Western Boreal Growth and Yield (WESBOGY) Association

Long Term Study (LTS) of growth and development of mixed stands of spruce and aspen

Experimental Design, Data Collection and Database Maintenance Manual

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Version 4.2

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Changes included in this version of the LTS manual

This manual updates the previous (2013) version of the WESBOGY LTS manual.

In addition to a number of minor editorial changes, major changes include:

1) Updates to text to improve clarity and readability;
2) Update to introduction to include new literature with citations – Section 1;
3) Update to figure 1 to include 5 year measurement schedule after age 26/27 measurement – Section 3;
4) Update to include the use of high-resolution imagery for stem mapping - Section 7.8;
5) Clarification of measurement years for 3 year measurement intervals. “Measurements and Tending during Measurement Years 23 or 24, and 26 or 27” - Section 14;
6) Adoption of a 5 year remeasurement schedule after age 26/27 “Measurements and Tending after Measurement Years 31 or 32” – Section 15;
7) Modification of total height to define total height as vertical height – Section 17.3 Data Dictionary;
8) Addition of lean measurement for trees leaning more than 20°. Defined in the data dictionary – Section 17.3 Data Dictionary;
9) Agency name changes – Section 17.3 Data Dictionary:
    a. Mercer (MER) replaces Daishowa Marubeni (DMI) ;
    b. GOA replaces Alberta Sustainable Resource Development (SRD);
    c. Saskatchewan Big River (SBR) replaces Canadian Wood Fibre Centre (CFS).

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1 Introduction

Mixedwood stands, comprised primarily of mixtures of trembling aspen (*Populus tremuloides* Michx.) and white spruce (*Picea glauca* (Moench) Voss, are a prominent component of the boreal forest in Western Canada (Rowe 1972; DeLong et al. 1990). Mixedwood forests represent a range of early- to mid-seral successional stages (Chen and Popadiouk 2002) and develop most commonly on mesic and subhygric sites (Lieffers et al. 1996) where successional pathways are less predictable than on dry or wet sites (Andison and Kimmins 1999). When aspen and white spruce regenerate at approximately the same time following disturbance, aspen will form an overstory above spruce, except in gaps, for at least 50 to 60 years. After that time, white spruce begins to grow through the canopy and aspen decreases in dominance and basal area. In the absence of fire, wind, harvesting, or other large-scale disturbance, the mixedwood stand may become a spruce-dominated stand over the ensuing 100 to 200 years (Chen and Popadiouk 2002; Bergeron et al. 2014). White spruce may also establish naturally in the understory of mature aspen stands when there is spruce seed available from nearby seed trees (e.g., Kabzems and Garcia 2004). Under fully-stocked boreal mixedwood stands light levels reach minimum values between 10 and 25 years after disturbance (Lieffers et al. 2002), but increase to 15-20% of full sunlight or higher at around age 40, which is adequate to allow establishment of white spruce (Groot et al. 1997; Comeau et al. 2006).

There are a number of advantages to managing mixedwoods as such rather than attempting to convert them to pure white spruce or aspen stands. Mixedwoods support sustainable management objectives such as preserving species and structural diversity, protecting wildlife habitat and food, and preserving visual esthetics (e.g., Peterson and Peterson 1995; Comeau 1996; Macdonald et al. 2010). Yield (Kweon and Comeau 2019) and long-term site productivity may also be enhanced by the presence of aspen, which takes up nutrients and retains them within the system (Pastor 1990; Macdonald et al. 2010). The risk of attack by white pine weevil (*Pissodes strobi* Peck) (Stiell and Berry 1985; Alfaro 1996; Taylor et al. 1996) is lower in mixedwood than pure conifer stands. The risk of *Armillaria* root disease is also lower in mixedwood than pure conifer stands (Morrison et al. 1991; Gerlach et al. 1997). Overstory aspen is an effective nurse crop for young spruce through reducing the incidence of growing season frost and by providing protection from environmental extremes (Groot and Carlson 1996; Pritchard and Comeau 2004; Voicu and Comeau 2006; Filipescu and Comeau 2011) and an aspen canopy reduces the vigor of understory competitors such as bluejoint reedgrass (*Calamagrostis canadensis* (Michx.) Beauv.) (Lieffers and Stadt 1994; Constabel and Lieffers 1996; Groot and Carlson 1996; Groot 1999; Comeau et al. 2004; Voicu and Comeau 2006).

In addition to the biological advantages, economic benefits can also be derived by managing mixedwoods which, historically, have been underutilized in favor of more valuable pure conifer stands. Mixedwoods are currently increasing in value because they are a good source of high-quality fibre, because markets for aspen are expanding, and because they can potentially provide greater diversity of products than single-species stands (MacDonald 1996). White spruce is expensive and difficult to establish in pure stands following disturbance (Lieffers et al. 1996; MacDonald 1996), whereas mixedwoods may be easier to establish and may also produce higher quality spruce stems than result from more open growing conditions (Anon. 2000). Finally, overall yield from mixedwood stands may be higher than from single-species stands because of the physical, phenological, and successional differences in growth strategy that exist between aspen and white spruce (Man and Lieffers 1999; MacPherson et al. 2001; Comeau et al. 2005; Macdonald et al. 2010; Kabzems et al. 2016; Kweon and Comeau 2019).

Following harvesting of upland mixedwood stands, aspen generally regenerates vigorously from root sprouts and dominates during early stages of development of the subsequent stand. When conditions are ideal, aspen can regenerate to very high densities, sometimes exceeding 100,000 stems per hectare at age 2 (Steneker, 1976; Bella, 1986; Frey et al. 2003). However, self-thinning generally occurs rapidly due to the shade intolerance of this species and its susceptibility to drought and disease (Peterson and Peterson, 1992). Although there have been numerous studies dealing with aspen self-thinning, few are based on annual re-measurements beginning immediately after harvest and others are limited by the number of re-measurements. More commonly juvenile aspen mortality is represented using chronosequence data or partial datasets using periodic re-measurements (Pollard, 1971; Ek and Brodie, 1975; Bella, 1986). Although insight into the self-thinning of juvenile aspen has been obtained from these studies, we currently lack juvenile aspen mortality functions for growth modeling. The lack of these functions is a major limitation in modeling the dynamics of young aspen and mixedwood stands.

Although results from past studies are sometimes contradictory (Petersen and Peterson, 1992), in some stands early juvenile spacing of aspen can accelerate the growth of residual trees (Bickerstaff, 1946; Steneker, 1976; Perala, 1978), accelerating achievement of merchantable diameter and improving the quality of the stand. However, thinning of aspen (as with most other species) typically results in reduced total standing volumes at harvest (Bella and Yang, 1991). Rice et al. (2001) found that, while thinning of young aspen (5 to 15 years old) resulted in reduced gross stand volume, it did not significantly change merchantable volumes 15 years after treatment. They also found that thinning resulted in significant increases in diameter growth of the remaining trees. Height and height growth were increased by thinning in 3 of the 7 stands that they studied. In contrast, a study by Penner et al. (2001) found no benefit to thinning a stand with 4000 to 5000 stems per hectare at age 20, due to the fact that unspaced plots had self-thinned to densities (1000 to 2000 stems·ha^{-1}) similar to those of treated plots by age 36. During the 16 years following thinning to 1100 stems·ha^{-1} very little mortality was observed. In their study, frequency distributions of tree diameters 16 years after thinning showed substantial reductions in the number of trees in smaller size classes and only some increases in the numbers of trees in larger size classes on the good site.

Several studies demonstrate that aspen can reduce growth of overtopped white spruce when it is present at densities above about 1000 stems per hectare (Filipescu and Comeau 2007 a,b). Studies also indicate that reducing aspen densities can increase light levels (Comeau et al. 2006; Filipescu and Comeau 2007a) and spruce growth (Coopersmith and Hall 1999; Coopersmith et al. 2000; Bokalo et al. 2007; Kabzems et al. 2016). Treatments which reduce competition from aspen and other broadleaved trees can provide substantial increases in growth of white spruce (e.g. Lees, 1966; Biring et al., 1999; Biring et al., 2000; Jobidon, 2000; Pitt et al. 2004; Pitt et al. 2010; Pitt et al. 2015). Reducing aspen densities by removal of aspen using manual, mechanical, or chemical spacing treatments or removal of aspen around crop conifers, is widely used to improve growing conditions for white spruce. Studies in northern B.C. and Alberta indicate that light levels underneath aspen canopies are related to the basal area of aspen (Comeau et al. 2006; Lieffers et al., 2002). Comeau et al. (2006) suggest that maintaining total aspen basal area below 8 m^{2}ha^{-1} may provide near optimal conditions for growth of white spruce.

Competition has an immediate effect on diameter growth of conifers, while impacts upon height growth do not generally appear until severe competition levels are reached or competition remains at sufficient intensity for a period of time. As a result, the ratio of height to root collar diameter (HDR) increases in response to increases in level of competition (Tesch et al. 1993; Wagner et al. 1999; Coopersmith and Hall1999; Coopersmith et al. 2000; Opio et al. 2000). For white spruce, HDR values exceeding 55 to 60 are considered to indicate stress. In addition to competition, HDR is influenced by a range of environmental factors, including variations in spring, summer and fall growing conditions, soil resource availability, and stem sway and bending (Opio et al. 2000).

Despite substantial interest in mixedwood management, practical experience and long-term data on outcomes of different management practices in the western boreal are limited. The WESBOGY long-term study was initiated in 1990 in response to an identified need for information on the effects of aspen density on spruce and aspen growth. Results from measurements at age 9 in 4 installations are presented by Bokalo et al. (2007) and describe growth responses of both the aspen and spruce to precommercial thinning treatments that reduced aspen densities to different levels. This analysis indicated no significant effects of density on aspen size and no significant effect of aspen density on spruce height at year 9 (3–4 years after spacing). However, spruce root collar diameter (RCD) was significantly smaller in the unspaced compared to the spaced plots and the ratio of height to root collar diameter (HDR) for white spruce increased with increasing aspen density. Preliminary analysis of more recent data is indicating aspen growth responses to thinning as well as larger responses of the planted white spruce and more differentiation between treatments.

This document describes a long-term regional study of tree and stand development under controlled densities for aspen and white spruce. The objectives are to assess total and individual species productivity in the various densities and mixtures. Data on early stand growth, mortality and crown dynamics will be used in development of the Mixedwood Growth Model (MGM) and other models and results will be used to guide management practices.

This long-term research project is a regional cooperative effort by industrial, federal, provincial, and university researchers to evaluate the dynamics of mixedwood stand development following precommercial thinning. The long-term study is regional in scope and "forward looking" as it is based on the premise that future practices will be more intensive than those used today. In this sense it is not restricted to current operational management constraints and regulations.

The basic long-term study design calls for establishment and maintenance of installations throughout the region by the participants. The experimental design is based on the need to evaluate the effects of density and species mixture on growth and yield and crown dynamics in the boreal mixedwood. Now that this network of plantations is established, we foresee that the data and stands will be useful in studies of a wide variety of other ecological and mensurational questions related to mixedwood plantations.

2 Experimental Design

The long term study uses a randomized block design with each company or agency setting up and maintaining one block. Each block consists of two installations, one on a superior site and one on a median site. Effectively this means that the experiment for each agency (block) can be analyzed separately or in combination with other installations. Each installation has two replications of a series of 15 plots as described in Table 2-1.

Table 2-1. Experimental design for a block of plots.

Installation	Replication 1	Replication 2
Superior Site Installation	15 Plots	15 Plots
Median Site Installation	15 Plots	15 Plots

Guidelines for selection of installations are given below. Even though there will be variation in the interpretation of superior and median site, measurement of productivity using Site Index or other methods will be possible. For this study white spruce seedlings are planted in recent clearcut areas where aspen is already established. Square plots are used with buffers between plots.

A number of characteristics (constant conditions) will be considered fixed for this experiment. Microsite weeding and tending will be done annually within a 0.5 m radius of the spruce up to and including year 5. Within the 0.5m radius, all competing vegetation (trees, shrubs, and grass) will be removed once each year. Grass will be clipped and removed in mid-summer. There will be no fertilization. Repellent to reduce damage by rabbits or deer may be used in problem areas. Local seed sources and nurseries will be used for procurement of seedlings.

Two independent variables (treatments) are based on density levels of aspen and spruce. Aspen density will be at six levels -- 0, 200, 500, 1500, 4000 / ha and natural (unthinned). Spruce density will be at three levels -- 0, 500, and 1000 / ha. Initial planting of spruce will be at two densities (1000/ha and 2000/ha) corresponding to the low and high treatment densities for spruce. At Year 5, spruce and aspen will be thinned to treatment densities assigned to each plot; the objective is to achieve desired densities but retain potential crop trees with relatively uniform spacing. At 50 years, the stands will be assessed to determine harvest time for the aspen.

Table 2-2 illustrates the combinations of spruce and aspen densities to be established and measured, and the plot number associated with each treatment. For example, plot 9 will have a white spruce density of 500 stems per hectare and an aspen density of 500 stems per hectare after thinning. Note that the physical location of treatments (plot numbers) must be randomly assigned.

The wide range in aspen densities being created in this study is considered desirable so that interactions between the species and the timing of interactions are more likely to be detected. The sixth density level for aspen will be based on natural (untreated) regeneration density levels; this "control" level will permit evaluation of the three spruce density levels in natural stands of aspen. Cells for three treatment combinations in this table (0 spruce with 0, 200, 500 aspen) are not used since they represent unreasonable densities for a pure aspen stand.

Table 2-2. Plot numbers associated with spruce and aspen treatment densities.

	AW density (#/ha)					
SW density (#/ha)	**0**	**200**	**500**	**1500**	**4000**	**Natural**
1000	1	2	3	4	5	6
500	7	8	9	10	11	12
0	x	x	x	13	14	15

NOTES:
1. Plot numbers (1-15).
2. Empty cells (X) for extreme density combinations that are not of interest.
3. Row headers show spruce (SW) density; column headers show aspen (AW) density.
4. For each installation 30 individual plots are required.

The long-term study is designed to evaluate the effect of spruce and aspen density levels on the development of plantations from establishment to final harvest. Growth and yield (variables are listed below), mortality, crown size and shape, and spatial distribution will be measured and used in the development of a quantitative model of stand development. In addition, regional and site variation will be quantified.

3 Determining Tree Age and Measurement Year

The year and season the original aspen stand was harvested and the season and stock type of the spruce planted determine the biological age of the spruce and aspen and influence the schedule upon which treatments and measurements are made.

To ensure that all agencies are following a common treatment and measurement schedule, each agency has assessed the establishment of their installations and fixed the age of the aspen and spruce relative to the first measurement (1 full growing season after establishment). This standardized year is defined as “Measurement Year 1” which then must be related to calendar year. This process explicitly links calendar year to measurement year and assigns the correct age for the spruce and aspen into the future, ignoring replants and ingress. Note: an establishment survey, carried out at the time of planting, is referred to as “Measurement Year 0”. Nevertheless, some agencies did not carry out establishment measurements.

Because this process was not done initially (at the time of planting of the spruce), the age of the aspen and spruce relative to the timing of each treatment varies slightly from agency to agency. Appendix 17.1 presents the results of the assessment process by agency and installation. The table relates calendar year to measurement year considering all factors including year and month of aspen harvesting, year and month of spruce planting as well as stock type (if known).

There are 3 important points in time to consider when discussing the establishment and maintenance of an installation. These are: 1) the year the aspen was harvested; 2) the year the spruce was planted; and, 3) the year the spacing to treatment density was carried out. These all have important implications when reporting on growth responses.

To determine biological age of the aspen and spruce consider factors such as:

- AW - Summer logging versus winter logging and month. Harvesting before August 1st - aspen is assumed to have completed a full season of growth by the fall measurement. Harvesting after August 1st - aspen is assumed to have not completed a full season of growth by fall the measurement.
- SW - Stock type and season of planting should be considered when determining age. August 1st is cutoff date for spruce. For example, 1 – 0 stock planted in spring is 2 at the fall measurement, 1 - 0 stock planted in the fall (after August 1) is considered to have an age of 1 in the fall of that year and 2 in the fall of the following year.

Figure 3-1. Timing of measurements relative to assessed measurement year.

Measurement Year 0
Plot establishment
Establishment Survey, Site and Soils

↓

Measurement Years 1-3
Regular deciduous measurements for subplots (6,12,15)
Regular SW measurements

↓

Fall of Measurement Year 4
Regular deciduous measurements for subplots (6,12,15)
Regular SW measurements
AW "crop trees" tagged and measured

↓

Winter of Measurement Year 4 to Spring of Year 5
Thin to treatment density
After thinning verify condition code for both SW and AW

↓

Fall of Measurement Year 5
First measurement after thinning for both SW and AW
Subplots in plots 6,12,15 expanded to 2x2 then measured
Top Height Measurements begin for plots 6,12,15

↓

Measurement Years 6 -10
Regular annual measurements for both SW and AW
Vegetation assessments in Measurement Years 6 and 10
Top Height Measurements for plots 6,12,15

↓

Odd Measurement Years 11, 13, 15, 17, 19
Continued annual measurement of <u>only</u> the subplots in Natural AW plots (plots 6,12,15)
Top Height Measurements for plots 6,12,15

↓

Even Measurement Years 12, 14, 16, 18
All tagged trees in all plots measured
Vegetation in Measurement Year 16
Top Height Measurements for plots 6,12,15

↓

Fall of Measurement Year 20 or 21
All tagged trees in all plots measured (both SW and AW)
Subplots in plots 6,12,15 expanded to 5x5m then measured
Top Height Measurements for plots 6,12,15

↓

Fall of Measurement Year 23 or 24, and 26 or 27
All tagged trees in all plots measured (both SW and AW)
Top Height Measurements for plots 6,12,15

↓

Fall of Measurement Year 31 or 32 (and at subsequent 5 year intervals)
All tagged trees in all plots measured (both SW and AW)
Top Height Measurements for plots 6,12,15

4 Installation Establishment and Measurements for Measurement Year 0

4.1 *Installation Selection*

Each Agency will be responsible for the establishment, tending and measurement of one block of installations. Documentation of installation location and measurement procedures are based on a combination of the various permanent sample plot procedures already used by participating agencies (Munn-Kristoff, et al. 1988).

