STRIP CUTTING IN SHALLOW-SOIL UPLAND BLACK SPRUCE NEAR NIPIGON, ONTARIO. I. STUDY ESTABLISHMENT AND SITE CONDITIONS

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ABSTRACT

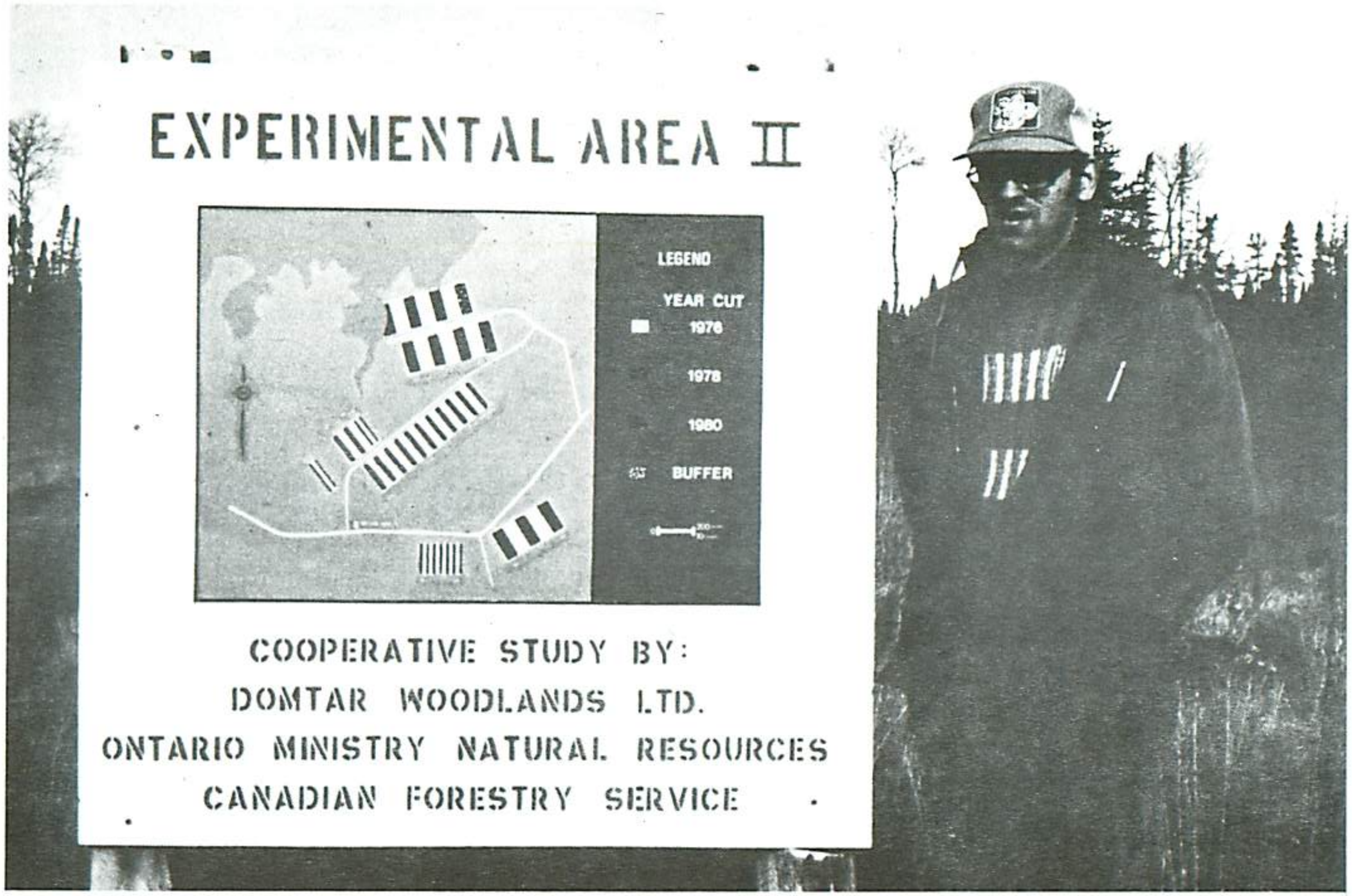
Establishment of a long-term, cooperative study of strip clearcutting in shallow-soil, upland, Black Spruce (*Picea mariana* [Mill.] B.S.P.)/Schreber's Feather Moss (*Pleurozium schreberi* [Brid.] Mitt.) forest near Nipigon, Ontario, is documented. Information is presented on experimental design, site conditions, and preharvest forest conditions. Chemical analyses of soils revealed highest concentrations of exchangeable nutrients in fermentation and humus layers of the organic (mor) mat. In the absence of natural wildfire, forest development in these overmature stands is toward a mixedwood consisting of Balsam Fir (*Abies balsamea* [L.] Mill.), Black Spruce, White Birch (*Betula papyrifera* Marsh.), and Trembling Aspen (*Populus tremuloides* Michx.). Shallowness of the mineral soils, treatment of the organic (mor) mat, and natural developmental trends are key elements in understanding and managing this fragile ecosystem.

RÉSUMÉ

Documentation relative à l'établissement d'une étude conjointe à long terme de la coupe rase par bandes dans la forêt montane à sol peu profond d'Épinette noire (*Picea mariana* [Mill.] B.S.P.) et d'Hypne de Schreber (*Pleurozium schreberi* [Brid.] Mitt.) près de Nipigon, Ontario. Des informations sont fournies sur le dispositif expérimental, les conditions de la station et les conditions prévalant dans cette forêt avant la coupe. Des analyses chimiques des sols ont révélé de fortes concentrations d'éléments nutritifs échangeables dans la couche en fermentation et dans la couche humifère du mor. Dans ces peuplements surannés, faute d'incendies naturels, la forêt évolue vers un mélange de Peuplier baumier (*Abies balsamea* [L.] Mill.), Épinette noire, Bouleau à papier (*Betula papyrifera* Marsh.) et Peuplier faux-Tremble (*Populus tremuloides* Michx.). Le peu de profondeur des sols minéraux, le traitement du mor et les tendances de l'évolution naturelle constituent des éléments clés dans l'intelligence et l'aménagement de cet écosystème fragile.

ACKNOWLEDGMENTS

The success of this project has depended upon the cooperation and long-term commitment of numerous individuals from the Ontario Ministry of Natural Resources, Domtar Forest Products, the Canadian Forestry Service and forestry consultants (e.g., see footnotes 6 through 9 in text). A number of people have given generously of their time, ideas and efforts. However, I wish to recognize the key contributions of two exceptional foresters, J.W. Fraser and G. Marek, who conceived the project in 1973, gave it an organizational framework, developed the design for the experimental and operational strip cutting, and ensured that work on the project proceeded according to the guidelines of the initial proposal. In addition, I gratefully acknowledge the talents of P.L. Copis, who has contributed ideas, surveyed and laid out two of the experimental strip cut areas, conducted supplementary surveys in the area, performed a liaison role with all cooperating agencies, analyzed and summarized data and prepared figures and tables for this report.



Frontispiece. Map of Study Area II (Peck Lake) indicating strip layout, widths and leave times.

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INTRODUCTION

Black Spruce (*Picea mariana*[1]) forests (Fig. 1 and 2) are found extensively in northern Ontario (Ketcheson and Jeglum 1972), and are the main source of wood fibre supporting the economically important pulp and paper industry (Tucker and Ketcheson 1973). The species occurs in monodominant stands in merchantable as well as non-merchantable swamps, and on mineral soil uplands usually in lower positions in the landscape adjacent to swamps. In addition to the main use of these forests in supplying fibre for paper, they provide some sawn lumber, and also important watershed, wildlife, and recreation values. It is important that lands covered with these forests be regenerated promptly after harvesting, to maintain their fibre-producing capabilities as well as other functions.

With the non-restricted clearcut harvesting method there are frequent failures in regeneration (e.g., Hosie 1953, Fraser *et al.* 1976), and a large backlog of non-regenerated lands has accumulated in Ontario (Anon. 1977, 1978). Poor natural regeneration in large clearcuts is usually explained by one of more of three major constraints: (1) an inadequate supply of viable seed, (2) unfavorable seedbed conditions, and (3) exposure of the ground surface to excessive heating and drying (cf. Roe et al. 1970). Consequently, in recent years, there have been increasing efforts to develop techniques of modified harvesting and site preparation to obtain natural regeneration from seed on cutover lands previously covered by Black Spruce forests. One type of modified clearcutting, strip clearcutting (Frontispiece, Fig. 1), has been strongly advocated in Ontario as one of the most practical and effective alternatives to non-restricted clearcutting (e.g., Robinson 1974, Marek 1975, Flowers, 1977; see also footnote 2).

Upland Black Spruce forest on shallow mineral soil over bedrock[3] (Fig. 3 and 4) is a common site type in the Nipigon as well

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[1]Nomenclature and author citations for vascular species follow those used by Gleason and Cronquist (1963) and for mosses those used by Ireland et al. (1980).

[2]Anon. 1977. Proposed policy for controlling the size of clearcuts in the northern forest regions of Ontario, 5th draft, October 1977. Ont. Min. Nat. Resour., Toronto, Ont. Unpublished guidelines.

[3]The Canadian System of Soil Classification (Canada Soil Survey Committee, Subcommittee on Soil Classification, 1978) defines 'shallow' mineral soils as those with a depth to lithic contact of less than 100 cm, and further divides 'shallow' into 'extremely shallow' -- 20 cm deep or less, 'very shallow' -- 20 to 50 cm deep, and 'shallow' -- 50 to 100 cm deep.

as other Precambrian areas in Ontario (Robinson 1974). Frequently, these are patterned complexes with organic soils alternating with shallow-soiled ridges (Fig. 5). Owing to the shallowness of the mineral soil and the irregular and often rugged bedrock-controlled topographies, these sites present a difficult problem when one is attempting to prescribe a harvest-regeneration system which will quickly re-establish a productive forest following harvest (Fig. 6). The bedrock near the surface, and the stoniness of the thin veneer of soil elsewhere, make for difficult planting conditions, and care is needed to minimize erosion and exposure, both of which militate against regeneration. A system proposed to handle these 'fragile'[4] Black Spruce-shallow soil ecosystems is that of alternate strip clearcutting, followed by 'delicate' scarification to expose enough of the desirable mineral soil seedbed to achieve satisfactory stocking (Robinson 1974, Marek 1975).

Objectives

The present report documents the establishment of a long-term study of regeneration response to alternate strip clearcutting, in shallow-soil, predominantly upland Black Spruce forests over 100 years old near Nipigon, Ontario. The specific objectives of this report are:

(1) to document the design of the regeneration study in experimental strip cuts, and the procedures for operational strip cuts;

(2) to present baseline data on site and soil conditions; and

(3) to present information on preharvest stand composition, structure, and condition.

Background to Cooperative Strip Cutting Project at Nipigon

In December 1973, the Canada-Ontario Joint Forestry Research Committee accepted a "Joint Proposal by the Ontario Ministry of Natural Resources (OMNR), the Great Lakes Forest Research Centre (GLFRC), and

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[4]One type of fragile site defined by the Ontario Ministry of Natural Resources is "A shallow site which has less than 12" [30 cm] of mineral soil over bedrock. These sites are usually intermixed with pockets of deeper soil. When the shallow areas represent more than 40% of the forest type, it will be considered fragile and to require M.H.C. (modified harvest cutting)." *From* Ontario Ministry of Natural Resources, November 8, 1975, 'Instructions for the Implementation of Circular T.S. 2.00.05.01 dated October 6, 1972: Control of Logging Methods on Crown Land.'

Figure 1. Study Area III (Phoney Lake), showing 20-m (foreground) and 40-m (background) alternate strip clearcuts, and a patch clearcut (upper right). Note Trembling Aspen (upper right) clumps and individuals scattered through the Black Spruce forest.

Figure 2. An upland Black Spruce/Schreber's Feather Moss forest on a shallow-soil site. From Study Area III (Phoney Lake).

Figure 3. Soil pit in Study Area III (Phoney Lake), in a crest position (topographic site type 4). Horizons from top down included living Schreber's Feather Moss, a dark upland moss humus, an eluviated grey Ae, a reddish-brown B, and the underlying bedrock.

Figure 4. Shallow-soil, upland site, previously covered by Black Spruce forest, harvested as a single large clearcut. A difficult site to regenerate.

Figure 5. A peaty drainageway dominated by sedges and grasses (light-colored) between bedrock ribs (foreground and background) in a patterned, shallow-soil site previously covered by Black Spruce forest.

Figure 6. Regeneration of Black Spruce on a shallow-soil upland site adjacent to a forest edge. Note Reindeer Lichen (*Cladina* spp.) in foreground.

Domtar Woodlands Limited (now Domtar Forest Products) for Strip Cutting of Upland Black Spruce." This signaled the beginning of a long-term project which has become a notable example of cooperative applied research, involving federal, provincial and industrial foresters. It has also been the vehicle for the development of other related studies in silviculture and environmental impact.

The overall objective of the joint proposal was "to determine if strip cutting is an economically and biologically acceptable method of harvesting and regenerating black spruce on upland sites with shallow soil." This was broken down into four specific sub-objectives:

1. To determine the incremental logging costs of strip cutting, i.e., the *increase* in harvesting costs directly attributable to strip cutting rather than to clearcutting. (This is expected to be a 3-year study.)

2. To determine the biological effectiveness of strip cutting as a means of regenerating black spruce on fragile upland sites. (This will require sufficient replication by years to evaluate the effects of climate and other variables on establishment and growth of regeneration and on the extent of windfall in the residual strips. A reasonable estimate is 7 to 10 years.)

3. To determine the overall cost-effectiveness of strip cutting as a means of harvesting and regenerating black spruce on fragile upland sites. (Regeneration of the areas cut in the second coup must be included in this calculation. A reasonable estimate of the time required is 7 to 10 years.)

4. To assess the relative impact of strip cutting and clear-cutting on the upland Black Spruce ecosystem. (It is expected that most of the necessary information will be obtained from work directed at goal 2 above.)

The above objectives do not clearly convey the magnitude of the undertaking, and the fact that the proposal included operational harvesting as well as detailed research studies. In fact, the principal basis of the project was to be the operational harvesting of approximately 8800 ha of Black Spruce forest, mainly on upland sites, located in the Nipigon Working Circle (formerly the St. Lawrence License) of Domtar's operation located at Red Rock, Ontario. The alternate stripcutting system was to be employed, using 40-m-wide strips for both first and second cut strips. The second cut strips (equivalent to 'final cut strips' and 'residual strips') were to be harvested two full growing seasons after the first cut. The relatively short, two-year leave period was thought adequate to achieve satisfactory regeneration, and also to avoid excessive blowdown in the residual strips in these overmature, unstable forests. In the first year (1974-1975) the gross area of the operational strip cuts would be 338 ha; in the second and each subsequent year it was expected to be between 800 and 1200 ha.[5]

In addition to the operational strips, experimental areas, each with a gross harvest area of 40 to 50 ha, were to be studied intensively to relate regeneration to site conditions, and to obtain other supporting information on, for example, seedling autecology and direct seeding. These areas were to be harvested in the same manner as the operational areas.

In the joint proposal, the responsibilities of the cooperators were set down (Appendix I) with the provision that they could be changed, by mutual agreement, on the basis of experience gained as the project progressed. In addition, the project would be coordinated by a Working Group[6], which would oversee technical and scientific details of the project, and a Policy Group[7] which would handle major problems, such as changes in responsibilities, assignment of priorities, allocation of resources, and disposition of results.

In order to fulfill the objectives above, two studies were initiated by GLFRC, one by D.E. Ketcheson concerning extra costs of strip cutting, the other by the author of the present report on the biological effectiveness of strip cutting. As a start on the economic study, GLFRC contracted with the Pulp and Paper Institute of Canada for the design of a study to determine the incremental logging costs

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[5]Between 1974 and 1978, the operational strip clearcutting actually involved 691.7 and 177.9 ha of first and second cut strips, respectively.

[6]The original Working Group consisted of two representatives from each agency: OMNR -- G.T. Marek, Nipigon, and F.C. Robinson, Toronto Domtar -- H.J. Iverson, Nipigon (now Cornwall) and J.F. McConnell, Nipigon; and GLFRC -- J.W. Fraser and D.E. Ketcheson, Sault Ste. Marie. McConnell was replaced by N. Carl, who in turn was replaced by W.B. McEwan. Ketcheson has been replaced by J.K. Jeglum, and Fraser by R.L. Fleming.

[7]The original Policy Group consisted of R.M. Dixon, OMNR, Toronto, M.J. Rouse, Domtar, Montreal, and R.A. Haig, GLFRC, Sault Ste. Marie. Subsequently, Dixon has been replaced by W.K. Fullerton, Toronto, Rouse by A.J. Ross, Montreal, and Haig by C.R. Sullivan, Sault Ste. Marie.

of strip cutting. The report of this study[8] suggested that one of the aspects of extra costs which could be estimated was road costs. Subsequently, work was devoted to developing a road cost model (Ketcheson 1977). To aid OMNR in calculating amounts to reimburse companies for harvesting with the strip cut method, Ketcheson has done additional work estimating other extra costs (Ketcheson 1979).

GLFRC has also initiated a regeneration study entitled "Ecological Assessment of Strip Cutting in Upland Black Spruce", based on permanent plots for which assessments were to be carried out by contract. It was recognized that this study would necessarily be long-term, with assessments extending at least to five years following harvesting. (Robinson [1974] recommended a regeneration period of seven years.) In addition, it was thought to be essential to gather information on natural forest conditions prior to harvest, in order to determine initial site, seedbed, regeneration, and vegetation conditions more precisely.

STUDY AREA

The study area is located in the Central Plateau Section, B.8, of the Boreal Forest Region (Rowe 1972). It is close to the Nipigon Section, B.10, to the west, and the Superior Section, B.9, to the south. It also occurs in Geraldton Site District Number 5 of Hills' 3W Site Region (1959).

The climate according to the Thornthwaite system is microthermal (C'_2) and humid (B_2) (Sanderson 1948). The summers are cool and short, the winters long and cold. The mean daily maxima and minima for July and January, respectively, are 23 and 11°C, and -11 and -23°C (Chapman and Thomas 1968). Mean annual length of growing season is 155 days. Mean annual precipitation is 737 mm and mean May through September precipitation 406 mm. However, precipitation in the study area may be somewhat higher than this because of its location on the leeward side of Lake Nipigon. Winds at Geraldton, Ontario, about 60 km from the study area, are most frequent from the west, and wind speeds with highest yearly averages (exceeding 14 km/hr) are out of the west, southwest, and south (Anon. 1975).

The study area is moderately broken, with frequent bedrock ridges and escarpments, and glacially deposited moraines and eskers,

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[8]Bartholomew, A., and Winner, H.I. 1974. The evaluation of incremental costs of modified harvest cutting in the Nipigon Division, Domtar Woodlands Limited. Report on a contract study funded by Great Lakes Forest Research Centre, Sault Ste. Marie, carried out by the Pulp and Paper Research Institute of Canada, Contract Serial No. 05V-0169, PPRIC #6109. 27 p.

elevated on the order of 30 to 60 m above the lower levels of the topography. Much of the topography is bedrock controlled, with relatively shallow deposits of ground moraine till covering the bedrock (*cf.* Zoltai 1965, 1967) (Fig. 3 to 6). There are numerous lakes, ponds, streams, and drainageways. Drainage is irregular with numerous drainage blockages and meandering, slow-flowing streams.

The study area has a diversity of bedrock types. A generalized map of the geology of the area (Map D, Pye 1969) shows that the main rocks in the vicinity of the strip cut areas are Precambrian (Archean) rocks of the Keewatin formation, including acidic and basic lavas, volcanic tuff, volcanic breccia, iron formation, slate, and greywacke. Diabase layers occurring as flat-topped cuestas (like mesas) to the southwest of the study areas along the Gorge Creek road, and acid igneous rocks (e.g., granite, syenite, diorite, quartz diorite, quartz and feldspar prophyries, pegmatite) which are dominant to the southeast of the area, are found as local outcrops. The study area, located at 400 m above sea level, is above the 285 m level of glacial Lake Minong, which occupied the Lake Superior basin, and also above the level of glacial Lake Kelvin, which occupied the Nipigon basin (Zoltai 1965, 1967).

The glacial drift is predominantly a shallow, undulating till of ground moraine of fine sandy and silty textures, usually with high stone and boulder content (Zoltai 1967). Its thickness varies from 0 m on bedrock ridges to 4.5 m on less broken areas. Larger moraines and drumlins are common; these are composed of compacted sandy till, commonly containing more carbonates than the till in surrounding areas. Glaciofluvial deposits such as eskers, kames, and outwash plains are also common. The glacial features and bedrock ridges are usually oriented from northeast to southwest, the direction of ice movement in the area.

Soils in the area include brunisols and luvisols, generally beneath mixedwood and hardwood forests; podzols generally beneath conifer forests; folisols (i.e., organic mats over bedrock with mineral soil less than 10 cm deep) usually beneath conifer forests; and gleysols and organic soils in low, wet depressions and along lakes (Canada Soil Survey Committee, Subcommittee on Soil Classification, 1978).

