Stand Survey & Growth Modeling for the Fort St. John TSA

Prepared for

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Project: CFC–004

January 17, 2003

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Executive Summary

Riverside Forest Products Ltd., as part of their Forest Practices Code (FPC) pilot project on TFL 49, developed a prototype silviculture survey and modeling system to assess reforestation obligations at the landscape level. This report describes the first steps in adapting the prototype system for use in the Fort St. John TSA. The initial Riverside system uses stand, site and tree information collected in surveys 10 years post-harvest to predict merchantable volumes 80 years post-harvest for lodgepole pine and interior spruce stands. Silviculture obligations are met if the overall average predicted merchantable volume meets or surpasses the target merchantable volume set for the harvested area.

For the Fort St. John TSA, the model to predict future merchantable volumes was re-fit to use survey data 15 years post-harvest as the inputs and provide merchantable volumes for lodgepole pine and interior spruce stands 80, 90 and 100 years post-harvest as the outputs. In addition, the post-stratification procedures for the survey data have been simplified and improved using inventory attributes and target stocking standards as the variables to assign plots to the required strata for determination of future merchantable volumes.

The proposed survey methodology uses a combination of *full-measure* and *count-plots* established on a 100 m grid. The *full-measure* plots are established on the 200 m grid where all trees are measured for height, species, and health condition. The *count-plots* are established on a 100 m grid between the full-measure plots where less detailed measurements are taken. Pins are used to mark the location of the full-measure plots so they can be relocated and included in subsequent surveys. This will then provide data that can be used to estimate change in these young stands over time. In addition, the use of a grid allows linkage to a growth and yield monitoring program where permanent sample plots can be established on a small subset of the points used for the full measure plots.

To fully implement the silviculture survey and modeling system in the Fort St. John TSA additional work is required to improve estimates of site productivity and include projections of aspen and mixedwood merchantable volumes and changes in species composition in the model. The later are dependent on improved growth and yield modeling of aspen and mixedwood stands which has been identified as a high priority for the TSA.

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1. INTRODUCTION

1.1 BACKGROUND

Participants in the Fort St. John Results Based Forest Practices Code pilot project expressed interest in adapting the prototype silviculture survey and modeling system developed by Riverside Forest Products for TFL 49.[1,2] The prototype system, developed for lodgepole pine (Pl) and interior spruce (Sx) stands, was completed in 2001-02 by Riverside as part of their Results Based Code pilot project. The primary objectives of the system were to assess reforestation performance at a level of resolution above the individual cutblock, allow silviculturalists more options to achieve the desired stand at harvest for the lowest costs, and to highlight the relationships between silviculture activities and future yields. A key component of the prototype system is the ability to compare silviculture performance against a predetermined target. The major steps in the system are to:

1) Use a simple survey to collect information on regenerated stands.
2) Use the survey information to predict future harvest volume.
3) Compare the predicted volume to a target future volume for those blocks.

This results based system ensures that overall silviculture performance goals are achieved while avoiding the high cost of micro-managing individual blocks and portions of blocks.

1.2 PROJECT GOAL & OBJECTIVES

The primary goal of this project is to adapt the Riverside silviculture survey and modeling system to the Fort St. John TSA for the results based code pilot project. The system will be adapted for Pl and Sx this year and aspen (At) and At/conifer mixtures in subsequent years.

The specific objectives of this project are to:

1) Re-fit the Pl and Sx models developed for Riverside with different post-harvest times for the survey and subsequent harvest.[3]
2) Identify potential linkages between the survey and modeling system and monitoring requirements.
3) Provide sufficient information to describe the survey and modeling system in the Fort St. John sustainable forest management plan (SFMP).
4) Assess the direct applicability of the Riverside system to the Fort St. John TSA and document required adjustments, including those needed for At and At/conifer stands. (The intent is that adjustments not addressed in this project will be included in a future research proposal[4]).

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[1] J.S. Thrower & Associates. 2002. Stand surveys and growth modeling for the TFL 49 results-based pilot project: final report. Contract report for Riverside Forest Products Ltd. January 2002.

[2] Martin, P.J., Browne-Clayton, S., McWilliams, E. 2002. A results-based system for regulating reforestation obligations. For. Chron. 78(4):492-498.

[3] The Riverside models used 10 years post-harvest as the survey time and 80 years post-harvest as the future harvest time.

[4] Current indications are that there will be an FII call for research proposals in February 2003.

1.3 Terms of Reference

This project was completed by J.S. Thrower & Associates Ltd. (JST) for Canadian Forest Products Ltd. (Canfor), Fort St. John operations. The JST project team was Eleanor McWilliams, *MSc RPF*, Jim Thrower, *PhD RPF,* Ian Cameron, *MSc RPF,* and Guillaume Thérien, *PhD*. The Canfor project leaders were Don Rosen and Greg Taylor, *RPF*.

Three main groups collaborated in developing this system: the Ministry of Forests lead policy development and provided the TASS simulations; the licensees (Riverside and Canfor) lead operational implementation; and J.S. Thrower & Associates lead the design of the survey and modeling system. Key contributors from the Ministry of Forests were Pat Martin, *RPF,* Lorne Bedford, *RPF*, Ken Polsson, and Wendy Bergerud. Shane Browne-Clayton, *RPF*, is the Riverside project leader, and Gary Bouthillier (Resource West Consulting Ltd., Kelowna) provided valuable input into the survey design.

2. STAND SURVEY

2.1 OVERVIEW

The key components of the proposed stand survey (described below) are:

1) Stands are surveyed 15 years after harvest to estimate the predicted merchantable volume (PMV) at a given age (80, 90, or 100 years after harvest).
2) Sample plots are located on a 100 m grid (generated from UTM coordinates), and all grid points in the net area to be reforested (NAR) are sampled.
3) Full-measure plots are located on the 200 m grid points, and count plots are located on the 100 m grid points.
4) Both plot types use a 3.99 m radius plot (50 m^2) to measure tree attributes. A 5.64 m radius site index plot (100 m^2) is established at the full-measure plots to collect site tree data.
5) Measurements in full-measure plots include:
   a) Species, height (visually estimated), and health of all trees.
   b) An assessment of stocked or not stocked for each quadrant (a stocked quadrant must contain at least one healthy free-growing tree).
   c) An assessment of non-productive area and brush.
   d) Height and age of one site tree per species.

   Full-measure plots are marked with a steel[5] pin and GPS coordinates are taken for future relocation to include in subsequent surveys.
6) Measurements in count plots are also recorded by quadrant and include only:
   a) An assessment of stocked or not stocked for each quadrant, and why quadrants are not stocked (e.g., brush, non-productive (NP) area, health).
   b) A tally of trees by species.

2.2 SURVEY OBJECTIVES

The goal of the survey is to describe stand characteristics in sufficient detail to estimate the PMV at 80, 90, or 100 years after harvest to compare with a target merchantable volume (TMV) for that age. The objectives of the stand survey are to:

1) Measure tree conditions, stand structure, and site productivity (where possible) to predict future volume.
2) Produce inventory labels.
3) Identify potential areas for silviculture treatments.
4) Update block maps to define areas where volume should be predicted and where other values take precedence (e.g., wildlife).

[5] Any type of pin that can be located with a metal detector is acceptable.

2.3 Target Population

The target population to sample in a given year is the NAR created from harvesting 15 years previously. For example, the target population to sample in the year 2003 is the NAR from harvesting in 1988. The modeling procedures developed in this project assume stands are surveyed 15 years after harvest.

2.4 Post-Stratification

Three primary objectives to post-stratify the target population are to:

1) Assess regeneration performance. Stands are grouped to calculate TMV and PMV.
2) Delineate forest-cover polygons.
3) Identify areas for silviculture treatments.

A secondary objective to post-stratify the target population is to:

1) Improve integration of silviculture and inventory records and the link between silviculture decision-making and timber supply.

The target population is post-stratified using information from the inventory labels and target stocking standards (TSS). For each defined stratum, a TMV is set, and data from all plots are pooled to determine an overall mean number of stocked quadrants (MSQ), effective age, and site index to calculate the PMV. The procedures for post-stratification are described in Sections 2.5.2 and 2.6.1, and the procedures to compile the data are described in Section 4.

2.5 Office Procedures

2.5.1 Map & Previous Data

A Silviculture Prescription (SP) map (or equivalent) should be used to develop the plot locations of the stand survey and should be updated following each survey. This map should show block boundaries, NP area, non-commercial cover (NCC), wildlife tree patches (WTPs), riparian management areas (RMAs), permanent access structures (PASs), and temporary roads. If permanent sample points were established in a previous survey (Section 5.1), the data should be downloaded to hand-held computers for comparison and error checked during the survey. The surveyor should be familiar with the block history.

2.5.2 Office Stratification

Prior to field sampling, the following information should be added to the survey map:

1) Transfer NAR boundary to the survey map (the NAR is the target area to sample).
2) Transfer TSS boundaries from the SP to the survey map.

Standards units (SUs) can be combined if they have: a) the same TSS; and b) the same preferred and acceptable (p+a) species. Record the TSS and the p+a species for each unit (this information is required during the survey).