Both replications for each installation should be on a common soil type. Each replication requires a minimum area of 1.35 - 2.4 ha (depending on width of buffer discussed below) with relatively uniform physical (slope and aspect) conditions, which has been cutover within about 24 months of setup date, and with evidence of uniform natural aspen regeneration (>4000/ha). Height of aspen regeneration should be less than 1.5m; aspen height below 1.5m will ensure that competition has not become a serious factor for survival of planted spruce. Variation in location of landings, skid roads, and access roads may require separation between plots or groups of plots. As a consequence, each replication may require much more than the nominal area. Large scale photography, acquired after harvesting, may assist in preliminary location of individual plots within the cut block. Convenient (all weather) access is desirable.

The following checklist is provided to summarize desirable conditions for plots:
1. Evidence of uniform aspen regeneration > 4000 trees per ha,
2. Mid or upper slope position with slope less than 30 per cent,
3. Uniform soil conditions over the entire replication,
4. Similar aspect to other plots in the replicate and installation.

It is suggested that after plots are located, but before completion of the setup, a soil scientist or ecologist be consulted to ensure that there are no hidden, major differences in the soil and site conditions among the plots.

Wherever possible, a formal reservation should be placed on the installation area both within the agency and with the corresponding provincial land management agency. Where appropriate, activities should be coordinated with the local provincial managers and with other companies working in the forest management unit to avoid conflict with established reforestation requirements.

4.2 *Plot and Buffer Establishment*

Treatment plots and buffers are located within each cutblock avoiding landings, skid trails and access roads.

4.2.1 Treatment Plots

Plots are square with 20 m sides and 28.3 m diagonal (0.04 ha) with corners and the center permanently marked. This size will ensure adequate numbers of trees are present in the plots over the entire life of the study (8-40 spruce and 20-160 aspen trees at harvest time). Small subplots will be established in the natural density aspen plots to describe early growth and survival of aspen. Buffers will also be established around each plot as described below.

4.2.2 Buffer strips

Treatments and activities applied to the plot are also to be applied in a buffer around each plot. A buffer is desirable to minimize aboveground and belowground influences on a treated plot from outside vegetation (or natural conditions) since these conditions may be very different from the treatment within the plot.

Strong and LaRoi (1983) reported radial root spread of spruce trees growing in mixed aspen/spruce stands ranging from 4 m at age 20 to 8.4 m at age 58. Voicu and Comeau (2006) report that influences on soil moisture and light levels likely to impact spruce growth extend over a distance less than 40% of the height of adjacent aspen stands. Based on these preliminary results, it appears that a 5-10 m buffer should be adequate. The difficulty with a wider buffer is the cost of treating large plots; area for plots with a 10 m buffer (0.12 ha) is more than double that of a 5 m buffer (0.05 ha). In addition, larger homogeneous areas are required for the plots. For convenience of layout and maintenance it is probably better to use either 5 or 10, not a value between these limits (
Table 4-1).

A 10 m buffer on each of the 4 sides of the treatment plot is preferred to minimize possible influences from sources outside the treated area. Unfortunately, cost is a major consideration and therefore some participants may be forced to consider using a 5 m buffer. The final choice will be made independently by each participant for their installations.

The activities required to establish and maintain the buffer should follow the procedures applied to the plot with the exception that <u>tree measurements are NOT to be taken in the buffer</u>. This means that if spruce trees are planted in the plot then the buffer should include planting of spruce at the same density and spacing. Tending around the spruce trees is applied in the buffer as well as in the plot. When thinning to aspen treatment density occurs, the buffer area must be thinned as well. <u>The general rule is that any treatment or activity applied to the plot should also be applied in the buffer</u>.

Table 4-1. Specifications for two alternative buffer zones.

5 m buffer	**10 m buffer**
30 x 30 m treatment plot (0.09 ha)	40 x 40 m treatment plot (0.16 ha)
0.05 ha buffer area; reduced cost	0.12 ha buffer area; greater cost
1 row of conifer planted in buffer; less plot insulation; if aspen is the dominating influence this may not be so significant	2, 3 rows of spruce planting; better plot insulation
easier to locate 30x30 m homogeneous areas	40x40 m areas more difficult to locate
root extension into the plot from trees located outside the buffer is likely by age 50 years	root extension into the plot from trees located outside the buffer is not likely
shading more likely from external sources	shading less likely from external sources
litter deposit more likely from external sources	litter deposit less likely from external sources

4.2.3 *Plot numbering*

Plot numbers (1-15) should be randomly assigned to the plot locations after they have been established on the ground. This in turn assures random assignment of aspen and spruce treatment densities to particular physical locations in each installation.

4.2.4 *Surveying Plot and Buffer Corners*

Record distance and azimuth, or UTM coordinates, from a permanent monument to the plot center. Record actual azimuths and distances from the plot center to plot and buffer corners. The plot center, plot corners, and buffer corners will be identified using aluminum or steel posts (recommended: 16 gauge tubing, 4' long). Treatments and associated plot numbers must be randomly assigned to a physical location. Posts will be color coded: center -- red; plot corners -- blue; buffer corners -- white.

While orientation of the plot along cardinal directions is ideal, other orientations are acceptable. The following procedure is based on the AFS PSP Procedures (Alberta Forest Service 1990, section 2.1.1) and assumes that plots are oriented along the cardinal directions.

Locate the plot center post. With a Staff compass (Brunton Pocket Transit or transit) set up at the plot center, locate the plot and buffer corner posts using the following azimuths and distances (Table 4-2). Be sure to remove the metal center post if it is not aluminum. Verify the location of corners by measuring the lengths of each side of the plot. The length of each side should be 20 ± 0.15 m. If not, relocation of corners is required.

Table 4-2. Azimuths and distances from center to plot and buffer corners.

Corner	**Azimuth (degrees)**	**Distance (m)**
NE	45	14.14
NE Buffer	45	21.21(5m); 28.28(10m)
SE	135	14.14
SE Buffer	135	21.21; 28.28
SW	225	14.14
SW Buffer	225	21.21; 28.28
NW	315	14.14
NW Buffer	315	21.21; 28.28

4.3 *Planting and Tree Numbering of Spruce Trees*

This applies to all plots planted with white spruce (ie. all plots except plots 13, 14, and 15).

Plant local source (wild seedlot collections) spruce at 2000/ha initial density for the high density plots (plots 1-6). Plant local source spruce at 1000/ha initial density for the low density plots (plots 7-12). Planting lines should be marked prior to planting to ensure that lines fall within the plot boundary. The same stock should be used throughout each installation. Early planning for acquisition of sufficient planting stock is essential.

Seedling requirements (10m buffer):
2880 / replication = (6 plots x 0.16ha x 2000/ha) + (6 plots x 0.16ha x 1000/ha)
5760 / installation
11520 / agency (two installations).

All spruce trees within the 20m x 20 m measurement plots (720 per replication) are to be numbered and tagged, when planted, using a six digit code consisting of the row number (2 digits), tree number (2 digits) within the line, and with two additional digits coded as "00" digits to indicate ingress between planted stock (in anticipation of ingress). Trees are numbered sequentially along the planted rows. Odd numbered rows are numbered in a south to north direction, while even numbered rows are numbered in a north to south
Figure 4-1 and Figure 4-2). Pigtails or other metal stakes should be placed in the ground on the west side of each tree (again, consistency between agencies is desirable). The first line of spruce is that along the west boundary of the plot. From the time of establishment until year 5 when the thinning is undertaken, only the spruce trees are measured (except aspen in natural plots 6, 12 and 15). Note that trees in the buffer areas around the measurement plot area are not tagged or measured.

Figure 4-1. Numbering white spruce on high density (plots 1-6).

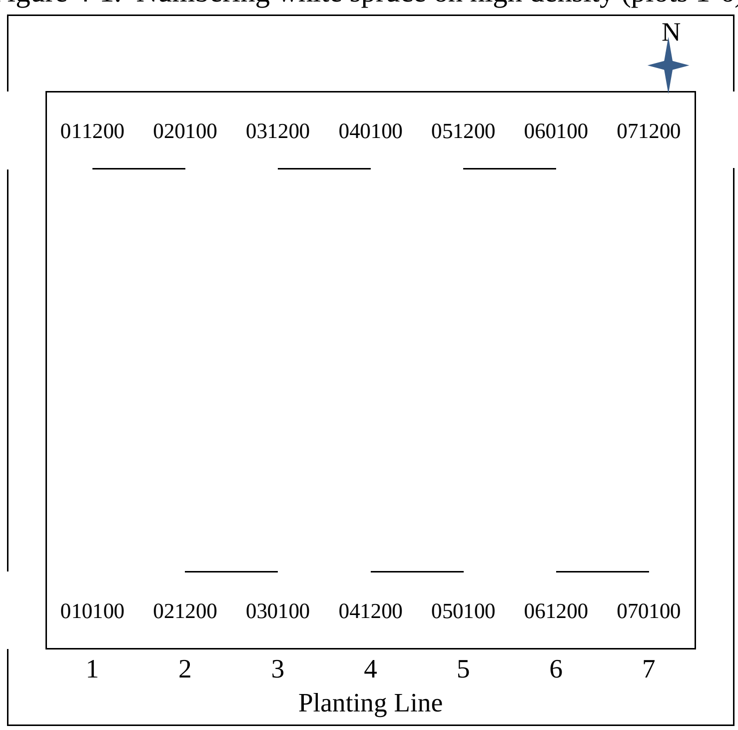
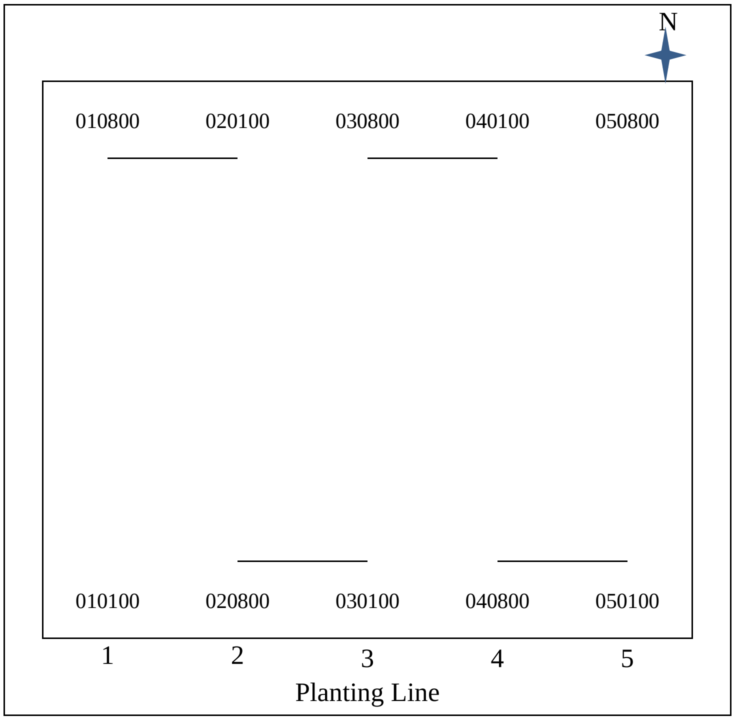


Figure 4-2. Numbering white spruce on low density (plots 7-12).



4.4 *White Spruce Plot Establishment Measurements*

All spruce are to be measured in the fall (August-October) of the year of plot establishment. This is referred to as the "Establishment Measurement" and describes the tree characteristics of the growing stock immediately after planting. Note: An "Establishment Measurement" was not completed by all Agencies. The LTS data dictionary (Section 17.3) describes the tree measurements and related variables.

4.5 *Natural Density Aspen Subplots (plots 6, 12, and 15)*

Since aspen sprouting occurs well into the early life of the stand and early patterns of aspen growth are not well documented, it is desirable to take measurements on some aspen trees during this early development period. Because aspen establishes at high (even excessive) densities and due to the high cost of tree measurements, small subplots are required to keep the number of aspen trees measured at an acceptable level. For this reason, up to the time of thinning to treatment density, aspen are only measured in subplots of the natural aspen density plots (plots 6, 12 and 15).

At plot establishment, the main 20x20m plot is partitioned into four 1x1m subplots within the SW ¼ of the main plot as shown in Figure 4.3.

Subplots are numbered 91, 92, 93 and 94. The remaining ¾ of the 20x20m plot is numbered 95. All hardwood trees (aspen, balsam poplar, and paper birch) are consecutively numbered and tagged in each subplot using a six-digit code consisting of the subplot number (2 digits, in place of row number) and tree number (4 digits). Record Type is used to indicate the subplot size on the tree data form. Valid Record Types (RTYP) are summarized in Table 4-3.

Table 4-3. Un-thinned plots (6, 12, and 15): subplot size and expansion summary.

Year	**Size (m)**	**Area (ha) per subplot**	**Record Type(s)****	**Figure**
1	1x1	.0001	11	5-3
5	2x2	.0004	22 + 11	8-1
20 or 21	5x5	.0025	55 + 22 + 11	14-1 14-2
*	20x20	.0400	66 + 55 + 22 + 11	
* Not implemented until density declines further				
** To indicate that expansion is cumulative. For example, for trees with numbers 92xxxx and Record Type 22, plot size is .0003 ha. Trees with numbers 92xxxx and Record Type 11, are the set of trees found on the 1x1 m (.0001 ha) subplot. The total count of trees in these two sets is the count of trees on the .0004 ha subplot 92.				

Figure 4-3. Un-thinned plots (6, 12, and 15): 1x1 m subplots. The 1x1 m subplots are indicated by the shaded area. Trees within the 1x1 m subplots (shaded) are numbered 91xxxx, 92xxxx, 93xxxx, 94xxxx as needed.

4.6 *Aspen Subplot Establishment Measurements*

All aspen in the four 1x1 subplots established in plot 6, 12 and 15 are to be measured immediately after plot establishment. The LTS data dictionary (Section 17.3) describes the tree measurements and related variables.

4.7 *Plot Photos*

During the measurement of each plot, photos are to be taken from the SW corner post of the plot towards the plot center post. A second photo is to be taken from the NE corner post of the plot towards the plot center post (Figure 4-4). Upload the digital photographs onto your agency folder in the Wesbogy shared drive under LTS photos. The digital photo naming convention is as follows:

Agency_year_installation_replication_plot#_SWorNE

e.g.   LPCSR_2008_SUP_REP2_plot01_NE.jpg

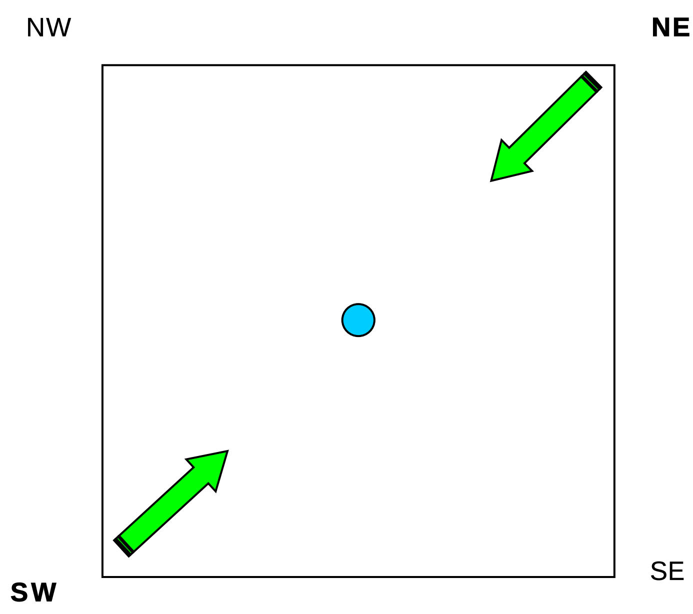


Figure 4-4. Photograph each plot from the south-west (SW) and north-east (NE) corner posts, towards plot center (depicted by green arrows).

4.8 *Plot Tending*

Clean and weed the micro-site (0.5 m radius) for first 5 years around each spruce in both plot and buffer. Remove (by cutting) all competing vegetation (trees, shrubs, and grass) in mid-to-late summer (after completion of growth) including removal of dead grass material. Record in the journal the approximate number of hardwood trees removed at each visit as well as removal method (hand/brush saw), cost and time. The purpose of the cleaning and weeding is to ensure that planted spruce trees are given the best possible chance to survive over the course of the experiment. This treatment will be applied to all plots (including natural density aspen plots 6 and 12), **EXCEPT** plots with no planted spruce (plots 13 and 14) and the completely untreated plot (plot 15).

4.9 *Installation and Plot Location Maps*

Location and access should be completely documented using a series of maps of different scales to assist in locating each of the installations and tie points. The maps should be supported by written directions outlining access from a major village/town/city and major tie points. The maps and written descriptions have two main purposes. The first is to provide adequate directions for a person not familiar with the study area to locate the cutblock containing a replicate of plots. The second purpose is to illustrate the location of the 15 plots within the cutblock, relative to one another.

Three maps are recommended: small scale, medium scale and large scale.

1) A small scale map (approx. 1:50,000) showing the relative location of the installation relative to towns/cities with major highways and roads marked with an (E). Also include road names and distance to the nearest town or significant tie point.

2) A medium scale map (approx. 1:15,000) of the area. The map should show all seismic lines, trails, creeks, lakes, roads, cutblocks, and any other pertinent features. Each plot within the cutblock should be clearly marked. Most importantly, tie points used in the large scale map should be clearly identified on this map for reference purposes. Also include road names and distances to the nearest town or significant tie point .

3) A large scale map (approx 1:1500) showing plot locations and their relative position to one another. The map should clearly identify replication and plot number. Distances and directions or GIS coordinates should be recorded from each plot to other plots and/or a natural or man-made tie point. Acceptable tie points are:

    - Where roads cross creeks, i.e. culverts or bridges
    - The center of road junctions
    - Where transmission lines cross roads
    - The point where roads pass into cutblocks

    Tie points with distances and azimuths should be clearly identified on the map (E)? along with written descriptions. The maps initially may be hand drawn but later should be digitized into a GIS.

Aerial photographs or orthophotos for reference are desirable, and if possible, they should be recent photos taken after the site was harvested.

4.10 *Site and Soils*

Site, soil and vegetation information is required to provide descriptive information on the ecological characteristics of each replication. Data collection will use forms and standards presented in the ASRD (2003) "Ecological Land Survey Site Description Manual (2nd Edition)", with modifications as described below. At establishment or soon after, site and soil information should be collected. (Unless desired for other purposes, vegetation assessments are completed starting in year 6 as described in 8.4) The manual and forms are available on the WESBOGY Shared Drive.