Three experimental areas were located within 25 km of each other (Fig. 7). All three study areas were in lower positions in the landscape on uplands adjacent to drainageways, streams or lakes. Although they were predominantly upland Black Spruce, they all encompassed some lowland Black Spruce (Black Spruce swamp). In the vicinity of all areas were higher uplands supporting mixedwood forests. These higher uplands tended to have deeper tills over bedrock than the shallow-soil upland Black Spruce sites.

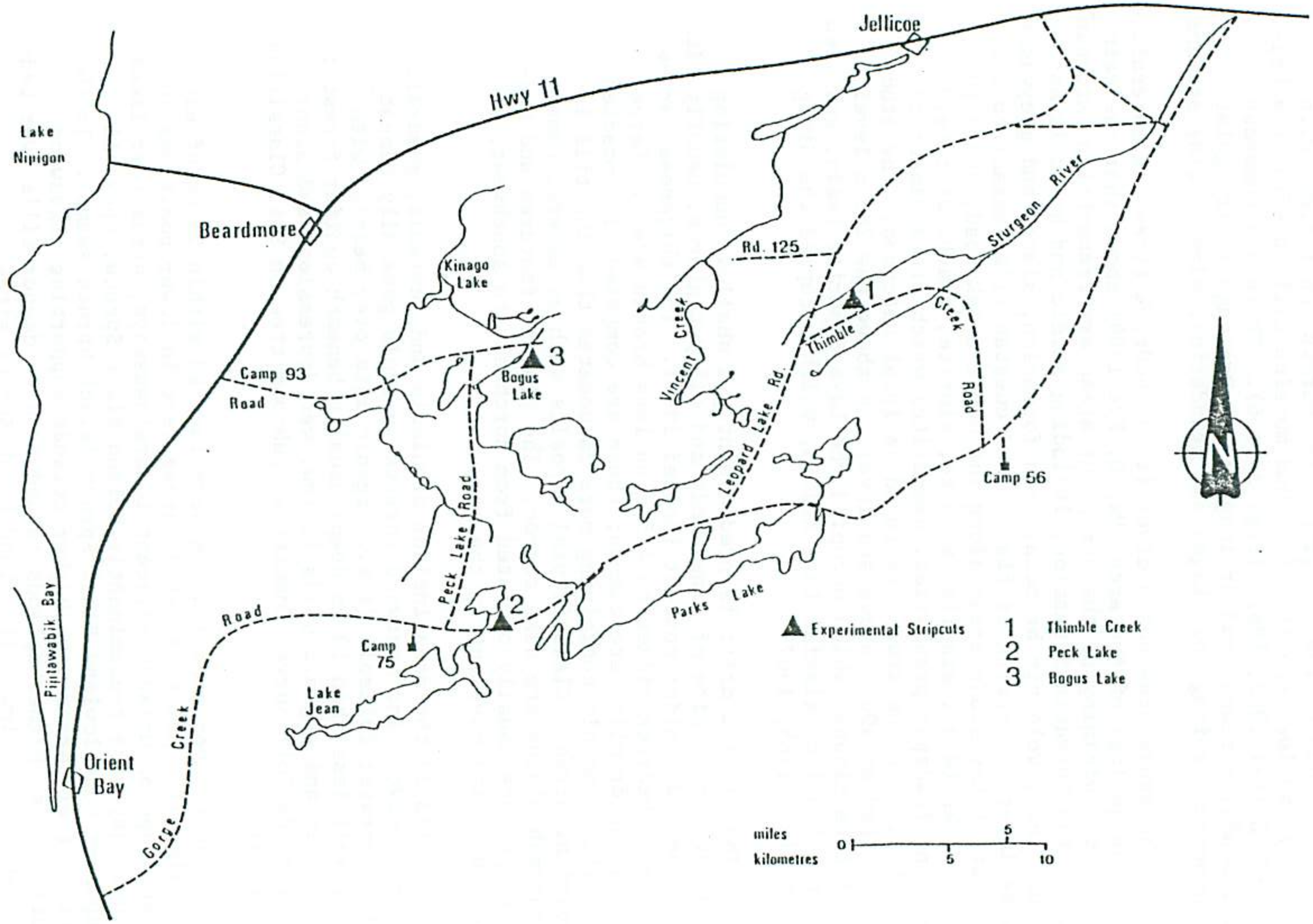

Figure 7. Location of Study Areas I to III in relation to Beardmore and Domtar's limits.

The sites in the experimental strip cut areas included a broad range of moisture conditions from dry to wet, and were usually on relatively shallow mineral soils overlying bedrock, with some deeper pockets of stoney till. There were some sites in the study areas that fit the description of patterned sites (Bedell and MacLean 1952), consisting of bedrock ridges alternating with swampy swales (Fig. 5).

The most frequently occurring ground vegetation is a continuous mat of Schreber's Feather Moss (Fig. 2 and 4), often with sparsely distributed herbs and low shrubs such as Bunchberry (*Cornus canadensis*) and Blueberry (*Vaccinium angustifolium* and *V. myrtilloides*). On dry crest sites, Reindeer Lichen (*Cladina* spp.) is common (Fig. 6); on wet drainageway sites, Labrador tea (*Ledum*) *groenlandicum*), Speckled Alder (*Alnus rugosa*), *Sphagnum* spp., and sedges and grasses are abundant (Fig. 5); and in areas where hardwoods occur, broad-leaved herbs such as Aster (*Aster* spp.) and Bluebell (*Mertensia paniculata*) become abundant.

METHODS

Operational Strips

The general prescription for operational strip clearcutting -- 40-m-wide, alternate strips, two-year leave period between first and final cuts, and shallow scarification just to the mineral soil soon after cutting -- was set out by the Ontario Ministry of Natural Resources (G. Marek, Nipigon District, pers. comm.). Soon after the operational cuts began, strip widths were increased to 60 m, to allow easier turning of the skidder in the strips, and to decrease the element of risk to the ground fellers from falling trees. It was left to the company to decide when to cut: uplands could be cut in either summer or winter, whereas swamps, if too wet, had to be cut in winter to enable the ground workers to move more easily, to prevent the skidders from getting stuck, and to avoid churning and rutting of the peat.

The Nipigon District OMNR designated the areas to be strip cut in the project. These consisted primarily of stands classified as 'softwood slope' and 'shallow-soil -- rock showing', sites 2 and 3 in the Domtar system (Appendix II-A). Domtar located and constructed roads, while OMNR marked the side boundaries of the strips to be cut. Adjustment of the basic strip cutting design to include, for example, small patch cuts at odd places such as road junctions, was done by mutual agreement between OMNR and Domtar. Decisions on stream and lake reserves were made by OMNR.

The main harvesting technique was tree-length, conventional cut-and-skid, with a wheeled-skidder plus operator, and two or three fellers on the ground. Trees were delimbed and detopped in the strip and skidded to landings at roadside. Usually first cut strips on one side of the haul road faced the residual strips on the opposite side (Frontispiece, Fig. 1); this was done to avoid bottlenecks at the log landings, and also to avoid excessive blowdown caused by wind tunnelling effects within long strips. OMNR carried out cut inspections and encouraged low stumps and high utilization. However, when there was deep snow, some high stumps were left after the manual cutting operation.

In some areas, Koehring-Watrous harvesters which cut, delimb, buck and load in one operation were used, and various feller-buncher machines with cutting heads combined with wheeled-skidders to draw out tree-length logs were employed on a trial basis.

OMNR contracted out scarification of the strip cuts to private operations, and gave prescriptions for depth of scarification and degree of exposure of mineral and other horizons. As a general rule 'delicate' scarification (G. Marek, OMNR Nipigon District, pers. comm.), was prescribed, i.e., exposure of upper mineral soil or lower humus (H) layers of the organic mat as the preferred seedbed. Scarification was usually carried out in the same year as the cut, but was sometimes delayed until the following year. The two types of scarification employed were flanged barrels pulled by a wheeled-skidder, and the TTS Disc Trencher with Lapland Discs carried by a wheeled skidder.

Experimental Strips

Location: The original intent of the Working Group was to locate the experimental areas on sites with 'extremely' to 'very shallow' soils[3], these being the 'shallow soil-rock showing' site type in the Domtar system (Appendix II-A). However, due to operational and road location constraints, the experimental areas all had to be located in the 'softwood slope' site type, for which the soil is not as shallow, although the soils here were still classed as 'shallow soils' (less than 100 cm, Canada Soil Survey Committee, Subcommittee on Soil Classification, 1978[3]).

Strip widths and leave times: The design for the experimental strip clearcuts was based on the operational strip cut procedures. The variables of strip width and leave time were though to be the key factors in attempts to fine-tune the silvicultural prescription.

The joint proposal specified that three experimental areas, each totalling 40 to 50 ha, would be cut with 20-, 40-, and 80-m-wide strips, and that the intervening residual strips would be left for either two or four years before removal. The experimental areas would be harvested in the same manner as the operational areas. Therefore, strip lengths would be about 180 m, but in practice this varied considerably depending upon variations in the topography, site conditions, and road location. Other aspects of the experiment were to be decided upon in subsequent Working Group meetings, or in the detailed assessment methods written into the yearly contracts for assessments.

Three experimental areas (I, II and III) were established in each of three successive years, 1974, 1975 and 1976. The three areas are also called the Thimble Creek Area (I), the Peck Lake Area (II), and the Phoney Lake Area (III), and are shown on Domtar's Nipigon Working Circle in Figure 7. This replication was considered minimal for assessing the influence of year-to-year weather variations.

For each area, there were 16 strips each of the 20-, 40-, and 80-m widths (e.g., Frontispiece, Fig. 9 and 10). All of these were to be scarified by OMNR as soon as possible after the first cuts. Of the 16 strips of each width, eight would be cut initially, four of the residual strips two full growing seasons after harvesting, and the four remaining residual strips after four full growing seasons. In addition, eight 40-m 'control' strips, not to be scarified, were established in each area, four strips to be cut initially, and the four residuals after two growing seasons. The layouts for the three study areas are shown in Figures 8 through 10.

Areas of experimental strips: The expected area for the experimental strips, based on strips 180 m long, was 46 ha. However, owing to variations in strip lengths and allowance for buffer strips (areas left to provide a forested border for a cut strip at the edge of a block of strips), the three experimental areas varied from 47.1 ha to 58.4 ha. The widths of the road rights-of-way between the blocks of strips were generally 60 m.

Layout of sample lines and quadrats: The regeneration study was based on 1400 permanent quadrats established in each of the three study areas (Fig. 8-11). Five parallel sampling lines were laid out perpendicular to the long axis of the strips. The lines were numbered 1 to 5, with line 1 closest to the haul road. Lines were usually 30 m apart, with 30 m between the front end of the strip and line 1, and 30 m between line 5 and the back end of the strip. However, in some cases where the strips were shorter, owing to topographic or forest type irregularities, the lines were closer.

Five 2-m x 2-m quadrats were evenly spaced between strip borders in each strip, along each of the five lines; hence there were 25 quadrats per strip. Quadrats were placed on the side of the line farthest from the road, and numbered sequentially from left to right (from the point of view of a person standing with his back to the haul road and facing into the strip). Quadrats 1 to 5 were along line 1, quadrats 6 to 10 along line 2, quadrats 11 to 15 along line 3, etc. Spacing between the quadrats was 2, 6, and 14 m for the 20-, 40-, and 80-m strips, respectively. The quadrat corners lying on the line were permanently marked with wire

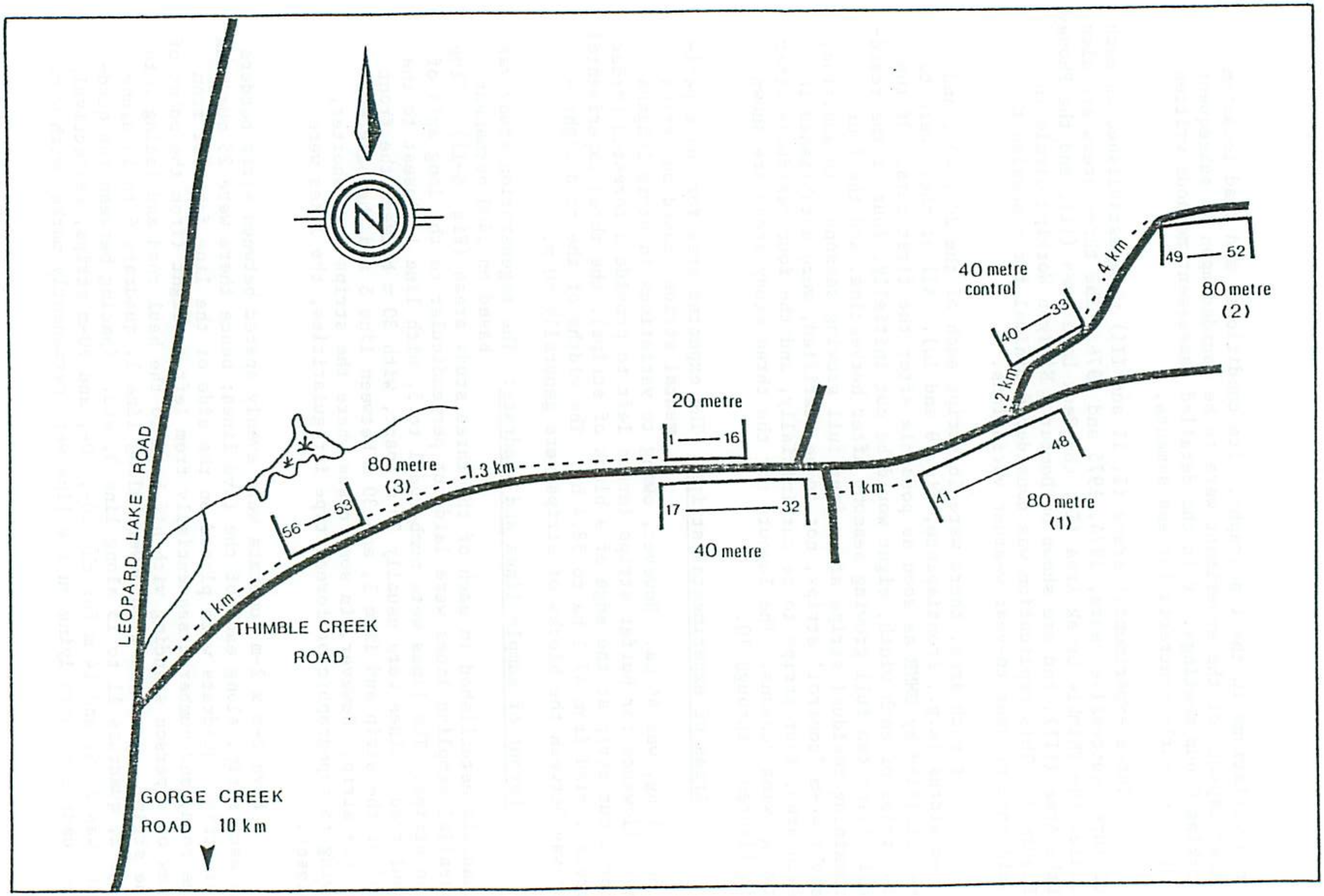

Figure 8. Layout of the alternate strip clearcuts in Study Area I (Thimble Creek).

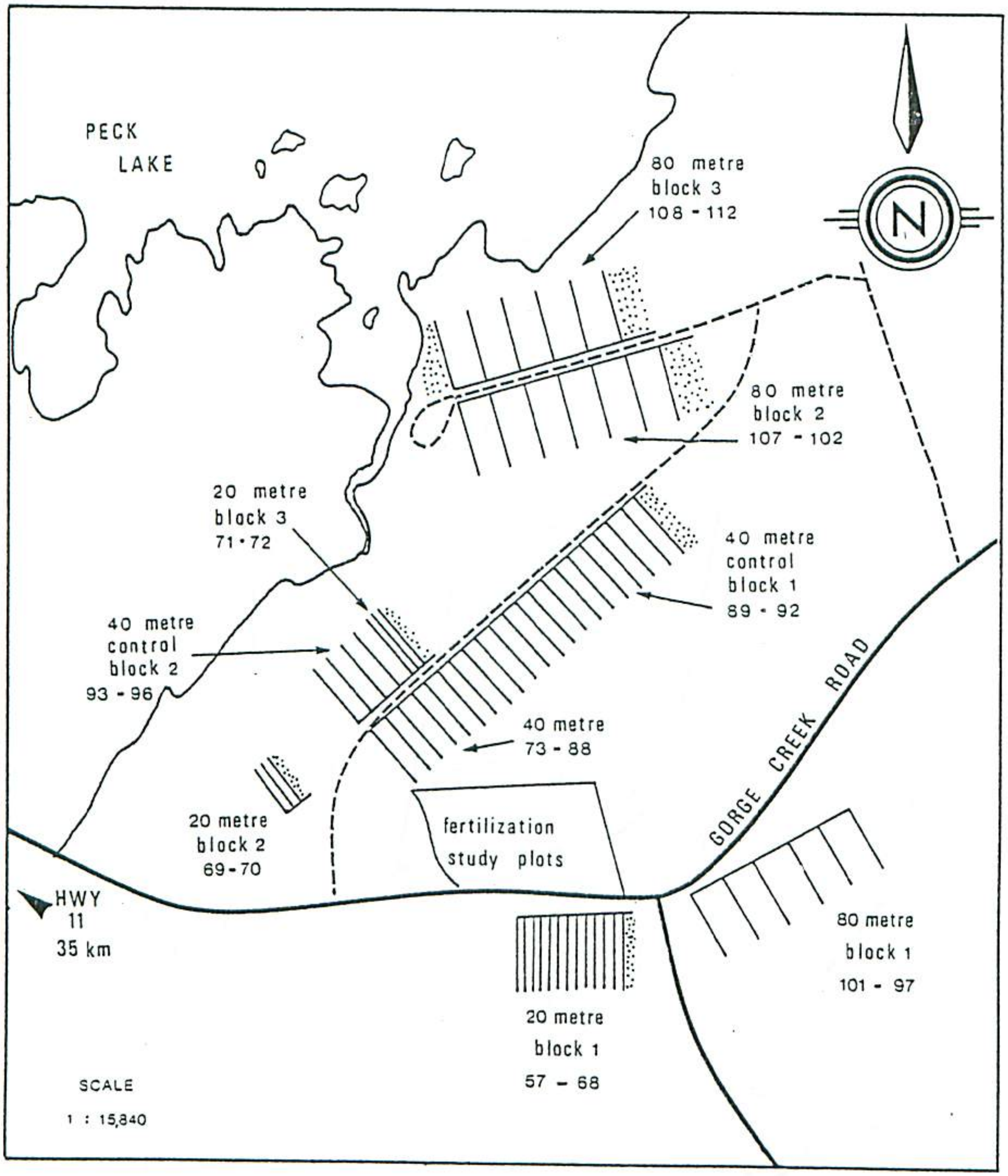

Figure 9. Layout of the alternate strip clearcuts in Study Area II (Peck Lake).

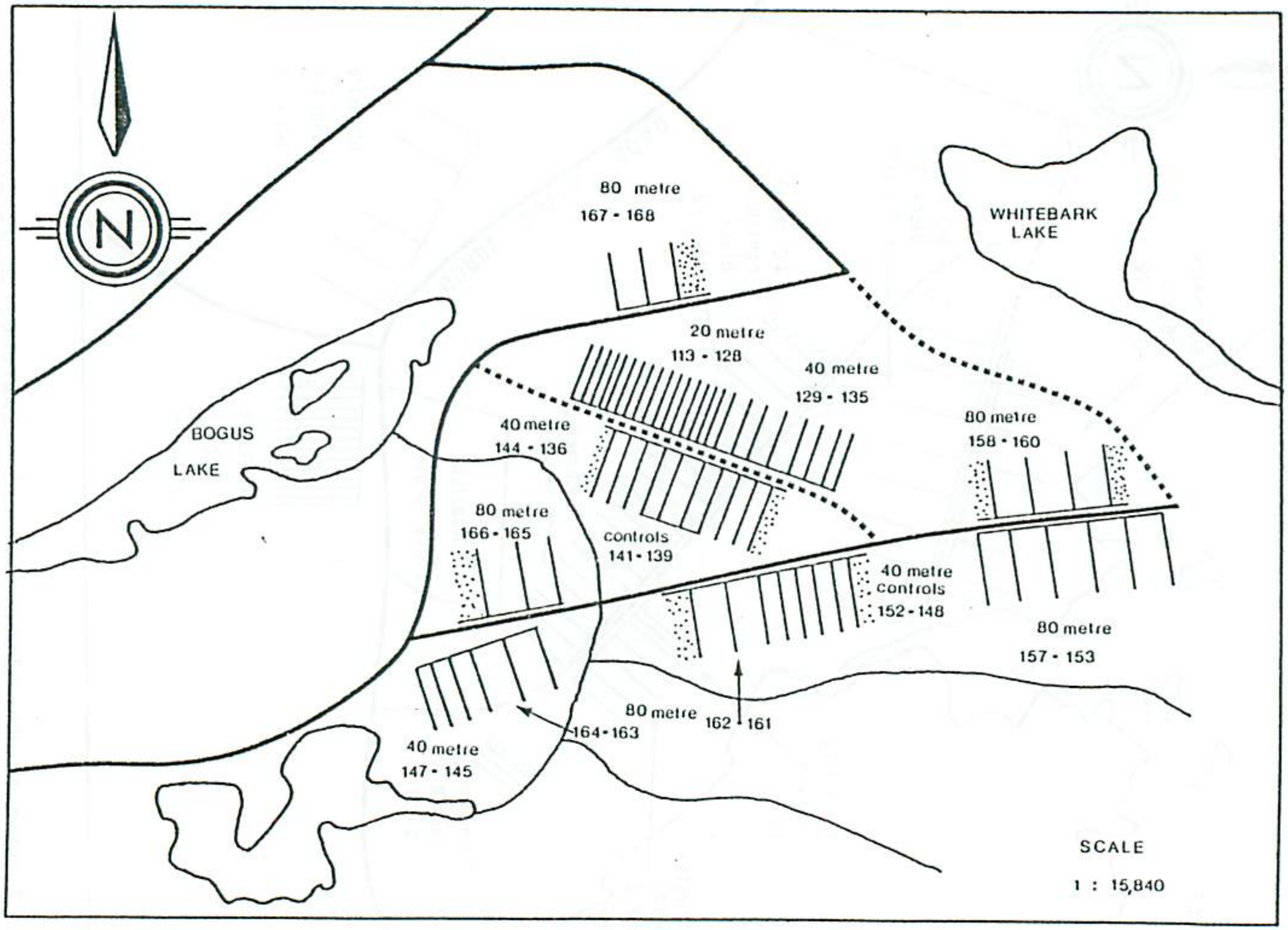

Figure 10. Layout of the alternate strip clearcuts in Study Area III (Phoney Lake).