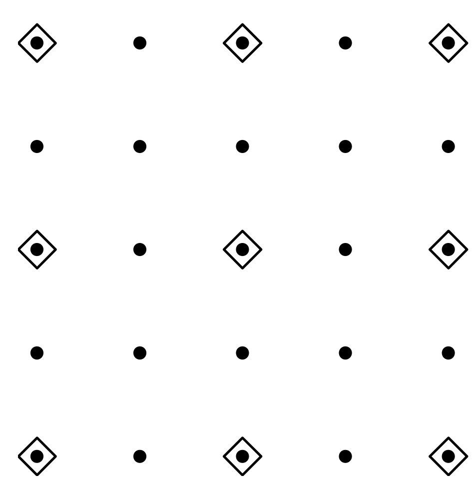

Figure 1. Example of sample points on a 100 (•) and 200 (◇) m grid.

2.5.3 Plot Locations

Sample plots are located on a 100 m grid (Figure 1) using UTM NAD 83 coordinates. These grid points can be generated in the GIS by plotting points evenly divisible by 100. Plot locations should be marked on the map prior to field sampling and all points in the NAR should be sampled.

2.6 FIELD SAMPLING

2.6.1 Stratification

During field sampling the following information should be added to the survey map:

1) Update NAR boundaries if necessary.
2) Map inventory polygons. Follow current procedures to map inventory polygons using species composition, site productivity, and stand density. Distinguish between areas considered SR and NSR.
3) Map potential treatment units. If the cutblock contains a viable treatment unit, add to the map the approximate location of the treatment unit and describe the treatment opportunity.

2.6.2 Full-Measure Plots

Each full-measure plot includes a 50 m^2 (3.99 m radius) plot divided into quadrants along cardinal directions to measure tree attributes and a 100 m^2 (5.64 m radius) plot to collect height and age data from site trees (located at the same plot center) (Figure 2). Suitable site trees have three or more years height growth above breast height. Site tree data should be collected from one tree of each species located in the site index plot with a suitable site tree.

Plot Location

Full-measure plots are established on the 200 m grid. Plot centers should be permanently marked with a steel pin and GPS coordinates recorded. Plot locations should be documented in the GIS. These sample points should not be visible when walking through the stand to avoid treating the plot area differently than other portions of the stand (which may bias the information from the sample point at subsequent measurements).

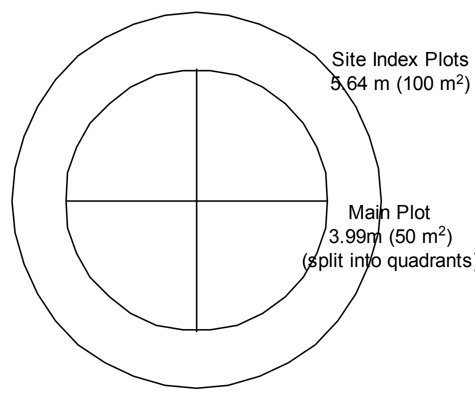

Figure 2. Full-measure and count plot design.

Main Plot – 50 m^2

<u>Quadrant Information</u> - Record each quadrant as stocked if it contains at least one healthy tree of an acceptable species that is free of brush competition (according to current free growing regulations). If a non-stocked quadrant could support tree growth, comment on why there are no trees (e.g., type of NP ground, missed plantable spots, brush competition, health problems).

<u>Tree Information</u> - Data for each tree in the plot includes:

i) Quadrant number (1-4).
ii) Tree species.
iii) Height (measure some for reference and visually estimate others).

iv) Forest health codes (use the same codes used in other silviculture surveys).

Brush Information - In each quadrant record percent cover and average height of brush by species.

NP Area Information - In each quadrant record the type and percent cover of NP area (e.g., rock, water).

Site Index Plots – 100 m²

Record site index information for one site tree of each species from the site index plot located at each plot center. Site trees are:

i) The tallest tree in the 100 m^2 plot for that species.
ii) Undamaged (stem damage resulting in less than 5% reduction in height growth).
iii) Not overtopped by other trees or competing vegetation where height growth may be affected.

The second tallest tree can be measured for site index if the tallest is not suitable. This must be noted on the field card. Information collected for each tree should include:

i) Total height.
ii) Age at breast height (yrs).
iii) Total age (yrs).
iv) Rank in height relative to other trees in the plot of that species (e.g., tallest, 2nd tallest, etc.).

2.6.3 Count Plots

Count plots consist of a 50 m^2 plot to collect stocked quadrant information.

Plot Location

Count plots are established at the 100 m grid points between each full-measure plot. Count plots are not permanently marked, and GPS coordinates are not recorded.

Main Plot – 50 m²

Quadrant Information - Record each quadrant as stocked if it contains at least one healthy tree of an acceptable species that is free of brush competition (the same as in full-measure plots). For non-stocked quadrants, record whether the quadrant is NP (and type of NP) or could support tree growth. If a non-stocked quadrant can support tree growth, comment on why there are no trees (e.g., missed plantable spots, brush competition, health problems, etc.).

Tree Information - Tally the number of trees by species. This is used to estimate stand density and species composition.

3. PREDICTING FUTURE VOLUME

3.1 OVERVIEW

The same TASS simulations used to develop equations for Riverside were used in this project. TASS was used to simulate 433 different Pl and Sx stand types with varying species composition, stand density, spatial distributions, and ingress patterns. The simulated stands were surveyed using the stem maps generated for a range of young stand ages using the procedures described in Section 2. Survey statistics were compiled and compared to merchantable volumes 80, 90, and 100 years after harvest. The single best predictor of future volume was mean number of stocked quadrants (MSQ). A quadrant is considered stocked when it has at least one healthy tree of an acceptable species that is free of brush competition.

Based on these results, a model was developed to predict merchantable volumes 80, 90, and 100 years after harvest from survey data collected 15 years after harvest. Model inputs include species composition (limited to Pl, Sx, or PlSx), MSQ, site index, and effective total stand age (determined from site index and total average site tree height).

3.2 OBJECTIVES

The goal of predicting future stand merchantable volumes is to compare the estimates with target merchantable volumes to measure silviculture performance. The objectives of the modeling are to:

1) Predict stand merchantable volumes 80, 90, and 100 years after harvest.
2) Use the simplest method that accounts for key factors influencing future volume.

3.3 MODEL DEVELOPMENT

3.3.1 TASS Simulations

The TASS simulations generated a wide range of stand structures to develop and test a model to predict future merchantable volumes from stand survey data. These simulations were completed by the MOF Research Branch and included 433 combinations of planting and natural stand densities, species compositions, and spatial and temporal distributions (Table 1). The various factors were combined in a factorial structure so that initial stand density[6] ranged from 400 to 9,400/ha and species composition ranged from 100% Pl or Sx and a full range of mixtures.

Table 1. Factors in the matrix of TASS runs used for model development.

Factor	Level
Site Index	20 m
Species	Pl, Sx
Planting Density (no/ha)	0, 400, 800, 1,000, 1,200, 1,400 [a]
Natural Density (no/ha)	0, 400, 800, 1,200,1,600, 2,000, 5,000, 8,000
Spatial distribution of naturals	Random, Clumped [b]
Ingress period of naturals	TASS default (truncated Normal (2, 1.5)), Poisson (4.0) [c]

[a] Planting was assumed to occur one year after harvest with one year old stock.
[b] Naturals were apportioned 75% to clumps and 25% random, with an average of 25 trees/clump.
[c] Normal (2.0, 1.5) is a Normal distribution with mean of 2.0 and standard deviation of 1.5. Poisson (4.0) is a Poisson distribution with a mean and variance of 4.0.

[6] The number of trees simulated by TASS prior to mortality.

The height vigor coefficient was included in all simulations (so top height trees track the height-age curve for the assigned site index, regardless of stand density). Each TASS simulation was for a 3.0 ha block (100 x 300 m). No operational adjustment factors (OAFs) were applied, however, the natural clumped distributions with no planting resulted in holes distributed throughout the stands.

The following were generated for each TASS simulation:

1) A standard run summary with output from ages 1 – 15 and then every five years to age 120.
2) Stem maps for ages 10, 13, 15, and 18 years. These included x-y coordinates, species, and heights. Stand density at these ages varied due to ingress and mortality patterns simulated in TASS.

3.3.2 Simulated Surveys

We simulated surveys in each stand using the survey procedures (Section 2) where plots were established on randomly oriented 25 m grids. This gave about 48 plots for each simulated survey (a 25 m grid gives 16 plots/ha, each stand is 3 ha). For each plot, the species and height of each tree in each quadrant was recorded. For each of the 433 TASS simulations, 30 surveys were simulated for each of ages 10, 13, 15, and 18 years, for 51,960 simulated surveys (Table 2).

3.3.3 Model Fitting [7]

The Riverside project showed that MSQ was the best predictor of future volume (Table 2). Several equation forms were tested with the best fit provided by a quadratic equation:

$$PMV = a + b*MSQ + c*MSQ^2$$

Where **PMV** is *predicted merchantable volume* at a defined post-harvest time; ***a***, ***b***, and ***c*** are coefficients (Appendix I); and **MSQ** is the number of *mean stocked quadrants* from the sample of a stand or stratum. Analyses showed that anamorphic curves (parameters *b* and *c* are held constant) could be fit to the data with separate intercepts (parameter *a*) for each of 12 stand age and species combinations. In the Riverside project, four stand ages (5, 7, 10, and 13) were used to represent the range of potential stand ages 10 years post-harvest. The three species groups were pure Pl (≥ 80% Pl based on stand density at the time of the survey), pure Sx (≥ 80% Sx based on stand density at the time of the survey), Pl/Sx mix (21-79% Pl and Sx based on SPH at the time of the survey). Two mixed species groups were tested (one Pl leading and

Table 2. Mean number of stocked quadrants (MSQ) from 30 simulated surveys at age 15 using TASS with different combinations of planted and natural Pl.

