C5 FOREST MANAGEMENT PLAN 2006–2026

APPENDIX 8A. GROWTH AND YIELD

FMU C5

FOREST MANAGEMENT PLAN

Growth and Yield

Forest Management Branch
Resource Analysis Section
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1.0 VOLUME SAMPLING

Volume sampling in the C5 Forest Management Unit (FMU) was initiated in 1997. The objective was to create enough inventory sample plots to provide a sound basis for the development of yield curves and volume tables by setting up 1000 temporary sample plots (TSP) over 2 years. In 1997, 500 plots were installed and another 500 plots had been scheduled for 1998. Owing to budget constraints, the 1998 sampling did not occur. In addition, some plots were lost as a result of technical and clerical issues, while others fell into non-forested polygons when the AVI photography was re-interpreted. As a result, only 457 forested TSPs were available for C5.

A random approach was used when selecting candidate stands for sampling. A list of potential stands for each of the broad sampling strata was generated, including replacements. The original document used to establish a stratified random sample is no longer available[1]. If the intended stand was considered to be inaccessible, the contractor was instructed to sample the next random stand rather than select a more convenient stand. A limited number of replacements were generated with the initial sample design and candidate stand selection; however, no details are available on how often the replacement stands were selected in preference to the primary list.

The number of samples acquired per sampling stratum was tested against the areas found in the initial AVI land base file and it was found to be proportional. Some modifications were made to put additional samples into unique stands.

Using a triangular pattern, three plots were established in each stand. The starting position for the first plot was random, but the remaining two plots were placed using a fixed design relative to the random plot. Appendix 2 contains the documentation produced by PLFD in 1997, with details on the sample design[2]. Some of the more important details include the following.

- 100 m^2 (plot radius=5.642 m) circular plots were used.
- Diameters were measured for all trees greater than 7 cm at breast height.
- Heights were measured on 4-5 trees in stands with variable tree heights, and 3 trees for more uniform stands.

AVI RE-INTERPRETATION

Both ecological- and AVI-based yield curves have been explored in-house for the C5 FMU in the past (Jack Heidt, pers.com). There was little evidence of a relationship between the plot volumes and the stand ages assigned through previous inventories. Neither set of curves appeared to be very accurate, as seen through weak statistics and visual assessment. Curves were not released due to the unusually poor strength of the best-fit relationships. In a number of instances, the inventory age assigned to the stand appeared to be inaccurate. There were also situations where the field label for a stand did not resemble the photo-interpreted label, suggesting an error in assigning attributes.

[1] Unable to locate document

[2] Appendix 2: Southern Rockies Landscape Planning Pilot Project Field Sampling Component Part 2 Terms of Reference. Some non-digitized graphs/illustrations are absent.

It was determined that further examination of the plot attributes may be required. The C5 area was one of the first areas in the province to be inventoried under the AVI 2.1 system, and there may have been problems resulting from inexperience with the new protocols. To rectify these issues, the aerial photography for approximately 25% of C5 was re-interpreted, as suggested by the Forestry Corp[3]. Existing TSP locations were then linked to the new AVI polygons through the GPS co-ordinates for the plot center. The error associated with digitized polygon boundaries was considered during the linkage process. The updated inventory appeared to fix the majority of the previous problems, and allowed meaningful volume-to-age relationships to be developed.

Individual Tree and Plot Volumes

Individual tree volumes were calculated using Huang's taper equations[4] and the natural subregion-specific coefficients, given the GPS location of the plot. If the field crew did not record the tree height, it was predicted using Huang's equations[5]. Otherwise, measured heights were used when available.

Merchantable stems were defined as having a 15 cm stump diameter outside bark, and a 10 cm top diameter inside bark. These dimensions were applied to both coniferous and deciduous volumes. The minimum log length was set at 2.4 m. Stump height was set at 30 cm above ground level. Dead trees were assigned a volume of zero and retained in the database, as were nil tallies. Nil tallies were defined as plots where a plot was installed, but no trees above the tag limit were present to be sampled.

No deductions were made for cull in the yield curves, as cull will be accounted for in the timber supply analysis (TSA). Trees without fatal or major stem defect-related damage codes were treated as healthy trees. It was assumed that all species of merchantable size would be used.

C5 Volume Adjustment Approach

In May 2005, the planning team requested the volumes for C5 be recalculated to a 15/11[6] merchantability to be consistent with the utilization standard applied in the quota allocations within the management unit.

Individual tree volumes were recalculated using the new top diameter, and then summed up at the plot level. This data was then re-linked to the AVI attributes using the same approach as the original 15/10 plot information. The number of available plots for comparison was unchanged from the original analysis.

The average difference in volume for stands between 90 and 120 years old was compared in order to develop a conversion ratio. This range of ages coincided with the expected minimum harvest age, where the volume difference will be most influential on the plan. An area-weighted

[3] *The Forestry Corp. 1998. 'Southeast Slopes AVI Verification'.*
[4] *Huang, Shongming. 1994. Ecologically based individual tree volume estimation for major Alberta tree species. Report #1. Multiple equations*
[5] *Huang, Shongming. 1994. Ecologically based individual tree volume estimation for major Alberta tree species. Report #1. Equation [6]*
[6] *Refers to the stump diameter inside bark /top diameter outside bark.*

approach was used to ensure the dominant yield strata on the landscape would drive the relationship. There is an average difference of 5.18 m^3/ha, or -2.6% relative to the 15/10 volumes. A 2.6% deduction was applied in the current TSA process.

STRATIFICATION OF AVI DATA

Identification of Forested Plots

AVI attributes were the only variables used to stratify the data prior to developing yield curves. Field variables were considered, but not used due to complications with correction factors needed to properly tie these variables to the inventory. Curves based on ecological variables were not developed because these stand attributes were never re-linked to the plots with the new AVI attributes.

Of the available 491 TSPs, only 457 had proper linkages to forest cover types. Plots without a valid linkage, or plots that were linked to labels for either grass or shrub were removed. This often happened if the GPS location for the TSP relocated the plot into either grasslands or shrub label under the new AVI line work. This was a valid attribute assignment, as the plot position was consistent with the original inventory. Since the AVI line work was re-drawn with more precision, smaller patches of forest in a non-uniform stand could be extracted as individual polygons. The edges of stands were also affected by the re-interpretation, and had a tendency to become more distinct and jagged in appearance. If a plot contained inadequate information to allow it to be assigned to a forested stratum, it was also removed.

Unproductive plots were deleted, since these stands would not be present in the net land base (NLB). Deletions based on management objectives affected 57 plots. Land base updates for harvesting and disturbances that occurred since the re-interpretation of the AVI were not accounted for. Rules used to define the NLB were considered either through plot deletions, or through changes in yield strata. There were 406 volume-sampling plots remaining after localizing the data to the NLB.

Definitions for Variables Used in Stratification

Cover group was one of the base variables used for yield stratification. The percentages used to define this variable followed the PLFD in-house rules.

Table 1. Cover group assignments and a description of how they influenced yield group assignment.

% Conifer Closure	%Deciduous Closure	AVI Cover Group	Yield Group	Description
100	0	C	C	Pure conifer – further subdivided
90	10	C	C	Pure conifer – further subdivided
80	20	C	C	Pure conifer – further subdivided
70	30	CD	CD	Conifer-leading mixedwood
60	40	CD	CD	Conifer-leading mixedwood
50	50	CD	CD	Conifer-leading mixedwood
40	60	DC	DECLB	Broad deciduous landbase
30	70	DC	DECLB	Broad deciduous landbase
20	80	D	DECLB	Broad deciduous landbase
10	90	D	DECLB	Broad deciduous landbase
0	100	D	DECLB	Broad deciduous landbase

Density was often used in conjunction with the cover group. Low density refers to stands with either an A or B AVI crown closure, while high density refers to stands with either a C or D AVI density attribute. NSR refers to the natural subregion. Only the Montane and Subalpine Subregions had been sampled on the C5 land base. Natural subregions were assigned based on the GPS location of the plot, rather than using the township-grid system. NSR had the greatest influence on the yield curves when assigning coefficients during volume calculations.

The leading species of the stand was considered to be the first species listed in the AVI attributes. While this approach does allow for the questionable call of an "Aw-leading CD stand", none of these stands were present in this data set and modifications were not necessary. Species groupings were applied at this stage. Pa, Pf and P was grouped with Pl, Se was grouped with Sw, and Fa was grouped with Fb.

Stratification Information for the Conifer-Leading Stands

Table 2 shows the number of temporary sample plots by forested cover group after the unproductive plots were deleted. These plots were divided into finer strata if there were an adequate number of plots to support this. The D and DC cover groups were combined into the "DecLB" strata. The C5 land base is dominated by conifer stands, and a roughly proportional number of plots were installed in the C cover group. Having a large number of available plots allowed the use of additional AVI attributes to further divide the broad C strata. These included attributes such as the leading species of the stand, density and the natural subregion. Details regarding strata for the conifer-leading stands can be found in Table 4, along with a listing of the number of plots found in each stratum.

Table 2. Number of TSPs by forested cover groups.

Cover Group	Number of Plots
C	323
CD	19
DC	14
D	50
Total	406

Selecting strata for predicting the conifer volumes was not a straightforward process, as some combinations of the stratification variables had very few plots associated with them. Grouping these questionable strata together was preferable to fitting guide curves[7], due to problems with uneven data distribution along the age range. Combinations were selected that were biologically reasonable and produced functionally different yield curves. These groupings are reflected in Table 4 by the letter codes attached to the equation number.

Cover group, leading species and natural subregion were the common variables used to stratify the conifer-dominated stands. Spruce- and pine-leading stands in the Montane Subregion did not show a large difference in volumes with respect to density, so this variable was not used to stratify the data. In the subalpine, density made a difference in the yield curves, so it was included when defining volume strata.

There were only enough data to produce a viable yield curve for the low-density Douglas Fir (Fd) for the Montane Subregion. High-density Fd stands are present on the land base, but were not sampled enough to develop a yield curve. (*Note*: If the low-density stands are not going to be harvested, they should be made a subjective deletion on the land base.) The 10 Fd-leading plots that were not found in low-density Montane stands were used in developing deciduous estimates, but not for coniferous estimates. It was recommended to either collect additional inventory information for this stratum, or apply the low-density Fd to the rest of the Fd stands with care.

A comment should be made about the types of spruce found in each natural subregion. The clear majority of the plots in the Subalpine NSR had Engelmann Spruce (Se) as a leading species, while the spruce plots in the Montane typically had White Spruce (Sw) as a leading species. Stands dominated by either of the two species appeared to have different growth patterns, especially at older ages. In the Montane, there were not enough plots to stratify the data by both NSR and crown closure. There were not enough plots to examine any volume differences by species across subregions. These two species were collectively referred to as Sx. Black Spruce (Sb) stands were not present on the land base or in the inventory data.

[7] *Also known as an indicator variable approach, and refers to using a qualitative variable to influence the magnitude of the curves.*

Table 3. Number of plots, by the leading species in the AVI, for the spruce-leading plots for each natural subregion.