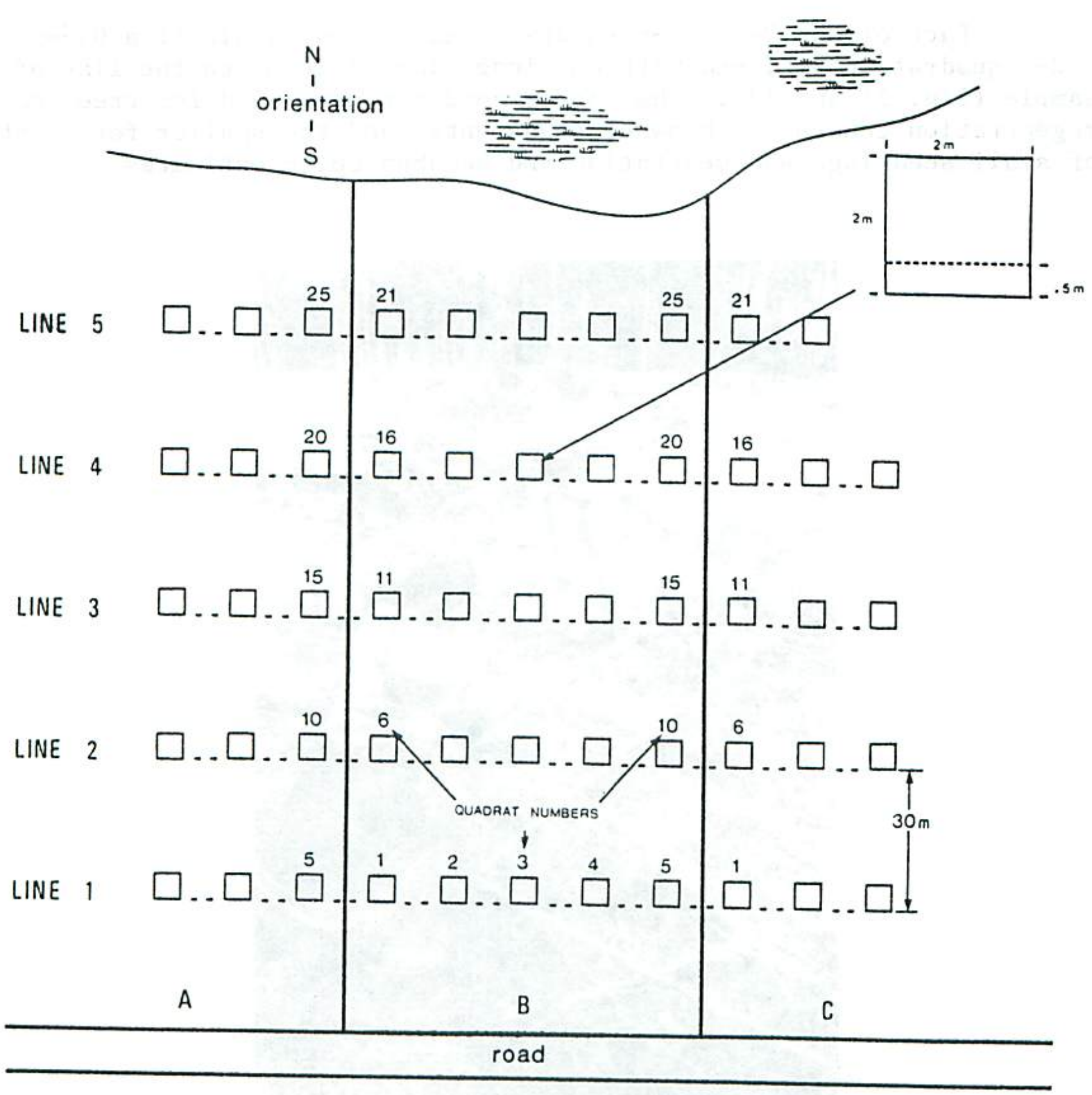

Figure 11. Layout of permanent quadrats along sample lines. Spacing between quadrats was usually 2 m for the 20-m strips, 6 m for the 40-m strips, and 14 m for the 80-m strips.

pins (or a painted spot where there was only rock), and each line was marked at the strip borders with a flagged witness stake.

Each of the 2-m x 2-m quadrats had nested within it a 0.5-m x 2-m quadrat, positioned with one long side adjacent to the line of sample (Fig. 11 and 12). The larger quadrats were used for tree and regeneration counts and browse assessments, and the smaller for counts of small seedlings and vegetation and seedbed cover estimates.

Figure 12. Layout of 2-m x 2-m (*ca.* 1-milacre) quadrat.

Initially in laying out the sample blocks in Area I the strip margins were put in first, the sample lines and quadrats later. However, with this approach it was found that the strip borders were not always parallel, and hence distances between quadrats varied from line to line and strip to strip. Hence, for subsequent layouts the sample lines and quadrats were positioned first, and then the strip borders were flagged. The distances between quadrats and lines, as well as other details of methods, were recorded in the final reports prepared by the contractors.[9]

Harvesting, site preparation and assessment schedule: A summary of the timing and type of harvesting, site preparation, and quadrat assessments is presented in Table 1. It was not possible to control a number of operational variables. Time of harvesting was governed by the fact that the three areas were composed of different proportions of swamp and upland. Since Areas I and II were predominantly uplands, they were summer cuts. However, in Area I some strips could not be completely cut in the summer because the ground was swampy, and they had to be left and cut during the following winter. Area II, since it was lower and wetter, was cut in the winter.

In areas cut in the summer there is more compaction and scraping off of the organic mat on uplands by skidder wheels, and this favors regeneration. However, since the areas are subsequently scarified differences in regeneration that are due to season of harvest will probably be impossible to detect.

The type of scarification also varied from flanged barrels drawn behind a large wheeled skidder in Area I, to the TTS Disc Trencher drawn behind a large skidder in Areas II and III. Analyses (not presented in this paper) of exposure of various seedbed types, and relations of these to seedling influx, may show differences between these two scarification treatments.

As was the original intent, these variables, plus inherent differences in site between the three areas, may make it difficult to interpret differences between areas because of weather variations.

In harvesting the second cut strips in Area I, skidders travelled through some of the first cut (20-m) strips, disturbing some of the newly established reproduction. This happened in strips where a large number of residual Trembling Aspen (*Populus tremuloides*) prevented easy passage by the skidders. The narrowness of the strips also made harvesting within strip borders difficult.

It was decided not to scarify the two-year leave, second-cut strips for several reasons: (i) because of the possibility that more

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[9]"Final reports on ecological assessment of strip cutting in upland black spruce": 1974. H. Bax, kbm Forestry Consultants Inc., Thunder Bay; 1975, D.J. Reid, kbm Forestry Consultants; 1976, D. MacAlpine, kbm Forestry Consultants; 1977, D.J. Reid, kbm Forestry Consultants; 1978, R. Crossfield, Dames and Moore, Toronto; 1979, R. Crossfield, Dames and Moore, Toronto.

Table 1. Schedule of times and types of harvesting, site preparation, and assessments. The italicized items have not yet been completed. Those identified by years only have not yet been started.

	Preharvest Assessment	Harvesting Methods	Scarification or Prescribed Burning	Postharvest Assessment Year 1	Postharvest Assessment Year 3	Postharvest Assessment Year 5
Area I - Thimble Creek						
(a) First cut strips scarified - 24 control - 4	June-August 1974	June-July 1975 Conventional cut and skid, tree length.	July 1975 Skidder pulling flanged barrels weighing either 360 or 680 kg.	June-August 1976	June-August 1978	1980
(b) Second cut strips 2-year leave scarified - 12 control - 4		September 1977 Conventional cut and skid, tree length.	No scarification. Regarded as 'clearcut' with no site preparation	No assessment	No assessment	*1982*
(c) Second cut strips 4-year leave scarified - 12		September-October 1979 Leave seed tree groups.	*Scarify, as soon as possible after cut.*	No assessment	No assessment	*1984*
Area II - Peck Lake						
(a) First cut strips scarified - 24 control - 4	June-August 1975	December-March 1976-1977 Some Koehring, the rest conventional cut and skid, tree length.	July 1977 T.T.S. Disc Trencher with Lapland Discs.	July-August 1977	June-August 1979	*1981*
(b) Second cut strips 2-year leave scarified - 13[a] control - 4		December-March 1978-1979 Some Koehring, the rest conventional cut and skid, tree length	No scarification. Regarded as 'clearcut' with no site preparation.	No assessment	No assessment	*1983*
(c) Second cut strips 4-year leave scarified - 11[a]		*1980-1981 Leave narrow strips of seed trees.*	*Scarify, as soon as possible after cut.*	No assessment	No assessment	*1985*
Area III - Phoney Lake						
(a) First cut strips scarified - 24 control - 4	June-July 1976	September-October 1976 Conventional cut and skid, tree length.	Strips 146, 164 - fall 1977; remainder in summer 1978 T.T.S. Disc Trencher with Lapland Discs. Strip 152 burned 1978; Strip 150 burned 1979.	June-August 1978	*1980*	*1982*
(b) Second cut strips 2-year leave scarified - 12 control - 4		September-October 1979 Conventional cut and skid, tree length.	No scarification. Regarded as a 'clearcut' with no site preparation.	No assessment	No assessment	*1984*
(c) Second cut strips 4-year leave scarified - 12		*1981 Partial cut (shelterwood) with careful logging to preserve advance growth.*[b]	*No scarification, except that caused in the logging process*	No assessment	No assessment	*1986*

[a] Owing to a harvesting error, one extra strip was cut (strip number 75).

[b] Proposed, but not yet approved by the Working Group.

skidder disturbances would occur on the narrower strips, (ii) because the absence of nearby seed trees would logically demand that site preparation be followed by some seeding or planting effort (more chance of disturbance and source of error), and (iii) because the non-scarified strips would provide a non-scarified, clearcut condition for comparison with the scarified strips. It was also decided not to assess these non-scarified "clearcuts" until five years had passed, since only the final assessment would be of interest.

In the course of the study it was suggested that prescribed burning be used to site prepare the first cut strips and obtain natural regeneration by seed. D.J. McRae, Forestry Officer in charge of prescribed burning at GLFRC, helped to set up a substudy for the burning of the four first cut control strips for Area III. Each strip would be burned separately, the four burns being conducted over a range of burning conditions. The objective was to remove as much of the upland humus as possible, and the range of conditions would help determine the best fire burning indices for conducting small prescribed burns in the upland Black Spruce cover type. To date it has been possible to conduct burns in only two of the strips.

Another modification of the design concerns the final cut strips in the 4-year-leave blocks. It was decided to test the effects of various seed tree systems to regenerate these strips. It was proposed that groups of seed trees be left in Area I (Fig. 13), that a narrow strip of trees be left on the west side of each strip in Area II, and that one or more partial (shelterwood) cuts be conducted in Area III, with careful logging to preserve advance growth. The first two methods were agreed upon by the Working Group, but the third was postponed until more field inspection could be carried out and a more definite plan could be formulated.

<u>Basic site and regeneration data collected</u>: Six major types of information were collected by contract in the permanent quadrats:

i) general site conditions, including placement in one of four topographic site types -- drainageway, lower slope, upper slope, and crest (Appendix II-A);

ii) tree and regeneration density and frequency, by height and diameter classes (Appendix II-B);

iii) seedbed conditions, both living and non-living (Appendix II-C);

iv) seedling-seedbed relationships (Appendix II-C);

v) vegetation, consisting of cover estimates for all species (Appendix II-D);

Figure 13. Regeneration of the residual, second cut strips, with the group seed tree method.

vi) moose browse (Appendix II-E).

Moose browse assessments were added to the original assessment schedule by D.A. Welsh, Canadian Wildlife Service, in 1977.

Site type information was collected only once at the start of the experiment, whereas the other information types are being collected before and after harvesting. For the first cut strips, assessments are being made at years 1, 3 and 5 after harvesting; for the residual strips, assessments will be made only at year 5 after cutting (Table 1).

In addition to the six major items above, other more specific data were also collected:

i) Height and age measurements of 20 to 25 dominant trees were taken in each of the three areas. This was done by contract.

ii) In each of the first cut control strips in each area 25-50 additional quadrats were placed in order to gain more reliable measures for the controls.

iii) A detailed tree density survey was carried out for Area II.

iv) A detailed tree age survey was carried out in Area III.

The detailed tree density survey was carried out in Area II in 1977. The marked, 2-m x 2-m quadrats were used as the centres of larger, rectangular plots sampled along the lines. The widths of the rectangular plots were adjusted for the various strip cuts in such a way that plot size was always 24 m^2. For each plot, trees were tallied by species, measured for DBH, and classified in categories of erect, leaning, down, down and dead, and old stumps.

The detailed tree age survey was carried out in 1979 in Area III. Fifteen tree discs were collected from each of the four topographic site types, from stumps in cutover strips in the area. Discs were cut from just above the root flare, between 15 and 25 cm above the ground surface, from average-sized to large stumps.

Soil surveys and analyses: An extensive soil depth survey was carried out by the Canadian Forestry Service for the three study areas in the summers of 1976 and 1977. Depths were taken systematically at the second and fourth quadrats along lines 1, 3 and 5 for each strip in each area. Depths of the organic mantle (LFH on mineral soils, peat on organic soil sites) and of the mineral soil were recorded. Maximum depth to which the soil was probed was 75 cm, this being the length of the soil probe. Definite bedrock hits within 75 cm of the surface were distinguished from those where it was not known if the rock hit was bedrock or loose rock in till.

Twenty-four soil pits, two for each of the four topographic classes in each of the three study areas, were described, and samples were collected for analysis by the Canadian Forestry Service between 11 and 28 July, 1977. Organic horizons were given von Post humification ratings of H1 to H10 (Canada Soil Survey Committee, Subcommittee on Soil Classification 1978). For selected mineral soil samples, textural analyses were performed. Undisturbed samples of known volume were obtained for bulk density determinations. Bulk density measurements were used to convert element concentrations from weight per unit weight of soil to weight per unit volume of soil, the latter being a preferable unit for comparing relative concentrations of elements between horizons of greatly varying bulk densities (e.g., Hoyle 1973).

For samples of both organic and mineral horizons, measures were obtained for pH, cation exchange capacity (CEC), nitrogen (N), ammonium (NH_4^+-N), nitrate (NO_3^--N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Both water-pH and $CaCl_2$-pH (0.1N $CaCl_2$) were obtained (Greweling and Peech 1965). CEC was done by the neutral normal ammonium acetate method. "Total' N was that obtained with the Kjeldahl method. Total concentrations for the other elements were obtained by digestion with strong acids -- nitric, sulfuric, and perchloric and hydrofluoric acids. P was determined with the molybdophosphoric acid method using a Spectronic 20, K using flame emission spectroscopy, and Ca and Mg using an atomic absorption spectrophotometer.

Exchangeable NH_4^+-N and NO_3^--N were extracted with 2N KCl and determined titrimetrically after steam distillation (Black 1965). P was extracted with Bray and Kurtz Solution Number 1, and determined on a Spectronic 20. K, Ca, and Mg were extracted with neutral normal ammonium acetate, and determined as above.

RESULTS

General Forest Cover and Site Conditions

For large blocks of forest land encompassing each of the study areas, Domtar's forest inventory data were summarized to give a general picture of forest and site conditions for the area (Table 2). The forest types, in order of decreasing areal extent, are Spruce (predominantly Black Spruce), mixedwood, hardwood, and spruce-pine. Spruce-pine was relatively common in the vicinities of Areas I and III, but almost absent from the vicinity of Area II.

The main merchantable conifer species in the three study areas include Balsam Fir (*Abies balsamea*), Jack Pine (*Pinus banksiana*), Black Spruce, and White Spruce (*Picea glauca*). The main merchantable hardwood species in the area include Trembling Aspen and White Birch (*Betula papyrifera*). Mixedwood consists of stands with 25% to 75% volume of hardwood species mixed with conifer species. The spruce-pine type is mainly Black Spruce and Jack Pine, with the secondary species achieving at least 25% of the stand volume.

In the forest inventory system used by Domtar, each stand on the forest inventory map is classified into one of seven 'site types', defined on the basis of main forest cover and important terrain characteristics. Site type was assessed as a secondary feature following the delineation of stands based on cover and composition. There are undoubtedly some misclassifications of individual stands as a result of difficulties in interpreting transitional and patterned sites. Nonetheless, these site types provide a general picture of the kind and extent of site variation to be encountered in the vicinity of each of the study areas.

Table 2. General forest cover types and site types for the three study areas, as determined from Domtar's forest inventory. Data were summarized for a large block of land encompassing each of the three study areas.

	Forest Blocks Encompassing:			
	Area I (Thimble Creek)	Area II (Peck Lake)	Area III (Phoney Lake)	All Areas
Total productive forest area summarized (ha)	9,546	12,987	8,912	31,445
Cover Type (%)				
Spruce	48.8	46.1	54.8	49.4
Spruce-pine	11.9	0.2	6.3	5.5
Mixedwood	27.8	40.0	26.6	32.5
Hardwood	11.4	13.7	12.2	12.6
Total	99.9	100.0	99.9	100.0
Site Type (%)				
1. Lowland flat	20.1	18.3	18.2	18.8
2. Softwood slope	25.0	23.5	29.7	25.7
3. Shallow soil-rock showing	1.9	3.4	7.1	4.0
4. Moderately deep to deep soil - mixedwood	27.8	35.2	21.7	29.2
5. Sand, flat to rolling - Jack Pine	7.2	.02	3.0	3.1
6. Rugged upland	1.8	9.4	11.6	7.7
7. Moderately deep to deep soil - hardwood	16.1	10.1	8.7	11.5
Total	99.9	99.9	100.0	100.0

The three study areas are similar in the areal extent of the various site types (Table 2). The three most common site types are the moderately deep to deep soils with mixedwoods (4), the softwood slopes (2), and the lowland flats (1). Site types 1, 2 and 3 are mostly Black Spruce-dominated. These site types show similar areal extents for all three areas -- predominant softwood slopes (2), smaller, but still significant areas of lowland flats (1), and relatively small areas of shallow soil with rock showing (3). The areas of site type 3 increase from Areas I through III. Sand flat to rolling with Jack Pine (5), rugged uplands (6), and moderately deep to deep soil with hardwoods (7) are less common site types in the study areas.

Specific Site Conditions for the Experimental Areas

Site types: On the basis of Domtar's site type system, Area I was predominantly a softwood slope, whereas Area II had equal proportions of softwood slopes and lowland flats. Area III had a predominance of softwood slopes but also had a relatively high value for lowland flats, much of which was not included in the experimental strips, and also smaller amounts of rugged upland and moderately deep to deep soil with mixedwood.

Each permanent quadrat was classified into one of four topographic site types: crest, upper slope, lower slope, or drainageway. In Areas I and II the lower slope and upper slope positions were most common, with drainageway and crest positions of lesser areal extent (Table 3). However, for Area III upper slope was most common, with lesser amounts in crest and lower slopes and a very low proportion in drainageway.

It is clear from these two site type classifications that Area II is the lowest, wettest area, whereas Area III is the highest and driest, in terms of general location in the landscape.