Naturals		Planted Density (no/ha)					
Spatial Distribution	Stand Density (no/ha)	0	400	800	1,000	1,200	1,400
Random	0		1.87	3.30	3.62	3.78	3.84
	400	1.54	2.75	3.63	3.84	3.93	3.95
	800	2.48	3.16	3.74	3.91	3.96	3.97
	1,200	3.04	3.49	3.86	3.94	3.98	3.98
	1,600	3.38	3.69	3.91	3.97	3.98	3.99
	2,000	3.62	3.79	3.94	3.98	3.99	4.00
	5,000	3.98	3.99	4.00	4.00	4.00	4.00
	8,000	4.00	4.00	4.00	4.00	4.00	4.00
Clumped	400	0.88	2.40	3.56	3.81	3.91	3.95
	800	1.59	2.68	3.67	3.86	3.93	3.96
	1,200	2.18	3.09	3.73	3.90	3.96	3.97
	1,600	2.62	3.24	3.80	3.92	3.97	3.98
	2,000	2.90	3.45	3.85	3.94	3.97	3.99
	5,000	3.81	3.90	3.97	3.99	4.00	4.00
	8,000	3.98	3.99	4.00	4.00	4.00	4.00

[7] Further details of the model fitting procedures are provided in Appendix I.

Sx leading), but they did not provide a better fit than a single mixed group.

The same species groups were used in this project as for Riverside, but the age of the stand survey was changed to 10, 13, 15, and 18. In addition, the PMV was 80, 90, and 100 years post-harvest for this project and was 80 years for Riverside.

Two procedures were used to fit the equations for 80, 90, and 100 years post-harvest. First, three separate sets of anamorphic equations were fit for each post-harvest age. Second, one set of anamorphic equations was fit for all three post-harvest times.[8] The first procedure resulted in equations that better fit the data, but the three equations overlapped at low MSQ values (< 1.5) resulting in inconsistent predictions. For example, for the same MSQ value the PMV 80 years post-harvest was slightly higher than the PMV 90 years post-harvest. The second procedure resulted in equations that provided a good fit to the data and produced consistent results. As a result, these equations were chosen as the final set (Figure 3).

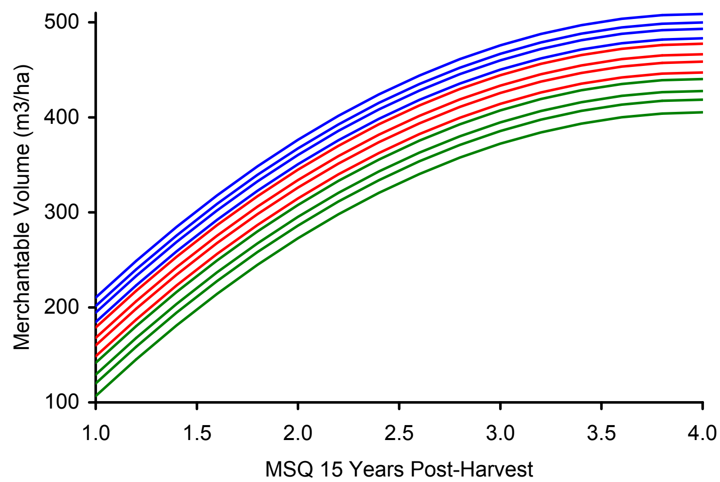

Figure 3. Anamorphic curves showing merchantable volume 80 (—), 90 (—) and 100 (—) years after harvest by MSQ 15 years post-harvest. Effective stand ages of 10, 13, 15, and 18 years are displayed from bottom to top in each set of curves. These curves are for pure Pl at site index 20 m.

3.3.4 Site Index

As a first approximation for this project, the procedures to incorporate different site indices and stand ages will follow the methods developed for the Riverside project. For Riverside and this project, the equations to predict future merchantable volume were fit with data from TASS simulations of site index 20 stands. Subsequently adjustment factors were developed for site indices other than 20. An objective of this year's Riverside project is to improve the current model's ability to predict future volumes across a range of site indices. The results of this initiative will be available March 31, 2003.

Fixed Site Index for Target and Predicted Volumes

The objective of the volume comparison is to focus on the impacts that silviculture performance has on volume growth. For each stratum, the same site index estimates should be used to set the target merchantable volume and determine the PMV. The differences in volume are then associated with differences in stand structure, and not on potential differences in site index. Site index estimates should be based on the best available information for each block (e.g. Site Index Adjustment, growth intercepts, SIBEC). In most cases, with the surveys occurring 15 years post-harvest, the site trees should be tall enough to use growth intercept equations.

[8] In the first case different *b* and *c* coefficients were fit for each post-harvest time. In the second case, *b* and *c* were held constant across the three post-harvest times.

Effective Age – Early Height Growth

Early height growth is a function of many variables including site productivity, stock and planting quality, and brush and health impacts; as a result, early height growth can be highly variable. Implicit in TASS and the prediction models are a set of site curves (height-age curves) that define site tree height growth. Once a site index has been chosen for a stratum, there is a defined height-age curve that the site trees follow. Furthermore, for the purposes of this project, the height-age curve is assumed to represent the target height growth pattern. If management practices result in trees growing faster or slower than assumed, then licensees should be rewarded or penalized accordingly. To achieve this, the following steps can be taken:

1) Determine a site index for the leading species in the stratum.
2) Calculate the average site tree height of the leading species from the survey data.
3) Determine the effective total stand age by using the average site tree height and the appropriate height-age curve.

If management practices are better than assumed in the height-age model, then the effective total stand age is older than the physiological age. The reverse is also true (Figure 4).

This method depends on average, realistic site index estimates. If estimated site indices are low, then effective stand ages would be too high on average. These higher ages would not represent better stand management practices, but would be higher because productivity is better than estimated.

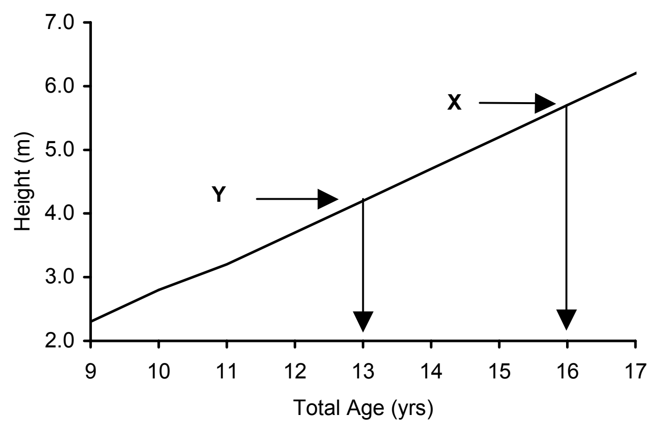

Figure 4. Height-age curve for Pl site index 20 m. Assume the target is set so the stand is 15 years total age 15 years post-harvest. For a site index 20 m stand, site trees are assumed to be 5.2 m tall. If the site trees are growing better than expected (X), the effective total stand age is 16 years. If they are poorer than expected (Y), the effective total stand is 13 years.

Volume Adjustment by Site Index

The equations for predicted merchantable volume were fit with data for site index 20. Ideally, separate equations would be fit for the full range of site indices; this is currently being tested for Riverside. As an alternative, adjustment factors have been developed to correct for different site indices.

Merchantable volumes at ages 80, 90, and 100 for a range of site indices and initial stand densities were expressed as a percentage of merchantable volume at age 80, 90, and 100 for site index 20 (Figure 5). Similar relationships were found for Pl and Sx, and planted and natural stands. The general pattern observed was percent volume increasing (for site index < 20) or decreasing (for site index > 20) below approximately 2,000 SPH and then remaining fairly constant above this density. Table 3 shows the adjustment factors developed using these results. For stands under 2,000/ha these multipliers will slightly under predict volume for site index > 20 m and slightly over predict for site index < 20 m.

3.3.5 Brush and Health Impacts

Brush and health impacts are incorporated into the system by defining if a quadrant is stocked (where stocked quadrants must contain at least one tree which meets the current free-growing standards for health and brush).

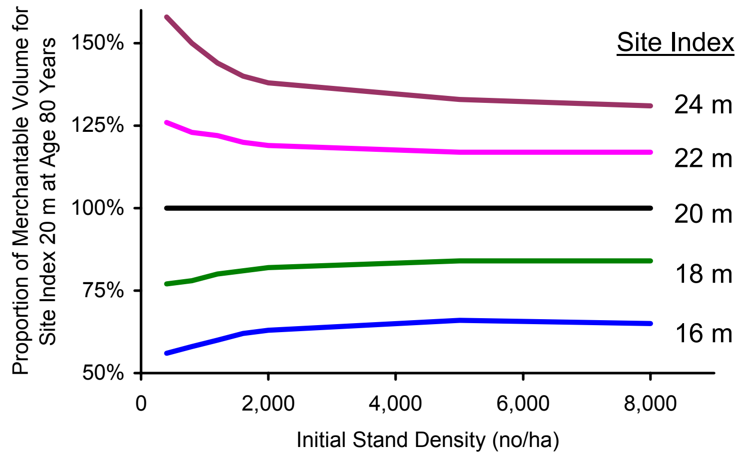

Figure 5. Proportion of merchantable volume (m3/ha) for Pl at age 80 by site index and initial stand densities. Data are from TIPSY.

