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**Contents**



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# SELECTION CUTTING IN RED SPRUCE

## *A Comparison of Methods Establishment Report*

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## Abstract

A mature two-cohort forest of red spruce provided the initial setting for this long-term research into unevenaged silviculture. The 32 ha trial was established in 2000, comparing two replications of single tree selection, group selection, clearcut, and untreated natural forest development. The single tree method employed basal area retention guides to direct the treatment, while the group selection was applied on a land area basis. Measurements of permanent sample plots at five year periods will track merchantable tree growth, stand quality, tree regeneration, vegetation change, deadwood dynamics, and soil compaction.

This establishment report fully describes the trial before and after initial treatment, discusses the silvicultural methods used along with guidelines for future treatments, and presents a brief summary of treatment responses measured up to 8 years after the initial intervention.

# Big Indian Lake Selection Cutting Trial


Aerial view of selection cutting trial looking southeast - taken April 1, 2004 .

# INTRODUCTION

This long-term research trial was established in 2000 to study the response of red spruce *(Picea rubens* Sarg.) forests to two methods of selection harvesting. The trial will provide comparison of these methods to traditional clearcutting practices and to natural forest development. In the first year a preparatory cut was carried out to establish extraction trails and remove a cohort of large residual red spruce. This was followed by another harvest in 2004 to treatment specifications. The trial will continue with periodic harvests and silvicultural tending by following a long-term treatment guide. A permanent sampling system will monitor changes and treatment effects on a broad range of parameters related to timber growth, regeneration, and ecosystem conditions. This establishment report describes all aspects of the trial and presents summaries from before and after treatment.

Selection harvesting is an uneven-aged management system that may emulate natural "gap replacement" stand development patterns (Chambers et al. 1999, Kelty et al. 2003, Fraver et al. 2002). It is often proposed as an alternative to clearcutting and is recommended where the ecological and aesthetic value of intact forest cover is desired (Doyon et al. 2005). Selection harvesting can help maintain habitat for plant and animal species that require interior, late seral stand conditions (Battles et al. 2001). Retaining forest cover in harvested areas can be beneficial for water quality and storage (Lewis 1998), as well as aesthetics and recreation value (Silvennoinen et al. 2002). By maintaining a number of age and diameter classes, continuous regeneration and growth can occur and seed production will be ongoing within the stand (Sullivan and Sullivan 2001). Where the management goal is to provide stands that can contribute long-term ecological values, the selection system should make provision for the development of large snags and coarse woody debris, species diversity, and structural diversity, since the repeated harvest entries associated with selection cutting has potential to sanitize sites and eliminate important ecological components.

Selection cutting is a challenging practice that must simultaneously manage multiple features including, harvest of crop trees, quality of retained trees, development of understories, and establishment of regeneration. An inherent risk exists in continuously retaining a portion of financially mature trees, which may suffer losses between harvest cycles. Through a scientific understanding of forest response to different harvest treatments, effective selection cutting techniques can be developed to assist operational decisions at the stand level, as well as strategic modelling at a landscape level.

## Partnerships

This study is conducted as a joint partnership between Bowater Mersey Paper Company Limited and the Nova Scotia Department of Natural Resources. Bowater Mersey Paper Company is the landowner and manager responsible for harvesting and tending operations. Professional foresters and ecologists with the Department of Natural Resources are responsible for the research and trial design, development of prescriptions, operational layout and marking, maintenance of a permanent forest sampling system, data analysis, and reporting. Other participants may become involved to undertake additional research related to the goals and objectives of the project.

## RESEARCH GOALS AND OBJECTIVES

The goal of this research is to develop a scientific understanding of forest response to selection cutting that will lead to effective selection management techniques and guidelines. It is designed to study treatment effects on growth and yield, tree quality, regeneration, age class structure, blowdown, and a range of ecological parameters including coarse woody debris, structural diversity, plant species diversity and dynamics of large retained legacy trees. The trial has a longterm outlook (75+ years) that will include periodic treatments and regular measurement cycles. It will involve management manipulations targeting basal area retention, light availability, species selection, and quality improvement. Three different forest management systems and an untreated control are being evaluated using two replications:

- Single tree selection
- Group selection
- Clearcut with tending
- Natural stand development with no intervention (Control)

### Management Implications

- Development of silvicultural guidelines for selection cutting.
- Quantification of treatment effects on growth and yield, and stand quality.
- Capability to model forest growth and other dynamic aspects of forest structure.
- Identification of ecological factors affecting biodiversity.
- Identification of treatment risks and constraints, such as blowdown, species suitability, and machine operability.
- Ability to extrapolate the extensive knowledge that exists for even-aged management to predict and model selection harvesting responses (e.g. the existing evenaged growth models developed over several decades of research could potentially be used to predict selection harvesting growth using the comparative results of this study).

### Treatment Objectives

#### *Selection Treatments*

- Develop an uneven-aged stand containing several cohorts and size classes.
- Sustain a continuous, healthy canopy of mature trees.
- Encourage continuous regeneration that favors climax species.
- Maintain or increase stand quality and the productive capacity to produce timber.
- Maintain ecological structures and functions that support biodiversity
- Control blowdown risk and limit losses to mortality.

### *Clearcut Treatment*

- Follow traditional even-aged management practices employed by Bowater Mersey Paper Company for naturally regenerating stands, in order to provide a realistic comparison of "current" practices.
- Optimize growth and yield through competition and density control using standard weeding, precommercial thinning, and commercial thinning treatments.
- Promote high stocking of red spruce regeneration and other commercially valuable species such as yellow birch and white pine (see Appendix I for scientific names of species).

### *Natural Stand Development*

- Monitor natural stand development through the expected transition from mature to old growth for experimental control and comparison.
- Replicates of unmanaged natural stand development will provide benchmark areas for assessing and comparing treatment effects on forest aspects important to ecosystem restoration and maintenance, such as productivity, structural diversity, biodiversity, disturbance dynamics, deadwood, and soil compaction.

## SITE DESCRIPTION

The trial is situated in Hants County, east of Big Indian Lake, on land owned and managed by Bowater Mersey Paper Company Ltd. (Figure 1). It is located in the St. Margaret's Bay ecodistrict on a "well drained, coarse textured, knolls and knobs (WMKK)" ecosection type (Neily et al. 2003). The dominant natural disturbance regime for this ecosection is described as "infrequent stand initiation", with wind as the primary agent. On the zonal sites forest succession is predicted to progress towards climatic climax stands of red spruce, eastern hemlock, and white pine. The Forest Ecosystem Classification for Western Nova Scotia (Neily et al. 2006), provides the following descriptions of the ecotypes, vegetation types, and soil types that were recorded within the trial:

- The site is primarily an ecotype 5 "Fresh-Medium Conifer", with some areas of ecotype 6 "Moist-Medium Mixedwood".
- The vegetation type W16 (Red spruce, Schreber's moss) predominates, occupying the "fresh-medium" ecotype 5 sites. This forest community is typically characterized by a red spruce, red maple, and balsam fir overstory, with an understory of balsam fir and red spruce regeneration. A W17 vegetation type (Red spruce - Balsam fir, stair-step moss) occurs less commonly, occupying the "moist-medium" ecotype 6 sites. This is similar to W16, but with a greater abundance of yellow birch and balsam fir. Both vegetation types support a forest floor cover of predominantly Schreber's moss, stair-step moss, and three-lobed bazzania, with sparse shrub and herb cover.

## Location of Big Indian Lake Selection Cutting Trial

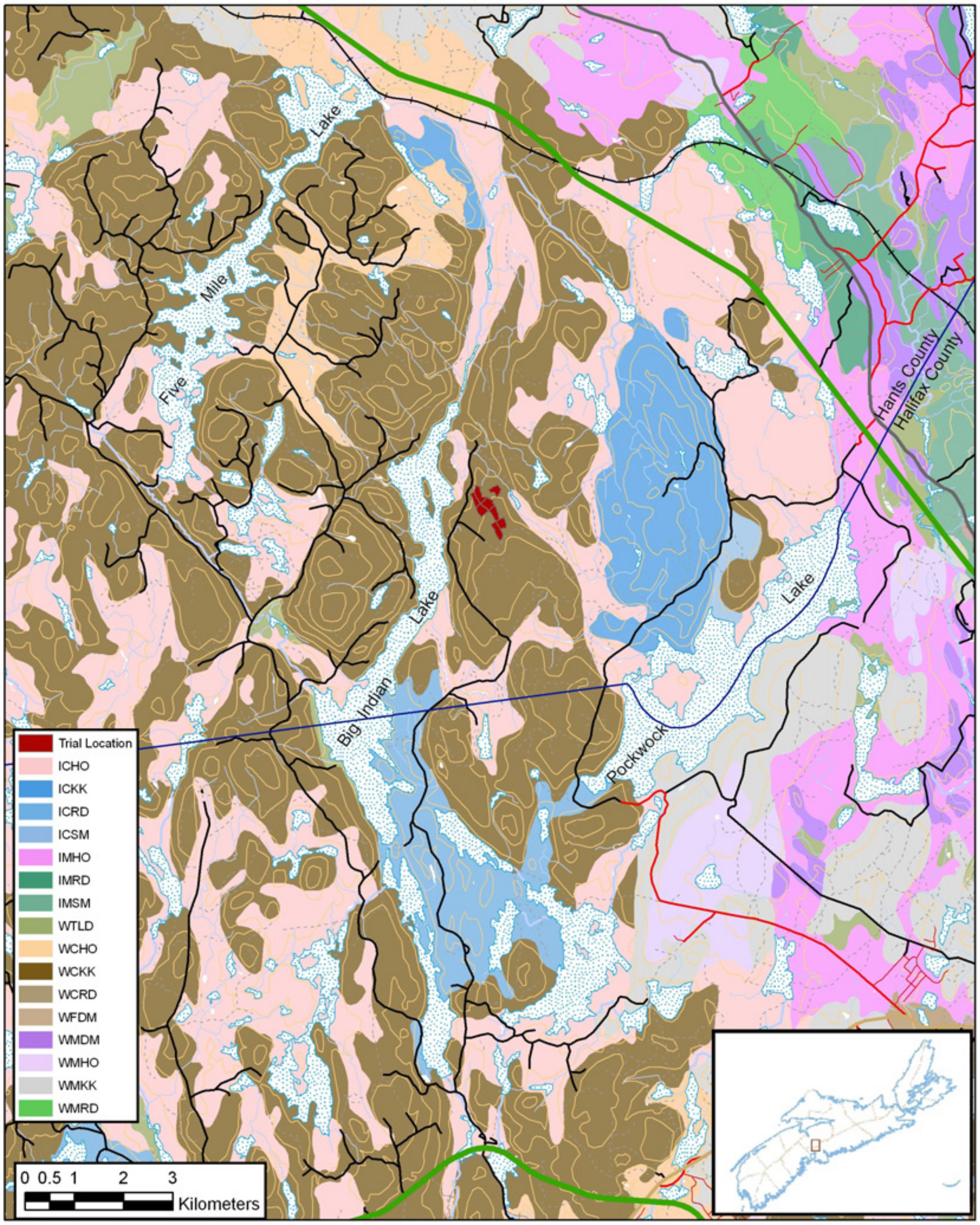



**Figure 1.** Location of Big Indian Lake selection cutting trial, overlaid on the ecosection layer of the Ecological Land Classification for Nova Scotia (Neily et al. 2003)

- Six soil types were observed, all from the ST2 and ST3 groups. These can be collectively described as fresh to moist, medium to coarse textured soils, derived from granitic parent material (Keys, 2007). Granite boulders and outcrop are common on the landscape and soils are often shallow and stony. These factors may limit tree stocking and machine operability in some areas. Appendix II contains a complete list of soil types found at the site.

A summary of the stand conditions based on permanent sample plot measurements made prior to the initial treatment in 2000 indicates that the trial site is uniformly dominated by red spruce forests (Table1). Balsam fir, red maple and yellow birch are also common but in much smaller quantities. The site shows historical signs of fire (charcoal was found at the forest floor/mineral soil interface) and blowdown (mound and pit). It appears to have two primary age classes, a residual component of large red spruce approximately 140 years of age which are distributed among a mixed red spruce, balsam fir, red maple, aspen stand approximately 90 years of age. This suggests a partial disturbance of some type in the early 1900's. The stand, if left undisturbed, would theoretically enter old growth stages within the next 25-50 years (Stewart et al. 2003).

**Table 1.** Summary of pre-harvest stand conditions for merchantable sized trees > 9.0 cm dbh (data from permanent sample plots established and measured in 2000).

| Block | Treatment type | Area (ha) | Species composition[1] | Average diameter (cm) | Average height (m) | Stems /ha | Ba/ha ($m^2$) | Total Volume ($m^3$) | Merch[2] Volume ($m^3$) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Control | 3.8 | 8RS 1RM 1YB BF LTA | 17.4 | 17.7 | 1897 | 49.8 | 361 | 330 |
| 6 | Control | 3.6 | 8RS 2RM BF YB WB | 19.2 | 17.5 | 1394 | 42.3 | 323 | 298 |
| 2 | Single tree | 3.9 | 7RS 1BF 1RM 1YB SM WB WP LTA | 19.2 | 17.4 | 1303 | 46.0 | 348 | 318 |
| 4 | Single tree | 4.2 | 7RS 2RM 1BF YB SM LTA | 17.1 | 18.4 | 1609 | 39.9 | 303 | 279 |
| 5 | Group | 4.2 | 8RS 1RM 1BF YB WS BS WP | 19.5 | 16.4 | 1269 | 42.3 | 305 | 278 |
| 7 | Group | 4.8 | 7RS 2RM YB BF LTA WB WS TA BE | 19.9 | 17.2 | 1206 | 36.3 | 273 | 252 |
| 3 | Clearcut | 3.4 | 8RS 1RM 1BF YB | 19.7 | 18.0 | 1044 | 39.7 | 294 | 271 |
| 8 | Clearcut | 4.3 | 8RS 1YB 1RM BF WB SM | 18.9 | 16.8 | 1434 | 43.7 | 328 | 299 |
| **Total** | | **32.2** | **8RS 1RM 1BF YB SM WB LTA WS WP BS TA BE** | **18.8** | **17.4** | **1395** | **42.5** | **317** | **291** |

1 Species codes: RS - Red spruce, RM -Red maple, BF - Balsam fir, YB - Yellow birch, WB - White birch, SM-Sugar maple, WP - White pine, BS - Black spruce, WS-White spruce, BE - Beech, TA - Trembling aspen, LTA - Large-toothed aspen
Numbers represent percent composition of basal area.

2 Merchantable volume calculated using metric Diameter-Height Ratio equations (Honer et al. 1983).

## METHODS

### Layout and Design

The 32 hectare trial site was divided into eight blocks of approximately 4 hectares (Figure 2). Each block was randomly assigned one of four treatments (Table 1), creating two replications of each treatment in a completely randomized design. A system of sample plots was established:

- Eight "multiplot permanent plots" (MPP) of 0.1 ha size were established in each block providing a total of 64 in the full trial (Figure 3). All commercial sized (> 9.0 cm dbh) live and dead trees were measured in each plot prior to and following treatments.
- Within each MPP sample plot 3 subplots were established to measure vegetation, tree regeneration, site conditions, and light availability.
- A 54 m triangular line transect was established in each MPP plot to measure coarse woody debris.
- Within the four selection cut treatment blocks 12 large legacy trees were selected for permanent retention. These were numbered and measured (Appendix III).
- Temporary soil compaction plots were established post harvest as part of another research trial (Keys, 2005).

All plots are located on sites capable of full stocking. Plots will be measured on a 5 year cycle, with pre and post harvest measurements made at all harvest cycles. Post harvest measurements update the pre harvest sample and only measure parameters that change due to treatment (ie. tree status, regeneration stocking, vegetation cover, coarse woody debris).

