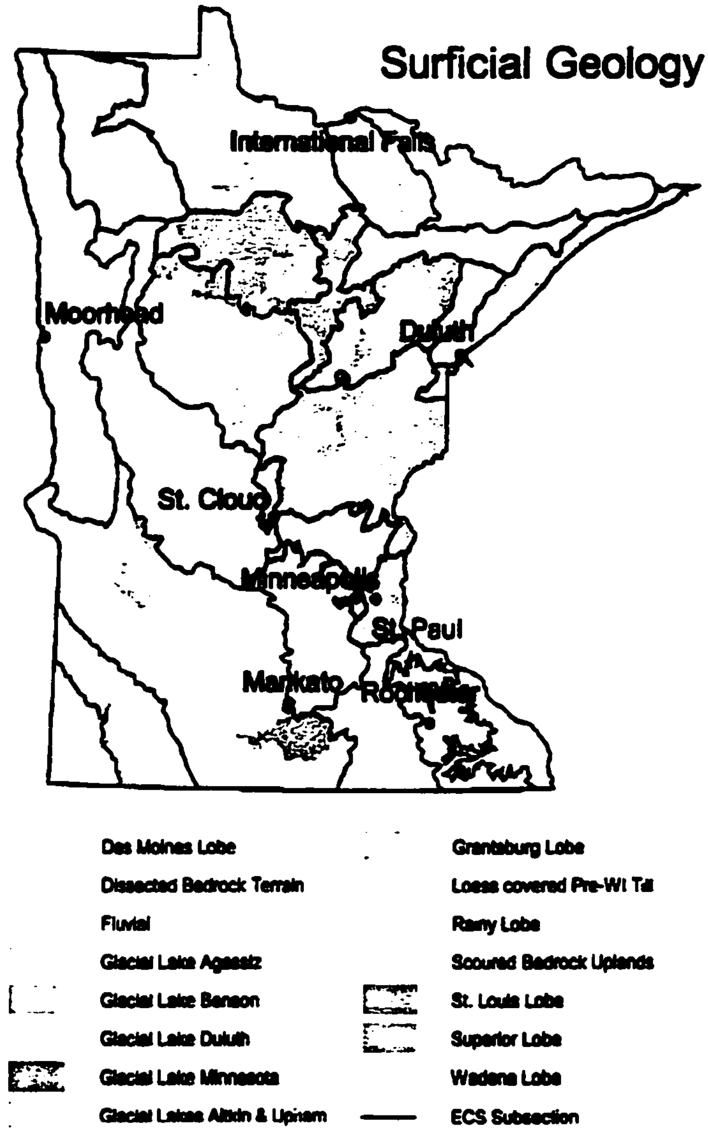

Figure 8. Map of Glacial Influence on Sub-section designations (Interagency Information Cooperative Website)

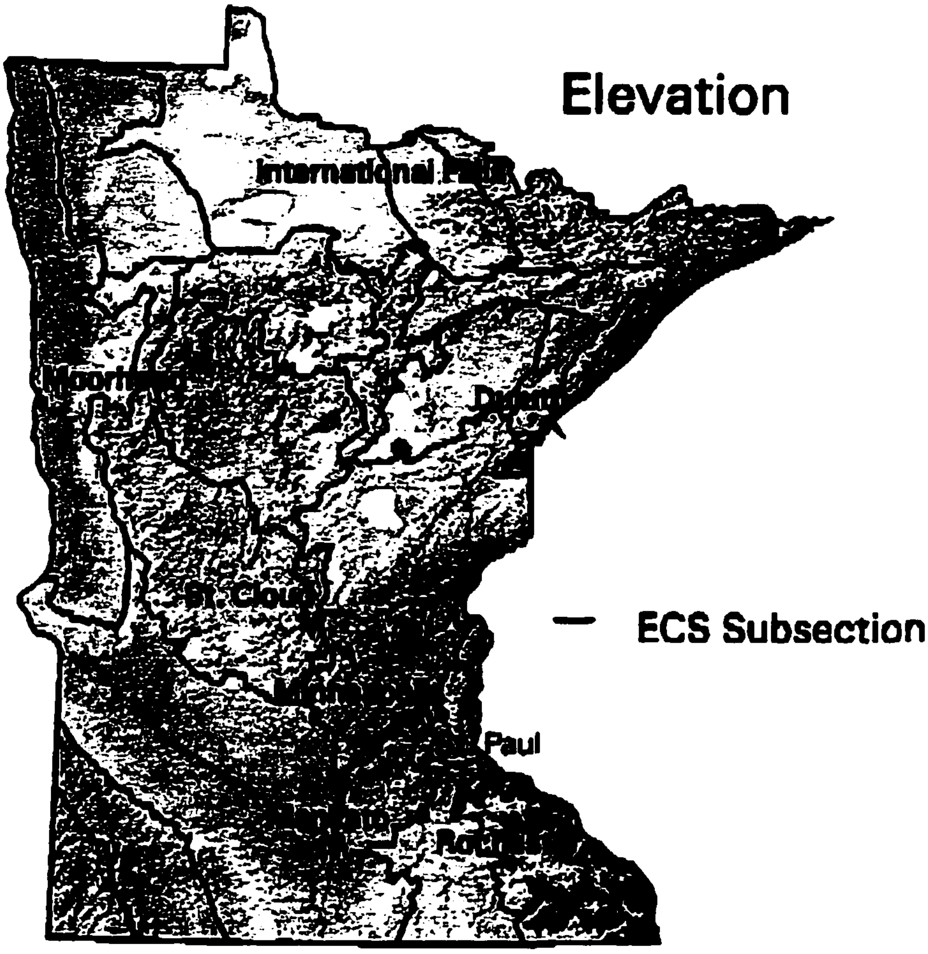

Figure 9: Elevation changes throughout Minnesota (Interagency Information Cooperative Website)

Elevation color scale – Green represents lower elevation increasing to Brown as highest elevation, with Eagle Mountain, near Grand Marais as the highest point in the state at 2,301 feet.

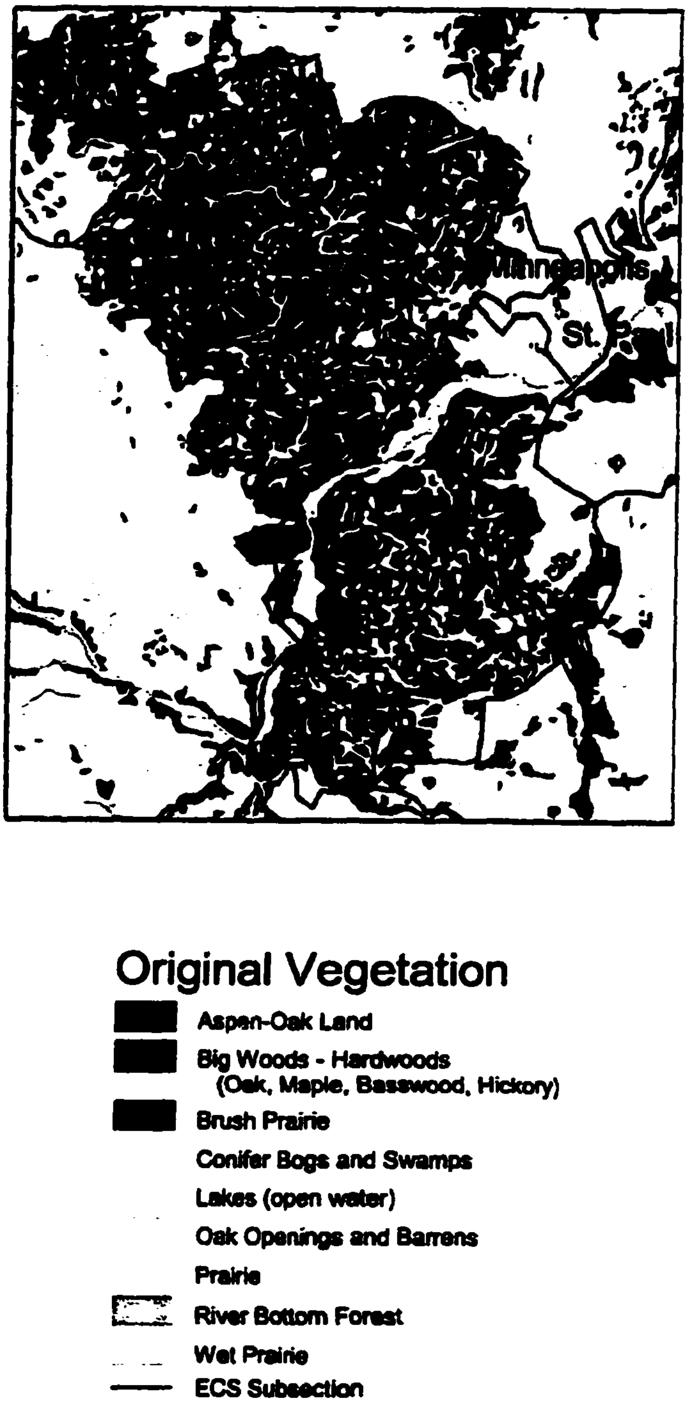

Figure 10. Native Vegetation used to determine Ecological Sub-section designations (Interagency Information Cooperative Website)

The sixth layer of the Ecological Classification system is the Land Type Association (LTA's). There are approximately 300 LTA's, defined by glacial formations, parent rock origins, topographic details, watershed and wetland patterns, but at a far more detailed level than shown in a Sub-section. At the LTA level, designations can be made on Aerial photos or satellite imagery, as demonstrated in Figure 11, with a common scale of 1:60,000. The polygon's size of an LTA may range from 1,000 – 10,000 acres.