Site Information

For each replication, one site form should be completed (at the soil pit). The Ecosite to which the replication belongs should be described under "Vegetation Classification" using the field guide that is appropriate for the location of the installation. Be sure to record the field guide that was used. The Access database has a Site Description Table for the input of the site information.

Soils

One soil pit should be established for each replicate. The soil pit should be located in a representative untended area, adjacent to but outside of any of the plots. The pit should be filled in and clearly marked for future excavation. Soil samples are not required unless needed to confirm soil classification or soil textures.
The Access database has two tables for data input of the soil information: Soil Description Table and Soil Horizon Table.

4.11 *Site Index of Adjacent Reserve Blocks*

An estimate of the site productivity for each of the WESBOGY installations and/or replications is required in order to predict future stand structure and yield as well to provide a benchmark of past growth and yield to which current growth and yield can be evaluated. The most accurate estimate of site index for any installation would be from the cutblock's pre-harvest assessment. If a pre-harvest assessment was not done, or these data are not available, there are several alternative options available to obtain a site index estimate. The most desirable method is to estimate site index from the reserve block (the same stand) adjacent to the installation. If this option is available then care must be taken to ensure that the ecosite of the reserve block is similar to that of the WESBOGY installation. The final option, and least desirable is to obtain the site index from a stand in the proximity of the WESBOGY installation although care must be taken to ensure that the ecosite (at least soil moisture regime and soil nutrient regime), topographic position, parent material, soil texture, and soil drainage of the stand is similar to that of the WESBOGY installation. It is assumed that both replications within an installation are on similar ecosites, if this is not the case it is suggested that each replication have an estimate of site index taken from a representative reserve block.

Plot Selection:

Randomly establish 5, 100m^2 circular plots (r = 5.6408m) in the reserve block or proximal stand. A detailed written assessment of the applicability of the SI plot to the WESBOGY site should be made. It is understood that this may be a very subjective assessment, but this will provide valuable insight in the future when we are comparing actual site index to previous estimated site indices. Plot centers should be GPS'd to identify plot locations. Detailed stand summaries and locations should be provided in written form. GPS files and any field notes should be uploaded to the WESBOGY Shared Drive.

Candidate Tree Selection:
Within each plot select the tree with the largest DBH. The candidate should be representative of the stand and not a wolf tree or tree with a broken top. The target species are white spruce and aspen so if a particular plot lacks an appropriate candidate another plot should be randomly selected. Note: many of the pre-harvest stands had a very small component of white spruce or no spruce therefore it may be impossible to obtain a white spruce site index.

Tree Measurements:
Record DBH, stump diameter, total height, and age at breast height (extracted using an increment borer 1.3m above average ground level). Digital data should be uploaded to the WESBOGY Shared Drive.

Site Index Estimation:
Site Index should be estimated using an average of the 5 ages and the 5 heights and a regionally approved set of site index equations.

Database Input:
The current Access database has a "Site Index Table" with fields for "SITE INDEX AW" and "SITE INDEX SW" and fields for a site index comment "SI_AW_C" and "SI_SW_C" . The site index comment field permits the input of codes to describe site index collection methods. The following are the allowed codes:

- PH – preharvest assessment
- RB – reserve block
- PS – proximal stand
- HA - actual height age estimation

This table has 4 records, one for each replication. It is possible to have up to 4 unique site index values, one for each combination of installation (MED and SUP) and replication (REPL 1 and 2). We leave the decision of how many Site Index estimates are needed to each agency since this is dependent on many factors.

4.12 *GPS locations*

Accurate Global Positioning System (GPS) information for each WESBOGY Long-Term Study plot will provide valuable information for communication with other resource users and an easy way for navigating in WESBOGY installations. The GPS locations are not intended to replace maps and photos but rather to complement them.

Measurement Units: Universal Transverse Mercator (UTM) NAD83 with Zones with ±3m error tolerance.

1) Primary access tie point (PATP_North and PATP_East). This point represents a general access point to a **replication**. This point should be vehicle accessible (ie. where one would park their vehicles). The point must be a feature that can be observed on a map, photo and in the field. Normally, a replication of plots would have a single primary tie point.

   Primary access tie point comment (PATP_C). Brief description of location and helpful notes.

2) Secondary access tie point (SATP_North and SATP_East). This point identifies the trail head or line that should be followed into the field to locate the nearest plot center.

   Secondary access tie point comment (SATP_C). Brief description of location, notes on where this path or line will lead to as well as helpful notes.

3) Plot Centers (UTM_North and UTM_East). This point identifies the plot center of each plot.

4) UTM zone should be put into field UTM_Zone.

5) The Primary, Secondary and plot center GPS coordinates should be identified on the access maps.

6) There are also fields for latitude and longitude coordinates (LAT and LONG) (filling these in is optional).

Database Input:
The current Access “GPS Coordinates Table” contains a record for each plot. This table has 60 records, one for each installation, replication and plot combination. It is possible to have up to 4 unique, PATP and SATP GPS coordinates, one for each replication. The comments for the primary and secondary tie points can be input into the PATP_C and SATP_C fields. Each plot center will have its own unique GPS coordinate (UTM_North, UTM_East).

4.13 *Plot Maintenance*

Any aspen and spruce trees that existed in the stand prior to harvest are considered veterans and should be removed. Any ingress conifers that have naturally regenerated in any of the plots since harvest should also be removed. The only conifers in the plots should be the planted spruce. NOTE: as the installation ages, it may be necessary to accept an ingress spruce or aspen to replace a dead tree.

4.14 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table Activities and History Table Measurements.

5 Measurements and Tending during Measurement Years 1, 2, and 3

5.1 *Plot Measurements*

The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. All spruce and aspen are to be measured after seasonal growth is complete. When stand densities are high, it may be desirable to measure aspen heights after leaf fall. The LTS data dictionary (Section 17.3) describes the tree measurements and related variables.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 5-1. summarizes the measurements to be made during re-measurement years 1, 2 and 3.

Table 5-1 Trees to be measured in relation to plot/subplot type and species for years 1, 2 and 3.

	Plot Type	Measured species
	Plots to be treated (all plots **except** 6, 12, and 15)	Conifer: All planted SW Deciduous: None
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All planted SW in full (20x20m) plots Deciduous in subplots 91, 92, 93, and 94 (1m x 1m): All deciduous species.

5.2 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7.

5.3 *Replanting Spruce Trees*

The replanting of spruce is permitted until and including measurement year 4. After measurement year 4 an acceptable natural spruce ingress tree can be used to replace a dead spruce. The purpose is to maintain densities near to the desired treatment densities. Replacement spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (Table 5-2). The new Establishment field is maintained for the life of the new tree. The replacement stock may come from several sources. Table 5-2 reflects the appropriate stock sources and codes to reflect the status of the new tree. If there is a second replacement, the establishment code is modified by adding an additional second identifier, see Table 5-2.

Table 5-2. Acceptable establishment codes for replaced spruce trees.

	New Establishment Code	Age	Establishment Code after a second replacement
New Nursery Stock	R	Biological age	RR
Transplants from Buffer	T	Age of transplanted tree	TT
Natural Ingress	I	Assessed in the field	II

5.4 *Plot Tending*

Clean and weed the micro-site (0.5 m radius for the first 5 years) around each spruce in both plot and buffer. Within the 0.5m radius, remove (by cutting) all competing vegetation (trees, shrubs, and grass) in mid-to-late summer (after completion of growth) including removal of dead grass material. Record in the journal the approximate number of hardwood trees removed at each visit as well as removal method (hand/brush saw), cost and time. The purpose of the cleaning and weeding is to ensure that planted spruce trees are given the best possible chance to survive over the course of the experiment. This treatment will be applied to all plots (including natural density aspen plots 6 and 12), **EXCEPT** plots with no planted spruce (plots 13 and 14) and the completely untreated plot (plot 15).

5.5 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot center and plot corner posts. Replace and retag where necessary.
2) Replace any tree tags if necessary.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) The tie-point for each plot must be confirmed. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

5.6 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

6 Measurements and Tending during Measurement Year 4

6.1 *Plot Measurements*

The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. All spruce and aspen are to be measured after seasonal growth is complete. The LTS data dictionary (Section 17.3) describes the tree measurement and related variables.

At the time of this measurement, before thinning, aspen crop trees (those that will not removed in the thinning) should be tagged (section 6.3) and measured. Note: In some installations the first measurement of aspen crop trees was deferred to Year 5.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Tree selection should favor potential aspen and spruce crop trees while retaining relatively uniform spacing.

Table 6-1 summarizes the measurements to be made during re-measurement year 4.

Table 6-1. Trees to be measured in relation to plot/subplot type and species in year 4.

	Plot Type	**Measured species**
	Plots to be treated (all plots **except** 6, 12, and 15)	Conifer: All planted SW Deciduous: All Tagged AW
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All planted SW in full (20x20m) plots Deciduous in subplots 91, 92, 93, and 94: All deciduous species.

6.2 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7

6.3 *Tree Numbering of Aspen Crop Trees*

Aspen numbering follows a method similar to that of the spruce. The "line" will be the area between spruce planting lines and will include a line "0" for the area between the left (west) boundary of the plot and the first spruce planting line. Aspen line 1 will include the area between spruce planting lines 1 and 2, and so forth. For example, an aspen tree located between row 1 and 2 and between planted SW 5 and 7 would have a tree number 0105xx where xx is not already used for another tree of any species.

6.4 *Replanting Spruce Trees*

The replanting of spruce is permitted until and including measurement year 4. After measurement year 4 an acceptable natural spruce ingress tree can be used to replace a dead spruce. The purpose is to maintain densities near to the desired treatment densities. Replacement spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (see Table 5-2). The **Establishment** field is maintained for the life of the new tree. The replacement stock may come from several sources. Table 5-2 reflects the appropriate stock sources and codes to reflect the status of the new tree. If there is a second replacement, the establishment code is modified by adding an additional second identifier, see Table 5-2.

6.5 *Thinning of Plots*

Thinning should be completed before the 5^{th} growing season begins. In all plots, except the natural density aspen plots (6, 12 and 15), aspen should be thinned to the designated treatment densities (Table 2-2). At this time the spruce are also thinned to the target densities for all plots.

A complete guide to thinning prepared by Paul Leblanc is available in the WESBOGY Shared Drive.

After the thinning has been completed, the condition codes need to be verified for both SW and AW to identify any damage during the thinning process. Other measurements are not required but the post-thinning condition codes need to replace the pre-thinning codes in the data for the year of thinning.

6.6 *Plot Tending*

Clean and weed the micro-site (0.5 m radius for the first 5 years) around each spruce in both plot and buffer. Within the 0.5 m radius, remove (by cutting) all competing vegetation (trees, shrubs, and grass) in mid-to-late summer (after completion of growth) including removal of dead grass material. Record in the journal the approximate number of hardwood trees removed at each visit as well as removal method (hand/brush saw), cost and time. The purpose of the cleaning and weeding is to ensure that planted spruce trees are given the best possible chance to survive over the course of the experiment. This treatment will be applied to all plots (including natural density aspen plots 6 and 12), **EXCEPT** plots with no planted spruce (plots 13 and 14) and the completely untreated plot (plot 15).

6.7 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot center and plot corner posts. Replace and retag where necessary;
2) Replace any tree tags if necessary;
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet;
4) The tie-point for each plot must be confirmed. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include

obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

6.8 *Maintenance of a Field Journal*

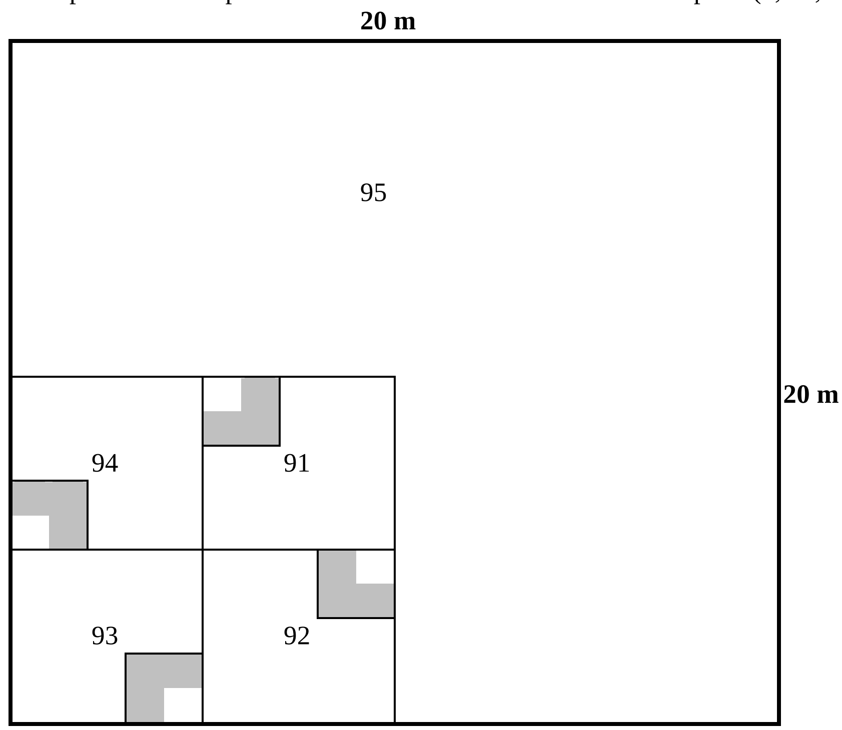
A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

7 Measurements and Tending during Measurement Year 5

7.1 *Expansion of Natural Density Aspen Subplots (plots 6, 12, and 15) to 2x2m*

Of the 15 plots in the basic treatment combinations, only plots 6, 12, and 15 are maintained at natural levels of aspen density. At plot establishment, four 1x1m subplots were established in the SW ¼ of the 20x20m main plot (Figure 7.1). Subplots were numbered 91, 92, 93, and 94. The remaining ¾ of the 20x20m plot was numbered 95. In year 5, the four 1x1m subplots in plots 6, 12 and 15 are expanded to 2x2m keeping the original 1x1m corner posts (Figure 7-1).

Figure 7-1. Expansion of subplots from 1x1m to 2x2m in the un-thinned plots (6, 12, and 15).



New untagged hardwood trees (AW, PB, and BW) within the shaded portion of the 2x2 m subplots are numbered 91xxxx, 92xxxx, 93xxxx, 94xxxx; with the first number following the last number used in the 1x1 m subplot. Care must be taken to avoid repeat tree numbers – check data for numbers from trees that may be dead or missing (ie. do not use any tree numbers that may have been used previously). Trees already recorded on the smaller subplots retain their numbers and provide data for the remaining 1x1 m portion of the 2x2 m subplot. Trees in the smaller subplots continue to be measured.

Record Type is used to indicate the subplot size on the tree data form. Note: The trees located in the original 1x1m plot maintain the RTYP 11 call and the <u>new trees</u> in the 2x2 are marked as RTYP 22.

7.2 *Plot Measurements*

The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. All spruce and aspen are to be measured after seasonal growth is complete. This is the first re-measurement after the thinning and the data file should now show both the AW and SW crop trees from all plots. The LTS data dictionary (Section 17.3) describes the tree measurements and related variables.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 7-1 summarizes the measurements to be made during re-measurement year 5.

Table 7-1. Trees to be measured in relation to plot/subplot and species in year 5.

	Plot Type	**Measured species**
	Treated plots (all plots **except** 6, 12, and 15)	Conifer: All tagged SW Deciduous: All tagged AW
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All tagged SW in full (20x20m) plots Deciduous in subplots 91, 92, 93, and 94: All deciduous species Top Height in subplots 91, 92, 93, 94 and 95.

7.3 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7.

7.4 *Top Height*

In 2010 a top height protocol was introduced to deal with the inability to accurately assess top height when using small sub-plots in the natural plots numbered 6, 12 and 15.

In growth and yield studies top height is represented by the 100 largest diameter trees/ha. In the WESBOGY Long-Term Study plots, aspen are measured in the untreated natural plots (plots 6, 12, and 15) within four – 1m x 1m plots until measurement year 5 (treatment year). These plots are then expanded to four – 2m x 2m plots at measurement year 6. It was intended that these 2m x 2m plots would eventually be expanded to 5m x 5m plots. However, because these natural plots continue to have very high densities, plot expansion has been delayed until measurement year 20 or 21 when aspen densities are more manageable. Using this small (1m x 1m and 2m x 2m) plot size makes it impossible to correctly calculate top height based on the small sample that they provide, and the small area sampled results in underestimation (bias) of top height. As a result, top heights determined for natural density plots cannot be compared to those for the other treatments.

In order to calculate top heights for these natural untreated LTS plots (plots 6, 12, and 15), an additional set of measurements are required.

This new protocol requires that the largest diameter aspen in each of the four (10m x 10m) quadrants of the full (20m x 20m) plot are located, tagged and measured, and their location in the plot recorded. Selection of the "largest diameter tree" will be done subjectively. Selecting one tree in each quadrant means that each full plot will be represented by 4 individual $100m^2$ plots, and provides a sample that is equivalent to measurement of the largest 100 trees per hectare.

Species of Interest

The species of interest for the top height survey are the two primary deciduous species: aspen and balsam poplar. The primary species is aspen, consequently it is necessary to measure the 4 largest diameter aspen that are in good condition (ie. without broken stems or major defects) in the 20 x 20 m plot (see detailed procedure below). If balsam poplar are present as dominants, then the largest-diameter balsam poplar in each quadrant of the plot are also measured (eg. when balsam poplar are present as dominants, then one balsam poplar and one aspen are measured for top height in each 10m x 10m quadrant, except in cases where there are no balsam poplar or no aspen available in a quandrant for measurement). Although other broadleaf species (ie. birch) may be present, this survey is to facilitate the comparison of treated to the untreated aspen so these other species are not to be measured. It is not necessary to apply this protocol to white spruce since all white spruce are measured at each re-measurement.

Data collection and numbering

In all cases a new record for the top height tree will be required in the database, which will be entered into the "Top Height Table" found in the Access Database. If the tree is already tagged and located in a subplot, it must also remain in the "Tree Measurements Table" with its original RTYP so that we maintain a record of its position within the sample plot.

All standard tree measurements (except for RCD) including spatial location will be recorded for each top height tree. The LTS data dictionary (Appendix 16-3) describes the tree measurements and related variables.