Leading Species	Montane	Subalpine
Engelmann spruce (Se)	11	67
White spruce (Sw)	33	2

Stratification Information for Mixedwoods and Deciduous-Leading Stands

In contrast to the conifer-leading stands, there was a limited amount of plot information available for developing yield curves for the other cover groups. As a result, a much broader stratification system was used for the CD, DC and D cover groups when fitting curves in order to compensate for the low number of available plots. Details for the conifer-leading mixedwood strata and the deciduous land base strata can be found in Table 4.

The deciduous volumes associated with the finely divided C strata were either not functionally distinct, or were not reasonable curves. All the data were merged and a single deciduous curve was fit. Grouping the data addressed the problem of curves for some strata having an exponential shape and predicting non-declining yields by improving the distribution of the plots across the range of inventory ages. This process is considered acceptable because observed deciduous volumes, while present in all C strata, were likewise uniformly very low in these strata; thus, the probability of introducing bias is low. There is also no planned deciduous harvest for C5, so the risk of error is low.

In order to satisfy management objectives for harvesting in the mixedwood strata, two yield curves were developed. The first was used to predict yields for the CD cover group. Only plots belonging to the CD cover group were used to predict both the coniferous and deciduous volumes, resulting in an accurate localized curve.

The second curve was developed for the general deciduous land base (DecLB), and was built using data form the DC and D cover groups. All the NLB plots from these two cover groups were used to predict both the coniferous and deciduous volumes. Since this stratum will not be considered harvestable in the TSA, the yield curves serve strictly as a baseline estimate for any future management decisions.

One arbitrary adjustment was made to the plot data when fitting the coniferous volumes for the DecLB strata. It was felt the deciduous polygons that contained a few wolf [8] Douglas Fir trees should not be allowed to influence the conifer yield predictions, as it was unlikely these stands would be harvested. Therefore, only pine and spruce volumes were used to predict future yields, as they tended to have more reasonable diameters given the AVI attributes for the stand.

[8] *Defined as a tree left over from a previous stand. Typically is older, if age data area available, or has a much larger diameter than the rest of the trees in the stand.*

Final Stratification Summary

Table 4 shows the yield strata, along with the models used to predict volume. Strata that share a common letter designation had their data pooled prior to fitting the model. Sx refers to both Sw and Se. Equations for the models, indicated by the number within the square brackets, can be found in Section 2.

Table 4. Model used for each yield strata.

Curve Number	Cover Group	Leading Species	Crown Closure	Natural Subregion	Equation for Coniferous	Equation for Deciduous
1	C	Fd	A + B	Montane	[1]a	[3]a
2	C	Pl	All	Montane	[1]b	[3]a
3	C	Pl	A + B	Subalpine	[1]c	[3]a
4	C	Pl	C + D	Subalpine	[1]d	[3]a
5	C	Sx	All	Montane	[1]e	[3]a
6	C	Sx	A + B	Subalpine	[1]f	[3]a
7	C	Sx	C + D	Subalpine	[1]g	[3]a
8	CD	All	All	All	[2]a	[2]b
9	D and DC	All	All	All	4[a]	[3]c

To summarize, the conifer-leading strata had individual curves developed for coniferous volume predictions, but shared a single deciduous yield curve. The conifer-dominant mixedwood strata had individual curves for predicting both coniferous and deciduous volumes. The deciduous land base strata had a single curve for each of the conifer and deciduous volumes, and was developed using data from the DC and D cover groups.

There are differences in the stratification rules relating to Douglas Fir stands. The yield curves were built using only the A+B density montane data, as 49 of 54 plots were from this stratum. The land base was stratified to exclude A+B density stands without an understorey, and included stand types that were not used to fit the curves (C+D density, subalpine Fd if present).

In order to apply the A+B density montane Fd curve to the rest of the land base, some form of validation needed to be performed (see Appendix 3). It was concluded that the remaining plots fit well with the predicted volume. The A+B montane curve can be applied to all Fd-leading stands in the C5 FMU.

Table 5 shows the number of plots used in the curves versus the area of the net land base represented by each curve. (*Note*: There are 20 Fd-leading plots that do not fall into a harvestable yield strata that are note accounted for in this table.)

Table 5. Number of plots used in the curves vs. the area of the net land base.

Yield Curve	Area (ha)	Percent of Area	Number of Plots	Percent of Plots
1	22,663.24	8.4	51	12.6
2	37,170.00	13.8	58	14.3
3	17,385.30	6.5	39	9.6
4	82,537.16	30.7	59	14.5
5	13,594.37	5.0	45	11.1
6	42,399.60	15.7	35	8.6
7	26,598.43	9.9	36	8.9
8	3301.18	1.2	19	4.7
9	23,586.27	8.8	64	15.8
Total	269,235.55		406	

2.0 YIELD CURVE DEVELOPMENT

Models Used

Yield curves were fit using one of the following models using the SAS procedure:

[1] volume = (1*[Age**B_1]*exp[-Age/100])

[2] volume = ([B_1*Age**B_2]* exp[-B_1*Age])

[3] volume = (B_1*[Age**B_2]*exp[-Age/N])

[4] volume = ([B_1*Age**B_2]* exp[-B_3*Age])

Where

- B_1 ,B_2 and B_3 are parameters to be estimated,
- exp is the natural logarithm
- Age refers to the AVI Inventory Age (calculated from plot installation year – AVI origin).

In the case of [3], parameter N was set based on past experience and professional opinion, rather than fit through regression. Note that while this will adversely affect statistical estimates of skew, it does not have any impact on the overall sums of squares.

In all cases, convergence was achieved. Inventory ages were not adjusted to account for the midpoints of any age classes. No adjustments need to be made in the TSA to ensure consistency between the curves and age class assignments.

Models were selected primarily on the basis of their biological fit. Due to cool temperatures and moist conditions in the subalpine, it was found there were longer-lived stands that held volumes at older ages. This translated into a more gradual, almost smooth growth pattern that did not decline as aggressively as other forest types. Older plot data from the montane were lacking, and may show there may be steeper decline. Redefining the curves with additional samples may also show a slightly faster volume increment at younger ages. Low-risk models have the tendency to decline once data became unavailable. The rate of decline seen in these models may not be as rapid as in the boreal or the foothills. Stands do eventually break apart, as seen by a lack of data past a given age, but there does not seem to be any indication of early break-up in the data. The maximum volumes seen in the yield curves rarely exceed the volumes suggested by the averages, which should keep the volume predictions reasonable.

There are some concerns with the volumes predicted at young ages. Because the model is constrained through 0, the model does not produce the typical arrival of merchantable volume at 50-60 years. Instead, a smooth curve connects stand establishment and maturity. The front end of the curve should be treated as extrapolation, as there is little data to support the predicted volumes. The minimum harvest age should be enforced to minimize the risk of using this portion of the curve. Alternate models were tested, but were unable to improve on this issue.

Other models that were considered, but rejected based on their biological behaviour or their statistical fit, included:

[5] $volume=((B_1*Age**B_2)* exp(-B_3*Age))$

[6] $volume=((B_1*Age**B_2)* exp(-Age/50))$

[7] $volume=(((B_4*IND)+B_1*Age**B_2)* exp(-B_1*Age))$

Where:

- IND is the indicator variable, and is set to either 0 or 1 depending on the strata,
- B_1 through B_4 are the corresponding parameters to be estimated.

Table 6 shows the coefficients for each model fit through non-linear regression. An asterisk was used to zero-fill empty columns. The equation number consists of the nonlinear equation number in square brackets, and the letter indicating the group of data that was pooled to produce the curve. Since guide curves were not used, there were no cases of shared data. For accurate duplication of the yield curves, the digital version should be used as the number of decimals have not been truncated.

Table 6. Equations with number of plots and components used to calculate r^2 value.

Yield Curve	Equation	B_1	B_2	B_3 or N
1 – CON	[1]a	1.3442000000	*	*
2 – CON	[1]b	1.3308000000	*	*
3 – CON	[1]c	1.3071000000	*	*
4 – CON	[1]d	1.3859000000	*	*
5 – CON	[1]e	1.4394000000	*	*
6 – CON	[1]f	1.3114000000	*	*
7 – CON	[1]g	1.3534000000	*	*
8 – CON	[2]a	0.3614713171	1.5077883611	*
9 – CON	[4]a	0.0000004438	5.1536782159	0.0581327747
1 to 7 – DEC	[3]a	0.0000000801	5.1965000000	20
8 – DEC	[2]c	0.0440476386	2.3304991340	*
9 – DEC	[3]c	0.0000405620	4.0762376241	25

Fit Statistics

Even though fit statistics are listed, the biology of the strata had more influence on yield curve selection than did the fit statistics. How well the curve fit the average volumes, by 30-year age classes, often acted as a surrogate for more detailed statistics. These numbers are included to give a better idea of how much confidence should be placed in the yield estimates.

R^2 values were calculated for each of the curves using the following formula:

[7] $$r^2 = 1 - \frac{\sum (Y_i - Y_{hat})^2}{\sum (Y_i - Y_{bar})^2}$$

The numerator may refer to the SSE, or the error associated with the residual. The denominator may refer to the SST, or the error associated with the corrected total.

Table 7 shows the equations along with the number of plots and the components used to calculate the r^2 value. The 10 plots for Fd not found in the montane were included when calculating the deciduous volumes in equation [3]a. The MSE and the Root MSE was taken directly from the SAS non-linear regression output. The significance of these variables is explained in the text.

Table 7. Fit Statistics.

Yield Curve	Equation	Number of plots	SSE	SST	R^2	MSEE	Root MSE
1 - CON	[1]a	51	1386969	1416217	0.021	34674.2	186.2
2 – CON	[1]b	58	1151864	1155000	0.003	20208.1	142.2
3 – CON	[1]c	39	608977	603522	–0.009	16025.7	126.6
4 – CON	[1]d	59	702552	767429	0.085	12113.0	110.1
5 – CON	[1]e	45	1668502	1713626	0.026	37920.5	194.7
6 – CON	[1]f	35	675709	694751	0.027	19873.8	141.0
7 – CON	[1]g	36	302608	321476	0.059	8645.9	93.0
8 – CON	[2]a	19	225396	248043	0.091	162271.0	402.8
9 - CON	[4]a	64	117739	121628	0.032	1930.1	43.9
1 to 7 - DEC	[3]a	323	433616	436890	0.007	1350.8	36.8
8 - DEC	[2]c	19	20314	22291	0.089	1195.0	34.6
9 - DEC	[3]c	64	640509	670117	0.044	10330.8	101.6

It should be noted that one curve had a negative calculated r^2 values. This is controversial yet feasible, and suggests that a statistically ideal best-fit curve would have the opposite slope to the one that has been chosen. This best-fit curve would be biologically impossible, as it would predict high volumes when the age was zero and would decline as age increased.

The r^2 values in Table 7 are low, but this is expected because of the high amount of variance in volumes for any given age. The alternative models produced curves that are biologically infeasible, and were not be selected despite having a higher r^2 value in some cases.

The MSE, or mean squared error, is an estimate of the variance of the data. In general, there is no critical value, but lower numbers relate to lower variances or a better fit to the data. The root MSE (RMSE) is an estimate of the standard deviation of the error associated with the data. Both these values are a function of the distribution of the data, rather than an indication of the suitability of the curve.