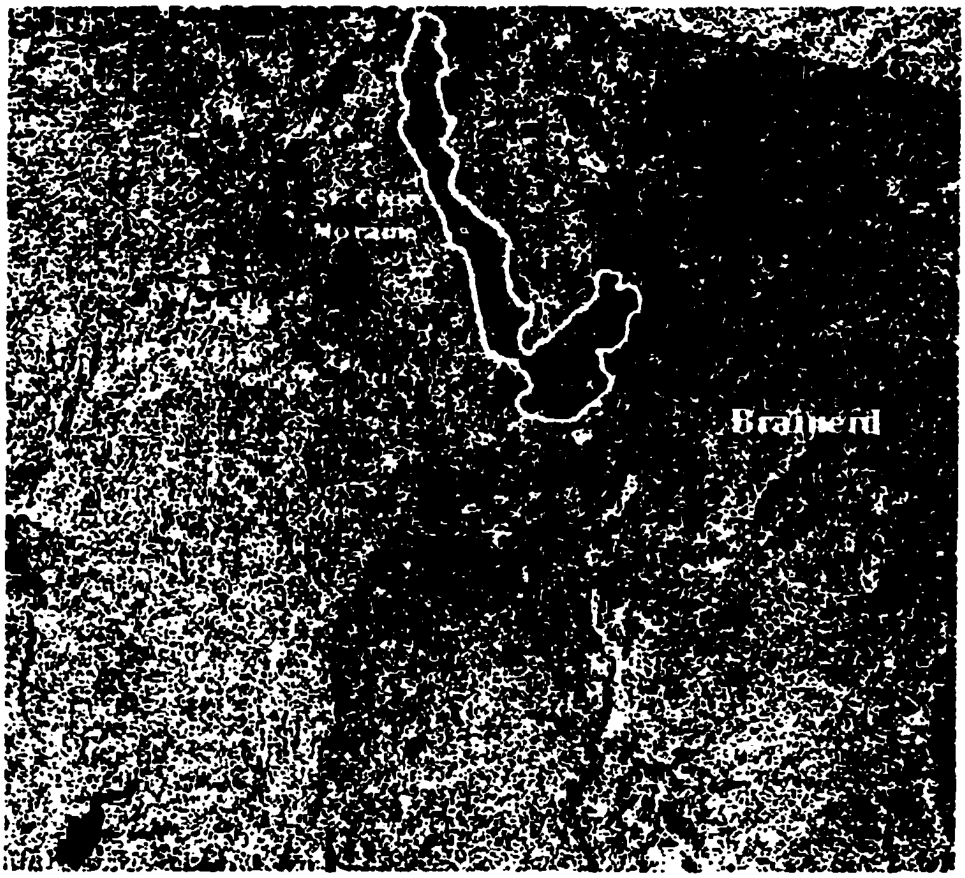

Figure 11. Satellite image showing the differences in vegetation distinguishing a different LTA

A further breakdown of the Land Type Association reveals the seventh layer of the system referred to as merely the Land Type. This level distinguishes units or stands ranging from 100 – 1000 acres in size displayed on a typical U.S. Geological Survey map at a 1:24,000 scale. The distinguishing features are not generally standardized at this level and are left to the individual managers to categorize. There may be an evaluation of the historic vegetation disturbance regimes (such as fire), abundance and distribution of wetland types, hydrology and soil types as well as small-scale topographic differences. An example of the use of disturbance regimes in the classification system is shown as Figure 12.

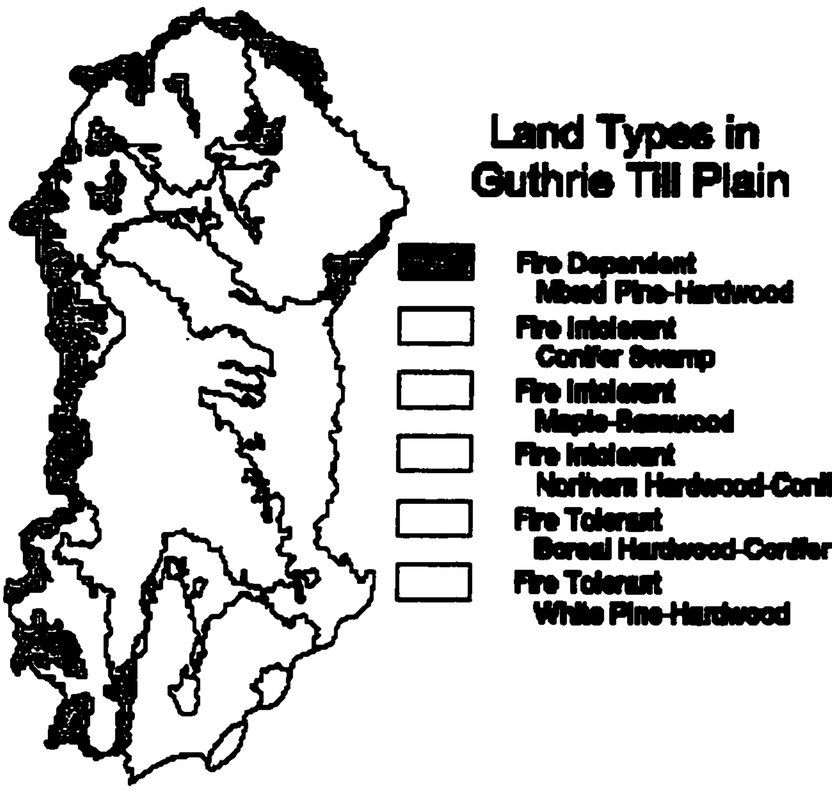

Figure 12. Land Types within the Guthrie Till Plain in the Chippewa National Forest in North -Central Minnesota show the use of fire toloerant vegetation as a method of determining Land Types

The smallest unit in the entire system is the Land Type Phase can cover areas as small as the manager requires, sometimes less than an acre in size, if the focus is at the individual species level. To characterize this level of information, a manager may evaluate plant communities and more specifically, indicator plants. There may also be an evaluation of water chemistry, soil texture, pH and physiographic classification related to drainage patterns. The aspect and slope of an individual stand may also affect this level of classification. At this level, it is up to the discretion of the land manager to categorize a stand. Figure 13 demonstrates the use of perched water tables to define quality habitats within a forest stand. This type of detail can be significant to the resource manager looking at specific habitat or microclimate data.

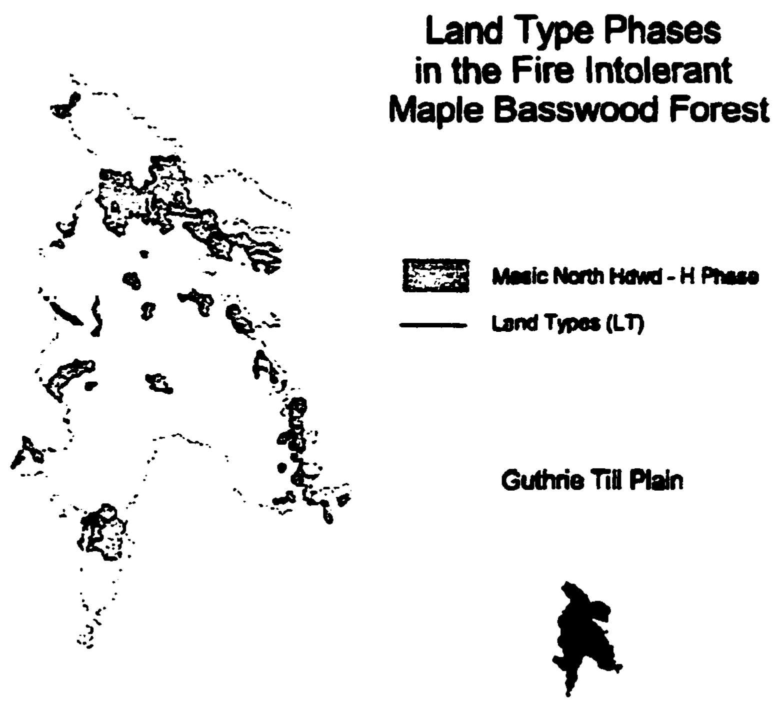

Figure 13. Mesic sites within a Maple Basswood forest that delineate special habitat, Designated in the ECS system as a Land Type

At the Land Type level, a field guide or key is recommended whenever categorizing information into a standardized format whether it's taxonomic nomenclature, soil series, or even mammal tracks. For a beginning resource student, the field guide can be the best way to become familiar with the details of a plant, forest or habitat. The same is true for the ECS, the best way to become familiar with the system is to study the components and the classification terminology. This can be accomplished through the use of an ECS key. The DNR describes the purpose of an ECS key as:

> *"The key is a communication tool. It is the result of classifying a large number of vegetation samples in an organized way that allows us to better understand and communicate how forests function. It allows us to compare different forest stands across Minnesota. It provides a way to communicate our experiences in managing similar forest types. The key does not describe ecosystems or communities with defined boundaries, rather it presents abstract concepts and the typical stand conditions that can be derived from a group of ecosystem/community samples." (Almendinger 1998)*

John Almendinger and Dan Hanson gathered a significant amount of data to define vegetation of a forest found in the Northern Minnesota Drift and Lake Plain section of Minnesota. Their data collection included over 2,000 vegetative plots that were sampled in stands near rotation age, identifying 591 vascular plant taxa and 103 moss taxa (Almendinger 1998). Soil profiles were taken on over 1,200 of those plots and over 150 plots had peat/water data. (Almendinger, 1998).

After analyzing the plots, the total sample was reduced to approximately 800 plots. The analysis criteria included the elimination of similar plots within the same stands, so the sample had better diversity by eliminating over-represented soil gradients.

While each ECS level is different due to varying components, most systems were developed after an accumulation of large amounts of data, similar to Almendinger and Hanson's project. Understanding the methodology and intensity of data collection needed to develop a field key allows the user to be confident in its' validity. As resource managers, the important aspect in any Ecological Classification system is the ability of the data to withstand analysis and repeatable results. Before accepting data, there is a benefit in reviewing the analytical process from which the data originated.

In comparison, Ontario, Canada uses a system entitled the Forest Ecosystem Classification (FEC) system. The first area to be classified was the Northeast Ontario Clay Belt region termed site region 3e (Jones et al 1983). Later classifications were developed for other areas of Ontario, including Northwest Ontario. Data gathered to support this system included landform features, such as slope and aspect, soil texture, moisture and drainage. Vegetative classes surveyed were primarily 50 years and older and were considered natural forest origin. The FEC system was designed to be a field guide for resource managers at the stand level. This level may be as small as 10 ha and is very similar to the Minnesota DNR's classification of the Land Type phase. This level of detail allows managers to quickly classify a stand, yet have enough management options to address the variety of conditions located within the region. Appendix 3 includes thiry-eight vegetative types included in the Northwest Ontario Forest Ecosystem Classification.

Utilization of Ecological Classification Keys

Field keys should be thought of as a communication tool. Keys are generally the result of thousands of samples, analyzed and evaluated for similarities and patterns. Rather than reading several thousand data sets, a manager reviews the data already organized and delivered in a concise package, easy to use in the field. An example of a Field Key for the Northern Minnesota Drift and Lake Plain Section in the Minnesota ECS is shown as Appendix 1.

A key provides a way to communicate management experience on similar forest types. Keys generally don't describe a defined boundary of a forest stand, but they present a concept of how a forest stand might respond with certain soil types, topography, soils, drainage, plant associations and nutrients. It's a manager's job to apply these concepts to the individual in which they work. As with any key system, there are generally instructions to follow that guide the process of classification.

The first distinguishing aspect of the key is the determination of the broad focus land classification. In the example of the Northern Minnesota Drift and Lake Plains Section, this would include a determination of a stand as a Terrestrial Forest or Wetland Forest. The key would generally define the distinguishing characteristics of each. The example used to describe a Terrestrial forest states "...Terrestrial forests are those without evidence of flooding, or ponding, or with organic soil horizons less than 10 cm thick" (Almendinger 1998).