3.4 SETTING TMVS

The TMV should be defined in a higher-level plan (possibly by site series and management zone). Policy decisions are required to set the values used to determine TMVs. The current approach described by Forest Practices Branch sets TMVs at 90% of the maximum PMV that could be attained with a very aggressive reforestation regime.[9] The maximum PMV for Riverside is determined using an MSQ of 4.0, site index 20 m, and an effective age of 12 years.[10] To determine the TMV, the maximum PMV is then multiplied by 0.9, and adjusted for lower TSS and different site index (Table 3) if required. It is important that the same equations are used to determine TMVs and PMVs so no bias is introduced.

Table 3. Volume multipliers to adjust target and predicted merchantable volume for different site indices.

Years from Harvest	Site Index (m)								
	14	15	16	17	18	19	20	21	22
80	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20
90	0.50	0.60	0.70	0.75	0.80	0.90	1.00	1.10	1.20
100	0.50	0.60	0.70	0.75	0.80	0.90	1.00	1.10	1.20

9 Forest Practices Branch. July 9, 2002. Sample design for the 2002 pilot of Riverside's new approach to silviculture obligations. Unpublished. Available from Pat Martin.

10 Riverside surveys are conducted 10 years post-harvest. An effective age of 12 assumes late winter harvest early in the calendar year, and 1-year-old stock planted in the spring so that the trees are 2 years old in the fall of the year harvesting occurred. Surveys are assumed to occur 10 years post-harvest in the fall.

4. TRACKING OBLIGATIONS

4.1 Overview

This section outlines the steps to summarize the survey data and determine PMVs at 80, 90, or 100 years post-harvest. The six main steps described below are:

1. Choose a post-harvest age for the PMV.
2. Post-stratify the surveyed area.
3. Determine effective age for each stratum.
4. Estimate the MSQ.
5. Estimate the PMV for site index 20.
6. Adjust the PMV for site index.

4.2 Choose a Post-Harvest Age for PMV

The model was developed to generate PMVs for 80, 90, or 100 years post-harvest; one of these post-harvest times should be chosen for the entire target population. Selecting one post-harvest time results in higher weights (higher volumes) for more productive sites when determining if the overall target volume is achieved. For example, using 80 years for high sites and 100 years for low sites more closely reflects potential future harvest ages; however, it also reduces the difference in the volume targets between high and low sites. The intent of the system is to focus proportionally more effort on the higher sites that provide better returns from silviculture investments.

4.3 Post-Stratify the Survey Area

Post-stratify the sampled area after the plot data has been entered into a spreadsheet or database. <u>This is done based on the plots location – not using the plot survey data</u>. The strata are based on: a) species group; b) site index[11]; c) SR or NSR[12]; and TSS (Figure 6, Table 4).

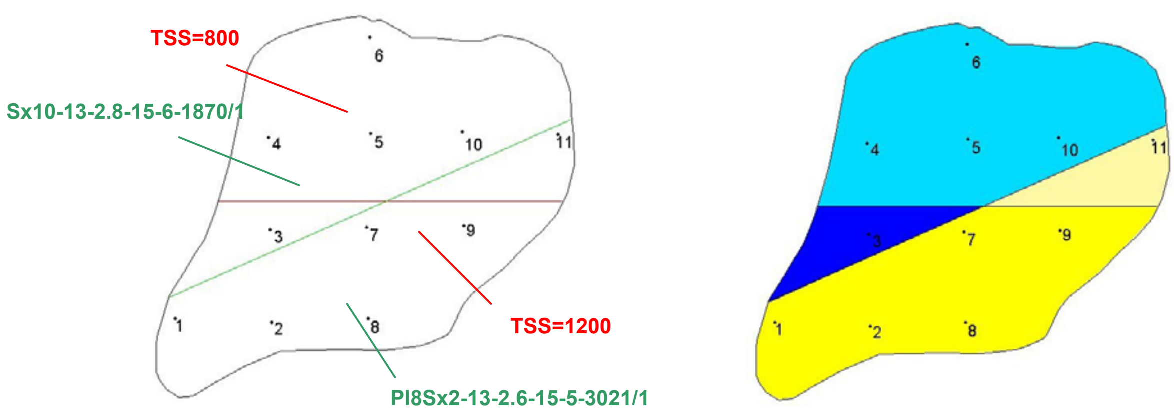

Figure 6. Block map showing plot locations, inventory polygons, and TSS (left) and strata for PMV calculations (right).

[11] Initial adjustments for site index (Table 3) result in a linear relationship between site index and PMV across MSQ values, suggesting there is no need to stratify by site index. However, site index is included as it is expected improved adjustments for site index will not be linear.

[12] The definitions of SR and NSR are a policy decision.

Table 4. Example showing inventory label, TSS and stratum.

Plot	Inventory label	Species group	Site index (m)	SR/NSR	TSS	Stratum
1	Pl8Sx2-13-2.6-15-5-3021/1	Pl	15	SR	1,200	Pl - SI 15 - SR -TSS 1200
2	Pl8Sx2-13-2.6-15-5-3021/1	Pl	15	SR	1,200	Pl - SI 15 - SR -TSS 1200
7	Pl8Sx2-13-2.6-15-5-3021/1	Pl	15	SR	1,200	Pl - SI 15 - SR -TSS 1200
8	Pl8Sx2-13-2.6-15-5-3021/1	Pl	15	SR	1,200	Pl - SI 15 - SR -TSS 1200
9	Pl8Sx2-13-2.6-15-5-3021/1	Pl	15	SR	1,200	Pl - SI 15 - SR -TSS 1200
11	Pl8Sx2-13-2.6-15-5-3021/1	Pl	15	SR	800	Pl - SI 15 - SR -TSS 800
3	Sx10-13-2.8-15-6-1870/1	Sx	15	SR	1,200	Sx - SI 15 - SR - TSS 1200
4	Sx10-13-2.8-15-6-1870/1	Sx	15	SR	800	Sx - SI 15 - SR - TSS 800
5	Sx10-13-2.8-15-6-1870/1	Sx	15	SR	800	Sx - SI 15 - SR - TSS 800
6	Sx10-13-2.8-15-6-1870/1	Sx	15	SR	800	Sx - SI 15 - SR - TSS 800
10	Sx10-13-2.8-15-6-1870/1	Sx	15	SR	800	Sx - SI 15 - SR - TSS 800

The strata shown in Figure 6 can be determined by overlaying the inventory polygons and the TSS strata. The Fort St. John requirements of stratification by licensee and management zone could also be included in the stratification without further requirements for mapping in the field. Information on stand type (conifer, deciduous, mixed-wood) can also be addressed by assigning inventory polygons to appropriate stand types. Defining divisions within the mixed-wood group will require more work to address changes in species composition over time. This will be tied to efforts to improve modeling of these stand types.

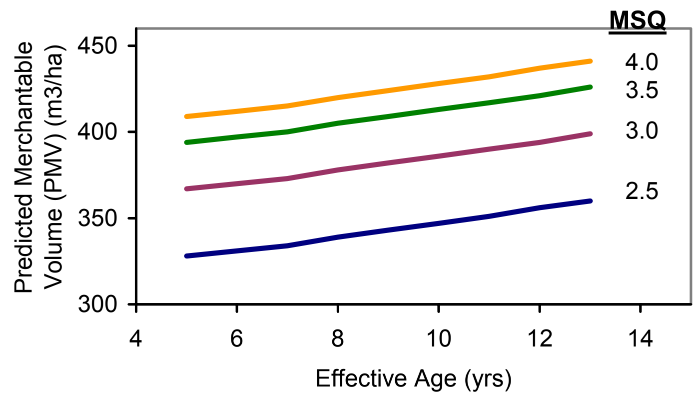

Figure 7. Relationship of PMV to effective age for different MSQs (Pl at site index 20 m).

The need to include effective age in the strata definition was examined. There is a constant linear relationship between effective age and PMV across MSQ values, thus there is no need to stratify based on age (Figure 7).

4.4 DETERMINE EFFECTIVE AGE FOR EACH STRATUM

Based on inventory information, each stratum will have a defined site index. Using data from all site index plots within the stratum calculate the average height of the site trees of the leading species. The effective stand age can then be derived by looking up the site index and average height in the effective age tables (Appendix II). For each Pl-Sx stratum, the effective ages for Pl and Sx should be determined separately using the appropriate tables and then averaged to give an effective age for the stratum.

4.5 Estimate the MSQ

Calculate the MSQ for the sample plots using all full-measure and count plots in the stratum.

4.6 Estimate the PMV for Site Index 20

Choose the appropriate PMV table (Appendix III) based on species composition and 80, 90, or 100 years post-harvest. Use MSQ and effective stand age to determine the PMV.

4.7 Adjust the PMV for Site Index

Multiply the PMV by the factor given in Table 3. This gives the final PMV for entry for the silviculture obligation ledger for comparison with the target merchantable volumes.

