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Forest Ecosystems and the Physical Environment, Duck Mountains, West Central Manitoba

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Forest Ecosystems and the Physical Environment, Duck Mountains, West Central Manitoba

SFM Network Project: Historical Disturbance Regime,
FML #3, West Central Manitoba

by

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EXECUTIVE SUMMARY

The objective of our SFMN project was to contribute to an understanding of the historic disturbance regime of FML #3 in the Duck Mountains of west-central Manitoba through the digital mapping of forest ecosites and the spatial analysis of physical controls (landform, drainage, local climate) on the distribution of forest ecosystems. Understanding linkages between disturbance and forest structure, and emulating natural disturbance through forestry practices, requires regional and historic perspectives on disturbance, climate, forest ecosystems and the physical landscape. The integration of climate records, stream flow observations, and geo-referenced biophysical data is the basis for linking the forest geography and history and, thereby, patterns of forest management and natural disturbance.

The distribution of the forest ecosystems of FML #3 reflects the interaction of topography, drainage, natural disturbance and human activities. There are steep gradients in soil moisture with relatively subtle changes in elevation and slope, and thus much local variability in forest vegetation. Despite this abiotic control on the distribution of boreal forest ecosystems, there are few SFMN studies of forest hydrology and geomorphology. Streams are both a cause of physical disturbance and vulnerable to the impacts of logging. Therefore our research included studies of flood history and stream bank stability, indicating that the streams of the Duck Mountains are inherently very active and unlikely to be affected by logging operations given appropriate forest management.

Our ecosite classification and digital date base represent a high resolution spatial model of the forest ecosystems and a framework for scaling up models of biophysical processes and associated ecological data. Biophysical processes operate locally over slopes, stream channels and forest stands, however, the regional structure of forest ecosystems and soil landscapes cannot be modeled simply from a an understanding of local physical and ecological processes. An assemblage of ecosites is the geographic expression of biophysical activity over time scales, which are longer than the diurnal and seasonal variability of ecological processes and closer to the time frame for forest management and planning. Our digital and spatial ecosite database supports forest management planning with data at appropriate spatial and temporal scales.

This research contributes to an understanding of the regional disturbance regime through the digital mapping of forest ecosites and the spatial analysis of physical controls on the distribution of forest ecosystems. It provides a framework for the spatial integration of various SFMN studies of natural disturbance, planning and implementation of forest management practices that emulate the natural disturbance.

ACKNOWLEDGEMENTS

This research was funded by the Sustainable Forest Management Network of Centres of Excellence. The industry partner, Louisiana Pacific Limited, provided substantial in-kind contributions of digital geographic data and logistical support in the field. Thanks to Margaret Donnelly, Peter Sigurdson, Ken Broughton, Vern Baumann and others at Louisiana Pacific Canada (Swan River, MB). We would also like to thank Manitoba Natural Resources and the Mixed Wood Forest Research and Advisory Committee for providing camping at the Welman Lake Campground and accommodation at the Goldeneye Field Station. Advice on the remote sensing aspects of this study were provided by Dr. Brad Willson, Lakehead University, Dr. Ron Hall, Canadian Forest Service, and Dr. Gerardo-Arturo Sanchez-Azofeifa, University of Alberta. Thanks also to Kevin Whitmire, Jason Tuchelt, Nathan Richea, Antoine Beriault, Jennifer Stroich, for their assistance in the field and laboratory, and to Dr. Mary Vetter, University of Regina, Cary Hamel University of Manitoba, and Richard Caners, University of Manitoba for their botany expertise.

INTRODUCTION

Over the past few decades, the value of forested land has been increasingly appreciated by users of the natural resources and by the broader public. Forests are no longer viewed as just a source of timber; their importance for education, recreation, fish and wildlife, aesthetics, maintaining biodiversity and regulating global climate is now being emphasized (Treitz and Howarth, 1996). Appropriate management achieves the sustainable use of natural resources without degrading other resource values. Resource managers are required to identify, assess and manage vegetation communities so that multiple use objectives are met. Modern forest management requires an understanding of ecological principles that govern the functioning of forest ecosystems (Zoladeski, *et al*., 1995). The ecosystem approach provides a common scientific basis for the management of resources (Klinka, *et al.,* 1980; Bailey, 1997). Ecological land classification and the use of common geo-referenced databases promotes communication between resource managers which leads to decreased conflict and uncertainty among various users (Mitchell, 1995). Ecological land classification maps and digital databases organize ecological information into a format that provides structure for ecologically based management practices (Beckingham, *et al.,* 1996). These data support informed management decisions based on ecosystem functions and interrelationships. They also provide a framework for the organizing, overlaying and updating of forest management interpretations which can be applied for a wide variety of uses including, harvest and silviculture planning, wildlife management, and protecting ecologically unique or endangered areas (Beckingham, *et al.* 1996).

A major theme of the SFM-NCE is documenting natural disturbance regimes of the southern boreal forest relative to current forestry practices. Understanding the role of disturbance, and emulating natural disturbance through forestry practices, requires regional and historic perspectives on disturbance, climate and forest ecosystems. The spatial distribution of forest ecosystems reflects local environmental gradients, with variation in topography, drainage and soil characteristics, and natural disturbance and human activities. The project reported here provides baseline data on the spatial variability of boreal forest ecosystems for the planning of forest practices that emulate natural disturbance. Whereas landform and genetic materials are the basis for ecological land classification at sub-regional (ecosection and ecosite) scales, they are major consideration in few, if any, SFMN projects and generally are not readily available to forest managers.. The complex interaction of topography, surficial materials and hydrologic processes is expressed geographically as the mosaic of lakes, wetlands and riparian zones and as strong gradients of soil moisture, and thus vegetation, near streams and wetlands. These abiotic controls on forest structure, biodiversity and disturbance, at the landscape scale, have generally not been considered for boreal forest ecosystems.

Forest and landscape change is strongly linked to climate variation and change, since climate controls the rates of nearly all biophysical processes (*e.g*., photosynthesis, evapotranspiration, stream flow, fire, erosion). Therefore, climate data and the understanding of climate variability and change are essential for most modeling, monitoring and management of natural resources. In the Canadian interior, prolonged dry or wet weather strongly influence the resistance of soil and vegetation to these extreme hydroclimatic events, because forest ecosystems and soil landscapes respond to variability in the surface and shallow subsurface water balances (Lemmen and Vance, 1999). As a result, the sustainability of forestry depends on adjustment of land use and management systems to climatic variability, the periodic fluctuation of atmospheric conditions (*e.g.*, drought, early frosts, storms) and to climatic change, a significant departure from previous average condition.

The concept of ecological classification is based upon grouping regional ecosystems into similar and functional units, which respond to disturbance in a similar and predictable way (Beckingham, *et al.*,1996). The ecosite level groups land units that develop under similar environmental influences including climatic, topographic and edaphic conditions. An assemblage of ecosites is the geographic expression of biophysical activity over time scales that are longer than the diurnal and seasonal tempo of ecological processes and closer to the time frame for forest management and planning. Ecological land classification is a prerequisite for many ecologically oriented management or planning, providing an essential framework for the identification and description of ecosystem elements and landscapes. Various ecological land classification systems have been developed throughout Canada. Presently, Manitoba is in the process of establishing an ecosystem classification for the Mid-Boreal Upland Ecoregion. To date, mapping of ecological land classes, especially ecosites, has been very limited in Manitoba (Wells, 1987). The main use of these classification systems has been the training of forest managers in field applications.

At the ecosite scale, forest stand characteristics are strongly influenced by topography, soil conditions and local climate (Beckingham, *et al.*,1996). Other SFMN research projects (*e.g.,* Bergeron, *et al.*,1999) refer to the influence of landform and drainage on the local variability of forest composition and susceptibility to natural disturbance. Discussions with our SFMN colleagues suggested, however, that research had not been initiated at the landscape (regional) scale to examine relationships among landform, surficial materials, drainage and the spatial variability of boreal forest ecosystems. Our project in the Duck Mountains of west-central Manitoba presented various opportunities for pursuing such research:

- The industry partner, Louisiana Pacific Ltd. (LP), had previously identified surficial geology, soil and landform as the least understood and mapped components of the forest ecology of FML #3. They supplied much digital topographic, forest cover and satellite image data. Maps of ecological land classes can be derived using remote sensing and GIS technology, which facilitate the processing and analysis of the large amounts of data required for ecological land classification. (Knapik, *et al.* 1988).
- Our intensive field surveys of ecosites provided the opportunity to collect related data on soils, landforms and geomorphic activity.
- The geomorphology and surficial geology of the Duck Mountains are typical of the southern boreal forest, in terms of the impact of continental glaciation on the distribution of soil (parent materials), wetlands, lakes and streams.

The cumulative impacts of human activities on runoff and sediment yield is a significant issue in all commercial forests. It has been the subject of considerable research and mitigation strategy in the montane forests of western North America (*e.g*., Montgomery, *et al*., 1995; Rogers, 1996), where orographic precipitation and steep slopes favour high rates of runoff and sediment production. There has been relatively little study of watershed processes in the boreal forest as related to logging, disturbance, and biodiversity (Veeman, *et al*., 1998). With previous research on runoff and erosion in the Riding Mountain section of the Manitoba escarpment (*e.g*., Newbury and Gaboury, 1987.), logging was not an issue as most of this area is a national park. A model of runoff and sediment yield is an important component of integrated resource management and the improved forecasting and monitoring of sustainable forest management.

Objectives and Experimental Design

The principle research objective was to contribute to an understanding of the historical disturbance regime of FML #3 in the Duck Mountains of west-central Manitoba (Figure 1) through the digital mapping of forest ecosites and the spatial analysis of physical controls (landform, drainage, local climate) on the distribution of forest ecosystems. While forest inventory maps exist for FML #3, the map units represent stand age structure and composition and thus a variety of environmental controls on the distribution of forest ecosystems. We have constructed a higher-resolution spatial model of the forest mosaic by combining classified satellite imagery with digital soil and topographic data (Hadwen and Sauchyn, 2001). At this ecosite scale, forest boundaries and patterns tend to reflect physical factors. A ecosite database and digital ecological land classification map provide forest managers a basis for planning and implementation of forest management strategies and practices that emulate the natural disturbance at appropriate spatial scales. This research also is a framework for the spatial integration of various SFMN studies of natural disturbance. This project is based on the use common and easily attainable data sources, which would be available to resource managers and forestry companies.