The second distinguishing aspect of the key is to determine the Ecological System that best characterizes the site. To accomplish this, key's are generally set up with a list of plant indicators. These plant indicators provide an accurate representative of a certain ecological classification. If the site has been highly disturbed making it difficult to categorize or if vegetation could be categorized under two systems, A further analysis of the soil properties and landform affinity may be necessary.

The third aspect of the key is to determine the Native Plant Community. The key provides two lists of diagnostic plants with the same letter description. Each plant identified in the Native plant list has a corresponding number. The instructions of the Key state "…for each list with the same letter, sum the numbers of the plants present on the site. From the list with the highest number, proceed to the next dichotomy (a,b,c...) as instructed or until the name of the community is encountered…" (Almendinger 1998). If there are sites that have plant overlap, the key recommends referencing the complete handbook for a more detailed assessment.

Becoming familiar with a ECS key may rely on a resource manager becoming more familiar with resource assessment that was not a traditional component of the job. Where trees were inventoried for basal area and site index, a manager may now need to determine dominant vegetative cover on the forest floor and sample soils for texture and productivity before making recommendations as to the silvicultural prescription of a stand. As more data is gathered, the consistency of using an established key will make the assessment more accurate and effective.

Field Implementation of the ECS by Resource Technicians:

So, how does the resource technician or manager utilize the ECS system in the field, and what are the field techniques necessary to determine a classification? The ECS classifies large and small land areas according to specific geology, climate, topography, plant communities, soil types, and other ecological factors.

This information isn't new. Common field techniques can be found throughout the scientific literature. The ECS is attempting to bring all of those sources into one single system. The initial problem with streamlining many systems into one is the problem of terminology, knowing the definitions of a Domain, Province, Division, Section, Subsection, Land Type Associate, Land Type and down to the Land Type Phase designation is the first step to understanding the system, but what about utilization?

DNR officials describe the ECS as a way to explain the ecological potential of vegetation on any piece of land. By using the tools of an ECS, land managers can merely ID plant communities and then categorize what can be expected from the ecological components of that community. To apply those tools, a technician would first need to determine several factors related to their particular application. These have been laid out in a step-by step process, for general review, but each use of the ECS may be unique, dependent upon the manager's objectives and the data available.

Step 1

Determine the objective of your project and the corresponding scale/acres evaluated.

ECS system has many scales of application ranging from the Domain at over 1:30,000,000 covering polygons of 1,000,000's of square miles to the Land Type phase at greater than 1:24,000 with polygons generally < 100 acres and even < 1 acre.

Step 2

Determine the ECS data available for your particular area.

Conduct literature searches to determine if data is available or contact resource agencies within the area to determine accessible data.

If data is lacking, research the protocol necessary to gather the missing data.

Step 3

Determine the keys required to classify according to ECS
(*e.g.* plants, trees, soil, specific habitat keys)

Step 4

Determine information necessary to utilize each key and gather field data.
A listing of typical field assessments is on the following page.

Step 5

Interpret field data and determine level of confidence in data collection, if confidence is lacking, re-evaluate Step1 and repeat data collection. If data collection appears successful, incorporate your objectives with the assistance provided by an ECS application.

Typical field assessments in an ECS

An evaluation of a forest stand may rely on the traditional location of stands. Stands may be categorized by cover type and age class, but a further evaluation of stand origin may reveal the disturbance regime critical to the ecological system. To determine stand origin, a soil core may reveal evidence of burned debris or sedimentation indicative of a flood. Large standing snags with charcoal may be one of the best clues that a fire had occurred within the stand. It may be beneficial to search the early Public Land Survey records to review vegetative communities that historically existed.

Once a stand is established, a field technician may survey the stand based on an accepted method of plot establishment. Traditionally accepted methods may utilize a line transect with pre-determined plot locations distanced along transects. Other field protocols may call for specific plot dimensions to be established within a stand, generally avoiding the edge affect of the stand. Regardless of the method for plot establishment, once at the plot, the ECS generally uses the Releve method (Grigal 1980) of vegetative sampling as a standard. To remain consistent in data collection, adoption of this method may be beneficial. Measurement of D.B.H., ages, species % cover and live leaf collection to determine organic recycling into the soil may also reveal information about site productivity.

In reviewing several applications of ECS, there is a strong emphasis on the knowledge and identification of plant communities. A resource technician would be well prepared if dominant herbaceous layers were as well known as most overstory vegetation. To assist resource technicians preparation for the Border Lakes Subsection area of Minnesota, Appendix 2 – 13 of this paper include a list of common tree, shrub and herbaceous vegetation.

Another aspect of the ECS is the topic of Relative Abundance defined as some measure of the amount of a species in a sample. Examples include the concepts of density, number of breeding pairs, biomass, basal area, frequency, cover, territorial area, presence or absence of species. Many field technicians are already gathering this data in as survey methodology on traditional resource surveys, but the ECS system requires much more detail than traditionally recorded.

Soil Characterization that corresponds with ECS data may relate to soil horizon depth, bulk density, soil texture, soil series and physiographic characteristics of drainage. These field procedures are commonly referenced in texts, but can also be found at the Natural Resource Conservation Service, Soil Manual referenced in the on-line resources section of this paper (pg 43).

To demonstrate the use of the ECS system, an example of a forest located near Grand Marais is presented. As previously stated, a resource technician should review existing data or conduct surveys of soils; topography, climate, hydrology, vegetation, as well as a detailed forest survey of the existing stand. The analysis may include an introductory description of the area as well as the more detailed vegetative data.

An example of an ECS summary for a stand:

A 45-acre forest stand located in the Border Lakes Subsection within the Northern Superior Uplands Section within the Laurentian Mixed Forest Province within the Coniferous Forest Biome. Pre-Cambrian bedrock ledges characterize this subsection and the evidence on the landscape reveal the effects of the most recent Wisconsin glaciation (retreated ~ 10,000 years ago).

The area has consistently shallow soils with exposed bedrock throughout the region. Where there are soils, they are likely derived from glacial till. Soils are best described as coarse-loamy to coarse soil textures with small amounts of sand and clay soil in the western portion of the subsection. About 5 percent of the unit are occupied by organic soils, generally confined to the Spruce bogs of the region (Pers.com. Kawishiwi Ranger District). The soils are classified as Ochrepts, with localized Aquents and Hemists according to the Soil Series maps produced at the University of Minnesota Soils Laboratory.

The slope varies significantly based on presence of bedrock and glacial till. The highest point in the subsection, as well as Minnesota, is Eagle Mountain, which has a marked elevation point of 2301 feet, but there are many area of ledge that range from 1,500 to 2,000 feet above sea level.

Climate in this subsection is traditionally known for short somewhat cool summers and long relatively cold winters. Annual precipitation averages 28 inches (71 mm) and the mean annual temperature is 2 C. Growing season length ranges from 108 to 123 days depending upon aspect. There are over 300 lakes larger than 160 acres that cover about 13% of the subsection's surface. Rivers in this subsection include the Vermillion, the Sioux, the Moose, the Portage, the Kawishiwi, and the Brule. (Heinselman, 1996)

Presettlement vegetation as studied by Heinselman (1974) described the major forest communities as jack pine forest, white pine-red pine forest, and hardwood- conifer forest. Balsam fir, white spruce, paper birch, and trembling aspen dominated the hardwood conifer mix. Stands in this section originated by a fire disturbance regime, with the average pre-settlement interval between ground fire years calculated at approximately four years. Ground fires are described as fires that are low intensity which serve the purpose of reducing understory competition. For Pre-settlement times, Heinselman calculated a 100-year average of rotation fires, a more intensive fire that rotated the stand from mature to young forest. Pollen records indicate that the fire history has not changed substantially for several thousand years (Heinselman 1973), but concern over fire suppression efforts in the last century by forest managers have caused some to question the alteration of these natural fire patterns. In the Border Lake subsection, some individual stands have been greatly affected by fire suppression efforts in the last eight decades. But, most of the subsection remains forested similar to pre-settlement vegetation due to the Wilderness designation of the Boundary Waters Canoe Area creating a remote access situation which tends to hinder suppression efforts.

The stand is comprised of *Pinus banksiana* indicator as the dominant overstory tree with an age class of 98 years, Site Index of 58, Basal area of 60 sq.feet per acre, yielding 18 cords per acre. The *Pinus banksiana* dominates in the understory with a recent ground fire producing 2,000 stems per acre regeneration, with scattered *Acer rubrum* understory. The dominant herbaceous layer has areas of dense *Vaccinium*. A forest resource technician may continue the data collection process to include soil sampling, watershed drainage, topography and climate if necessary.

This summary is far more detailed than the traditional forest stand survey may reveal and much of the ECS success is based on a technician's ability to adapt to a broader focus of resource knowledge than traditionally required. An entry-level resource technician may find more challenges to conducting field surveys than were encountered in previous decades. One suggestion to the technician, develop a strong knowledge base of forest communities and associations of both flora and fauna. In preparation for this MF report, field surveys and literature research were conducted in order to provide some examples of forest and non-forest plant communities within the Border Lakes subsection. This research revealed twelve characteristic communities common in this area. While this is not an all-inclusive list, it can be a good reference for the technician attempting to categorize a stand based on the concept of ECS communities. (see Appendices 2 a –2 l).

Case Studies of ECS

The following are examples of ECS implemented in the field as presented by John Almendinger (1997).

Kettle River Plant Restoration:

At Banning State Park in central Minnesota, ECS Land Type Phase (ELTP), the smallest classification in the ECS system was used to characterize attributes such as bedrock types, water table depth, slope gradient, characteristic rare plants and animals, as well as many other factors. When the Kettle River Dam, located within the park, was removed in 1992, the lake behind it reverted to a river for the first time since 1906. Data from ECS Land Type Phase several miles upstream (similar to the area formerly covered by the impoundment) worked as a template to guide plant species selection toward restoring the newly exposed shoreline. The NR specialist allowed the land and vegetation to tell the managers what would be best based on what naturally occurred in an area of similar attributes (Almendinger 1997).

Minnesota State Power Right of Way Spraying:

In 1995, Minnesota State Power (MSP) used the concept of ECS when attempting to control trees and shrubs under power lines. In areas of shallow groundwater, the application of a killing dose of herbicides by MSP was previously a concern due to the close relationship between the groundwater and metropolitan drinking water sources. MSP technicians read bedrock geology information contained on the ECS Land Type Phase maps, making it possible to avoid using chemicals in areas that would potentially contaminate groundwater. By accurately matching the geology of the area to the rate of application of herbicides, MSP reduced herbicide applications by more than 65 percent, with limited effect to the kill rate of the herbicide. This reduced the amount of potential contamination in shallow systems, ultimately reducing a potential environmental catastrophe. (Almendinger 1997)

Red-Shouldered Hawk Wildlife Project:

Wildlife biologists had noticed some changes in local population numbers of red-shouldered hawks. Observationally, the impression was that red-shouldered hawks were becoming increasingly rare due to the loss of large unbroken forest habitat necessary for their feeding and reproductive needs. A method of surveying nest use within a territory uses tape-recorded hawk screams in hopes of getting a response from an occupied and defended territory. After plotting these proven responses and corresponding territories, ECS Land Type Associations were overlaid to determine a pattern to Hawk territories. The ECS Land Type Associations represented forest stands of 1,000 to 10,000 acres and showed areas defined by glacial formations, parent rock origins, topographic details, watershed and wetland patterns and broad forest types. The sites where hawks responded with a territorial defense call, fit almost exactly into a specific LTA containing hilly hardwood forests interspersed with wetlands. (Almendinger 1997) This comparative showed a clear pattern to the Hawk's territories indicating distinct areas of location based on soil types and other significant ecological features rather than a random pattern as previously believed.