In the Top Height Table, trees will be identified as top height trees by setting their RTYP as 44. Once a tree has been selected, measured and entered as a top height tree, it is maintained in the Top Height Table and re-measured in subsequent measurement years, even if it is no longer the largest tree. It retains the RTYP of 44 in the Top Height Table. Tracking all dominant trees over time is intended to track how often dominant trees switch their ranking.

Since it is possible for top height trees to be trees that are already tagged in existing subplots or to be untagged there are three possible situations that may be encountered:

a) a top height tree falls in an existing (1m x 1m or 2m x 2m) subplot in the SW corner.
b) a top height tree does not fall in an existing subplot but is located in the SW corner where subplots exist.
c) a top height tree falls outside an existing subplot and not in the SW corner (ie. it is in the NW, NE or SE quadrant of the plot) but within the 20mx20m plot

Scenario a - a top height tree falls in an existing subplot in the SW quadrant
Under this scenario the tree number will remain the same, however the duplicate record in the Top Height Table will have an RTYP of 44. This means that the tree will be in the Tree

Measurements Table with its original RTYP of 11 or 22 and will also be in the Top Height Table with an RTYP of 44.

Scenario b - a top height tree does NOT fall in an existing subplot but is in the SW corner where the existing subplots are.

Under this scenario the tree will be tagged as a new tree. The tree number will begin with a 91, 92, 93 or 94 depending on which sub-quadrant of the 10 m x 10 m subplot the tree is located in

- 91=NE sub-quadrant
- 92= SE sub-quadrant
- 93=SW sub-quadrant
- 94=NW sub-quadrant

This is important because when we expand to 5 m x 5 m subplots it is necessary to know that the tree exists in the SW quadrant of the 20 m x 20 m plot and also which sub – quadrant of the SW quadrant the tree is in(see Figure 5-4). The actual tree number will be the next consecutive tree number for the trees in the particular sub-quadrant.
Note: the tree record will have an RTYP of 44 and will only be in the database in the Top Height Table. When the plot is expanded to 5 m x 5 m it will then be duplicated in the Tree Measurements Table with an RTYP of 55.

Scenario c - a top height tree is located outside the SW quadrant but within the 20mx20m plot (*ie*. It is in the NW, NE or SE quadrants of the main plot)

In this case the tree will be tagged as a new tree using the following numbering convention: 95 plus a quadrant identifier 1 (NW), 2 (NE), or 3 (SE), and a 3 tree digit tree number. The first top height tree would be numbered 951001. The 95 indicates that the tree is from one of the 3 unsampled quadrants of the 20 m x 20 m plot, the 1 identifies it as being in the NW quadrant. The three digit tree number should be unique for each tree within any of these 3 quadrants, as the 95 identifies the tree as being within any of the three 10 m x 10 m quadrants. The quadrant identifier (1, 2, or 3) is included in the tree number to aid in future field location of the trees for re-measurement.

Note: the tree record will have an RTYP of 44 and will only be in the Top Height Table. When the plot is expanded to 20mx20m it will then be duplicated in the Tree Measurements Table with an RTYP of 66.

Re-measurement Schedule

Re-measurement of top height trees will occur on the same schedule as the measurements for the natural plots (plots 6, 12, and 15). *Note*: at each re-measurement, it is necessary to confirm that the current tree is still the top height tree (largest dbh) in the quadrant. If another tree has a larger dbh, the larger tree is handled as a new top height tree (discussed above). All previously selected top height trees must be re-measured and both new and previously selected trees will appear in the Top Height Table. This is done because there is a good chance that several of the top trees will switch rank over time and we want to be able to track these changes. If there are more than 4 top height trees being measured in any quadrant, please contact the WESBOGY researcher to discuss a reasonable course of action.

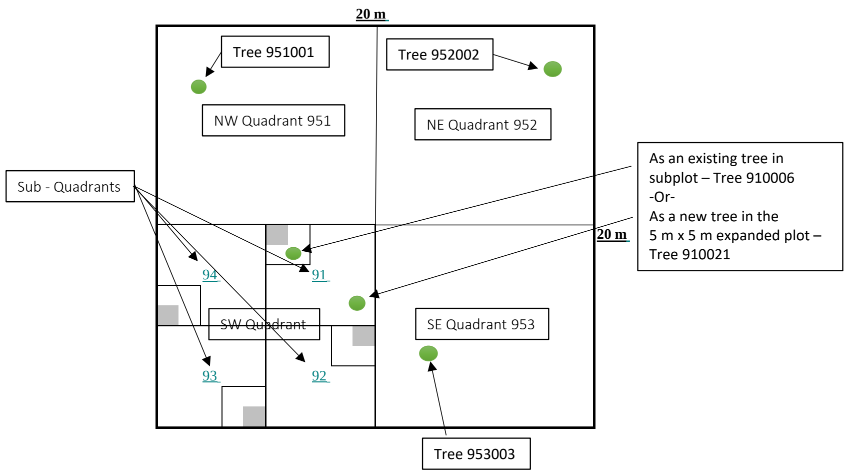


Figure 7-2. Top height tree numbering.

7.5 *Plot Tending*

This (age 5) is the final year of the tending of the spruce. Clean and weed the micro-site (0.5 m radius) around each spruce in both plot and buffer. Within the 0.5m radius, remove (by cutting) all competing vegetation (trees, shrubs, and grass) in mid-to-late summer (after completion of growth) including removal of dead grass material. Record in the journal the approximate number of hardwood trees removed at each visit as well as removal method (hand/brush saw), cost and time. The purpose of the cleaning and weeding is to ensure that planted spruce trees are given the best possible chance to survive over the course of the experiment. This treatment will be applied to all plots (including natural density aspen plots 6 and 12), **EXCEPT** plots with no planted spruce (plots 13 and 14) and the completely untreated plot (plot 15).

7.6 *Replacement of Dead Aspen or Spruce After Thinning*

The replacement of aspen or spruce using natural regeneration, where appropriate, is permitted to maintain treatment densities. This is permitted only after the plots have been treated. The purpose is to maintain densities near to the desired treatment densities. Replacement aspen or spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (see Table 5-2). The new **Establishment** field is maintained for the life of the new tree. The replacement tree is considered ingress and given a new Establishment code of "I" for ingress. If there is a second replacement of the tree, the establishment code is modified by adding an additional "I" , i.e. "II".

7.7 *Removal of Conifer and Deciduous Ingress*

Any conifer ingress trees (not used as a replacement tree, see section 7.6) in all plots must be removed before they reach 1.3m in height.

Any deciduous ingress (not used as a replacement tree, see section 7.6) in all treated plots must be removed before they reach 1.3m in height.

Shrubs are **NOT** removed, except for those within 50 cm of a planted white spruce (stem).

7.8 *Mapping of Tree Locations*

All tree locations within the plot are to be mapped. However, the trees in the buffers are not included. Tree mapping will be delayed until after thinning to treatment density has taken place since this significantly reduces the effort required for mapping, making such work feasible. Mapping tree locations will be of value for two purposes: 1) location of trees at re-measurement time, and 2) evaluation of between-tree competition based on spatial location measures.

Transit and stadia techniques are a reasonable method to map tree locations if completed before aspen get above 2 m or after leaves fall in late summer. Accurate laser survey instruments, with an electronic compass may also be used. Use of a handheld compass is not acceptable.

A Haglof Postex Laser may also be used for mapping tree locations in plots. GOA staff have found that this instrument is accurate and easy to use.

An alternative procedure used by AFS states that "A staff compass (or Brunton pocket transit/tripod) and a metric tape are used to determine the azimuth and distance to the center of each tree, at breast height, from the plot center. Azimuths are recorded from 0 - 360 degrees and distances are measured to the nearest 0.1 m (AFS PSP Manual Section 2.1.4.9).

High resolution digital photography that has been orthorectified may also be used for mapping, if available.

Trees should be mapped using the plot center or any plot corner as reference points. The use of a single reference point (plot center) is encouraged but where more than one reference point is used, then the second, third, and additional reference points need to be mapped relative to the initial reference point..

Expected number of trees to be mapped (per replication):
Aspen: (2 plots x 0 trees/plot)+(2 x 8)+(2 x 20)+(3 x 60)+(3 x 160)+(3 x ~ 200) = ~ 1316 trees
Spruce: (6 x 40)+(6 x 20)+(3 x ~ 5) = ~ 375 trees

7.9 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot centers and plot corners. Replace and retag where necessary.
2) Replace any tree tags if necessary.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) The tie-point for each plot must be confirmed. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

7.10 Maintenance of a Field Journal

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

8 Measurements and Tending during Measurement Year 6

8.1 *Plot Measurements*

The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. All spruce and aspen are to be measured after seasonal growth is complete. The LTS data dictionary (Section 17.3) describes the tree measurements and related variables.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 8-1 summarizes the measurements to be made during re-measurement year 6.

Table 8-1. Trees to be measured in relation to plot/subplot and species in year 6.

	Plot Type	**Measured species**
	Treated plots (all plots **except** 6, 12, and 15)	Conifer: All tagged SW Deciduous: All tagged AW
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All tagged SW in full (20x20m) plots Deciduous in subplots 91, 92, 93, and 94: All deciduous species. Top Height in subplots 91, 92, 93, 94 and 95.

8.2 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7

8.3 *Top Height*

Top Height in subplots 91, 92, 93, 94 and 95 should be measured according to the protocol described in section 7.4

8.4 *Vegetation Assessment*

Vegetation information is required to provide descriptive information on the ecological characteristics of each replicate set of treatments. Data collection will use forms and standards presented in the ASRD (2003) "Ecological Land Survey Site Description Manual (2nd Edition)", with modifications as described below. The manual and the forms are available on the WESBOGY Shared Drive.

Vegetation data will be collected to provide basic descriptive information on the dominant species present on the site. To provide reasonable sampling of each replication and to obtain a representative sample across the treatment densities , data will be collected within the 20 m x 20 m measurement plots in treatment plots 1, 4, 6, 7, 10, 12, 13 and 15 (0, 1500 and natural aspen density plots). Measurements are to be completed in year 6, 10, and 16, during the period between mid-July to mid-August. Exhaustive and complete species lists within the measurement plots are not needed for this purpose. For each stratum, record cover of the dominant species (all tree species, up to 5 shrubs, and up to 10 herbs (including ferns, grasses, sedges, rushes, etc.), and any bryophytes with greater than 5 % cover). Sedges, willows or other problematic species only have to be identified to genus. Distribution and vigor do not need to be recorded. Total cover and average height is also recorded for each stratum (bottom of front of form).

The database has two separate tables for entry of the vegetation data: the Vegetation_Species Table and the Vegetation_Strata Table. These tables are linked and both must be filled in.

8.5 *Replacement of Dead Aspen or Spruce*

The replacement of aspen or spruce using natural regeneration, where appropriate, is permitted to maintain treatment densities. This is permitted only after the plots have been treated. The purpose is to maintain densities near to the desired treatment densities. Replacement aspen or spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (see Table 5-2). The new Establishment field is maintained for the life of the new tree. The replacement tree is considered ingress and given a new Establishment code of "I" for ingress. If there is a second replacement of the tree, the establishment code is modified by adding an additional "I" , i.e. "II".

8.6 *Removal of Conifer and Deciduous Ingress*

Any conifer ingress (not used as a replacement tree, see section 8.5) must be removed before it reaches 1.3m in height.

Any deciduous ingress (not used as a replacement tree, see section 8.5) in treated plots must be removed before it reaches 1.3m in height.

Shrubs are **NOT** removed.

8.7 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition of tags on all the plot center and plot corner posts. Replace and retag where necessary.
2) Replace any missing tree tags.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) Confirm the tie-point for each plot. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

8.8 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

9 Measurements and Tending during Measurement Years 7, 8 and 9

9.1 *Plot Measurements*

The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. All spruce and aspen are to be measured after seasonal growth is complete. The LTS data dictionary (Section 17.3) describes the tree measurements and related variables.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 9-1 summarizes the measurements to be made during re-measurement years 7, 8, and 9.

Table 9-1. Trees to be measured in relation to plot/subplot and species for years 7, 8 and 9.

	Plot Type	**Measured species**
	Treated plots (all plots **except** 6, 12, and 15)	Conifer: All tagged SW Deciduous: All tagged AW
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All tagged SW in full (20x20m) plots Deciduous in subplots 91, 92, 93, and 94: All deciduous species. Top Height in subplots 91, 92, 93, 94 and 95.

9.2 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7.

9.3 *Top Height*

Top Height in subplots 91, 92, 93, 94 and 95 should be measured according to the protocol described in section 7.4.

9.4 *Replacement of Dead Aspen or Spruce*

The replacement of aspen or spruce using natural regeneration, where appropriate, is permitted to maintain treatment densities. This is permitted only after the plots have been treated. The purpose is to maintain densities near to the desired treatment densities. Replacement aspen or spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (see Table 5-2). The new Establishment field is maintained for the life of the new tree. The replacement tree is considered ingress and given a new Establishment code of "I" for ingress. If there is a second replacement of the tree, the establishment code is modified by adding an additional "I" , i.e. "II".

9.5 *Removal of Conifer and Deciduous Ingress*

Any conifer ingress (not used as a replacement tree, see section 9.4) must be removed before it reaches 1.3m in height.

Any deciduous ingress (not used as a replacement tree, see section 9.4) must be removed before it reaches 1.3m in height in treated plots.

Shrubs are **NOT** removed.

9.6 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot center and plot corner posts. Replace and retag where necessary.
2) Replace any tree tags if necessary.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) Confirm the tie-point for each plot. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

9.7 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

10 Measurements and Tending during Measurement Year 10

10.1 *Plot Measurements*

The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. All spruce and aspen are to be measured after seasonal growth is complete. The LTS data dictionary (Section 17.3) describes the tree measurements and related variables.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 10-1 summarizes the measurements to be made during re-measurement year 10.

Table 10-1 Trees to be measured in relation to plot/subplot and species for year 10.

	Plot Type	Measured species
	Treated plots (all plots **except** 6, 12, and 15)	Conifer: All tagged SW Deciduous: All tagged AW
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All tagged SW in full (20x20m) plots Deciduous in subplots 91, 92, 93, and 94: All deciduous species. Top Height in subplots 91, 92, 93, 94 and 95.

10.2 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7

10.3 *Top Height*

Top Height in subplots 91, 92, 93, 94 and 95 should be measured according to the protocol described in section 7.4

10.4 *Vegetation Assessment*

Vegetation information is required to provide descriptive information on the ecological characteristics of each replicate set of treatments. Data collection will use forms and standards presented in the ASRD (2003) "Ecological Land Survey Site Description Manual (2nd Edition)", with modifications as described below. The manual and the forms are available on the WESBOGY Shared Drive.

Vegetation
Vegetation data will be collected to provide basic descriptive information on the dominant species present on the site. To provide reasonable sampling of each replication and to obtain a representative sample across the treatment densities , data will be collected within the 20 m x 20

m measurement plots in treatment plots 1, 4, 6, 7, 10, 12, 13 and 15 (0, 1500 and natural aspen density plots). Measurements are to be completed in year 6, 10, and 16, during the period between mid-July to mid-August. Exhaustive and complete species lists within the measurement plots are not needed for this purpose. For each stratum, record cover of the dominant species (all tree species, up to 5 shrubs, and up to 10 herbs (including ferns, grasses, sedges, rushes, etc.), and any bryophytes with greater than 5 % cover). Sedges, willows or other problematic species only have to be identified to genus. Distribution and vigor do not need to be recorded. Total cover and average height is also recorded for each stratum (bottom of front of form).

The database has two separate table for entry of the vegetation data: the Vegetation_Species Table and the Vegetation_Strata Table. These tables are linked and must both be filled in.

10.5 *Replacement of Dead Aspen or Spruce*

The replacement of aspen or spruce using natural regeneration, where appropriate, is permitted to maintain treatment densities. This is permitted only after the plots have been treated. The purpose is to maintain densities near to the desired treatment densities. Replacement aspen or spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (see Table 5-2). The new Establishment field is maintained for the life of the new tree. The replacement tree is considered ingress and given a new Establishment code of "I" for ingress. If there is a second replacement of the tree, the establishment code is modified by adding an additional "I" , i.e. "II".

10.6 *Removal of Conifer and Deciduous Ingress*

Any conifer ingress (not used as a replacement tree, see section 10.5) must be removed before it reaches 1.3m in height.

Any deciduous ingress (not used as a replacement tree, see section 10.5) in treated plots must be removed before it reaches 1.3m in height.

Shrubs are **NOT** removed.

10.7 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot center and plot corner posts. Replace and retag where necessary.
2) Replace any tree tags if necessary.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) The tie-point for each plot must be confirmed. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include

obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

10.8 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

11 Measurements and tending during Odd Measurement Years 11, 13, 15, 17, 19

11.1 *Plot Measurements*

Measurement of tagged hardwoods in the natural un-thinned sub-plots (plots 6,12,15) will continue annually. Planted spruce is not measured in these plots during the odd years. There is no measurement of spruce or aspen in the thinned plots during the odd years. The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. The LTS data dictionary (Section 17.3) describes the tree measurements and related variables.

During the Odd Measurement Years, it is not necessary to tag and measure any new ingress. Only existing tagged hardwoods will be measured. This will allow better evaluation of survival trends during the coming years. Analysis of data from the first installations reaching 10 years has shown that natural density aspen plots (6, 12, and 15) still have densities that are much higher than expected after 10 years (10,000 stems/ha). High density levels of natural aspen cannot be maintained and it is expected that substantial additional self-thinning mortality will occur between age 10 and 20 years.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 11-1summarizes the measurements to be made during re-measurement years 11, 13, 15, 17, 19.

Table 11-1. Trees to be measured in relation to plot/subplot, species for odd numbered years from age 11-19.

	Plot Type	**Measured species**
	Treated plots (all plots **except** 6, 12, and 15)	Conifer: None Deciduous: None
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: None Deciduous in subplots 91, 92, 93, and 94: All deciduous species. Top Height in subplots 91, 92, 93, 94 and 95.

11.2 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7

11.3 *Top Height*

Top Height in subplots 91, 92, 93, 94 and 95 should be measured according to the protocol described in section 7.4

11.4 *Removal of Conifer and Deciduous Ingress*

During the Odd Measurement Years it is not necessary to remove ingress.