There are a few assumptions that were made during yield curve development that must be carried over into the TSA. These include the following.

- Cull, breakage and waste should be deducted from the final volume predictions.
- Minimum harvest ages should be applied. The model that was used to predict volumes is designed to be accurate for mature and over-mature stands, at the expense of young stands. A minimum harvest age of 70 or greater is recommended.
- A death age should be assigned to stands to prevent the optimization model from holding volumes on the landscape, as the models do not aggressively decline after 250 years.

Timber Supply-related Adjustments

Additional work was done with the growth and yield information between the time of development and their application in the timber supply analysis (TSA). This work includes:

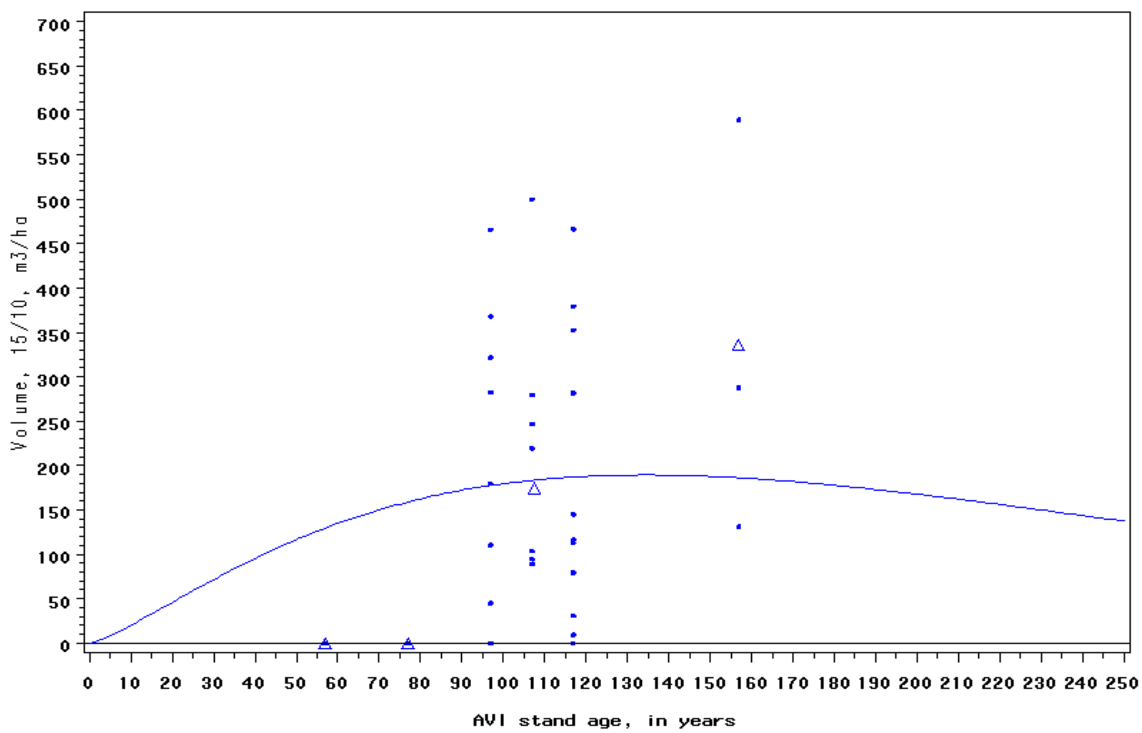
- Validation of the Fd curves. Due to changes in the application of the Fd curves, the data was re-examined to ensure that the original curve was still suitable for its new purpose.
- Development of additional curves: Appendix 2 describes any modifications to the original yield curves, as well as the development of the new C-Re curve for regenerating blocks. This appendix also discusses other inputs required for the TSA that were not derived from yield data.

Replacement yield tables are not available, as the adjustments were made within the TSA modelling software. If these tables are required, they will be produced on request.

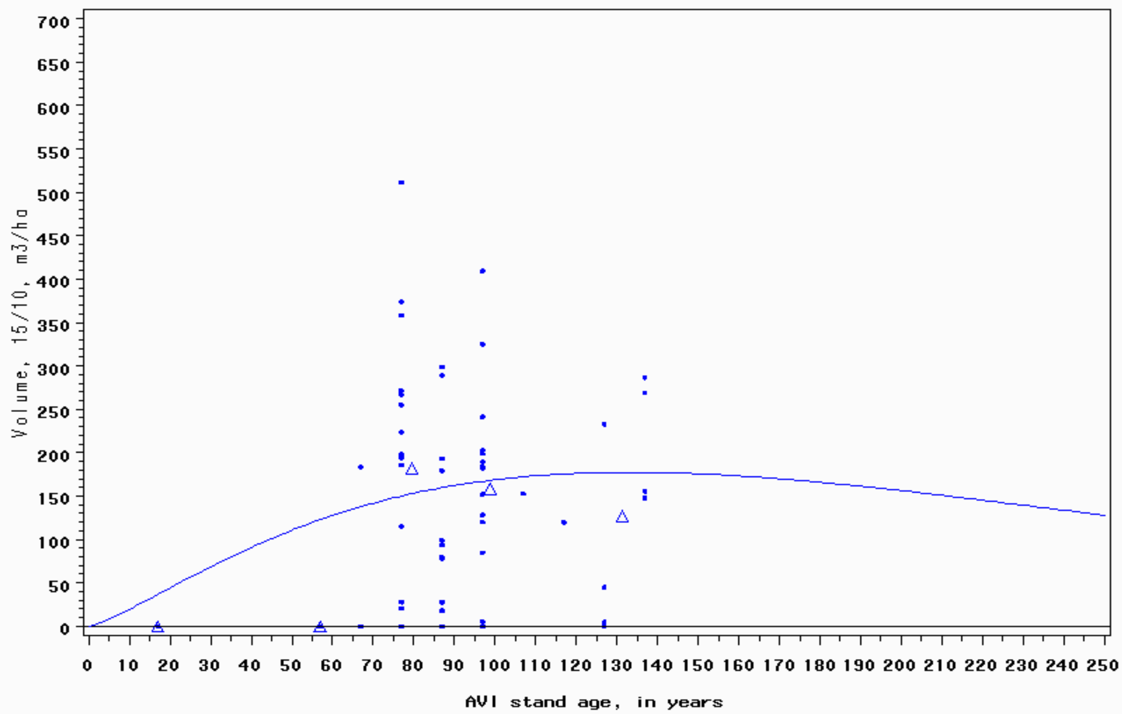
APPENDIX 1. REVISED YIELD CURVES (JANUARY 20, 2003)

The following graphs show the yield curves along with the information used to develop them. The equation numbers listed may be changing in the new documentation to account for the change in yield strata. For all graphs, the dots represent the scatter of the original data. The triangles represent the average values for 30-year age classes, and the averages were calculated for both axis. All volumes are measured to 15/10 merchantability.

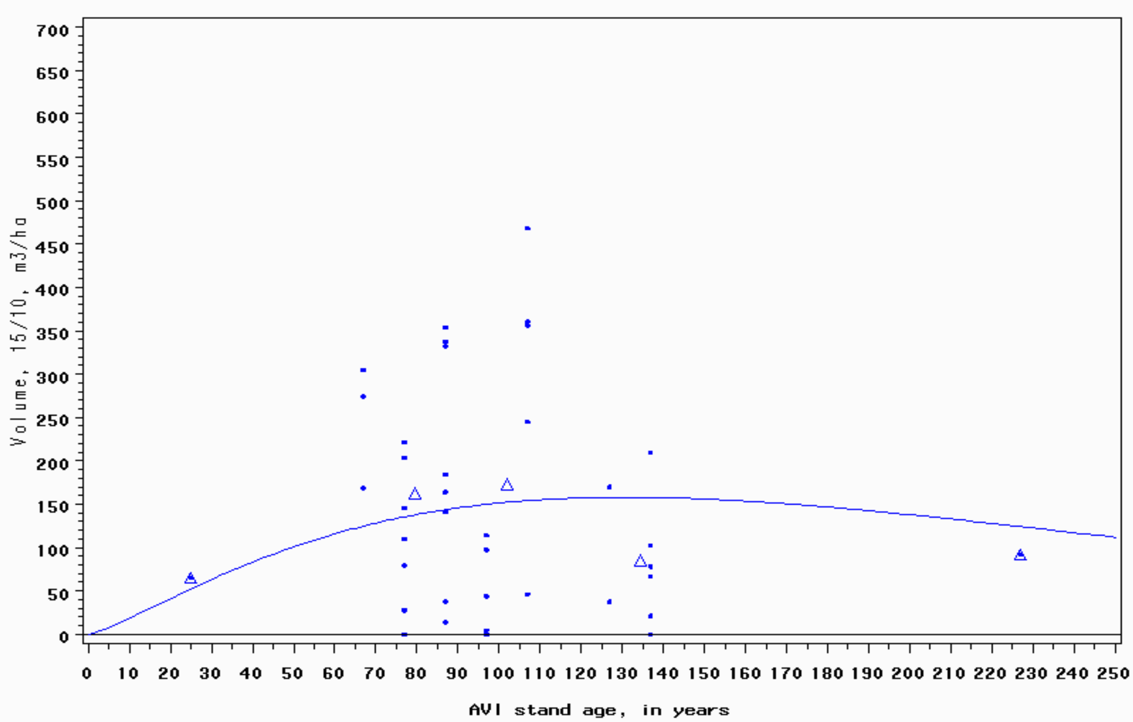
Graph 1: Equation [1]A
Conifer 15/10 volumes for low-density Douglas Fir stands in the Montane Subregion



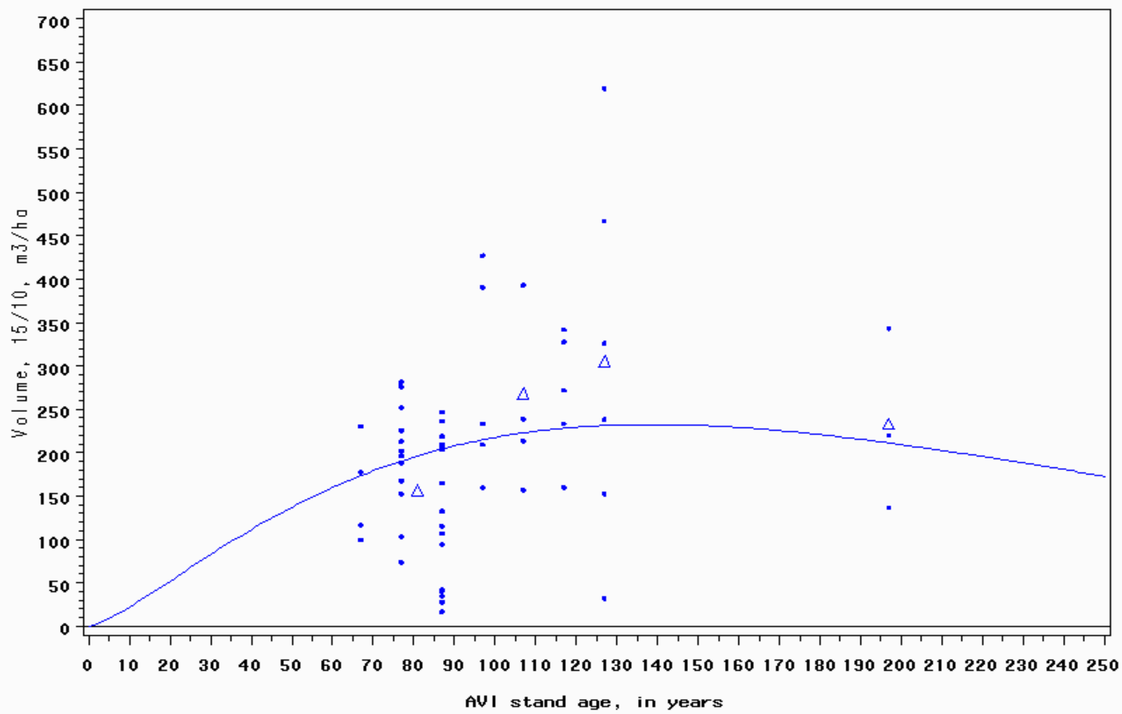
Graph 2: Equation [1]B
Conifer 15/10 volumes for all densities of Pine stands in the Montane Subregion