In conjunction with the surveying of ecosites, hundreds of tree cores were collected to establish forest age structure. The tree ring data serve other purposes related to our study. At dry sites, tree growth is limited by the availability of soil moisture, and therefore ring width variation in these trees is a proxy of annual and seasonal precipitation. Thus proxy paleoclimatic data are commonly used to supplement and extend instrumental records. The instrumental records are relatively short, generally less than 100 years. Records of this length are very unlikely to capture the annual and seasonal extremes that characterize the climate and hydrology of a region. The proxy data of highest resolution are derived from tree rings. In seasonal climates, trees preserve a continuous record of annual climate. Dendroclimatology, the study of tree rings in relation to climate, enables the reconstruction of long climatic histories with annual resolution (Fritts, 1976). With the counting and cross-dating of tree rings, the timing of events and conditions that influence tree growth can be established (Schweingruber, 1988). A master chronology of tree ring width variation is the basis for assigning calendar years to the growth rings of dead wood (floating chronologies) extending our temporal perspective on the annual climate and tree growth. The dendrochronology of the western Canadian interior has been the subject of relatively recent research (Luckman and Innes 1991; Case and MacDonald, 1995; Sauchyn and Beaudoin, 1998; Sauchyn, 2000; Case, 2000; St.George and Nielsen, 2000; Sauchyn and Skinner, 2001; Watson, and Luckman, 2001).

A second research objective is to establish the physical controls on forest ecosystems, from the spatial analysis of topographic and hydrologic data, and from the analysis of hydrologic regimes from historical and field measurements. Measured and modeled hydrologic variability among years, as a function of climate, and among watersheds, as a function of topography and geology, serves as a baseline from which to evaluate the cumulative impacts of forestry operations. The long-term goal is to assist with developing practices and strategies for forest resource management, that account for the natural variation in geomorphic and hydrologic systems and the impacts of forestry on these systems. There has been relatively little study of watershed processes in the boreal forest as related to logging, disturbance, and biodiversity. A model of runoff and sediment yield is an important component of integrated resource management and the improved forecasting and monitoring of sustainable forest management. The research design includes a program of long-term monitoring, including reference sites and sampling protocols to be inherited by the industry partner, Louisiana Pacific, as the basis for detecting change in stream channel stability and sediment budgets, and other indicators of cumulative impacts of forest management.

METHODS

The research objectives were achieved through a combination of field data collection and spatial analysis of the forest ecosystem and soil landscapes. Using the ArcInfo GIS and EasiPace image analysis system at the University of Regina, we mapped the forest ecosystems of FML #3 based on the ecosite classification described below. The resulting database includes detailed field surveys of more than 200 forest ecosites, classified satellite imagery, and associated digital geographic data. Analysis of these data was focused on the control of topography, soil and drainage on local variability in the forest ecosystems. Scale is a major theme in the mapping and interpretation of forest structure and disturbance. We have been careful to define the spatial scope of our study as corresponding to the ecosite scale.

Our research also involved frequent interaction with other SFMN researchers, especially our colleagues in the Manitoba node, and participation in various network activities, including various meetings of in Swan River and Winnipeg and the SFMN Forestry Field Camp at Hinton, Alberta and an SFMN student exchange in the remote sensing laboratory of Dr. Arturo Sanchez-Azofeifa at the University of Alberta. We coordinated our surveys with field activities of the industry partner, Louisiana Pacific, and other network researchers working in the Duck Mountains, in particular, the graduate students and research assistants working under the supervision of Dr. Norm Kenkel of the University of Manitoba.

Study Area

The study area is located in Forest Management Lease #3 in the Duck Mountains of west-central Manitoba (Figure 1). With the Turtle and Riding Mountains to the south and the Porcupine and Pasquia Hills to the north, the Duck Mountain upland comprises the Manitoba Escarpment. Prior to the onset of Pleistocene glaciation, the gradual westward rise of the plains was interrupted by a number of steep ascents that had developed where more resistant bedrock overlies weaker bedrock. The first of these steps is the Manitoba Escarpment, which separates the Manitoba Plain from the Saskatchewan Plain (Fulton, 1989).

The topography of the Duck Mountains (Figure 2), hummocky moraine with many small lakes and streams and a deranged drainage pattern, reflects successive glaciations of the pre-glacial upland (Klassen, 1979). The glacial drift is mostly till, but includes outwash deposits of stratified sediment. Thickness varies from 15 m to 60 m on the north and east facing escarpments to approximately 230 m on the upland. Remnants of melt-water channels cross the upland, and are occupied by lakes and streams, such as the Shell and Roaring Rivers. The steep east-facing escarpment drops 245 m to the Manitoba Plains. The east- and northwest-facing slopes of the upland have been deeply incised by streams, forming gullies and valleys, whereas the southwest flank is a gently rolling till plain. Shale from the Riding Mountain Formation and limestone of Upper Cretaceous age occasionally appear in outcrops on the north- and east-facing escarpments.

The Duck Mountains have a moist, micro thermal climate with mean annual precipitation of about 500 mm. Nearly 70% of the precipitation falls as rain during May through September. The higher elevation results in increased precipitation and lower temperatures, supporting southern boreal forest, part of the Mid-Boreal Upland Ecoregion, a diverse forest mosaic, open and treed fens, bogs, and water (Acton, *et al*., 1998; Beckingham, *et al*., 1996). Mixed wood and conifer stands tend to dominate higher elevations within the interior of the upland. Mixed forest of trembling aspen (*Populus tremuloidides*), balsam poplar (*Populus balsamifera*), jack pine (*Pinus banksiana*), white birch (*Betula papyrifera*) and white spruce (*Picea glauca*) populates the upland. Trembling aspen stands tend to be located on the periphery and lower elevations of the upland region. Black spruce (*Picea mariana)* and tamarack (*Larix laricina*) surround wetland vegetation (Zoladeski, *et al*, 1995). The structure and dynamics of the forest stands have recently been described in considerable detail by Hamel and Kenkel (2001). The forests of the Duck Mountains have been a source of timber since the time of European settlement on the surrounding plains. Forestry is currently an important economic activity, with large tracts of forest harvested and replanted on an annual basis. Temporary and permanent roads have been constructed to provide access to this resource. Forested areas are also used for recreational purposes. Agricultural activities dominate in the surrounding region. Grazing and hay land are near the base of the escarpment, with crop production dominant in the Swan River valley. Water levels on the uplands are managed with dams and reservoirs, whereas drainage canals are located on the surrounding plains to expedite run-off. Stream channel modification and re-construction have reduced the impact of streams on adjacent agricultural land.

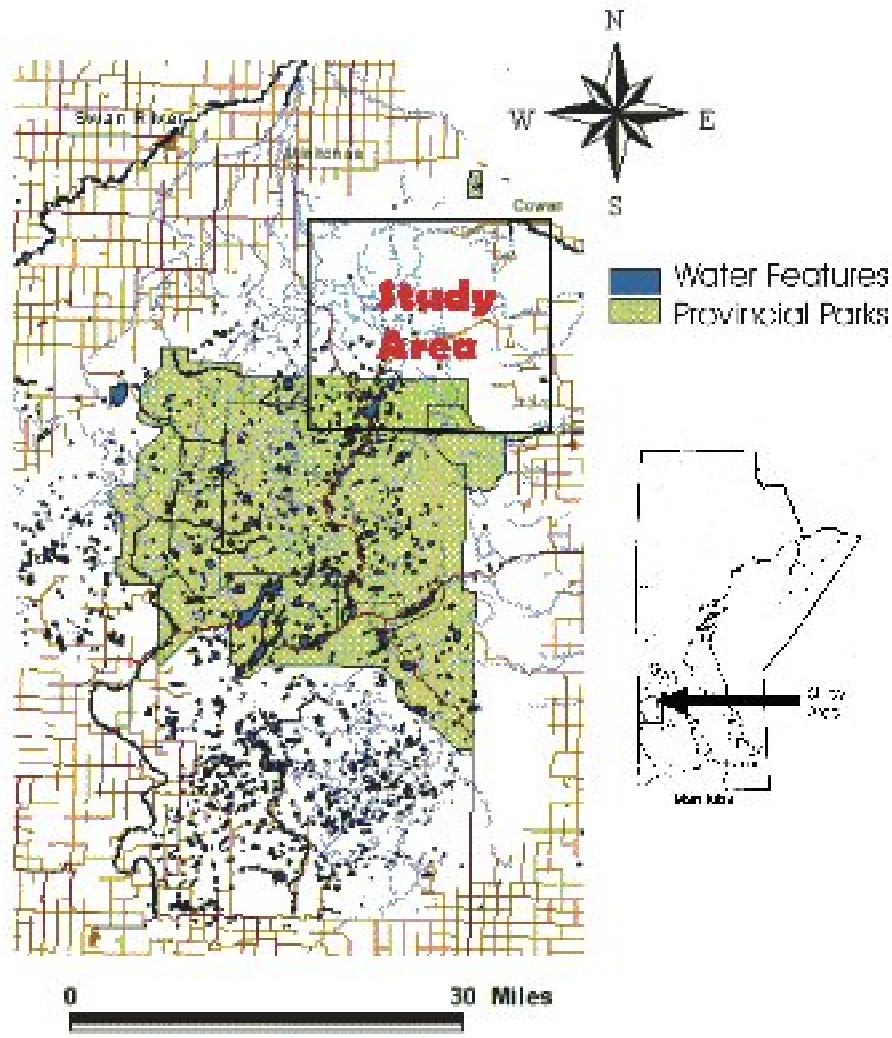

Figure 1. The location of study area in Forest Management Lease #3 in the Duck Mountains of west-central Manitoba.