An example calculation is presented in Appendix IV.

5. POTENTIAL LINK TO OTHER SURVEY SYSTEMS & MONITORING

5.1 LINK TO OTHER SURVEYS

The stand survey can be linked with other surveys by using a common sample grid for all surveys. Full-measure plots (Section 2) located on the 200 m grid point can be included in all surveys. This will provide the data to develop a chrono-sequence of measurements over time similar to a permanent sample plot. The 200 m grid points are marked with steel pins and GPS (post-processed) UTM coordinates recorded to assist plot relocation for subsequent surveys. The permanent markers at these 200 m sample plots should be installed at the first survey completed in a stand.

As an example, the same plot locations could be measured during pay plot surveys following planting, stocking surveys, and a pole-stage survey done at 30 years of age. The same plot size (3.99 m radius) must be used and the same measurements (species, quadrant, estimated heights, damage codes, percent brush cover and brush height[13]) must be taken during each survey. This provides data to track changes over time to give feedback on silviculture treatments, and provides data to indirectly check PMV estimates by providing growth data to check TASS projections. We recommend the costs and benefits of this approach be examined.

5.2 LINK TO GROWTH & YIELD MONITORING

Accurate projections of future merchantable volumes are critical to the success of the proposed survey and modeling system. Establishing a set of monitoring plots to track actual growth and yield of a representative sample of post-harvest regenerated stands provides data to check predicted volumes. The proposed permanent points (one every 4.0 ha on a 200 m grid) provide information on early stand development (approximately ages 0 – 30) if full-measure plots are repeatedly established over this period. After approximately age 30, larger plots will be needed to obtain accurate estimates of volume and volume growth.

One option to consider is linking the survey system with the proposed growth and yield monitoring program by establishing the growth and yield monitoring plots on the same grid used in the survey system. For example, the growth and yield monitoring plots could be established on a 5.0 km grid using the same UTM base as the 200 m grid used for the full-measure survey plots. If this were done, the growth and yield monitoring plots would not have to be established immediately after harvest to obtain information on early stand growth. Early stand data would be obtained from re-measured full-measure survey plots.

5.3 MONITORING SITE PRODUCTIVITY

The repeat measurement of the full measure survey plots will also provide valuable information to track the changes in top height (and site index) over time.

[13] If brush is a significant management issue, then surveys should be done at the same time of the year to ensure consistent % cover estimates.

6. FURTHER WORK REQUIRED

6.1 BACKGROUND

A meeting was held November 5, 2002 in Fort St. John to discuss the applicability of the Riverside system to the Fort St. John TSA. The preceding sections of this report document the work done in the current fiscal year to begin adapting the Riverside system to the Fort St. John TSA. This section documents the top priority issues identified at the November 5 meeting to be addressed in subsequent fiscal years.

6.2 SAMPLE SIZE

The meeting participants agreed that survey plots would be installed on a 100 m grid (i.e., one plot/ha; the same as on Riverside's TFL 49). However, the appropriateness of this sample intensity and the potential to reduce the intensity should be examined after the first year of data collection is complete.

6.3 EARLY HEIGHT GROWTH & SITE PRODUCTIVITY

This survey system relies heavily on measurements of early height growth and site index. These measurements impact the survey system and the link to the volume predictions – which is the core of this system. Furthermore, the information from these surveys will be used to update inventory files and will likely be used for stand-level growth and yield modeling for timber analysis. However, forest managers in the area are generally uncertain of the reliability of current site index estimation tools for the Ft. St. John TSA area. Some of the items discussed where additional work is needed include:

1) Check the growth intercept equations. The meeting participants agreed to use growth intercepts to estimate site index in this survey (where stands are measured 15 years after harvest). However, some trees at these ages may have only a few years growth above breast height, which may introduce additional variation (and possibly bias) into the estimates.
2) Examine early height growth patterns. This survey system relies heavily on the assumption that early height growth patterns in the Ft. St. John area are the same as was used to develop the site index equations, growth intercepts, and the growth models on which this survey is developed. Some practitioners expect that early height growth may be different on some sites in the area (e.g., wet areas).
3) Identify a minimum breast height age and height for estimating site index.
4) Develop ecologically-based site indices for the TSA. There is a need to improve the estimates of potential site index in the TSA. This will positively impact harvest forecast for the area and provide key information for the SFMP. The two main approaches to consider are:
    a. SIBEC estimates with PEM or TEM. Some practioners believe that the SIBEC estimates for the area under-estimate site productivity. The MOF recently release the second approximation SIBEC estimates, which may address some of these potential under-estimates; however, this should be checked, and more work will be needed to improve these estimates, if required. This approach will also require a completed PEM or TEM for the area.
    b. Site index adjustment (SIA) with PEM, TEM, or biophysical model. An SIA project will provide the same results as the SIBEC approach but has the additional advantage of developing site index estimates that more accurately reflect the actual landbase. The

SIA approach can also be done without a completed PEM or TEM, and can be retrofit in the future if a TEM or PEM is completed.

An additional consideration is that a growth and yield monitoring program is being developed for the Fort St. John TSA. There is the option to use the growth and yield monitoring as a subset of the plots for an SIA project for the TSA.

5) Develop an overall plan to address site productivity issues in the short and longer term. The general issue of site productivity in the TSA is that it includes many related components and impacts many aspects of forest management and planning. Consequently, it is worth considering developing a plan to specifically address these and other related issues. This could be done under a general growth and yield plan, or in a plan that specifically addresses site productivity.

6.4 Plot Size – Sample Size for Aspen Stands

The recommended plot size for coniferous stands (3.99 m radius) is potentially larger than needed for many At stands that may have 200,000 or more stems/ha. Different plot and sample size combinations should be tested at different stand ages to determine optimal procedures.

6.5 Development of a Mixed-Wood G&Y Model

The meeting participants generally agreed that a collaborative effort is desired to promote developing a mixed-wood growth model. One of the first strategic decisions is to decide between taking advantage of work already completed and calibrate an existing model (e.g., TASS) or to commit to the substantial work of developing a new model. It is also important to decide on the appropriate scope for collaborative work to ensure that local issues are adequately addressed. Once these decisions are made, a plan to collect the required data can be developed. Again, the proposed growth and yield monitoring plots could provide a portion of the data required for model calibration. Additional data from designed experiments (such as WESBOGY trials) will also be required.

6.6 PMV Models for Other Species

This first approximation of the survey and modeling system addresses only the relatively simple stand types in the area (i.e., Pl, Sx, and PlSx). More work is needed to adapt the system to different stand types to implement the system across the TSA. The meeting participants agreed that initially the focus would be coniferous stands, and that the models developed for Pl and Sx (adapted to different survey and harvest ages) would be appropriate. The following species substitutions could be used in the interim:

1) For Bl use Sx.
2) For Lt use Pl.
3) For Sb use Sx.

In the future, the system should be refined to include projections for coniferous stands, mixed-wood stands (coniferous and deciduous leading), and deciduous stands. High priority species combinations were identified as:

1) At
2) AtSx
3) AtPl
4) PlAt

5) SxAt
6) Ep = At

The largest concern is the lack of a mixed-wood model. The meeting participants agreed there is a need to support mixed-wood modeling.

6.7 Predicting Future Species Composition

Predicting change in species composition was not addressed in this system. Again, the ability to address this issue depends on having a mixed-wood model that has this capability. This is another reason to promote some form of mixed-wood modeling for the area.

APPENDIX I – MODEL FITTING DETAILS

A total of 51,960 (433 TASS runs X 30 surveys X 4 ages) observations were used to fit the equation PMV = a + b*MSQ + c*MSQ^2 (Table 5). Parameters b and c were held constant (at 265.774 and –33.251, respectively) to produce anamorphic curves. A separate intercept (parameter a) was estimated for each species, effective age, and harvest age combination (Table 6).

Table 5. Summary statistics for the fitted model.

Source	Degrees of Freedom	Sum of Squares (m^2)	Mean Square (m)	F value
Intercepts	36	269,782,204	7,493,950	21,506
MSQ	1	71,920,496	71,920,496	206,392
MSQ*MSQ	1	38,969,861	38,969,861	111,833
Error	155842	54,305,691	348	
		R^2 = 0.91	Root MSE = 18.8	

Table 6. Intercept (parameter a) estimates for the equation PMV = a + b*MSQ + c*MSQ^2.