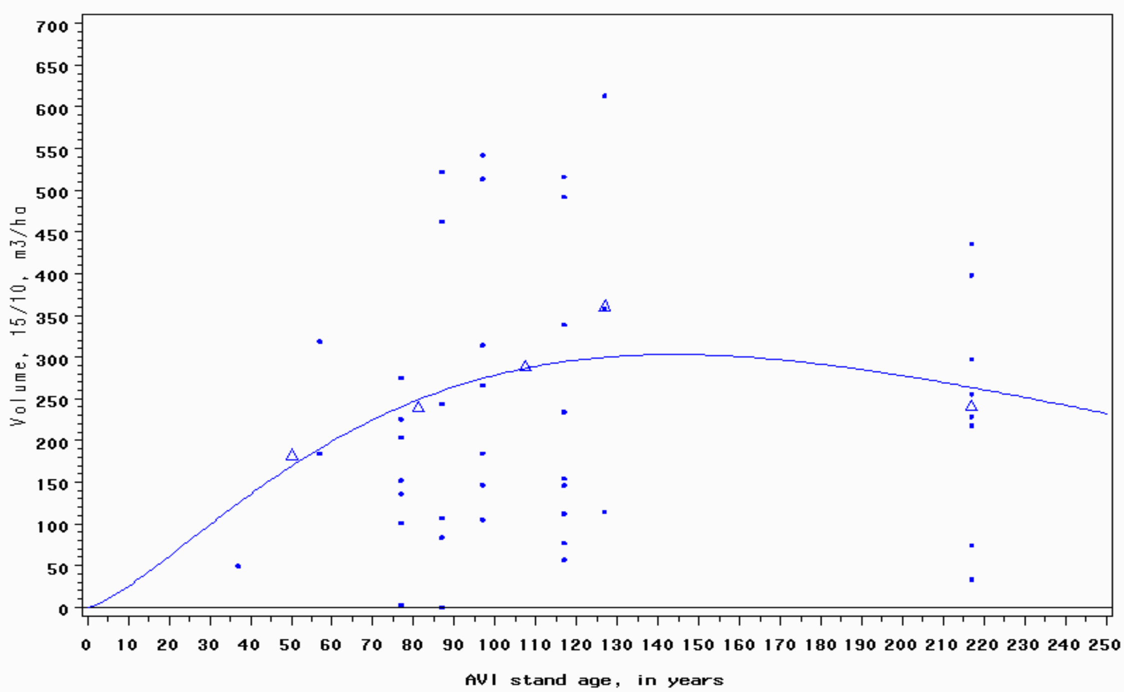
Graph 3: Equation [1]C
Conifer 15/10 volumes for low-density Pine stands in the Subalpine Subregion



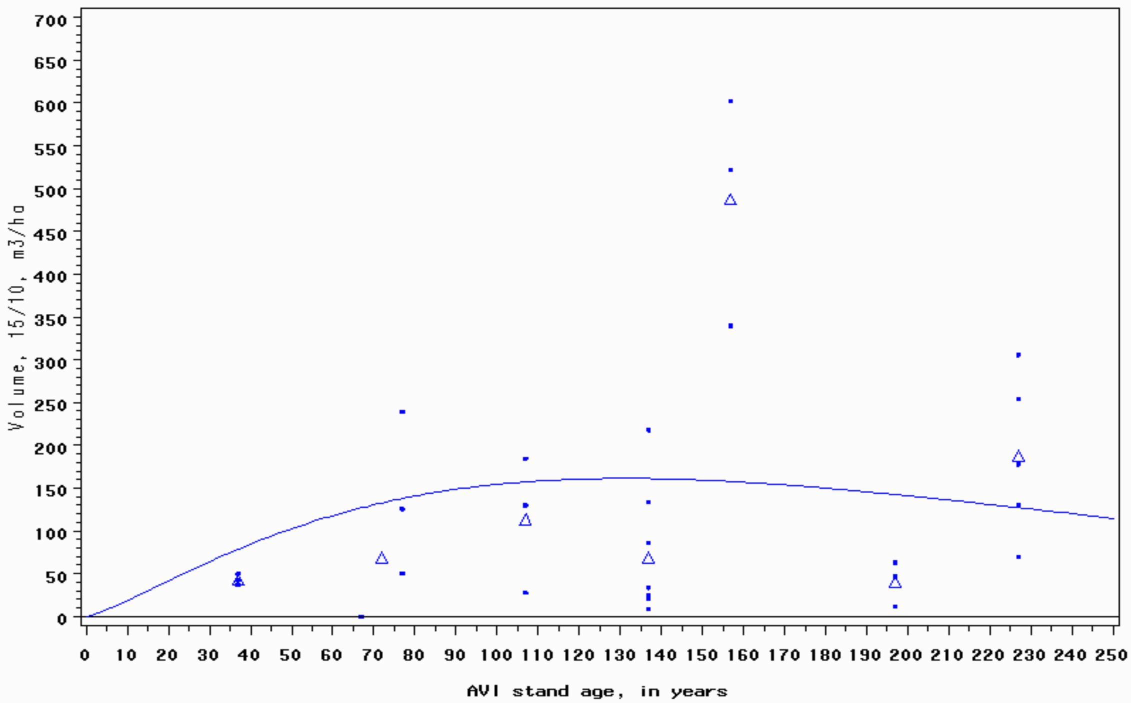
Graph 4: Equation [1]D
Conifer 15/10 volumes for high-density Pine stands in the Subalpine Subregion



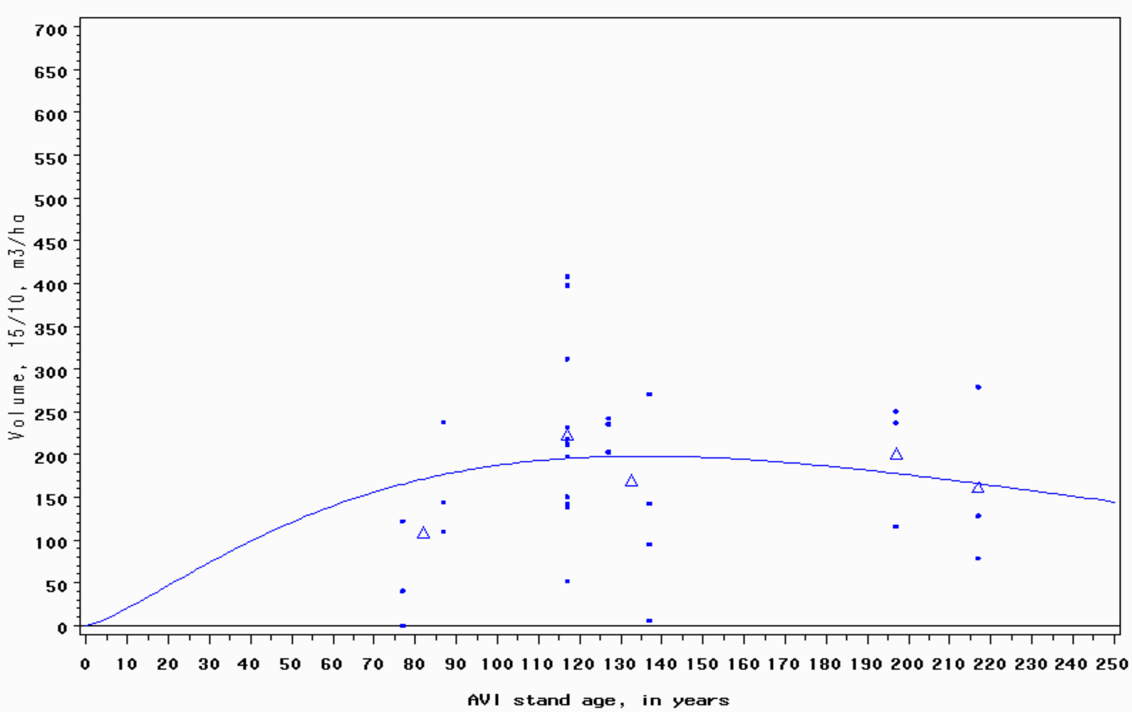
Graph 5: Equation [1]E
Conifer 15/10 volumes for all densities of Spruce stands in the Montane Subregion



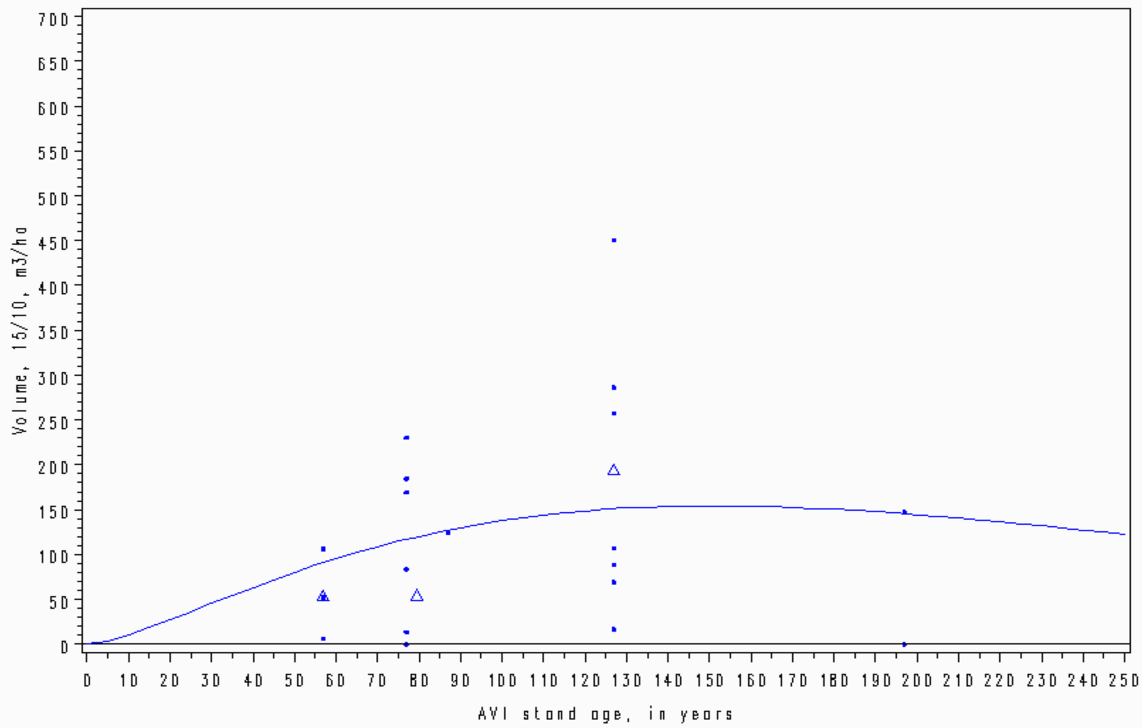
Graph 6: Equation [1]F
Conifer 15/10 volumes for low-density Spruce stands in the Subalpine Subregion