Data is stored in the Forest Research Inventory System (FRIS). The structure for all plot and subplot databases is outlined in Appendix IV.

#### *Multiplot Permanent Plots (MPP)*

Circular plots with a radius of 11.28m (0.04ha) were established to measure merchantable sized trees (>9.0 cm dbh) (Figure 3). Plot centers were marked by a metal survey stake and cap displaying the block and plot numbers. UTM coordinates of plot centers are listed in Appendix V. Within each plot all merchantable sized live and dead trees were numbered with a metal tag at stump and painted number on stem. A line was painted around the circumference of each tree at breast height for dbh measurements. Ingrowth will be numbered sequentially as it occurs. The following was recorded for each numbered tree:

- Species
- Status (living, cut, dead standing, or dead down)
- Dbh (mm)
- Dominance (dominant, co-dominant, intermediate or suppressed)
- Crop potential (not a crop tree, crop tree, likely to die, poor quality, or poor growth potential)

# Layout of Big Indian Lake Selection Cutting Trial

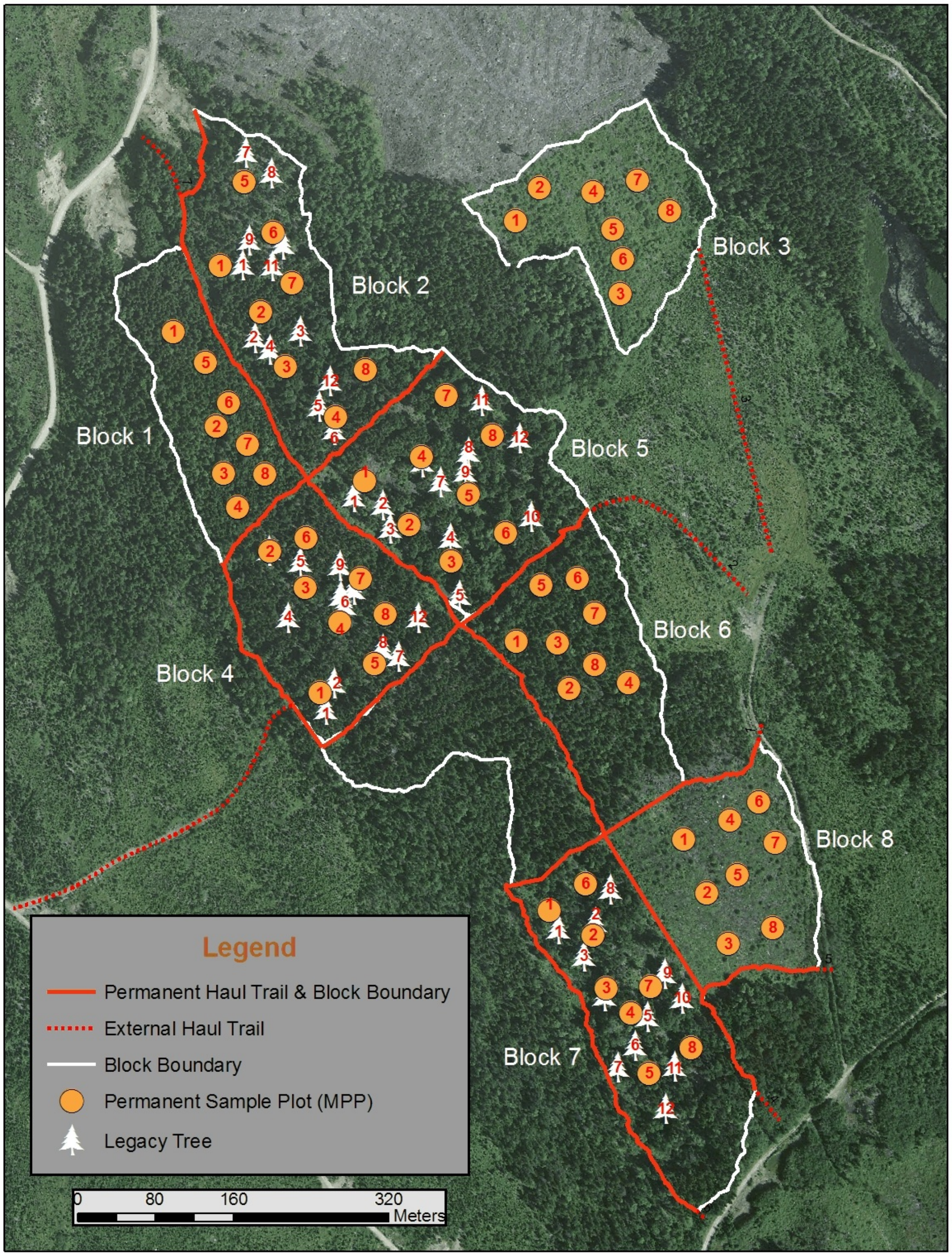



**Figure 2.** Layout of Big Indian Lake selection cutting trial (2007 aerial photography).

## Sample Plot Diagram

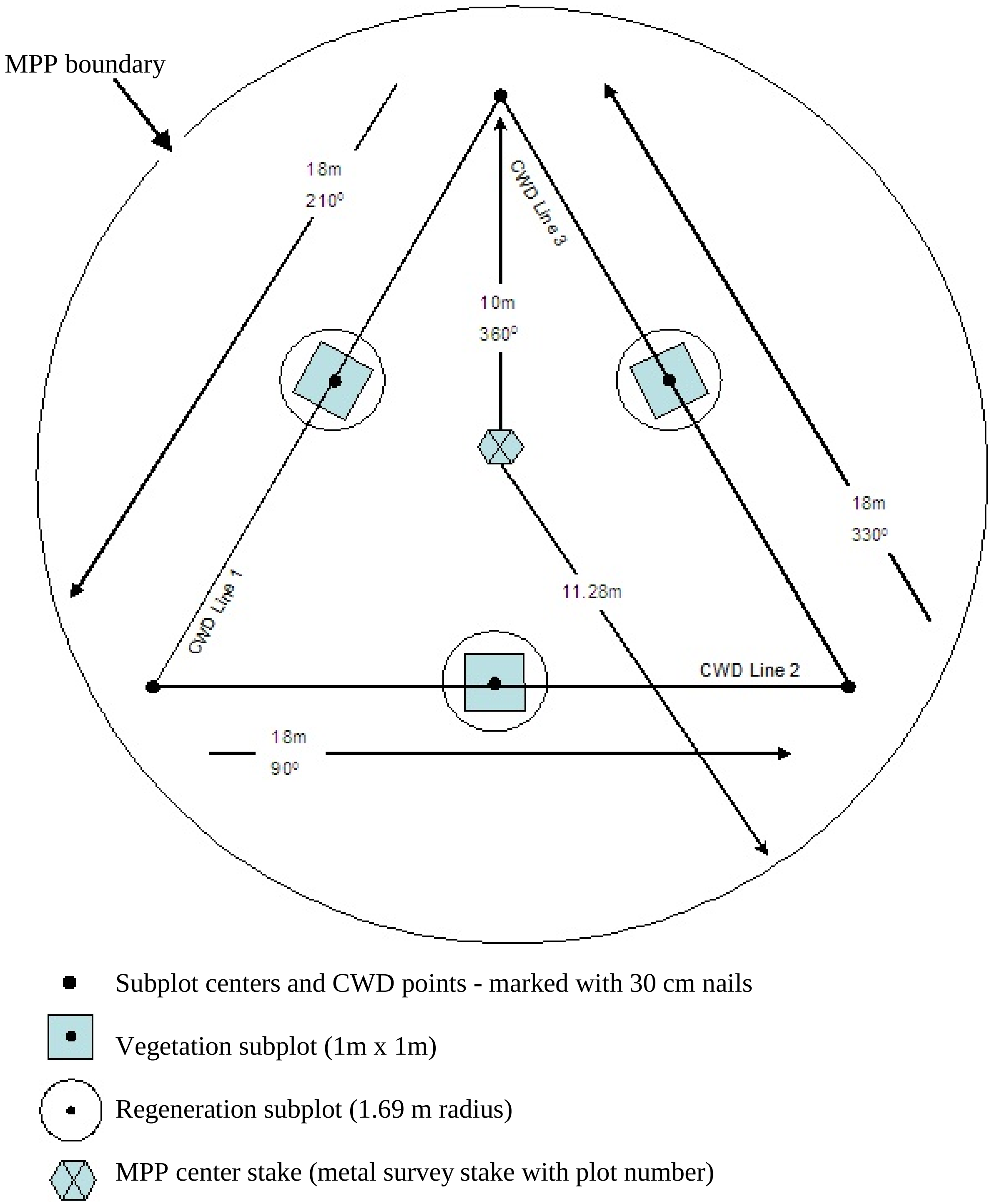



**Figure 3.** Sample plot design showing multiplot permanent plot (MPP) layout with nested coarse woody debris, vegetation and regeneration subplots.

- Number of stems (for coppice)
- Tree origin (seed or coppice)
- Height (dm) and crown length (dm) of two live trees in each plot. The full height range was covered collectively across the 8 plots in each block.
- Height (dm) of all snags (standing dead) to a minimum top diameter of 10cm.
- Top diameter (cm) of broken snags if greater than 10 cm (visual estimate).
- Decay class of snags (4 classes, see Appendix VI)
- Age (stump) was determined from a sample of cut trees
- Soil type and stoniness class were assessed and recorded in each plot
- Legacy tree measurements were all recorded in a legacy tree file associated with the MPP database. This record consists of species, dbh, height, status, decay class, and damage.

All parameters were measured prior to treatment. Following the preparation harvest in 2000 tree status was re-evaluated (ie living, dead or cut) in the treated blocks (2,4,5 and 7) in order to quantify the harvest operation. This data was stored as year 2000B. In 2003 and following the final harvest in 2004, tree status was again reassessed in blocks 2, 4, 5, 7. In 2007 snags in all blocks were assessed for status and decay class, as well as height and top diameter to a minimum10 cm top (so that snag volumes could be calculated and compared to pre-treatment measures made in 2000). A full re-measurement was made in June 2008.

***Vegetation Sub Plots (VEG)***

Subplots for tracking vegetation and tree regeneration were permanently established by setting 30 cm galvanized spikes at plot center, with heads at ground level. These are traceable using a metal detector, to allow plots to be found after harvesting. Seedlings, saplings, and non-tree vegetation were measured using different sized subplots, all of which center on the galvanized spikes.

- a 1m x 1m plot was used in 2000 (prior to treatment) to measure vegetation cover (%) and the density of trees less than 130 cm in height, as follows:

- density of tree seedlings by species and height class (1-5 cm, 6-30 cm, 31-130 cm) (Appendix VII).
- percent cover of vegetation (excluding trees) by species and height class (1-5 cm, 6-30 cm, 31-130 cm) (Appendix VIII).

- a circular plot of 1.69 m radius (9 $m^2$) was used in 2000 (prior to treatment) and in 2006 (2 years post-treatment) to assess the stocking and density of unmerchantable sized trees ($\leq$ 9.0 cm dbh), as follows:

- in 2000 the density and stocking of trees over 130 cm in height was recorded by species and height class (131-400 cm, 401-700 cm, >700 cm)
- in 2006 the stocking of trees was recorded in each of the six height classes (1-5 cm,

6-30 cm, 31-130 cm, 131-400 cm, 401-700 cm, >700 cm) by species, height class, and distance class from plot center (<101 cm, 102-134 cm, 135-169 cm). Distance classes provide variable plot sizes of 3.2 $m^2$, 5.6 $m^2$, 9 $m^2$, which enables stocking to be calculated at tree spacings of 1.8 m (3000 stems/ha), 2.4 m (1800 stems/ha), 3.0 m (1100 stems/ha).

- attributes including micro topography, relief, soil type, drainage, site limitations, percent of plot on haul trail (post harvest only) (Appendix II)

### *Coarse Woody Debris Plots (CWD)*

Triangular shaped line transects, measuring 18m on a side, were established to measure coarse woody debris (Figure 3). The corners of the triangles were permanently marked with 30 cm galvanized spikes. This is similar marking to the vegetation subplots, which are located at the mid point of each transect line.

Downed dead wood was recorded if the diameter at line intersect was > 9.0 cm and pieces were leaning at $\leq 45^{O}$ from vertical. Coarse woody debris was measured prior to treatment in 2000 and again in 2006. The following data was recorded and stored in FRIS under CWD:

- species
- diameter class (2 cm)
- decay class (Appendix VI)
- slope of line (if > 15 percent)
- slope of piece (if > 15 degrees)

### *Soil Compaction*

This trial site was included as part of a soil compaction study by Keys (2005). Samples were taken from untraveled control areas as well as on temporary extraction trails with moderate traffic (3-7 harvest machine passes) and permanent haul trails with heavy traffic (8+ harvest machine passes). Thirty samples were taken from control and heavy traffic areas. In moderate traffic areas 30 samples were taken from both the center of the extraction trail and the wheel track. Samples were taken at 1 m intervals on haul trails to a depth of 10 cm using a 5 cm diameter soil corer. Soil bulk density was used to determine the level of compaction.

## Operations

### *Harvest*

The harvest took place in two stages, a preparatory cut during the fall and winter of 2000, followed by a final harvest in January 2004. Bowater Mersey Paper Company contractor, "Looke Can-cut", carried out both operations using Timberjack 1270 single-grip harvesters and Timberjack 1210 forwarder. During the preparation harvest, a permanent extraction trail was established though the center of the site and between block boundaries, effectively dividing the trial into recognizable treatment blocks while providing good access throughout

(Figure 2). At this time blocks three and eight were clearcut. Within the selection treatment blocks access was established by cutting 4 meter wide parallel trails on 24 meter centers. These temporary access trails are expected to regenerate naturally and contribute fully to the growing area of the treatment blocks. Temporary trail area represented 13 percent to 17 percent of treatment block area on the ground (Table 2), however some of this growing space is occupied at the tree canopy level. During the preparatory cut poor quality stems were removed as encountered and all large spruce trees greater than 40 cm in diameter were harvested with the exception of 12 preselected legacy trees in each block.

The trial site was left to stabilize for four years before completing the final single tree and group selection treatments. The single tree harvest was guided by a residual basal area target of 23 $m^2$/ha. Harvesting was controlled by marking the trees for cutting in the MPP's, thus providing the contractor with frequent examples for training and calibration as he moved through the rest of the treatment blocks. In the group selection blocks an area based target of 20 percent removal was used. Patches were marked and cut out between extraction trails to create openings 14m x 28m (approx. 400 $m^2$). Patch locations were subjectively chosen to favour future stand development by harvesting lower stocked, overmature, or blowdown susceptible areas with the least growth potential. In order to ensure that the harvest openings were well distributed throughout the stand a prescribed number of patches per extraction trail was calculated based on total trail length (2/trail in block 7; 3/trail in block 5). Effort was made to retain small saplings in the cut patches.

**Table 2.** Size and number of temporary extraction trails established during the 2000 preparation harvest to access treatment blocks.

| Block | Size (ha) | Number of Trails[1] | Trail Width (m) | Trail Spacing Between Centers (m) | Trail Length (m) | | Trail Area[2] | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Average | Total | Hectares | Percent of Treatment Block |
| 2 | 3.9 | 13.5 | 4 | 24 | 115 | 1550 | .62 | 16 |
| 4 | 4.2 | 10 | 4 | 24 | 155 | 1550 | .62 | 15 |
| 5 | 4.2 | 10 | 4 | 24 | 180 | 1800 | .72 | 17 |
| 7 | 4.8 | 14.5 | 4 | 24 | 105 | 1550 | .62 | 13 |

1 Half trails shared with neighbouring blocks (1 in block 2 & 7; 2 in blocks 4 & 5) are denoted as .5

2 Some of the overhead trail area is occupied by tree canopy, thus actual growing space impact may be somewhat less than indicated.