Similar success was achieved by DNR biologists mapping known sharp-tailed grouse mating habitat in conjunction with Land Type Association maps. There was good correlation between the Ecological Land Types and the known habitat boundaries of sharp-tail, thereby giving biologists a better understanding of what constituted viable sharp-tail habitat. The ECS system may be able to give managers the ability to predict where a species may be found or where management plans may never be successful due to ecological limitations. If managers can refine their efforts to the areas where success can almost be predicted, it will make investing limited resources of time and money more efficient. This efficiency will not only be evident economically, but in the health of the ecosystem as well.

Conclusion

The ultimate goal of an Ecological Classification System (ECS) is to provide a method for physical and biological information to be categorized in a standard format that managers can review and incorporate into their traditional management plans or modify their techniques to incorporate an ECS format. Several practical examples were presented in this MF report, which provided good anecdotal support for the system. Certainly there will be many more examples to follow as more managers utilize this system.

The most important feature relates to an ECS as a tool to allow resource managers the opportunity to communicate with managers throughout the resource disciplines. Certainly, it's obvious that resource managers will be able to communicate better if all are using the same system. But more importantly, resource managers may develop a better understanding of the environment's capabilities for supporting a forest or wetland, providing wildlife habitat, producing a certain plant species, or having a unique aesthetic appeal, etc. With a better understanding, it is only logical that better decisions will be made and the standard format will allow successes to be shared and adopted more easily among agencies of state, county and federal origins, as well as internationally.

Entry-level resource technicians have an opportunity to begin their careers in a new an innovative way by adopting the philosophy of an ECS and following through with the detailed field assessments necessary to succeed. The ability to share information with fellow colleagues in multiple disciplines will only be an enhancement to a career, which already carries with it a strong sense and obligation of land stewardship.

To accurately use ECS, a resource technician must become familiar with terminology and data available from traditional sources as well as online sources. Table II denotes some internet web sites that provide detailed information related to ECS as well as other resource data.

Table II. Internet web sites related to ECS, soil surveys and forest planning.

Great Lakes Ecological Assessment	http://econ.usfs.msu.edu/gla/
USDA Soil Survey Manual	http://www.statlab.iastate.edu/ssmnew/chap3toc.html
Minnesota DNR -ECS	(http://www.dnr.state.mn.us/ebm/ecs/index.html)
Interagency Information Cooperative	http://www.iic.state.mn.us/finfo/ecs/
Canadian Soil Taxonomy	http://www.soils.rr.ualberta.ca/correlations/index.cfm
Subsection Forest Planning	http://www.dnr.state.mn.us/forestrv/subsection/index.html

A strong motivation for the Minnesota DNR to incorporate an ECS was the increasing environmental issues that focused on a variety of issues from general pollution to the loss of biodiversity of both plants and animals in Minnesota. The goals of implementing ECS into traditional resource management professions include the increased predictive nature that accompanies a better understanding of the ecological system. The more familiar managers are with their classifications, the better the ability to predict where a species may be naturally found and what has been successful in other applications of a similar land classification. If a success can be repeated on multiple scales in multiple management settings, it is inevitable that the health of an ecosystem will improve, and isn't that why resource managers entered the field? If ecosystem health is not deemed a motivating factor, then possibly the opinion of the Minnesota public can motivate managers to adopt this concept.

The attitudes of society tend to be changing from supportive of resource extraction to be more concerned with the effects of resource extraction on the overall ecological system. The use of ECS can be viewed as a new tool to understand the relationships between single resource components and the entire ecological system. For a resource technician to use this tool, they must learn to combine existing inventories and data focused on single components of ecosystems such as timber, water, wildlife or soil, to develop a broad-spectrum overview of the landscape. Resource technicians must come to the field equipped with the necessary guides, tools and tally sheets available to a gather the data to complete and accurate ECS, if a particular aspect of a resource is unfamiliar, conduct a literature search or resource database to get the information needed. This information may not be restricted to government agencies.

Recent state legislation in Minnesota is driving the Minnesota DNR to move toward an integrated approach for all resource projects. The legislative directive is to involve private citizens in the goal for better resource management by developing shared management goals for ecosystems. This is another example of where ECS can provide a common ground of communication between the various disciplines within resource management. It is the goal of the resource technician to learn the tools of ECS so that they can speak the language of the future.

Literature Cited

Almendinger, J. and D. Hanson. 1998. Identification, description and ecology of forested, native plant communities. Draft manual, MN DNR Publ., Grand Rapids, MN. iii + 86 pp.

Almendinger, J., 1997. Now you're talking my language. Fish and Wildlife Today. MN DNR Publication, St. Paul, MN. 6 pp.

Barnes, B.V. 1984, Forest land classification: experiences, problems, perspectives. Proceedings of the Symposium. March, 1984. Univ. of Wisconsin, Madison, WI. 110 pp.

Curtis, J. T. 1959. The vegetation of Wisconsin: an ordination of plant communities. Univ. of Wisconsin Press, Madison, WI. 39 pp.

ECOMAP. 1993. National hierarchical framework of ecological units. Unpublished administrative paper. U.S. Dept. Agr., Forest Service. Washington, D.C. 20 pp.`

Gleason, H. A. 1926. The individualistic concept of the plant association. Bull. of the Torrey Bot. Club 53:7-26

Grigal, D.F. and L.K Kernik. 1980. Floristic analysis of the ecological land types of the Chippewa National Forest. Unpublished report. U.S. Dept. of Agr., Chippewa National Forest. Cass Lake, MN. 23 pp.

Grigal, D.F. and H.F. Arneman. 1970. Quantitative relationships among vegetation and soil classification from northeastern Minnesota. Can. J. Bot. 48: 555-568.

Grossman, D., K Goodin, X. Li, and D. Faber-Langendoen. 1994. Standardized National Vegetation Classification System Manual. Admin. Man. U.S. Geo. Sur., Washington, D.C. 86 pp.

Heinselman, M.L. 1996. The boundary waters wilderness ecosystem. Univ. Minnesota Press. St. Paul, MN. 334pp.

Heinselman, M.L. 1974. Interpretation of Marschner's map of original vegetation of Minnesota. United States Forest Serv. Bull. St. Paul, MN. 4 pp.

Heinselman, M.L. 1973. Fire in the virgin areas of the Boundary Waters Canoe Area, Minnesota. Quaternary Res. 3:329-82

Host, G. and J. Pastor. 1998. Modeling forest succession among ecological land units in northern Minnesota. Conservation Ecology 15: 12 pp. October 20,2000.

Host, G. E., C. W. Ramm, E. A. Padley, K. S. Pregitzer, J. B. Hart and D. T. Cleland. 1993. Field sampling and data analysis methods for development of ecological land classifications: an application on the Manistee National Forest. North Central Forest Experiment Station General Technical Report NC-162. 47 pp.

Host, G. E. and K. S. Pregitzer. 1991. Ecological species groups for upland forest ecosystems of northwestern Lower Michigan. Forest Ecol. and Management 43:87-102.

Host, G. E., K. S. Pregitzer, C. W. Ramm, D. P. Lusch and D. T. Cleland. 1988. Variation in overstory biomass among glacial landforms and ecological land units in northwestern Lower Michigan. Canad. J. Forest Res.18:659-668.

Host, G. E., K. S. Pregitzer, C. W. Ramm, J. B. Hart and D. T. Cleland. 1987. Landform-mediated differences in successional pathways among upland forest ecosystems in northwestern Lower Michigan. Forest Sci. 33:445-457.

Howard, J. A. and C. W. Mitchell. 1985. Phytogeomorphology. John Wiley and Sons, NY, NY.

Johnson, L. B., G. E. Host, J. K. Jordan and L. L. Rogers. 1991. Use of GIS for landscape design in natural resources management: habitat assessment and management for female black bear. Proceedings of GIS/LIS. 507-517.

Jones, R.K, G. Pierpoint, G. Wickware, J. Jegium, R. Arnup and J. Bowles. 1983. Field guide to forest ecosystem classification for the clay belt, site region 3e. Ontario Ministry of Natural Resources, Maple, Ontario. 161 pp.

Kent, M. and P. Coker. 1992. Vegetation description and analysis: a practical approach. CRC Press, Boca Raton, FL.

McNab, W.H. and P.E. Avers. 1994. Ecological subregions of the United States: section descriptions. WO-WSA-5. Washington, DC: U.S. Dep. Agr. Forest Serv. ECOMAP Team. 267 p.

Soil Survey Staff, U.S. Department of Agriculture, 1951. Soil survey manual. U.S. Dept. of Agr. Handbook 18. 21 pp.

Whittaker, R. H. 1953. A consideration of climax theory: the climax as a population and pattern. Ecol. Monog. 23:41-78.

Appendix 1: Field Key for Northern Minnesota Drift and Lake Plain Section of the Ecological Classification System

FIELD KEY TO FORESTED NATIVE PLANT COMMUNITIES

Draft Version 1.0
J.C. Almendinger & D. S. Hanson
June 1998

NORTHERN MINNESOTA DRIFT & LAKE PLAIN SECTION

This field key applies to all forested communities in the Northern Minnesota Drift & Lake Plain ecological Section. This is one of ten Sections in Minnesota, and is broadly characterized as a region of young, deep, calcareous drift within the Laurentian Mixed Forest ecological Province. This ecological Section contains entirely Hubbard and Cass Counties and portions of Clearwater, Beltrami, Koochiching, Itasca, St. Louis, Carlton, Aitkin, Crow Wing, Morrison, Todd, Wadena, Otter Tail, Becker, Mahnomen, and Polk counties.

Terrestrial Forests

FIRE-DEPENDENT PINE/OAK SYSTEM

Component Native Plant Communities

- Poor Pine Forest
- Dry Pine/Oak Woodland
- Dry Pine Forest
- Dry-Mesic Pine/Oak Forest
- Dry-Mesic Pine Forest

Typical Soil Properties

Mor soil humus, commonly with charcoal at the contact with mineral soil; surface texture sandy loam or coarser; no water-impeding subhorizons; excessively to well-drained, lacking 2-chroma colors OR standing water in the upper two meters.