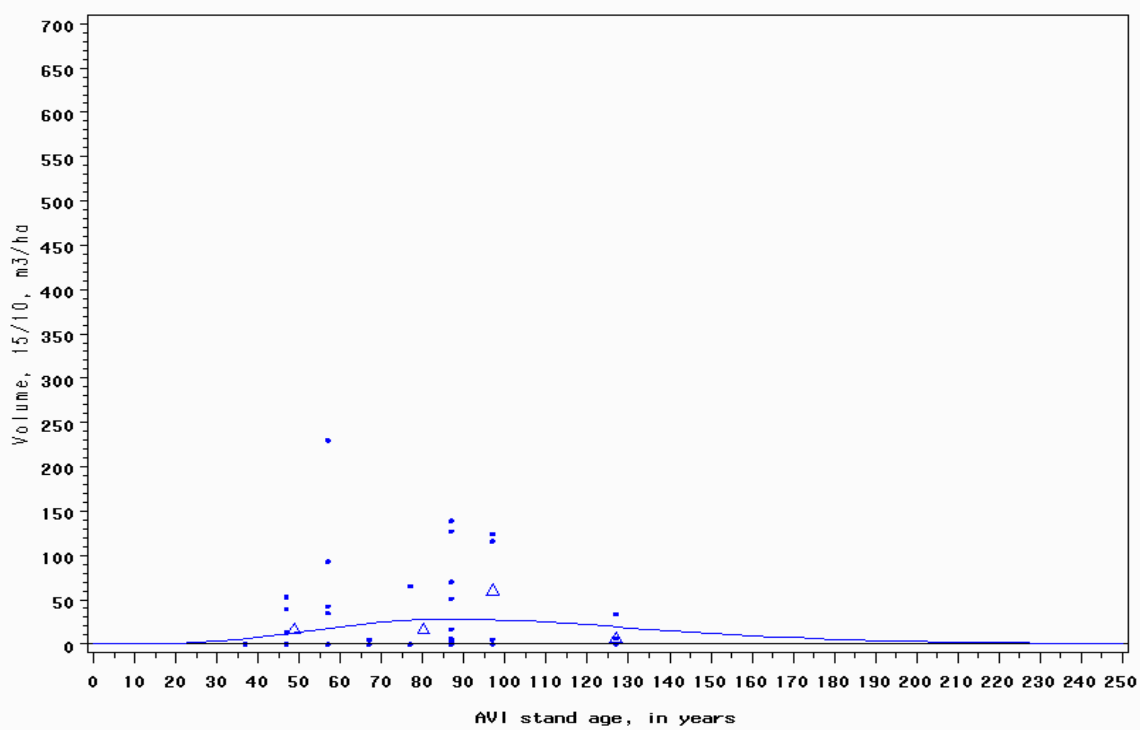
Graph 7: Equation [1]G,
Coniferous 15/10 volumes for high-density Spruce stands in the Subalpine Subregion

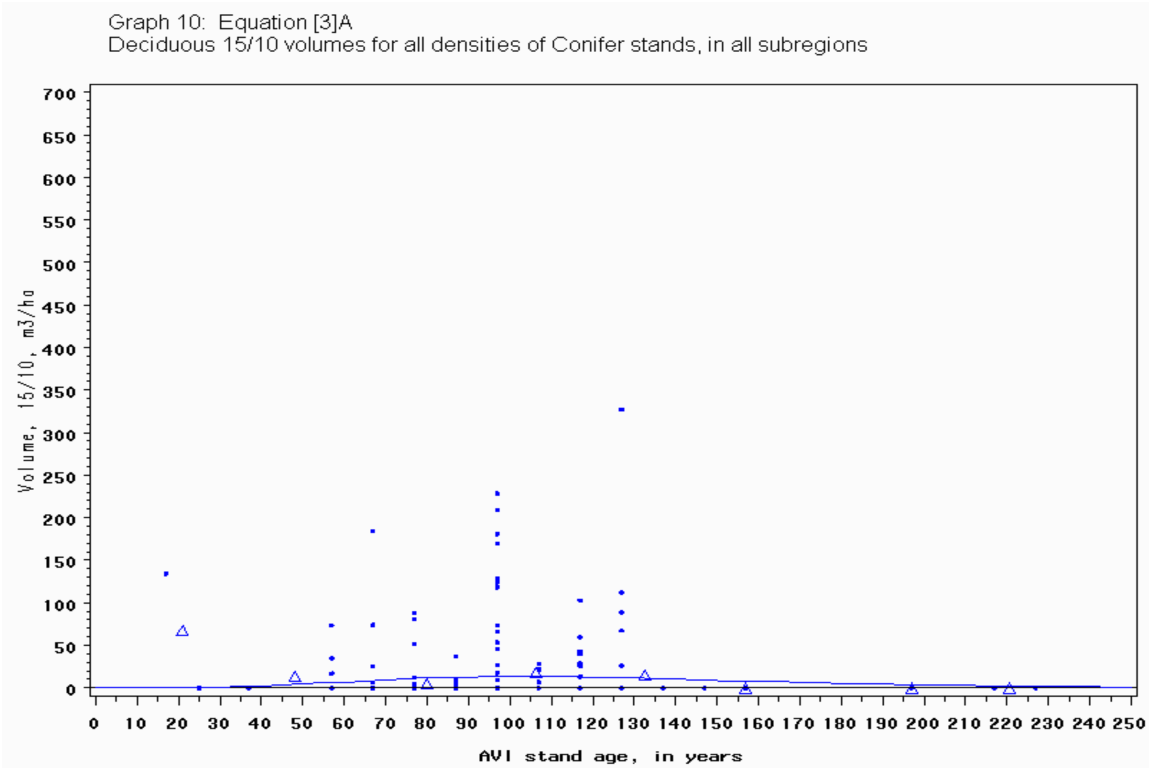


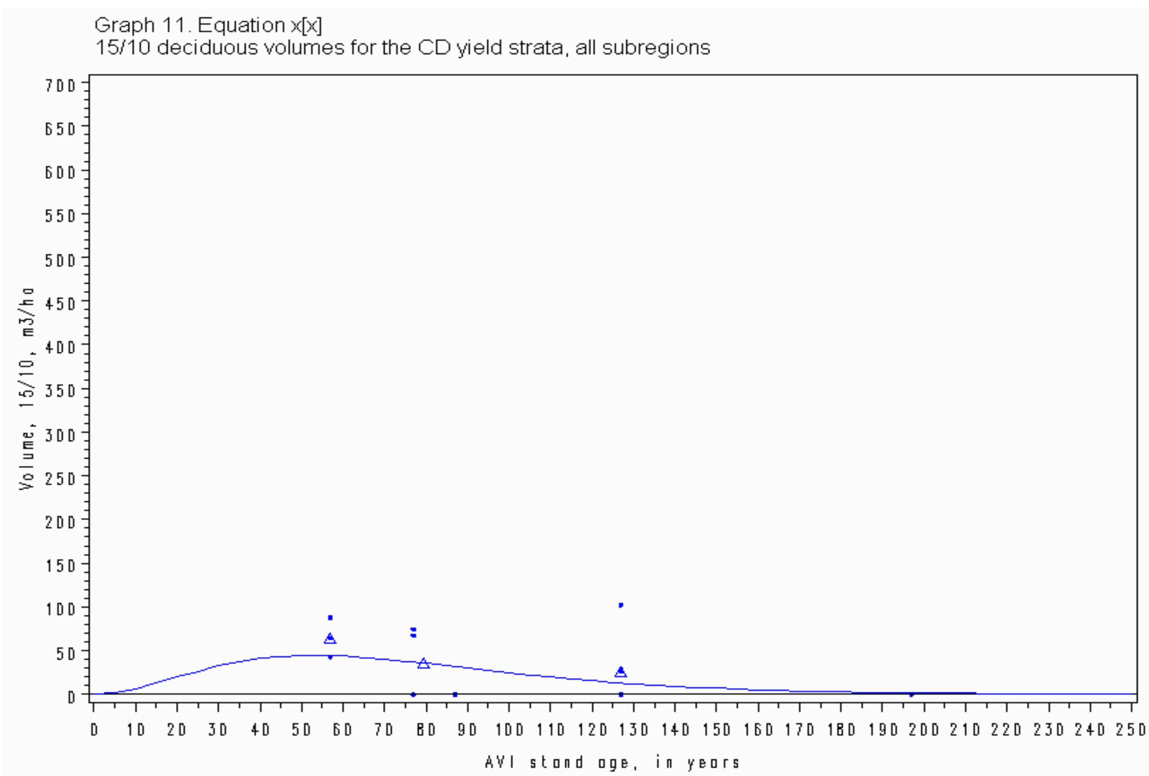
Graph 8. Equation x[x]
15/10 conifer volumes for the CD yield strata for all subregions