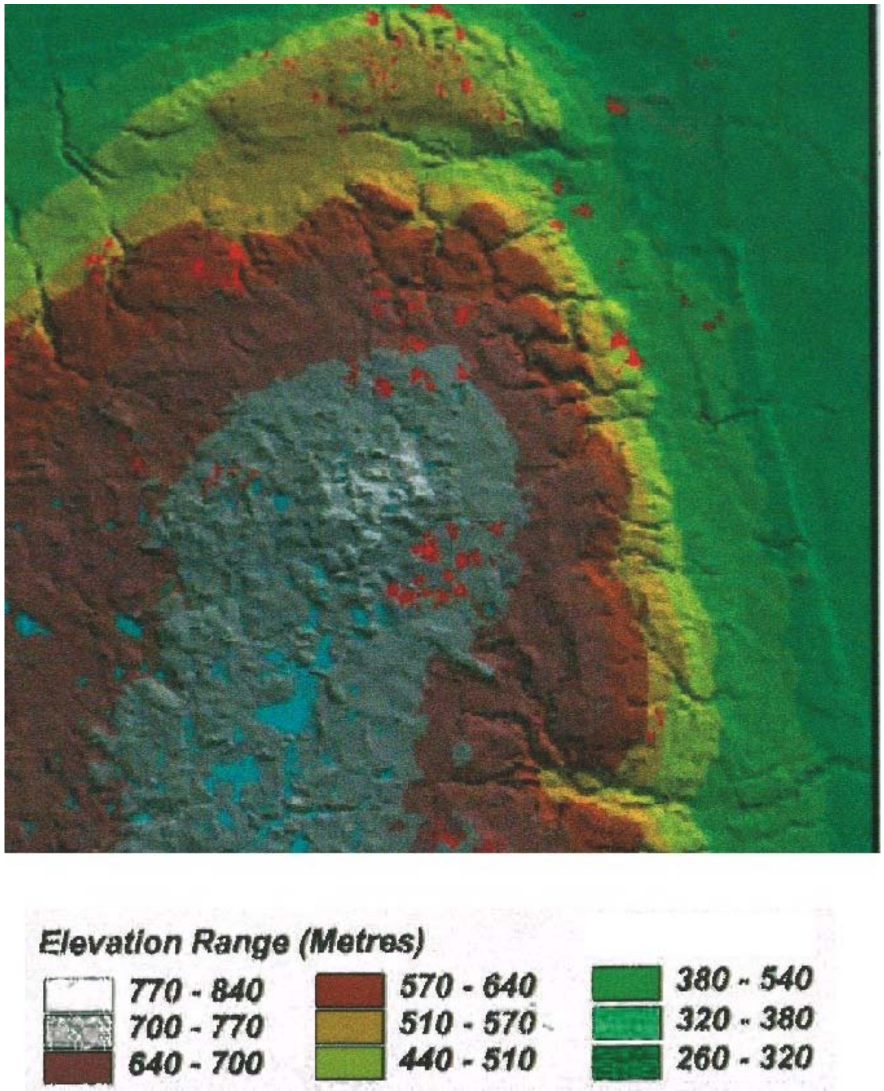

Figure 2. A digital elevation model (DEM) of the project study area in the north-eastern sector of the Duck Mountains.

Ecosite Mapping

Nine townships (approximately 840 km^2) in the northeastern part of the Duck Mountain upland were selected from FMU #13 as a representative study area (Figure 3). These townships were selected on the basis that 1) the area is relatively undisturbed in terms of recent logging and recorded fire, 2) it includes parts of both the northern and eastern escarpments, 3) it contains a wide diversity of forest cover types, and 4) there is moderate access via roads, trails and logging routes. The ecological land classification of this area is based on five months of field data collection and existing digital geospatial data (satellite images, soils surveys, surficial geology and topographical data). These vast quantities of data were processed and analyzed using computing resources, including the ArcInfo GIS and EasiPace image analysis system, in the Department of Geography and Prairie Adaptation Research Collaborative at the University of Regina.

Existing forest inventory maps were consulted for the selection of sample sites (Figure 3). This insured that all forest cover types were sampled appropriately and to prevent disproportional sampling. Many of the initial sites were not sampled in the field due either to poor accessibility, or unsuitability of the site as a result of disturbance, or other factors. These sites were then replaced with comparable sites that were accessible and suitable for sampling. Care was taken to minimize possible ambiguity among sample sites and therefore the probability of erroneous classification. Thus transitional or ecotonal sites were avoided. Samples sites were established in areas of relatively homogeneous vegetation, slope and aspect, which were representative of the surroundings. Therefore anomalies and small area features were eliminated from the sample. These included linear ecosites such as riparian zones. Generally these would be too narrow to be resolved at a regional scale. All sites with recent evidence of disturbance, human or natural, were avoided. All sample sites were located a minimum of 50 metres from adjacent forest polygons as shown on the forest inventory maps. As well, sites were located a minimum of 50 meters from any human development or disturbance such as roads, hydro lines and buildings. Once a suitable site was located, 100 m^2 plots were established to record site and vegetation conditions. These 10x10 meter plots were randomly located within the larger homogeneous stand to minimize local sampling bias and the possibility of selecting a unique or non-representative sample.

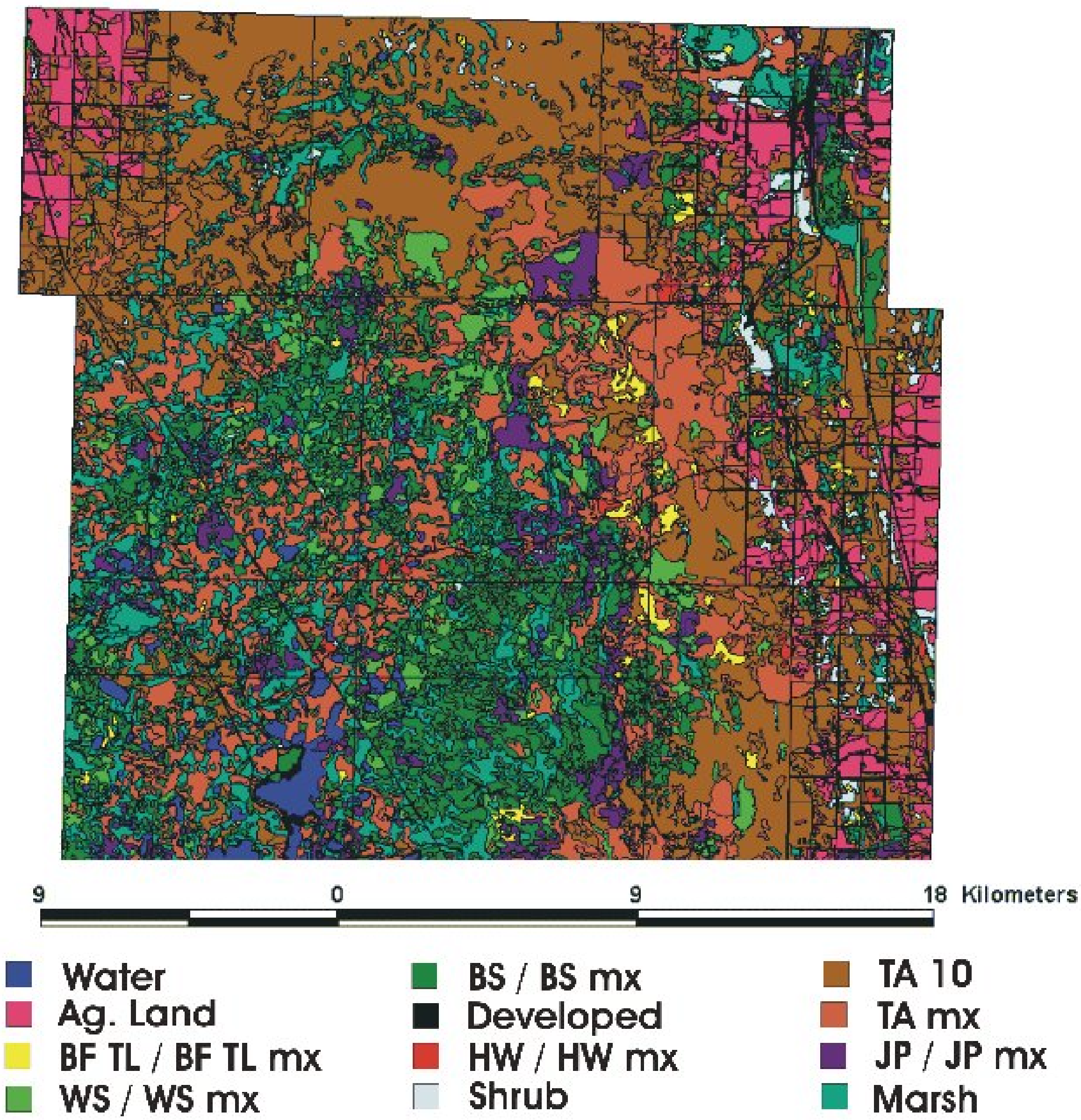

Figure 3. A forest inventory map of the nine townships that comprise the study area for the field sampling of ecosites.

A large amount of field data were collected to characterize the sample sites and for sufficient ground truth for the classification of remotely sensed imagery. Site description forms and sampling methods were adapted from the Province of British Columbia site description form (unpublished; BC Ministry of Environment), Alberta Energy and Natural Resources, Integrated Resource Site Manual (1985), the LP Pre-Harvest Survey Procedure Manual (Louisiana-Pacific Canada Ltd., 1999) and the Ecological Survey Site Description Manual (Canadian Forest Service, 1994). A completed field sheet is appended as Appendix A. 225 sites were sampled over the two-summer field season. A number of these stands were revisited later in the summer or the following year to ensure site and vegetation conditions had not changed over the field season. All sample sites were classified as Vegetation Types and Ecosite Phases according to the Forest Ecosystem Classification for Manitoba (Zoladeski, 1995) and Field Guide to the Mid-boreal Ecoregions of Saskatchewan (Beckingham *et al*., 1996) (Appendix B).

Principle site variables for the classification of ecosites are the local physical controls on vegetation growth: slope, aspect, topographic position, landform and parent material. Topography (slope, aspect and position) is a major criterion in ecosite classification (Beckingham, *et al*., 1999) because it controls drainage and radiation balance, and thereby the soil water balance. Slope and aspect were derived from a digital elevation model (DEM; Figure 3). Topographic position also was derived from the DEM through the use of a comparison grid overlay, that is, topographic position relative to surrounding gridded elevations. Since soil moisture varies seasonally and with changes in weather, it was inferred from slope, aspect, and topographic position. Sample sites were classified as water retaining or shedding sites and assigned a moisture status from 0 (dry) to 5 (wet).

Canopy composition is a critical criterion for ecosite classification (Beckingham *et al*., 1999). Tree species in the canopy are an indicator of soil moisture and nutrient regimes. The tree species also represent a major part of the vegetation classification and largely determine the spectral signal as recorded by digital satellite data. Canopy composition was determined from a supervised classification of Landsat TM digital data. The processing of these data included the use of ancillary and surrogate data in order to increase the classification accuracy. Training areas for the classifier were identified from aerial photographs and field observations made specifically for this purpose. During a preliminary classification, the imagery was classified according to eight vegetation types: 1) black spruce bog 2) black spruce and tamarack 3) black spruce upland 4) aspen 5) aspen mixed woods 6) conifer mixedwoods 7) regeneration 8) grasslands and agricultural land, and two non-vegetation classes: 1) water 2) gravel and pavement.

Dendroclimatology

From the hundreds of tree cores collected to establish forest age structure, some were from dry ecosites, where tree growth is limited by the availability of soil moisture. The most moisture-sensitive trees are those growing in open stands at dry sites, such as ridge tops and coarse soils. The dominant tree species at these sites is *Pinus banksiana* (jack pine). Sampling of two increment cores per tree was purposeful rather than random, in that, the oldest and most climate-sensitive trees are sought. The trees cores were stored in drinking straws for transport to the Tree Ring Laboratory at the University of Regina. An adequate sample size depends on the availability of suitable trees and on the consistency of the signal among trees. In the lab, the sample of tree cores was reduced to 28 (14 trees) based on the sensitivity (variability) of the ring width series and correlation among these series. The longest series had 179 annual rings.