### *Legacy Retention*

Prior to the initial treatment in the four selection treatment blocks, twelve of the largest trees (ten red spruce and two other) were systematically chosen from the oldest age class to be retained as permanent legacy trees (Figure 2)(Appendix III). Large "wolf" trees were included in the legacy tree selections to maintain some structural diversity within the treatment blocks. As these trees die they will be left on site to create large snags and coarse woody debris and replacements will be chosen prior to each harvest cycle in order to maintain 12 large living legacy trees in each selection treatment block.

### *Tending*

A common practice used on regenerating Bowater Mersey Paper Company harvesting blocks is the application of herbicides to reduce broadleaf competition on softwood crop tree species. In September 2006, 6 growing seasons after clearcut, the herbicide Vision® (glyphosate) was applied to Block 3 at a rate of 5.3 l/ha using a helicopter.
In September 2008, a similar treatment was applied to Block 8, using 2.75 l/ha of a new glyphosate formulation, VisionMax™.

## Prescriptions

### *Single Selection Method*

The prescription for the single tree selection relies on basal area to manage stocking levels and guide harvesting cycles. The long-term goal is to develop full stocking, distributed across several cohorts occupying a range of height strata. The basal area guidelines were developed using normal yield table growth projections for even-aged stands to estimate the merchantable sized (>9.0 cm dbh) basal area of different aged cohorts proportioned within a fully stocked multi-cohort stand (NSDLF, 1990). Table 3 illustrates the basis for the guideline, which assumes a 75 year rotation with average harvest cycles of 15 years. This could potentially produce 5 cohorts, each occupying 20 percent of growing space. A harvest will be triggered each time stand basal area returns to the projected fully stocked level (33 $m^2$/ha). The harvest will consist of removing a basal area equivalent to the oldest cohort (10 $m^2$/ha), thus reducing the post harvest residual basal area to 23 $m^2$/ha. Harvest selections were guided by the objectives of improving timber quality, optimizing growth and yield, and sustaining important ecological attributes (Table 4).

**Table 3.** Normal yield table estimates of merchantable sized basal area (> 9.0 cm dbh) in fully stocked softwood stands (LC5) containing 5 cohorts at 15 year age intervals, each occupying 20 percent stocking (NSDLF, 1990).

| Cohort Age (Years) | Basal Area at 20% of full stocking ($m^2$/ha) |
|---|---|
| 15 | 0.0 |
| 30 | 4.6 |
| 45 | 8.0 |
| 60 | 9.7 |
| 75 | 10.5 |
| **Total** | **32.8** |

**Table 4.** Tree selection guide ranked in descending order.

| Type | Reason/Description |
|---|---|
| **Remove** | |
| Temporary access trails | 24 m centers, 3 - 4 m width, relatively straight |
| All large spruce (> 40 cm dbh) | Financially mature; large tops pose hazard to future regen |
| Impending Mortality | Capture future losses due to current poor health or likely mortality |
| Poor form/species | Quality improvement / balsam fir, aspen, white birch, red maple, diseased beech |
| Competing stems/spacing | Improve growth |
| Crop trees | A diameter limit was calculated to help identify potential “crop” red spruce for removal during the final harvest:<br>BA Crop = BA Prescribed Harvest - BA poor trees (harvest priority)<br>Diameter limit = BA Crop allocated to the largest diameter red spruce |
| **Retain** | |
| Preferred tolerant & intermediate crop species | Red spruce, yellow birch |
| Preferred uncommon crop species | Sugar maple, white pine, disease free beech |
| Small trees with release potential | Future growth, young cohorts |
| Dying trees with low economic value | Most mature red maple and aspen were observed to have shoe string root rot infection (*Armillariella mellea*) with many dead or dying. Their ecological value may exceed the economic potential; competitive effects are declining; and sprouting may be reduced if stems are not cut. Future measurements will determine if the retained red maple and aspen die out, as expected. Potential may exist for the fungus to infect the spruce crop. |

### *Group Selection Method*

Group selection was conducted primarily on an area basis and as such required much less decision making and direction than the single tree selection. As with the single tree operation, the initial cut established access trails on 24 m centers and harvested all spruce trees larger than 40 cm dbh (except the legacies), as these were considered financially mature and their large crowns were deemed a potential hazard to future understories.

The final area based prescription was developed on an anticipated rotation of 75 years, with 5 cutting cycles spaced approximately 15 years apart (similar to the single tree cycles). Thus each cutting cycle should target the removal of 20 percent of stand area, distributed in small patches. For this initial treatment strips 14 m wide were cut out between extraction trails to create 14 m x 20 m patches (14 m x 28 m if the full extraction trail width is included). In both trial blocks, 29 patches were harvested. An equal number of patches were harvested along each extraction trail to ensure a good distribution throughout the stand (2/trail in block 7; 3/trail in block 5). The exact location of each patch was subjectively chosen to favour future stand development by harvesting lower stocked, overmature, or blowdown susceptible areas with the least growth potential.

### *Clearcut Method*

The clearcut treatments were conducted during the first cutting phase in fall 2000. All standing trees were cut and the merchantable wood was removed to roadside. The areas were then left to naturally regenerate, which is normal practice for this area and usually produces a high stocking of commercial species within five years (Stewart and Quigley, 2000). These areas will be managed to accurately reflect Bowater's normal intensive management silviculture for naturally regenerating red spruce. The clearcut blocks are surrounded by other clearcuts of similar age ( + - 5 yrs) and will follow practices employed on those sites. This is expected to include chemical weeding during the first ten years, followed by pre-commercial thinning (PCT). Once the stands reach merchantable size traditional harvest techniques will be employed according to the practices of the day, which may include commercial thinning, shelterwood, and clearcut. Management and monitoring of these blocks is expected to continue for the full length of the trial, which may exceed a full harvest rotation.

### *Untreated Control*

No harvesting or silvicultural activity will take place in the control blocks. These areas will develop naturally and be monitored and compared to treatment blocks for ecological features, biodiversity, disturbance processes, and growth patterns. These areas are expected to reach an old growth stage of development within the next 25 to 50 years.

# RESULTS

## Treatment Effects on Merchantable Sized Live Trees (from MPP database)

### *Volume*

Blocks 3 and 8 were clearcut in the fall of 2000, producing an average of 285m$^3$/ha of merchantable wood (Table 5, Figure 4 ).

A preparation cut in the single tree selection blocks 2 and 4 was carried out in 2000 to establish temporary extraction trails and harvest large "super canopy" red spruce (> 40 cm dbh). This removed 27 percent of the merchantable volume, producing 65 m$^3$/ha and 96 m$^3$/ha from these blocks, respectively (Figure 4). The final harvest to treatment specifications was completed in 2004 and produced an additional 111 m$^3$/ha and 85 m$^3$/ha from blocks 2 and 4, respectively. Overall, 60 percent of the initial volume was removed in the single tree harvests, yielding an average 178 m$^3$/ha and retaining 120 m$^3$/ha standing.
In group selection blocks 5 and 7 the preparation harvest removed 22 percent of merchantable volume producing 56 m$^3$/ha and 60 m$^3$/ha, respectively. The final cut in 2004 resulted in a cumulative harvest of 48 percent of initial volume, yielding an additional 54 m$^3$/ha and 82 m$^3$/ha from blocks 5 and 7, respectively. Overall, the group selection harvested 126 m$^3$/ha and retained 139 m$^3$/ha.

Volume calculations were based on measurements of diameter and height made prior to treatment in 2000 and do not reflect tree growth that occurred to 2004. A full re-measurement in 2008 indicates that growth of the retained trees has increased merchantable volume by 25 m$^3$/ha in the single tree blocks, 29 m$^3$/ha in the group selection blocks, and 14 m$^3$/ha in the controls (Table 5). The data also indicate that losses to mortality over this period ranged from 18 to 33 m$^3$/ha. Blowdown accounted for half of this loss in the single tree treatments, and a third of the loss in the group treatments. Levels of mortality were similar in the control blocks, however only 11% occurred as blowdown.

### *Basal Area*

Prior to treatment, basal areas were fairly similar between blocks, averaging 42.5 m$^2$/ha, providing a stocking level of approximately 70 percent (NSDLF, 1990). Most of this was composed of red spruce (Table 6).

The preparation harvest in the selection treatments reduced basal area by an average of 9.5 m$^2$/ha, retaining between 27.2 m$^2$/ha and 37.0 m$^2$/ha. The final harvest in the single tree treatments focused on uniformly thinning the stand to promote the retention and growth of quality red spruce and other shade tolerant crop trees and to create sufficient light penetration to promote regeneration. In both blocks 2 and 4 basal areas were reduced below the target level of 23 m$^2$/ha retained, to 20.5 m$^2$/ha and 14.4 m$^2$/ha respectively. This may be partially a reflection of the initial 70 percent stocking levels with associated natural holes, as well as wider spacing across the extraction trails.

**Table 5.** Production of merchantable sized wood (>9.0 cm dbh) from harvesting and tree growth between trial establishment in 2000 and the re-measurement in 2008.

| Treatment | Block | 1 Initial Volume 2000 | 2 Total Volume Harvested 2000+2004 | | Lost to Mortality * 2000 to 2008 | | 3 Standing Inventory 2008 re-measurement | Net Merchantable Growth between 2000 - 2008 (2+3-1) |
|---|---|---|---|---|---|---|---|---|
| | | ($m^3$/ha) | ($m^3$/ha) | (%) | CWD ($m^3$/ha) | Snag ($m^3$/ha) | ($m^3$/ha) | ($m^3$/ha) |
| **Control** | 1 | 330 | 0 | 0 | 2 | 27 | 348 | 18 |
| | 6 | 298 | 0 | 0 | 4 | 24 | 307 | 9 |
| | **Avg.** | **314** | **0** | **0** | **3** | **25** | **328** | **14** |
| **Single Tree** | 2 | 318 | 176 | 55 | 16 | 17 | 167 | 25 |
| | 4 | 279 | 181 | 65 | 11 | 15 | 126 | 28 |
| | **Avg.** | **299** | **178** | **60** | **14** | **16** | **146** | **25** |
| **Group** | 5 | 278 | 110 | 40 | 8 | 15 | 201 | 33 |
| | 7 | 252 | 142 | 56 | 8 | 10 | 135 | 25 |
| | **Avg.** | **265** | **126** | **48** | **8** | **13** | **168** | **29** |
| **Clearcut** | 3 | 271 | 271 | 100 | 0 | 0 | 0 | 0 |
| | 8 | 299 | 299 | 100 | 0 | 0 | 0 | 0 |
| | **Avg.** | **285** | **285** | **100** | **0** | **0** | **0** | **0** |

* Volume of trees that were alive in 2000 and subsequently blew down (CWD) or died standing (snag) and were not harvested. When initially measured in 2000, approximately one third was classed as “crop potential” quality in the control areas, and two thirds as “crop potential” in the treated blocks (based on analysis of data available in the MPP database).

## Volume of Merchantable Wood Harvested

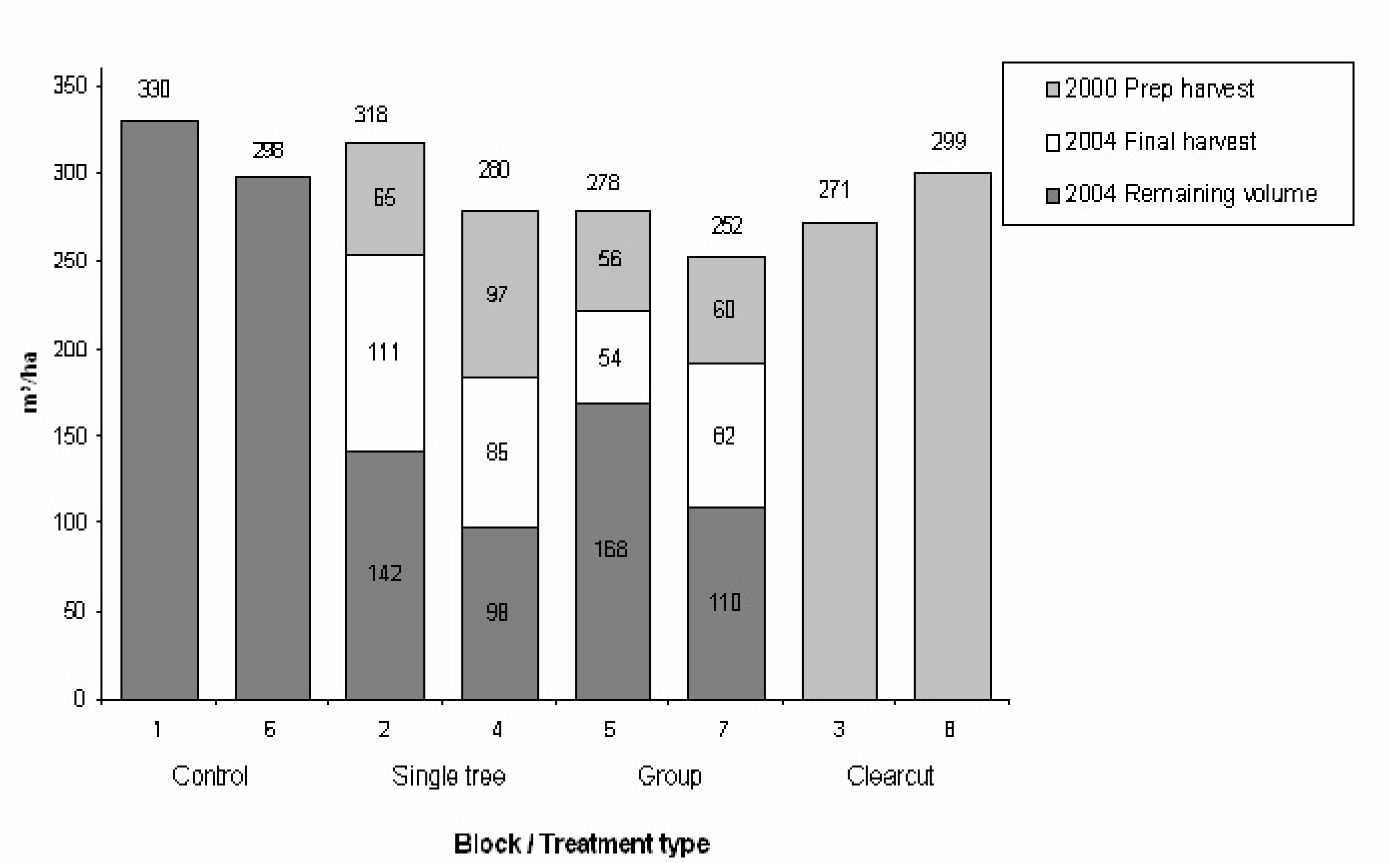



**Figure 4**. Merchantable wood volume harvested and retained in the 2000 preparation cut and 2004 final harvest (all volume calculations based on tree sizes measured prior to treatment in 2000).