11.5 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot center and plot corner posts. Replace and retag where necessary.
2) Replace any tree tags if necessary.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) The tie-point for each plot must be confirmed. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

11.6 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

12 Measurements and Tending during Even Measurement Years 12, 14, 16, 18

12.1 *Plot Measurements*

Complete measurement of both spruce and aspen in both the thinned and un-thinned plots will occur during the even years beginning in year 12. The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. The LTS data dictionary (Section 17.3) describes the tree measurement and related variables.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 12-1 summarizes the measurements to be made during re-measurement years 12, 14, 16, 18

Table 12-1 Trees to be measured in relation to plot/subplot, for even numbered years from age 12-18.

	Plot Type	**Measured species**
	Treated plots (all plots **except** 6, 12, and 15)	Conifer: All tagged SW Deciduous: All planted AW
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All planted SW in full (20x20m) plots Deciduous in subplots 91, 92, 93, and 94: All deciduous species. Top Height in subplots 91, 92, 93, 94 and 95.

12.2 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7

12.3 *Top Height*

Top Height in subplots 91, 92, 93, 94 and 95 should be made according to the protocol described in section 7.4

12.4 *Replacement of Dead Aspen or Spruce*

The replacement of aspen or spruce using natural regeneration, where appropriate, is permitted to maintain treatment densities. This is permitted only after the plots have been treated. The purpose is to maintain densities near to the desired treatment densities. Replacement aspen or spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (see Table 5-2). The new Establishment field is maintained for the life of the new tree. The replacement tree is considered ingress and given a new Establishment code of "I" for ingress. If there is a second replacement of the tree, the establishment code is modified by adding an additional "I" , i.e. "II".

12.5 *Removal of Conifer and Deciduous Ingress*

Any conifer ingress tree (not used as a replacement tree, see section12.4) in all plots must be removed before it reaches 1.3m in height.

Any deciduous ingress tree (not used as a replacement tree, see section 12.4) in all treated plots must be removed before it reaches 1.3m in height.

Shrubs are **NOT** removed.

12.6 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot center and plot corner posts. Replace and retag where necessary.
2) Replace any tree tags if necessary.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) The tie-point for each plot must be confirmed. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

12.7 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

13 Measurements and Tending during Measurement Year 20 or 21

13.1 *Expansion of Natural Density Aspen Subplots (plots 6, 12, and 15) to 5x5m*

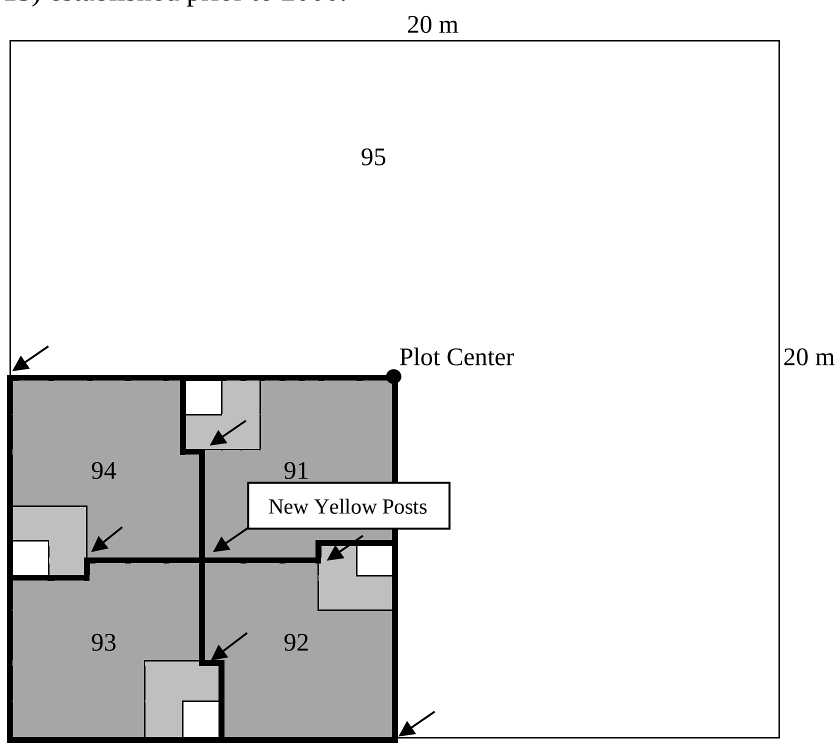
Depending on the measurement schedule for full measurements that a particular installation is following (odd year or even year, subplots will be expanded in Measurement Year 20 or 21. The four 2x2m subplots in plots 6, 12, and 15 are expanded to 5x5m, keeping the original 1x1m and 2x2m corner posts. (Figure 13-1 and Figure 13-2).

13.1.1 Subplot expansion for installations established prior to 2000

For installations set up before year 2000, subplots were centered on the quadrant boundary rather than on the corner and this causes a minor overlap when subplots are expanded (Figure 13-1). Expansion must be handled correctly to avoid double counting of some trees.

For installations established prior to 2000, there will need to be 7 new posts, (colour-coded yellow) to define the boundaries of the 5x5m subplots. The first should be placed at the center of the SW quadrant of the 20x20m plot. This post will be 7.07m from the SW corner of the main plot. Posts marking the NW and SE boundaries of the quadrant should be added next. These will be 10m from the SW corner of the main plot. The remaining 4 new posts will each be 3m from the quadrant center. The existing plot center post of the main 20x20m plot will mark the NE corner of the expansion.

Figure 13-1. Expansion of subplots from 2x2m to 5x5m in the un-thinned plots (6, 12, and 15) established prior to 2000.



Subplots expanded from 1x1m (white) to 2x2m (light grey) in measurement year 5. In year 20 or 21 the plots are expanded to 5x5m (dark grey). New untagged hardwood trees >1.3m tall within the shaded portion of the 5x5 m subplots are numbered 91xxxx, 92xxxx, 93xxxx, 94xxxx as needed with the first number following the last number used in the 2x2 m subplot. Care must be taken to avoid re-using any tree numbers – check the full (all years) database for the last number. Trees already recorded on the smaller subplots retain their number and RTYP and provide data for the remaining 1x1m and 2x2m portions of the subplot. Trees in the smaller subplots continue to be measured.

13.1.2 Subplot expansion for installations established in 2000 or later

Installations established in 2000 or later will require three new yellow posts (**Figure 13-2**). The first should be placed at the center of the SW quadrant of the 20x20m plot. This post will be 7.07m from the SW corner of the main plot. Posts marking the NW and SE boundaries of the quadrant should be added next. These will be 10m from the SW corner of the main plot.

Figure 13-2. Expansion of subplots from 2x2m to 5x5m in the un-thinned plots (6, 12, and 15) established in 2000 or later.

Subplots expanded from 1x1m (white) to 2x2m (light grey) in measurement year 5. In year 20 or 21 the plots are expanded to 5x5m (dark grey). New untagged hardwood trees > 1.3m tall within the shaded portion of the 5x5 m subplots are numbered 91xxxx, 92xxxx, 93xxxx, 94xxxx as needed with the first number following the last number used in the 2x2 m subplot. Care must be taken to avoid re-using any tree numbers – check the full (all years) database for the last number. Newly tagged trees in the 5x5m plots will have an RTYP of 55. Trees already recorded on the smaller subplots retain their number and RTYP and provide data for the remaining 1x1m and 2x2m portions of the subplot. Trees in the smaller subplots continue to be measured.

Table 13-1 Un-thinned plots (6, 12, and 15): subplot size and expansion summary.

Year	Size (m)	Area (ha) per subplot	Record Type(s)**	Figure
1	1x1	.0001	11	5-3
5	2x2	.0004	22 + 11	8-1
20 or 21	5x5	.0025	55 + 22 + 11	14-1 14-2
*	20x20	.0400	66 + 55 + 22 + 11	
* Not implemented until density declines further				
** To indicate that expansion is cumulative. For example, for trees with numbers 92xxxx and Record Type 22, plot size is .0003 ha. Trees with numbers 92xxxx and Record Type 11, are the set of trees found on the 1x1 m (.0001 ha) subplot. The total count of trees in these two sets is the count of trees on the .0004 ha subplot 92.				

13.2 *Plot Measurements*

The normal measurement time is late summer or fall, but could be as late as the following early spring before growth begins. All existing tagged spruce and aspen are to be measured. Additionally, on the expand plots (6, 12, 15) all the hardwoods, greater than 1.3 meters in height, found in the expanded 5x5m plot are to be measured. The LTS data dictionary (Section 17.3) describes the tree measurements and related variables.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 7-1 summarizes the measurements to be made during re-measurement year 20 or 21.

Table 13-2. Trees to be measured in relation to plot/subplot and species in year 20 or 21.

	Plot Type	Measured species
	Treated plots (all plots **except** 6, 12, and 15)	Conifer: All tagged SW Deciduous: All tagged AW
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All tagged SW in full (20x20m) plots Deciduous in 5mx5m subplots 91, 92, 93, and 94: All deciduous species.

13.3 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7

13.4 *Top Height*

Top Height in subplots 91, 92, 93, 94 and 95 should be measured according to the protocol described in section 7.4.

13.5 *Replacement of Dead Aspen or Spruce*

The replacement of aspen or spruce using natural regeneration, where appropriate, is permitted to maintain treatment densities. This is permitted only after the plots have been treated. The purpose is to maintain densities near to the desired treatment densities. Replacement aspen or spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (see Table 5-2). The new Establishment field is maintained for the life of the new tree. The replacement tree is considered ingress and given a new Establishment code of "I" for ingress. If there is a second replacement of the tree, the establishment code is modified by adding an additional "I" , i.e. "II".

13.6 *Removal of Conifer and Deciduous Ingress*

Any conifer ingress (not used as a replacement tree, see section 0) must be removed before it reaches 1.3m in height .

Any deciduous ingress (not used as a replacement tree, see section 0) in treated plots must be removed before it reaches 1.3m in height .

Shrubs are **NOT** removed.

13.7 *Mapping of Tree Locations*

Before the next re-measurement all tree locations within the expanded 5x5m plot are to be mapped. It is not necessary to map the tree locations at the time of measurement. Mapping tree locations will be of value for two purposes: 1) location of trees at re-measurement time, and 2) evaluation of between-tree competition based on spatial location measures.

Transit and stadia techniques are a reasonable method to map tree locations if completed before aspen get above 2 m or after leaves fall in late summer. Accurate laser survey instruments, with an electronic compass may also be used. Use of a handheld compass is not acceptable.

An alternative procedure used by AFS states that "A staff compass (or Brunton pocket transit/tripod) and a metric tape are used to determine the azimuth and distance to the center of each tree, at breast height, from the plot center. Azimuths are recorded from 0 - 360 degrees and distances are measured to the nearest 0.1 m (AFS PSP Manual Section 2.1.4.9).

High resolution digital photography that has been orthorectified may also be used for mapping, if available.

Trees should be mapped using the plot center or any plot corner as reference points. The use of a single reference point (plot center) is encouraged but where more than one reference point is used, then the second, third, and additional reference points need to be mapped relative to the initial reference point.

13.8 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot center and plot corner posts. Replace and retag where necessary.
2) Replace any tree tags if necessary.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) The tie-point for each plot must be confirmed. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

13.9 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

14 Measurements and Tending during Measurement Years 23 or 24, and 26 or 27

14.1 *Plot Measurements*

Complete measurement of both spruce and aspen in both the thinned and un-thinned plots will occur every three years beginning at measurement year 23. The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. The LTS data dictionary (Section 17.3) describes the tree measurement and related variables.

Note: In the natural plots (6, 12 and 15), all untagged trees in the 5m x 5m plots that have crossed the 1.3m height threshold should be identified, tagged (assigned an new tree number) and measured.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 14-1. Trees to be measured in relation to plot/subplot, for measurement years 23 or 24, 26 or 27, 29 or 30.Summarizes the measurements to be made during re-measurement years 23 or 24, 26 or 27.

Table 14-1. Trees to be measured in relation to plot/subplot, for measurement years 23 or 24, 26 or 27, 29 or 30.

	Plot Type	Measured species
	Treated plots (all plots **except** 6, 12, and 15)	Conifer: All tagged SW Deciduous: All planted AW
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All planted SW in full (20x20m) plots Deciduous in subplots 91, 92, 93, and 94: All deciduous species.

14.2 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7

14.3 *Top Height*

Top Height in subplots 91, 92, 93, 94 and 95 should be measured according to the protocol described in section 7.4

14.4 *Replacement of Dead Aspen or Spruce*

The replacement of aspen or spruce using natural regeneration, where appropriate, is permitted to maintain treatment densities. This is permitted only after the plots have been treated. The purpose is to maintain densities near to the desired treatment densities. Replacement aspen or spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (see Table 5-2). The new Establishment field is maintained for the life of the new tree. The replacement tree is considered ingress and given a new Establishment code of "I" for ingress. If there is a second replacement of the tree, the establishment code is modified by adding an additional "I" , i.e. "II".

14.5 *Removal of Conifer and Deciduous Ingress*

Any conifer ingress (not used as a replacement tree, see section 14.4) must be removed before it reaches 1.3m in height.

Any deciduous ingress (not used as a replacement tree, see section 14.4) in treated plots must be removed before it reaches 1.3m in height.

Shrubs are **NOT** removed.

14.6 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot center and plot corner posts. Replace and retag where necessary.
2) Replace any tree tags if necessary.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) The tie-point for each plot must be confirmed. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

14.7 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

15 Measurements and Tending During and After Measurement Years 31 or 32

15.1 *Plot Measurements*

Complete measurement of both spruce and aspen in both the thinned and un-thinned plots will occur every five years after measurement year 26/27 with this 5 year measurement cycle beginning at age 31 or 32. The normal measurement time is late summer or fall, but could be as late as the following spring before growth begins. The LTS data dictionary (Section 17.3) describes the tree measurement and related variables.

Note: On the natural plots (6,12 and 15), all untagged trees in the 5m x 5m plots that have crossed the 1.3m height threshold should be identified, tagged (assigned an new tree number) and measured.

Note: if using previous year's measurements as a guide for current measurements, it is important to use a "cleaned" copy of the previous year's data. This can be obtained from the current Access database.

Table 15-1 summarizes the measurements to be made during re-measurement years beginning in Measurement Year 31 or 32.

Table 15-1. Trees to be measured in relation to plot/subplot, for measurement years 31 or 32.

	Plot Type	**Measured species**
	Treated plots (all plots **except** 6, 12, and 15)	Conifer: All tagged SW Deciduous: All planted AW
	Untreated - natural plots (plots 6, 12, and 15)	Conifer: All planted SW in full (20x20m) plots Deciduous in subplots 91, 92, 93, and 94: All deciduous species.

15.2 *Plot Photos*

Photos of each measured plot should be taken following the protocol outlined in section 4.7

15.3 *Top Height*

Top Height in subplots 91, 92, 93, 94 and 95 should be measured according to the protocol described in section 7.4.

15.4 *Replacement of Dead Aspen or Spruce*

The replacement of aspen or spruce using natural regeneration, where appropriate, is permitted to maintain treatment densities. This is permitted only after the plots have been treated. The purpose is to maintain densities near to the desired treatment densities. Replacement aspen or spruce use the same tree number as the tree being replaced with an appropriate modification to the Establishment and Age fields (see Table 5-2). The new Establishment field is maintained for the life of the new tree. The replacement tree is considered ingress and given a new Establishment code of "I" for ingress. If there is a second replacement of the tree, the establishment code is modified by adding an additional "I" , i.e. "II".

15.5 *Removal of Conifer and Deciduous Ingress*

Any conifer ingress (not used as a replacement tree, see section 14.4) must be removed before it reaches 1.3m in height.

Any deciduous ingress (not used as a replacement tree, see section 14.4) in treated plots must be removed before it reaches 1.3m in height.

Shrubs are **NOT** removed.

15.6 *Installation and Plot Maintenance*

The following items are to be checked at each visit:

1) Check the condition and tags of all the plot center and plot corner posts. Replace and retag where necessary.
2) Replace any tree tags if necessary.
3) Rate the overall condition of the plot and buffer noting any damage and their location on the plot maintenance sheet.
4) The tie-point for each plot must be confirmed. This includes checking the distance and azimuth from the plot center to the tie-point. Keep in mind the distances are horizontal and must be adjusted for slopes exceeding 10%. Whenever possible, a second tie-point should be established in the event that the original tie-point is destroyed. Suitable tie-points include obvious bends in a nearby road, stream crossings such as bridges and culverts, or any other permanent land features.

15.7 *Maintenance of a Field Journal*

A journal should be maintained for all visits and other events affecting the installation. A digital copy of the field journal should be uploaded to the WESBOGY Shared Drive annually. The database has two tables for entry of the dates associated with plot activities and measurements called History Table_Activities and History Table_Measurements.