Landform Affinity

Outwash plains, dunes, deltas, kames, eskers, beaches, sand-capped stagnation moraine

Plant Indicators

Jack Pine, trees and understory (*Pinus banksiana*)
Red Pine, understory only (*Pinus resinosa*)
White Pine, trees only (*Pinus strobus*)
Prairie Willow (*Salix humilis*)
Snowberry (*Symphoricarpos albus*)
Blackberry (*Rubus occidentalis* complex)
Wintergreen (*Gaultheria procumbens*)
Pipsissewa (*Chimaphila umbellata*)
Ground Cedar (*Lycopodium complanatum* complex)
Cow-Wheat (*Melampyrum lineare*)
Poverty Grass (*Danthonia spicata*)
Feathermoss (*Pleurozium schreberi*)

MESIC HARDWOOD SYSTEM

Component Native Plant Communities

- Mesic Oak Forest
- Mesic Boreal Hardwood Forest
- Mesic Northern Hardwood Forest
- Rich Hardwood Forest
- Lowland Hardwood-Conifer Forest

Typical Soil Properties

Moder or mull soil humus with little or no charcoal at the contact with mineral soil; surface texture sandy loam or finer; typically with water-impeding subhorizon(s) often with some 2-chroma colors associated with the water-impeding horizon; well- to somewhat-poorly drained; standing water or gleyed subsoils generally deeper than 1m if present

Landform Affinity

Till plains, lake plains, drumlin fields, inactive alluvial terraces, stagnation moraine without sand caps OR with sand caps shallower than about 2m

Plant Indicators

Sugar Maple, trees only (*Acer saccharum*)
Ironwood, trees and understory (*Ostrya virginiana*)
Basswood, trees only (*Tilia americana*)
Leatherwood (*Dirca palustris*)
Common Pyrola (*Pyrola elliptica*)
Zig-Zag Goldenrod (*Solidago flexicaulis*)
Yellow Violet (*Viola pubescens*)
Shorthusk (*Brachyelytrum erectum*)
Bottlebrush Grass (*Elymus hystrix*)

Wetland Forests

FLOODPLAIN FOREST SYSTEM

Component Native Plant Communities

- Floodplain Forest

Typical Soil Properties

Soil humus absent OR accumulated from flotsam or higher terraces; soil texture sandy to silty and obviously stratified; flooded in most springs and usually well-drained to the water table by mid-summer

Landform Affinity

Active floodplains and point bars on rivers or streams

Plant Indicators

Silver Maple, trees and understory (*Acer saccharinum*)
Black Willow, trees and understory (*Salix nigra*)
Box Elder, trees and understory (*Acer negundo*)
Canada Anemone (*Anemone canadensis*)
Wild Cucumber (*Echinocystis lobata*)
Smooth Hedge-Nettle (*Stachys tenuifolia*)
Smaller Forget-Me-Not (*Myosotis laxa*)
Ontario Aster (*Aster ontarionis*)
Golden Alexanders (*Zizia aurea*)
Reed Canary-Grass (*Phalaris arundinacea*)

MINERAL-RICH WETLAND SYSTEM

Component Native Plant Communities

- Semiterrestrial Black Ash Forest
- Semiterrestrial White Cedar Forest
- Black Ash Swamp
- White Cedar Swamp
- Tamarack Swamp

Typical Soil Properties

Organic soils generally deeper than 10cm; most commonly amorphous, humified muck OR peat composed of minerotrophic *Sphagnum* mosses in Tamarack Swamp; interstitial water pH>6.4

Landform Affinity

Closed depressions, bases of slopes, or drains of any mineral-soil landform

Plant Indicators

N. White Cedar, trees and understory (*Thuja occidentalis*)
Goldthread (*Coptis groenlandica*)
Marsh-Marigold (*Caltha palustris*)
Long-Leaved Chickweed (*Stellaria longifolia*)
Red-Stemmed Aster (*Aster puniceus*)
Northern Bugleweed (*Lycopus uniflorus*)
Spotted Water-Hemlock (*Cicuta bulbifera*)
Crested Fern (*Dryopteris cristata*)
Fowl Manna-Grass (*Glyceria striata*)
Inland Sedge (*Carex interior*)
Soft-Leaved Sedge (*Carex disperma*)
Bristle-Stalked Sedge (*Carex leptalea*)
Magnificent Moss (*Plagiomnium cuspidatum* or *P. ellipticum*)

ACID PEATLAND SYSTEM

Component Native Plant Communities

- Forested Poor Fen
- Forested Bog

Typical Soil Properties

Organic soils generally deeper than 1m; composed of *Sphagnum* moss peat; hummock-and-hollow microtopography well-developed; interstitial water pH<6.4, usually<4.5

Landform Affinity

Raised peatlands, centers of large peatlands, or the interiors of small peatlands with well-developed moats of any mineral-soil landform

Plant Indicators

Cotton-Grass (*Eriophorum*, any species)
Few-Flowered Sedge (*Carex pauciflora*)
Few-Seeded Sedge (*Carex oligosperma*)
Sphagnum Moss, (*Sphagnum*, all peatland species except *S. warnstorfii*)

INSTRUCTIONS

First, determine which side of the key to use. Terrestrial Forests are on this side and Wetland Forests are on the reverse side. Terrestrial forests are those without evidence of flooding, or ponding, or with organic soil horizons less than 10cm thick.

Second, determine which **Ecological System** characterizes the site. This is done primarily by comparing the **Plant Indicators** listed for the Systems with the plants on the site. The plant indicators selected are widespread plants that have high fidelity within the Ecological System. If the vegetation is highly disturbed OR if the number of plant indicators present is roughly equal for two Systems, then use the **Typical Soil Properties and Landform Affinity** to help you determine the right System.

Third, use the dichotomous Keys presented below each Ecological System to determine the Native Plant Community. Each dichotomy presents two lists of diagnostic plants with the same letter, beginning with "a." The plant names are followed by numbers. For each list with the same letter, sum the *numbers* of the plants present on the site. From the list with the highest number, proceed to the next dichotomy (b,c, etc.) as instructed OR until you encounter the name of the community.

Hints ...

- For trees, pay attention as to whether they are diagnostic in the understory or overstory.
- If a Community dichotomy or System decision is difficult or ambiguous, try both key pathways.
- For difficult sites, prepare a list of plants on the site and compare your field notes with the full description of the Native Plant Community in the ELC Handbook that is a companion to this field key.

KEY TO THE NATURAL COMMUNITIES OF THE FIRE-DEPENDENT PINE/OAK SYSTEM

a.
Bearberry (*Arctostaphylos uva-ursi*) 6
Balsam Ragwort (*Senecio pauperculus*) 5
Gray Goldenrod (*Solidago nemoralis*) 4
Smooth Aster (*Aster laevis*) 3
Trailing Arbutus (*Epigaea repens*) 2
Jack Pine understory (*Pinus banksiana*) 1 .... go to b.

b.
Sky-Blue Aster (*Aster oolentangiensis*) 5
Carrion-Flower (*Smilax herbacea* or *S. lasioneura*) 4
Hawthorn (*Crataegus* spp.) 3
Yarrow (*Achillea millefolium*) 2 ....

... DRY PINE-OAK WOODLAND

b.
Trailing Arbutus (*Epigaea repens*) 5
Upright bindweed (*Convolvulus spithamaeus*) 4
Balsam Fir understory (*Abies balsamea*) 3
Two-flowered Cynthia (*Krigia biflora*) 1
Velvet-Leaved Blueberry (*Vaccinium myrtilloides*) 1 .... go to c

c.
Wood-Betony (*Pedicularis canadensis*) 4
Smooth Aster (*Aster laevis*) 3
Balsam Ragwort (*Senecio pauperculus*) 2
Bearberry (*Arctostaphylos uva-ursi*) 1 ....

... POOR PINE FOREST

c.
Fly Honeysuckle (*Lonicera canadensis*) 4
Red Maple understory (*Acer rubrum*) 3
Mountain Rice-Grass (*Oryzopsis asperifolia*) 2
Bracken (*Pteridium aquilinum*) 1 ....

... DRY PINE FOREST

a.
Rosy Twisted-Stalk (*Streptopus roseus*) 6
Yellow Bellwort (*Uvularia grandiflora*) 5
Round-Lobed Hepatica (*Hepatica americana*) 4
Hairy Solomon's-Seal (*Polygonatum pubescens*) 3
Red Maple understory (*Acer rubrum*) 2
Lady-Fern (*Athyrium angustum*) 1 .... go to d.

d.
Gray Dogwood (*Cornus foemina*) 6
Black Cherry (*Prunus serotina*) 5
Blue Giant-Hyssop (*Agastache foeniculum*) 4
Poison Ivy (*Rhus radicans*) 3
Wild Rose (*Rosa acicularis* or *R. blanda*) 2
Downy Violet (*Viola pubescens* or *V. canadensis*) 1 ....

... DRY-MESIC PINE/OAK FOREST

d.
Gaywings (*Polygala paucifolia*) 6
Green Alder (*Alnus viridis*) 5
Running Clubmoss (*Lycopodium clavatum*) 4
Fly Honeysuckle (*Lonicera canadensis*) 3
Balsam Fir understory (*Abies balsamea*) 2
Bunchberry (*Cornus canadensis*) 1 ....

... DRY-MESIC PINE FOREST

KEY TO THE NATURAL COMMUNITIES OF THE MESIC HARDWOOD SYSTEM

a.
Maidenhair Fern (*Adiantum pedatum*) 6
Lopseed (*Phryma leptostachya*) 5
Blue Cohosh (*Caulophyllum thalictroides*) 4
Jack-in-the-Pulpit (*Arisaema triphyllum*) 3 ....

... RICH HARDWOOD FOREST

a.
Spreading Dogbane (*Apocynum androsaemifolium*) 6
Round-Leaved Dogwood (*Cornus rugosa*) 5
Pale Vetchling (*Lathyrus ochroleucus*) 4
Bracken (*Pteridium aquilinum*) 3
Quaking Aspen understory (*Populus tremuloides*) 1
Pale Bellwort (*Uvularia sessilifolia*) 1 .. go to b.

b.
Spotted Water-Hemlock (*Cicuta maculata*) 6
Swamp Red Currant (*Ribes triste*) 5
Palmate Sweet Coltsfoot (*Petasites frigidus*) 4
Bladder Sedge (*Carex intumescens*) 3
Naked Mitrewort (*Mitella nuda*) 2
Bunchberry (*Cornus canadensis*) 1 ....