Relief, slope, aspect: Reliefs within the three study areas, 9.0, 6.0 and 15 m, are relatively low in comparison with the general maximum relief over the whole area, 30 to 60 m. Both Areas I and II had a majority of quadrats with slopes less than 1% (Table 4). In contrast, the majority of quadrats in Area III had slopes in the 1 to 10% and 11 to 50% classes. This shows that Area III has the greatest relief and steepest slopes, Area II has the lowest relief and gentlest slopes, and Area I is intermediate.

For those quadrats which had a detectable aspect in Areas I and II, the aspects were more or less equally divided among the four points of the compass. In Area III, however, the west and south

Table 3. Site conditions in relation to topographic site types in Study Areas I, II and III. Each area represented by 1400 quadrats.

Site Condition	Topographic Site Type				
	Drainageway	Lower Slope	Upper Slope	Crest	All Site Types
Percentage of Quadrats					
Area I	10	39	42	8	100
Area II	11	51	35	3	100
Area III	5	19	57	19	100
Domtar Site Type[a] (% of Quadrats)					
Area I					
1 - Flat-lowland	2	1	0	0	0
2 - Softwood slope	98	99	100	100	99
Area II					
1 - Flat-lowland	20	48	61	73	50
2 - Softwood slope	80	49	39	27	49
3 - Shallow soil-rock showing	0	3	0	0	1
Area III					
1 - Flat-lowland	29	29	10	18	16
2 - Softwood slope	71	71	78	72	75
4 - Moderately [deep] to deep soil-mixedwood	0	< 0.5	2	3	2
6 - Rugged upland	0	0	11	8	8

[a] All seven site types used by Domtar are given in Table 1.

Table 4. Slope and aspect in Areas I, II and III. Each area is represented by 1400 quadrats.

	Study Area		
	I	II	III
Slope (% of quadrats)			
Flat (up to 1%)	59	67	8
1 to 10%	34	30	52
11 to 50%	5	3	35
51 to 100%	2	<0.5	3
> 100%	1	0	1
Aspect (% of quadrats)			
Flat	44	67	7
North	12	8	15
East	15	7	10
South	11	7	38
West	18	11	31

aspects predominate, and this in combination with its generally more elevated position in the landscape could result in relatively drier seedbeds and hence, poorer regeneration for this area than for the other two areas.

Soil depth: In the depth survey 28% of the soil probes definitely hit bedrock within 75 cm of the surface (Table 5). The percentage of bedrock hits increased from the lowest to highest topographic positions. Study Area I had the highest percentage (40%) of bedrock hits, Area II the lowest (14%), and Area III was intermediate (29%).

There was a high percentage of hits (54% over all) of rock of undetermined type, either bedrock or loose rock in till (Table 5). In contrast, only 18% of the probes had organic plus mineral depths exceeding 75 cm.

The organic mantle was deepest in the drainageways and thinnest on the crests (Table 5). The mean depth of organic mantle for all topographic positions combined was twice as great in Area II

Table 5. Frequency of bedrock and other rock hits, and mineral and organic mantle depths. Data from uncut strips plus strips that had been cut but not scarified. Topographic positions are: 1-drainageways, 2-lower slope, 3-upper slope, and 4-crest. Study areas are I-Thimble Creek, II-Peck Lake, and III-Phoney Lake. Parentheses () enclose ranges.

	Topographic Site Type/Study Area							
	1	2	3	4	1 to 4			
	I-III	I-III	I-III	I-III	I	II	III	I-III
No. of probes	65	224	294	53	200	180	256	636
Definite bedrock hits (%)[a]	22	26	29	43	40	14	29	28
Definite bedrock hits where mineral soil < 30 cm (%)	20	21	24	38	33	10	26	24
Mean depth of mineral soil where bedrock was encountered (cm)	8.6	13.4	12.1	8.3	13.6	19.4	7.3	11.8
	(0-76.2)	(0-71.1)	(0-76.2)	(0-33.0)	(0-76.2)	(0-58.4)	(0-40.6)	(0-76.2)
Rock hits, not determined if bedrock or rock in till (%)[a]	43	49	63	43	48	48	64	54
Organic plus mineral depth > 75 cm[a]	35	25	8	14	12	38	7	18
Depth of organic mantle								
Mean (cm)	36	31	17	16	18	36	18	23
Values > 75 cm (%)[a]	11	11	0	0	2	15	1	5
Values ≥ 40 cm (%)[b]	29	27	2	4	7	36	4	14

[a] Bedrock or rock hits were recorded if within 75 cm of the ground surface, this depth being the length of the soil probe.

[b] Organic soils are defined as having 40 cm of organic mantle when the surface layer has a humic or mesic state of decomposition, or 60 cm when the surface layer is fibric (Canada Soil Survey Committee, Subcommittee on Soil Classification, 1978).

(36 cm) as in Areas I and III (18 cm in each), reflecting the predominance of lower topographic classes in Area II.[10] The percentage of organic depths exceeding 75 and 40 cm reflects the same trends. Fourteen percent of all soil probes had organic depths equal to or greater than 40 cm, which is the defining depth for organic soils in the Canadian system of soil classification when the surface layer is in a humic or mesic state of decomposition (Canada Soil Survey Committee, Subcommittee on Soil Classification 1978).

Soil horizons: A summary of the soil horizons and their general features is given in Table 6. For most soil pits, the ground surface was covered with a continuous layer of living Feather Moss, predominantly Schreber's Feather Moss in the upland topographic site types (Table 6; Fig. 2 and 3). *Sphagnum* moss mounds were common in the drainageway site type, and sedges and grasses were also often abundant (Fig. 5). The organic horizons beneath the living moss layers were described with the L, F, H (litter, fermentation, humus) letter designations for all of the topographic site types regardless of whether the soil was an organic soil or a mineral soil. F layers in upland soils are usually comparable to 'fibric' (Of, H1 to H3) in organic soils, moderately decomposed humus to 'mesic' (Om, H4 to H6) and well decomposed humus to 'humic' (Oh, H7 to H10) (Canada Soil Survey Committee, Subcommittee on Soil Classification, 1978).

Commonly just beneath the living moss, there was an F or FH horizon consisting of a fibrous matrix of moss remains (Feather Moss or *Sphagnum*), leaf and twig remains, and humus particles (Table 6). In the summary of the data, poorly decomposed Feather Moss and *Sphagnum* samples were kept separate, because of possible differences in nutrient contents. White and yellow strands of fungal mycelia were abundant in the Feather Moss-derived organics, and commonly were closely enveloping tree roots as mycorrhizal unions. The mean depths of these surficial, poorly decomposed layers varied from a few cm to 30 cm. The pH (dried sample rewetted) means for Feather Moss-derived material ranged from 3.7 to 4.9, for *Sphagnum*-derived material from 4.0 to 4.8.

Beneath the F and FH layers were H layers (Table 6). Charcoal was often found in the H layer, and this suggests that the stands may have been of fire origin. In drainageways, upper and lower H

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[10] In Area II, topographic position 2 actually had a greater mean depth of organic and a higher frequency of values $\geq$ 40 cm (47 cm and 57%) than did topographic position 1 (35 cm and 32%). In this area, there was a high proportion of organic soil sites which were not clearly in drainageways, and which were therefore classified as being on lower slopes.

Table 6. Soil horizon characteristics for the 24 soil pits studied for all three study areas.

Horizon Designation(s)	Depth to Horizon from Surface--Mean (No. of Values) Range (cm)		Horizon Thickness--Mean (No. of Values) Range (cm)		Decomposition Class (H1-H10, Organic) or Texture (Mineral)	Mean (No. of pH Values), Range		
						Water	0.1N $CaCl_2$	
Topographic Site Type 1 (Drainageway)								
LF	0	(1)	6.3	(1)	H3 (*Pleurozium* peat, fibric)	4.9	4.4	(1)
FH, H	0	(3)	10.2 7.6-11.4	(3)	H1-H3 (*Sphagnum* peat, fibric)	4.0 3.8-4.3	3.4 3.2-3.6	(3)
FH, H_1	8.4 6.4-11.4	(3)	17.8 5.1-27.9	(3)	H4, H6 (mesic peats)	5.2	4.7	(1)
H, H_2	16.5 0 -39.4	(6)	48.5 22.9-88.9[a]	(6)[a]	H7-H10 (humic peats)	5.6 4.4-6.1	5.1 3.9-5.8	(5)
Groundwater or seepage level	24.9 10.2-63.5	(5)	-		-	-	-	
"C"	64.9 30.5-116.8[a]	(6)[a]	N.A. 22.9-61.0[a]		Silt loam (1 det.) and sandy loam (1 det.)	6.9 (5.9-7.9)	6.3 (5.2-7.2)	(1)
Topographic Site Type 2 (Lower Slope)								
LF, F	0	(2)	19.1 7.6-30.5	(2)	H2-H3 (*Sphagnum* peat, fibric)	4.8	4.4	(1)
FH, LFH	0	(4)	14.9 10.2-25.4	(4)	H2-H3 (*Pleurozium* peat, some litter, fibric)	4.4 3.7-4.8	3.9 3.0-4.5	(4)
H, H_1	21.2 10.2-30.5	(3)	21.2 5.1-35.6	(3)	H4-H7 (2 mesic, 1 humic peat)	6.0 5.9-6.2	5.5 5.4-5.7	(2)
Ah	12.7	(1)	7.6	(1)	-	5.6	4.9	(1)
Ae	10.2	(1)	0 -5.1		Silt loam (1 det.)	-	-	
BC	12.7 12.7-12.7	(2)	38.7 14.0-63.5	(2)	Loamy sand (1 det.)	5.3 4.8-5.8	4.7 4.2-5.2	(2)
C	34.5 11.4-66.0	(5)	52.1 27.9-80.0	(5)[a]	-	5.9 5.6-6.3	5.2 4.9-5.5	(3)
Gley	54.6	(1)	34.3	(1)[a]	Silt loam (1 det.)	8.1	7.6	(1)
Groundwater or seepage level	51.5 20.3-88.9	(6)	-		-	-	-	

(cont'd)

Table 6. Soil horizon characteristics for the 24 soil pits studied for all three study areas. (concl'd)

Horizon Designation(s)	Depth to Horizon from Surface--Mean (No. of Values) Range (cm)		Horizon Thickness--Mean (No. of Values) Range (cm)		Decomposition Class (H1-H10, Organic) or Texture (Mineral)	Mean (No. of pH Values), Range		
						Water	0.1N $CaCl_2$	
Topographic Site Type 3 (Upper Slope)								
F, FH	1.8 0 -12.7	(7)	10.9 7.6-15.2	(7)	Poorly decomposed fibrous	3.9 3.5-4.9	3.3 2.8-4.4	(6)
Ae	9.3 7.6-10.2	(3)	4.2 1.3-8.9	(3)	-	-	-	
Ahe	15.2 -	(1)	5.1 -	(1)	-	4.1	3.5	(1)
Bf	14.7 10.2-20.0	(5)	22.9 6.4-45.7	(5)	-	4.9 4.5-5.3	4.5 3.9-4.7	(5)
BC	23.6 20.3-26.7	(2)	45.7 10.2-81.3	(2)	Loamy sand (1 det.)	5.7 5.2-6.3	5.2 4.9-5.6	(2)
C	42.7 17.8-81.3	(5)	30.0 10.2-58.4[a]	(5)[a]	-	5.5 5.3-5.8	4.9 4.5-5.1	(4)
Seepage	73.5	(1)	-		-	-	-	
Topographic Site Type 4 (Crest)								
FH	0 -	(6)	8.7 6.4-12.7	(6)	Poorly decomposed fibrous	3.7 3.1-3.9	3.2 2.5-3.5	(6)
Ae	7.9 6.4-10.2	(5)	3.3 2.5-7.6	(5)	Silt loam (2 dets.)	-	-	
Bf	11.2 8.3-15.2	(5)	19.8 12.7-27.9	(5)	-	5.2 4.7-5.7	4.7 4.3-5.1	(5)
B	12.7 -	(1)	10.2 -	(1)	-	-	-	
BC	33.0 33.0-33.0	(2)	12.1 6.4-17.8	(2)	-	5.7 5.6-5.7	5.1 5.1-5.1	(2)

[a]Denotes the inclusion of a value that was deeper than the pit that was dug.

NOTE: det. = Determination. Only laboratory determinations of textures are given.

horizons were often distinguished on the basis of degree of decomposition. The upper H was moderately decomposed (H4 to H6 ≃ Oh) (Canada Soil Survey Committee Subcommittee on Soil Classification, 1978).

Moderately decomposed H layers occurred in drainageways and lower slopes, varied from 5 cm to 36 cm deep, were usually dark-colored, composed of Feather Moss (but sometimes *Sphagnum*) peat plus woody debris and litter from the forest, and had pH (water) means of 5.2 to 6.0 (Table 6).

Well decomposed H layers occurred predominantly in the drainageways (Table 6). The depths of this layer varied from 23 cm to more than 89 cm, and the pH (water) averaged 5.6. It was not possible to determine the composition of these layers, owing to their advanced state of decomposition, but often woody material could be recognized.

Mineral horizons included Ah, Ahe, Ae, Bf, BC, C and Gley horizons (Table 6). The textures of these materials were usually silt loams, but fine sandy loams and loamy fine sands were also present. The pH (water) means were usually somewhat higher than those for overlying organic materials. In crest locations, the mineral soil was often so shallow over bedrock that no C was judged to be present.

Groundwater or seepage levels in the soil pits were found in all but one of the pits for drainageways and lower slopes (Table 6). The mean depth to water for drainageways was 25 cm, and the groundwater was usually in the well decomposed humus (Oh) above the organic-mineral interface. The mean depth to water for lower slopes was 52 cm, and here it was located mainly in the C horizon. A zone of seepage was found in one of the upper slope stands; no seepage or groundwater levels were found in the crest positions. Owing to the closeness of the bedrock to the surface, seepages, indicated in particular by Speckled Alder, extend further up into upland positions than would be the case for deeper mineral soils. Furthermore, perched groundwater may be found in all three upland topographic sites, because of irregularities in the bedrock topography.

Soil chemistry: Total and exchangeable element (ion) concentrations, expressed as weights per unit volume of soil, are presented in Tables 7 and 8.

Total N attains highest concentrations in the moderately decomposed and well decomposed humus (H) layers of drainageways and lower slopes; there are also relatively high values in the FH horizons of lower slope, upper slope and crest (Table 7). Raw *Sphagnum* peat has lower concentrations than the better-decomposed H layers over which

Table 7. Mean total element concentrations ($\overline{X}$) of soils expressed on a weight/unit volume basis, for samples from 24 soil profiles studied in Areas I, II and III. Values represent those derived following extraction in strong acids. For each mean ($\overline{X}$) the number of values (n) and their coefficient of variation (CV) are also given.

	No. of Values (n)	Element (mg/cc soil) N		P		K		Ca		Mg	
		$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV
Drainageway											
Sphagnum H(H1-H3)	3	0.317	25	0.017	35	0.033	45	0.110	24	0.037	32
Moderately decomposed H(H4-H6)	3	2.332	13	0.098	41	0.138	25	1.216	43	0.263	34
Well decomposed H(H7-H10)	6	3.902	39	0.232	66	0.521	84	3.993	57	0.869	95
C	4	0.510	69	0.658	11	20.463	16	9.443	32	11.120	40
Lower Slope											
Sphagnum H(H1-H3)	1	0.818	--	0.034	--	0.030	--	0.844	--	0.178	--
FH(+F)	4	1.231	50	0.069	39	0.312	33	0.588	69	0.174	39
Moderately and well decomposed H(H4-H10)	3	2.309	20	0.212	15	0.835	38	2.530	59	0.780	5
Ae	1	0.320	--	0.072	--	15.831	--	4.671	--	2.304	--
BC	2	0.483	1	0.636	30	20.718	--	6.626	19	9.199	46
C	5	0.515	77	0.517	42	26.067	7	17.570	117	14.372	62
Upper Slope and Crest											
FH(+F)	13	1.092	32	0.055	27	0.478	82	0.438	69	0.219	70
Ae	7	0.497	43	0.082	41	13.514	18	2.739	52	2.304	28
Bf	10	0.662	39	0.367	22	15.264	67	4.821	40	6.502	38
BC	5	0.571	94	0.336	38	18.870	22	4.719	15	5.437	85
C	5	0.195	32	0.570	31	22.822	6	8.114	42	9.498	29

Table 8. Mean cation exchange capacity and exchangeable element (or ion) concentrations of soils expressed on a weight/unit volume basis, for samples taken from 24 soil profiles studied in Areas I, II and III. For each mean ($\overline{X}$) the number of values (n) and their coefficient of variation (CV) are also given.

	No. of Values (n)	CEC (me/100g)		NH_4 (µ/cc)		NO_3 (µ/cc)		P (mg/cc)		K (mg/cc)		Ca (mg/cc)		Mg (mg/cc)	
		$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV	$\overline{X}$	CV
Drainageway															
Sphagnum H(H1-H3)	3	111.0	9	2.425	97	2.522	98	0.001	--	0.035	14	0.163	31	0.037	32
Moderately decomposed H(H4-H6)	3	137.2	3	5.776	49	7.949	40	0.004	50	0.041	51	1.736	42	0.597	109
Well decomposed H(H7-H10)	6	135.9	18	1.860	39	3.843	29	0.015	107	0.015	67	4.071	41	0.435	50
C	4	6.6	65	0.764	130	1.985	78	0.009	78	0.014	43	3.147	36	0.462	68
Lower Slope															
Sphagnum H(H1-H3)	1	154.0	--	1.128	--	1.745	--	0.001	--	0.027	--	1.755	--	0.202	--
FH(+F)	4	106.8	5	17.199	79	27.497	96	0.003	33	0.081	51	0.758	65	0.119	53
Moderately well decomposed (H4-H10)	3	124.4	33	14.211	164	19.903	128	0.006	33	0.050	100	2.829	68	0.372	52
Ae	1	6.4	--	2.888	--	6.357	--	0.032	--	0.018	--	0.144	--	0.028	--
BC	2	7.5	6	3.147	21	6.079	15	0.014	114	0.021	33	0.611	80	0.094	57
C	5	6.1	33	2.212	83	2.547	66	0.017	59	0.023	61	3.335	135	0.348	103
Upper Slope and Crest															
FH(+F)	13	100.1	26	7.187	90	7.496	92	0.005	100	0.071	39	0.418	75	0.077	65
Ae	7	8.1	32	3.452	110	4.476	91	0.011	82	0.034	29	0.211	39	0.037	27
Bf	10	10.4	39	2.042	49	3.861	56	0.008	63	0.023	52	0.232	41	0.037	38
BC	5	5.7	90	1.756	144	3.507	85	0.014	129	0.027	85	0.358	76	0.062	71
C	5	4.6	38	0.987	36	2.996	15	0.018	83	0.027	96	2.190	157	0.213	124

it develops. Mineral horizons also have lower total concentrations of N than do H and FH layers. In lower slope the Ae has the lowest value among mineral horizons, whereas in upper slope and crest the C horizon has the lowest value. The other elements -- P, K, Ca and Mg -- generally attain highest total concentrations in the C and BC horizons, and have progressively lower concentrations in horizons closer to the surface.

Cation exchange capacities are greatest in organic horizons and least in mineral horizons (Table 8). NH^{+}_{4}-N and NO_{3}^{-}-N followed the same pattern as total N, achieving highest values in FH and H layers and lowest values in mineral horizons. Exchangeable K, Ca and Mg, however, showed trends quite different from those of the comparable totals, and were often higher in one of the organic horizons than in the C horizon. If one can assume that exchangeable concentrations provide a better indication of the relative fertility of soil horizons, this suggests that the humus and fermentation layers supply the most nutrition.

To compare the relative quantities measured by the two methods of extraction, exchangeable values were expressed as multiples of totals. Mean exchangeable NH_4-N and NO_3-N weights were always less than .05 times the weight of the comparable total N value in the same horizon. However, in the *Sphagnum*, H, FH, and Ae layers the mean exchangeable values of P, K, Ca and Mg often exceeded 0.1 of the mean total value, and in some cases (K, Ca and Mg) even exceeded 1.0.

To portray the variation in elements among horizons the total element concentration of each horizon is expressed as a multiple of the amount contained in the C horizon (Table 9). Total N in the H and FH layers is between 4.6 and 7.5 times that in the C horizon. N in upper mineral layers is 2.6 to 3.4 times that in the C horizon, in the upper slope and crest location. The other elements usually have concentrations in the H and FH layers of 0.1 or less than those in the C horizon; upper mineral horizons contain between 0.2 and 0.8 of the amounts in the C horizon.

When exchangeable concentrations are expressed as multiples of the concentrations in the C, NH_4-N and NO_3-N again show highest multiples in the H and FH layers (Table 10). Upper mineral horizons in upper slope and crest are also still higher than in the C. The other elements, however, now achieve higher multiples in upper horizons -- H, FH and upper mineral -- sometimes achieving values almost three times higher than those in the C horizon. This tendency is particularly apparent for K. This suggests that the upper organic horizons have better nutrient-supplying capabilities than does the original parent material, not only for forms of N but also for P, K, Ca and Mg.