Species Group	Effective Stand Age	Harvest Year 80	90	100
Pl	10	-125.795	-83.818	-47.877
Pl	13	-112.412	-72.415	-37.995
Pl	15	-103.252	-64.571	-31.166
Pl	18	-90.706	-53.625	-22.172
Pl/Sx	10	-117.915	-68.010	-26.232
Pl/Sx	13	-101.912	-54.627	-15.127
Pl/Sx	15	-91.287	-45.669	-7.640
Pl/Sx	18	-76.796	-33.467	2.379
Sx	10	-104.378	-42.623	5.494
Sx	13	-84.540	-26.874	17.499
Sx	15	-71.391	-16.477	25.378
Sx	18	-53.674	-2.759	36.497

APPENDIX II – TABLES TO DETERMINE EFFECTIVE AGE

Table 7. Total height (m) by total age and site index for Pl.[14]

Total	SI										
age	15	16	17	18	19	20	21	22	23	24	25
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3
3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6
4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0
5	0.7	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.2	1.3	1.4
6	0.9	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.8
7	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	2.0	2.1	2.2
8	1.4	1.5	1.6	1.6	1.8	1.9	2.1	2.3	2.4	2.6	2.8
9	1.6	1.7	1.8	2.0	2.1	2.3	2.5	2.7	3.0	3.2	3.4
10	1.9	2.0	2.1	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4.1
11	2.1	2.3	2.5	2.7	2.9	3.2	3.5	3.8	4.1	4.4	4.8
12	2.4	2.6	2.9	3.1	3.4	3.7	4.0	4.4	4.7	5.1	5.4
13	2.7	3.0	3.2	3.5	3.8	4.2	4.6	4.9	5.3	5.7	6.1
14	3.0	3.3	3.6	3.9	4.3	4.7	5.1	5.5	6.0	6.4	6.8
15	3.4	3.7	4.0	4.4	4.8	5.2	5.7	6.1	6.6	7.0	7.5
16	3.7	4.1	4.4	4.8	5.2	5.7	6.2	6.7	7.2	7.7	8.2
17	4.1	4.4	4.8	5.2	5.7	6.2	6.7	7.3	7.8	8.3	8.9
18	4.4	4.8	5.2	5.7	6.2	6.7	7.3	7.8	8.4	9.0	9.5
19	4.7	5.2	5.7	6.1	6.7	7.2	7.8	8.4	9.0	9.6	10.2
20	5.1	5.6	6.1	6.6	7.1	7.7	8.3	8.9	9.6	10.2	10.8
21	5.4	5.9	6.5	7.0	7.6	8.2	8.8	9.5	10.1	10.8	11.5
22	5.8	6.3	6.9	7.4	8.0	8.7	9.4	10.0	10.7	11.4	12.1
23	6.1	6.7	7.3	7.9	8.5	9.2	9.9	10.6	11.3	12.0	12.7
24	6.5	7.0	7.7	8.3	8.9	9.6	10.4	11.1	11.8	12.5	13.3
25	6.8	7.4	8.0	8.7	9.4	10.1	10.8	11.6	12.3	13.1	13.8
26	7.1	7.8	8.4	9.1	9.8	10.6	11.3	12.1	12.8	13.6	14.4
27	7.4	8.1	8.8	9.5	10.2	11.0	11.8	12.5	13.3	14.1	14.9
28	7.8	8.5	9.2	9.9	10.6	11.4	12.2	13.0	13.8	14.6	15.4
29	8.1	8.8	9.5	10.3	11.0	11.9	12.7	13.5	14.3	15.1	16.0
30	8.4	9.1	9.9	10.6	11.4	12.3	13.1	13.9	14.8	15.6	16.5
Years to BH	7.2	6.9	6.6	6.4	6.1	5.8	5.5	5.3	5.1	4.9	4.7

[14] These are the site curves currently used in TASS. They are not in the current versions of Site Tools or Tipsy. The Thrower (1994) and Nigh and Love (1999) Pl curves are spliced together by using the Nigh/Love curve below breast height age 0, the Thrower curve above breast height 2, and linearly interpolating heights between breast height age 0 and 2. Nigh, G.D. 1999. Smoothing top height estimates from two lodgepole pine height models. B.C. Min. For., Res. Br., Victoria, B.C. Ext. Note 30. J.S. Thrower and Associates Ltd. 1994. Revised height-age curves for lodgepole pine and interior spruce in British Columbia. Report to the Res. Br., B.C. Min. For., Victoria, B.C. 27 p.

Table 8. Total height (m) by total age and site index for Sx.[15]

Total Age	SI 15	16	17	18	19	20	21	22	23	24	25
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
4	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
5	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5
6	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7
7	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.0
8	0.6	0.7	0.7	0.8	0.8	0.8	0.9	1.0	1.1	1.2	1.2
9	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.2	1.3	1.4	1.4
10	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.4	1.5	1.6	1.7
11	1.2	1.3	1.3	1.3	1.3	1.4	1.5	1.6	1.7	1.8	2.0
12	1.3	1.4	1.4	1.5	1.5	1.6	1.7	1.8	2.0	2.2	2.4
13	1.4	1.5	1.6	1.7	1.7	1.8	2.0	2.2	2.4	2.6	2.8
14	1.5	1.7	1.8	1.9	1.9	2.0	2.3	2.5	2.7	3.0	3.3
15	1.7	1.8	2.0	2.1	2.2	2.3	2.6	2.9	3.1	3.4	3.7
16	1.9	2.1	2.2	2.4	2.5	2.7	3.0	3.3	3.6	3.9	4.3
17	2.1	2.3	2.5	2.7	2.8	3.0	3.3	3.7	4.0	4.4	4.8
18	2.3	2.5	2.8	3.0	3.1	3.4	3.7	4.1	4.5	4.9	5.3
19	2.5	2.8	3.1	3.3	3.5	3.7	4.2	4.6	5.0	5.4	5.9
20	2.8	3.1	3.4	3.6	3.8	4.1	4.6	5.0	5.5	6.0	6.5
21	3.0	3.3	3.7	4.0	4.2	4.5	5.0	5.5	6.0	6.5	7.0
22	3.3	3.6	4.0	4.3	4.6	5.0	5.5	6.0	6.5	7.1	7.6
23	3.6	3.9	4.3	4.7	5.0	5.4	5.9	6.5	7.0	7.6	8.2
24	3.8	4.2	4.7	5.0	5.4	5.8	6.4	7.0	7.6	8.2	8.8
25	4.1	4.6	5.0	5.4	5.8	6.2	6.8	7.4	8.1	8.7	9.4
26	4.4	4.9	5.3	5.8	6.2	6.7	7.3	7.9	8.6	9.3	9.9
27	4.7	5.2	5.7	6.2	6.6	7.1	7.8	8.4	9.1	9.8	10.5
28	5.0	5.5	6.1	6.5	7.0	7.5	8.2	8.9	9.6	10.4	11.1
29	5.3	5.9	6.4	6.9	7.4	8.0	8.7	9.4	10.2	10.9	11.7
30	5.6	6.2	6.8	7.3	7.8	8.4	9.2	9.9	10.7	11.5	12.2
Years to BH	11.5	11.1	10.7	10.4	10.4	10.2	9.7	9.2	8.9	8.5	8.2

[15] These are the site curves currently used in TASS. They are not in the current versions of Site Tools or Tipsy. These curves result from the splicing together of the juvenile height curves by Nigh and Love (2000) and the height-age curves by Goudie (1984). Nigh, G.D. and B.A. Love. 2000. Juvenile height development in interior spruce stands of British Columbia. West. J. Appl. For. 15: 117-121. Goudie, J.W. 1984. Height growth and site index curves for lodgepole pine and white spruce and interim managed stand yield tables for lodgepole pine in British Columbia. B.C. Min. For., Res. Br. Unpubl. Rep. 75 p.

APPENDIX III – TABLES TO ESTIMATE VOLUME 80, 90, & 100 YEARS POST-HARVEST

The following tables are used to predict future merchantable volumes for site index 20 based on MSQ and effective age values from surveys 15 years post-harvest. In all tables, PMVs for effective ages 10, 13, 15, and 18 were obtained from the fitted equations; all other values were linearly interpolated.

Table 9. Predicted merchantable volumes 80 years post-harvest for pure Pl site index 20 stands.

	Effective Total Age								
MSQ	10	11	12	13	14	15	16	17	18
1.0	107	111	116	120	125	129	133	138	142
1.1	126	131	135	140	144	149	153	157	161
1.2	145	150	154	159	163	168	172	176	180
1.3	164	168	172	177	181	186	190	194	199
1.4	181	186	190	194	199	204	208	212	216
1.5	198	203	207	211	216	221	225	229	233
1.6	214	219	223	228	232	237	241	245	249
1.7	230	234	239	243	248	252	257	261	265
1.8	245	249	254	258	263	267	272	276	280
1.9	259	264	268	273	277	282	286	290	294
2.0	273	277	282	286	291	295	299	304	308
2.1	286	290	295	299	304	308	312	317	321
2.2	298	302	307	311	316	321	325	329	333
2.3	310	314	319	323	328	332	336	340	345
2.4	321	325	329	334	338	343	347	351	356
2.5	331	335	340	344	349	353	358	362	366
2.6	340	345	349	354	358	363	367	371	376
2.7	349	354	358	363	367	372	376	380	384
2.8	358	362	367	371	376	380	384	389	393
2.9	365	370	374	379	383	388	392	396	400
3.0	372	377	381	386	390	395	399	403	407
3.1	379	383	387	392	397	401	405	409	414
3.2	384	389	393	398	402	407	411	415	419
3.3	389	394	398	403	407	412	416	420	424
3.4	393	398	402	407	411	416	420	424	429
3.5	397	402	406	410	415	420	424	428	432
3.6	400	405	409	413	418	423	427	431	435
3.7	402	407	411	416	420	425	429	433	437
3.8	404	408	413	417	422	427	431	435	439
3.9	405	409	414	418	423	428	432	436	440
4.0	405	410	414	419	423	428	432	436	440

Table 10. Predicted merchantable volumes 80 years post-harvest for pure Sx site index 20 stands.