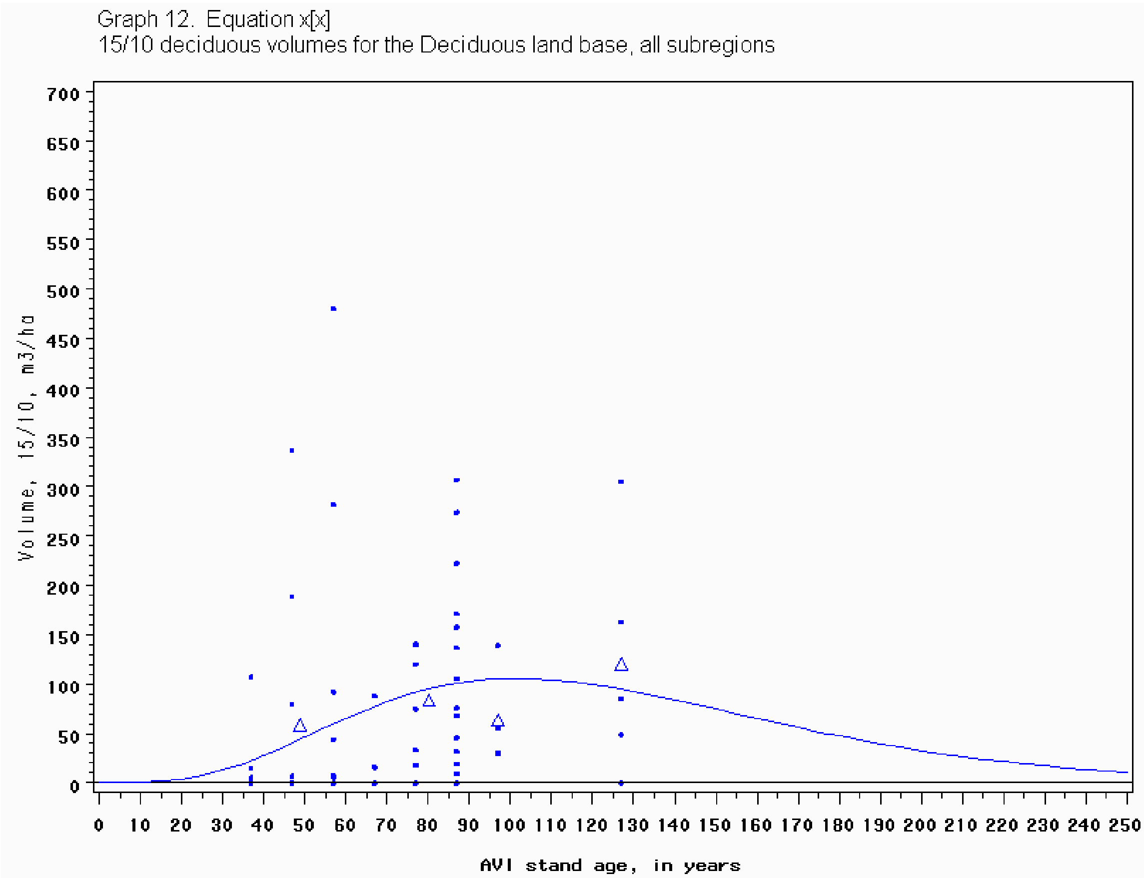


Graph 9. Equation x[x]
15/10 conifer volumes for the Deciduous landbase, all subregions




Graph 10: Equation [3]A
Deciduous 15/10 volumes for all densities of Conifer stands, in all subregions
Volume, 15/10, m3/ha
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250
AVI stand age, in years


Graph 11. Equation x[x]
15/10 deciduous volumes for the CD yield strata, all subregions
Volume, 15/10, m3/ha
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250
AVI stand age, in years


Graph 12. Equation x[x]
15/10 deciduous volumes for the Deciduous land base, all subregions
Volume, 15/10, m3/ha
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250
AVI stand age, in years

APPENDIX 2. SUPPLEMENTAL YIELD CURVES DEVELOPED FOR THE TSA

April 18, 2006

Changes to the Natural Stand Empirical Yield Curves Prior to the TSA

The yield equations described previously were used to produce periodic volume tables for conifer and deciduous volume by strata. Volume tables up to 300 years of age were developed by LFD in 2003 by manually bringing the SAS outputs from the yield curve program into Excel. Fields were created to account for MAI, 5-year periodic value, and the 6-year regeneration lag that was chosen at the time. A data dictionary for the volume tables was neither produced nor requested.

The volume tables produced by LFD were re-formatted by The Forestry Corp, and the 6-year regeneration lag was removed and proportional adjustments made before they were used in the timber supply model. The volumes were adjusted to account for the following reductions:

- Stand retention percentages (3%).
- Cull reduction (2.6%) to conifer volumes. No cull reductions were applied to the deciduous volumes.

The adjustment was a “sum of the multipliers”, i.e. conifer volumes were reduced by 5.6%.

The maximum age for some yield classes was greater than 300 years (see the documentation on the classified land base). If the lifespan was higher than 300 years, the yield curves were extended and it was assumed the volume at 300 years old remained constant.

Managed Stand Yield Curves

Managed stand yield curves were identical to the natural stand yield curves after the modifications for regeneration lag and proportional adjustments. Regeneration lag was incorporated into the TSA models by adjusting the ages of harvested stands. The age adjustment for regeneration in both the Woodstock and Patchworks TSA models was 5 years for most curves. The exception was a 10-year regeneration lag that was applied to the Douglas fir yield curve.

Additional Managed Stand Yield Curve for Post-1991 Blocks (C-Re Cover Type)

All stands in the classified landbase must be assigned to a cover type and yield curve, and the Planning Standard requires areas harvested after March 1, 1991, to be assigned to a yield curve using survey results or reforestation targets. Survey results and reforestation targets are stored in the Alberta Regeneration Information System (ARIS), which is a non-spatial database that tracks reforestation information by block. Each block is given a unique identifier in ARIS called opening number. Blocks were identified in the landbase classification process; however, not all the spatially explicit blocks had an opening number. Without a link between the reforestation information and the block areas in the landbase, it was not possible to assign an accurate yield curve to all blocks. Therefore, all blocks harvested post-1991 were assigned to one "regenerating" cover type (C-Re) and the ARIS information for post-1991 blocks was used to create an area-weighted yield curve for that cover type.

A yield curve (R) was developed for post-1991 blocks by area-weighting the natural stand empirical yield curves that were developed for the C5 FMU, after the adjustments were made for regeneration lag and proportional adjustments. A 5-year regeneration lag was applied to these stands.

The information used for the area-weighting was an ARIS opening summary report (Opening Summary Apr 4 '05 A2,C1,C2,C3,C05,C5.xls) provided by SRD to The Forestry Corp on April 4, 2005.

The first step in developing the regenerating yield curve was to assign yield strata to post-'91 blocks. The decision rules for assigning yield strata are provided in Figure 1. Cover group, leading species, crown class and natural subregion were all required to designate the yield strata.

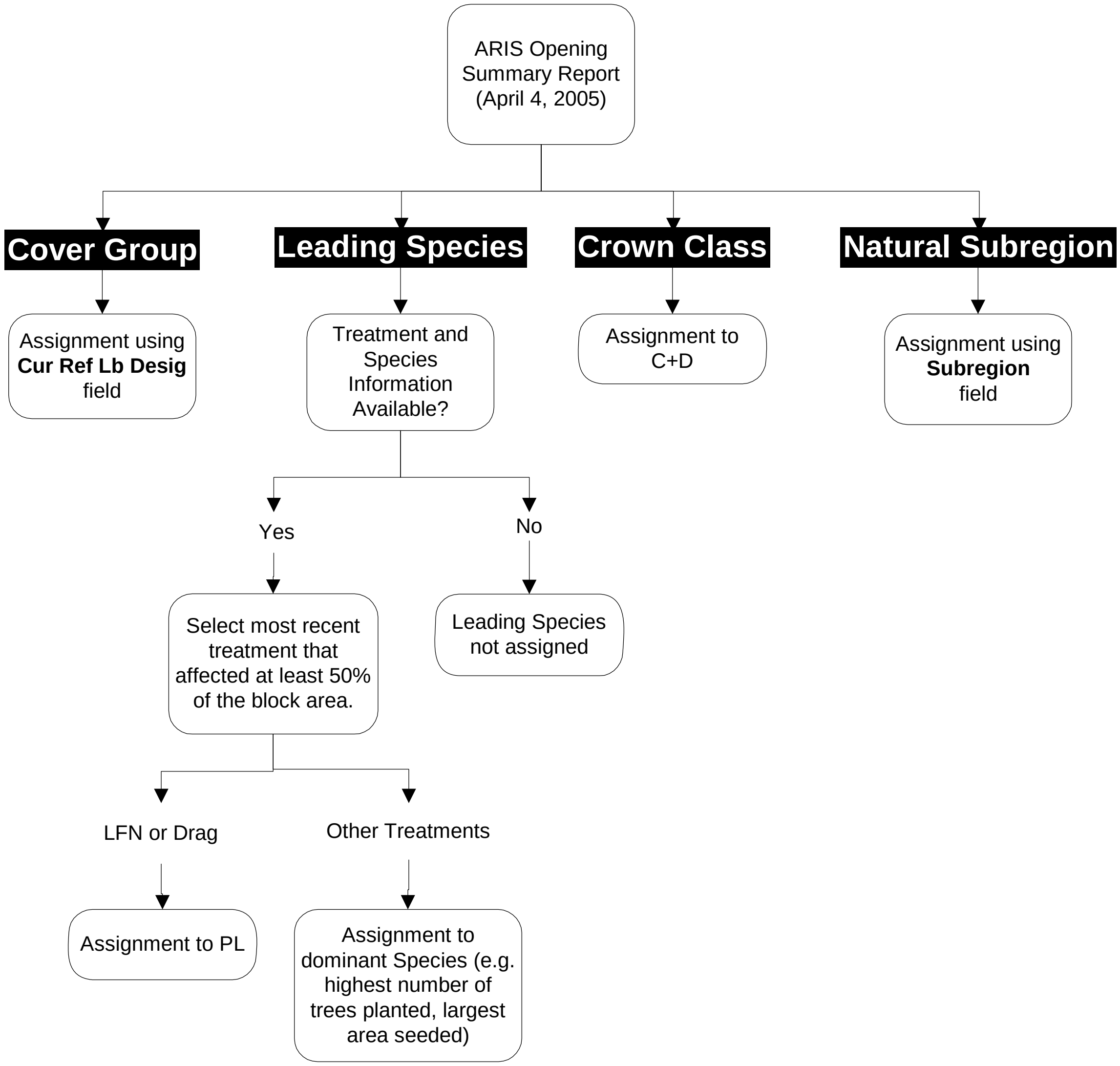


Figure 1. Assignment of post-91 blocks in ARIS to yield curve.

In addition to yield strata, the stocking status was required because there are existing blocks that do not currently meet the reforestation standards. The decision rules for assigning stocking status are provided in Figure 2. Disposition holders are obligated to reforest; therefore, non-LFS blocks are given the highest stocking status, with the exception of stands that have low stocking percentage after multiple surveys. For NSR blocks with LFS regeneration responsibility, conservative assumptions of 60% and 40% of the natural stand yield curve volume were used as a precautionary measure.