Table 9. Total element concentrations expressed as multiples of the concentrations in the C horizon. Multiples are presented for drainageways (Class 1), and upper slope plus crest (Classes 3 and 4). Derived from Table 7.

Horizon	N	P	K	Ca	Mg
Drainageways (Class 1)					
Sphagnum humus (H1-H3, fibric)	0.6	<0.5	<0.5	<0.5	<0.5
Moderately decomposed humus (H4-H6, mesic)	4.6	0.1	<0.5	0.1	<0.5
Well decomposed humus (H7-H10, humic)	7.6	0.4	<0.5	0.4	0.1
C	1.0	1.0	1.0	1.0	1.0
Upper Slopes and Crests (3 and 4)					
FH	5.6	0.1	<0.5	0.1	<0.5
Ae	2.6	0.1	0.6	0.3	0.2
Bf	3.4	0.6	0.7	0.6	0.7
BC	2.9	0.6	0.8	0.6	0.6
C	1.0	1.0	1.0	1.0	1.0

Preharvest Forest Conditions

Cover type, canopy, stand condition: According to the Domtar forest inventory maps, all three areas were predominantly (91 to 98%) the softwood cover type, although small portions of mixedwood and hardwood were also included (Tables 11 to 13). In all areas Black Spruce was the leading dominant in over 90% of the quadrats and in 98% of those in Area II. The most common leading dominants after Black Spruce included Jack Pine, Trembling Aspen, and White Birch. For quadrats where Black Spruce was the leading dominant, secondary species included most commonly the species just cited plus Balsam Fir. Black Spruce-dominated quadrats which had no secondary dominant showed decreasing frequencies from drainageway to crest; hence, the upper topographic locations had secondary dominants more commonly than the lower. Species that clearly had highest frequencies in drainageways

Table 10. Exchangeable element or ion concentrations expressed as multiples of the concentrations in the C horizon. Multiples are presented for drainageways (Class 1), and upper slope plus crest (Classes 3 and 4). Derived from Table 8.

Horizon	NH_4-N	NO_3-N	P	K	Ca	Mg
Drainageway (Class 1)						
Sphagnum humus (H1-H3, fibric)	3.2	1.3	0.1	2.5	0.1	0.1
Moderately decomposed humus (H4-H6, mesic)	7.6	4.0	1.3	2.9	0.6	1.3
Well decomposed humus (H7-H10, humic)	2.4	1.9	1.7	1.1	1.3	0.9
C	1.0	1.0	1.0	1.0	1.0	1.0
Upper Slope and Crest (Classes 3 and 4)						
FH	7.3	2.5	0.2	2.6	0.2	0.4
Ae	3.5	1.5	0.6	1.3	0.1	0.2
Bf	2.1	1.3	0.4	0.9	0.1	0.2
BC	1.8	1.2	0.7	1.0	0.2	0.3
C	1.0	1.0	1.0	1.0	1.0	1.0

Table 11. Preharvest forest conditions in Area I (Thimble Creek).

Forest Condition	Topographic Site Type				
	Drainage-way	Lower Slope	Upper Slope	Crest	All
No. of quadrats	158	718	484	40	1400
Cover type (% of quadrats)					
Softwood	94	96	86	85	91
Mixedwood	3	1	8	10	5
Hardwood	2	3	6	5	5
Leading dominant[a] (% of quadrats)					
Opening - no trees	5	0	0	0	1
Black Spruce	91	93	93	91	93
White Spruce	0	1	<0.5	0	<0.5
Jack Pine	0	1	2	1	1
Balsam Fir	1	1	<0.5	0	1
Trembling Aspen	1	3	4	9	4
White Birch	0	<0.5	<0.5	0	<0.5
Black Ash	2	0	0	0	<0.5
Secondary species when black spruce dominates (% of quadrats)					
No other species	67	42	12	6	29
White Spruce	1	<0.5	0	0	<0.5
Jack Pine	15	46	59	75	50
Balsam Fir	8	2	4	4	4
White Cedar	2	<0.5	0	0	<0.5
Trembling Aspen	5	8	24	14	15
White Birch	2	2	1	2	2
Canopy closure (% of quadrats)					
Crowns touching	1	12	<0.5	0	5
Medium	77	71	76	69	74
Scattered	21	18	24	31	22
Over-stocked	0	0	0	0	0
Black Spruce dominants					
DBH (cm)					
Mean	29.1 (1)	16.4 (12)	17.6 (13)	-	17.5 (26)
Range	-	10.8-25.4	9.2-28.7	-	9.2-28.7
Height (m)					
Mean	18.0 (1)	17.7 (9)	16.8 (12)	-	17.2 (22)
Range	-	14.5-19.0	14.0-18.0	-	14.0-19.0
Age (years)[b]					
Mean	103 (1)	114 (12)	112 (13)	-	113 (26)
Range	-	93-136	93-141	-	93-141
Site class[c]					
Mean	0.8 (1)	1.2 (9)	1.3 (12)	-	1.2 (22)
Range	-	0.7-1.9	0.6-2.2	-	0.6-2.2
Site index (age at 50 years)[c]					
Mean	11.6 (1)	10.6 (9)	10.2 (12)	-	10.4 (22)
Range	-	8.4-11.9	7.7-12.5	-	7.7-12.5

[a] All ten tree species found in the study areas are listed in Appendix II-B.

[b] Age at stump height + 6 years.

[c] Determined from Plonski (1974).

Table 12. Preharvest forest conditions in Area II (Peck Lake).

Forest Condition	Topographic Site Type: Drainage-way	Lower Slope	Upper Slope	Crest	All
No. of quadrats	158	718	484	40	1400
Cover type (% of quadrats)					
Softwood	100	99	94	95	98
Mixedwood	0	1	5	5	2
Hardwood	0	0	<0.5	0	<0.5
Leading dominant[a] (% of quadrats)					
Opening - no trees	0	0	1	5	1
Black Spruce	100	100	96	93	98
White Birch	0	0	3	3	1
Secondary species when Black Spruce dominates (% of quadrats)					
No other species	91	88	82	65	85
Balsam Fir	0	2	0	0	1
White Cedar	6	3	<0.5	0	2
Trembling Aspen	1	4	16	32	9
White Birch	2	3	2	3	2
Canopy closure (% of quadrats)					
Crowns touching	1	9	4	3	6
Medium	57	75	76	76	73
Scattered	41	16	18	21	20
Over-stocked	0	0	0	0	0
Black Spruce dominants					
DBH (cm)					
Mean	24.9 (3)	23.5 (10)	23.2 (13)	-	23.5 (26)
Range	24.2-26.5	17.2-28.7	18.0-28.2	-	17.2-28.7
Height (m)					
Mean	18.9 (3)	18.8 (10)	18.5 (13)	-	18.7 (26)
Range	17.7-19.7	15.4-20.5	16.1-22.5	-	15.4-22.5
Age (years)[b]					
Mean	96 (3)	108 (10)	110 (13)	-	108 (26)
Range	82-110	70-138	98-126	-	70-138
Site class[c]					
Mean	0.4 (3)	0.7 (10)	0.8 (13)	-	0.7(26)
Range	(-0.1)-0.8	0.4-1.0	(-0.1)-1.5	-	(-0.1)-1.5
Site index (Age at 50 years)[c]					
Mean	12.9 (3)	12.2 (10)	11.6 (13)	-	12.0 (26)
Range	11.6-14.5	10.9-13.0	9.7-14.5	-	9.7-14.5

[a] All ten tree species found in the study areas are listed in Appendix II-3.

[b] Age at stump height + 6 years.

[c] Determined from Plonski (1974).

Table 13. Preharvest forest conditions in Area III (Phoney Lake).

Forest Condition	Topographic Site Type: Drainage-way	Lower Slope	Upper Slope	Crest	All
No. of quadrats	72	269	795	264	1400
Cover type (% of quadrats)					
Softwood	100	98	89	86	91
Mixedwood	0	2	11	14	9
Hardwood	0	0	0	0	0
Leading dominant[a] (% of quadrats)					
Black Spruce	100	96	92	81	91
Jack Pine	0	4	3	14	5
Balsam Fir	0	0	<0.5	0	<0.5
Trembling Aspen	0	0	3	<0.5	2
White Birch	0	0	1	4	2
Secondary species when Black Spruce dominates (% of quadrats)					
No other species	35	26	7	3	12
Jack Pine	8	28	29	40	29
Balsam Fir	11	3	5	5	5
Tamarack	1	0	0	0	<0.5
Trembling Aspen	13	21	31	14	25
White Birch	32	21	29	38	28
Canopy closure (% of quadrats)					
Crowns touching	53	66	76	55	69
Medium	47	33	18	41	27
Scattered	0	<0.5	6	5	5
Over-stocked	0	0	0	0	0
Black Spruce dominants					
DBH (cm)					
Mean	15.8 (2)	22.9 (3)	19.6 (14)	22.9 (2)	20.0 (21)
Range	14.8-16.7	19.7-27.7	15.5-26.2	21.2-24.6	14.8-27.7
Height (m)					
Mean	13.7 (2)	18.9 (3)	17.4 (14)	19.5 (2)	17.5 (21)
Range	13.1-14.3	17.7-20.4	14.6-20.1	18.0-21.0	13.1-21.0
Age (years)[b]					
Mean	105 (2)	121 (3)	126 (14)	123 (2)	123 (21)
Range	84-125	102-132	105-139	108-138	84-139
Site class[c]					
Mean	2.0 (2)	0.9 (3)	1.4 (14)	0.8 (2)	1.3 (21)
Range	1.8-2.3	0.2-1.3	0.4-2.4	0.2-1.3	0.2-2.4
Site index (age at 50 years)[c]					
Mean	8.1 (2)	11.6 (3)	10.0 (14)	12.0 (2)	10.3 (21)
Range	7.5-8.7	10.2-13.8	7.2-13.0	10.2-13.8	7.2-13.8

[a] All ten tree species found in the study areas are listed in Appendix II-B.

[b] Age at stump height + 6 years.

[c] Determined from Plonski (1974).

and lower slopes were Black Ash (*Fraxinus nigra*), White Cedar (*Thuja occidentalis*) and Tamarack (*Larix laricina*); those with highest frequencies in upper slope and crest were Jack Pine and Trembling Aspen. Balsam Fir, though distributed across all topographic positions, showed a slight preference for drainageways.

Canopy closure was rated similarly for Areas I and II, about 75% medium, 20% scattered, and 5% crowns touching (Table 11 and 12). The 20% scattered was undoubtedly due to the frequent blowdown openings observed in these overmature forests. Area III had 67% of quadrats with crowns touching, 27% medium, and only 5% scattered (Table 13). Less frequent blowdown in Area III could explain the greater canopy closure.

Data from the seedbed assessment on the occurrence and cover of throwmounds (including the openings in the organic mat created by the throwmound) showed that windthrow in Areas I and II was greater than in Area III (Table 14). The location of Area III in a sheltered bowl to the east of a high ridge could explain the lower blowdown. Further, there was more blowdown in the upper slopes and crests of all three areas, probably because of the greater degree of exposure and shallower soils in these higher topographic locations.

The detailed density survey for Area II (Table 15) gave confirming evidence on the relation of blowdown to topographic site position. The total numbers of dead Black Spruce trees (standing and down) plus old stumps increased from low to high topographic positions, paralleling the trend for throwmounds.

The question of relationship of blowdown openings to advance growth was addressed in designing the contract assessments. At each quadrat, preharvest assessments were made to determine whether 'conspicuous' advance growth, i.e., seedlings or saplings over breast height, was present nearby, and if the quadrat was influenced by blowdown, i.e., received additional light as a result of a blowdown opening. There was a highly significant ($P > 99\%$) chi-square between the presence of advance growth and blowdown openings for Area II, but non-significant chi-squares for Areas I and III. The lack of correspondence of results between the three areas was probably owing to differences in interpretation by the contractor of the assessment categories in the three different years of assessment. To elucidate regeneration dynamics of overmature Black Spruce forests, quantitative studies of reproduction in open and closed canopy situations, and also of exposed mineral soil versus Feather Moss substrates, are required.

years is generally accepted, though with rotations of < 100 years, 30% of the rotation may be the minimum..." (Ford-Robertson 1971).

To gain a better appreciation of the age structure, the distribution of trees by age class intervals is presented (Table 16). Areas I and II have the largest number of trees in the 100 to 109 year age interval, and Area III has the largest number in the 110 to 119 year age interval.

Table 16. Tree ages collected by contract: numbers of trees by 10-year age intervals. Ages taken at stump height, about 30 cm above the ground. Aging for Areas I (Thimble Creek), II (Peck Lake) and III (Phoney Lake) was done in 1974, 1975 and 1976, respectively.

	Age Interval							
Area	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139
I	-	-	2	6	10	4	2	2
II	1	1	2	7	8	5	1	1
III	-	1	-	2	1	8	5	4

Some of the variation in ages could have been due to differences in the number of years seedlings take to grow to stump height, *ca* 30 cm. Since the above results suggesting uneven-aged stands were somewhat unexpected, more detailed tree-age data were collected in 1979 from Study Area III (Phoney Lake) (Table 17). There was a mean age of about 124 years, 7 years more than the first estimate. The difference may be explained by the fact that the ages of the second data set were taken closer to the ground, and also that the second data set was taken three years after the first data set. The detailed second data set (Table 17) suggests that there are no differences in age among the site types, and that the dominant trees are predominantly even-aged, between 120 and 129 years old. Nonetheless, there were some younger individuals, and it is quite possible that reproduction of Black Spruce continued for a number of years, possibly up to two decades, following the wildfire that burned the preceding stand and gave rise to the present stand.

It is hypothesized from the age data, and from the frequent occurrence of charcoal in the humus layers of the organic mats, that the forests in Areas I and II arose during the same wildfire event, sometime in the 1860s, and that Area III arose about a decade earlier from another wildfire. The data suggest that even though there was an initial wave of seedlings after the fire, reproduction of Black Spruce continued for several years after this. They also suggest that some trees, which were considerably older than average, survived these fires. It has been observed for natural wildfires that individuals and groups of trees do survive in sheltered, often low, locations in the landscape.

Table 17. Detailed tree age survey: numbers of trees by 5-year age intervals for Area III (Phoney Lake). Ages taken on the stump, just above the root flare, usually 15-25 cm above the ground. Aging done in 1979.

Site Type[a]	Age Interval											
	100–104	105–109	110–114	115–119	120–124	125–129	130–134	135–139	140–144	145–149	Mean	Range
1	1	-	1	1	6	5	-	-	-	1	122.8	101-148
2	-	-	1	3	6	5	-	-	-	-	122.2	111-127
3	-	-	1	-	3	11	-	-	-	-	124.9	114-128
4	-	-	-	1	5	8	1	-	-	-	124.5	118-130

[a]Site type 1 = drainageway; 2 = lower slope; 3 = upper slope; 4 = crest.

Hatcher (1963) was unable to determine precisely the origin of uneven-aged Black Spruce forests in Quebec. He found that many stands that appeared even-aged were actually uneven-aged with both even- and uneven-aged components. He suggested such mechanisms as several fire events, or severe blowdowns followed by reinvasion by seedlings. Many of the presumably even-aged Black Spruce stands in the Nipigon District thought to be derived from one wildfire may actually have more complex histories, involving one or more waves of regeneration following severe disturbances, as well as understory reproduction in mature and over-mature stands as canopies open up gradually as a result of individual tree mortality. Detailed studies of age distribution by diameter classes, with ages taken exactly at ground level, are required to ensure better understanding of the dynamics of Black Spruce forests. Long-term studies of permanent plots in cutovers, however, would give even better information on stand development.

All three areas were excellent growing sites, with mean site classes ranging from 0.7 to 1.3, and mean site indices ranging from 10.3 to 12.0 m at 50 years (Tables 11 to 13). Unfortunately, the tree sample for heights and ages was not large enough to permit a valid assessment of the relationship of growth to topographic site type. However, the detailed density survey for Area II gave additional insight into site-growth relationships.

Mean diameters at breast height were greatest (18.1 cm) in drainageways, and decreased progressively as topographic position became higher (Table 15). The drainageways can support good growth if seepage is rapid, if water levels are not too high, and if *Sphagnum* development is not great. However, tree densities were lower in drainageways, and this wider spacing could explain, at least in part, the larger tree diameters.

Table 14. Preharvest frequency and cover of throwmounds in the study areas by topographic site type. Throwmound was counted as in quadrat if either the mound or the hole created by the mound was in quadrat.

	Topographic Site Type							
	Drainageway		Lower Slope		Upper Slope		Crest	
Area	% F	% C	% F	% C	% F	% C	% F	% C
Area I (Thimble Creek)	6.2	3.2	7.6	2.4	11.8	2.7	12.0	3.8
Area II (Peck Lake)	4.4	1.3	3.5	1.0	8.5	2.8	20.0	5.1
Area III (Phoney Lake)	0.0	0.0	1.1	0.4	2.0	1.1	2.6	1.2

The detailed density survey for Area II gave more details about the condition of the forest (Table 15). The number of living Black Spruce trees was highest in upper slope position, intermediate in lower slope, and lowest in crest and drainageway. Living Black Spruce saplings did not show the same pattern; high numbers were in lower slope, lower numbers were in the other site types. A relatively small proportion of the living trees, 1.3%, had leans exceeding 30° from vertical. Hence, at any one time the number of trees in the process of falling down is small. However, the numbers of standing and fallen dead trees, plus old stumps, showed that natural thinning has been going on for some time. Stand density in the recordable past was at least as high as 0.600 Black Spruce per 2-m x 2-m quadrat (1500 per ha), whereas at present, it is 0.451 per quadrat (1128 per ha). The basal area per acre, 94.1 cm^2/2-m x 2-m, or 23.5 m^2/ha, was 58% of that given for normal site class 1 stands by Plonski (1974), and this suggests that these stands are considerably understocked.

Black Spruce size, age, growth: Tree heights for the areas averaged between 17 and 19 m, diameters at breast height between 18 and 24 cm (Tables 11 to 13). The largest tree measured was 22.5 m tall and 28.7 cm DBH.

Mean ages at stump height were 107 (in 1974), 102 (1975) and 117 (1976) years, for Areas I to III, respectively (Tables 11 to 13). The most striking feature of the age data was the large difference between maximum and minimum ages recorded, 48, 56 and 55 years in Areas I, II and III. These data suggest that the stands are uneven aged, i.e., "...composed of intermingling trees that differ markedly in age. NOTE: By convention, a minimum range of 10 to 20

Table 15. Detailed density survey for black spruce in Area II (Peck Lake), for uncut strips in 1977. Numbers of trees and stumps in various conditions were sampled in 24-m^2 plots, but densities are expressed in number per 2-m x 2-m quadrat to be comparable with values in Tables 18 to 20.

	Topographic Site Type				
	Drainageway	Lower Slope	Upper Slope	Crest	All
Number of 24-m^2 plots	74	383	238	19	714
Trees					
(1) Living, erect	0.329	0.424	0.482	0.325	0.431
(2) Living, 30-60° lean	0.005	0.0004	0.004	0	0.002
(3) Living, > 60° lean	0.002	0.002	0.005	0.035	0.004
(4) Dead, standing and down	0.063	0.065	0.113	0.132	0.082
(5) Old stumps	0.074	0.064	0.073	0.053	0.067
(6) Cut stumps[a]	0.007	0.019	0.009	0	0.014
Total living (1-3, 6)	0.406	0.445	0.500	0.360	0.451
Total dead (4 + 5)	0.137	0.129	0.186	0.185	0.149
Saplings					
(1) Living, erect	0.074	0.134	0.074	0.079	0.106
(2) Living, 30-60° lean	0	0.008	0.003	0.009	0.006
(3) Living, > 30° lean	0	0.003	0.004	0.009	0.003
(4) Dead, standing and down	0	0	0	0	0
(5) Old stumps	0	0.0008	0	0	0
(6) Cut stumps[a]	0	0.0004	0	0	0
Total living (1-3, 6)	0.074	0.145	0.081	0.097	0.115
Total dead (4 + 5)	0	0.0008	0	0	0
Tree mean DBH (cm, all living)	18.1	16.4	16.0	14.2	16.3
Tree mean basal area (cm^2)	257.30	211.24	201.06	158.37	208.66
Mean ba/2-m x 2-m quadrat (cm^2)[b]	88.2	94.1	100.5	57.0	94.1

[a]During harvesting, some individuals in the leave strips were mistakenly cut.

[b]Calculated by multiplying the total living tree densities/2-m x 2-m quadrat x the mean tree basal area (cm^2).

A better estimate of site-growth relationships may be the mean basal area per 2-m x 2-m quadrat (Table 15). The greatest basal area per quadrat was in upper slope, with slightly decreasing values for lower slope and drainageway, and the lowest value for crest. This does not match with Clemmer's (1977)[11] suggestion that the lower slope position gives the best growth. Clemmer's suggestion is quite plausible, however, if one considers that the lower slopes may have a better nutrient regime because they receive nutrients seeping off the crest and upper slope position, and that moisture is plentiful but not excessive as it may be in the drainageways. With the confounding influence of variable densities among the site types, a better way to judge relative productivity is with growth studies of plantations of controlled densities among the various site positions.