	Effective Total Age								
MSQ	10	11	12	13	14	15	16	17	18
1.0	128	135	141	148	155	161	167	173	179
1.1	148	154	161	168	174	181	187	193	198
1.2	167	173	180	187	193	200	206	211	217
1.3	185	192	198	205	211	218	224	230	236
1.4	203	209	216	222	229	236	241	247	253
1.5	219	226	233	239	246	252	258	264	270
1.6	236	242	249	256	262	269	275	281	286
1.7	251	258	265	271	278	284	290	296	302
1.8	266	273	280	286	293	299	305	311	317
1.9	281	287	294	300	307	314	319	325	331
2.0	294	301	307	314	321	327	333	339	345
2.1	307	314	320	327	334	340	346	352	358
2.2	319	326	333	339	346	352	358	364	370
2.3	331	338	344	351	357	364	370	376	382
2.4	342	349	355	362	368	375	381	387	393
2.5	352	359	365	372	379	385	391	397	403
2.6	362	368	375	382	388	395	401	407	413
2.7	371	377	384	391	397	404	410	416	422
2.8	379	386	392	399	406	412	418	424	430
2.9	387	393	400	407	413	420	426	432	437
3.0	394	400	407	414	420	427	433	438	444
3.1	400	407	413	420	426	433	439	445	451
3.2	406	412	419	425	432	439	445	450	456
3.3	411	417	424	430	437	444	449	455	461
3.4	415	421	428	435	441	448	454	460	466
3.5	419	425	432	438	445	451	457	463	469
3.6	421	428	435	441	448	454	460	466	472
3.7	424	430	437	444	450	457	463	469	474
3.8	425	432	439	445	452	458	464	470	476
3.9	426	433	440	446	453	459	465	471	477
4.0	427	433	440	447	453	460	466	472	477

Table 11. Predicted merchantable volumes 80 years post-harvest for Pl/Sx site index 20 stands.

	Effective Total Age								
MSQ	10	11	12	13	14	15	16	17	18
1.0	115	120	125	131	136	141	146	151	156
1.1	134	140	145	150	156	161	166	170	175
1.2	153	158	164	169	174	180	185	189	194
1.3	171	177	182	187	193	198	203	208	213
1.4	189	194	200	205	210	216	220	225	230
1.5	206	211	217	222	227	233	237	242	247
1.6	222	228	233	238	244	249	254	258	263
1.7	238	243	248	254	259	264	269	274	279
1.8	253	258	263	269	274	279	284	289	294
1.9	267	272	278	283	288	294	298	303	308
2.0	281	286	291	297	302	307	312	317	322
2.1	294	299	304	310	315	320	325	330	335
2.2	306	311	317	322	327	332	337	342	347
2.3	317	323	328	333	339	344	349	354	359
2.4	328	334	339	344	350	355	360	365	370
2.5	339	344	349	355	360	365	370	375	380
2.6	348	354	359	364	370	375	380	385	389
2.7	357	363	368	373	379	384	389	394	398
2.8	366	371	376	382	387	392	397	402	407
2.9	373	379	384	389	395	400	405	409	414
3.0	380	385	391	396	401	407	412	416	421
3.1	386	392	397	402	408	413	418	423	428
3.2	392	397	403	408	413	419	424	428	433
3.3	397	402	408	413	418	424	428	433	438
3.4	401	407	412	417	423	428	433	438	442
3.5	405	410	416	421	426	432	436	441	446
3.6	408	413	419	424	429	435	439	444	449
3.7	410	416	421	426	432	437	442	447	451
3.8	412	417	423	428	433	439	443	448	453
3.9	413	418	424	429	434	439	444	449	454
4.0	413	419	424	429	434	440	445	449	454

Table 12. Predicted merchantable volumes 90 years post-harvest for pure Pl site index 20 stands.

	Effective Total Age								
MSQ	10	11	12	13	14	15	16	17	18
1.0	149	153	156	160	164	168	172	175	179
1.1	168	172	176	180	184	188	191	195	198
1.2	187	191	195	199	203	206	210	214	217
1.3	205	209	213	217	221	225	228	232	236
1.4	223	227	231	234	238	242	246	250	253
1.5	240	244	248	251	255	259	263	267	270
1.6	256	260	264	268	272	276	279	283	286
1.7	272	276	280	283	287	291	295	298	302
1.8	287	291	294	298	302	306	310	313	317
1.9	301	305	309	313	316	320	324	328	331
2.0	315	319	322	326	330	334	338	341	345
2.1	328	331	335	339	343	347	351	354	358
2.2	340	344	348	351	355	359	363	366	370
2.3	352	355	359	363	367	371	374	378	382
2.4	363	366	370	374	378	382	385	389	393
2.5	373	377	380	384	388	392	396	399	403
2.6	382	386	390	394	398	402	405	409	413
2.7	391	395	399	403	407	411	414	418	422
2.8	400	403	407	411	415	419	423	426	430
2.9	407	411	415	419	423	427	430	434	437
3.0	414	418	422	426	430	433	437	441	444
3.1	421	424	428	432	436	440	443	447	451
3.2	426	430	434	438	441	445	449	453	456
3.3	431	435	439	443	446	450	454	458	461
3.4	435	439	443	447	451	455	458	462	466
3.5	439	443	447	450	454	458	462	466	469
3.6	442	446	450	453	457	461	465	469	472
3.7	444	448	452	456	460	464	467	471	475
3.8	446	450	454	457	461	465	469	473	476
3.9	447	451	455	458	462	466	470	473	477
4.0	447	451	455	459	463	467	470	474	477

Table 13. Predicted merchantable volumes 90 years post-harvest for pure Sx site index 20 stands.

	Effective Total Age								
MSQ	10	11	12	13	14	15	16	17	18
1.0	190	195	200	206	211	216	221	225	230
1.1	209	215	220	225	230	236	240	245	249
1.2	228	234	239	244	249	255	259	264	268
1.3	247	252	257	262	268	273	277	282	287
1.4	264	270	275	280	285	290	295	300	304
1.5	281	286	292	297	302	307	312	317	321
1.6	297	303	308	313	318	324	328	333	337
1.7	313	318	324	329	334	339	344	348	353
1.8	328	333	339	344	349	354	359	363	368
1.9	342	348	353	358	363	368	373	378	382
2.0	356	361	366	372	377	382	387	391	396
2.1	369	374	379	385	390	395	400	404	409
2.2	381	386	392	397	402	407	412	416	421
2.3	393	398	403	409	414	419	423	428	433
2.4	404	409	414	419	425	430	434	439	444
2.5	414	419	424	430	435	440	445	449	454
2.6	424	429	434	439	445	450	454	459	463
2.7	433	438	443	448	454	459	463	468	472
2.8	441	446	451	457	462	467	472	476	481
2.9	448	454	459	464	469	475	479	484	488
3.0	455	461	466	471	476	482	486	491	495
3.1	462	467	472	477	483	488	492	497	502
3.2	467	473	478	483	488	494	498	503	507
3.3	472	478	483	488	493	498	503	508	512
3.4	477	482	487	492	498	503	507	512	516
3.5	480	486	491	496	501	506	511	516	520
3.6	483	488	494	499	504	509	514	519	523
3.7	486	491	496	501	506	512	516	521	525
3.8	487	492	498	503	508	513	518	522	527
3.9	488	493	499	504	509	514	519	523	528
4.0	488	494	499	504	509	515	519	524	528

Table 14. Predicted merchantable volumes 90 years post-harvest for Pl/Sx site index 20 stands.

	Effective Total Age								
MSQ	10	11	12	13	14	15	16	17	18
1.0	165	169	173	178	182	187	191	195	199
1.1	184	189	193	197	202	206	211	215	219
1.2	203	207	212	216	221	225	229	234	238
1.3	221	226	230	235	239	244	248	252	256
1.4	239	243	248	252	257	261	265	269	273
1.5	256	260	265	269	274	278	282	286	290
1.6	272	277	281	285	290	294	299	303	307
1.7	288	292	297	301	306	310	314	318	322
1.8	303	307	312	316	321	325	329	333	337
1.9	317	321	326	330	335	339	343	347	351
2.0	331	335	339	344	348	353	357	361	365
2.1	343	348	352	357	361	366	370	374	378
2.2	356	360	365	369	374	378	382	386	390
2.3	367	372	376	381	385	390	394	398	402
2.4	378	383	387	392	396	401	405	409	413
2.5	389	393	398	402	406	411	415	419	423
2.6	398	403	407	412	416	421	425	429	433
2.7	407	412	416	421	425	430	434	438	442
2.8	415	420	424	429	433	438	442	446	450
2.9	423	428	432	436	441	445	450	454	458
3.0	430	435	439	443	448	452	456	461	465
3.1	436	441	445	450	454	459	463	467	471
3.2	442	446	451	455	460	464	468	472	477
3.3	447	451	456	460	465	469	473	477	481
3.4	451	456	460	465	469	474	478	482	486
3.5	455	459	464	468	473	477	481	485	489
3.6	458	462	467	471	476	480	484	488	492
3.7	460	465	469	474	478	482	487	491	495
3.8	462	466	471	475	480	484	488	492	496
3.9	463	467	472	476	481	485	489	493	497
4.0	463	468	472	476	481	485	489	494	498

Table 15. Predicted merchantable volumes 100 years post-harvest for pure Pl site index 20 stands.