**Table 6.** Basal area ($m^2$/ha) of live merchantable sized trees before and after treatments.

| Treatment | Block | Species | 2000 Initial Condition ($m^2$/ha) | 2000 Prep. Cut ($m^2$/ha) | 2004 Final Cut ($m^2$/ha) | 2008 Re-measurement ($m^2$/ha) |
|---|---|---|---|---|---|---|
| Control | 1 | Red Spruce | 37.7 | n/a | n/a | 41.7 |
| | | Balsam Fir | 0.9 | n/a | n/a | 0.6 |
| | | Largetooth Aspen | 0.8 | n/a | n/a | 0 |
| | | Yellow Birch | 3.0 | n/a | n/a | 2.6 |
| | | Red Maple | 7.4 | n/a | n/a | 5.9 |
| | | **Total** | **49.8** | **n/a** | **n/a** | **50.7** |
| | 6 | Red Spruce | 30.9 | n/a | n/a | 33.2 |
| | | Balsam Fir | 0.8 | n/a | n/a | 0.4 |
| | | White Birch | 0.6 | n/a | n/a | 0.4 |
| | | Yellow Birch | 1.4 | n/a | n/a | 1.1 |
| | | Red Maple | 8.6 | n/a | n/a | 7.6 |
| | | **Total** | **42.3** | **n/a** | **n/a** | **42.7** |
| Single tree | 2 | Red Spruce | 28.2 | 21.5 | 15.2 | 17.1 |
| | | White Pine | 0.5 | 0.5 | 0.5 | 0.6 |
| | | Balsam Fir | 2.6 | 1.6 | 0.7 | 0.8 |
| | | Largetooth Aspen | 0.2 | 0.2 | 0.2 | 0 |
| | | White Birch | 0.3 | 0.3 | 0.0 | 0 |
| | | Yellow Birch | 5.5 | 5.4 | 3.5 | 3.9 |
| | | Sugar Maple | 0.7 | 0.3 | 0.0 | 0.1 |
| | | Red Maple | 7.9 | 7.1 | 0.5 | 0.6 |
| | | **Total** | **46.0** | **36.9** | **20.5** | **23.2** |
| | 4 | Red Spruce | 27.5 | 18.6 | 13.5 | 16.3 |
| | | Balsam Fir | 0.8 | 0.5 | 0.2 | 0.7 |
| | | Largetooth Aspen | 0.5 | 0.5 | 0.0 | 0 |
| | | Yellow Birch | 1.5 | 1.3 | 0.2 | 0.3 |
| | | Sugar Maple | 0.4 | 0.4 | 0.1 | 0.1 |
| | | Red Maple | 9.2 | 5.8 | 0.4 | 0.4 |
| | | **Total** | **39.9** | **27.1** | **14.4** | **17.7** |
| Group | 5 | Red Spruce | 30.0 | 23.6 | 18.3 | 21.2 |
| | | White Spruce | 0.2 | 0.2 | 0.1 | 0.1 |
| | | White Pine | 0.4 | 0.4 | 0.4 | 0.4 |
| | | Balsam Fir | 2.3 | 1.2 | 1.0 | 1.4 |
| | | Yellow Birch | 3.0 | 2.9 | 2.4 | 2.4 |
| | | Red Maple | 6.3 | 5.5 | 3.4 | 3.9 |
| | | **Total** | **42.3** | **33.8** | **25.7** | **29.4** |
| | 7 | Red Spruce | 24.0 | 17.7 | 11.3 | 13.8 |
| | | White Spruce | 0.1 | 0.0 | 0.0 | 0 |
| | | Balsam Fir | 0.2 | 0.0 | 0.0 | 0.3 |
| | | Trembling Aspen | 0.1 | 0.1 | 0.0 | 0 |
| | | Largetooth Aspen | 0.6 | 0.2 | 0.2 | 0.2 |
| | | Beech | 0.1 | 0.0 | 0.0 | 0 |
| | | White Birch | 0.4 | 0.4 | 0.0 | 0 |
| | | Yellow Birch | 1.9 | 1.9 | 1.5 | 1.5 |
| | | Red Maple | 8.8 | 7.8 | 3.2 | 3.6 |
| | | **Total** | **36.3** | **28.1** | **16.3** | **19.4** |

**Table 6. (Cont'd)**

| Treatment | Block | Species | 2000 Initial Condition ($m^2$/ha) | 2000 Prep. Cut ($m^2$/ha) | 2004 Final Cut ($m^2$/ha) | 2008 Re-measurement ($m^2$/ha) |
|---|---|---|---|---|---|---|
| Clearcut | 3 | Red Spruce | 29.3 | 0.0 | 0.0 | 0.0 |
| | | Balsam Fir | 1.1 | 0.0 | 0.0 | 0.0 |
| | | Yellow Birch | 1.6 | 0.0 | 0.0 | 0.0 |
| | | Red Maple | 7.6 | 0.0 | 0.0 | 0.0 |
| | | **Total** | **39.7** | **0.0** | **0.0** | **0.0** |
| | 8 | Red Spruce | 30.7 | 0.0 | 0.0 | 0.0 |
| | | Balsam Fir | 0.5 | 0.0 | 0.0 | 0.0 |
| | | White Birch | 0.7 | 0.0 | 0.0 | 0.0 |
| | | Yellow Birch | 4.8 | 0.0 | 0.0 | 0.0 |
| | | Sugar Maple | 0.4 | 0.0 | 0.0 | 0.0 |
| | | Red Maple | 6.6 | 0.0 | 0.0 | 0.0 |
| | | **Total** | **43.7** | **0.0** | **0.0** | **0.0** |

The group selection focused on removing a percentage of area (20 percent) in fixed patch sizes. This limited stand and tree quality improvement potential to the selection of patches which were overmature, understocked, or at risk of blowdown (eg. knolls, wet soils, etc). In block 5 basal area was reduced to 25.7 $m^2$/ha, while in block 7 only 16.3 $m^2$/ha was retained.

As with the volume calculations, these figures are based on tree size measurements made in 2000 and do not reflect growth to 2004. The re-measurement in 2008 shows basal area growth on retained trees of approximately 3 $m^2$/ha in the selection treatments, compared to less than 1 $m^2$/ha in the controls (Table 6).

***Species and Quality***

The initial composition of shade tolerant crop species was similar in the four selection treatment blocks (Table 6). Red spruce dominated with an average basal area of 27.4 $m^2$/ha (67 percent of BA), while the stocking of yellow birch, white pine, and sugar maple raised the basal area of preferred crop species by 3.5 $m^2$/ha across the 4 blocks (to an overall average of 75 percent of BA).

The single tree selection treatment favoured the retention of red spruce and increased the composition by 19 percent, from 65 percent to 84 percent (comparison of changes in basal area proportions measured between 2000 and 2008, from Table 6) . The overall composition of preferred crop species increased from an average 75 percent to 94 percent, primarily reflecting the increased dominance of red spruce. Conversely, the composition of red maple declined from a pretreatment average of 19.9 percent of basal area to a post treatment of 2.6 percent. Balsam fir composition also declined from an initial average of 3.9 percent of basal area to 2.6 percent post treatment.

The group selection treatment was less able to target species and red spruce composition increased slightly from 68 percent to 70 percent. Overall the composition of preferred crop species increased from 75 percent to 80. Red maple composition declined slightly from 19.2 percent to 15.7 percent, while balsam fir composition dropped from 3.2 percent to 2.4 percent.

Improvement in stem quality followed a similar trend, with the percentage of retained trees classed as “acceptable growing stock” increasing from 83 percent to 93 percent in the single tree blocks and from 83 percent to 87 percent in the group selection (Figure 5). Most of this reflected an increase in the proportion of quality red spruce, with little change in the percentages of acceptable balsam fir and yellow birch and a decline in the percentage of quality red maple.

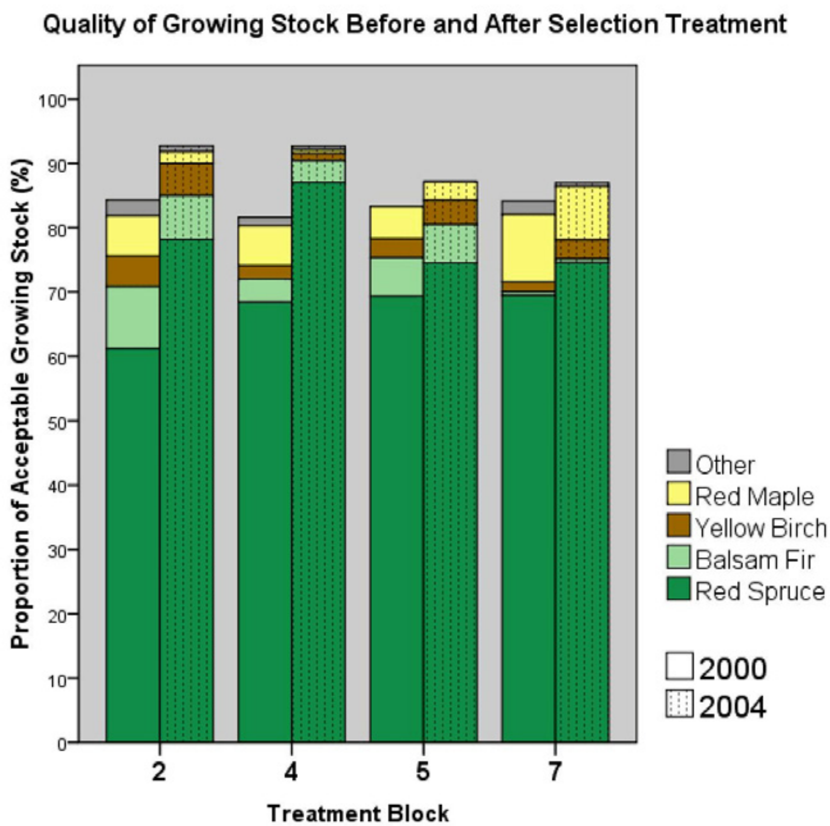



Figure 5. Change in the percentage of acceptable quality growing stock by species after selection treatment.

**Treatment Effects on Dead Wood (from MPP and CWD databases)**

Large (>9.0 cm diameter) dead wood occurs as both standing snags (> 45 degrees) and as downed coarse woody debris ($\leq$ 45 degrees). Snags are measured using the multiplots (MPP), while coarse woody debris is tracked by line transect using the CWD plots.

***Volume***

Prior to treatment, the volume of dead wood averaged 72.7 $m^3$/ha over the entire trial and was evenly distributed between coarse woody debris (36.3 $m^3$/ha) and snags (36.4 $m^3$/ha) (Table 7). With the completion of harvesting treatments in 2004, the volume of dead wood increased in both selection treatments, by an average of 11.5 $m^3$/ha (14 percent) in the single tree and 12.9 $m^3$/ha (20 percent) in the group selection. In comparison, dead wood volume increased by a similar amount, 14.4 $m^3$/ha (19 percent), in the control blocks and decreased by 10.9 $m^3$/ha (15 percent) in the clearcuts.

Both selection treatments experienced a decline of approximately 50 percent in the volume of snags, with a corresponding increase in the volume of coarse woody debris. Results were somewhat inconsistent in the group selection treatments, with block 5 having the lowest decline in snag volume (4.8 $m^3$/ha) and block 7 having a decline of 21.8 $m^3$/ha, similar to the single tree treatments. With only a small proportion of the area of the group selection blocks treated, this level of decline in block 7 was unexpected, but may partially reflect the focus of harvesting on patches of trees at risk. By comparison, the increase in deadwood in the control blocks was evenly distributed between snags and coarse woody debris, while in the clearcut blocks all standing wood was felled, resulting in the elimination of snags and an increase in coarse woody debris.

**Table 7**. Volume of dead wood (snags and coarse woody debris) before and after harvest.

| Treatment | Block | Pre-Treatment (2000) ($m^3$/ha) | | | Post-Treatment (2006) ($m^3$/ha) | | | Change(2006-2000) ($m^3$/ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CWD | Snag | Total | CWD | Snag | Total | CWD | Snag | Total |
| Control | 1 | 15.3 | 40.6 | 55.9 | 25.5 | 51.9 | 77.4 | 10.2 | 11.3 | 21.5 |
| | 6 | 57.2 | 36.6 | 93.8 | 61.9 | 38.8 | 100.7 | 4.7 | 2.2 | 6.9 |
| | **Average** | **36.3** | **38.4** | **74.7** | **43.7** | **45.4** | **89.1** | **7.4** | **7.0** | **14.4** |
| Single Tree | 2 | 41.7 | 47.8 | 89.5 | 74.5 | 22.5 | 97.0 | 32.8 | -25.3 | 7.5 |
| | 4 | 32.3 | 37.3 | 69.6 | 65.7 | 19.3 | 85.0 | 33.5 | -18.0 | 15.5 |
| | **Average** | **37.0** | **42.5** | **79.5** | **70.1** | **20.9** | **91.0** | **33.1** | **-21.6** | **11.5** |
| Group | 5 | 38.3 | 22.1 | 60.4 | 53.3 | 17.3 | 70.6 | 15.0 | -4.8 | 10.2 |
| | 7 | 34.4 | 32.5 | 66.9 | 71.8 | 10.7 | 82.5 | 37.5 | -21.8 | 15.7 |
| | **Average** | **36.4** | **27.3** | **63.7** | **62.6** | **14.0** | **76.6** | **26.2** | **-13.3** | **12.9** |
| Clearcut | 3 | 34.8 | 43.7 | 78.5 | 68.7 | 0.0 | 68.7 | 33.9 | -43.7 | -9.8 |
| | 8 | 35.9 | 31.3 | 67.2 | 55.2 | 0.0 | 55.2 | 19.3 | -31.3 | -12.0 |
| | **Average** | **35.4** | **37.5** | **72.9** | **62.0** | **0.0** | **62.0** | **26.6** | **-37.5** | **-10.9** |
| **Total** | **Average** | **36.3** | **36.4** | **72.7** | **na** | **na** | **na** | **na** | **na** | **na** |

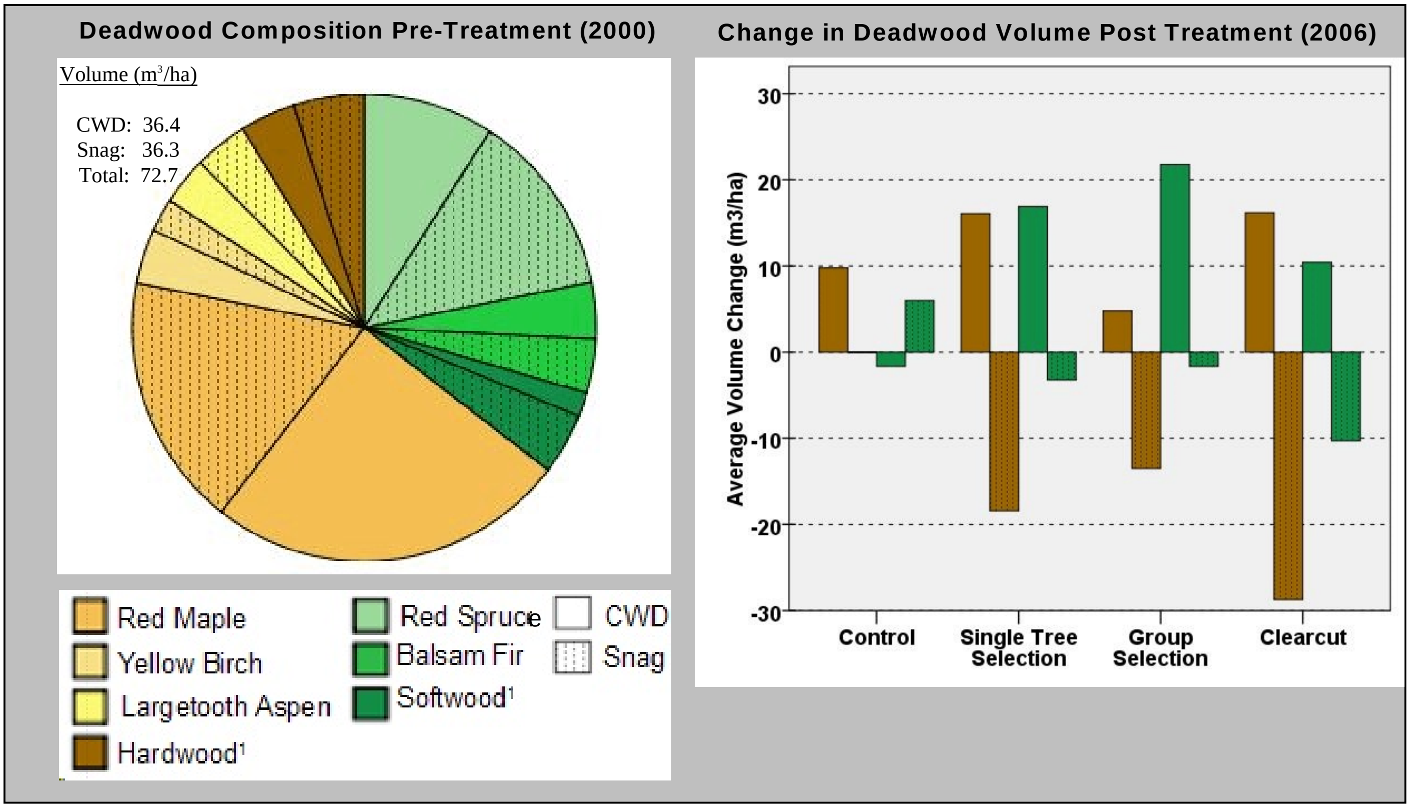



**Figure 6.** Composition of deadwood volume across all blocks prior to harvest, and the changes following the four different treatment. Snag and Coarse Woody Debris (CWD) distributions are shown by species prior to treatment, and by hardwood and softwood group post treatment.