Forest structure and composition: The structure and composition of forests in the three areas before cutting is portrayed in Tables 18 to 20, and Figure 14 portrays this graphically for Area I. The greatest frequencies[12] and densities for Black Spruce were for the smallest individuals (0 to 9.9 cm tall), and values decreased for progressively larger individuals up to and including saplings. For tree-size individuals, frequency and density increased slightly, being greatest in diameter classes 15 to 19.9 cm and 20 to 24.9 cm. The frequencies and mean densities in 2-m x 2-m quadrats for Black Spruce seedlings, saplings, and trees were 55.0% and 4.194, 2.6% and 0.035, and 18.1% and 0.222, respectively. All species combined showed a pattern similar to that of Black Spruce, except that the magnitudes of values were greater. The stocking of Black Spruce seedlings in the natural forest is marginally acceptable (between failure and desirable) according to the Ontario Ministry of Natural Resources stocking standards (Robinson 1974), but the 87% stocking of all species shows that there is a significant level of total advance growth in the natural forest.

A variance:mean ratio was calculated for each of the size classes of each of the species, to determine the pattern of aggregation

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[11]Clemmer, E. 1977. On the processes regulating the growth of Black Spruce stands in northwestern Ontario. M.Sc. Thesis, Univ. New Brunswick. 119 p.

[12]In the following section, the terms 'frequency' and 'stocking' are used interchangeably, and unless quadrat size is otherwise specified, they refer to the percentage of occurrences of particular height or diameter size classes in 2-m x 2-m quadrats.

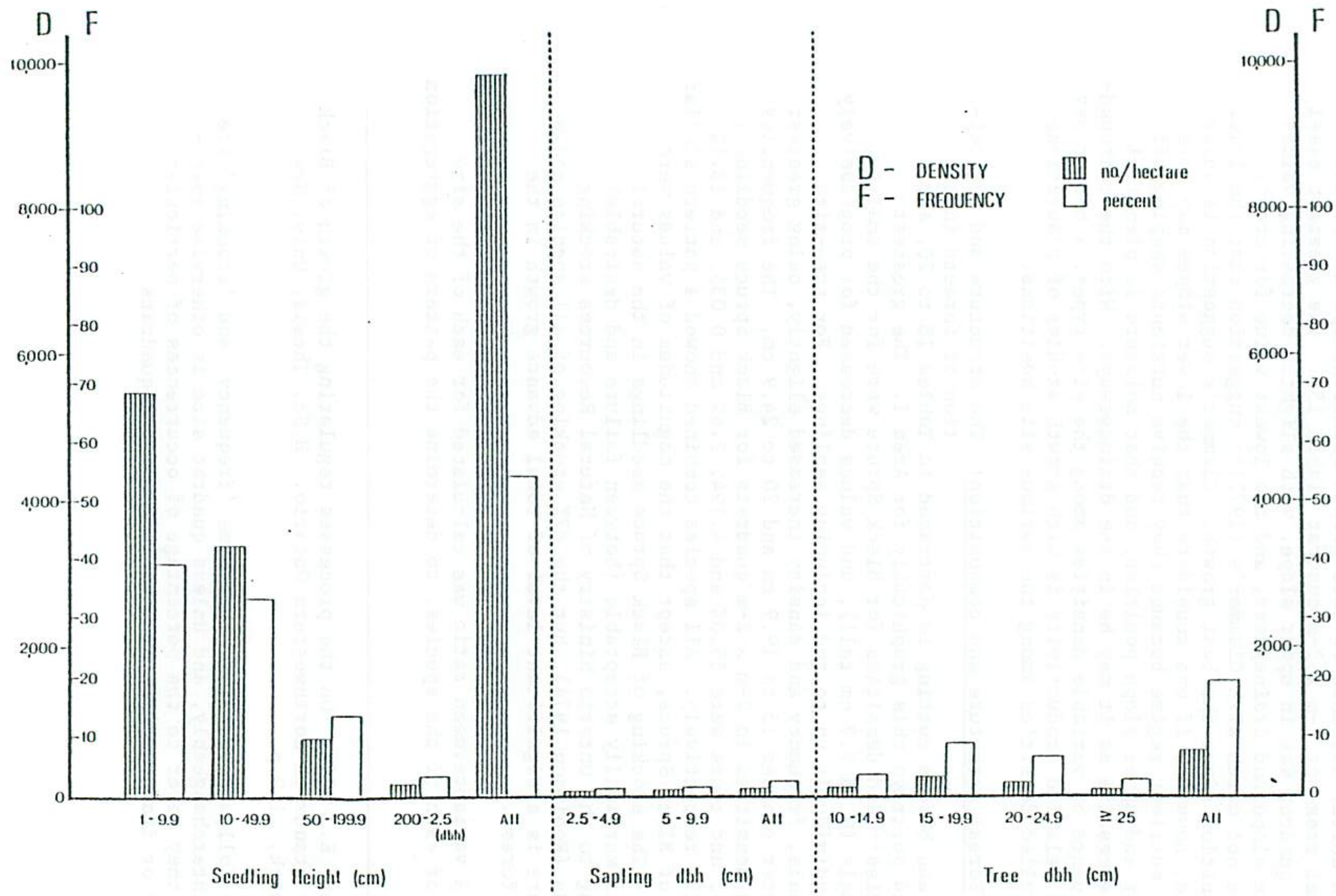

Figure 14. Preharvest density and frequency in Area I of various size classes of Black Spruce seedlings, saplings and trees.

or randomness (Tables 18 to 20). This test makes use of the equality of mean and variance of the poisson distribution. If the ratio is less than one, a regular distribution is indicated, if greater than one, a contagious distribution (Greig-Smith 1964). For the better-sampled species, a contagious (aggregated) distribution was frequently obtained for seedling and sometimes for sapling sizes. For tree sizes, especially those greater than 15 cm, the distribution was close to one which suggested a more or less random distribution. The contagious distribution of reproduction may be related to openings in the canopy caused by blowdown and mortality, but this is a hypothesis that requires testing.

The relative frequencies of saplings and trees in the preharvest forest suggested that more Balsam Fir than Black Spruce had developed when canopies were still quite closed (Table 21). Other species may have germinated on the forest floor, but if they did, few survived to the sapling stage. However, in the seedling size class four species were abundant as seedlings--Balsam Fir, Black Spruce, White Birch, and Trembling Aspen (Table 21). Clearly, the hardwood component increases as the forest becomes overmature and as the canopy opens up.

Differences in natural regeneration did appear among the topographic site types, but in general were not great. Saplings of both Black Spruce and Balsam Fir increased in frequency from drainageway to crest (Table 22). For seedlings, only Trembling Aspen showed a clear increase from drainageway to crest; the other main species showed no distinct preferences for topographic position.

It is a frequently observed phenomenon that the exposed mineral substrates created by tip-up mounds regenerate especially abundantly to Black Spruce and White Birch (Fig. 15), but also to Balsam Fir and Trembling Aspen. Consequently, it might be predicted that in the absence of harvesting or fire, the forest could develop into a mixedwood consisting of the above four species. Owing to the susceptibility of Balsam Fir to spruce budworm and stem breakage, however, it is probable that Black Spruce would maintain a dominant role in such a forest. The volume yield of such a secondary forest might not be as good as the original fire origin stand (*cf.* Sirén 1955), owing to lower densities of trees. Also, the proportion of the preferred pulp species, Black Spruce, would diminish while other less desirable species would increase.

SILVICULTURAL IMPLICATIONS

It is essential that forest management be based on a firm knowledge and appreciation of forest ecology and forest ecosystems (Bormann 1970, Marek 1975). Understanding of the structure and function of ecosystems--i.e., units of nature which include both organisms

Table 18. Preharvest forest structure and composition in Area I (Thimble Creek). Based on 1400 2-m x 2-m quadrats, all site types combined.

	SIZE CLASSES OF TREE SPECIES												
	Seedling Height (cm)					Sapling DBH (cm)			Tree DBH (cm)				
	1-9.9	10-49.9	50-199	200-2.4 DBH	All	2.5-4.9	5.0-9.9	All	10-14.9	15-19.9	20-24.9	≥ 25	All
Black Spruce													
% frequency	39.0	33.0	13.1	3.4	54.0	1.1	1.4	2.4	3.6	8.6	6.9	2.6	19.4
Density	2.200[a]	1.374	0.317	0.045	3.936	0.014	0.017	0.031	0.040	0.100	0.073	0.026	0.238
Variance/Mean	3.9[b]	10.9	4.3	1.8	17.9	1.4	1.7	2.0	1.2	1.3	1.0	1.0	1.2
t-Value	78.3**	261.0**	87.2**	21.5**	448.0**	10.2**	17.2**	25.7**	5.6**	8.9**	0.7	-0.7	6.1**
Balsam Fir													
% frequency	61.0	41.3	27.1	7.4	70.3	4.6	2.8	7.2	1.8	1.2	0.6	0.5	4.1
Density	5.548[a]	1.653	0.501	0.109	7.811	0.069	0.030	0.100	0.024	0.012	0.006	0.005	0.048
Variance/Mean	4.3[b]	7.4	2.6	2.4	18.1	2.2	1.1	1.9	2.8	1.0	1.0	1.0	1.9
t-Value	86.7**	169.7**	41.4**	38.2**	451.2**	32.4**	3.0**	24.3**	47.6**	-0.3	-0.2	-0.1	24.0**
Jack Pine													
% frequency	< 0.05	< 0.05	0.0	0.3	0.4	0.0	0.1	0.1	0.1	0.6	2.0	2.0	4.5
Density	0.003[a]	0.001	0.0	0.003	0.006	0.0	0.001	0.001	0.001	0.007	0.020	0.020	0.048
Variance/Mean	1.0[b]	1.0	0.0	1.0	2.3	0.0	1.0	1.0	1.0	1.2	1.0	1.0	1.1
t-Value	< 0.05	<0.05	0.0	-0.1	35.1**	0.0	<0.05	< 0.05	<0.05	5.1**	-0.5	-0.5	1.9
White Birch													
% frequency	28.0	10.9	4.7	0.5	32.2	0.1	0.0	0.1	0.3	0.4	0.1	0.4	0.9
Density	1.797[a]	0.298	0.081	0.006	2.182	0.001	0.0	0.001	0.004	0.004	0.001	0.004	0.012
Variance/Mean	4.8[b]	6.0	2.7	1.2	19.6	1.0	0.0	1.0	2.0	1.0	1.0	1.0	1.7
t-Value	101.5**	133.4**	44.3**	6.5**	490.6**	<0.05	0.0	<0.05	26.4**	-0.1	<0.05	-0.1	18.4**
Trembling Aspen													
% frequency	2.0	6.3	2.5	0.3	8.7	0.1	0.1	0.1	0.1	0.2	0.4	1.3	1.9
Density	0.103[a]	0.126	0.032	0.004	0.264	0.001	0.003	0.004	0.001	0.004	0.005	0.014	0.024
Variance/Mean	3.6[b]	3.3	1.5	1.4	8.2	2.0	4.0	6.0	1.0	3.0	1.3	1.1	1.6
t-Value	68.5**	60.2**	13.3**	10.5**	191.2**	26.5**	79.3**	132.2**	<0.05	52.8**	7.4**	2.4*	14.9**
All Species													
% frequency	75.0	62.3	41.3	11.4	85.9	5.8	4.1	9.5	5.7	11.0	10.1	6.8	28.3
Density	9.708[a]	3.507	0.961	0.166	14.340	0.085	0.051	0.136	0.071	0.126	0.108	0.070	0.375
Variance/Mean	6.1[b]	9.0	3.2	2.2	24.4	2.1	1.5	2.2	1.8	1.3	1.0	1.0	1.4
t-Value	134.0**	211.8**	60.0**	31.7**	618.2**	29.8**	12.8**	31.0**	21.7**	8.0**	0.7	-0.2	9.5**

[a] Densities are based on counts in 1 m^2 quadrats, multiplied by 4 to make them comparable with counts for other height and diameter classes made in 2-m x 2-m quadrats. To convert to number per hectare, multiply by 2500.

[b] Variance/mean ratio based on variances and means calculated for values in 1 m^2 quadrats.

**Probability greater than 99% that there is a contagious distribution of individuals in this size class.

* Probability greater than 95% that there is a contagious distribution of individuals in this size class.

Table 19. Preharvest forest structure and composition in Area II (Peck Lake). Based on 1400 2-m x 2-m quadrats, all site types combined.

	SIZE CLASSES OF TREE SPECIES												
	Seedling Height (cm)					Sapling DBH (cm)			Tree DBH (cm)				
	1-9.9	10-49.9	50-199	200-2.4 DBH	All	2.5-4.9	5.0-9.9	All	10-14.9	15-19.9	20-24.9	≥ 25	All
Black Spruce													
% frequency	34.0	34.4	16.1	1.9	51.9	5.3	7.5	11.6	14.4	17.8	6.6	2.9	35.4
Density	1.934[a]	1.414	0.282	0.021	3.651	0.064	0.085	0.149	0.171	0.204	0.070	0.029	0.474
Variance/Mean	3.9[b]	8.7	3.1	1.1	15.7	1.4	1.2	1.5	1.2	1.1	1.1	1.0	1.2
t-Value	77.5**	204.1**	54.7**	3.1**	388.1**	11.4**	4.9**	13.4**	5.0**	2.1*	1.4	0.5	4.0**
Balsam Fir													
% frequency	26.0	27.9	23.9	3.9	47.9	4.6	2.8	7.1	1.4	0.3	0.1	0.0	1.6
Density	0.957[a]	1.229	0.442	0.053	2.681	0.057	0.032	0.089	0.015	0.003	0.001	0.0	0.019
Variance/Mean	2.2[b]	8.4	2.7	1.8	10.7	1.3	1.2	1.4	1.2	1.0	1.0	0.0	1.3
t-Value	31.6**	196.4**	44.2**	20.1**	255.9**	9.1**	6.2**	10.8**	4.7**	-0.1	<0.05	0.0	7.4**
Jack Pine													
% frequency	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Density													
Variance/Mean													
t-Value													
White Birch													
% frequency	10.7	7.2	3.6	0.5	19.8	0.3	0.0	0.3	0.4	0.2	0.0	0.0	0.6
Density	1.477[a]	0.219	0.088	0.006	1.790	0.004	0.0	0.04	0.004	0.002	0.0	0.0	0.006
Variance/Mean	5.6[b]	7.1	4.3	1.2	23.7	2.0	0.0	2.0	1.0	1.0	0.0	0.0	1.0
t-Value	131.0**	160.5	86.8**	5.7**	599.8**	26.4**	0.0	26.4**	-0.1	<0.05	0.0	0.0	-0.2
Trembling Aspen													
% frequency	1.0	3.3	1.9	0.3	4.5	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.2
Density	0.017[a]	0.080	0.024	0.003	0.124	0.001	0.0	0.001	0.001	0.0	0.001	0.001	0.002
Variance/Mean	1.3[b]	4.5	1.9	1.0	5.1	1.0	0.0	1.0	1.0	0.0	1.0	1.0	1.0
t-Value	8.7**	92.0**	22.7**	-0.1	108.1**	<0.05	0.0	<0.05	<0.05	<0.0	<0.05	<0.05	<0.05
All Species													
% frequency	53.0	56.3	41.4	6.7	76.9	10.1	10.1	18.4	16.1	18.4	6.9	3.1	37.4
Density	4.428[a]	3.074	0.914	0.086	8.502	0.126	0.119	0.244	0.191	0.210	0.074	0.032	0.506
Variance/Mean	5.5[b]	8.4	3.5	1.5	19.6	1.4	1.2	1.5	1.2	1.1	1.0	1.1	1.1
t-Value	119.6**	196.9**	66.8**	14.1	492.7**	10.5**	5.2**	12.1**	4.1**	1.7	1.2	1.5	3.3**

[a]Densities are based on counts in 1 m^2 quadrats, multiplied by 4 to make them comparable with counts for other height and diameter classes made in 2-m x 2-m quadrats. To convert to number per hectare, multiply by 2500.

[b]Variance/mean ratio based on variances and means calculated for values in 1 m^2 quadrats.

**Probability greater than 99% that there is a contagious distribution of individuals in this size class.

*Probability greater than 95% that there is a contagious distribution of individuals in this size class.

Table 20. Preharvest forest structure and composition in Area III (Phoney Lake). Based on 1400 2-m x 2-m quadrats, all site types combined

	SIZE CLASSES OF TREE SPECIES												
	Seedling Height (cm)					Sapling DBH (cm)			Tree DBH (cm)				
	1-9.9	10-49.9	50-199	200-2.4 DBH	All	2.5-4.9	5.0-9.9	All	10-14.9	15-19.9	20-24.9	≥ 25	All
Black Spruce													
% frequency	39.0	26.8	9.5	3.9	50.7	2.0	3.4	5.1	9.6	14.2	9.2	3.5	30.8
Density	2.483[a]	0.974	0.167	0.047	3.671	0.020	0.036	0.056	0.109	0.161	0.096	0.036	0.401
Variance/Mean	4.8[b]	6.0	2.8	1.4	17.3	1.0	1.1	1.2	1.2	1.1	1.0	1.0	1.1
t-Value	101.6**	131.6**	48.5**	10.8**	432.0**	-0.5	2.250*	4.0**	4.4**	2.1*	-0.5	0.1	3.9**
Balsam Fir													
% frequency	28.0	22.4	17.8	4.0	39.6	5.1	3.2	7.7	0.6	0.4	0.1	0.1	1.1
Density	1.263[a]	0.791	0.390	0.060	2.504	0.066	0.037	0.104	0.006	0.004	0.001	0.001	0.011
Variance/Mean	3.9[b]	4.8	3.4	1.9	14.0	1.8	1.2	1.7	1.0	1.0	1.0	1.0	1.0
t-Value	77.8**	100.8**	64.6**	23.6**	343.5**	20.5**	6.2**	18.5**	-0.1	-0.1	<0.05	-0.3	-0.3
Jack Pine													
% frequency	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	1.6
Density	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	0.011	0.016
Variance/Mean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0
t-Value	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	-0.3	-0.4
White Birch													
% frequency	21.0	7.6	3.9	0.8	24.2	0.4	0.1	0.4	0.6	0.6	0.0	0.0	1.1
Density	1.172[a]	0.211	0.076	0.009	1.466	0.004	0.001	0.005	0.006	0.006	0.0	0.0	0.011
Variance/Mean	5.1[b]	4.9	3.1	1.2	21.7	1.3	1.0	1.3	1.0	1.0	0.0	0.0	1.0
t-Value	107.2**	102.3**	55.4**	4.2**	548.4**	8.7**	<0.05	7.4**	-0.1	-0.1	0.0	0.0	-0.3
Trembling Aspen													
% frequency	2.0	2.6	1.3	0.1	4.0	0.1	0.0	0.1	0.0	0.4	0.1	0.4	0.9
Density	0.029[a]	0.049	0.018	0.001	0.096	0.001	0.0	0.001	0.0	0.004	0.001	0.004	0.009
Variance/Mean	1.6[b]	3.3	2.0	1.0	6.5	1.0	0.0	1.0	0.0	1.0	1.0	1.0	1.0
t-Value	15.7**	61.8**	27.1**	<0.05	145.6**	<0.05	0.0	<0.05	0.0	-0.1	<0.05	-0.1	-0.2
All Species													
% frequency	56.0	43.7	28.3	8.6	70.0	7.5	6.6	13.0	10.7	15.5	9.9	5.1	34.2
Density	4.944[a]	2.025	0.651	0.116	7.738	0.091	0.074	0.165	0.121	0.174	0.103	0.051	0.449
Variance/Mean	0.691[b]	6.4	3.4	1.6	25.0	1.5	1.1	1.5	1.1	1.0	1.0	1.0	1.1
t-value	1.562**	143.1**	63.2**	16.4**	634.4**	14.1**	3.2**	12.6**	3.4**	1.3	-0.5	-0.6	3.1**

[a] Densities are based on counts in 1 m^2 quadrats, multiplied by 4 to make them comparable with counts for other height and diameter classes made in 2-m x 2-m quadrats. To convert to number per hectare, multiply by 2500.

[b] Variance/Mean ratio based on variances and means calculated for values in 1 m^2 quadrats.

**Probability greater than 99% that there is a contagious distribution of individuals in this size class.

*Probability greater than 95% that there is a contagious distribution of individuals in this size class.

and non-living components, interacting with each other and influencing each other's properties--allows us to see more clearly how managerial practices affect the working of the systems. From this viewpoint, forest managers should always obtain good preharvest information, not only on the present forest composition and structure, but also on the tree growth, advance growth, understory vegetation, forest floor, topographic position, and moisture regime. Such information can be used to make better decisions on how best to harvest and regenerate, and/or how to use various forest ecosystems for other purposes.

The following discussion of management implications deals with three main topics: the shallowness of the soils, forest origin and development, and the management of the organic (mor) mat lying over the mineral soil.

Figure 15. Regeneration of Black Spruce on mineral soil in the cavity created by a throwmound. Bedrock is exposed in the cavity: Schreber's Feather Moss is on the mound.