The increment cores were processed in the Tree Ring Lab at the University of Regina, following standard procedures (Stokes and Smiley 1968; Ferguson 1970; Schweingruber 1988). They were glued to tree core mounts and finished with progressively finer sandpaper to expose the growth rings. Ring widths were measured to within .001 mm using a 40X stereomicroscope, a Velmex UniSlide digitally-encoded traversing table, an AcuRite III digital counter, a Quick-Chek QC-1000 digital measuring device that records movement of the measuring stage, and the ring-width measuring software MEDIR. The software and statistical methods for processing ring-width data are described in Grissino-Mayer, *et al.* (1996). The program COFECHA verifies the cross-dating of tree-ring series, enabling the detection of anomalous series and missing or false rings. The program ARSTAN converts raw ring widths to index chronologies (averaged standardized ring widths). The data are first detrended to remove low frequency variation (mostly growth trend) and enhance the high-frequency climate signal. The raw data are fit with a negative exponential curve, which conforms to the theoretical decrease in annual tree growth increments with increasing trunk diameter. A least squares regression is used where the exponential curve is not the best fit. The raw ring widths are then divided by estimates from the line or curve. Finally, a biweight robust estimate of the mean ring-width index for each year is computed from the series that comprise the tree chronology for a specific site.

Flood History and Stream Bank Stability

Data were collected to determine the frequency and significance of previous stream flows in the Duck Mountains. These data support the analysis of inter-annual variability and long-term hydrologic trends and the assessment of the impacts of forest harvesting and climate change on water resources (Herrington, *et al*., 1997; Hengeveld, 2000). Environment Canada supplied historical daily weather and water data for tens of stations in and around the Duck Mountains. The monitoring of precipitation and stream flow began in 1904 and 1912, respectively. Other secondary data included a digital elevation model (DEM), and associated slopes and elevations, for deriving drainage basin areas and selecting representative field sites and stream reaches. Benchmarks, gauging stations and reference sites already exist on the larger streams.

Peak stream flows, which tend to dominate the geomorphic and hydrologic histories of watersheds, were reconstructed from the cross-sectional geometry of stream channels, and the distribution and caliber of flood deposits. These types of proxy records extend and augment instrumental hydrometric records. Study reaches were established along permanent streams from the headwaters to the locations of existing hydrometric stations beyond the uplands. A limited number of representative and accessible study reaches and cross-sections were carefully chosen with long-term monitoring in mind. These sites could be the basis for the detection of change in stream channel stability and sediment budgets, and other indicators of cumulative impacts on hydrologic and geomorphic systems and riparian ecosystems. Reaches of stream channels were classified according to position in the watershed, geology, elevation, land use, and stream width, depth, velocity, discharge, slope and bed roughness (Harrelson *et al*, 1994). A reach includes an entire meander with hydraulics characteristic of the stream. Regional relationships for natural stream channels, derived from a sample of reaches of various channel sizes and associated drainage areas, can serve as a baseline for environmental assessments. Newbury and Gaboury (1993) recommend walking up the reach a fair distance in order to obtain the most representative site. They also indicate that the cross-section should be selected where the best evidence exists for the channel boundaries. Channel boundaries mark the bank full stage and are maintained by flood flows.

Site selection, for the larger stream reaches, was based on existing reference sites and benchmarks established by Environment Canada. Accessibility also played a role in site selection, especially for the reaches located in the upland. The procedures and techniques for surveying stream cross-sections are relatively standard and universal to permit comparisons over time and among sites (Harrelson *et al*. 1994; Newbury and Gaboury, 1993). An automatic level and a stadia rod were used to survey the cross-sections (Figure 4**).** To determine stream discharge, a stream cross section is divided into a number of smaller units of equal width and uniform bed conditions. Total stream discharge is the sum of the unit discharge measurements. Unit discharge is the product of the unit cross-sectional area and mean velocity measured with a flow meter at $6/10^{ths}$ of the depth of the stream for each unit.

Figure 4. Surveying the cross-sectional geometry of a headwater stream.

Bank flow discharge was estimated from the size of the bedload, which remains in contact with the streambed and usually moves only during high stages (Newbury and Gaboury, 1993). At each cross section, the lengths of the x, y and z-axes of 30 clasts were randomly sampled. Critical tractive velocity is directly proportional to clast diameter. Bank full discharge is then estimated from the width and depth of the channel cross section and the critical velocity calculation. These methods are effective in providing data on high flows for ungauged streams and where floods exceeded the capacity of gauges to record them. Data on stream bank erosion and mass wasting were collected using the approach in Thorne (1998). The results are qualitative, time specific and subjective. They cannot substitute for detailed, repeated data collection, however, processes can be interpreted from channel form, using careful observation and applying geomorphological concepts (Thorne, 1992). The location, extent and distribution of bank materials, erosion scars, and mass failures were documented, as well as the stratigraphy of the alluvial sediments (Beriault, 2001). The location, extent and relative age of valley side instability also were documented. Stream reaches were classified according to stream gradient, an indication of available geopotential energy. Within the Duck Mountain study area, sites above or on the escarpment were classified as steep; those between the escarpment and the flood plain were classified as moderate, and sites on the flood plain were classified as low gradient. Sites were selected in the proximity of concurrent research on ecosites and paleo stream flows.

SUMMARY OF DATA ANALYSIS

Ecosite Mapping

The field data were used to classify the 225 study plots into ecosites and vegetation types (V-type). The results (Figures 5 & 6) illustrate that a small number of V-types and ecosites dominate the study area. Dominant V-types include Aspen Hardwood and Trembling Aspen Mixedwood/Tall Shrub. Low Bush Cranberry is the prevailing ecosite type, representing 141 of 225 sites. It is considered the reference ecosite for the Mid-Boreal Ecoregion for moderate moisture and nutrient status. The ecosite data are also were applied to assessing the accuracy of the ecological land classification map derived from remotely sensed and other georeferenced data (Figure 7).

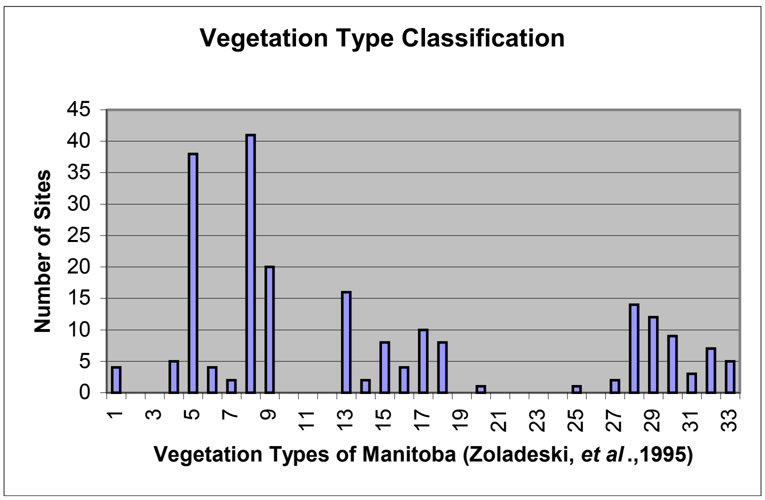

Figure 5. Sample sites according to the vegetation types of Manitoba (Zoladeski, *et al*., 1995)

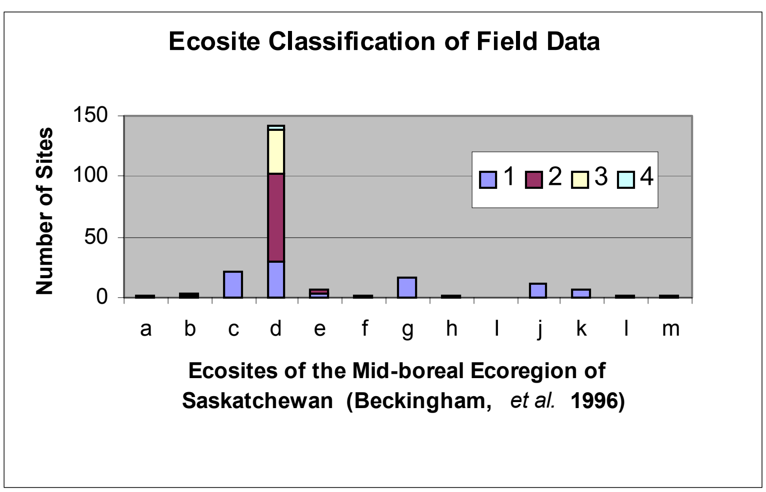

Figure 6. Sample sites according to ecosites classification in Appendix B.

Figure 7. Land cover classification of the northeastern Duck Mountains.

Preliminary results suggest that vegetation type is not directed correlated with elevation, slope, and aspect, but rather the topographic control on drainage is reflected in the distribution of forest ecosystems. Slope, soils and surficial geology have obvious control over drainage and thus still play an important function in determining vegetation and ecosite class. Greater emphasis on determining moisture characteristics will contribute to improved ecological classification. This includes deriving drainage patterns from the DEM and digital satellite data. Classification of the digital satellite imagery (Figure 7) initially had low accuracy, mostly as the result of confusion between the lowland and upland black spruce as well as among hardwood species. Accuracies of all classes were improved with the addition of surrogate data on drainage and moisture content, ancillary data on vegetation indices and from principle component analysis of the spectral data.

Dendroclimatology

Dendroclimatic reconstruction is based on the statistical relationship between ring width indices and meteorological data. Although there are no long weather records for the Duck Mountains, there are several climate stations nearby. Rather than using data from a single station, we obtained archival climate data from Environmental Canada's gridded database for the period 1961-94. This database has been constructed from the interpolation of station data to the nearest intersections on a prairie-wide grid. The standardized ring widths correlated with measured annual and seasonal precipitation. None of the correlations involving temperature variables were significant, as expected, because the sampled trees were from the driest ecosites, where lack of soil moisture limits tree growth. Thus these trees preserve a record of precipitation variability. Ring width is most highly correlated ($r = 0.567$; $p < 0.05$) with precipitation during August to July, that is, the 12 months prior to end of the growing season. Most tree growth occurs during May-July in response to the moisture stored from rain and snow melt since the preceding August.