[1] pre-treatment softwood and hardwood include "unknown" and "other" species.

### *Species*

Prior to treatment, deadwood was composed of approximately one third softwood species and two thirds hardwood (Figure 6). Red spruce made up most of the softwood, while the hardwood consisted primarily of red maple. The distribution of snags and coarse woody debris was fairly even within species groups. Following treatment, all harvest types experienced a decline in snags and an increase in coarse woody debris. The largest volume declines were among hardwood snags (approx. 12 - 28 $m^3/ha$), which was not quite matched by the increase in hardwood coarse woody debris, probably reflecting losses due to some crushing and breakage of the more decayed stems. In the selection treatments softwood snags decreased very little, while softwood coarse woody debris increased substantially. In the clearcuts the loss of softwood snags was matched by the increase in coarse woody debris. By comparison, in the control blocks there was an increase in softwood snags and hardwood coarse woody debris.

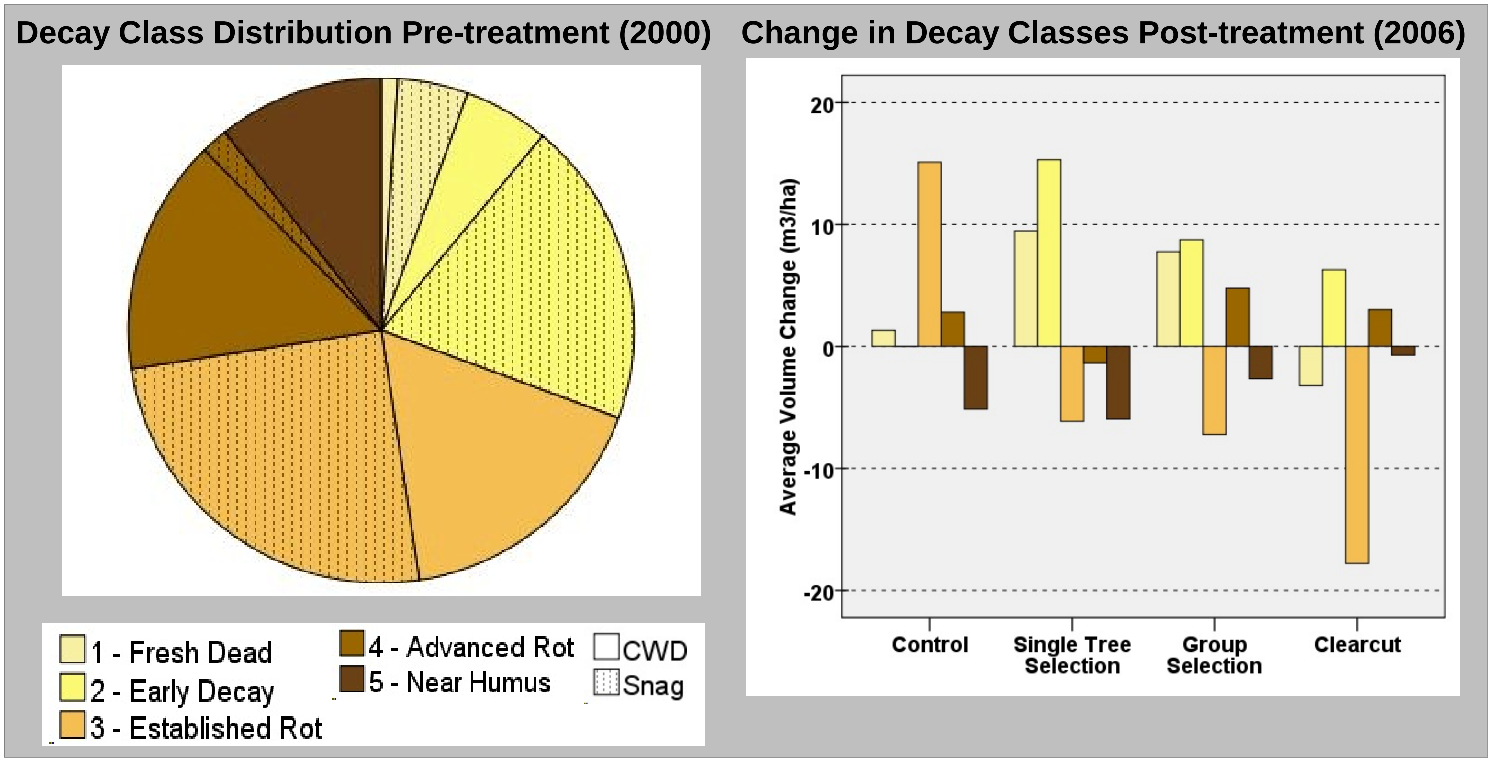



**Figure 7.** Distribution of deadwood volume by decay class across all blocks prior to harvest, and the changes following the four different treatments. Snag and Coarse Woody Debris (CWD) distributions are shown prior to treatment.

***Decay***

Figure 7 illustrates that in the pre-treatment stand fresh dead wood occurred predominately as standing snags, with a trend of increasing coarse woody debris levels through subsequent decay classes. This suggests that most sound trees died standing, then fell or broke up as they decayed, although a past blowdown event, or fungal mortality may produce similar patterns.

All treatments produced a pulse of freshly dead wood, as well as a substantial decline in the volume of decay class 3, indicating some destruction of pre-existing deadwood during harvesting (note, in the clearcuts the apparent decline in decay class 1 is due to the six year span between treatment and measurement). By contrast, the control blocks experienced a relatively large increase in decay class 3 material, partially due to the mortality of red maple with pre-existing decay from shoestring root rot (*Armillariella mellea*).

## Pre-treatment Ground Vegetation Assessment (from VEG database)

Table 8 lists the non-tree understory vegetation, which was measured in early September 2000 prior to the initial treatment. Typical of well stocked mature conifer forest, understory vegetation was fairly limited and consisted primarily of a "moss" layer covering 25.7 percent of the soil surface. Although not measured, the non-vegetated portion of forest floor was observed to be primarily covered with leaf and needle litter. Only the most common species were recorded, which consisted of 10 mosses, 2 liverworts, and 2 lichens. Three-lobed bazzania dominated, followed by Schreber's moss, and broom moss. The herbaceous layer only covered 1.2 percent of the area and contained fourteen recorded species, of which the most common were wood sorrel, gold thread, bunch berry, and wild-lily-of-the-valley. Two species of shrub and six ferns (and allies) were recorded, both groups having less than 1 percent cover.

**Table 8.** Cover (%) of non-tree vegetation prior to treatment (2000).

| Moss | | Herbaceous | | Ferns | | Shrubs | |
|---|---|---|---|---|---|---|---|
| Species | Cover (%) | Species | Cover (%) | Species | Cover (%) | Species | Cover (%) |
| 3-Lob. Bazzania | 10.73 | Wood Sorrel | 0.30 | Bracken | 0.28 | Blueberry | 0.06 |
| Schreber's Moss | 5.05 | Goldthread | 0.20 | Cinnamon | 0.13 | Lambkill | 0.01 |
| Broom Moss | 3.39 | Bunchberry | 0.15 | New York | 0.08 | | |
| Braided Moss | 2.73 | Wild Lily of the Valley | 0.15 | Hay Scented | 0.06 | | |
| Stair Step Moss | 2.08 | Sarsaparilla | 0.08 | Wood | 0.03 | | |
| Sphagnum spp. | 0.91 | Painted Trillium | 0.06 | Ground Pine | 0.02 | | |
| Fern Moss | 0.28 | Starflower | 0.05 | | | | |
| Wavy Dicranum | 0.16 | Ind.Cucumber Root | 0.05 | | | | |
| Haircap Moss | 0.15 | Rose Twisted Stalk | 0.04 | | | | |
| Shaggy Moss | 0.11 | Sedge | 0.03 | | | | |
| Cup Lichen | 0.09 | Partridgeberry | 0.02 | | | | |
| Plume Moss | 0.02 | Blue Bead Lily | 0.01 | | | | |
| Mnium spp. | 0.01 | Indian Pipe | 0.01 | | | | |
| **Total Cover** | **25.71** | | **1.15** | | **0.6** | | **0.07** |

## Treatment Effects on Regeneration (from VEG database)

Prior to the initial treatment in 2000, the density of regeneration was assessed in six height classes, ranging from 1 cm seedlings to saplings over 7 m tall. The stocking of saplings over 1.3m tall was assessed at 3 m spacing. In May 2006 (2 years after the final selection harvest and 6 years after the preparatory treatments and clearcut) stocking was measured for all six height classes, using an assessment at 3 different spacings: 1.8 m, 2.4 m, and 3.0 m.

### *Pre-Treatment Regeneration Density (2000)*

Prior to treatment the forest floor was occupied by a high density (447,344 stems/ha) of small "emergent" seedlings (1-5 cm height) composed of 83 percent red spruce, 10 percent balsam fir, 5 percent yellow birch, and 3 percent red maple (Table 9). Established seedlings, ranging in height from 6 to 130 cm, occurred at a much lower density (19,376 stems/ha) and consisted primarily of balsam fir (69 percent) and red spruce (24 percent). Saplings, ranging in height from 1.3 m to over 7 m, occurred at a density of 1938 stems/ha, which was composed of approximately two thirds balsam fir and one third red spruce.

**Table 9.** Average density of tree regeneration by species and height class across trial site prior to initial harvest treatment (2000).

| Species | Height Class<br>Emergents<br>1 - 5 cm<br>*(stems/ha)* | <br>Seedlings<br>6 - 130 cm<br>*(stems/ha)* | <br>Saplings<br>> 130 cm<br>*(stems/ha)* | Total<br>*(stems/ha)* |
|---|---|---|---|---|
| Red Spruce | 370,000 | 4,688 | 685 | 375,373 |
| Balsam Fir | 44,635 | 13,438 | 1,247 | 59,320 |
| Yellow Birch | 20,781 | 0 | 6 | 20,787 |
| Red Maple | 11,927 | 1,198 | 0 | 13,125 |
| Aspen | 0 | 52 | 0 | 52 |
| **Total** | 447,343 | 19,376 | 1,938 | 468,657 |

### *Post-Treatment Regeneration Stocking (2006)*

Prior to treatment, the stocking at 3 m spacing of sapling sized trees (>130 cm height and < 9.1cm dbh) ranged from 42 percent to 79 percent between blocks (average 57 percent), with both red spruce and balsam fir having similar average stocking of 34 percent (Table 10). The crop potential of these trees is difficult to gauge due to the effects of suppression associated with their understory position. In all treatment types sapling stocking declined, hardwood regeneration increased, and a high stocking of established softwood and hardwood seedlings (6-130 cm height) was observed (88-100 percent).

In the clearcut blocks virtually no pre-existing spruce and fir saplings survived but hardwood saplings subsequently developed. In the single tree selection cuts the stocking of spruce and fir saplings declined on average from 68 to 28 percent. The group selection blocks had the highest retention of sapling stocking (46 percent) likely reflecting the area not treated.

**Table 10.** Stocking at 3.0 m spacing of saplings (height > 130 cm, dbh < 9.1cm) before initial treatment, and of saplings and seedlings (height 6 -130cm) two years after final treatment.

| Treatment | Block | Species | Pre-treatment (2000) Sapling Stocking % | Post-Treatment (2006) Sapling Stocking % | Post-Treatment (2006) Seedling Stocking % |
|---|---|---|---|---|---|
| Control | 1 | Red Spruce | 33 | 21 | 88 |
| | | Balsam Fir | 4 | 4 | 71 |
| | | Red Maple | | | 4 |
| | | Yellow Birch | 4 | | |
| | | **Total** | **42** | **25** | **96** |
| | 6 | Red Spruce | 38 | 46 | 63 |
| | | Balsam Fir | 33 | 38 | 67 |
| | | Red Maple | | | 25 |
| | | Yellow Birch | | | 4 |
| | | **Total** | **63** | **63** | **92** |
| Single Tree | 2 | Red Spruce | 29 | 4 | 88 |
| | | Balsam Fir | 42 | 21 | 71 |
| | | Red Maple | | | 46 |
| | | Yellow Birch | | | 50 |
| | | Other | | | 13 |
| | | **Total** | **58** | **25** | **100** |
| | 4 | Red Spruce | 50 | 13 | 88 |
| | | Balsam Fir | 54 | 21 | 75 |
| | | Red Maple | | 8 | 83 |
| | | Yellow Birch | | | 29 |
| | | Other | | | 4 |
| | | **Total** | **79** | **38** | **100** |
| Group | 5 | Red Spruce | 33 | 21 | 83 |
| | | Balsam Fir | 38 | 25 | 79 |
| | | Red Maple | | 8 | 88 |
| | | Yellow Birch | | | 46 |
| | | Other | | | 21 |
| | | **Total** | **50** | **46** | **100** |
| | 7 | Red Spruce | 46 | 17 | 75 |
| | | Balsam Fir | 46 | 29 | 79 |
| | | Red Maple | | 4 | 88 |
| | | Yellow Birch | | | 33 |
| | | Other | | | 38 |
| | | **Total** | **67** | **46** | **100** |
| Clearcut | 3 | Red Spruce | 21 | | 58 |
| | | Balsam Fir | 29 | 4 | 54 |
| | | Red Maple | | 17 | 71 |
| | | Yellow Birch | | | 8 |
| | | Other | | 13 | 13 |
| | | **Total** | **42** | **29** | **92** |
| | 8 | Red Spruce | 38 | | 71 |
| | | Balsam Fir | 25 | | 25 |
| | | Red Maple | | 13 | 71 |
| | | Yellow Birch | | 8 | 29 |
| | | Other | | 13 | 21 |
| | | **Total** | **58** | **25** | **88** |

Post-treatment stocking of established seedlings (6-130cm) was 100 percent in all four selection harvest blocks, which had similarly high average stocking levels of red spruce (84 percent), balsam fir (76 percent), and red maple (76 percent). Yellow birch stocking averaged 40 percent and was most heavily concentrated in the extraction trails. While a similar species mix regenerated following clearcut, the stocking levels were lower, averaging 90 percent overall and 64 percent for red spruce, 40 percent for balsam fir, 71 percent for red maple, and 18 percent for yellow birch.

By comparison, stocking of saplings remained relatively constant in the control blocks over the six year measurement period. Regeneration of both seedlings and saplings was dominated by spruce and fir, with hardwood occurring at much lower levels than the treated sites.