... LOWLAND HARDWOOD-CONIFER FOREST

b.
Leatherwood (*Dirca palustris*) 6
Pointed-Leaved Tick-Trefoil (*Desmodium glutinosum*) 5
Ironwood understory (*Ostrya virginiana*) 4
Lowbush Blueberry (*Vaccinium angust.*) 3
Red Oak understory (*Quercus rubra*) 2
Wild Honeysuckle (*Lonicera dioica*) 1 .. go to c.

c.
Yellow Birch any size (*Betula alleghaniensis*) 6
Common Oak-Fern (*Gymnocarpium dryop.*) 5
Jack-in-the-Pulpit (*Arisaema triphyllum*) 4
Wild Ginger (*Asarum canadense*) 3
Zig-Zag Goldenrod (*Solidago flexicaulis*) 2
Rattlesnake-Fern (*Botrychium virginianum*) 1 ....

... NORTHERN HARDWOOD FOREST

c.
Black Cherry (*Prunus serotina*) 6
Lowbush Blueberry (*Vaccinium angust.*) 5
Columbine (*Aquilegia canadensis*) 4
Poison Ivy (*Rhus radicans*) 3
Round-Lvd Dogwood (*Cornus rugosa*) 2
One-sided Pyrola (*Pyrola secunda*) 1 ..go to d.

d.
Peduncled Sedge (*Carex pedunculata*) 6
Green-Fl. Pyrola (*Pyrola chlorantha*) 5
Rattlesnake-Fern (*Botrychium virgin.*) 4
Leatherwood (*Dirca palustris*) 3
Ironwood understory (*Ostrya virginiana*) 2 ....

... MESIC BOREAL HARDWOOD FOREST

d.
Northern Bedstraw (*Galium boreale*) 6
Red Raspberry (*Rubus strigosus*) 5
Wild Rose (*Rosa acicularis* or *R. blanda*) 4
Spreading Dogbane (*Apocynum androsaem.*) 3
Wild Honeysuckle (*Lonicera dioica*) 2
Red Maple understory (*Acer rubrum*) 1 ..

... MESIC OAK FOREST

KEY TO THE NATURAL COMMUNITIES OF THE MINERAL-RICH WETLAND SYSTEM

a. Leatherleaf (*Chamaedaphne calyculata*) 3
Bog Willow (*Salix pedicellaris*) 2
Marsh Cinquefoil (*Potentilla palustris*) 1 ....

... **TAMARACK SWAMP**

a. Black Ash, understory (*Fraxinus nigra*) 3
Alder-Leaved Buckthorn (*Rhamnus alnifolia*) 2
Blue-bead Lily (*Clintonia borealis*) 1 .... go to b.

b. Wood Nettle (*Laportea canadensis*) 3
Side-Flowering Aster (*Aster lateriflorus*) 2
Mad-Dog Skullcap (*Scutellaria lateriflora*) 1 .... go to c.

c. Flat-Topped Aster (*Aster umbellatus*) 3
Rosey Twisted-Stalk (*Streptopus roseus*) 2
Rattlesnake-Fern (*Botrychium virginianum*) 1 ....

... **SEMITERRESTRIAL BLACK ASH FOREST**

c. Water-Parsnip (*Sium suave*) 3
Interior Sedge (*Carex interior*) 2
Bluejoint Grass (*Calamagrostis canadensis*) 1 ....

... **BLACK ASH SWAMP**

b. Labrador Tea (*Ledum groenlandicum*) 3
Small N. Bog-Orchid (*Platanthera obtusata*) 2
Goldthread (*Coptis groenlandica*) 1 .... go to d.

d. Beaked Hazel (*Corylus cornuta*) 4
Spurred Gentian (*Halenia deflexa*) 3
Common Oak-Fern (*Gymnocarpium dryopteris*) 2
Kidney-Leaf Violet (*Viola renifolia*) 1 ....

... **SEMITERRESTRIAL WHITE CEDAR FOREST**

d. Small Cranberry (*Vaccinium oxycoccus*) 4
Heartleaf Twayblade (*Listera cordata*) 3
Poor Sedge (*Carex paupercula*) 2
Marsh Skullcap (*Scutellaria galericulata*) 1 ....

... **WHITE CEDAR SWAMP**

KEY TO THE NATURAL COMMUNITIES OF THE ACID PEATLAND SYSTEM

a. Few-Seeded Sedge (*Carex oligosperma*) 3
Tufted Cotton-Grass (*Eriophorum spissum*) 2 ....

... **FORESTED BOG**

a. Wire-Sedge (*Carex lasiocarpa*) 3
Creeping Sedge (*Carex chordorrhiza*) 2
Buckbean (*Menyanthes trifoliata*) 1 ....

... **FORESTED POOR FEN**

Appendix 2a – 2l: Plant Communities in the Border Lakes Subdivision of the Ecological Classification System

Appendix: 2a. Alder Cover type

Characteristics:

The Alder/Willow Wetland, slow moving subsurface water with dense, nearly impenetrable cover of tall shrubs

Indicator Species:	
Speckled Alder	*Alnus rugosa*
Willows	*Salix pedicellaris*
Associated Trees:	
Black Spruce	*Picea mariana*
Associated Shrubs:	
Green Alder	*Alnus crispa*
Dogwood	*Cornus stolonifera*
Winterberry	*Ilex verticillata*
Sweet Gale	*Myrica gale*
Meadowsweet	*Spirea alba*
Highbush Cranberry	*Viburnum opulus*
Labrador Tea	*Ledum groenlandicum*
Late Low Blueberry	*Vaccinium angustifolium*
Associated Herbaceous:	
White Panicled Aster	*Aster lanceolatus*
Bluejoint Reedgrass	*Calamagrostis canadensis*
Marsh Bellflower	*Campanula aparinoides*
Joe Pye Weed	*Eupatorium maculatum*
Boneset	*Eupatorium perfoliatum*
Sensitive Fern	*Onoclea sensibilis*
Arrowleaf Tearthumb	*Polygonatum sagittatum*
Green Bulrush	*Scirpus atrovirens*
Marsh Fern	*Thelypteris palustris*

Appendix: 2b. Sphagnum Bog/Successional Black Spruce Forest Cover Type

Characteristics:

The Sphagnum/Black Spruce Bog is characterized by shallow open water, floating mats of vegetation, and waterlogged peat

Indicator Species:	
Cotton Grass	*Eriophorum vaginatum*
Leatherleaf	*Chamaedaphne calyculata*
Wool Fruited Sedge	*Carex lasiocarpa*
Purple Pitcher Plant	*Sarracenia purpurea*
Sphagnum Moss	*Sphagnum girgensohnii*
Associated Trees:	
Black Spruce	*Picea mariana*
Tamarack	*Larix laricina*
Associated Shrubs:	
Bog Birch	*Betula pumila*
Bog Rosemary	*Andromeda glaucophylla*
Leatherleaf	*Chamaedaphne calyculata*
Bog Laurel,	*Kalmia polifolia*
Large Cranberry,	*Vaccinium macrocarpon*
Small Cranberry,	*Vaccinium oxycoccus*
Associated Herbaceous:	
Wool Fruited Sedge,	*Carex lasiocarpa*
Purple Pitcher Plant,	*Sarracenia purpurea*
Round Leaf Sundew,	*Drosera rotundifolia*
Wild Calla or Water Arum,	*Calla palustris*

Appendix: 2c. Cedar Swamp Cover Type

Characteristics:

Peat depth of 1' - 10', surface of humocks and hollows with water flow generally just below the surface, pH of 6.0 - 7.0, relatively rich in magnesium, calcium, and other nutrients

Indicator Species:

White Cedar	*Thuja occidentalis*
Black Ash	*Fraxinus nigra*

Associated Trees:

White Cedar	*Thuja occidentalis*
Tamarack	*Larix laricina*
Black Spruce	*Picea mariana*
Balsam Fir	*Abies balsamea*
Paper Birch	*Betula papyrifera*

Associated Shrubs:

Speckled Alder	*Alnus rugosa*
Red Osier Dogwood	*Cornus stolonifera*
Leatherleaf	*Chamaedaphne calyculata*
Bunchberry	*Cornus canadensis*
Creeping Snowberry	*Gaultheria hispidula*
Labrador Tea	*Ledum groenlandicum*
Twinflower	*Linnea borealis*
Marsh Cinquefoil	*Potentilla palustris*
Dewberry	*Rubus pubescens*
Willows	*Salix pedicelle*
American Yew	*Taxus canadensis*
Late Low Blueberry	*Vaccinium angustafolia*
Velvet Leaf Blueberry	*Vaccinium myrtilloides*

Cedar Swamp Continued

Associated Herbs:

Marsh Marigold	*Caltha palustris*
Two Seeded Sedge	*Carex disperma*
Three Seeded Sedge	*Carex trisperma*
Blue Bead Lily	*Clintonia borealis*
Goldthread	*Coptis trifolia*
Wood Horsetail	*Equisetum sylvaticum*
Tawny Cotton Grass	*Eriophorum virginicum*
Orange Jewelweed	*Impatiens capensis*
Canada Mayflower,	*Maianthemum canadense*
Naked Mitrewort	*Mitella nuda*
Cinnamon Fern	*Osmunda cinnamomea*
Bog False Solomon's Seal	*Smilacina stellata*
Starflower	*Trientalis borealis*
Wild White Violet	*Viola macloskeyi*
Runnng Clubmoss	*Lycopodium clavatum*
Stiff Clubmoss	*L. annotinum*
Blue Flag Iris	*Iris versicolor*
One-Sided Pyrola	*Pyrola secunda*
Rough Bedstraw	*Galium asprellum*
Ciliolate Aster	*Aster ciliolatus*
Club Spur Orchid	*Platanthera orbiculata*
Blunt Leaf Orchid	*P. obtusata*

Appendix: 2d. Muskeg and Marsh Cover Type

Characteristics: generally standing water with limited tree cover

Signature Species	
Blue Flag Iris	*Iris versicolor*
Cattail	*Typha latifolia*
Associated Trees:	
Black Spruce	*Picea mariana*
Associated Shrubs:	
Speckled Alder	*Almus rugosa*
Labrador Tea	*Ledum groenlandicum*
Late Low Blueberry	*Vaccinium angustifolium*
Associated Herbs:	
Sedge	*Carex vaginata*

Appendix: 2e. Surface Waters and Margins with open H_20 Cover Type

Characteristics:

Generally small, slow moving, shallow, and muddy bottomed water with shores that support marsh or bog communities

Associated Trees:

Black Spruce	*Picea mariana*

Associated Shrubs:

Speckled Alder	*Alnus incana*
Labrador Tea	*Ledum groenlandicum*
Late Low Blueberry	*Vaccinium angustifolium*

Herbs

Sedge	*Carex brunnescens*

Ground Cover

Feather Moss	*Ptilium crista-castrensis*
Spiky Dicranum Moss	*Dicranum flagellare*
Hair Cap Mosses	*Polytrichum commune*
Sphagnum Moss	*Sphagnum fuscum*

Appendix: 2f. Spruce/Fir Forest Cover Type

Characteristics:

Cool moist, climax forest

Indicator Species:

Balsam Fir	*Abies balsamea*
White Spruce	*Picea glauca*
Paper Birch	*Betula papyrifera*

Sub-types Species:

The Black Spruce/Feathermoss Community
The Fir/Birch Community
The Upland White Cedar Community

The Black Spruce/Feathermoss Community

Indicator Trees:

Black Spruce	*Picea mariana*
Jack Pine	*Pinus banksiana*
Balsam Fir	*Abies balsamea*
Quaking Aspen	*Populus tremuloides*
Paper Birch	*Betula papyrifera*
White Spruce	*Picea glauca*

Indicator Shrubs:

Mountain Maple	*Acer spicatum*
Bunchberry	*Cornus canadensis*
Beaked Hazel	*Corylus cornuta*
Low Bush Honeysuckle	*Diervilla lonicera*
Trailing Arbutus	*Epigea repens*
Twinflower	*Linnaea borealis*
Late Low Blueberry	*Vaccinium angustifolium*

Indicator Herbaceous:

Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Moccasin Flower	*Cypripedium acaule*
Canada Mayflower	*Maianthemum canadense*

Ground Cover

Dicranum Mosses	*Dicranum polysetum*
Running Clubmoss	*Lycopodium clavatum*
Schreber's Feathermoss	*Pleurozium schreberi*
Hair Cap Moss	*Polystrichum commune*

Spruce/Fir Forest Continued:

Plants of the Fir/Birch Community

Associated Trees:

Balsam Fir	*Abies balsamea*
Paper Birch	*Betula papyrifera*
Black Spruce	*Picea mariana*
White Cedar	*Thuja occidentalis*
White Spruce	*Picea glauca*
Quaking Aspen	*Populus tremuloides*

Associated Shrubs:

Moose Maple	*Acer spicatum*
Bunchberry	*Cornus canadensis*
Beaked Hazel	*Corylus cornuta*
Low Bush Honeysuckle	*Diervilla lonicera*
Twinflower	*Linnaea borealis*
Dewberry	*Rubus flagellaris*

Associated Herbaceous:

Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Blue Bead Lily	*Clintonia borealis*
Canada Mayflower	*Maianthemum canadense*
Sweet Bedstraw	*Galium asprellum*
Rose Twisted Stalk	*Streptopus rosea*
Starflower	*Trientalis borealis*
Violets	*Viola septentrionale*

Ground Cover

Spiky Dicranum Moss	*Dicranum flagellare*
Ground Pine Clubmoss	*Lycopodium obscurum*
Schreber's Feathermoss	*Pleurozium schreberi*

Plants of the Upland White Cedar Community

Associated Trees:

White Cedar	*Thuja occidentalis*
Balsam Fir	*Abies balsamea*
Paper Birch	*Betula papyrifera*
White Spruce	*Picea glauca*

Associated Tall Shrubs:

Mountain Maple	*Acer spicatum*
Red Osier Dogwood	*Cornus sericea*
American Yew	*Taxus canadensis*

Spruce/Fir Forest Continued:

Associated Short Shrubs:	
Bunchberry	*Cornus canadensis*
Twinflower	*Linnaea borealis*
Dewberry,	*Rubus flagellaris*
Thimbleberry	*Rubus parvifolia*
Associated Herbaceous:	
Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Blue Bead Lily	*Clintonia borealis*
Gold Thread	*Coptis trifolia*
Sweet Bedstraw	*Galium triflorum*
Canada Mayflower	*Maianthemum canadense*
Naked Mitrewort	*Mitella nuda*
One Flowered Pyrola	*Moneses uniflora*
One Sided Pyrola	*Pyrola secunda*
Rose Twisted Stalk	*Streptopus rosea*
Starflower	*Trientalis borealis*
Violets	*Viola renifolia*
Ground Cover	
Spiky Dicranum Moss	*Dicranum flagellare*
Ground Pine Clubmoss	*Lycopodium obscurum*
Schreber's Feathermoss	*Pleurozium schreberi*

Appendix: 2g. Bedrock/Lichen Covertype

Characteristics:

Bare rock surfaces with minimal soil coverage and often only lichen cover

Associated Trees	
Black Spruce	*Picea mariana*
Jack Pine	*Pinus banksiana*
Associated Shrubs	
Juneberries	*Amelanchier sanguinea*
Willows	*Salix humilis*
Bearberry	*Arctostaphylos uva-ursi*
Low Bush Honeysuckle	*Diervilla lonicera*
Wine Leaf Cinquefoil	*Potentilla tridentata*
Late Low Blueberry	*Vaccinium augustifolium*
Associated Herbaceous	
Everlasting	*Antennaria neglecta*
Pearly Everlasting	*Anaphalis margaritacea*
Wood Anemone	*Anemone Quinquefolia*
Large Leaf Aster	*Aster macrophyllus*
Bristly Sarasparilla	*Aralia hispida*
Bluebell (Harebell)	*Campanula rotundifolia*
Pale Corydalis	*Corydalis sempervirens*
Canada Mayflower	*Maianthemum canadense*
False Solomon Seal	*Smilacina racemosa*
Starflower	*Trientalis borealis*
Cow Wheat	*Melampyrum linare*
Associated Ground Cover	
Reindeer Lichen	*Cladonia rangiferina*
Ladder Lichen	*Cladoniaceae verticillata*

Appendix: 2h. Mixed Northern Hardwood Covertype

Characteristics:

This subsection is believed to be the northern edge of the climax deciduous forest and is characterized by the following species:

Indicator Species

Basswood	*Tilia americana*
Yellow Birch	*Betula alleghaniensis*
Red maple	*Acer rubra*
Bur oak	*Quercus macrocarpa*
Northern Red Oak	*Quercus rubra*

Sub-types

- Maple/Oak
- Maple/Aspen/Birch
- Maple/Aspen/Birch/Fir

Plants of the Maple/Oak Community

Associated Trees:

Quaking Aspen	*Populus tremuloides*
Balsam Fir	*Abies balsamea*
Red Pine	*Pinus resinosa*
Paper Birch	*Betula papyrifera*
White Pine	*Pinus strobus*

Associated Shrubs:

Juneberries	*Amelanchier sanguinea*
Sweet Fern	*Comptonia peregrina*
Beaked Hazel	*Corylus cornuta*
Wintergreen	*Gaultheria procumbens*
Bebb Willow	*Salix bebbiana*
Late Low Blueberry	*Vaccinium angustifolium*

Associated Herbaceous:

Large Leaf Aster	*Aster macrophyllus*
Cow Wheat	*Melampyrum lineare*
Canada Mayflower	*Maianthemum canadense*
Bracken Fern	*Pteridium aquilinum*

Associated Ground Cover:

Reindeer Lichen	*Cladonia rangiferina*
Dicranum Moss	*Dicranum montanum*
Fern Moss	*Thuidium delicatulum*

Mixed Hardwood Forest –Continued

Plants of the Maple/Aspen/Birch Community

Associated Trees:

Red Maple	*Acer rubrum*
Quaking Aspen	*Populus tremuloides*
Paper Birch	*Betula papyrifera*
Large Tooth Aspen	*Populus grandidentata*
Balsam Fir	*Abies balsamea*
Jack Pine	*Pinus banksiana*
White Pine	*Pinus strobus*
Black Spruce	*Picea mariana*
White Spruce	*Picea glauca*

Associated Shrubs:

Mountain Maple	*Acer spicatum*
Green Alder,	*Alnus crispa*
Bunchberry	*Cornus canadensis*
Round Leaf Dogwood	*Cornus rugosa*
Beaked Hazel	*Corylus cornuta*
Low Bush Honeysuckle	*Diervilla lonicera*
Fly Honeysuckle	*Lonicera canadensis*
Dewberry	*Rubus pubescens*
Late Low Blueberry	*Vaccinium angustifolium*

Associated Herbaceous:

Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Blue Bead Lily	*Clintonia borealis*
Jewelweed	*Impatiens biflora*
Horsetail	*Equisetum arvense*
Canada Mayflower	*Maianthemum canadense*
Interrupted Fern	*Osmunda claytonia*
Bracken Fern	*Pteridium aquilinum*
Shinleaf	*Pyrola elliptica*
Rose Twisted Stalk	*Streptopus rosea*
Starflower	*Trientalis borealis*

Associated Ground Cover:

Ground Pine Clubmoss	*Lycopodium obscurum*

Mixed Hardwood Forest –Continued

Plants of the Maple/Aspen/Birch/Fir Community

Associated Trees:	
Red Maple	*Acer rubrum*
Quaking Aspen	*Populus tremuloides*
Paper Birch	*Betula papyrifera*
Balsam Fir	*Abies balsamea*
White Spruce	*Picea glauca*
Black Spruce	*Picea mariana*
Associated Shrubs:	
Mountain Maple	*Acer spicatum*
Bunchberry	*Cornus canadensis*
Beaked Hazel	*Corylus cornuta*
Twinflower	*Linnaea borealis*
Dewberry	*Rubus pubescens*
Late Low Blueberry	*Vaccinium angustifolium*
Associated Herbaceous:	
Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Blue Bead Lily	*Clintonia borealis*
Gold Thread	*Coptis trifolia*
Moccasin Flower	*Cypripedium acaule*
Sweet Bedstraw	*Galium asprellum*
Canada Mayflower,	*Maianthemum canadense*
Cow Wheat	*Melampyrum linare*
Bracken Fern	*Pteridium aquilinum*
Rose Twisted Stalk	*Streptopus rosea*
Starflower,	*Trientalis borealis*
Associated Ground Cover:	
Bristly Club Moss	*Lycopodium annotinum*
Ground Pine Clubmoss	*Lycopodium obscurum*
Running Club Moss	*Lycopodium clavatum*
Schreber's Feathermoss	*Pleurozium schreberi*

Appendix: 2i. Jack Pine Cover Type

Characteristics:

Sub-types

Jack Pine/Black Spruce
Jack Pine/Fir
Jack Pine/Oak

Plants of the Jack Pine/Black Spruce Community

Associated Trees:

Jack Pine	*Pinus banksiana*
White Pine	*P. strobus*
Red Pine	*P. resinosa*
Black Spruce	*Picea mariana*
White Spruce	*P. glauca*
Quaking Aspen	*Populus tremuloides*
Large Leaf Aspen	*P. grandidentata*
Paper Birch	*Betula papyrifera*
Balsam Fir	*Abies balsamea*
Red Maple	*Acer rubrum*

Associated Shrubs:

Pipsissewa	*Chimaphila umbellata*
Bunchberry	*Cornus canadensis*
Beaked Hazel	*Corylus cornuta*
Low Bush Honeysuckle	*Diervilla lonicera*
Trailing Arbutus	*Epigea repens*
Wintergreen	*Gaultheria procumbens*
Twinflower	*Linnaea borealis*
Late Low Blueberry	*Vaccinium angustifolium*

Associated Herbaceous:

Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Moccasin Flower	*Cypripedium acaule*
Dwarf Rattlesnake Orchid	*Goodyera repens*
Canada Mayflower	*Maianthemum canadense*

Associated Ground Cover:

Reindeer Lichens	*Cladonia rangiferina*
Dicranum Mosses	*Dicranum montanum*
Running Clubmoss	*Lycopodium clavatum*
Schreber's Feathermoss	*Pleurozium schreberi*
Hair Cap Moss	*Polystrichum commune*

Jack Pine Cover Type Continued
Plants of the Jack Pine/Fir Community

Associated Trees:

Jack Pine	*Pinus banksiana*
Quaking Aspen	*Populus tremuloides*
Balsam Fir	*Abies balsamea*
Black Spruce	*Picea mariana*
White Spruce	*Picea glauca*
Paper Birch	*Betula papyrifera*

Associated Shrubs:

Mountain Maple	*Acer spicatum*
Round Leaf Dogwood	*Cornus rugosa*
Beaked Hazel	*Corylus cornuta*
Fly Honeysuckle	*Lonicera canadensis*
Bunchberry	*Cornus canadensis*
Low Bush Honeysuckle	*Diervilla lonicera*
Trailing Arbutus	*Epigea repens*
Creeping Snowberry	*Gaultheria hispidula*
Wintergreen	*G. procumbens*
Twinflower	*Linnaea borealis*
Wild Rose	*Rosa acicularis*
Late Low Blueberry	*Vaccinium angustifolium*
Velvet Leaf Blueberry	*V. myrtilloides*

Associated Herbaceous :

Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Blue Bead Lily	*Clintonia borealis*
Gold Thread	*Coptis trifolia*
Moccasin Flower	*Cypripedium acaule*
Dwarf Rattlesnake Orchid	*Goodyera repens*
Canada Mayflower	*Maianthemum canadense*
Bracken Fern	*Pteridium aquilinum*
Shinleaf	*Pyrola elliptica*
Pale Pea	*Lathyrus ochroleucus*
Rough Bedstraw	*Galium boreale*
Starflower	*Trientalis borealis*

Associated Ground Cover:

Clubmoss	Lycopodium annotinum
Ground Pine Clubmoss	*L. obscurum*
Running Club Moss	*L. clavatum*
Schreber's Feathermoss	Pleurozium schreberi

Jack Pine Cover Type Continued
Plants of the Jack Pine/Oak Community

Associated Trees:	
Jack Pine	*Pinus banksiana*
Red Oak	*Quercus rubra*
Northern Pin Oak	*Q. ellipsoidalis*
Red Maple	*Acer rubrum*
Bur Oak	*Quercus macrocarpa*
Pin Cherry	*Prunus pensylvanica*
Associated Shrubs:	
Green Alder	*Alnus crispa*
Sweet Fern	*Comptonia peregrina*
Bunchberry	*Cornus canadensis*
Beaked Hazel	*Corylus cornuta*
Low Bush Honeysuckle	*Diervilla lonicera*
Trailing Arbutus	*Epigea repens*
Creeping Snowberry	*Gaultheria hispidula*
Wintergreen	*G. procumbens*
Common Juniper	*Juniperus communis*
Twinflower	*Linnaea borealis*
Fly Honeysuckle	*Lonicera canadensis*
Late Low Blueberry	*Vaccinium angustifolium*
Associated Herbaceous:	
Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Moccasin Flower	*Cypripedium acaule*
Dwarf Rattlesnake Orchid	*Goodyera repens*
Canada Mayflower	*Maianthemum canadense*
Cow Wheat	*Melampyrum linare*
Bracken Fern	*Pteridium aquilinum*
Starflower	*Trientalis borealis*
Associated Ground Cover:	
Reindeer Lichens	*Cladonia rangiferina*
Clubmoss	*Lycopodium annotinum*
Ground Pine Clubmoss	*L. obscurum*
Running Club Moss	*L. clavatum*
Schreber's Feathermoss	*Pleurozium schreberi*

Appendix: 2j. Red Pine Forest

Characteristics: Typically, well drained sandy soil, possible bedrock dominant soils

Associated Trees:	
Red Pine	*Pinus resinosa*
White Pine	*P. strobus*
Jack Pine	*P. banksiana*
Paper Birch	*Betula papyrifera*
Red Oak	*Quercus borealis*
Red Maple	*Acer rubrum*
Balsam Fir	*Abies balsamea*
Black Spruce	*Picea mariana*
White Cedar,	*Thuja occidentalis*
Associated Shrubs:	
Green Alder	*Alnus crispa*
Bearberry	*Arctostaphylos uva-ursi*
Pipsissewa	*Chimaphila umbellata*
Sweet Fern	*Comptonia peregrina*
Bunchberry	*Cornus canadensis*
Beaked Hazel	*Corylus cornuta*
Low Bush Honeysuckle	*Diervilla lonicera*
Wintergreen	*Gaultheria procumbens*
Common Juniper	*Juniperus communis*
Twinflower	*Linnaea borealis*
Late Low Blueberry	*Vaccinium angustifolium*
Associated Herbs:	
Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Blue Bead Lily	*Clintonia borealis*
Moccasin Flower	*Cypripedium acaule*
Greater Rattlesnake Orchid	*Goodyera tesselata*
Canada Mayflower	*Maianthemum canadense*
Cow Wheat	*Melampyrum linare*
Bracken Fern	*Pteridium aquilinum*
Rose Twisted Stalk	*Streptopus roseus*
Starflower	*Trientalis borealis*
Associated Ground Cover:	
Schreber's Feathermoss	*Pleurozium schreberi*
Hair Cap Moss	*Polystrichum commune*
Reindeer Lichens	*Cladonia rangiferina*
Clubmoss	*Lycopodium annotinum*
Ground Pine Clubmoss	*L. obscurum*
Running Club Moss	*L. clavatum*

Appendix: 2k. White Pine Cover Type

Associated Trees:	
White Pine	*Pinus strobus*
Red Pine	*P. resinosa*
Jack Pine	*P. banksiana*
Balsam Fir	*Abies balsamea*
Paper Birch	*Betula papyrifera*
Quaking aspen	*Populus tremuloides*
White Spruce	*Picea glauca*
Black Spruce	*P. mariana*
Red Maple	*Acer rubrum*
Associated Shrubs:	
Mountain Maple	*Acer spicatum*
Beaked Hazel	*Corylus cornuta*
Bunchberry	*Cornus canadensis*
Low Bush Honeysuckle	*Diervilla lonicera*
Twinflower	*Linnaea borealis*
Fly Honeysuckle	*Lonicera canadensis*
Dewberry	*Rubus pubescens*
Late Low Blueberry	*Vaccinium angustifolium*
Associated Herbaceous:	
Wild Sarsaparilla	*Aralia nudicaulis*
Large Leaf Aster	*Aster macrophyllus*
Canada Mayflower	*Maianthemum canadense*
Bracken Fern	*Pteridium aquilinum*

Appendix: 2L Aspen/Birch Forest

Characteristics:

The northern forest subsequent to logging or other disruption with an abundance of herbaceous in understory, dense *Acer spicatum* and *Corylus cornuta*.

Indicator Species:

Quaking Aspen	*Populus tremuloides*
Paper Birch	*Betula papyrifera*
Balsam fir (understory)	*Abies balsamea*

Associated Shrubs:

Mountain Maple	*Acer spicatum*
Dewberry	*Rubus pubescens*
Late Low Blueberry	*Vaccinium angustifolium*
Beaked Hazel	*Corylus cornuta*
Bush Honeysuckle	*Diervilla lonicera*
Wild Rose	*Rosa acicularis*
Twinflower	*Linnaea borealis*
Fly Honeysuckle	*Lonicera canadensis*

Associated Ground Cover:

Wild Sarsaparilla	*Aralia nudicaulis*
Twisted stalk	*Streptopus roseus*
Blue-Bead Lily	*Clintonia borealis*
Canadian Mayflower	*Maianthemum canadense*
Large-Leaf Astor	*Aster macrophyllus*
Starflower	*Trientalis borealis*
Bunchberry	*Cornus canadensis*
Fragrant Bedstraw	*Galium triflorum*
Running Club Moss	*Lycopodium clavatum*
Naked Mitrewort	*Mitella nuda*
Schreber's Moss	*Pleurozium schreberi*
Plume Moss	*Ptilium crista-castrensis*
Shaggy Moss	*Rhytidiadelphus triquestrus*

Appendix 3: Northwest Ontario Forest Ecosystem Classification System

38 Vegetative Communities

Mainly Hardwood
V 1 – Balsam Poplar Hardwood and Mixedwood
V 2 – Black Ash Hardwood and Mixedwood
V 3 – Other Hardwoods and Mixedwoods
V 4 – White Birch Hardwood and Mixedwood
V 5 - Aspen Hardwood
V 6 – Trembling Aspen (White Birch) – Balsam Fir/ Mountain Maple
V 7 - Trembling Aspen - Balsam Fir/ Balsam Fir Shrub
V 8 - Trembling Aspen (White Birch) / Mountain Maple
V 9 - Trembling Aspen Mixedwood
V10 - Trembling Aspen-Black Spruce-Jack Pine/Low Shrub
V11 –Trembling Aspen – Conifer/Blueberry/Feathermoss

Conifer Mixedwood
V12 – White Pine Mixedwood
V13 – Red Pine Mixedwood
V14 – Balsam Fir Mixedwood
V15- White Spruce Mixedwood
V16- Balsam Fire-White Spruce Mixedwood/Feathermoss
V17 – Jack Pine Mixedwood/Shrub Rich
V18 - Jack Pine Mixedwood/Feathermoss
V19 – BlackSpruce Mixedwood/Herb Rich
V20- BlackSpruce Mixedwood/Feathermoss

Conifer
V21 – Cedar (Inc. Mixedwood)/ Mountain Maple
V22 – Cedar (Inc. Mixedwood)/ Speckled Alder/Sphagnum
V23- Tamarack (Black Spruce)/Speckled Alder/Labrador Tea
V24 - White Spruce – Balsam Fir/Shrub Rich
V25 – White Spruce – Balsam Fir/ Feathermoss
V26 - White Pine Conifer
V27 – Red Pine Conifer
V28 – Jack Pine/Low Shrub
V29 - Jack Pine/Ericaceous Shrub/Feathermoss
V30 – Jack Pine – Black Spruce/Blueberry/Lichen
V31 - Black Spruce – Jack Pine/Tall Shrub/Feathermoss
V32 – Jack Pine-Black Spruce/Ericaceous Shrub/Feathermoss
V33 - Black Spruce/Feathermoss
V34 - Black Spruce/Labrador Tea/Feathermoss (Sphagnum)
V35 - Black Spruce/Speckled Alder/Sphagnum
V36 - Black Spruce/Bunchberry/Sphagnum (Feathermoss)
V37 - Black Spruce/Ericaceous Shrub/Sphagnum
V38 - Black Spruce/Leatherleaf/Sphagnum

Vegetative types listed in the NorthWest Ontario Forest Ecosystem Classification Systems Field Guide