Shallowness of the Mineral Soils

The study areas were predominantly Black Spruce/Schreber's Feather Moss type on shallow rocky tills on uplands. In spite of the fact that the sites included practically none of the 'shallow soil-rock showing' site type of the Domtar system and were almost exclusively classed as 'softwood slope', nonetheless, the soils were quite shallow. One quarter of the soil depth survey points had less than 30 cm mineral soil over bedrock. Further, one half of the soil probes encountered solid rock (rock in till, boulder pavement, or bedrock) within 75 cm of the surface and some considerable proportion of these must have been bedrock. Therefore, these sites were definitely shallow-soil sites[3], and they probably were 'fragile' shallow soil sites as defined by the Ministry.[4]

Table 21. Preharvest relative frequency of species in the tree (≥ 10 cm DBH), sapling (2.5 to 9.9 cm DBH), and seedling (< 2.5 cm DBH) size classes in Study Area I (Thimble Creek). Based on absolute frequencies from Table 18.

	Preharvest		
	Trees	Saplings	Seedlings
Black Spruce	63	24	33
Balsam Fir	13	73	42
Jack Pine	15	1	0.2
White Birch	3	1	19
Trembling Aspen	6	1	5
Σ Rel. Freq.	100	100	99

If one considers the shallowness of the mineral soils, it is significant that these areas supported highly productive, site class 1 Black Spruce, and every effort should be made to maintain this productivity. From this viewpoint, harvesting and site preparation should be carried out with great care to preserve what little mineral soil there is (*cf.* Robinson 1974). This thin veneer of mineral soil is important as a reserve of mineral nutrients, as one of the best seedbed types owing to its excellent moisture-retaining properties, as a substrate for planting in those areas where natural regeneration is not adequate, and for root anchorage.

The primary activities which have the greatest impact on mineral soil erosion are roads (e.g., Mattice 1977) and site preparation. Good guidelines are available on road construction (e.g., Curran and Etter 1975, Case and Rowe 1978). With regard to site preparation, the prescription for 'delicate' scarification, with removal of the organic mat in furrows just down to the surface of the mineral, or leaving some few centimetres of humus over or mixed with the mineral, is an excellent compromise with the need to minimize soil erosion and at the same time achieve enough mineral exposure for a satisfactory catch of seedlings. Since it is desirable to minimize the amount of soil disturbance, the amount of receptive mineral surface can be either increased or decreased by regulating the distance between the furrows, not by increasing depth of furrow.

Table 22. Preharvest frequency of main species in the sapling (2.5 to 9.9 cm DBH) and seedling (< 2.5 cm DBH) size classes among the topographic site types. Based on 1400 2-m x 2-m quadrats from Area I (Thimble Creek).

	Topographic Site Type			
	Drainageway	Lower Slope	Upper Slope	Crest
Saplings				
Balsam Fir	3.6	5.4	9.4	9.2
Black Spruce	0.9	1.7	3.1	5.5
Seedlings				
Balsam Fir	61.6	68.4	77.1	65.1
Black Spruce	52.7	54.5	55.4	57.8
White Birch	31.3	32.9	38.9	28.4
Trembling Aspen	4.5	8.5	10.2	10.1

Stand Origin, Succession, and Compositional Changes

The forests in all three study areas undoubtedly arose following wildfires in standing timber. All the study areas had peaty drainageways and depressions interspersed throughout, in which Black Spruce maintains itself as dominant. Periodic wildfires through the centuries have favored the spreading of Black Spruce from the wetter locations of the landscape onto the uplands. Wildfires in standing timber favor the reseeding of Black Spruce as a result of incomplete burning of the cone-bearing, club-shaped tops, in contrast to complete consumption of the seed-bearing cones and fruits of Balsam Fir, White Birch, and Trembling Aspen.

Another species favored by fire is Jack Pine, especially on deep sandy outwash, but also on the higher, drier, crest locations of shallow soil sites. The intergradation of Black Spruce and Jack Pine on shallow sites requires clarification. Undoubtedly, some of the key factors explaining the relative proportions of these species are proximity of Black Spruce seed source in drainageways, relative moistness of site as it relates to seedling establishment, and soil depth as it relates to blowdown susceptibility.

It is significant that Black Spruce does reproduce to an important level in the understory of these overmature stands. As indicated in its seedling composition, the preharvest forest seems to be developing into a mixedwood with Balsam Fir and White Birch increasing relative to Black Spruce (Tables 21 and 22). Trembling Aspen seedlings are not important here, probably because of the intolerance of the species to shade.

Management of the Organic (Mor) Mat

As early as 1922, Moore (1922*b*) reported experiments showing that the organic mat of a forest ecosystem provides a higher supply of nutrients to pine seedlings than do the underlying mineral horizons, and recent studies with seedlings of Jack Pine (Winston 1974) and Black Spruce (Jeglum 1979) show the same thing. It is also well known that in the Black Spruce ecosystem, as well as in other northern temperate forest ecosystems, the majority of the fine feeder roots occur in the fermentation and humus layers of the organic mor mat (e.g., Moore 1922*a*, Hoyle 1963, Weetman 1965), and that many of the nutrient needs of Black Spruce are met by this layer (Stoeckeler 1945, Weetman 1968). Consequently, it is not surprising that the chemical analyses of soils in the present study showed that exchangeable nutrients are higher in the organic mat than in underlying mineral horizons.

From these considerations, the author agrees with the silvicultural prescription that a very conservative approach be taken in site preparation, and that the scarification expose just enough receptive seedbed (mineral, humus, mineral-humus mix) to provide optimum spacing of seedlings for maximum wood volumes at rotation. Scarification which achieves the above, and thereby minimizes disturbance not only to mineral soil but also to the organic mat, has been termed 'delicate' scarification (G. Marek, OMNR, Nipigon District, pers. commun.).

For this ecosystem it may be advantageous to establish a relatively high density of Black Spruce seedlings, and to achieve an early canopy closure[11]. Early canopy closure may produce conditions of moisture and temperature in the rooting layer which favor optimum N supply. In addition, heavy shading favors the development of Schreber's Feather Moss and moss peat. Weetman and Timmer (1967) suggest a natural interdependence of this Feather Moss and Black Spruce, maintaining that the moss and moss humus provide a rapid means of entry of nitrogen from rainfall, and nitrogen washed from tree crowns, into the nitrogen cycle of the stand. It may be that Black Spruce is better adapted than the other major tree competitors--White Spruce, Balsam Fir, Trembling Aspen and White Birch--to the acid moss humus formed by Schreber's Feather Moss. Comparative autecological studies of these species should be carried out to test the influence of different humus and mineral soil types on seed germination and seedling growth (*cf.* Jeglum 1979).

It is possible that sites with thick moss-humus accumulations may require the removal of the upper, poorly decomposed, dry layers by burning to obtain a rejuvenation of site productivity (Sirén 1955, Weetman 1962, Weetman and Nykvist 1963). Increased productivity may be effected by (i) release of nutrients following the wildfire and (ii) warmer ground temperatures early in the development of these stands. There may, however, be some deleterious impacts on these shallow sites, such as loss of nutrients, accelerated erosion, and a delay in the influx of regeneration onto these sites. These are some of the questions which need to be answered by continuing studies of the functions and processes of Black Spruce ecosystems.

LITERATURE CITED

ANON. 1975. Canadian normals: Volume 3--Wind, 1955-1972. Dep. Environ., Atmosph. Environ. Serv., Downsview, Ont.

ANON. 1977. Proceedings of the national forest regeneration conference, Quebec City, 19-21 Oct. 1977. Can. For. Assoc., Ottawa, Ont. 244 p.

ANON. 1978. Proceedings of Ontario Conference on Forest Regeneration. March 29 to 31, 1978, Thunder Bay, Ont. Ont. Min. Nat. Resour. 123 p.

BEDELL, G.H.D., and MACLEAN, D.W. 1952. Nipigon growth and yield survey: Project H-69. Can. Dep. Resour. and Devel., Agron. Br., Silvic. Res. Note No. 101. 51 p.

BLACK, C.A., *Ed.* 1965. Methods of soil analysis. Part 2. Chemical and microbiological properties. Amer. Soc. Agron., Agron. Ser. No. 9. 1199 p.

BORMANN, F.H. 1970. The ecosystem concept--necessary basis for land use. p. 19-25 *in* Proc. Golden Anniv. Mett., New England Sec., Soc. Amer. For., Boston, Mass.

CANADA SOIL SURVEY COMMITTEE, SUBCOMMITTEE ON SOIL CLASSIFICATION. 1978. The Canadian system of soil classification. Can. Dep. Agric. Publ. 1646. Supply and Services Canada, Ottawa, Ont. 164 p.

CASE, A.G., and ROWE, D.A. Environmental guidelines for resource road construction. Can. For. Serv., St. John's, Nfld. Inf. Rep. N-X-162. 41 p.

CHAPMAN, L.J., and THOMAS, M.K. 1968. The climate of northern Ontario. Can. Dep. Transp., Meteorol. Br., Climatol. Stud. No. 6. 58 p.

CURRAN, H.J.B., and ETTER, H.M. 1976. Environmental design for northern road developments. Dep. Environ., Environ. Protec. Serv., Northwest Region, Environ. Impact and Assess. Rep. EPS-8-EC-76-3. 45 p. plus appendices.

FLOWERS, J.F. 1977. Proposed clearcut policy for Ontario. p. 1-4 *in* Seminar on clearcutting, Thunder Bay, Ont., Feb. 22-24, 1977. Ont. Prof. For. Assoc.

FORD-ROBERTSON, F.C., *Ed.* 1971. Terminology of forest science, technology practice and products: English language version. Soc. Amer. For., Washington, D.C. 349 p.

FRASER, J.W., HAAVISTO, V.F., JEGLUM, J.K., DAI, T.S., and SMITH, D.W. 1976. Black spruce regeneration on strip cuts and clearcuts in the Nipigon and Cochrane areas of Ontario. Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-246. 33 p.

GLEASON, H.A., and CRONQUIST, A. 1963. Manual of vascular plants of northeastern United States and adjacent Canada. D. van Nostrand Co., Princeton, N.J. 810 p.

GREWELING, T., and PEECH, M. 1965. Chemical soil tests. Cornell Univ. Agric. Exp. Stn. Bull. 960. 59 p.

GREIG-SMITH, P. 1964. Quantitative plant ecology. Butterworths, London. 256 p.

HATCHER, R.J. 1963. A study of black spruce forests in northern Quebec. Can. Dep. For., For. Res. Br., Dep. For. Publ. No. 1018. 37 p.

HILLS, G.A. 1959. A ready reference to the description of the land of Ontario and its productivity. Ont. Dep. Lands and For., Div. of Res., Maple, Ont., Prelim. Rep. 142 p.

HOSIE, R.C. 1953. Forest regeneration in Ontario. Univ. Toronto, For. Bull. No. 2. 134 p.

HOYLE, M.C. 1973. Nature and properties of some forest soils in the White Mountains of New Hampshire. USDA For. Serv., Upper Darby, Pa., Res. Pap. NE-260. 18 p.

IRELAND, R.R., BIRD, C.D. BRASSARD, G.R., SCHOFIELD, W.B., and VITT, D.H. 1980. Checklist of the mosses of Canada. Nat. Mus. Can., Publ. in Bot. No. 8. 75 p.

JEGLUM, J.K. 1979. Effects of some seedbed types and watering frequencies on germination and growth of black spruce: a greenhouse study. Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-292. 33 p.

KETCHESON, D.E. 1977. The impact of strip cutting on logging road costs. Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-263. 19 p. plus Appendix.

KETCHESON, D.E. 1979. A study of the cost of strip cutting black spruce stands in northern Ontario. Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-301. 23 p.

KETCHESON, D.E. and JEGLUM, J.K. 1972. Estimates of black spruce and peatland areas in Ontario. Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-172. 29 p.

MAREK, G.T. 1975. Ecosystem management on shallow sites in the Lake Nipigon-Beardmore area. p. 195-200 *in* Black Spruce Symposium. Can. For. Serv., Sault Ste. Marie, Ont. Symp. Proc. O-P-4.

MATTICE, C.R. 1977. Forest road erosion in northern Ontario: a preliminary analysis. Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-254. 27 p.

MOORE, B. 1922*a*. Humus and root systems in certain northeastern forests in relation to reproduction and competition. J. For. 20: 235-254.

MOORE, B. 1922*b*. Influence of certain soil factors on the growth of tree seedlings and wheat. Ecology 3: 65-83.

PLONSKI, W.L. 1974. Normal yield tables (metric). Ont. Min. Nat. Resour., Div. For. 40 p.

PYE, E.G. 1969. Geology and scenery: North Shore of Lake Superior. Ont. Dep. Mines, Geol. Guide Book No. 2. 143 p.

ROBINSON, F.C. 1974. A silvicultural guide to the black spruce working group. Ont. Min. Nat. Resour., Div. For., For. Manage. Br. 44 p.

ROE, A.L., ALEXANDER, R.R. and ANDREWS, M.D. 1970. Engelmann spruce regeneration practices in the Rocky Mountains. USDA Production Res. Rep. 115. 32 p.

ROWE, J.S. 1972. Forest regions of Canada. Dep. Environ., Can. For. Serv., Ottawa, Ont. Publ. No. 1300. 172 p.

SANDERSON, M. 1948. The climates of Canada according to the new Thornthwaite classification. Sci. Agric. 28: 501-517.

SIREN, G. 1955. The development of spruce forest on raw humus sites in northern Finland and its ecology. Acta For. Fenn. 62.4. 408 p.

STOECKELER, J.H. 1945. Nutrients in duff and humus layers increase growth of forest plantations. USDA For. Serv., St. Paul, Minn., Lake States For. Exp. Stn. Tech. Notes No. 226. 1 p.

TUCKER, T.L., and KETCHESON, D.E. 1973. Forestry in Ontario: from resource to market. Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-185. 69 p.

WEETMAN, G.F. 1962. Mor humus: a problem in a black spruce stand at Iroquois Falls, Ont. Pulp. Pap. Res. Inst. Can., Tech. Rep. Series No. 277 (Woodl. Res. Ind. No. 130). 18 p.

WEETMAN, G.F. 1965. The decomposition of confined black spruce needles on the forest floor. Pulp Pap. Res. Inst. Can., Tech. Rep. No. 411 (Woodl. Res. Ind. No. 165). 18 p.

WEETMAN, G.F. 1968. The effects of thinning and urea treatments on the raw humus soils of black spruce forest in northern Quebec. Trend 12: 15-18.

WEETMAN, G.F., and NYKVIST, N.B. 1963. Some mor humus, regeneration and nutrition problems and practices in north Sweden. Pulp Pap. Res. Inst. Can., Tech. Rep. No. 317 (Woodl. Res. Ind. No. 139). 15 p.

WEETMAN, G.F., and TIMMER, V. 1967. Feather Moss growth and nutrient content under upland black spruce. Pulp Pap. Res. Inst. Can., Tech. Rep. No. 503 (Woodl. Res. Ind. No. 183). 38 p.

WINSTON, D.A. 1974. Bioassay pot trials with forest soils: a question of horizon. Dep. Environ., Can. For. Serv., Ottawa, Ont. Bimon Res. Notes 30(5): 32-33.

ZOLTAI. S.C. 1965. Glacial features of the Quetico-Nipigon area, Ontario. Can. J. Earth Sci. 2: 247-269.

ZOLTAI, S.C. 1967. Glacial features of the north-central Lake Superior region, Ontario. Can. J. Earth Sci. 4: 515-528.

APPENDICES

APPENDIX I

RESPONSIBILITIES OF THE COOPERATING AGENCIES

Ontario Ministry of Natural Resources (OMNR) Nipigon Forest District

OMNR is recognized as the lead agency, and as such will have primary responsibility for the overall organization and execution of the work, and for liaison among the three cooperating agencies. Specific responsibilities are timber administration, supervision of harvesting operations (on both operational and experimental areas), planning and implementation of site preparation, and assessment of windfall (if necessary) on both operational and experimental areas. Planting cost data will be provided to both Domtar and GLFRC, as necessary, for the calculation of overall regeneration costs, and for determination of amounts to be paid to the company in lieu of the incremental cost of strip cutting.

Domtar Woodlands Limited (Domtar) Nipigon Division

Domtar will be responsible for preparing management and operating plans, implementing and controlling cutting (on both operational and experimental areas) to meet the requirements of the project, and collecting and providing productivity and cost data required for the incremental logging cost study. The most challenging task of the company will be to devise logging systems that will maximize the efficiency of strip cutting.

Great Lakes Forest Research Centre (GLFRC) Canadian Forestry Service

GLFRC will be responsible for conducting and/or contracting the incremental logging cost study, conducting and/or contracting regeneration studies and assessing the results, conducting necessary supporting research, and making an overall evaluation of strip cutting as a method of harvesting and regenerating upland Black Spruce. GLFRC will also be responsible for any special treatments required for research purposes on the experimental area.

It is noted that GLFRC has already contracted with the Pulp and Paper Research Institute of Canada for the design of a study to determine the incremental logging costs of strip cutting. This design is to be submitted by January 31, 1974, and the three cooperating agencies will be jointly responsible for accepting, rejecting or modifying the design and implementing the study. [This requirement was satisfied by a report from PPRIC to GLFRC, cited in footnote 8, page 8.]

APPENDIX II

DATA CODING KEYS

II-A General Site Information

Columns

1- 3	Stand No.
4- 6	Quadrat No.
7- 8	Data type - enter "G" for general.
9-10	Year - enter "4" for 1974, etc.
11-12	General forest cover "S" (softwood), "M" (mixedwood) "H" (hardwood), from company type map.
13-14	Height of trees, "A" over 60', "B" 40' to 60', "C" under 40'.
15-16	Canopy closure, "1" crowns touching, "2" crowns not touching, "3" open forest, "4" over-stocked, very dense.
17-18	Company site types.

Flat -- lowland	1
Softwood slope	2
Shallow soil -- rock showing	3
Moderate to deep soil -- mixedwood	4
Sand flat to rolling -- Jack Pine	5
Rugged upland	6
Moderate to deep soil -- hardwood	7

19-20	Blank.
21-22	Leading tree species number.
23-24	Secondary tree species number.
25-26	Percentage of secondary tree species.
27-28	Tertiary tree species number.
29-30	Percentage of tertiary tree species.

Columns

Tree Species Code

No trees	0
Black Spruce	1
White Spruce	2
Jack Pine	3
Balsam Fir	4
Cedar	5
Tamarack	6
Trembling Aspen	7
White Birch	8
Balsam Poplar	9
Black Ash	10
Alder-Birch group	11

(continued)

APPENDIX II (continued)

31-32	Understory Type	
	Black Spruce/*Pleurozium*	1
	" " /*Alnus rugosa/Pleurozium*	2
	" " /*Alnus rugosa/Sphagnum* and graminoids	3
	" " /*Alnus crispa/Pleurozium*	4
	" " /*Cladina*	5
	" " /*Maianthemum* and *Cornus/Pleurozium*	6
	" " /*Ledum* and *Pleurozium (Sphagnum* secondary*)*	7
	" " /*Ledum* and *Sphagnum (Pleurozium* secondary*)*	8
	" " /*Alnus rugosa/Pleurozium* and *Clintonia*	9
	Trembling Aspen-Black Spruce/*Pleurozium* and *Aster* and *Cornus*	10
	Black Spruce-Trembling Aspen/*Alnus crispa*	11
	Black Spruce-Jack Pine/*Pleurozium*	12
	Trembling Aspen-Black Spruce/*Clintonia*	13
	Balsam Fir/*Cornus* and *Clintonia*	14
	Black Ash/*Alnus rugosa*	15
	White Birch/*Cornus* and *Clintonia*	16
	Black Spruce/*Sphagnum* and graminoids	17
	" " /*Alnus crispa/Sphagnum* and graminoids	18

33-34 Topographic position - general

Drainageway	1	(I)
Transitional	2	(II)
Upper slope	3	(III)
Crest	4	(IV)

35-36 Topographic position - specific (1-4 same as above)

37-38 Blowdown present Yes...1 No...blank

39-40 Conspicuous advanced growth. If yes, code in the number of the leading species. If no, leave blank.

41-43 Slope class

Flat		1
Gentle slopes	1- 10%	2
Moderate slopes	10- 50%	3
Steep slopes	50-100%	4
Very steep	100% + (over 45°)	5

43-44 Aspect

Flat		0
North quadrant	(315°- 45°)	1
East quadrant	(35°-135°)	2
South quadrant	(135°-225°)	3
West quadrant	(225°-315°)	4

II-B <u>Regeneration and Tree Data</u>

<u>Columns</u>

1- 3 Strip No.