## Soil Compaction

The average soil bulk density for untraveled control areas was 0 .99 Mg/m$^3$ (Table11). In the temporary extraction trails that experienced moderate traffic (3-7 harvest machine passes) mean bulk density was 8 percent higher (1.05 Mg/m$^3$) in the center of the haul trail and 26 percent higher(1.25 Mg/m$^3$) in the wheel tracks than in the control areas. In the main haul trails, which experienced repeated heavy traffic (8+ harvest machine passes), soil density was 50 percent higher (1.48 Mg/m$^3$) than control areas. The growth limiting bulk density values for the soil types found at the site are 1.65-1.70 Mg/m$^3$ (Keys, 2005).Values above the growth limiting bulk density were found in some samples both in the moderate traffic areas within the wheel track and in areas experiencing heavy traffic levels.

**Table 11.** Soil bulk density (Db) measured on main haul trails (heavy traffic), temporary extraction trails (moderate traffic) and untraveled control areas following harvest in 2004[1].

| Treatment [2] | Mean Db (Mg/m$^3$) | Std. Dev. | Db range (Mg/m$^3$) | Mean increase (%) |
|---|---|---|---|---|
| Untraveled Control | 0.99 | 0.18 | 0.61-1.32 | --- |
| Moderate Traffic (Center trail) | 1.05 | 0.18 | 0.72-1.41 | 8 |
| Moderate Traffic (Wheel Track) | 1.25 | 0.17 | 0.92-1.66 | 26 |
| Heavy Traffic | 1.48 | 0.18 | 1.11-1.73 | 50 |

[1] Adapted from Keys 2005
[2] Moderate traffic = 3-7 harvester and forwarder passes on temporary extraction trails within treatement blocks; and heavy traffic levels = 8 or more harvester and forwarder passes on permanent haul trails established between treatment blocks.

### Legacy Tree Retention in Selection Treatments (from MPP database)

The basal area of the 12 legacy trees retained within each of the selection harvest blocks ranged from 0.5 $m^2$/ha to 0.7 $m^2$/ha (Appendix III). This represented from 1.3 to 1.7 percent of the pre-treatment basal area of live trees. These trees were selected from the oldest and largest trees in the stand. The shortest was a 15.2 m sugar maple with a 51 cm diameter and the tallest was a 24.8 m red spruce with a 68 cm diameter. The composition of legacy trees in each block was similar, with average heights ranging from 20.1 m to 21.4 m and average diameters ranging from 47 cm to 53 cm. Each block had 10 red spruce, 1 yellow birch, and 1 other species (yellow birch, sugar maple, red maple, white pine). As of 2008 eleven of the original 48 legacy trees have died. Two were accidentally harvested, five blew down, and four died as standing snags. These will be replaced with new selections prior to the next harvest cycle.

## FUTURE MANAGEMENT CONSIDERATIONS

### Single Tree Selection

Although normal yield table projections of 15 year growth intervals over a 75 year rotation were used to develop the single tree prescription, it is not expected that a highly regulated 5-cohort structure will develop. These projections provide a logical starting point to theoretically provide multi-cohort growing space that favours regeneration, understory development, and crop tree growth at different times in the rotation cycle. Unlike some systems (eg. Q-factor) there is no desire to regulate age class structure, diameter distributions, or time periods between harvests. The initial treatment is expected to generate a strong regeneration response that produces a dense, well stocked, new cohort capable of growing to large sapling size prior to the next harvest. Understory saplings may be particularly vulnerable to damage during the second harvest. However variations in the growing space, which is highest in the access trails, and lowest where the harvesters could not reach to the center of thinned strips, may present future access opportunities.

It is anticipated that the next harvest will be triggered in 15 to 20 years when the basal area of merchantable sized trees regrows to 33 $m^2$/ha. The 5 year MPP re-measurement cycle will monitor this growth, which is expected to occur primarily on the residual crop trees and through ingrowth of currently unmerchantable sized saplings and poles. While the initial harvests focus on crop improvement, successive harvests are expected to increasingly consist of large diameter “crop” trees selected from the oldest and largest age class using a diameter limit calculation.

### Group Selection

While a 15 year harvest cycle is suggested, it is expected that the actual period between group selection harvests will follow the same period as the single tree harvests, and thus depend on the basal area catchup rates for the single tree blocks. This is suggested mostly for ease of planning joint operations and should be revisited if the period between harvests becomes too variable.
A challenge is recognized in that the dominant cohort is currently estimated to be 90 years of age, and thus may be 150 years old at the last cutting cycle. While this is a similar age to the oldest cohort that was present at the start of the trial, it is unclear how patches of this age will perform, and thus prescription adjustments may be required.

**Ecological Considerations**

To mitigate the potential of intensive selection cutting to simplify stands and reduce structural complexity through frequent entries for tending and harvesting, the following guidelines were developed:

- retain permanent large legacy trees, replacing those that die.
- represent tree species diversity in all stages of growth
- retain uniquely formed trees (eg. wolf) and cavity trees (may be legacy trees).
- enhance horizontal and vertical structural diversity during cutting and tending.
- provide for coarse dead wood - an average of 13 $m^3$/ha of coarse woody debris and 52 snags per hectare ($\geq$20 cm dbh), are reported for unmanaged stands of these vegetation types (Neily et al. 2006).

**Pre-Commercial Thinning**

Density control of the growing stock will be used to increase growth rates, concentrate growth on crop trees, and manage species composition. Spacing should be carried out within height classes, with each class treated independently of the others. Trees should only be spaced when in direct competition with each other within the same height class, for example a potential crop tree from a tall class should not be removed to make space for a tree from a shorter class, and visa versa. Pre-commercial thinning should be conducted shortly after harvest.

Aerial view of block 5 looking southwest towards block 4 - taken October 4, 2006 .

# LITERATURE CITED


Battles, J.J., A.J Shlisky, R.H. Barrett, R.C. Heald and B.H Allen-Diaz. 2001. The effects of forest management on plant species diversity in a Sierran conifer forest. Forest Ecology and Management 146: 211-222.

Chambers, C. L, W.C. Mc Comb, and J.C. Tappeiner II. 1999. Breeding bird responses to three silvicultural treatments in the Oregon Coast Range. Ecological Applications 9 (1): 177-185.

Doyon, F., D. Gagnon and J.F. Giroux. 2005. Effects of strip and single-tree selection cutting on birds and their habitat in a southwestern Quebec northern hardwood forest. Forest Ecology and Management. 209: 101-115.

Fraver, S., R.G. Wagner and M. Day. 2002. Dynamics of coarse woody debris following gap harvesting in The Acadian forest of central Maine, U.S.A. Can. J. For. Res. 32: 2094-2105.

Honer, T.G., M.F. Ker, and I.S. Alemdag. 1983. Metric timber tables for the commercial tree species of central and eastern Canada. Can For. Serv. Information Report M-X-140. 139 pp.

Kelty, M.J. D.B. Kittredge Jr. T. Kyker–Snowmanand and A.D. Leighton. 2003. The conversion of even-aged stands to uneven aged structure in southern New England. Northern Journal of Applied Forestry 20(3):109-116.

Keys, K. 2005. Quantifying ground disturbance and soil compaction after forest harvesting. Report Nova Forest Alliance Model Forest. 32 pp.

Keys, K. 2007. Forest soil types in Nova Scotia - identification, description, and interpretation. NSDNR Manual FOR 2007-2. 46 pp. [accessed on March 4, 2009] Available at: http://gov.ns.ca/natr/forestry/reports/NS-Soils.pdf

Lewis, J. 1998. Evaluating the impacts of logging activities on erosion and suspended sediment transport in the Casper Creek watershed. 15 pp. In proceedings of the conference on coastal watersheds: the Caspar Creek Story. 1998. Ukiah, CA. Gen. Tech. Rep. PSW-GTR-168, USDA Forest Service, Pacific Southwest Research Station. 149 pp.

Neily, P.D., E.J. Quigley, L. Benjamin, B. Stewart, and A.P. Duke. 2003. Ecological Land Classification for Nova Scotia. Volume 1 - Mapping Nova Scotia’s Terrestrial Ecosystems. Report DNR 2003-2. 83 pp. [accessed on: Feb 5, 2008] Available at: http://www.gov.ns.ca/natr/forestry/ecosystem/pdf/ELCrevised2.pdf

Neily, P.D., K. Keys, E.J. Quigley, and B. Stewart. 2006. Forest ecosystem classification for Nova Scotia’s Western Ecoregion. Unpublished Interim Report. NSDNR, Forestry Division, Ecosystem Management Group. 72 pp.

NSDLF. 1990. Revised normal yield tables for Nova Scotia softwoods. Forest Research Report No. 22. Nova Scotia Dept. of Lands and Forests, Truro. 45pp. [accessed on May 15, 2008] Available at http://www.gov.ns.ca/natr/forestry/reports/report22.pdf

Silvennoinen, H., T. Pukkala, and L. Tahvanainen. 2002. Effect of cuttings on the scenic beauty of a tree stand. Scand. J. For. Res. 17: 263-273.

Stewart, B.J., and E.J. Quigley. 2000. Regeneration survey of five year old clearcuts in Nova Scotia. Forest Research Report. Nova Scotia Department of Natural Resources Report FOR 2000-3. 17pp. [accessed on May 15, 2008] Available at http://www.gov.ns.ca/natr/forestry/reports/REPORT66.pdf

Stewart, B.J., P.D. Neily, E.J. Quigley, A.P. Duke, and L. K. Benjamin. 2003. Selected Nova Scotia Old Growth Forests: Age, Ecology, Structure, Scoring. Forestry Chronicle 79(3):632-644. http://www.gov.ns.ca/natr/forestry/planresch/oldgrowth/ForChrDisclaimer.htm

Sullivan, T.P. and D.S. Sullivan. 2001. Influence of variable retention harvest on forest ecosystems. II. Diversity and population dynamics of small mammals. Journ. App. Eco. 38 : 1234-1252.

Arrangement of red spruce and red maple crowns in unthinned area - taken February 17, 2000.

# APPENDIX I: Species List

| Common Name | Scientific Name | Common Name | Scientific Name |
|---|---|---|---|
| **Trees** | | **Bryophytes & Lichens** | |
| Balsam fir | *Abies balsamea* | Three-lobed bazzania | *Bazzania trilobata* |
| Red maple | *Acer rubrum* | Cub lichen | *Cladonia spp.* |
| Sugar maple | *Acer saccharum* | Broom moss | *Dicranum scoparium* |
| Yellow birch | *Betula alleghaniensis* | Wavy dicranum | *Dicranum polysetum* |
| White birch | *Betula papyrifera* | Stair step moss | *Hylocomium splendens* |
| American beech | *Fagus grandifolia* | Braided moss | *Hypnum imponens* |
| Eastern larch | *Larix laricina* | Mnium | *Mnium spp.* |
| White spruce | *Picea glauca* | Schreber's moss | *Pleurozium schreberi* |
| Black spruce | *Picea mariana* | Haircap moss | *Polytrichum commune* |
| Red spruce | *Picea rubens* | Plume moss | *Ptilium crista-castrensis* |
| White pine | *Pinus strobus* | Shaggy moss | *Rhytidiadelphus triquetrus* |
| Large-toothed aspen | *Populus grandidentata* | Sphagnum moss | *Sphagnum spp.* |
| Trembling aspen | *Populus tremuloides* | Fern moss | *Thuidium delicatulum* |
| Aspen | *Populus spp.* | | |
| Eastern hemlock | *Tsuga canadensis* | **Herbaceous** | |
| **Woody Shrubs** | | Sarsaparilla | *Aralia nudicaulis* |
| | | Sedge | *Carex spp.* |
| Lambkill | *Kalmia angustifolia* | Blue bead lily | *Clintonia borealis* |
| Blueberry | *Vaccinium spp.* | Goldthread | *Coptis trifolia* |
| | | Bunchberry | *Cornus canadensis* |
| **Ferns & Fern Allies** | | Wild lily of the valley | *Maianthemum canadense* |
| Hay scented fern | *Dennstaedtia punctilobula* | Indian cucumber root | *Medeola virginiana* |
| Wood fern | *Dryopteris spp.* | Partridgeberry | *Mitchella repens* |
| Ground Pine | *Lycopodium obscurum* | Indian pipe | *Monotropa uniflora* |
| Cinnamon fern | *Osmunda cinnamomea* | Wood sorrel | *Oxalis acetosella* |
| Bracken fern | *Pteridium aquilinum* | Rose twisted stalk | *Streptopus roseus* |
| New York fern | *Thelypteris noveboracensis* | Starflower | *Trientalis borealis* |
| | | Painted trillium | *Trillium undulatum* |
| **Fungi** | | | |
| Shoe string root rot (Honey mushroom) | *Armillariella mellea* | | |

# APPENDIX II: Microsites in Permanent Sample Plots (MPP)

| Block | Treatment type | MPP Plot | VEG Sub Plot | Soil type[1] | Drainage | Percent of plot on haul trail | Site limitations | Percent of site with limitations | Relief |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Control | 1 | 1 | ST2 | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 2 | 1 | ST3 | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 3 | 1 | ST2 | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 3 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | 4 | 1 | ST2 | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |
| | | 5 | 1 | ST3 | Imperfect | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |
| | | 6 | 1 | ST2 | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |
| | | 7 | 1 | ST2 | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |
| | | 8 | 1 | ST3 | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 3 | | Well | 0 | Nil | 0 | Hum/hollow |
| 2 | Single tree | 1 | 1 | ST2 | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |
| | | 2 | 1 | ST3 | Well | 10 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Imperfect | 20 | Nil | 0 | Hummock |
| | | 3 | 1 | ST3 | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 15 | Nil | 0 | Hummock |
| | | | 3 | | Imperfect | 0 | Nil | 0 | Flat |
| | | 4 | 1 | ST3 | Imperfect | 0 | Nil | 0 | Hummock |
| | | | 2 | | Imperfect | 25 | Slash | 40 | Flat |
| | | | 3 | | Imperfect | 0 | Nil | 0 | Flat |
| | | 5 | 1 | ST3-G | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 80 | Slash | 30 | Hummock |
| | | | 3 | | Excessive | 60 | Slash | 30 | Flat |
| | | 6 | 1 | ST2 | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 7 | 1 | ST3 | Well | 0 | Stoniness | 40 | Hummock |
| | | | 2 | | Well | 80 | Nil | 0 | Flat |
| | | | 3 | | Well | 60 | Slash | 40 | Hollow |
| | | 8 | 1 | ST3-G | Imperfect | 25 | Slash | 30 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hollow |
| | | | 3 | | Imperfect | 60 | Nil | 0 | Hummock |