The statistical relationship between standardized ring widths from *Pinus banksianna* (jack pine) and instrumental precipitation records from Environment Canada is the basis for our reconstruction of August-July precipitation for the period 1831-1999 (Figure 8). This curve indicates that 1961 was the driest single year for the past 169 years. The tree rings also record the prolonged drought of the 1930s. However, drought was more common in the 19th century, from the late 1830s to the late 1860s and just prior to the EuroCanadian settlement of the Duck Mountain region in the 1890s. This drought history conforms to records from further west (Sauchyn and Skinner, 2001) that indicate that the 20th century had the least drought of the past 500 years.

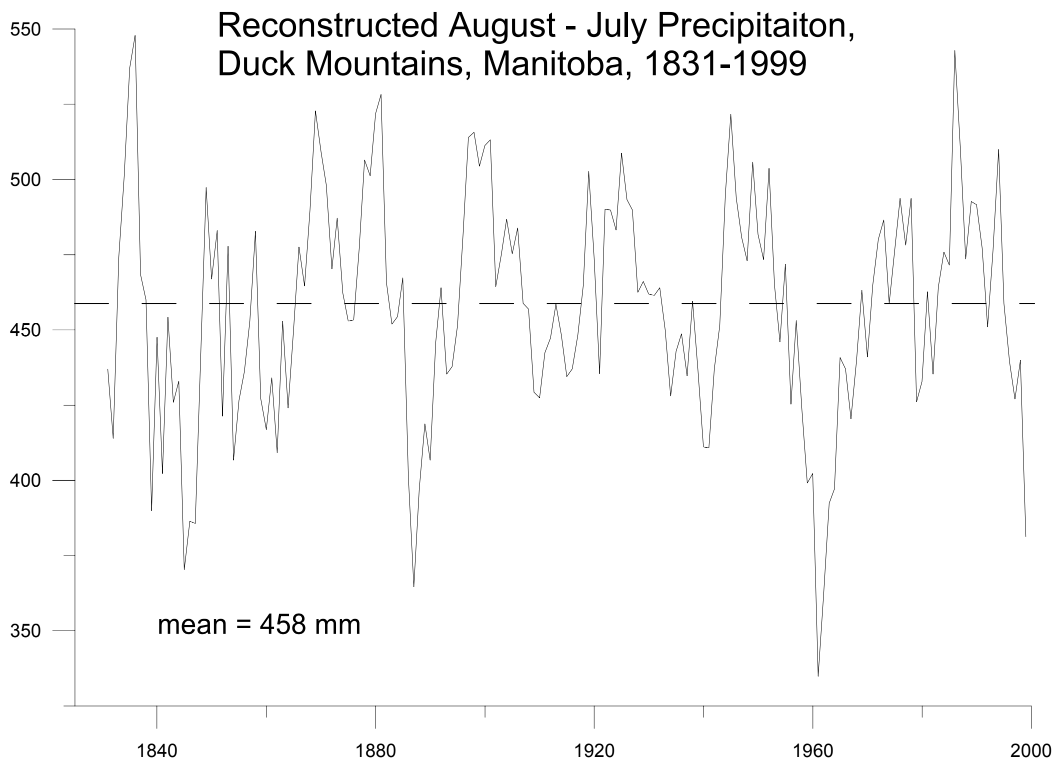

Figure 8. August - July precipitation reconstructed from the growth rings of *Pinus banksianna* (jack pine).

Flood History and Stream Bank Stability

Stream reconnaissance worksheets were tabulated for seventeen sites in the Duck Mountains. At a high percentage of the sites, there was active bank erosion on the outside of meanders, with most sites characterized by erosion of the bank toe. Parallel and impinging flow were the dominant erosional processes at all sites, with piping and sheet erosion being far less common. The severity of erosion activity was rated as mild or significant for the majority of sites. Bank erosion was more severe in the lower gradient reaches, although it was also significant in the moderate gradient reaches. Sites were often impacted by multiple bank failure modes, with shallow slides more common in the steep gradient reaches. Cantilever failure was dominant in the moderate gradient reaches in the Duck Mountains. Streambeds in low gradient reaches were covered with silt or fine sand with little material larger than pebble sized. Bedrock is exposed in the stream bank at four study sites, in steep and moderate gradient reaches near the base of the escarpment. Mid-channel deposits and point bars are common. Channel bars were often associated with bank failures. The moderate gradient reaches were characterized by coarser gravel and cobble sized material; the streambed was often armoured with boulders and cobble in steep gradient reaches. The extent of bank instability tended to be at the reach scale. Wet earth flows were observed only in the steep gradient reaches. Groundwater was often observed seeping from the stream bank or valley side of failure sites in the Duck Mountains.

Streams in the Duck Mountains are populated by beavers that contribute to the large quantity of woody debris in the channels associated with high magnitude erosional events of recent years. No direct evidence was found of forestry or agricultural impacts, although the abundance of fine sediment in low gradient reaches may be related to human activities. Drainage and stream channel engineering in response to channel migration are common in the Duck Mountains. Streams have been modified and straightened in many reaches, with dredged material and riprap used to fill and re-surface migrating meanders. One contrasting example of stream engineering was observed: this was a reach that was re-engineered in conjunction with the construction of a new ford crossing. This reach was restored complete with meanders, pools and riffles. The effectiveness of this approach could not be assessed since the construction was recent.

MANAGEMENT APPLICATIONS

Whereas ecological processes operate locally, and thus require the monitoring of organisms and communities, forest ecosystems are managed at a coarser scale. Thus an ecosite classification and digital maps are a framework for the scaling up of biophysical processes and associated ecological data. An assemblage of ecosites is the geographic expression of biophysical activity over time scales which are longer than the diurnal and seasonal variability of ecological processes and closer to the time frame for forest management and planning. The ring width variation is a record of climatic variability. Given the strong links between weather and disturbance, the reconstruction of annual climate from standardized ring widths is the major aspect of our study of the regional climate. Our digital ecosite database and corresponding digital maps represent a spatial framework for sustainable forest management planning and the interpretation of research at other scales, in particular, studies of stand dynamics. Therefore the database was developed in consultation with Louisiana-Pacific staff and SFMN researchers. We are working with L-P staff to implement the project deliverables, in particular, the GIS-based products.

CONCLUSIONS

The distribution of the forest ecosystems of FML #3 reflects the interaction of topography, drainage, natural disturbance and human activities. The geomorphology and surficial geology of the Duck Mountains are typical of the southern boreal forest, in terms of the impact of continental glaciation on the geography of soil (parent materials), wetlands, lakes and streams. There are steep gradients in soil moisture with relatively subtle changes in elevation and slope, and thus much local variability in forest vegetation. Landform and drainage also influence susceptibility to natural disturbance, especially fire. Despite these physical controls on boreal forest ecosystems, discussions with co-investigators in SFMN suggest that research had not been previously initiated at the landscape (regional) scale to examine relationships among landform, surficial materials, drainage and the spatial variability of boreal forest ecosystems. Our digital and spatial ecosite data base will enable researchers and forest managers to examine these relationships and will support forest management planning with data at appropriate spatial and temporal scales.

The abundance of unconsolidated material and a short geomorphic history have resulted in deep valleys that are susceptible to erosion and contain large volumes of sediment. The magnitude and frequency of precipitation events in the Duck Mountains over the preceding five years may also have contributed to the observed instability. Recent rainfall events may have exceeded local thresholds, resulting in disequilibrium and heightened sensitivity. Little direct evidence of logging impacts was observed. The deranged drainage pattern of the uplands may be mitigating the impacts of tree harvesting. The abundance of fine sediment in low gradient reaches suggests erosion of the adjacent agricultural land is producing sediment. Most of the anthropogenic impacts on streams has been caused by straightening of channels, which increases the effective gradient of a reach, and therefore stream competence and erosion. Structures that stabilize banks ultimately lead to higher erosion activity elsewhere in the reach. The unrestricted erosion of adjacent banks leads to the development of a progressively sharper meander turn, reducing the hydraulic radius. This increases boundary shear stress on lower regions of the bank, accelerating the rate of erosion, which in turn leads to an increase in bank mass wasting. Restoration of selected stream reaches in the Duck Mountains has accommodated the inherent meandering of streams (Newbury and Gaboury, 1993).

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Appendix A: **Ecosite Classification, Field Sheet - Duck Mountain, Mb.**

Plot ID: 121

Location:
Lower end of northern escarpment along highway

Date: Aug 3/99
Time: 3:00pm
Slope: 4-6 degrees

Aspect: 30 degrees
Elevation: 457m

GPS UTM Coordinate:
- GPS II: 0360204 5760787
- Waypoint: 119
Air Photo #: 86
Photo Roll #: Canon 3
Photo: # 9, 10 - Understory
11 - Canopy

Dominate Canopy Vegetation
TA10

Dominate Understory Vegetation
Beaked Hazelnut, Green Alder, Mountain Maple

Vegetation Type **(Field):** V5 Aspen Hardwood
(Lab): V5 Aspen Hardwood

Ecosite Type **(Field):** d2 low-bush cranberry
(Lab): d2 low-bush cranberry

Site Description:

- Located at the Bottom of the Northern Escarpment Along the highway.
- 100% Trembling Aspen canopy
- Very dense high shrubs content including Beaked Hazelnut, Green Alder, Mountain Maple
- High-bush Cranberry and Dogwood also present in lower amounts
- Dominate understory species include Canada Western Violet, Kidney Violet, Woodland Strawberry, wintergreen and Northern Bedstraw.
- Uncovered leaf litter is approx. 50%
- Very thick Canopy and dense shrub cover (canopy at 3m close to 90% closure)
- Little light reaching the canopy floor

Crown Closure Estimate:

a) A (6-30%) $\boxed{\text{b) B (31-50\%)}}$ c) C (51-70%) d) D (71-100%)

Dominate Tree Species (Canopy):

a) Pine $\boxed{\text{b) Aspen}}$ c) Birch d) White Spruce e) Fir f) Black Spruce g) Tamarack h) Non Forested

Stand Origin:

Minimum: **Maximum:** **Average:** **Comments: No cores taken, TA Mature**

Topo-Position: **Surface Shape** **Micro Topography** **Moisture Regime**

a) Crest a) Concave a) Smooth a) Very Xeric (Extremely Dry)
b) Upper Slope b) Convex b) Micro Mounded b) Xeric (Dry)
c) Middle Slope c) Straight c) Slightly Mounded c) Mesic (Moist)
d) Lower Slope d) Strongly Mounded d) Hygric (Wet)
e) Toe e) Extremely Mounded e) Hydric (water at/near surface)
f) Depression