4- 6 Quadrat No. (see METHODS for sequence)

(continued)

APPENDIX II (continued)

7- 8	Data type - enter "R"
9-10	Year - enter "4" for 1974, "5" for 1975, etc. "B" if second time in one year an assessment is done.
11-12	Species Code No. 0 - No trees 1 - Black Spruce 2 - White Spruce 3 - Jack Pine 4 - Balsam Fir 5 - Cedar 6 - Tamarack 7 - Trembling Aspen 8 - White Birch 9 - Balsam Poplar 10 - Black Ash 11 - Alder-Birch Group
13	Height Class 1 (seedlings 0-9.9 cm tall): Presence in the 2 m x 2 m plot, P = present, blank = nil
14	Height Class 1 (seedlings 0-9.9 cm tall): Total number to a maximum of 9 in the 2 m x 1/2 m plot.
15	Height Class 1 advance growth seedlings (0-9.9 cm tall) in the 2 m x 1/2 m plot.
16	Height Class 2 (10-49 cm tall): Total number to a maximum of 9 in the 2 m x 2 m plot.
17-18	Height Class 3 (50-199 cm tall): Total number to a maximum of 9 in the 2 m x 2 m plot.
19-20	Height Class 4 (200 cm tall to 2.4 cm DBH): Total number to a maximum of 9 in the 2 m x 2 m plot.
21	Diameter Class 1 (2.5-4.9 cm DBH): Total number to a maximum of 9 in the 2 m x 2 m plot.
22	Diameter Class 2 (5-9.9 cm DBH): as in (21).
23	Diameter Class 3 (10-14.9 cm DBH): as in (21).
24	Diameter Class 4 (15-19.9 cm DBH): as in (21).
25-26	Enter DBH in centimetres of a tree ≥ 20 cm DBH.
27-28	Enter DBH in centimetres of a tree ≥ 20 cm DBH.
	Next sequence is identical to 11-28 above.
29-30	Species Code Number.
31	Height Class 1: Presence (2 m x 2 m plot).
32	Height Class 1: Total number, maximum 9 (2 m x 1/2 m plot)
33	Height Class 1: Advance growth, maximum 9 (2 m x 1/2 m plot)
34	Height Class 2: Total number, maximum 9 (2 m x 2 m plot)
35-36	Height Class 3: Total number, maximum 9 (2 m x 2 m plot)
37-38	Height Class 4: Total number, maximum 9 (2 m x 2 m plot)
39	Diameter Class 1: Total number, maximum 9 (2 m x 2 m plot)
40	Diameter Class 2: Total number, maximum 9 (2 m x 2 m plot)
41	Diameter Class 3: Total number, maximum 9 (2 m x 2 m plot)
42	Diameter Class 4: Total number, maximum 9 (2 m x 2 m plot)

(continued)

APPENDIX II (continued)

43-44	Tree ≥ 20 cm DBH in centimetres
45-46	Tree ≥ 20 cm DBH in centimetres
	Next sequence is identical to 29-42 above.
	NOTE: Spaces for trees ≥ 20 cm not included.
47-48	Species Code Number
49	Height Class 1: Presence (2 m x 2 m plot)
50	Height Class 1: Total number, maximum 9 (2 m x 1/2 m plot)
51	Height Class 1: Advance growth, maximum 9 (2 m x 1/2 m plot)
52	Height Class 2: Total number, maximum 9 (2 m x 2 m plot)
53-54	Height Class 3: Total number, maximum 9 (2 m x 2 m plot)
55-56	Height Class 4: Total number, maximum 9 (2 m x 2 m plot)
57	Diameter Class 1: Total number, maximum 9 (2 m x 2 m plot)
58	Diameter Class 2: Total number, maximum 9 (2 m x 2 m plot)
59	Diameter Class 3: Total number, maximum 9 (2 m x 2 m plot)
60	Diameter Class 4: Total number, maximum 9 (2 m x 2 m plot)
	Next sequence is identical to 47-60 above.
	NOTE: Spaces for trees ≥ 20 cm again not included.
61-62	Species Code Number.
63	Height Class 1: Presence (2 m x 2 m plot)
64	Height Class 1: Total number, maximum 9 (2 m x 1/2 m plot)
65	Height Class 1: Advance growth, maximum 9 (2 m x 1/2 m plot)
66	Height Class 2: Total number, maximum 9 (2 m x 2 m plot)
67-68	Height Class 3: Total number, maximum 9 (2 m x 2 m plot)
69-70	Height Class 4: Total number, maximum 9 (2 m x 2 m plot)
71	Diameter Class 1: Total number, maximum 9 (2 m x 2 m plot)
72	Diameter Class 2: Total number, maximum 9 (2 m x 2 m plot)
73	Diameter Class 3: Total number, maximum 9 (2 m x 2 m plot)
74	Diameter Class 4: Total number, maximum 9 (2 m x 2 m plot)
	Spaces for a fifth species:
75-76	Species Code No.
77-78	Height Class (if diameter class use 5-8 for Diameter Class 1-4).
79	"p" for Height Class 1 in 2 m x 2 m plot
80	Number in the height or diameter class, maximum 9 (in the 2 m x 2 m plot).

II-C <u>Seedbed Conditions</u>

<u>Columns</u>

1- 3	Strip No.
4- 6	Quadrat No. (see METHODS for sequence)
7- 8	Data type "S1" ("S2" if second sheet needed).
9-10	Year "4" for 1974, "5" for 1975, etc.
	Hereafter all records represent percentage coverage:
	P = < 1% coverage

(continued)

APPENDIX II (continued)

X = 1.0-4.9% coverage
1 = 5.0-14.9% coverage
2 = 15.0-24.9% coverage
3 = 25.0-34.9% coverage
4 = 35.0-44.9% coverage
5 = 45.0-54.9% coverage
6 = 55.0-64.9% coverage
7 = 65.0-74.9% coverage
8 = 75.0-84.9% coverage
9 = 85.0-94.9% coverage
C = 95.0-100% coverage

11 Total shrubs
12 Total graminoids (grasses, sedges)
13 Total broad-leaved herbs (include *Gaultheria, Linnaea*)
14 Total mosses (include liverworts) live and dead
15 Total mosses on wood (living or dead wood)
16 Total lichens (include *Peltigera*, lichens fallen from above).
17 Total lichens on wood (living or dead wood)
18 Total Feather Mosses (*Dicranum, Pleurozium, Ptilium, Hylocomium, Thuidium*) live and dead.
19 "Dead" feather mosses -- dried, browned, apparently dead
20 Total *Sphagnum* mosses (live and dead)
21 "Dead" *Sphagnum* mosses -- dried, browned, apparently dead
22 Total aquatic mosses (*Mnium, Drepanocladus*) in lows or puddles
23 Pioneer mosses
24 Algae
25 Burned wood and unrecognizable burned material
26 Tree trunks, large branches (≥ 10 cm diameter) on or above ground (logging or natural: include recent windfalls; if rotten place in #28).
27 Stumps and roots (natural or from cutting or scarification; if rotten place in #28).
28 Exposed rotten and decomposed wood (logs, stumps, branches, stems, bark - 1 cm).
29 "Slash" -- tops and branches elevated above ground (< 10 cm stems; if ≥, estimate in #26; natural + disturbance)
30 Average height of slash where it occurs (1 = 0-49 cm, 2 = 50-99 cm, 3 = 1-1.9 m, 4 = 2-2.9 m, 5 = ≥ 3 m)
31 Stems, wood pieces (1-10 cm) and bark *on* ground surface
32 Needles, fine twigs, (fine bark [1 cm] and cones on ground) (thin or thick) (logging or natural)
33 Broad-leaf litter (alder, aspen)
34 Exposed dark upland duff (F and FH layers), scraped or disturbed or exposed. Beneath feather mosses or broad-leaf litter.
(Rate exposed wood under appropriate category above.)

(continued)

35 Dark lowland muck or peat, exposed by tire churning or scarification. (Rate exposed wood under appropriate category above.)
36 *Sphagnum* peat, exposed as a result of scraping or pruning off of living layers.
37 Ah horizon and H horizon
38 Ae horizon
39 B and/or C horizon
40 Mineral soil mixed with humus or other debris
41 Mineral soil superimposed on humus
42 Throwmound of windfall, total area influenced
43 Total rock (whether from disturbance or not)
44 Total water (whether from disturbance or not)
45 Tire track, obvious print or rut
46 Percent tire track filled with water
47 Moose droppings (number of piles)
48 Bear droppings (number of piles)
49 Obvious logging skidway (yes = 1; no = blank)
50 Disturbance after cutting (machinery) (% quadrat disturbed)

<u>Relation of seedling to seedbed conditions</u>

<u>Columns</u>

51-52 Species Code Number
53-54 Number of individuals with SAME conditions in next four categories
55-56 Seedbed type (use column number for seedbed conditions indicated on "S1" Data Page, i.e., if seedbed is moss on wood, record 15)

<u>Special seedbed conditions</u>

<u>Columns</u>

57-58
1 - Micro-crevice or moist micro-depression, beside stump
2 - Same as above, beside log, branch or stem (1-10 cm)
3 - Ditto, beside a fine stem 1 cm drain
4 - Ditto, beside a cone on ground
5 - Ditto, beside a rock
6 - On thick, fine litter category (#32)
7 - On thin, fine litter category (#32)
8 - On sides or pushed up ridge of tire track
9 - In bottom of tire track
10 - The condition of seedling establishment was created by a windfall and throwmound

---

S1 Columns 23 and 50 first used in 1978 survey.

(continued)

59 Seedling origin -- leave blank for seedlings of seed origin, insert "1" for layers.

60 Degree of shading *for this set of individuals* of this species
- 1 - Exposed for most of the time to sun.
- 2 - Light shade by tree, light slash, log or boulder, and/or N-NE aspects. Sun hits seedling(s) most of the time.
- 3 - Intermediate shade tree, slash, log or boulder, and/or steep N-NE aspects, and/or class 3 open forest canopies. Sun hits seedling(s) about half of the time.
- 4 - Heavy shade from dense slash, log or stump, dense undergrowth and/or class 1 or 2 canopy shade. Sun spots, or short duration (few hours) of sun on seedling(s).
- 5 - Shade for most of the time. Sun may occasionally hit seedling(s).

61-70 Repeat the same information.

71-80 As in columns 51-60.
If second page is required:

Columns

1- 3 Stand No.
4- 6 Quadrat No.
7- 8 Data type S2
9-10 Year 4 = 1974, 5 = 1975, 6 = 1976.
11-12 Species Code Number
13-14 Number of individuals with same condition
15-16 Seedbed types
17-18 Special seedbed conditions as previously stated
19 Seedling origin blank for seedling of seed origin, 1 for layer origin
20 Degree of shading for this set of individuals of this species
21-30 Repeat as Columns 11-20.
31-40 Repeat

II-D Vegetation Data

Columns

1- 3 Stand No.
4- 6 Quadrat No.
7- 8 Data type ("V1")
9-10 Year
11 *Abies balsamea*
12 *Agropyron trachycaulum*
13 *Agrostis hyemale*
14 *Agrostis tenuis*
15 *Alnus crispa*
16 *Alnus rugosa*
17 *Amelanchier* spp.
18 *Anaphalis margaritacea*
19 *Anemone quinquefolia*
20 *Aralia hispida*

(continued)

APPENDIX II (continued)

21 *Aralia nudicaulis*
22 *Aster ciliolatus*
23
24 *Aster macrophyllus*
25 *Aster puniceus*
26 *Aulacomnium palustre*
27 *Betula glandulifera*
28 *Betula papyrifera*
29 *Bromus ciliatus*
30 *Calamagrostis candensis*
31 *Caltha palustris*
32 *Carex aenea*
33 *Carex aquatilis*
34 *Carex brunnescens*
35 *Carex crawfordii*
36 *Carex deflexa*
37 *Carex disperma*
38 *Carex gynocrates*
39 *Carex houghtonii*
40 *Carex intumescens*
41 *Carex leptalea*
42 *Carex paupercula*
43 *Carex tenuiflora*
44 *Carex trisperma*
45 *Carex vaginata*
46 *Chamaedaphne calyculata*
47 *Cinna latifolia*
48 *Cirsium muticum*
49 *Cladina stellaris* (= *C. alpestris*)
50 *Cladina mitis*
51 *Cladina rangiferina*
52 *Coptis trifolia*
53 *Cornus canadensis*
54 *Cornus stolonifera*
55 *Corydalis sempervirens*
56 *Dicranum polysetum*
57 *Diervilla lonicera*
58 *Dryopteris austriaca* (incl. var. *spinulosa*)
59 *Dryopteris cristata*
60 *Epigaea repens*
61 *Epilobium angustifolium*
62 *Epilobium glandulosum*
63 *Epilobium palustre*
64 *Equisetum arvense*
65 *Equisetum sylvaticum*
66 *Eriophorum angustifolium*
67 *Eriophorum spissum*
68 *Fragaria virginiana*
69 *Galium triflorum*
70 *Gaultheria hispidula*
71 *Geranium bicknelli*
72 *Geranium richardsonii*
73 *Geum allepicum*
74 *Geum macrophyllum*
75 *Glyceria canadensis*
76 *Glyceria striata*
77 *Goodyera oblongifolia*
78 *Goodyera repens*
79 *Gymnocarpium dryopteris*
80 *Habenaria hyperborea*

Columns (Sheet 2)

1- 3 Stand No.
4- 6 Quadrat No.
7- 8 Data type ("V2")
9-10 Year

11 *Hieracium* spp.
12 *Hylocomium splendens*
13 *Rhytidiadelphus triquetrus*
14 *Juncus brevicaudatus*
15 *Juncus vaseyi*
16 *Kalmia polifolia*
17 *Larix laricina*
18 *Ledum groenlandicum*
19 *Symphoricarpos albus*
20 *Linnaea borealis*
21 *Lonicera canadensis*
22
23 *Lonicera dioica*
24 *Lonicera hirsuta*
25 *Lonicera involucrata*
26 *Lonicera villosa*
27 *Lycopodium annotinum*
28 *Lycopodium clavatum*
29 *Lycopodium complanatum*
30 *Lycopodium obscurum*

(continued)

31 *Lycopodium tristachyum*
32 *Maianthemum canadense*
33 *Marchantia* spp.
34 *Melampyrum lineare*
35 *Mertensia paniculata*
36 *Mitella nuda*
37 *Mnium* spp.
38 *Oryzopsis asperifolia*
39 *Oryzopsis canadensis*
40 *Oryzopsis pungens*
41 *Peltigera* spp.
42 *Petasites frigidis*
43 *Petasites sagittatus*
44 *Picea glauca*
45 *Picea mariana*
46 *Pinus banksiana*
47 *Pleurozium schreberi*
48 *Poa* spp.
49 *Polygonum cilinode*
50 *Polytrichum commune*
51 *Polytrichum juniperinum*
52 *Polytrichum piliferum*
53 *Populus balsamifera*
54 *Populus tremuloides*
55 *Potentilla fruticosa*
56 *Potentilla norvegica*
57 *Prunus pensylvanica*
58 *Ptilium crista-castrensis*
59 *Ribes glandulosum*
60 *Ribes hirtellum*
61 *Rosa acicularis*
62 *Rubus hispidus*
63 *Rubus pubescens*
64 *Rubus strigosus*
65 *Salix* spp.
66
67 *Schizachne purpurascens*
68 *Scirpus cyperinus*
69 *Smilacina trifolia*
70 *Solidago canadensis*
71 *Solidago rugosa*
72 *Solidago uliginosa*
73 *Sorbus* spp.
74 *Sphagnum nemoreum* (= *S. capillaceum*)
75 *Sphagnum fuscum*
76 *Sphagnum magellanicum*
77 *Sphagnum squarrosum*
78 *Sphagnum wulfianum*
79 *Sphagnum angustifolium*
80 *Thuidium* spp.

<u>Columns</u> (Sheet 3)

1- 3 Stand No.
4- 6 Quadrat No.
7- 8 Data type ("V3")
9-10 Year
11 *Thuja occidentalis*
12 *Trientalis borealis*
13 *Typha latifolia*
14 *Vaccinium angustifolium*
15 *Vaccinium myrtilloides*
16 *Vaccinium oxycoccus*
17 *Viola* spp.
18 *Athyrium filix-femina*
19 *Listera cordata*
20 *Monotropa uniflora*
21 *Carex adusta*
22 *Clintonia borealis*
23 *Prunus virginiana*
24 *Viburnum edule*
25 *Pohlia nutans*
26 *Ribes triste*
27 *Sphagnum girgensohnii*
28 *Comandra livida*
29 *Cypripedium acaule*
30 *Bazzania trilobata*
31 *Acer spicatum*
32 *Botrychium virginianum*
33 *Habenaria obtusata*
34 *Streptopus roseus*
35 *Sphagnum compactum*
36 *Corallorhiza trifida*
37 *Corallorhiza maculata*
38 *Pyrola virens*
39 *Pyrola secunda*
40 *Moneses uniflora*

(continued)

41	*Carex leptonervia*	61	*Carex canescens*
42	*Cladonia coniocraea*	62	*Pyrola minor*
43	*Carex castanea*	63	*Sphagnum subsecundum*
44	*Thelypteris phegopteris*	64	*Carex pauciflora*
45	*Fraxinus nigra*	65	*Myrica gale*
46	*Circaea alpina*	66	*Carex lasiocarpa*
47		67	*Dryopteris noveboracensis*
48	*Osmunda claytoniana*	68	*Prunus virginiana*
49	*Actaea rubra*	69	*Corylus cornuta*
50	*Lonicera oblongifolia*	70	*Carex interior*
51	*Equisetum scirpoides*	71	*Equisetum pratense*
52	*Ptilidium* spp.	72	*Cladonia* spp. (Crustose spp.)
53	*Habenaria orbiculata*	73	*Cladina uncialis*
54	*Taxus canadensis*	74	*Stellaria* spp.
55	*Ranunculus lapponicus*	75	*Menyanthes trifoliata*
56	*Sphagnum warnstorfii*	76	*Drepanocladus* spp.
57	*Drosera rotundifolia*	77	*Cystopteris fragilis*
58	*Rhamnus alnifolia*	78	*Heracleum lanatum*
59	*Cladina arbuscula*	79	
60	*Pyrola elliptica*	80	*Dicranum* spp. (other than *D. polysetum*)

II-E <u>Moose Browse</u>

<u>Columns</u>

1- 3	Stand Number
4- 6	Quadrat Number
7- 8	Data Type "M1"
9-10	Year ("6" for 1976, "7" for 1977, etc.)
11-12	Species Number
13-14	Number of stems (0.5 m high-2.4 cm DBH) present on 2 m x 2 m plot
15-16	Number of Stems Browsed
17-18	Number of Stems Sheared
19-26	Next Species (repeat 11-18 above)
27-34	Next Species
35-42	Etc.

Species Number	Species Name	Common Name
1	*Picea mariana*	Black Spruce
2	*Picea glauca*	White Spruce
3	*Pinus banksiana*	Jack Pine
4	*Abies balsamea*	Balsam Fir
5	*Thuja occidentalis*	Cedar
6	*Larix laricina*	Tamarack
7	*Populus tremuloides*	Trembling Aspen

APPENDIX II (concluded)

Species Number	Species Name	Common Name
8	*Betula papyrifera*	White Birch
9	*Populus balsamifera*	Balsam Poplar
10	*Fraxinus nigra*	Black Ash
11	*Acer pensylvanicum*	Striped Maple
12	*Acer spicatum*	Mountain Maple
13	*Alnus crispa*	Green Alder
14	*Alnus rugosa*	Speckled Alder
15	*Amelanchier* spp.	Service Berries
16	*Betula glandulosa* var. *glandulifera*	Dwarf Birch
17	*Cornus stolonifera*	Red Osier Dogwood
18	*Corylus cornuta*	Beaked Hazel
19	*Diervilla lonicera*	Bush Honeysuckle
20	*Lonicera canadensis*	Fly Honeysuckle
21	*Lonicera dioica*	Wild Honeysuckle
22	*Lonicera hirsuta*	Hairy Honeysuckle
23	*Lonicera involucrata*	Black Twinberry
24	*Lonicera oblongifolia*	Swamp Fly Honeysuckle
25	*Lonicera villosa*	Mountain Fly Honeysuckle
26	*Prunus pensylvanica*	Pin Cherry
27	*Prunus virginiana*	Choke Cherry
28	*Ribes glandulosum*	Skunk Currant
29	*Ribes hirtellum*	Wild Gooseberry
30	*Rosa acicularis*	Wild Rose
31	*Rubus hispidus*	Dewberry
32	*Rubus pubescens*	Dwarf Blackberry
33	*Rubus strigosus*	Red Raspberry
34	*Salix bebbiana*	Beaked Willow
35	*Salix petiolaris*	[Willow]
36	*Salix* spp.	[Willows]
37	*Sambucus pubens*	Red-berried Elder
38	*Sorbus* spp.	Mountain Ash
39	*Taxus canadensis*	Ground Hemlock
40	*Viburnum cassinoides*	Wild Raisin
41	*Viburnum edule*	Squashberry
42	*Viburnum trifolia*	High-bush Cranberry
43	*Ledum groenlandicum*	Labrador Tea
44	*Rhamus alnifolia*	Alderleaf Buckthorn
45	*Taxus canadensis*	Ground Hemlock

Stems browsed by moose and deer are broken off. These can be separated easily from stems browsed by hares and rodents as these animals cut the stem. Hare browsing, which by position is most likely to be confused with moose, has a characteristic smooth angular surface, not broken.