	Effective Total Age								
MSQ	10	11	12	13	14	15	16	17	18
1.0	185	188	191	195	198	201	204	207	210
1.1	204	208	211	214	218	221	224	227	230
1.2	223	226	230	233	236	240	243	246	249
1.3	241	245	248	251	255	258	261	264	267
1.4	259	262	266	269	272	276	279	282	285
1.5	276	279	283	286	289	293	296	299	302
1.6	292	296	299	302	306	309	312	315	318
1.7	308	311	314	318	321	325	328	331	334
1.8	323	326	329	333	336	339	342	345	348
1.9	337	340	344	347	350	354	357	360	363
2.0	351	354	357	361	364	367	370	373	376
2.1	364	367	370	373	377	380	383	386	389
2.2	376	379	382	386	389	393	396	399	402
2.3	388	391	394	397	401	404	407	410	413
2.4	398	402	405	408	412	415	418	421	424
2.5	409	412	415	419	422	425	428	431	434
2.6	418	422	425	428	432	435	438	441	444
2.7	427	431	434	437	441	444	447	450	453
2.8	436	439	442	445	449	452	455	458	461
2.9	443	447	450	453	457	460	463	466	469
3.0	450	453	457	460	463	467	470	473	476
3.1	456	460	463	466	470	473	476	479	482
3.2	462	465	469	472	475	479	482	485	488
3.3	467	470	474	477	480	484	487	490	493
3.4	471	475	478	481	485	488	491	494	497
3.5	475	478	482	485	488	492	495	498	501
3.6	478	481	485	488	491	495	498	501	504
3.7	480	484	487	490	494	497	500	503	506
3.8	482	485	489	492	495	499	502	505	508
3.9	483	486	489	493	496	500	503	506	509
4.0	483	486	490	493	497	500	503	506	509

Table 16. Predicted merchantable volumes 100 years post-harvest for pure Sx site index 20 stands.

	Effective Total Age								
MSQ	10	11	12	13	14	15	16	17	18
1.0	238	242	246	250	254	258	262	265	269
1.1	258	262	266	270	274	277	281	285	289
1.2	277	281	285	289	292	296	300	304	308
1.3	295	299	303	307	311	315	318	322	326
1.4	312	316	320	324	328	332	336	340	343
1.5	329	333	337	341	345	349	353	357	360
1.6	346	350	354	358	362	365	369	373	377
1.7	361	365	369	373	377	381	385	389	392
1.8	376	380	384	388	392	396	400	403	407
1.9	390	394	398	402	406	410	414	418	421
2.0	404	408	412	416	420	424	428	431	435
2.1	417	421	425	429	433	437	441	444	448
2.2	429	433	437	441	445	449	453	457	460
2.3	441	445	449	453	457	461	464	468	472
2.4	452	456	460	464	468	472	475	479	483
2.5	462	466	470	474	478	482	486	489	493
2.6	472	476	480	484	488	492	495	499	503
2.7	481	485	489	493	497	501	504	508	512
2.8	489	493	497	501	505	509	513	516	520
2.9	497	501	505	509	513	516	520	524	528
3.0	504	508	512	516	520	523	527	531	535
3.1	510	514	518	522	526	530	533	537	541
3.2	515	519	523	527	531	535	539	543	546
3.3	520	524	528	532	536	540	544	548	551
3.4	525	529	533	537	541	545	548	552	556
3.5	528	532	536	540	544	548	552	556	559
3.6	531	535	539	543	547	551	555	559	562
3.7	534	538	542	546	550	554	557	561	565
3.8	535	539	543	547	551	555	559	563	566
3.9	536	540	544	548	552	556	560	564	567
4.0	537	541	545	549	553	556	560	564	568

Table 17. Predicted merchantable volumes 100 years post-harvest for Pl/Sx site index 20 stands.

	Effective Total Age								
MSQ	10	11	12	13	14	15	16	17	18
1.0	206	210	214	217	221	225	228	232	235
1.1	226	230	233	237	241	244	248	251	254
1.2	245	249	252	256	260	263	267	270	273
1.3	263	267	270	274	278	282	285	288	292
1.4	281	284	288	292	296	299	303	306	309
1.5	298	301	305	309	312	316	320	323	326
1.6	314	318	321	325	329	332	336	339	342
1.7	329	333	337	341	344	348	351	355	358
1.8	344	348	352	356	359	363	366	370	373
1.9	359	362	366	370	374	377	381	384	387
2.0	372	376	380	383	387	391	394	398	401
2.1	385	389	393	396	400	404	407	411	414
2.2	398	401	405	409	412	416	419	423	426
2.3	409	413	417	420	424	428	431	434	438
2.4	420	424	428	431	435	439	442	445	449
2.5	430	434	438	441	445	449	452	456	459
2.6	440	444	447	451	455	459	462	465	469
2.7	449	453	456	460	464	468	471	474	478
2.8	457	461	465	468	472	476	479	483	486
2.9	465	469	472	476	480	483	487	490	493
3.0	472	476	479	483	487	490	494	497	500
3.1	478	482	486	489	493	497	500	503	507
3.2	484	487	491	495	499	502	506	509	512
3.3	489	492	496	500	504	507	511	514	517
3.4	493	497	500	504	508	512	515	518	522
3.5	497	500	504	508	512	515	519	522	525
3.6	500	503	507	511	514	518	522	525	528
3.7	502	506	509	513	517	521	524	527	531
3.8	504	507	511	515	518	522	525	529	532
3.9	505	508	512	516	519	523	526	530	533
4.0	505	509	512	516	520	523	527	530	533

APPENDIX IV - EXAMPLE CALCULATION

Introduction

This example is based on data collected on four blocks in the Fort St. John TSA in August 2002. It follows the procedures outlined in Section 4 assuming:

1) The four blocks represent the target population.
2) Target stocking standard was 1,200 for all blocks.
3) Blocks were surveyed 15 years after harvest. In reality, not all blocks were surveyed 15 years after harvest so adjustments had to be made to crop tree heights. For example, if a block was actually surveyed 13 years after harvest, two years average crop tree leader growth was added to average crop tree height to approximate crop tree height 15 years after harvest. It was assumed that MSQ would be the same 15 years after harvest as at the time of the survey.
4) Different site index values than those recorded in the surveys. The site index values recorded in the surveys are based on SIBEC data and in comparison to the crop tree heights and ages for most blocks appear low. New site index values were chosen for this example to approximate site indices closer to the true values.[16]

Choose a Post-harvest Age for PMV

For this example 90 was chosen as the target post-harvest age.

Post-Stratify the Surveyed Area

Three strata were identified based on species, site index, SR versus NSR, and TSS (Table 18)

Table 18. Description and stratification of Fort St. John blocks surveyed in August 2002.

			Stratum			
CP/Block	Inventory label[a]	Area (ha)	Species	Site index	SR/NSR	TSS
306-2	Pli9Bl1-11-2.2-15-7-4233/1	19.9	Pl	15	SR	1,200
111-3	Sx10-13-2.8-15-6-1870/1	16.6	Sx	20	SR	1,200
111-4	Sx9Pli1-13-2.6-15-5-3021/1	16.8	Sx	20	SR	1,200
306-2	Sx7Bl2Pli1-12-2.1-15-6-5200/1	29.8	Sx	20	SR	1,200
304-6	Sx10-14-3.1-18-6-1539/1	57.4	Sx	22	SR	1,200

[a] Inventory label, including SIBEC based site index from actual survey data. Site index values listed under Stratum are approximate site indices based on height and age data.

[16] In future surveys it is recommended that growth intercept equations be used to determine site indices rather than SIBEC estimates.

Determine Effective Age, MSQ, and PMV

All of the survey plots were assigned to one of the three strata, and stratum average crop tree heights and mean stocked quadrants were calculated. The average crop tree height and site index were then used to determine the effective age using one of the tables in Appendix II. The effective age and MSQ are then used to determine PMV for site index 20 using one of the tables from Appendix III. Finally, the site index 20 PMV is adjusted to reflect the site index for the stratum (Table 19).

Table 19. Calculated effective ages, MSQs and PMVs for each stratum.

Species	Stratum Site index	Stratum SR/NSR	TSS	Avg Site Tree Ht	Effective Age	MSQ	PMV_{20} (m^3/ha)	Site index Adjustment	PMV (m^3/ha)
Pl	15	SR	1,200	3.0	14	4.0	463	0.6	278
Sx	20	SR	1,200	3.2	17	4.0	524	1.0	524
Sx	22	SR	1,200	3.1	15	4.0	515	1.2	618

Compare PMVs and TMVs

For this example TMVs were determined by:

1) Determining the PMV for MSQ = 4.0, effective age = 17, and site index = 20.
2) Multiplying the PMV from step 1 by 0.9 and by the appropriate site index adjustment for the stratum.

In this example, the total predicted merchantable volume exceeds the target by 6,736 m^3 or 48 m^3/ha (Table 20).

Table 20. PMVs and TMVs for each stratum and the population totals.

Species	Stratum Site index	Stratum SR/NSR	TSS	PMV (m^3/ha)	TMV (m^3/ha)	Area (ha)	PMV (m^3)	TMV (m^3)
Pl	15	SR	1,200	278	256	19.9	5,528	5,094
Sx	20	SR	1,200	524	472	63.2	33,117	29,805
Sx	22	SR	1,200	618	566	57.4	35,473	32,484
Total						*140.5*	*74,118*	*67,383*