| Block | Treatment type | MPP Plot | VEG Sub Plot | Soil type[1] | Drainage | Percent of plot on haul trail | Site limitations | Percent of site with limitations | Relief |
|---|---|---|---|---|---|---|---|---|---|
| 3 | Clearcut | 1 | 1 | ST2-G | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Slash | 75 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 2 | 1 | ST2 | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | 3 | 1 | ST2 | Well | 0 | Vegetation | 50 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hollow |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 4 | 1 | ST3 | Imperfect | 0 | Vegetation | 40 | Flat |
| | | | 2 | | Imperfect | 0 | Vegetation | 40 | Hummock |
| | | | 3 | | Imperfect | 0 | Vegetation | 70 | Flat |
| | | 5 | 1 | ST2 | Well | 0 | Slash | 40 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 40 | Slash | 60 | Hummock |
| | | 6 | 1 | ST2 | Well | 0 | Nil | 0 | Hollow |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Slash | 80 | Flat |
| | | 7 | 1 | ST3-L | Well | 50 | Slash | 50 | Flat |
| | | | 2 | | Well | 100 | Slash | 0 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 8 | 1 | ST3-G | Imperfect | 60 | Slash | 0 | Flat |
| | | | 2 | | Imperfect | 0 | Slash | 25 | Hummock |
| | | | 3 | | Poor | 0 | Moisture | 30 | Hollow |
| 4 | Single tree | 1 | 1 | ST3 | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 3 | | Imperfect | 60 | Moisture | 25 | Hum/hollow |
| | | 2 | 1 | ST2 | Well | 0 | Slash | 30 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 3 | 1 | ST3 | Imperfect | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 0 | Vegetation | 50 | Hummock |
| | | | 3 | | Well | 50 | Nil | 0 | Hummock |
| | | 4 | 1 | ST2 | Well | 50 | Nil | 0 | Hollow |
| | | | 2 | | Well | 0 | Slash | 50 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | 5 | 1 | ST2 | Well | 20 | Nil | 0 | Hollow |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 20 | Nil | 0 | Hum/hollow |
| | | 6 | 1 | ST2 | Well | 25 | Slash | 40 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 40 | Nil | 0 | Hummock |
| | | 7 | 1 | ST3 | Imperfect | 70 | Slash | 50 | Hum/hollow |
| | | | 2 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 3 | | Imperfect | 0 | Nil | 0 | Flat |
| | | 8 | 1 | ST2 | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |

| Block | Treatment type | MPP Plot | VEG Sub Plot | Soil type[1] | Drainage | Percent of plot on haul trail | Site limitations | Percent of site with limitations | Relief |
|---|---|---|---|---|---|---|---|---|---|
| 5 | Group | 1 | 1 | ST3 | Imperfect | 30 | Stoniness | 50 | Hum/hollow |
| | | | 2 | | Imperfect | 0 | Nil | 0 | Flat |
| | | | 3 | | Imperfect | 0 | Slash | 30 | Flat |
| | | 2 | 1 | ST2 | Well | 0 | Nil | 0 | Hollow |
| | | | 2 | | Well | 100 | Nil | 0 | Hummock |
| | | | 3 | | Well | 50 | Nil | 0 | Hummock |
| | | 3 | 1 | ST3-G | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 10 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 4 | 1 | ST3-G | Well | 0 | Nil | 0 | Hollow |
| | | | 2 | | Imperfect | 0 | Slash | 20 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Hollow |
| | | 5 | 1 | ST3-L | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | 6 | 1 | ST2-L | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 7 | 1 | ST3-G | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |
| | | 8 | 1 | ST3-G | Well | 100 | Slash | 70 | Flat |
| | | | 2 | | Well | 20 | Slash | 45 | Flat |
| | | | 3 | | Well | 0 | Stoniness | 30 | Flat |
| 6 | Control | 1 | 1 | ST2-G | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |
| | | 2 | 1 | ST3 | Imperfect | 0 | Nil | 0 | Flat |
| | | | 2 | | Imperfect | 0 | Nil | 0 | Hum/hollow |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 3 | 1 | ST2-G | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Stoniness | 30 | Flat |
| | | 4 | 1 | ST2 | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Imperfect | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 5 | 1 | ST2 | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 6 | 1 | ST2-G | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Stoniness | 40 | Hummock |
| | | 7 | 1 | ST2-G | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 8 | 1 | ST2 | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |

| Block | Treatment type | MPP Plot | VEG Sub Plot | Soil type[1] | Drainage | Percent of plot on haul trail | Site limitations | Percent of site with limitations | Relief |
|---|---|---|---|---|---|---|---|---|---|
| 7 | Group | 1 | 1 | ST3 | Poor | 0 | Moisture | 0 | Flat |
| | | | 2 | | Imperfect | 0 | Moisture | 50 | Hum/hollow |
| | | | 3 | | Imperfect | 70 | Moisture | 60 | Hum/hollow |
| | | 2 | 1 | ST2-G | Well | 100 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Slash | 30 | Hummock |
| | | 3 | 1 | ST2 | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 20 | Nil | 0 | Hum/hollow |
| | | | 3 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | 4 | 1 | ST2-G | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Stoniness | 20 | Hum/hollow |
| | | 5 | 1 | ST2 | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 100 | Slash | 60 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |
| | | 6 | 1 | ST2 | Well | 0 | Slash | 50 | Hummock |
| | | | 2 | | Well | 40 | Nil | 0 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | 7 | 1 | ST2-G | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Slash | 40 | Flat |
| | | 8 | 1 | ST3-G | Imperfect | 0 | Stoniness | 30 | Hum/hollow |
| | | | 2 | | Imperfect | 60 | Slash | 80 | Flat |
| | | | 3 | | Imperfect | 0 | Nil | 0 | Hum/hollow |
| 8 | Clearcut | 1 | 1 | ST2 | Well | 0 | Nil | 0 | Flat |
| | | | 2 | | Well | 0 | Nil | 0 | Hum/hollow |
| | | | 3 | | Imperfect | 0 | Nil | 0 | Flat |
| | | 2 | 1 | ST2 | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Flat |
| | | | 3 | | Imperfect | 60 | Nil | 0 | Hummock |
| | | 3 | 1 | ST2-G | Well | 0 | Slash | 30 | Hummock |
| | | | 2 | | Well | 0 | Slash | 30 | Hum/hollow |
| | | | 3 | | Well | 0 | Nil | 0 | Hummock |
| | | 4 | 1 | ST2-G | Well | 0 | Nil | 0 | Hollow |
| | | | 2 | | Well | 0 | Slash | 40 | Flat |
| | | | 3 | | Well | 0 | Slash | 20 | Flat |
| | | 5 | 1 | ST2-G | Well | 0 | Slash | 30 | Hummock |
| | | | 2 | | Well | 0 | Slash | 40 | Hum/hollow |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 6 | 1 | ST2-L | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Slash | 30 | Flat |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 7 | 1 | ST2 | Well | 0 | Nil | 0 | Hummock |
| | | | 2 | | Well | 0 | Nil | 0 | Hummock |
| | | | 3 | | Well | 0 | Nil | 0 | Flat |
| | | 8 | 1 | ST2-G | Well | 0 | Slash | 40 | Hummock |
| | | | 2 | | Well | 60 | Slash | 80 | Hollow |
| | | | 3 | | Well | 0 | Slash | 50 | Hum/hollow |

[1] Soil types **ST2**: Fresh, Medium - Coarse Textured; **ST3**: Moist, Medium - Coarse Textured. Suffix “**G**”- granite phase, “**L**”- loamy phase (Keys, 2007)

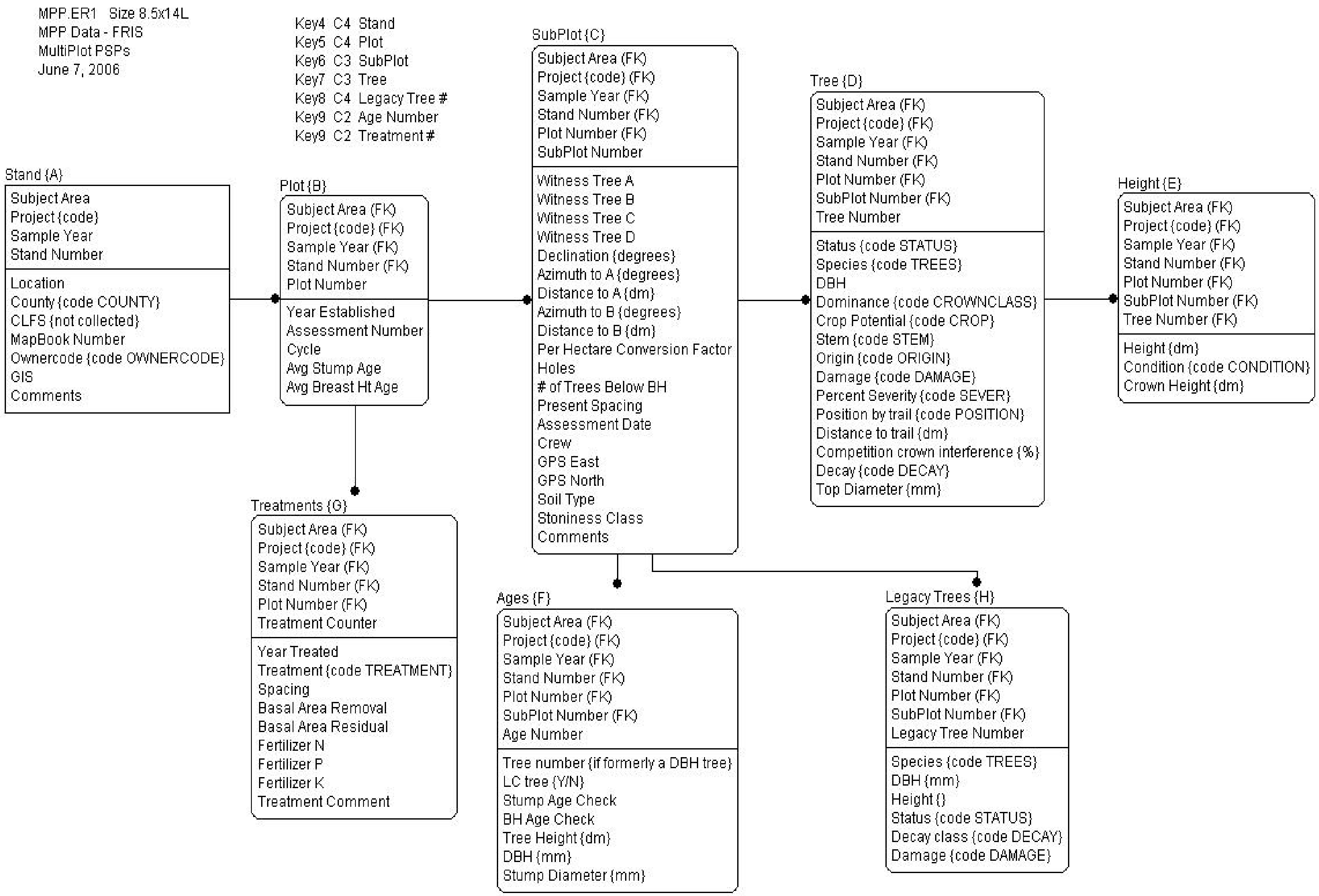
# APPENDIX III: Legacy Trees

(status, height, dbh measured July 2008)

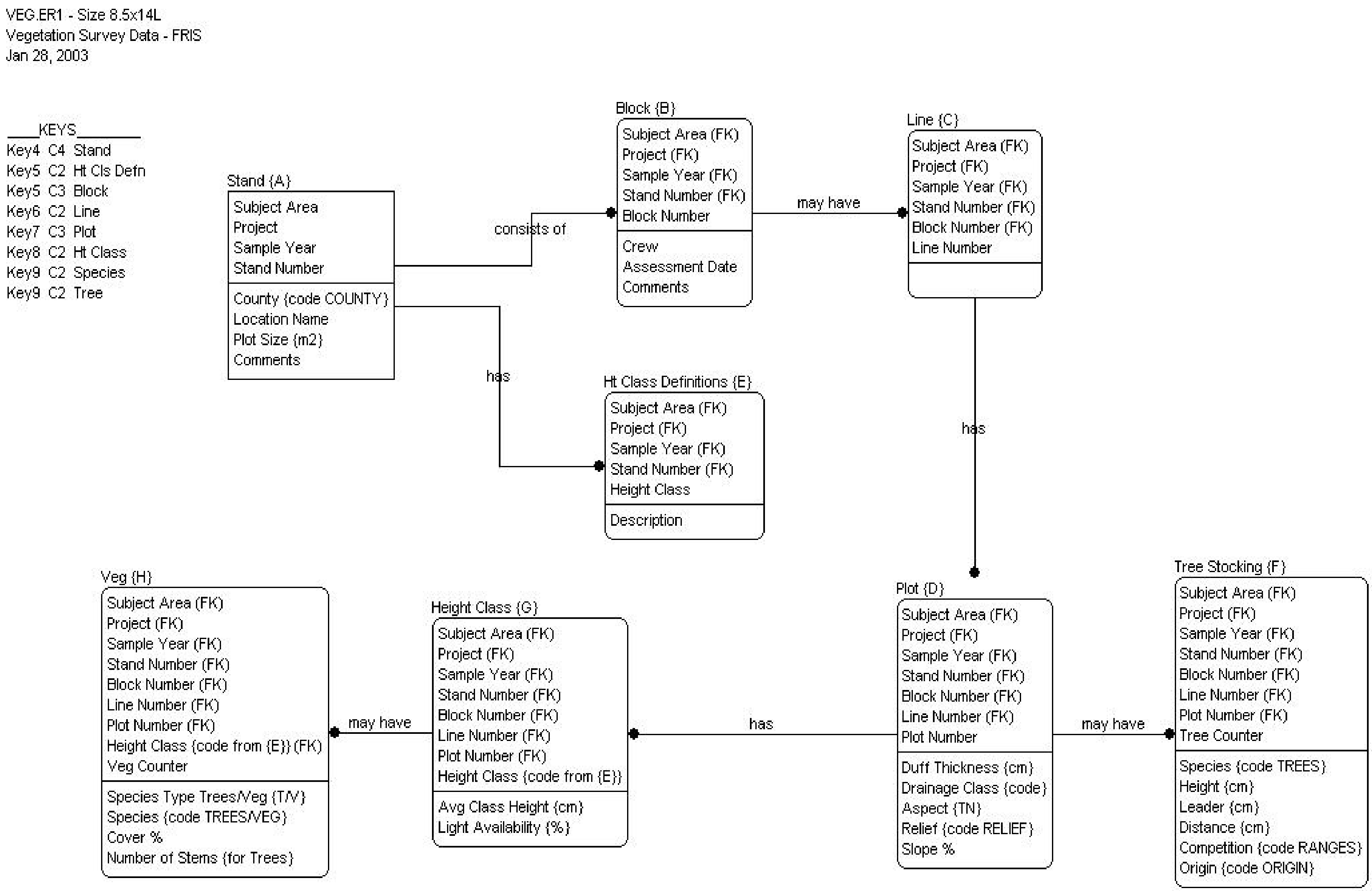
| Block | Tree # | Species | 2008 Status | Height (m) | DBH (cm) | Block | Tree # | Species | 2008 Status | Height (m) | DBH (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2** | 1 | Red Spruce | live | 19.7 | 49 | **5** | 1 | Red Spruce | cut | | 48 |
| | 2 | Red Spruce | live | 21.4 | 45 | | 2 | Red Spruce | live | 22.8 | 48 |
| | 3 | Red Spruce | live | 24.8 | 68 | | 3 | Red Spruce | down | | 48 |
| | 4 | Sugar Maple | live | 15.2 | 51 | | 4 | Red Spruce | live | 21.3 | 68 |
| | 5 | Red Spruce | live | 21.4 | 53 | | 5 | Red Spruce | live | 21.6 | 64 |
| | 6 | Red Spruce | live | 23.2 | 67 | | 6 | Red Spruce | live | 21.2 | 43 |
| | 7 | Red Spruce | live | 20.9 | 44 | | 7 | Red Spruce | live | 23.4 | 45 |
| | 8 | Red Spruce | down | | 52 | | 8 | Red Spruce | live | 19.2 | 44 |
| | 9 | Red Spruce | snag | | 57 | | 9 | Red Spruce | snag | | 66 |
| | 10 | Red Spruce | live | 18.6 | 48 | | 10 | Yellow Birch | live | 17.7 | 47 |
| | 11 | Red Spruce | down | | 49 | | 11 | White Pine | live | 22.2 | 53 |
| | 12 | Yellow Birch | live | 19.2 | 49 | | 12 | Red Spruce | live | 22.1 | 62 |
| | | **Average** | | **20.5** | **53** | | | **Average** | | **21.3** | **53** |
| | | **Total basal area ($m^2$/ha)** | | | **0.7** | | | **Total basal area ($m^2$/ha)** | | | **0.7** |
| | | **Percent of initial basal area** | | | **1.5** | | | **Percent of initial basal area** | | | **1.7** |
| **4** | 1 | Red Spruce | live | 20.4 | 42 | **7** | 1 | Red Spruce | down | | 48 |
| | 2 | Red Spruce | live | 24.3 | 48 | | 2 | Red Spruce | live | 18.9 | 43 |
| | 3 | Red Spruce | live | 21 | 49 | | 3 | Red Spruce | live | 20.3 | 50 |
| | 4 | Red Spruce | live | 20.1 | 50 | | 4 | Red Spruce | live | 17.3 | 45 |
| | 5 | Red Spruce | snag | | 52 | | 5 | Yellow Birch | live | 17.8 | 44 |
| | 6 | Red Spruce | live | 23 | 51 | | 6 | Red Spruce | live | 21.7 | 53 |
| | 7 | Red Spruce | live | 23.4 | 51 | | 7 | Red Spruce | live | 20.7 | 43 |
| | 8 | Red Spruce | down | | 43 | | 8 | Red Spruce | cut | | 41 |
| | 9 | Red Spruce | snag | | 46 | | 9 | Red Spruce | live | 22.4 | 53 |
| | 10 | Yellow Birch | live | 18.4 | 40 | | 10 | Yellow Birch | live | 18.3 | 57 |
| | 11 | Red Spruce | live | 23.6 | 58 | | 11 | Red Spruce | live | 21 | 54 |
| | 12 | Red Maple | live | 18.5 | 38 | | 12 | Red Spruce | live | 22.6 | 52 |
| | | **Average** | | **21.4** | **47** | | | **Average** | | **20.1** | **49** |
| | | **Total basal area ($m^2$/ha)** | | | **0.5** | | | **Total basal area ($m^2$/ha)** | | | **0.6** |
| | | **Percent of initial basal area** | | | **1.3** | | | **Percent of initial basal area** | | | **1.7** |