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17 Appendices

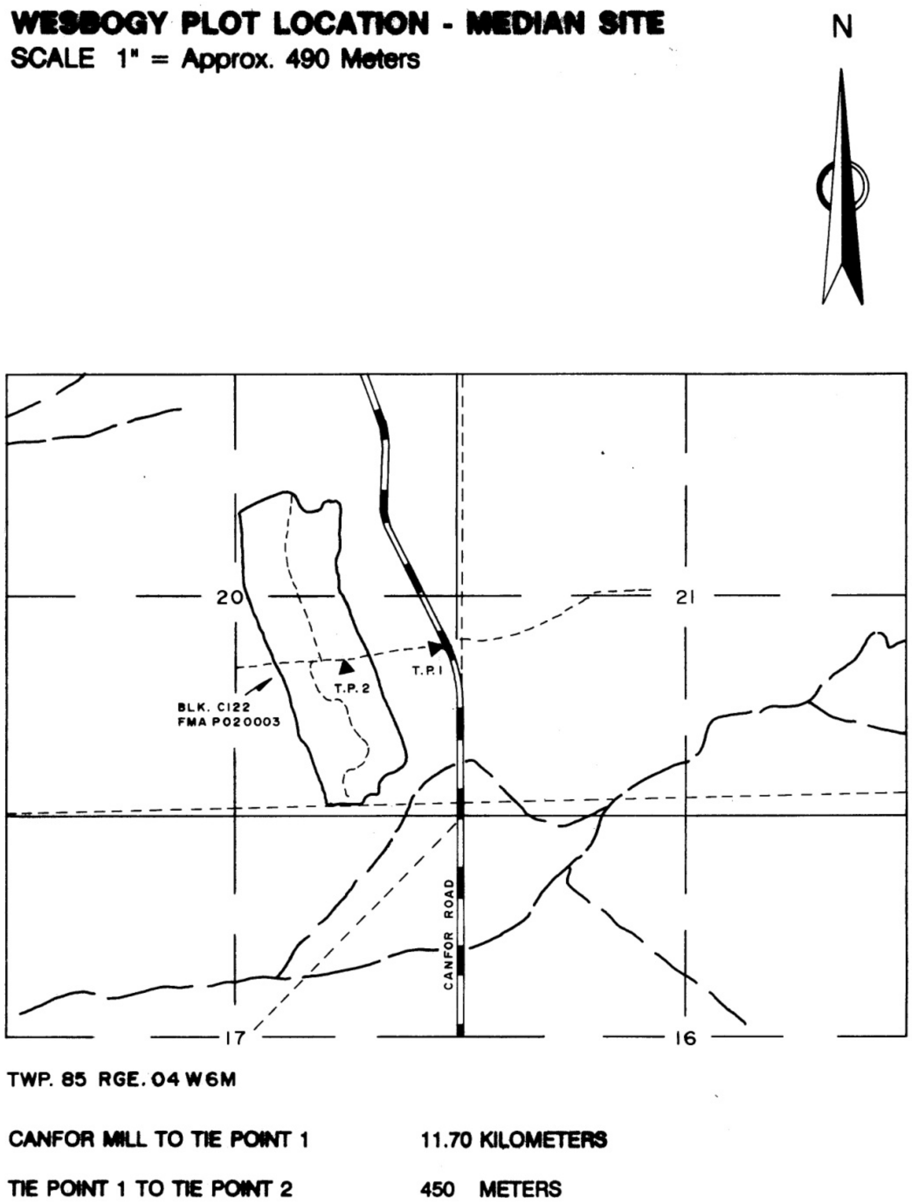
17.1 *Results from the installation age assessment process by agency and installation.*

Note that only selected ages are shown and do not include all measurement ages.

ALPAC	**Date Aspen**	**Date Spruce**								**Thinned July of 00**									
	Harvested	**Planted**	**Calendar Year**	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2008*	*2013*	*2016*	*2019*	*2024*	
Superior	Dec-93	Jun-94	**Measurement Year**	0 and 1	2	3	4	5	6	7	8	9	10	15	20	23	26	31	
Aw Age at 1	1		**Aspen Age**	no	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*15*	*20*	*23*	*26*	*31*	
Sw Age at 1		*2*	**Spruce Age**	no	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*16*	*21*	*24*	*27*	*32*	
	Date Aspen	**Date Spruce**								**Thinned July of 06**									
	Harvested	**Planted**	**Calendar Year**	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2016*	*2021*	*2024*	*2027*	*2032*
Median	Jan-01	Jul-01	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	2		**Aspen Age**	yes	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*16*	*21*	*24*	*27*	*32*
Sw Age at 1		*2*	**Spruce Age**	yes	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*16*	*21*	*24*	*27*	*32*
CANFOR	**Date Aspen**	**Date Spruce**								**Thinning Sept of 05**									
	Harvested	**Planted**	**Calendar Year**	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2015*	*2020*	*2023*	*2026*	*2031*
Superior	*Jun-98*	*Jul-00*	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	*4*		**Aspen Age**	yes	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*18*	*23*	*26*	*29*	*34*
Sw Age at 1		*3*	**Spruce Age**	yes	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*17*	*22*	*25*	*28*	*33*
	Date Aspen	**Date Spruce**								**Thinning Sept of 06**									
	Harvested	**Planted**	**Calendar Year**	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2016*	*2021*	*2024*	*2027*	*2032*
Median	*Jun-98*	*Jul-01*	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	*5*		**Aspen Age**	yes	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*19*	*24*	*27*	*30*	*35*
Sw Age at 1		*3*	**Spruce Age**	yes	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*17*	*22*	*25*	*28*	*33*
MERCER	**Date Aspen**	**Date Spruce**								**Thinned July of 98**									
	Harvested	**Planted**	**Calendar Year**	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2007*	*2012*	*2015*	*2018*	*2023*
Median and Superior	*Oct-91*	*Jul-92*	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	2		**Aspen Age**	yes	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*16*	*21*	*24*	*27*	32
Sw Age at 1		*2*	**Spruce Age**	yes	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*16*	*21*	*24*	*27*	32
LPDC	**Date Aspen**	**Date Spruce**								**Thinned Aug of 05**									
	Harvested	**Planted**	**Calendar Year**	*2001*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2015*	*2020*	*2023*	*2026*	*2031*
Median	Jan-01	May-01	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	1		**Aspen Age**	no	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*15*	*20*	*23*	*26*	*31*
Sw Age at 1		*2*	**Spruce Age**	no	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*16*	*21*	*24*	*27*	*32*
	Date Aspen	**Date Spruce**																	
	Harvested	**Planted**	**Calendar Year**	*2004*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2018*	*2023*	*2026*	*2029*	*2034*
Superior	Feb-04	May-04	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	1		**Aspen Age**	no	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*15*	*20*	*23*	*26*	*31*
Sw Age at 1		*3*	**Spruce Age**	no	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*17*	*22*	*25*	*28*	*33*
LPSR	**Date Aspen**	**Date Spruce**								**Thinning May of 04**									
	Harvested	**Planted**	**Calendar Year**	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*1999*	*2005*	*2006*	*2007*	*2011*	*2016*	*2018*	*2021*	*2026*
Median and Superior	*Aug-96*	*Sep-98*	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	*3*		**Aspen Age**	yes	*3*	*4*	*5*	*6*	*7*	8	*9*	*10*	*11*	*12*	*17*	*22*	*25*	*28*	*33*
Sw Age at 1		*2*	**Spruce Age**	yes	*2*	*3*	*4*	*5*	*6*	7	*8*	*9*	*10*	*11*	*16*	*21*	*24*	*27*	*32*
NWT	**Date Aspen**	**Date Spruce**							**Thinned May of 98**										
	Burned	**Planted**	**Calendar Year**	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2008*	*2013*	*2016*	*2019*	*2024*
Median and Superior	Apr-92	Jul-93	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	3		**Aspen Age**	yes	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*17*	*22*	*25*	*28*	*33*
Sw Age at 1		*3*	**Spruce Age**	yes	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*17*	*22*	*25*	*28*	*33*
AAF	**Date Aspen**	**Date Spruce**								**Thinned Oct of 97**									
	Harvested	**Planted**	**Calendar Year**	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2007*	*2012*	*2015*	*2018*	*2020*
Median	Jun-91	Aug-92	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	2		**Aspen Age**	yes	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*16*	*21*	*24*	*27*	*32*
Sw Age at 1		*2*	**Spruce Age**	yes	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*16*	*21*	*24*	*27*	*32*
SBR	**Date Aspen**	**Date Spruce**							**Thinning Fall of 96**										
	Harvested	**Planted**	**Calendar Year**	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2007*	*2012*	*2015*	*2018*	*2023*
Median and Superior	Jun-92	Fall 92	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	1		**Aspen Age**	yes	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Sw Age at 1		*2*	**Spruce Age**	yes	*2*	*3*	*4*	*5*	*6*	7	*8*	*9*	*10*	*11*	*16*	*21*	*24*	27	*32*
WFR	**Date Aspen**	**Date Spruce**							**Thinning Aug of 96**										
	Harvested	**Planted**	**Calendar Year**	*1993*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2007*	*2012*	*2015*	*2018*	*2023*
Median	1989	Jun-93	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	4		**Aspen Age**	yes	4	5	6	7	8	9	10	11	12	13	18	23	26	29	34
Sw Age at 1		*2*	**Spruce Age**	yes	*2*	*3*	*4*	*5*	*6*	7	*8*	*9*	*10*	*11*	*16*	*21*	*24*	27	*32*
	Date Aspen	**Date Spruce**							**Thinning Aug of 96**										
	Harvested	**Planted**	**Calendar Year**	*1993*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2007*	*2012*	*2015*	*2018*	*2023*
Superior 1	1987	Jun-93	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	6		**Aspen Age**	yes	6	7	8	9	10	11	12	13	14	15	20	25	28	31	36
Sw Age at 1		*2*	**Spruce Age**	yes	*2*	*3*	*4*	*5*	*6*	7	*8*	*9*	10	*11*	16	*21*	*24*	*27*	*32*
	Date Aspen	**Date Spruce**							**Thinning July of 97**										
	Harvested	**Planted**	**Calendar Year**	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2009*	*2014*	*2017*	*2020*	*2025*
Superior 2	1988	Jun-94	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	7		**Aspen Age**	no	7	8	9	10	11	12	13	14	15	16	21	26	29	32	37
Sw Age at 1		*2*	**Spruce Age**	no	*2*	*3*	*4*	*5*	*6*	7	*8*	*9*	10	*11*	16	*21*	*24*	*27*	32
WGP	**Date Aspen**	**Date Spruce**							**Thinning May of 96**										
	Harvested	**Planted**	**Calendar Year**	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2006*	*2011*	*2014*	*2017*	*2022*
	Jul-88	*Aug-91*	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	*5*		**Aspen Age**	yes	5	6	7	8	9	10	11	12	13	14	19	24	27	30	35
Sw Age at 1		*2*	**Spruce Age**	yes	*2*	*3*	*4*	*5*	*6*	7	*8*	*9*	*10*	11	*16*	*21*	*24*	27	*32*
SPA	**Date Aspen**	**Date Spruce**							**Thinning Summer of 95**										
	Harvested	**Planted**	**Calendar Year**	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2005*	*2010*	*2013*	*2016*	*2021*
Median and Superior	Jun-90	Fall 90	**Measurement Year**	0	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Aw Age at 1	1		**Aspen Age**	yes	1	2	3	4	5	6	7	8	9	10	15	20	23	26	31
Sw Age at 1		*2*	**Spruce Age**	yes	*2*	*3*	*4*	*5*	*6*	7	*8*	*9*	*10*	*11*	*16*	*21*	*24*	27	*32*

17.2 *Examples of installation and plot location maps*

The following are included with the permission of Daishowa Marubeni Int (DMI).



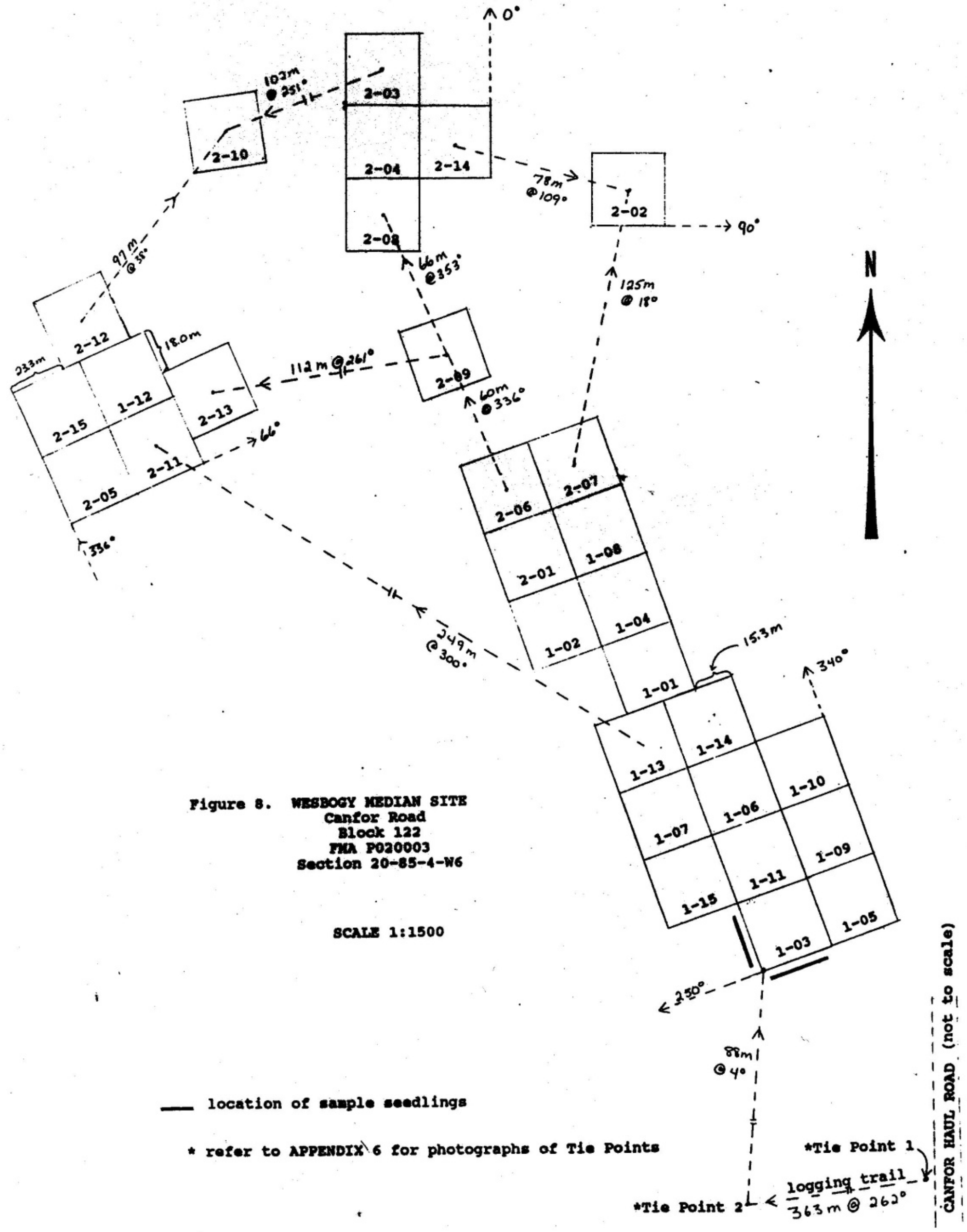


Figure 8. WESBOGY MEDIAN SITE
Canfor Road
Block 122
FMA P020003
Section 20-85-4-W6

SCALE 1:1500

location of sample seedlings

* refer to APPENDIX 6 for photographs of Tie Points

17.4 *Data Dictionary*

VARIABLE *required	FULL NAME	FIELD TYPE	UNITS	DESCRIPTION
RTYP *	RECORD TYPE	Numeric	NA	Record Type is a two-digit field that identifies the type of data being portrayed. The benefit of these codes is that they provide an easy way to separate data before and after thinning to treatment density as well as other types of data and conditions. This will help to study the tree growth responses due to thinning treatment, and it will be particularly useful when the data from several agencies are combined in analysis. Record Type 09 indicates the trees before thinning. This code is only for white spruce because we do not tag aspen in treated plots before the thinning. Record Type10 indicates the trees after thinning and includes both spruce and aspen. For the natural density aspen plots (6, 12 and 15), subplot size is also identified by Record Type. For example, trees recorded in a 2x2 m subplot the Record Type will be "22". Other codes identify site, soil, and other vegetation data. Allowable codes: 01Site Description (Form 2002 - 1) 02Soils data (Form 2002 - 2) 05Vegetation data (Form 2002 - 3) 09 **Spruce Tree data before thinning 10 **Spruce and aspen Tree data after thinning 11 *Tree data (all species) from 1x1 m sub-plots 22 *Tree data (all species) from 2x2 m sub-plots (all tree species) 44 *Top height trees 55 *Tree data (all species) from 5x5 m sub-plots (all tree species) 66*Tree data from final expansion (20x20 m excluding the 10x10 area in subplots) (All tree species) -------- *Natural density aspen plots (6, 12, and 15) ** All other plots
AGCY *	AGENCY	Text		This field contains up to 6 characters to denote the agency or company responsible for this particular block of plots. Allowable codes: GOA Alberta SRD, PLFD Division, Edmonton Alberta Agiculture and Forestry ALPAlberta-Pacific Forest Industries Inc Boyle CFRCanadian Forest Products Ltd, Alberta Operations Grande Prairie MPR.Mercer Peace River LPCSRLouisiana-Pacific Canada Swan River, Manitoba LPCDCLouisiana-Pacific Canada Dawson Creek, B.C. NWTNorthwest Territories, Renewable Resources WFRWestFraser (Alberta Plywood Ltd, Slave Lake) SBRSaskatchewan Big River WGPWeyerhaeuser Canada Ltd, Alberta Division Grande Prairie SPASaskatchewan Ministry of Environment, Prince Albert
BLK *	BLOCK	Numeric		Each company or agency will set up and maintain one or more blocks. Allowable codes: 0-24
INST *	INSTALLATION	Text		Each block consists of two installations; one on a superior site and one on a median site. This field will contain 3 characters in uppercase: Allowable codes: SUPSuperior site installation MEDMedian site installation
REPL *	REPLICATION	Numeric		Each installation consists of two replicates of a series of 15 plots. Allowable codes: 01Replication number 1 02Replication number 2
PLOT *	PLOT	Numeric		Plot numbers are specified by treatment density according to Table 2-2.