Canopy Composition: **Plot #121**

Main Canopy: **TA**

Understory Trees > 5m: **TA**

Understory Trees < 5m: **Mountain Maple 5m tall dense canopy**

Tree #	Species	DBH (cm)	Heights (m)	Ht to Live	Story	Age	Comments
1	TA	20.4	20	10	M		
2	TA	14.0	20	8.5	M		
3	TA	16.2	10.5	7.5	M		
4	TA	50.9	24	12	O		Fungus growth, decay present
5	TA	59.9	23	12	O		
6	TA	17.1	12.5	8	M		
7	TA	17.0	12.5	8	M		
8	TA	47.2	25	13	O		
9	TA	15.8	11	7	M		
10	TA	17.0	13	9	M		
11	TA	8.7	9	7	M		
12	TA	57.2	23	12	M		
13	TA	58.4	24	12	M		
14	TA	18.9	12.5	9	M		
15							

Understory Species Composition **Plot #121**

	% Cover	Comments
Bare Soil / Rock	0	
Dead Fall	2-3	
Leaf Litter	50-60	Large areas of leaf litter with no vegetation cover

Tall Shrubs	% Cover	Comments
Mountain Maple	50	
Beaked Hazelnut	30	
High-bush Cranberry	10	

Low Shrub	% Cover	Comments
Aspen Suckers	3	
Choke Cherry	2	
Low-bush Cranberry	2	
Pincherry	1	
Snow Berry	2	
Saskatoon	3	
Rose	1	
Dogwood	2	General area contains more dogwood (5%)

Forbs	% Cover	Comments
Sweet scented bedstraw	2-3	
Dewberry	2	
Strawberry	3	
Bishops cap	5	
Lindley's aster	5	
Kidney Violet	3	
Canada western violet	5-7	
Red and white baneberry	3	
Coltsfoot	1	
Starflower	1-2	
Cinquefoil	1-2	
Wild lily of the valley	2-3	
Bluebell	2-3	
Bracken Fern	2	
Wild sarsaparilla	2	
Starflower Solomon Seal	1-2	
Northern bedstraw	1	

Mosses	% Cover	Comments
Un-Identified	< 1	Small amount of moss on rotting wood

Grasses	% Cover	Comments
Rough- leaved mountain rice	< 1	

Soil Conditions: **Plot #121**

Organic Matter Thickness	3 cm – Very thin Mainly well decomposed, with the exception of the leaf litter on the surface
Humus Form	Ah – 15-17cm – mixing of Organics and mineral soils. Transition – dark on top lighter at deeper depths.
A Horizon Thickness	3-60cm Sandy Loam 60-70cm Sandy (extremely sandy)
Surface Texture	Organic
Effective Texture	Sandy Loam
Mottles	None Present at depths to 1m
Gley	None Present at depths to 1m
Coarse Fragment	No real large coarse fragments. Some coarse sands and very small gravels occur throughout the pit

Soil Pit Dug: $\boxed{\text{Yes}}$ / No **Pit Dug at Position -** NW NE SE SW $\boxed{\text{Middle}}$

Samples Taken: **A: 25 cm** **B: 85 cm** **C:N/A cm** **Profile Sketch**

Drainage: Well

Depth to ground Water: $\boxed{\textbf{Unknown}}$ **/** **cm**

Standing Water: **Present /** $\boxed{\textbf{Absent}}$

Comments:
- Very Dry Soils
- Rich
- Large sand content at depths of 85-90 cm
-

Humus	A Horizon	Soil Texture	Soil Depth	Coarse Fragments	PH	Seepage	Nutrient Regime
$\boxed{\text{Mor}}$	Ae Hor Present	Coarse	Extremely Shallow	a) High	Acidic	Present	Very Poor
Moder	A Hor. Absent	$\boxed{\text{Medium/fine}}$	$\boxed{\text{Shallow to Deep}}$	- Sandy Soils	$\boxed{\text{Neutral}}$	$\boxed{\text{Absent}}$	Poor
Mull	Ah Hor. Present			>35 %	Alkaline		Medium
				- Loamy Soils			$\boxed{\text{Rich}}$
				>70 %			Very Rich
				$\boxed{\text{b) Low to Interm}}$			

Appendix B

Ecosystem Classification of the Mid-boreal Ecoregion

(A Summarry of ecosite fact sheets contained in Beckingham, *et al.* 1996; Field Guide to Ecosites of the Mid-boreal Ecoregions of Saskatchewan)

a Lichen

General Discription:

This ecosystem has dry conditions with rapidly drained acidic soils and poor nutrient status due to the coarse-textured glaciofluvial or eolian parent material. Plants that are indicative of this ecosyem include **bearberry, reindeer lichen, bog cranberry, and blueberry**. **Open jack pine stands** dominates this ecosite, which is commonly carpeted with **lichen covering the forest floor** and a thin organic layer typically less than 5 cm thick. This ecosite is more prevalent in the Mid-Boreal Lowland Ecoregion.

Successional Relationship:

Due to the dry nature of this ecosite, succession to Black Spruce is commonly slower than the fire return interval. Therefore, pine is mantained for relativly log periods and can colonize the site and dominate the canopy in a fire climax community.

Site Charateristics:

Moisture Regime:	subxeric, xeric, very xeric
Nutrient Regime:	poor
Topographic Position:	midslope, level, uperslope, crest, lowerslope

Soil Conditions:

Soil Nutrient Regime: Poor
Soil Moisture Regime: Xeric

Indicator Species:

reideer lichen	bear berry
blueberry	bog cranberry
awned hair-cap	sand heather

Common Plants:

		Ecosite Phase a1: lichen jP
Tree	jack pine	***
Shrubs	bearberry	*
	blueberry	*
	bog cranberry	*
	green alder	(*)
	sand heather	(*)
Forbs	wild lily-of-the-valley	*
Mosses	Schreber's moss	***
	cushion moss	*
Lichen	Reindeer Lichen	***

b Blueberry

General Discription:
This ecosite tends to be subxeric to submesic as a result of relatively coarse textured glaciofluvial overlying morainal parent materials. This ecosite is in both nutrient and moisture regime between the lichen ecosite (a) and the low-bush cranberry ecosite (d). The blueberry ecosite has species characteristics of the lichen ecosite such as **jack pine, blueberry, bearberry, and bogcranberry**, and speciecs characterisic of the low-bush cranberry ecosite, such as **aspen, white spruce, wild sarsaparilla, and bunchberry**. This ecosite has a higher frequency of occurrence in the Mid-Boreal Lowland Ecoregion.

Successional Relationships:
The pine, aspen, and white birch-dominate phases of this ecosite, may in some cases, succeed to white spruce, however, the process is slow due to the dry nature of this ecosite

Site Charateristics:
Moisture Regime: submesic, subxeric, mesic, xeric
Nutrient Regime: poor, medium
Topographic Position: midslope, level, crest, uperslope

Soil Conditions:
Soil Nutrient Regime: Medium
Soil Moisture Regime: Submesic

Indicator Species:

blueberry	hair wild rye
bearberry	bog cranberry
wild sarsaparilla	Labrador tea
cream colour vetching	

Common Plants:

		Ecosite Phase			
		b1: jP-tA	**b2: tA(wB)**	**b3: tA-wS**	**b4: wS(jP)**
Tree	jack pine	***			***
	aspen	***	***	***	
	white spruce	*	(*)	***	***
	white birch	(*)	*		
Shrub	**green alder**	***	*	*	***
	blueberry	*	*	***	*
	bog cranberry	*	*	*	*
	bearberry	*	*	***	***
	twin-flower	*	*	*	*
	prickly rose	*	*	*	*
	Labrador tea	*	*	*	
	aspen	(*)		*	

	saskatoon		(*)	(*)	(*)
	white spruce			*	*
	Canada buffalo-berry				(*)
Forb	bunchberry	*	*	*	
	wild sarsaparilla	*	*	*	
	stiff club-moss	(*)			
	wild lily-of-the valley	*	*	*	*
	northern starflower	*			
	cream cloured vetching	(*)		(*)	
	bastard toad flax				*
Grass	hairy wild rye	(*)	(*)		
Moss	Schreber's moss	***		***	***
	stair-step moss	*		*	*
	knight's plume moss	*			*
Lichen	reindeer lichen	(*)		(*)	*

c Labrador tea - submesic

General Discription:
This ecosite has a subxeric to subhygric nutrient poor substrate. Labrador tea and bog cranberry are indicative of the relatively acidic surface soil conditions. **It occurs in upland (midslope and upper slope) or level topographic** positions dominantly on morainal or glaciofuvial parent materials. There is commonly a **two tiered evern aged canopy where faster growing jack pine comprise the higher level and the slower growing black spruce form a secondary canopy below the pine**. While the Labrador tea - submesic ecosite has plant community types similar to the Labrador tea - hygric ecosite (g), the submesic ecosite tends to occur in upper topographic positions, has no mottles within the top 25 cm of soil, and a thinner organic layer. This ecosite covers a higher poportion of the landscape area in the Mid-Boreal Upland Ecoregion than in the Mid-Boreal Lowland Region.

Successtional Relationships:
Successionally mature stands that develop on these ecosites may be dominated by black spruce. Residual pine occuring in the climax community are generally very old. The successionally mature stage is rare due to the high frequency of fire.

Site Charateristics:
Moisture Regime: submesic, mesic, subxeric
Nutrient Regime: poor, medium
Topographic Position: midslope, level, upper slope, crest

Soil Characteristics
Soil Nutrient Regime: Poor
Soil Moisture Regime: Submesic

Indicator Species:

jack pine	black spruce
Labrador tea	bog cranberry
Schreber's moss	

Common Plants:

		Ecosite Phase c1 Labrador tea - submesic jP-bS
Tree	jack pine	***
	black spruce	*
Shrub	green alder	***
	Labrador tea	*
	bog cranberry	*
	blueberry	*
	twin-flower	*
	black spruce	(*)

Forb	bunchberry	*
	wild lily-of-the valley	*
	northern starflower	(*)
Moss	Schreber's moss	***
	stair-step moss	*
	knight's plume moss	*
	cushion moss	*
Lichen	reindeer lichen	(*)

d Low -brush cranberry

General Discription:
This is the reference ecosite for the Midboreal ecoregions because it has a mesic moisture regime and a medium nutrient regime. Generally, these ecosites have moderately fine to fine textured till or glaciolacustriene parent materals. This ecosite covers a relatively large portion of the Mid-Boreal Upland Ecoregion. It is far less common in the Mid-Boreal Lowland Ecoregion because a high proportion of the landscape of the Lowland Ecoregion consists of low lying wetland areas. **Mountain maple (*Acer spicatum*) and brush huneysuckle (*Diervilla lonicerra*)** community types of the low-bush cranberry ecosite are only in the eastern portion of Saskatchewan.

Successtional Relationships:
Pioneer decidious tree species such as aspen, balsam poplar, and white birch are replaced by white spruce and balsam fir as these sites develop successionally. Along with a change in canopy composition is a change in understory structure and understory species composition and abundance. Generally, as a stand successionally matures, the coniferous canopy cover increases, and understory species structure and diversity declines. This results in a stand with low cover of shrub, forbs and grass speecies and high moss cover.