# APPENDIX IV: Erwin Diagrams for Forest Research Inventory System (FRIS)

Multiplot Permanent Plot ( MPP)



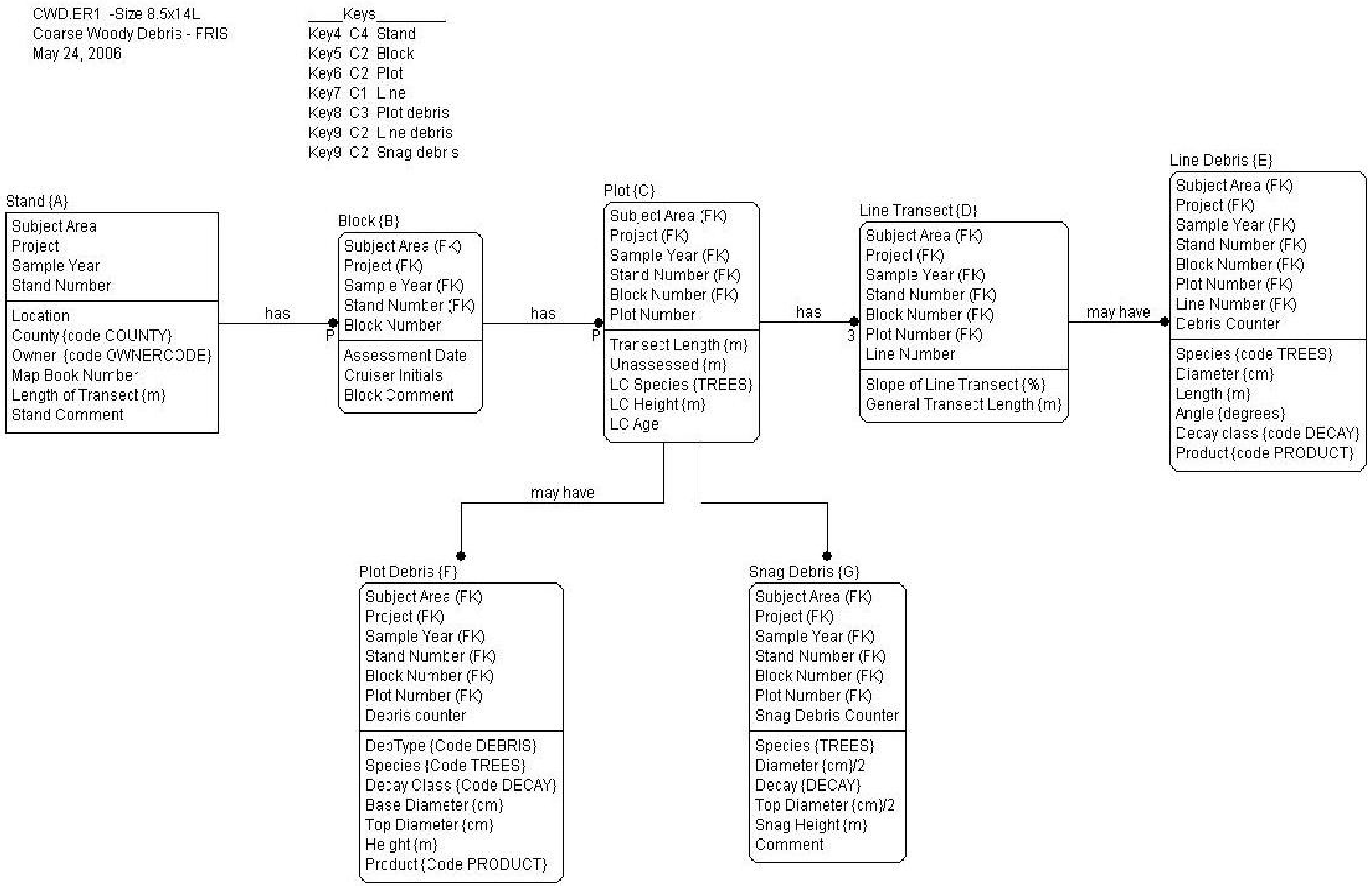
**APPENDIX IV (Cont'd)**
Erwin diagram for FRIS
Vegetation (VEG)



## APPENDIX IV (cont'd)

Erwin Diagram for FRIS

Coarse Woody Debris (CWD)



# APPENDIX V: Permanent Sample Plot Coordinates

**(UTM Nad83, Zone 20)**

| Block | Plot | Easting | Northing | Block | Plot | Easting | Northing |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 428480 | 4964480 | 5 | 1 | 428677 | 4964327 |
| | 2 | 428524 | 4964383 | | 2 | 428722 | 4964282 |
| | 3 | 428531 | 4964335 | | 3 | 428765 | 4964245 |
| | 4 | 428546 | 4964300 | | 4 | 428734 | 4964352 |
| | 5 | 428513 | 4964448 | | 5 | 428783 | 4964314 |
| | 6 | 428536 | 4964407 | | 6 | 428821 | 4964274 |
| | 7 | 428556 | 4964365 | | 7 | 428760 | 4964414 |
| | 8 | 428574 | 4964334 | | 8 | 428808 | 4964373 |
| 2 | 1 | 428528 | 4964547 | 6 | 1 | 428832 | 4964163 |
| | 2 | 428569 | 4964500 | | 2 | 428886 | 4964115 |
| | 3 | 428595 | 4964444 | | 3 | 428874 | 4964161 |
| | 4 | 428646 | 4964392 | | 4 | 428948 | 4964120 |
| | 5 | 428553 | 4964633 | | 5 | 428857 | 4964220 |
| | 6 | 428582 | 4964581 | | 6 | 428895 | 4964227 |
| | 7 | 428602 | 4964529 | | 7 | 428912 | 4964192 |
| | 8 | 428677 | 4964441 | | 8 | 428913 | 4964139 |
| 3 | 1 | 428831 | 4964593 | 7 | 1 | 428866 | 4963887 |
| | 2 | 428856 | 4964627 | | 2 | 428911 | 4963863 |
| | 3 | 428939 | 4964518 | | 3 | 428924 | 4963808 |
| | 4 | 428911 | 4964623 | | 4 | 428950 | 4963783 |
| | 5 | 428931 | 4964584 | | 5 | 428969 | 4963721 |
| | 6 | 428942 | 4964554 | | 6 | 428903 | 4963915 |
| | 7 | 428956 | 4964635 | | 7 | 428970 | 4963810 |
| | 8 | 428989 | 4964603 | | 8 | 429011 | 4963748 |
| 4 | 1 | 428630 | 4964110 | 8 | 1 | 429007 | 4963958 |
| | 2 | 428579 | 4964255 | | 2 | 429030 | 4963912 |
| | 3 | 428616 | 4964218 | | 3 | 429042 | 4963857 |
| | 4 | 428651 | 4964182 | | 4 | 429051 | 4963980 |
| | 5 | 428687 | 4964140 | | 5 | 429059 | 4963924 |
| | 6 | 428616 | 4964269 | | 6 | 429081 | 4963999 |
| | 7 | 428672 | 4964227 | | 7 | 429098 | 4963957 |
| | 8 | 428697 | 4964190 | | 8 | 429093 | 4963880 |

# APPENDIX VI: Decay Classes

General Description of the Bole Appearance Used to Assess Five Stages of Decay

**I.** Freshly dead, bark intact, branches intact (including small), needle/leaf retention, bole sound, bole raised off ground on branches

**II.** Beginnings of decay but rot not established in wood that was sound at time of death. Bark mostly intact, branch stubs, bole not raised on branches, bole mostly sound

**III.** Rot becoming established. Bark loose and mostly flaked off, bole beginning to rot but maintaining structural strength - round, straight, not sinking into ground

or

Mummified snag. Dry, hard, barkless rampike. Typical 1 or 2 decades following stand initiating disturbance such as fire or budworm.

**IV.** Advanced decay. Bark mostly absent, bole mostly decayed with some sound wood present. Colonized with vegetation. Lacking structural strength - bole oval and bending to shape of ground. Last stage for snags which will be rotted, wobbly, and could be easily pushed over.

**V.** Rotted through, becoming humus. Sunken into mound on the ground, but retaining a woody character, not yet part of forest floor.

Aerial view of block 8 looking southwest toward block 7 - taken October 4, 2006

# APPENDIX VII: Density of Regeneration

(Prior to initial harvest in 2000)

| Height Class (cm) | Species | 1 Control | 2 Single | 3 Clearcut | 4 Single | 5 Group | 6 Control | 7 Group | 8 Clearcut | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 - 5 | Red Spruce | 739,583 | 453,333 | 461,667 | 277,500 | 470,417 | 364,167 | 52,083 | 141,250 | **370,000** |
| | Balsam Fir | 35,000 | 115,833 | 57,083 | 40,000 | 73,750 | 16,250 | 6,667 | 12,500 | **44,635** |
| | Yellow Birch | 12,917 | 80,000 | 17,083 | 12,500 | 17,917 | 5,833 | 2,917 | 17,083 | **20,781** |
| | Red Maple | 11,667 | 5,833 | 13,333 | 11,667 | 13,750 | 5,833 | 19,167 | 14,167 | **11,927** |
| | **SubTotal** | **799,167** | **654,999** | **549,166** | **341,667** | **575,834** | **392,083** | **80,834** | **185,000** | **447,344** |
| 6 - 30 | Red Spruce | 5,833 | 18,750 | 0 | 1,667 | 417 | 2,500 | 417 | 0 | **3,698** |
| | Balsam Fir | 3,750 | 417 | 0 | 833 | 0 | 1,250 | 5,833 | 0 | **1,510** |
| | Red Maple | 2,917 | 833 | 0 | 833 | 417 | 0 | 2,083 | 0 | **885** |
| | Largetooth Aspen | 0 | 0 | 0 | 417 | 0 | 0 | 0 | 0 | **52** |
| | **SubTotal** | **12,500** | **20,000** | **0** | **3,750** | **834** | **3,750** | **8,333** | **0** | **6,146** |
| 31-130 | Red Spruce | 0 | 1,250 | 833 | 0 | 0 | 417 | 5,416 | 0 | **990** |
| | Balsam Fir | 417 | 5,833 | 4,583 | 30,000 | 833 | 15,833 | 33,750 | 4,167 | **11,927** |
| | Red Maple | 0 | 0 | 0 | 417 | 417 | 1,667 | 0 | 0 | **313** |
| | **SubTotal** | **417** | **7,083** | **5,416** | **30,417** | **1,250** | **17,917** | **39,166** | **4,167** | **13,229** |
| 131-400 | Red Spruce | 46 | 93 | 93 | 279 | 232 | 464 | 882 | 186 | **284** |
| | Balsam Fir | 0 | 372 | 1,950 | 2,043 | 325 | 1,300 | 1,950 | 697 | **1,080** |
| | **SubTotal** | **46** | **465** | **2,043** | **2,322** | **557** | **1,764** | **2,832** | **883** | **1,364** |
| 401-700 | Red Spruce | 372 | 93 | 232 | 279 | 0 | 325 | 232 | 418 | **244** |
| | Balsam Fir | 46 | 279 | 93 | 46 | 0 | 46 | 186 | 139 | **104** |
| | **SubTotal** | **418** | **372** | **325** | **325** | **0** | **371** | **418** | **557** | **348** |
| > 700 | Red Spruce | 139 | 186 | 46 | 139 | 418 | 232 | 0 | 93 | **157** |
| | Balsam Fir | 0 | 139 | 46 | 93 | 232 | 0 | 0 | 0 | **64** |
| | Yellow Birch | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **6** |
| | **SubTotal** | **185** | **325** | **92** | **232** | **650** | **232** | **0** | **93** | **226** |

# APPENDIX VIII: Average Cover of Vegetation

(By species and height class prior to treatment in 2000)

| Height Class | | | | | |
|---|---|---|---|---|---|
| 0-5cm | | 6-30cm | | 31-130cm | |
| Species | Mean cover (%) | Species | Mean cover (%) | Species | Mean cover (%) |
| Three-lobed bazzania | 10.73 | Bunchberry | 0.15 | Bracken fern | 0.23 |
| Schreber's moss | 5.05 | Sarsaparilla | 0.08 | Cinnamon fern | 0.05 |
| Broom moss | 3.39 | Painted trillium | 0.04 | | |
| Braided moss | 2.73 | Rose twisted stalk | 0.03 | | |
| Stair step moss | 2.08 | Indian cucumber root | 0.03 | | |
| Sphagnum | 0.91 | Wood sorrel | 0.03 | | |
| Fern moss | 0.28 | Sedge | 0.03 | | |
| Wavy dicranum | 0.16 | Starflower | 0.03 | | |
| Haircap moss | 0.15 | Wild lily of the valley | 0.02 | | |
| Shaggy moss | 0.11 | Ground pine | 0.02 | | |
| Plume moss | 0.02 | Indian pipe | 0.01 | | |
| Cup lichen | 0.09 | Cinnamon fern | 0.08 | | |
| Mnium | 0.01 | New York fern | 0.08 | | |
| Wood sorrel | 0.27 | Hay scented fern | 0.06 | | |
| Goldthread | 0.20 | Bracken fern | 0.05 | | |
| Wild lily of the valley | 0.13 | Wood fern | 0.03 | | |
| Partridgeberry | 0.02 | Blueberry | 0.06 | | |
| Painted trillium | 0.02 | Lambkill | 0.01 | | |
| Starflower | 0.02 | | | | |
| Indian cucumber root | 0.02 | | | | |
| Rose twisted stalk | 0.01 | | | | |
| Blue bead lily | 0.01 | | | | |
| New York fern | 0.01 | | | | |
| Wood fern | 0.01 | | | | |
| Blueberry | 0.01 | | | | |
| **Total** | **26.44** | | **0.84** | | **0.28** |