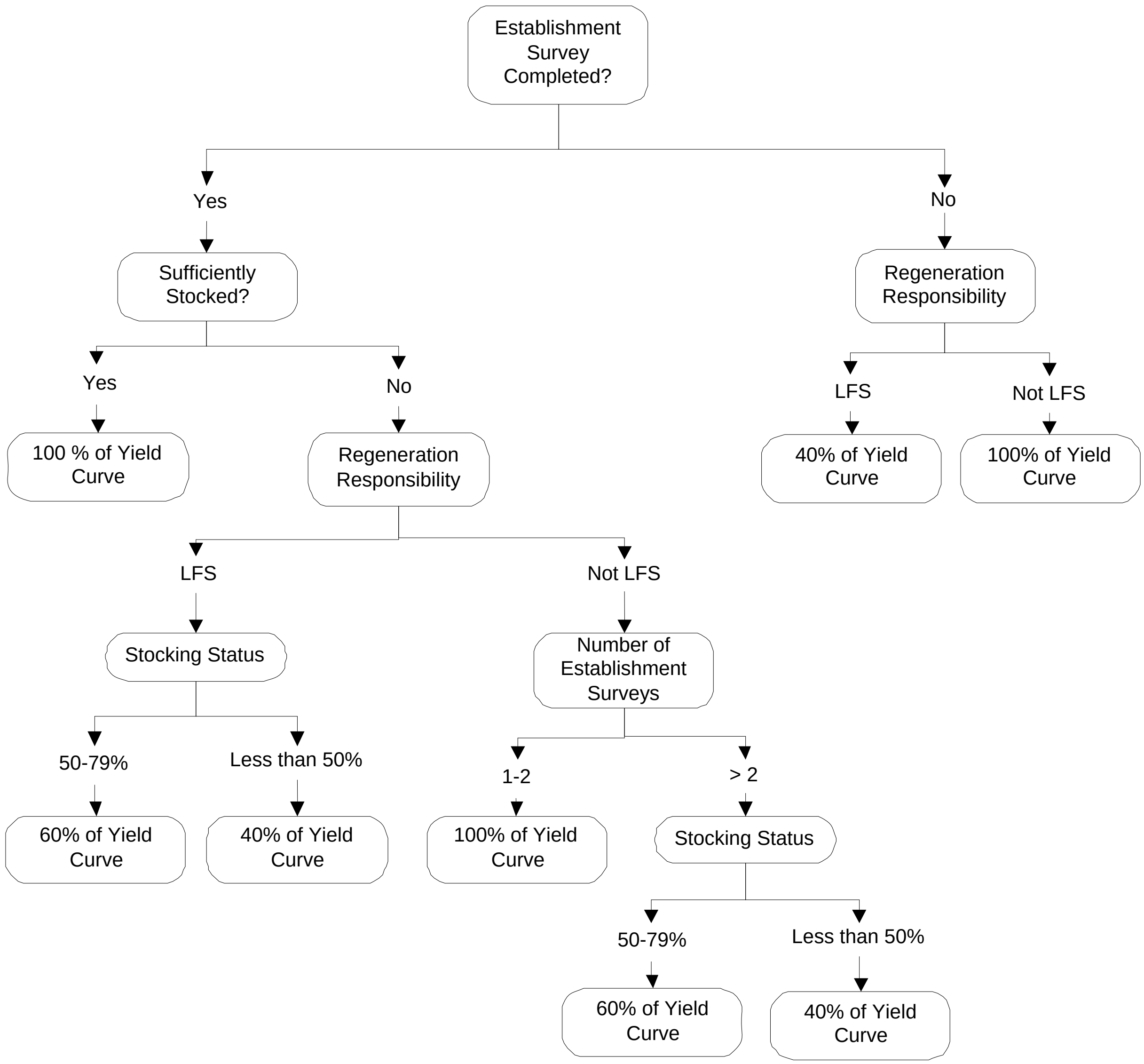


Figure 2. Assignment of post-'91 blocks in ARIS to stocking status.

Block areas provided in the ARIS opening summary report were used for the area-weighting. Table 1 shows the areas and proportions of the natural stand yield curves used in the development of the regenerating yield curve.

Table 1. Area weighting for the regenerating (R) yield curve.

Yield Curve	Number of ARIS Openings	ARIS AOP Area (ha) by % stocking				Prop of ARIS AOP Area			
		80+% (SR)[1]	50-79% (NSR)[2]	<50% (NSR)[3]	Total	80+% (SR)[1]	50-79% (NSR)[2]	<50% (NSR)[3]	Total
1 C-Fd-All	1	7	0	0	7	0%	0%	0%	0%
2 C-Pl-All-M	91	1,013	7	46	1,066	13%	0%	1%	14%
4 C-Pl-CD-SA	387	4,735	184	248	5,167	61%	2%	3%	67%
5 C-Sx-All-M	5	64	0	16	80	1%	0%	0%	1%
7 C-Sx-CD-SA	64	628	59	34	721	8%	1%	0%	9%
8 CD-All	18	616	0	0	616	8%	0%	0%	8%
9 D/DC-All	5	99	0	0	99	1%	0%	0%	1%
Total	**571**	**7,162**	**250**	**344**	**7,756**	**92%**	**3%**	**4%**	**100%**

[1] The original yield curve volumes (I.e. at 100%) will be used for SR areas in the area-weighting.

[2] 60% of the original yield curve volumes will be used for NSR areas with 50-79% stocking in the area-weighting.

[3] 40% of the original yield curve volumes will be used for NSR areas with <50% stocking in the area-weighting.

Additional Yield Curves for Partial Harvest Treatments

Additional yield curves were required for partial harvest treatments modelled in the TSA. These yield curves were developed by proportionately reducing the natural stand yield curves, after adjustments were made for cull. Two proportional reductions were used: 60% for FireSmart and 50% for non-FireSmart partial harvest treatments. The 60% reduction represented 60% removal of the standing volumes, and retention of 40% of the stand structure. No increased rate of volume recovery after treatment was modeled for either rate.

The proportional adjustments were the sum of the multipliers. In the TSA models, the actual reduction to the natural stand empirical yield curves was 62.6% and 52.6%, calculated as the sum of the percent volume removal and cull. Partial harvest curves were developed for all yield strata, including the regenerating strata (R).

The 50%-reduction partial harvest yield curves were also applied to a list of AVI stands provided by SRD. This list was derived for stands with CC modifiers in AVI, where a portion of the AVI stand was inside an existing block as identified from other data sources. The status of the standing timber in these stands outside of the block is unknown, and a conservative yield estimate was desired, therefore the standing volumes were reduced.

More discussion on partial harvest and the related yield curves can be found in the preferred management scenario (PFMS) documentation, including details on how they were applied and any related transitions. Partial harvests are also discussed in Objective 40 Forest Management (FM) Activity 3, but are also referenced in Object 15: FM Activity 8 and Objective 30: FM Activity 7.

Additional Yield Curves for Merchantable Volumes

Additional volume curves were required for one of the TSA modeling tools (Patchworks) for calculating the growing stock of stands in the managed landbase that are above the minimum harvest age. These curves were developed for conifer volumes only.

The merchantable volume yield curves were created where the volume was set at “0” until the minimum harvest age, and then after that age, the curve was the same as the standing volume yields. Merchantable volume yield curves were developed for natural, managed and partially harvested yield curves.

Additional Curves for TSA Inputs

Additional curves were required for one of the TSA modeling tools (Patchworks) to allow the calculation of areas meeting specific criteria. These curves were in the form of a proportion, and consisted of two values: 1 or 0. Because curve values were multiplied by the area, a value of 1 ensured the stand areas contributed to the feature of interest, and 0 ensured it did not. These additional curve were developed for:

- cover type,
- yield curve,
- seral stage,
- highly susceptible to mountain pine beetle,
- landbase,
- greenup state (stands < 30 years old), and
- disturbance state (stands < 5 years old).

Additional Curves for Age

Additional curves were required for one of the TSA modelling tools (Patchworks) to calculate the age of each stand. These curves consisted of the age in years and were developed for all strata.

Adjustment for Merchantable Volume

In May 2005, the Planning Team requested the volumes for C5 be recalculated to a 15/11[9] merchantability to be consistent with the utilization standard applied in the quota allocations within the management unit.

Individual tree volumes were recalculated using the new top diameter, and then summed up at the plot level. This data was then re-linked to the AVI attributes using the same approach as the original 15/10 plot information. The number of available plots for comparison was unchanged from the original analysis.

The average difference in volume for stands between 90 and 120 years old were compared in order to develop a conversion ratio. This range of ages coincided with the expected minimum harvest age, where the volume difference will be most influential on the plan. An area-weighted approach was used to ensure that the dominant yield strata on the landscape would drive the relationship.

[9] *Refers to the stump diameter inside bark /top diameter outside bark.*

There is an average difference of 5.18 m3/ha, or approximately 2.6% relative to the 15/10 volumes. A 2.6% deduction was applied in the current TSA process to the outputs from the TSA scenarios.

The final volume calculation follows:

> Final volume = Initial volume * 0.944 (cull + stand retention) * 0.974 (merchantable volume adjustment)

Tabular data for the volume tables:

The following tables are available as external files, and can be found on the data cd-rom:

- C-Re curve creation.xls: An excel file highlighting the development of the C-Re curve.
- Yield_curve_graphs.xls: An excel file containing volume tables and graphs.
- C5_rd9_run91.yld : The raw yield file used as an input to Woodstock.

While these files are not formatted for presentation, they do reflect the inputs into the TSA and are included for reference.

APPENDIX 3. SOUTHERN ROCKIES LANDSCAPE PLANNING PILOT PROJECT FIELD SAMPLING COMPONENT

Southern Rockies Landscape Planning Pilot Project
Field Sampling Component
Part 2

Terms of Reference

1.0 Introduction

Land and Forest Service is conducting a Landscape Planning Pilot Project for an area in the Southern Rockies of Alberta known as the Livingstone-Porcupine area. The pilot project involves a field sampling component to test stratification and sampling methods to support the landscape planning process.

2.0 Objectives

This inventory is designed to provide the information needed to:

- Produce stand volume tables for the project area based on ecosite phase and AVI classification.
- Evaluate the potential of using ecosite phase as a basis for volume sampling.
- Evaluate the ability to collect and use broad ecosystem data for ecosystem-based forest management.

The purpose of this project is to establish a maximum of 1000 field plots in the Livingstone–Porcupine area. A total of 800 plots will be established in this initially and an additional 200 plots will be established in 1998 after preliminary data analysis is complete.

3.0 Tasks

The tasks for this project include:

- Planning field work from plot location maps.
- Establishing 800 plots according to methods described in section 5.0 of this terms of reference.
- Keypunching data.

4.0 Study Area

The study area includes the Livingstone–Porcupine area and is shown in Appendix 1. Only two natural subregions will be sampled: Subalpine (08) and Montane (09).

5.0 Specific Requirements

5.1 Plot Forms

At each plot, the following plot forms are to be completed:

1) Large-tree temporary sample plot form.
2) Stump tally form (in large tree plot).
3) Small tree plots tally form.
4) Dead and down woody material tally form.
5) Generalized wildlife assessment form.
6) Ecological assessment form.

These forms are shown in Appendix 2

5.2 Sampling Design

A total of 3 plots will be established in each stand randomly selected for sampling. The location of the first plot in each stand is given as a random point within the stand on 1:50,000 maps of the area. These points are numbered on the maps and will subsequently be used as the stand number on all plot forms. The remaining 2 plots within the stand are located in a triangular fashion @ 45 degrees and 270 degrees) from the first plot with a spacing of 100 metres where feasible.

If the stand is small, make sure all 3 plots fall within the stand by decreasing the distance of the spacing to 75 m and if necessary, to 50 m.

5.3 Plot Location Specifications

5.3.1 Recording Plot Locations

Plot locations are to be recorded digitally using a Global Positioning System (GPS) and supplied as a data file on completion of the contract. The system used by the contractor must be of high enough quality to obtain accurate locations under tree canopy and in areas of rough terrain. The contractor must have access to a base station and must have access to corrected data. The specifications of the GPS will be discussed with the successful contractor before initiation of the contract.