Site Charateristics:
Moisture Regime: mesic, submesic, subhygric
Nutrient Regime: medium, poor, rich
Topographic Position: midslope, upper slope, level, lower slope

Soil Characteristics
Soil Nutrient Regime: Medium
Soil Moisture Regime: Mesic

Indicator Species:
low-bush cranberry dewberry
wild sarsaparilla

Common Plants:

		Ecosite Phase			
		d1 - jP-bS-tA	**d2 - tA**	**d3 - tA-wS**	**d4 - wS**
Tree	jack pine	***			
	aspen	*	***	***	(*)
	white spruce		(*)	***	***
	white birch	(*)	*	*	(*)
	balsam fir			*	*
	black spruce	*		*	
	balsam poplar		*	*	(*)
Shrub	**low-bush cranberry**	*	*	*	(*)
	green alder	***	*	*	(*)

	balsam fir			*	***
	prickly rose	*	*	*	*
	twin-flower		*	*	*
	beaked hazelnut		***	(*)	
	bush honeysuckle	*		(*)	
	mountain maple			(*)	
	pin and choke cherry		(*)	(*)	
	saskatoon			(*)	
	willow		(*)		
Forb	stiff club-moss	***			
	wild sarsaparilla	*	***	*	*
	bunchberry	*	*	*	*
	dewberry	*	*	*	*
	wild strawberry	*	*		
	bishop'scap			*	
	tall lungwort			*	
	palmate-leaved coltsfoot	*	*	*	
	wild lily-of-the-valley	*	*	*	*
	common pink wintergrren		*	*	
	northern starflower	*			
	shield fern	(*)			
	lady fern	(*)			
	fireweed		*		
	cream colour vetching		*		
	Lindley's aster		*		
Grass	hairy wild rye	*			
	marsh reed grass		*		
Moss	stair-step moss	*		**	***
	Schreber's moss	***		*	***
	knight's plume moss	*			*

e Dogwood

General Discription:
The dogwood ecosite is subhygric and nutrient rich. These sites are commonly found in **midslope or lower slope topographic positions or near water courses** where they recieve nutrient-rich seepage or floodwaters for a portion of the growing season. Fine-texture morainal and glaciolacustrine parent materials are common and plant communities tend to be **high in species richness, cover, and diversity**.

Successtional Relationships:
Succession proceeds slowly after disturbance due to the proliferation of grass, forb, and shrub cover. This explosion of vegetational cover can make tree establishment (especially conferous) difficult and can be reduced early tree species growth rates. Once white spruce becomes established, high growth rates can be expected.

Site Charateristics:

Moisture Regime:	subhygric, mesic, hygric
Nutrient Regime:	rich, medium
Topographic Position:	midslope, lower slope, level, depression

Soil Characteristics
Soil Nutrient Regime: Rich
Soil Moisture Regime: Subhygric

Indicator Species:

balsam poplar	braccted honeysuckle
dogwood	currants
wild red raspberry	tall lungwort
sweet-scented bedstraw	oak fern
lady fern	shield fern

Common Plants:

		Ecosite Phase		
		e1: bP-tA	**e2: bP-wS**	**e3: wS**
Tree	**balsam poplar**	***	*	(*)
	aspen	***	*	(*)
	white birch	*	*	(*)
	white spruce	(*)	***	***
	balsam fir		(*)	***
Shrub	**river alder**	***	*	*
	dogwood	***	*	(*)
	low-bush cranberry	*	*	*
	prickly rose	*	*	*
	wild red raspberry	*	*	
	currant	*	*	(*)

	alder-leaved buckthorn	(*)	(*)	
	bracted honeysuckle	(*)	*	
	balsam poplar	(*)		
	mountain maple	(*)	(*)	
	high-brush cranberry	(*)		
	balsam fir		*	***
	bush-honeysuckle		(*)	
Forbs	**wild sarsaparilla**	***	*	***
	bunchberry	*	*	*
	dewberry	*	*	*
	fireweed	*		
	tall lungwort	*	*	*
	palmate-leaved coltsfoot	*		
	bishop's-cap	*	*	*
	sweet-scented bedstraw	*		*
	oak fern	**(*)**	**(*)**	*
	shield fern	(*)		*
	nothern starflower		*	
	woodland horsetail			*
	kidney-leaved violet			*
	wild lily-of-the valley			*
Moss	stair-step moss		*	***
	Schreber's moss		*	***
	knight's plume moss			*

f Ostrich fern

General Discription:

The ostrich fern ecosite (f) is subhygric and nutrient-rich. It frequently occurs on fluvial parent materials where periodic flooding replenishes the nutrients available for plants. It also **occurs where freshwater springs come to the surface** and in lower slope areas where seepage is prevalent. In approximately 90% of the plots sampled mottles or gley occurred within 25 cm of the soil surface which is indicitive of the high moisture avalability. This ecosite tends to **high in species richness, cover, and is uncommon in the Mid-Boreal Lowland Ecoregion.** It is howeverthe dominate ecosite along watercoarses of the Mid-boreal Lowland Ecoregion. The ostrich ferm mM-wE-bP-gA ecosite phase (f2) occurs exclusively in the Mid-Boreal Lowland Ecoregion and is the only ecological unit with **Manitoba maple (*Acer negundo*), white elm (*Ulmus americana*), and green ash (*Fraxinus pennsylvanica*). The ostrich fern ecosite tends to be the most productive in the Mid-Boreal ecoregions of Saskatchewan.**

Successtional Relationships:

Stand composed of **aspen, balsam poplar, white birch, Manitoba maple, white elm, and/or gree ash are successional to white spruce-dominated site**. If white spruce does not colonize this ecoregion after disturbance it may have difficulties becoming established due to the excessive compitition and/or frequent disturbance by floodingin flluvial environments. Historically, white spruce trees were common in areas consisting of the ostrich fern ecosite, but most large spruce have been harvested. After the selective harvest of white spruce, its regeneration has been inadequate. This may be due to the use of improper or improper or limited silvicultureal practices.

Site Charateristics:

Moisture Regime: subhygric, hygric, mesic
Nutrient Regime: rich, very rich
Topographic Position: level, upperslope, lower slope, depression

Soil Properties:

Soil Nutrient Regime: Very Rich
Soil Moisture Regime: Subhygric

Indicator Species:

balsam poplar	high-bush cranberry
dogwood	currants
ostrich fern	

<u>Common Plants:</u>

		Ecosite Phase		
		f1	**f2**	**f3**
Trees	**balsam poplar**	***	*	***
	white birch	***	*	*
	aspen	*		(*)
	Maitoba maple	(*)	***	
	green ash		*	
	white elm		*	
	white spruce		(*)	***
	balsam fir			*
Shrubs	mountain maple	***	(*)	
	beaked hazelnut	*		
	high-bush cranberry	*	*	
	low-bush cranberry			*
	dogwood	*	*	***
	current	*	*	*
	pin and choke cherry	*	*	
	green ash		*	
	river alder		(*)	*
	balsam poplar		*	
	Manitoba maple		***	
	white elm		*	
	prickly rose			*
	balsam fir			*
	bracted honeysuckle			*
	alder-leaved buckthorn			*
	wild red raspberry			*
Forbs	**ostrich fern**	***	***	***
	wild sarsaparilla	***	*	***
	meadow horsetail	*	*	
	dewberry	*	*	*
	bishop's-cap	*	*	*
	tall lugwort	*		*
	Lindley's aster	*		*
	lady fern	*		
	sweet-sented bedstaw	*	*	*
	northern bedstraw	*		*
	red and white baneberry	*	*	
	common pink wintergreen	*		
	great spurred violet		*	
	small enchanter's nightshade		*	
	shield fern		*	
	bunchberry		*	

	wild lily-of-the-valley			*
	woodland strawberry			*
	kidney-leaved violet			*
Grass	sedge	*	*	
Moss	ragged moss	*		*
	leafy moss			*

g Labador tea - hygric

General Discription:

The Labrador tea-hydric ecosite has a nutrient-poor substrate with imperfectly to **poorly drained soils**. **Labrador tea and bog cranberry are indicative of the relatively acidic surface soil conditions**. It dominatly occurs on the fine-textured till or glaciolacustriane parent material where the wet soil conditions promote the development of Gleysolic soils. While the labrador tea-hygric ecosite **has plant comunity types simular to the Labrador tea-submesic ecosite (c), the hygric ecosite tends to occur in lower topographical positions,** has mottles in the top 25 cm of the soil, has a thicker organic layer, and **may be dominated by black spruce rather than pine**. The high soil water water content associated with this ecosite creates a grater risk of the site modification when the soils are not frozen. This ecosite is not common in the Mid-Boreal Lowland Ecoregion of Saskatchewan.

Successtional Relationships:

Young and mature stands that develop in this ecosite often have a component of black spruce. The black spruce is often the same age as the pine but forms a secondary canopy due to the slower growth rates. Successionally mature stands are dominated by balck spruce with a small component of old residual pine.

Site Charateristics:

Moisture Regime: subhydric, hydric, subhydric
Nutrient Regime: poor, medium
Topographic Position: level, lower slope, midslope

Soil Characteristics:

Soil Nutrient Regime: Poor
Soil Moisture Regime: Hygric

Indicator Species:

black spruce	jack pine
Labrador tea	bog cranberry
feather moss	

Common Plants:

		Ecosite Phase
	g1:	**bS-jP**
Trees	balck spruce	***
	jack pine	*
Shrub	Labrador tea	***
	blueberry	(*)
	black spruce	(*)
	bog cranberry	*
	prickly rose	(*)
	twin-flower	(*)

Forbs	bunchberry	(*)
	wooland horsetail	(*)
	dwarf scouring rush	(*)
	palmate-leaves coltsfoot	(*)
Moss	Schreber's moss	***
	stair-step moss	***
	knight's plume moss	*
	peat moss	*
Lichen	reindeer lichen	*

h Horsetail

General Discription:
The horsetail ecosite is subhygric to hydric and nutrient rich. These sites are commonly found on fluvial or glaciolucustrine parent material where flooding or seepage enhances the substrate nutrient supply. With **high water tables, wet soil conditions,** and Gleysolic soils, organic matter tends to accumulate. **Horsetails commonly form a blanket over the forest floor.**

Successtional Relationships:
Succession on these sites is largely controled by high soil water content. Some sites that have peaty soil may have taken hundreds of years to develop. When the trees are removed, the water table may rise making tree establishment difficult; Understory vegetation development is agressive following disturbance (e.g. Calamagrostis canadensis). White spruce forms the canopy in the last successional stage.