VARIABLE *required	FULL NAME	FIELD TYPE	UNITS	DESCRIPTION
				Allowable codes: 1 to 15
DATE *	DATE	Numeric		Measurement date is recorded as year/month/day, without any separator characters. For example October 9th, 1990 is entered as "19901009". Allowable codes: yyyymmdd
TRNO *	TREE NUMBER	Numeric		A six-digit code is assigned all trees in both treatment and natural density plots. Refer to Sections 4.3, 4.5, 5.3, 6.3, 6.4, 7.6, 8.5, 9.4, 10.5, 12.4, 13.5, 14.4, and 15.4 for further description of methods for tree numbering on the different plots. For treatment plots (all plots <u>except</u> the natural density aspen plots 6, 12, and 15), the tree number consists of the planting row (2 digits), tree number (2 digits), and in-growth (2 digits) for both deciduous and coniferous species. Refer to Section 0 and 6.3 for a complete description of methods for tree numbering on treatment plots. For the natural density aspen plots (6, 12, and 15), the six-digit code consists of the subplot number (2 digits) and tree number (4 digits). Refer to Section 4.5 for a complete description of methods for tree numbering on natural density aspen plots. Allowable codes: 0-999999
SPP *	SPECIES	Text		Denotes tree species Allowable codes: FAAlpine fir FBBalsam fir FDDouglas-fir LAAlpine larch LTTamarack LWWestern larch PFLimber pine PJJack pine PLLodgepole pine PWWhitebark pine SBBlack spruce SEEngelmann spruce SWWhite spruce AWAspen PBBalsam poplar BWPaper birch
EST *	ESTABLISHMENT TYPE	Text		Denotes the origin of hardwoods and white spruce. Allowable codes: 'S' indicates that the aspen seedling is of sucker origin 'D' indicates the seedling (aspen or spruce) is of seed origin 'P' is the planted spruce 'R' is any spruce that has been replanted due to mortality 'T' is any spruce that has been replanted using a tree from the buffer. 'I' is any aspen that have been used to replace a dead aspen and spruce If a second replant, transplant or ingress tree is used the code is modified by placing an additional code with the existing, for example "RR" – replanted twice "II "– second ingress tree used "TT" – second transplant The establishment field can be modified to represent 3, 4 or 5 tree replacements.
RCD	ROOT COLLAR DIAMETER	Numeric	cm	RCD is measured just above the butt swelling, using small calipers. Record the measurement to 0.1 cm. When the tree passes 1.3 m height a both RCD and DBH will be recorded. RCD is then measured until **all** trees of that species in the **installation** are above 1.3 meters. If RCD is not measured, leave the field blank, do not enter 0. Allowable codes: 0.1-50.0

VARIABLE *required	FULL NAME	FIELD TYPE	UNITS	DESCRIPTION
DBH	DBH	Numeric	cm	After a tree reaches a height of 1.3 m, record its diameter at 1.3 m height. At the 1.3 m height, the measurement height point should be painted on the tree. To prevent damage to the tree, do not use nails. DBH measurements are recorded to the nearest 0.1-cm. The following measurement protocol is taken from the Alberta SRD/PLFD PSP manual: "Breast height is 1.3 meters from the point of germination. Breast height is determined using a straight stick 1.3 m long. Using a metal diameter tape, measure the tree's diameter to the nearest 0.1 cm making sure the tape is perpendicular to the stem. Diameters are always taken at 1.3 m unless there are large branches or swellings right at breast height. These defects are to be avoided and the diameter is taken immediately above or below the distortion and a comment noting the problem is made on the tally sheet in the shaded comments section (e.g. DBH taken above swell)." (PSP Manual Section 2.1.4.3) Allowable codes: 0.1-100.0
HT	TOTAL HEIGHT	Numeric	m	Total heights (vertical height)) should be measured to the nearest centimeter (0.01 m) for all live trees using a telescoping range pole. These poles are available to a maximum of 15 m. When use of a range pole becomes impractical other height measurement instruments (eg. Hypsometers) may be used. Trees taller than 3 m should be measured to the nearest 0.1 m Measurement using a height pole continues until tree are 6m – 11m in height. Then a hypsometer should be used to measure height. For trees leaning >20º, Total Height may be calculated using the Bole Length and the degree of Lean. Allowable codes: 0.01-100.00
LEAN	LEAN	Numeric	Degrees	Record the degree of lean for any tree leaning greater than 20 degrees off vertical. Trees must also show a Condition Code of either 35 or 58. (Note that LEAN must be measured if a tree is leaning by more than 20 degrees). Allowable codes: 20-90
HTI	HEIGHT INCREMENT	Numeric	cm	Record height increment (current leader length) to the nearest centimeter (0.01 m). This measurement is required in addition to total height so that actual growth can be summarized. Current height increment is measured at each re-measurement until tree height makes direct measurement impractical. Height increment is recorded to the nearest centimeter. Total height may decline if there is top kill or dieback, while the new terminal bud recovers and grows. Direct measurement of height increment gives a check on the total height and reduces the variation in total height which may occur from one measurement to the next. HTI is measured until trees are 3 meters. For trees taller than 3 m it is left blank and will be calculated by subtraction. Allowable codes: 0.00-200.00
CRN	NORTH CROWN RADIUS	Numeric	m	Measure the crown radius for all trees > 1.3 m height. Record the measurement to the nearest 0.1 m horizontally along the north direction from the center of the tree crown to the edge of the crown. Allowable codes: 0.0-30.0
CRW	WEST CROWN RADIUS	Numeric	m	Measure the crown radius for all trees > 1.3 m height. Record the measurement to the nearest 0.1 m horizontally along the west direction from the center of the tree crown to the edge of the crown. Allowable codes: 0.0-30.0
HTLC	HEIGHT TO LIVE CROWN	Numeric	m	The height from the root collar to the base of the live crown is recorded for all trees that have been measured for total height. This distance is measured to the nearest 0.01m for trees less than 3m tall and to 0.1m for trees greater than 3m tall. The base of the live crown is the lowest point on the bole with a relatively complete whorl of live branches. This should identify where the crown breaks up and excludes isolated lower live branches. Allowable codes: 0.00-100.00
CC1 * CC2	CONDITION CODES	Numeric		Condition codes were adopted based on the ASRD (GOA) codes. They are listed and described in appendix 17.4. Up to a maximum of 3 condition codes can be recorded for each tree. Each tree should have at least one condition code, i.e. the field of condition code 1 must be filled. For a normal, healthy tree, enter 0. If root collar diameter and total height

VARIABLE *required	FULL NAME	FIELD TYPE	UNITS	DESCRIPTION
CC3				are omitted, the tree condition code must be given to show the condition (e.g. dead and down, missing) of the tree. When overlapping codes are available, the most specific code should be used (eg. use 71 (Hypoxlon) if applicable rather than 61 (Stem Disease) or 02 (Disease). As long as there is a condition code describing the status of a tree, the information should be recorded as a standard condition code instead of including comments. Multiple codes should be recorded in the order of priority based on effect on tree. In some cases a new condition code may be needed to describe special tree conditions. New condition codes should not be used without prior discussion and approval. If dead tree is coded dead on the first tree code, the second condition code should explain the cause of death. Three separate fields. The first condition code is mandatory, while the second and third condition codes are optional. Up to a maximum of 3 condition codes can be recorded for each tree. Allowable codes: See Appendix 16-4
AZ	AZIMUTH	Numeric	Degrees	A staff compass and a metric tape are used to determine the azimuth and distance to the center of each tree, at breast height, from the plot center. Azimuths are recorded from 1-360 degrees and distances are measured to the nearest 0.1 m. Ensure that the compass has the correct declination and record this on the top of the tally sheet. For all plots except 6, 12 and 15 subplots, tree locations are to be mapped after thinning to treatment density. All hardwood and softwood ingress is removed before it reaches 1.3m. In the instances were an aspen or spruce tree is being used to replace a dead tree an azimuth and distance should be recorded and the proper EST and AGE fields updated. For plots 6, 12, and 15, the azimuth and distance should be recorded for every tree that reaches 1.3 m height. Allowable codes:1-360
DIS	DISTANCE	Numeric	m	Distance from plot center to a tree is measured to the nearest 0.1 m using a metric tape. Allowable codes: 0.0-28.0
AGE	AGE	Numeric		This is field age. Age is required for all planted spruce trees (all plots except 13, 14 and 15) and ingress conifer trees that reach 1.3 m height. Age is required for all deciduous trees in the natural density aspen plots (6, 12 and 15), following thinning all deciduous crop trees on thinned plots (all except 6, 12 and 15) and deciduous in-growth on any plot that reaches 1.3 m height. The age of conifer ingress white spruce can be determined by counting branch whorls. For deciduous trees it can be estimated by counting nodes and/or bud scars. For aspen ingress that is taller than 2 m (making it difficult to see nodes and bud scars), then compare to tagged stems in the plot that hare of similar size and health. Age is a required entry for each tree initially and at each re-measurement, previous year's age assessments should be used as a guide to estimate current years age. Allowable codes: 0-200
Measnum	Measurement Number	Numeric		This is a calculated field – do not fill in this field, it will be set during the installation aging and assessment procedure. This field links calendar year to the first measurement of spruce, after 1 full growing season. From this all other activities and treatments including assessment of sw and aw age are made.
AWAGE	Biological AW Age	Numeric		This is a calculated field – do not fill in this field, it will be set during the installation aging and assessment procedure. This field takes into consideration year of harvest and corresponds to measurement year (measnum) and calendar year.
SWAGE	Biological SW Age	Numeric		This is a calculated field – do not fill in this field, it will be set during the installation aging and assessment procedure. This field takes into consideration year of harvest and corresponds to measurement year (measnum) and calendar year.

17.5 *WESBOGY LTS Condition Codes*

Code	Description		Code	Description
00	Healthy		47	Witches Broom
01	Insects (generic only)		48	Frost Crack
02	Disease (generic only)		49	Dying (NO CC)
03	Rabbit Browsing		51	Conks/Blind Conks
04	Shepherds Crook		52	Open Scars
05	Browsing (Other)		53	Burls and Galls (DBH>9.1cm)
06	Fire		54	Fork
07	Mechanical		55	Pronounced Crook
08	Windthrow		56	Broken Top (<=10cm DIB at Break, DBH>9.1)(NO CC)
09	Climate		57	Limby
10	Flooding		58	Leaning (DBH>9.1cm + if sever NO CC)
11	Poor Planting		59	Broken Stem (>+10cm DIB at Break), DBH>9.1)(NO CC)
12	Suppression		60	Generic woodpecker feeding
13	Frost Heaving		61	Dead and Down (NO CC)
14	Erosion		62	Stem Insects (bark and Sawyer Beatles)
15	Missing		63	Stem Disease (Cankers)
16	Dead Top/Dieback		64	Foliar insects
17	Poor Seedbed		65	Foliar disease
18	Herbicide		66	Stem Form Defect (>=7.0cm DIB at point where stem form begins)
19	Western Gall Rust (only on Pine)		67	Closed Scars
20	Armillaria Root Rot		68	Atropellis canker
21	Moldy Planting Stock		69	Comandra Blister Rust
22	Multiple Leader		70	Elytroderma needle cost of pine
23	Poor Form		71	Hypoxylon Canker
24	Broken Top (New or Old)		72	Spruce cone Rust
25	Dead & Standing (NO CC)		73	Stalactiform Blister Rust
26	Snow press (NO CC)		74	Tomentosus Root Rot
27	Dead Top Dieback with NEW Leader		75	Spruce Spanworm
28	Sucker(s) from OLD Stump		76	Cone Maggot
29	Cut down		77	Coneworm
30	Terminal Weevil		78	Eastern Spruce Budworm
31	SW Gall Aphid		79	Mountain Pine Beetle
32	Tent Caterpillar		80	Spruce Beetle
33	Root Collar Weevil		81	Spruce Needle Rust
34	J-Root		82	Yellow Headed Spruce Sawfly
35	Leaning (NO CC)		83	Large Aspen Tortrix
36	Same Stump		84	Excavations by woodpeckers
37	Unknown		85	Yellow-bellied sapsucker feeding
38	Pitch Moth		86	Small mammal feeding on tree bole
39	DBH Taken on New Leader		87	Small Cavity
40	Nutrient Deficiency		88	Large Cavity
41	Mouse (feeding)		89	Hollow tree or hollow bole section
42	Ungulate feeding/rubbing		90	Beaver (feeding/harvesting)
43	Domestic livestock (rubbing)		91-96	Hawksworth Mistletoe Rating System
44	Nest		97	Not used
45	Other mammalian/avian evidence		98	Data changed by office
46	Sweep/Bow		99	Do not look for tree

Notes: No CC means no crown class.

WESBOGY LTS Condition Codes Descriptions

Condition Code		Description
00		Healthy - No Defect.
01	Insects	Damage or mortality due to destruction of plant parts or tissue by insects. Look for evidence of eggs, egg cases, nests, chewed plant parts, etc. Similar signs on plants located off site may aid in identification of insect mortality.
02	Disease	Damage or mortality caused by disease or fungi. Cankers, discoloration, rust spotting, fungal coverings, etc. help to identify mortality under this code.
03	Rabbit Browsing	Trees killed or damaged by rabbits can be identified by clean, sharp cut marks along the branches and stems (approximately 45^{o} angles). Chewed bark and needles also indicate rabbit damage.
04	Shepherd's Crook	Damage results in blackening and wilting of young shoots and leaves. Tips of the blackened shoots often bend back. On older leaves brownish black, irregularly shaped spots appear.
05	Browsing (other animals)	Mortality or damage due to browsing by ungulates or other animals (e.g. moose, cattle, beavers). Look for chewed tops with rough cuts or breaks.
06	Fire	Mortality or damage due to actual burning of the seedling or scorching by nearby flames. **Not to be used when seedlings are killed by sun scald**.
07	Mechanical	Trees killed or damaged by mechanical or physical means such as scarification machinery, trampling or crushing by animals, etc. Stem scars and rough breakage help to identify mortality under this code.
08	Wind Throw	Damage or mortality due to crushing by fallen or displaced logs, snags, branches, uprooted trees, etc.
09	Climate	Trees damaged or killed solely by climatic factors. These include death by freezing, sun scald, severe desiccation, ice accumulation, red belt, etc.
10	Flooding	Trees damaged or killed by drowning alone. Look for evidence of high water marks on the seedling, or in the immediate area. Pull tree out of ground and check roots to see if the root outer coverings is falling off and is blackened.
11	Poor Planting	Damage or mortality due to improper placement of nursery stock (hand or mechanical planting). Trees may have been planted too deep, too shallow, too loosely, or at an acute angle.
12	Suppression	Trees which have been suppressed by the surrounding vegetation for a period of time long enough to damage or kill them. Mortality may be due to severe lack of light, water, nutrients (removed by the competition) or by physical smothering (i.e. heavy grasses). Reference to the previous year's damage tally may help in determining this mortality call. A tree that is over topped by grass or shrubs is not necessarily suppressed. Look for a spindly main stem with very few long needles spaced wide apart or evaluate the last five increments. If the tree has only grown 1cm a year, it is probably suppressed.
13	Frost Heaving	This code is used only when mechanical frost action can be clearly identified as the direct cause of damage or mortality. Usually upheaval and separation of the seedling's root system from the soil occurs as a result of ice lens formation. This is most commonly associated with containerized seedlings planted in silty soil.
14	Erosion	Damage or mortality due to the removal of the seedling's seedbed, by the forces of water, wind or soil slumping. Trees killed by partial or total burial (deposited soil or organic matter) would also be tallied using this code.
15	Missing	This code is to be used when a seedling from the previous year's measurement cannot be located. It can also be used where the seedling was removed from the site and probably died (i.e. tag found, no morphological signs of live seedling remaining). Using in conjunction with code 25 **ONLY**.
16	Dead top/Dieback	Top is dead (die back) without any indication of insect or climate (frost) damage.
17	Poor Seedbed	This code is to be used only when the cause of death or damage for a seedling can be traced to the type of seedbed on which it is growing. In most cases the seedling will show signs of desiccation due to the poor moisture holding capacity of the seedbed material (e.g. rotten logs, dry clay).
18	Herbicide	Should only be used when the cutblock (or parts of the cutblock) has received a recent herbicide treatment; either before or after the stock was in place. Spruce seedlings exhibit needle loss and/or reddish brown coloration of stems and foliage. Deciduous species exhibit yellowish/brown leaf mottling and dieback of terminal growth. Hexazinone causes reddish brown coloration of conifer foliage and needle loss. Deciduous foliage turns red to black. Glyphosate causes chlorosis especially in new growing shoots. 2,4-D causes rapid growth and spiralling and twisting. If applied during conifer flush bad dieback similar to frost damage may occur. Often chemical damage will also be indicated by phytotoxicity spotting on exposed foliage.
19	Western Gall Rust(only in Pine)	This code is used when Lodgepole pine damage or death can be attributed to Western

Condition Code	**Description**
	Gall Rust. This is usually clearly identifiable due to swelling of succulent tissue (and subsequent formation of a gall) and the bright orange spores produced in that affected area. This gall can be on the main stem or a lateral branch.
20 Armillaria Root Rot	This code is utilized when a seedling is damaged or killed by Armillaria Root Rot. Identification of the disease is in recognizing mycelial fans of the cambium of damaged and dead trees. Pull tree out of ground and examine root collar.
21 Moldy Planting Stock	This code is usually used on Bareroot Planting Stock. Grey mold will usually be found around the root collar and lower branches.
22 Multiple Leader	This damage code is commonly used on planted stock. When a tree has two or more leaders, but is otherwise healthy this code should be entered. The tree is considered to have multiple leaders if all leaders are within 5cms (height) of each other. This code also applies to saplings and regeneration that appear forked. Be aware of normal branching of deciduous trees.
23 Poor Form	This code is used on trees which exhibit a general poor form, due to previous damage. It is commonly used with Advanced stock which was damaged by scarification activity.
24 Broken Top (New or Old)	It should be used as long as the broken top is noticeable and has some effect on the growth of the tree.
25 Dead Tree/Standing	Tree has no signs of being alive. A standing dead tree is one that is dead but still standing. No green foliage or buds present. The tree must be able to withstand a firm push. Record a diameter and species but do not record height. Pound nail into tree. **No crown class**.
26 Snow Press	This code is normally used for trees that show signs of being pressed down to the ground for a few years after germinating or being planted.
27 Dead Top Dieback with New Leader	This refers to stems that have had previous leader damage and a new leader has formed.
28 Sucker(s) (From Old stump)	Refers to stems that have been cut-down through thinning and have started to sucker. Do not re-use the previous stem number, but assign a new number to each sucker.
29 Cut Down	Self explanatory.
30 Terminal Weevil	Terminal leaders of Pine or Spruce bend over and die. Two or more years growth are affected. **Bore Holes** which are exit holes for the larvae **MUST** be present to use this code.
31 Spruce Gall Aphid	Galls located at the end of new growth and may persist for many years.
32 Forest Tent Caterpillar	A tent of silk forms on the tree and the caterpillars defoliate the tree.
33 Root Collar Weevil	This weevil feeds mainly on SW, Pj and Pl. They feed in the bark and cambial area of the host tree at or below the duff surface, causing copious flows of resin. The tunnels often girdle small trees. This insect allows root rots to enter the tree.
34 J-Root	This code is used after the tree has had a poor planting code in the previous measurement.
35 Leaning	Tree leaning more than 20° off of vertical axis.
36 Same Stump	Used when 2 or more trees can be distinguished above ground level but below DBH. Used a lot on Deciduous that have been cut down and re-sprouted at stump. Only call same stump when stems are >9.1cm, both are live and vigorous, and it is fairly clear they are forming ~separate crowns that happen to fork under BH. In this case the stems would each have their own tags. For situations where stems smaller than 9.1 cm in diameter share the same stump they can be noted in comments as “clumps”, but individual stems should not be tagged.
37 Unknown	This condition code is to be used only when there appears to be something affecting the tree but the other condition codes do not describe the situation. This would include burnt trees etc. A description of what is affecting the tree should be included as well in the comments column. In the event that this code is used for more than 5% of the tallies, it is up to the crew leader or a forester to decide on the cause of the condition.
38 Pitch Moth	Primary host is Lodgepole Pine. May weaken or kill the terminal leader, resulting in stem deformities and height growth reduction. Blisters are mainly on main stem and are characteristic resin coated up to 20mm in diameter.
39 DBH Taken on New Leader	
40 Nutrient Deficiency	This may occur on blocks that have had the humus layer removed by scarification (i.e.; Blade). Trees are chlorotic and usually in bare mineral soil. Usually noted on spruce. May be confused with flooding damage.
41 Mouse Feeding	Mice and voles can girdle seedlings and consume seeds. See Rangen and Roy (1997) for more detail.
42 Ungulate feeding/rubbing	Ungulate feeding on twigs is generally recognized by the ragged appearance of twig terminals. Rubbing of trees as antler rubs and feeding on bark also occurs; these conditions are further described in Rangen and Roy (1997). Antler rubs can also be associated with “scrapes” (smaller patches of scraped ground) and small tufts of hair

Condition Code	**Description**
	on twigs. .If the bark on aspen trees has been consumed ensure that ungulates (as opposed to other mammals) are responsible. The extent of the bitten area, track identity and grooves that indicate tooth size and pattern should all be inspected in order to differentiate ungulate bark feeding from similar feeding by small mammals (i.e. see code number 86 and applicable photograph).
43 Domestic livestock (rubbing)	Rangen and Roy (1997) describe rubbing of trees by livestock; rubbed trees are occasionally seen in areas where cattle grazing occurs. If this code is used, ensure that other signs in the general area (i.e. presence of cattle droppings, cow trails and grazed vegetation) also support this.
44 Nest	This code indicates the presence of a nest on a given tree in the PSP. It refers only to an "open" nest; cavity nests are excluded from this category as it is difficult to ascertain if a given cavity is indeed used as a nest site. Field guides that assist with the identification of "open" nests are available (see Harrison 1979). Of particular importance are colonial complexes of large nests on islands in lakes. Mammalian nests also exist and should be indicated as such if this is known. To do this, use the comments section which applies to a given tree and indicate as required. If the occupants of the nest can be identified, the identity can also be entered in the comments section.
45 Other mammalian/avian evidence	Other agents (i.e. bears, grouse, shrew, pocket gophers) which leave evidence on trees or leave evidence closely associated with trees are described in Rangen and Roy (1997)). Pocket gophers leave soil mounds (Rangen and Roy (1997)). Bears can leave a characteristic series of claw marks on aspen trees, indicating that the tree was scaled, and rotted stumps/logs are also occasionally ripped apart. In addition, it has been suggested that bark on live trees is occasionally consumed (see Hiratsuka 1987 for a depiction). Ensure that ripped up stumps/logs, etc. are accompanied by other evidence of bear.
46 Sweep/Bow	Is a gradual bowing or curving of the main tree system. It has no decay significance but may cause a loss of volume.
47 Witch's Broom	Yellow witches broom is the most conspicuous disease of spruce in the prairie provinces.
48 Frost Crack	A frost crack is a deep radial splitting of a trunk caused by an uneven shrinkage of the wood after a sudden drop in temperature. The cracks usually start at the base and extend up the trunk.
49 Dying	Tree is in distress and will die before next measurement.
51 Conk/Blind Conk	Conks appear most frequently on the underside of dead branch stubs or on the underside of live branches in the crown. Conks, by definition, are woody, shelflike basidiocarps (fruiting bodies) of wood-rotting fungi.
52 Open Scars	Open scars are wounds which have been penetrated through to the cambium. These wounds must not be healed over and may be caused by a variety of reasons such as fire, lightning, old blazing, machinery, animals, etc. Scars are considered to be entry points for decay fungi. Animal damage usually penetrates the cambium therefore code as an open scar. A common mistake is to call stem disease such as atropellis canker an open scar.
53 Burls and Galls	Burls are abnormal swelling of the main stem or branches resulting from abnormal wood cell development following disturbance to the cambial layer Galls are localized trunk and branch swelling of mainly tissue. There is little or no damage to the underlying wood. Do not mistake western gall aphid for a gall, it is a foliar insect.
54 Fork	Forks usually develop when there is malformation, injury or death of the terminal leader. Forks tend to be V-shaped and will only be recorded when above 1.3 m (DBH level). Forks below this point are recorded as same stump (condition code 28). Natural branching on deciduous trees is not to be recorded. A fork must be at least 7.0 cm DIB, 2.5 m past the fork to be considered. The ASRD PSP manual demonstrates the difference between forks and natural branching.
55 Pronounced Crook DBH $\geq$ 9.1 cm	This condition develops from the death of the terminal leader or the breaking off of a forked leader. When this occurs, a lateral branch takes over apical dominance. A crook is recorded when the inside bark diameter is at least 7.0 cm, 2.5 m above the defect.
56 Broken Top DBH $\geq$ 9.1 cm	Broken tops are recorded when the tree bole is less than 10 cm DIB (diameter inside bark) at the break. **No Crown Class**.
57 Limby	A tree is recorded as limby if more than 75% of the tree has live, low sweeping branches. In general, if the majority of the trees in a plot are limby then this code is not recorded.
58 Leaning	A tree is considered leaning if it is standing greater than 20º off of vertical. If the angle is greater than 45º to the ground, the tree has a severe lean. **No crown class if severe**.

Condition Code	Description
59 Broken Stem	A broken stem is recorded if the tree bole is greater than 10 cm DIB at the break. **No crown class**.
60 Generic woodpecker feeding (often smaller species)	Species such as the Black-backed woodpecker and Three-toed woodpeckers will often leave signs like this on old coniferous trees, and Hairy and Downy woodpeckers typically peel off scales (“scale”) and “peck” the bark as do Pileated woodpeckers in summer months (Conner 1979). Note the evidence of very small holes (arthropods) and holes made by the woodpeckers themselves. The appearance of tree trunks fed on in this manner is often reddish from a distance.
61 Dead or Down	A dead and down tree is one that was previously tagged and measured in a PSP plot but at the present time is now dead and no longer standing. The cause of death must be by natural causes (i.e. windfall, beavers, insect or disease, etc.). **No crown class**.
62 Stem Insects	This code is recorded when there is evidence of an insect infestation attacking the bole of the tree. Bark beetles are the most prevalent stem insects but sawyer beetles and others are included. .Bark beetles, Dendroctonus spp., are a very serious problem in Alberta. The adult female enters the bark in early summer and lays eggs in the tree's cambium. The eggs overwinter and hatch as larvae in the early spring. Damage to the tree is done by the larvae eating the cambium and usually results in death. The tree will not turn red until the next summer. Other symptoms of attack are piles of "sawdust" (frass) at the base of the tree, entry holes in the bark, and pitch tubes (the tree tries to push the beetles out with resin). The beetles also carry a blue stain that causes further deterioration of wood quality. Beetles attack all species of pines, spruce, and Douglas fir. Sawyer beetle infestations are common in burned timber.
63 Stem Disease	All diseases that infect the main stem are documented with this code. Included in this code are cankers, rusts, rotten branches and root rot. Stem cankers are caused by fungi that invade stems and branches resulting in localized areas of infection in the bark and underlying wood tissue. Cankers may be annual or perennial. In perennial cankers the infected area may be eventually exposed to the underlying wood when the dead bark sloughs off. A common stem canker on lodgepole pine is Atropellis piniphila. Exudation of resin from the bark surface is the first external symptom. They are sunken elongated on one side of the trunk and indicate resin flow. This can cause a distortion in growth and a blue-black stain on the wood. Stem rusts are also included in this condition code. Rusts are host specific parasitic fungi usually requiring two alternating living hosts. Stems and branches may be girdled resulting in large malformations or even death. In particular, Endrocronartium harknessii on young pines is a serious problem in Alberta. Spruce broom rust, Chrysomyxa arctostaphi, can also be noted but only if the broom is no longer green (i.e. red or missing needles). Large rotten branches typically appear on over -mature, decadent trees and can be indicative of decay. Large rotten branches are those well below the base of the live Crown and are > 5 cm in diameter, are unweathered, appear punky, and are weeping. Often a black ring appears on the stem surrounding the branch. Some of the typical symptoms of Armillaria root rot are reddish brown or yellowish foliage; mycelial fans form between the bark and wood around the base; fungal (shoestring) strands in the soil surrounding the diseased roots and honey mushrooms growing around the base of the diseased tree.
64 Foliar Insects	This condition code pertains to all insects that infest parts of the tree off the main stem. Included in this category are the tent caterpillar, spruce budworm, jack pine budworm, spruce gall aphid, etc. The forest tent caterpillar, Malacasoma disstria, causes severe defoliation in hardwood stands in Alberta resulting in a significant reduction in annual growth. The spruce budworm, Choristoneura fumiferana, infests mature white and black spruce, and balsam fir stands. This insect attacks the buds and new needles. Their feeding spreads to old needles and eventually kills the tree. The jack pine budworm, Choristoneura pinus, attacks stands of jack and lodgepole pine and is a relatively new forest pest in Alberta. This insect feeds and spreads in the same manner as the spruce budworm.
65 Foliar Disease	This code is used for all diseases that infect parts of the tree off the main stem. Needle casts and blights, and needle rusts are included in this condition code.
66 Stem Form Defects DBH $\geq$ 9.1 cm	This condition code is used when there is damage or a distortion resulting in a loss of volume. The point at which the stem form begins must be at least 7.0 cm DIB.

Condition Code	Description
	Included in this category are defects such as sweeps and bends, spiral grain, frost cracks, and windshake. A sweep or bend is the gradual bowing or curving of the main tree stem. If has no decay significance, but may cause a loss of volume in a sawlog. Spiral grain is the twisting of the grain seen in exposed wood or in the direction of the bark fissures. Spiralling frost cracks and scars also indicate the presence of spiral grain. A frost crack is a deep radial splitting of the trunk caused by uneven shrinkage of the wood after a sudden drop in temperature. The cracks usually start at the base and extend up the trunk. They may be reopened repeatedly by wind stresses or low temperatures. Windshake is a splitting in the wood along the grain or less frequently within an annual growth layer. It is caused by wind or snow stresses and is also known as ringshake.
67 Closed Scars	Wounds that had penetrated the cambium but have now healed over are considered closed scars. A closed scar is characterized by an irregular indentation in the bole of the tree that would result in loss of volume due to poor wood quality. Before healing over, the scar provided an entry point for disease. Frost crack is not included in this code.
68 Atropellis Canker	Widespread on pine, from small to large trees. Symptoms are elongated, sunken, cankers on the stem with copious yellowish resin flow. Wood is discoloured blue/black.
69 Comandra Blister Rust	Pl and Pj are hosts. Local occurrence only. Infected stems are spindle-shaped with conspicuous swelling of the bark. Fungus is orange-yellow in early summer. Cankers are circular and grow laterally as quickly as longitudinally. They thus girdle the stem faster than stalactiform. It should not be confused with western gall rust which is mainly a swelling of the wood. Alternate host is Indian Paint Brush.
70 Elytroderma Needle Cast	Mostly on Pl. Current years needles turn red in fall. In severe cases only current needles remain, giving branches a "lion's tail" appearance.
71 Hypoxylon Canker	Hosts are aspen and balsam poplar. Canker starts as a slightly sunken orange-yellowish area on stem. Eventually girdles the stem and has an orange/black appearance. A mycelial fan on the cambium is a reliable field symptom.
72 Spruce Cone Rust	Rust is only on spruce cones. Cones become prematurely brown then orange-yellow. When spores are abundant the forest floor has an orange colour.
73 Stalactiform Blister Rust	Pl and Pj are hosts. Local occurrence. Causes slight swelling of bark. Orange-yellow in summer. Cankers are elongated and grow faster longitudinally compared to Comandra. Alternate host is Bastard Toad Flax.
74 Tomentosus Root Rot	Most important on SW and Sb. Symptoms are excessive branch mortality, thinning of crown and openings in the stand. Disease develops slowly (over 15-20 years) so is not so obvious in regenerating stands.
75 Spruce Spanworm	Chiefly affects aspen. Damage shows mostly as holes in the leaves. Resembles forest ten caterpillar but no pupal cases or egg masses on the foliage. Caterpillars are typically light-green and have one prominent and two indistinct yellowish lines along each side of the body. The head is dark-brown.
76 Spruce Cone Maggot	No external symptoms. Dissected cone shows frass-filled spiral tunnel around the central axis.
77 Spruce Cone Worm	Feeding larvae expel frass which adheres to silken webbing on cone surface.
78 Eastern Spruce Budworm	First symptoms are webbing and frass in buds or on previous year's needles. Later, webbing is spun on branch tips. By late June tree crowns appear rust brown.
79 Mountain Pine Beetle	Main host is Pl. Symptoms are standing dead trees with beetle exit boles about eye-level. Accumulations of pitch or sawdust are conspicuous around entrance holes bored into the bark of trees by adult beetles from mid-July to mid-August.
80 Spruce Beetle	Hosts are SW and Se. Symptoms are standing dead trees with beetle exit holes about eye-level. Conspicuous boring dust accumulates on bark below holes until the wind blows it away.
81 Yellow-headed Spruce	Feed on needles in the upper crown of the tree. Partly chewed needles and needle stubs impart a brownish color and ragged appearance to the foliage. No webbing present. Found on all spruce.
82 Spruce Beetle Rust	Discoloration of needles. May find dot-like sexual fruiting structures on needles. Infected needles drop prematurely.
83 Large Aspen Tortrix	Affected foliage has a clumped, irregular appearance and leaves do not move as freely in the wind as uninfested leaves. Larval instars feed within rolled leaves or within 2 or more leaves pulled together and secured with silken webbing.
84 Excavations by woodpeckers	Feeding by Pileated woodpecker can occur on dead or senescent deciduous and

Condition Code	Description
(likely Pileated woodpecker)	coniferous trees, and feeding holes are thought to occur towards the base of the tree (Rangen and Roy 1997). Excavated holes indicate subcambial penetration (holes penetrate beneath the bark and into the sapwood) and large wood chips can be associated with excavations. Excavated feeding holes can be large. In such excavations, evidence of carpenter ants (burrows, sawdust) or other boring arthropods might also be found in the sapwood. In living trees with a sound bole, initial feeding holes might be more restricted. Elsewhere in North America, the Pileated woodpecker has been found to excavate holes extensively in winter and to a grater extent that other woodpeckers (Conner 1979). The Hairy woodpecker might also create deeper holes in trees, however, it is considered an opportunistic feeder (Sousa 1987) and spends a smaller portion of its time "excavating" during winter months (Conner 1979). In Iowa, it has also been found to generally feed at higher locations in trees (5-7m) (Sousa 1987).If this feeding evidence exists on a given tree, indicate in comments its extent.
85 Yellow-bellied sapsucker feeding	There is a characteristic pattern of regularly spaced small holes left by Yellow-bellied sapsucker (also see Hiratsuka 1987 for another depiction of sapsucker feeding). These are often found on birch, however they also have been observed on willows, and have been reported on aspen and pine (Rangen and Roy 1997, Hiratsuka 1987).
86 Small mammal feeding on tree bole (hare,porcupine, squirrel, bushy-tailed woodrat)	When hares feed on twigs, it is generally thought that twigs are clipped off in a characteristic razored fashion (Figure 106, Rangen and Roy, 1997). Small mammals such as porcupine, woodrat and squirrel might also feed on bark; however, if such feeding evidence occurs high in trees, one could probably rule out hare because hare do not climb trees (also see Hiratsuka 1987 for a depiction of porcupine feeding on pine). Ensure other evidence (i.e. tracks, pellets, etc.) Supports a specific determination of the agent involved. Also refer to Rangen and Roy (1997) for more information on how to identify the specific causes of girdling and refer to Murie (1975) for assistance on identifying tracks if this is required. Evidence of squirrel feeding is common and could also be indicated, however, the value of this information is probably less valuable.
87 Small Cavity	Small woodpeckers create small cavities (approximately 5 cm in diameter) in snags and stubs, however, height of the cavity above ground probably varies. Among the species which might use such cavities are smaller woodpeckers, kestrel, chickadee, nuthatch, swallow, wren, flycatchers, and small mammals (etc). One could explore whether such cavities are occupied by rubbing the bark with a stick. Should a cavity be occupied the occupant (if known) should be identified in the comments section.
88 Large Cavity	A large cavity is a round/excavated opening greater than or equal to 10 cm in diameter. The cavity in the figure was approximately 15 m high. Pileated woodpeckers have been known to excavate such cavities, however, a variety of species (birds as well as mammals) may use them as nest sites, roosting sites or dens. As in the case of smaller cavities, one could investigate the identity of the occupant by rubbing/tapping the bark of such trees with a stick. If might be possible to ascertain the identity of the tracks which are associated with the cavity, during winter, by checking surrounding snow cover and identifying tracks that appear to lead towards the cavity in the tree (see Murie 1975).
89 Hollow tree or hollow bole section	Hollow trees can be used as denning sites by bats and other birds and mammals. This condition code should be used to identify these sites.
90 Beaver (feeding-/harvesting)	Beaver girdle large trees in a characteristic fashion and evidence of their harvesting activities (i.e. cone shaped stumps) are well known to many. Refer to Rangen and Roy (1997) and Hiratsuka (1987) for more details.
91-96 Hawksworth Mistletoe Rating System	Dwarf mistletoes are parasitic flowering plants requiring living hosts. Mistletoe is usually recognized by swellings on branches and stems or by witches brooms. Heavy infestation makes trees susceptible to secondary attack (such as bark beetles), lower wood quality and growth losses (can be from 30-60%). The major tree hosts in Alberta are: lodgepole pine, Douglas fir and larch. The Hawksworth Rating System for mistletoe is used to determine the severity of mistletoe infestation on individual trees Hawksworth 1961, 1977). If a tree has mistletoe, record only the 90 series code, do not record 33 unless there is a second distinct foliar disease.
98 Data changed by office	
99 Do not look for Tree	