Site Charateristics:
Moisture Regime: subhygric, hydric
Nutrient Regime: rich, medium
Topographic Position: level, lower slope, depression, toe

Soil Characteristics:
Soil Nutrient Regime: Rich
Soil Moisture Regime: Hygric

Indicator Species:
common horsetail meadow horsetail

Common Plants:

		Ecosite Phase			
		h1: bP-tA	**h2: bP-wS**	**h3: wS-bS**	Tree
	aspen	*******	*****	**(*)**	
	balsam poplar	******	******	**(*)**	
	white spruce	**(*)**	*******	*******	
	white birch		**	(*)	
	balsam fir		*		
	black spruce			*)	
Shrub	willow	***			
	wild red raspberry	**			
	prickly rose	**		*	
	currant	*	*	*	
	twin-flower	*	*	*	
	dogwood	(*)			
	white spruce	(*)			
	aspen	*			
	balsam fir		*		

	bracted honeysuckle		*	
	low bush cranberry		*	*
	white spruce		*	
	white birch		*	
	Labrador tea			*
Forb	**meadow horsetail**	***	***	***
	common horsetail	***	*	***
	woodland horsetail		*	
	wild sarsaparilla	***	*	
	tall lungwort	*	*	*
	bunchberry	*	*	*
	wild lily-of-the-valley	*		
	wild strawberry	*		
	Lindley's aster	*		
	fireweed	*		
	northern bedstraw	*		
	red and white baneberry	*		
	dewberry		*	*
	bishop's-cap		*	*
	palmate-leaved coltsfoot		*	*
	common pink wintergreen		*	
Grass	**marsh reed grass**	***	*	*
Moss	Schreber's moss		**	***
	stair step moss		**	***
	knight's plume moss		*	*

i Gully

General Discription:
The gully ecosite is an unique ecological unit that occurs in drainage swales or channels where springs, small streams, and runoff provide a **continious supply of water** and nutrients. **The wet soil conditions facilitate the accummulation of organic matter**. Organic soils have develpoed over fluvial parent materials in nealy half the plots sampled. Approximately 70% of the sample sites with mineral soils had gley or mottles within 25 cm of the mineral soil surface and all sample sites with mineral soils had gley or mottles within 100 cm of the soil surface.

Successtional Relationships:
Due to a combination of the excessively wet conditions and the relatively frequent fluvial disturbance regime, trees have difficulty becoming established on this ecosite. The river alder gully ecosite phase (i1) could be considered an edaphic climax. However, it is transitional to the ostrich fern ecosite (f) where white spruce forms the canopy of the climax community.

Site Charateristics:
Moisture Regime: subhydric, hydric
Nutrient Regime: rich, very rich
Topographic Position: depression, toe, level

Soil Characteristics
Soil Nutrient Regime: Very Rich
Soil Moisture Regime: Hygric

Indicator Species:

river alder	dogwood
willow	ostrich fern
oak fern	shield fern

Common Plants:

		Ecosite Phase i1: river alder gully
Shrub	river alder	***
	dogwood	*
	currant	*
	wild red raspberry	*
	willow	*
	prickly rose	*
	bracted honeysuckle	*
	low-bush cranberry	*
	balsam poplar	*
Forb	ostrich fern	**
	woodland horsetail	*
	oak fern	*

	tall lungwort	*
	bishop's-cap	*
	dewberry	*
	shield fern	*
	sweet-sented bedstraw	*
Grass	sedge	*
	drooping wood-reed	*
Moss	woodsy leafy moss	*
	common tree moss	*
	brown moss	*

j Bog

General Discription:
The bog ecosite commonly has organic soils consisting of **slowly decomposing peat moss.** They are **poorly to very poorly drained and have a very poor to poor nutrient regime**. This ecosite occupies level and depresional where **water tends to be stagnant** and impeded drainage or high water tables enhance the accumulation of organic matter. **Stunted black spruce form a sparse canopy on the treed phase** (j1) of the bog ecosite. Along with the poor fen (k) and the rich fen (l) ecosites the bog dominates the flat landscape of the Mid-Boreal Lowland Ecoregion.

Successtional Relationships:
The bog ecosite is an edaphic climax that is maintaned by high water tables. The hydrarch succession to the bog ecosite is extremely slow.

Site Charateristics:
Moisture Regime: subhydric, hydric
Nutrient Regime: very poor, poor
Topographic Position: level, depression

Soil Characteristics
Soil Nutrient Regime: Very Poor
Soil Moisture Regime: Subhydric

Indicator Species:

black spruce	Labrador tea
bog cranberry	cloudberry
peat moss	smal-bog cranberry
slender hair-cap	

Common Plants:

		Ecosite Phase	
		j1: treed bog	**j2: shrubby bog**
Tree	black spruce	***	
Shrub	**Labrador tea**	***	***
	black spruce	*	***
	bog cranberry	*	*
	small bog cranberry	(*)	*
	leatherleaf		*
	northern laurel		*
Forb	**cloudberry**	*	*
Moss	**peat moss**	***	****
	Scheber's moss	***	(*)
	stair-step moss	*	

	knight's plume moss	(*)	
	slender hair-crap	**(*)**	**(*)**
Lichen	**reindeer lichen**	*****	*****
	deformed cup lichen		*

k Poor fen

General Discription:
The poor fen ecosite is intermediate in nutrient regime between the bog (j) and the rich fen (l) ecosites and as such has species characteristics of both. **Drainage is poor to very poor, however, there is movement of water through the substratum.** This ecosite occupies **level and depressional areas** where impeded drainage or high water tabels enhance the accumulation of organic matter. This organic matter consists of a combination of **bog type oganic matter such as peat moss (Sphagnum spp.) and fen-type organic matter such as sedges (Carex spp.), golden moss (Tomenthypnum nitens), tufted moss (Aulacomnium palustre), and brown moss (Drepanocladus spp). Both the black spruce and/or tamarack that dominate a sparse canopy on the treed phase (k1) of the poor fen ecosite are stunted and generally considered unmerchantable.** Along with the bog (j) and rich fen (l) ecosites, the poor fen dominates the flat landscape of the Mid-Boreal Lowland Ecoregion.

Successtional Relationships:
The hydrarch succession characteristic of this ecosite occurs over a period of hundreds of years. Thus, recovery from disturbance is extremely slow. Site disturbance can influence the hydrologic regime, resulting in changes in the direction and rate of succession. As these systems depend on water flow through them, impeding this flow can result in a reduction or elimination of tree cover and changes in the shrub, forb, grass layers.

Site Characteristics:

Moisture Regime:	subhydric, hydric
Nutrient Regime	poor, medium, very rich, very poor
Topographic Position	level, depression, toe

Soil Characteristics:
Soil Nutrient Regime: Medium
Soil Moisture Regime: Subhydric

Indicator Species:

black spruce	tamarack
Labrador tea	dwarf birch
willow	cloudberry
sedge	peat moss
golden moss	tufted moss
brown moss	

Common Plants:

Ecosite Phase

		k1: treed poor fen	k2: shrubby poor fen
Tree	black spruce	**	
	tamarack	**	
Shrub	**Labrador tea**	***	**(*)**
	black spruce	**	**
	bog cranberry	*	
	small bog cranberry	*	**(*)**
	leatherleaf		**
	dwarf birch		*
	bog rosemary		*
	tamarack		*
	willow		*
Forb	cloudberry	*	
Grass	**sedge**	*	*
	marsh reed grass		(*)
Moss	**peat moss**	***	*
	Schreber's moss	**	
	stair-step moss	*	
	tufted moss	*	**(*)**
	slender hair-cap	*	(*)
	golden moss		*
	cushion moss		*
Lichen	**reindeer lichen**	*	**(*)**

l Rich fen

General Discription:
The rich fen ecosite characterized by **flowering water and alkaline nutrient-rich conditions.** The soil is composed of organic matter derived from **decomposing sedges (*Carex spp.*), as well as golden moss (*Tomenthypnum nitenes*), tufted moss (*Aulacomnium palustre*), and brown moss (*Depanocladus spp.*)**. This ecosite occupies **level and depresional areas where the water table is at or near the surface for a portion of the growing season. Tamarack dominates the canopy in the treed phase while dwarf birch or willow from the canopy in the shrubby phase and sedges dominate the graminoid phase of the rich fen ecosite**. Along with the bog (j) and poor fen (k) ecosites, the rich fen ecosite dominates the flat landscape of the Mid-Boreal Lowland Region.

Successtional Relationships:
The rich fen is an early stage in the hydrarch succession. Species composition, direction, and rate of succession changes with the changing hydrlogic regime. As with other wetlands, rech fens have slow successional rates so recovery from disturbance may be also slow.

Site Charateristics:
Moisture Regime: Subhydric, hydric
Nutrient Regime: Medium, rich, poor
Topographic Position: level, depresional

Soil Characteristics
Soil Nutrient Regime: Rich
Soil Moisture Regime: Subhydric

Indicator Species:

tamarack	willow
dwarf birch	sedge
golden moss	tufted moss
brown moss	marsh reed moss

Common Plants:

		Ecosite Phase		
		l1	**l2**	**l3**
Tree	tamarack	**		
Shrub	dwarf birch	**	**	
	willow	**	***	*
	Labrador tea	*		
	northern laurel	*		
	river alder	*		
	tamarack	*		
	black spruce	(*)		

Forb	buck-bean	(*)		*
	marsh marigold	*		
	three-level Solomon's seal	*		
	marsh cinquefoil	(*)	*	
Grass	**sedge**	**	***	***
	marsh reed grass	*	**	*
	fowl bluegras		*	
Moss	peat moss	**	*	
	tufted moss	**	*	
	Schreber's moss	*		
	golden moss	*		
	brown moss	(*)	**	

m Marsh

General Discription:
The marsh ecosite is found in **level and depresional area and around the shorelines of water bodies and riparian zones.** The **water is above the rooting zone for at least a potion of the growing season**. This ecosite is dominated by a diversity of emergent **sedges and rushes.**

Successtional Relationships:
The marsh ecosite is near the begining stages of the hydrarch succession. The mash ecosite can be thought of as successional stable with changes in plant community composition being determined largely by disturbance regime and water level.

Site Charateristics:

Moisture Regime:	hydric, subhydric
Nutrient Regime:	rich, medium
Topographic Position:	level, depresional

Soil Characteristics:
Soil Nutrient Regime: Rich
Soil Moisture Regime: Hydric

Indicator Species:

cattail	reed grass
sedge	rush
bulrush	

Common Plants:

		Ecosite Phase m1: marsh
Shrubs:	willow	*
Forbs:	cattail	**
	northern willowherb	*
	wild mint	*
Grass:	reed grass	***
	sedge	**
Moss:	brown moss	**