5.3.2 Major Tie Point

The tie point or reference point of each stand type must be well marked on the ground so that it may be found at a future date. Plastic (orange, blue and yellow) seismic ribbon is tied to vegetation/trees at the tie point. The date of establishment, the initials of the crew, the stand type number, and the distance and bearing to the first plot are marked on ribbon with a permanent marker and hung at the point. For example, the marking, 83-10-27/50 m @ 273^o to TSP 5101/K.J., C.S. means the following:

83 – year, 1983,
10 – month, October,
27 – day, 27th,
50 m @ 273^o – 50 metres on a true bearing of 273^o,
to TSP 5101 – to temporary sample plot number 5101,
/K.J., C.S. – crews' initials.

A map with a major tiepoint is used (i.e., river, highway, junction, etc.) to help relocate the plot for check cruising. Use Permanent Sample Plot Form TM267 for this purpose. Declination is to be recorded in the comments section. Legal land description is recorded as the section and legal subdivision containing the centre of plot #1 (example in Appendix 1). Access is assessed using the following codes.

1- All weather road
2- Dry weather road
3- Deteriorating road
4- All terrain vehicles only
5- Helicopter access only

5.3.3 Location of Plot Centre

Plot centre is marked with a sturdy stake. This stake must remain in position until a possible future check of the samples is done (check cruise). Plastic ribbon, (orange, blue and yellow) with a four-digit AVI stand number and plot number written on it, is attached to the stake. Plots are numbered consecutively as they are established in the stand, starting with 01 in each stand and ending at number; for example, 1-0007, 2-0007, and 3-0007 (1-0007 would be plot 1 in AVI stand 7). Flag compass bearing to plot centre of plot number 1 with orange flagging every 10 to 20 m. Same to be done between plots 1 and 2, and 2 and 3.

5.3.4 Movement of Plot Centre

Discrepancies between stand boundaries and descriptions on maps versus those on the ground can occur because of incorrect mapping and variation of the stand. If a plot centre falls within mapped stands of a stocked productive forest, but is close enough to nonstocked or nonproductive forest type boundaries to be unrepresentative of that stand, the plot should be moved (offset) fully into the desired stand. The new plot centre is located by moving at 30 metre intervals, at an angle of 90^o or 270^o from the original tiepoint line, until the plot centre is well within the stand to be sampled. The distance from the original plot centre to the new plot centre is determined before the offsetting is done to eliminate the cruiser's personal bias (i.e., putting the new plot in a "nice" spot). Relocation of plot centres must be well documented on the stand record map. The next plot centre is located from the old original plot centre (i.e., before offsetting occurred).

If a plot centre falls on a seismic line or mapped trail, the plot is to be relocated in a direction perpendicular to the line or trail at a distance of 30 metres from the original location.

5.3.5 Correction for Slope

When the slope exceeds ±10%, compensation for the increased distance (slope distance) is necessary. Use the slope correction table (Table 1).

5.4 Plot Measurement

A variety of plots and transects will be used to collect information (Figure 1).

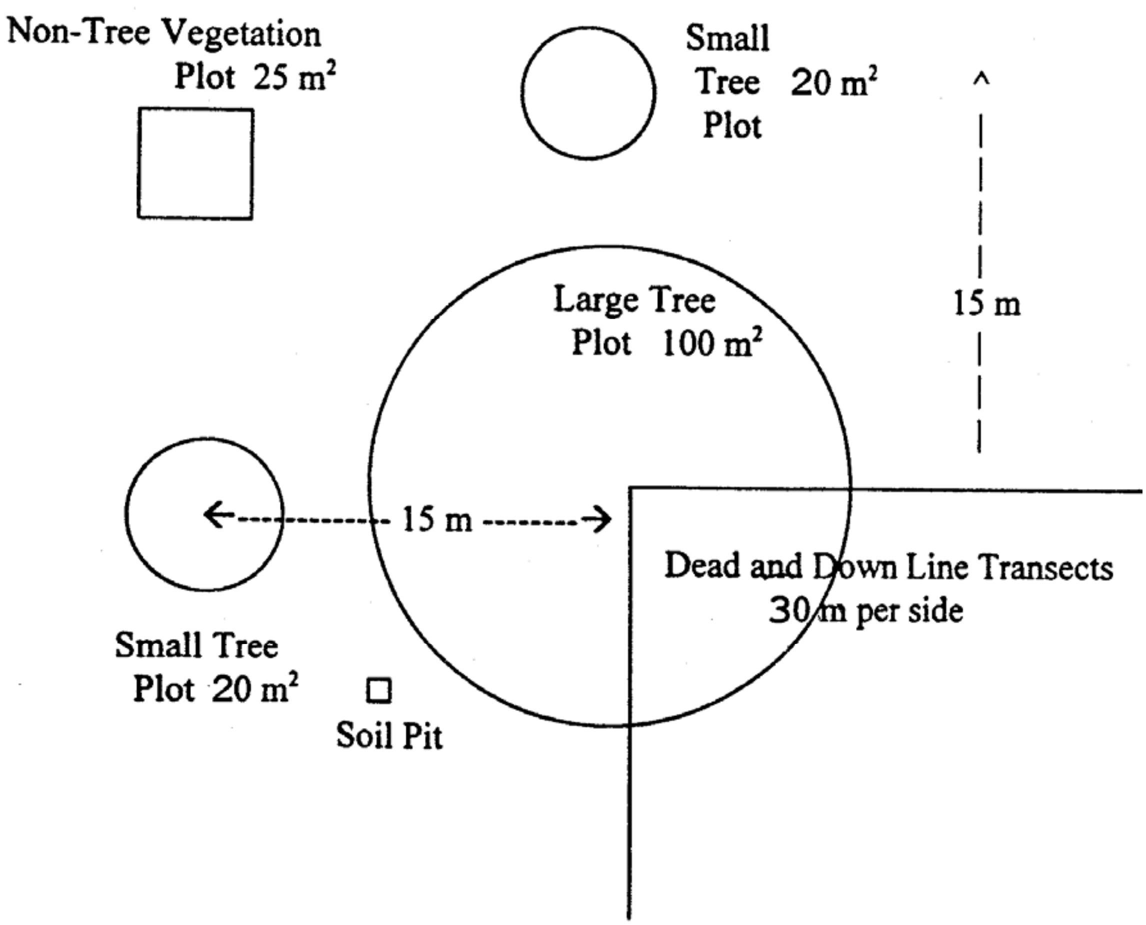


Figure 1. Sample Plot Layout

It should be noted that the placement of transects, plots and the soil pit may vary from the diagram shown above. Determination of some of the broad ecological information may also extend beyond the confines of the large tree plot.

Table 1. Slope Correction Factors and Tables

To convert slope distance (S.D.) horizontal distance (H.D.)

H.D. = S.D. X slope distance factor

To convert horizontal distance (H.D.) to slope distance (S.D.)

$$S.D. = \frac{H.D.}{\text{slope distance factor}}$$

SLOPE DISTANCE FACTORS

5.4.1 Large Tree Plot

From the plot centre, establish a 100 m^2 circular plot. This plot will have a radius of 5.64 m.

% slope		% slope		% slope	
10	0.995	40	0.928	70	0.819
11	0.994	41	0.925	71	0.815
12	0.993	42	0.922	72	0.812
13	0.992	43	0.919	73	0.808
14	0.990	44	0.915	74	0.804
15	0.989	45	0.912	75	0.800
16	0.987	46	0.908	76	0.796
17	0.986	47	0.905	77	0.792
18	0.984	48	0.902	78	0.789
19	0.982	49	0.898	79	0.785
20	0.980	50	0.894	80	0.781
21	0.979	51	0.891	81	0.777
22	0.977	52	0.887	82	0.773
23	0.974	53	0.883	83	0.769
24	0.972	54	0.880	84	0.766
25	0.970	55	0.876	85	0.762
26	0.968	56	0.872	86	0.758
27	0.965	57	0.869	87	0.754
28	0.963	58	0.865	88	0.751
29	0.960	59	0.861	89	0.747
30	0.958	60	0.857	90	0.743
31	0.955	61	0.854	91	0.740
32	0.952	62	0.850	92	0.736
33	0.950	63	0.846	93	0.732
34	0.947	64	0.842	94	0.729
35	0.944	65	0.838	95	0.725
36	0.941	66	0.835	96	0.721
37	0.938	67	0.831	97	0.718
38	0.935	68	0.827	98	0.714
39	0.932	69	0.823	99	0.711

Record natural region, location, plot number and AVI stand number on the large tree tally form. Proceed to measure all trees, both live and dead >=7.0 cm dbh, within the plot boundary. A tree is considered to be within the plot if the midpoint of the tree stem at breast height is on or within the defined boundary of the plot.

Trees must be numbered starting due North of plot centre and sweeping clockwise. Number trees with paper admission tickets stapled to trees at DBH facing plot centre. Last 2 digits of starting number must be 01.

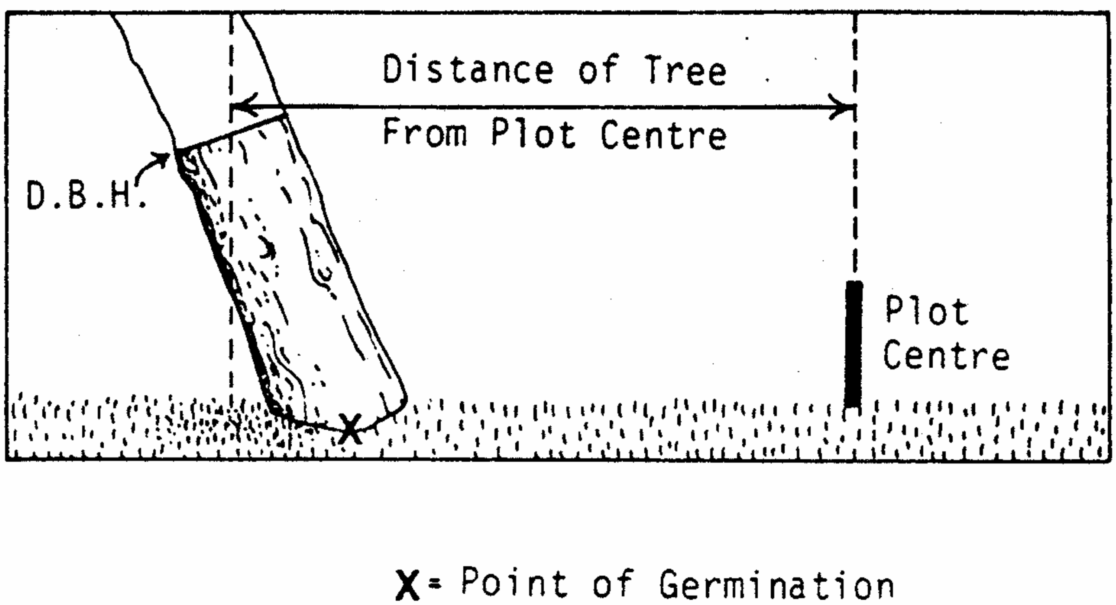


Figure 2.

1. Species Code

Table 2 lists the species to be measured. In addition to Table 2, the following codes are used:

Dead Conifer	DC
Dead Deciduous	DD
Dead, unable to make any species differentiation	DU
Nil Tally (No trees talliable)	NO

Trees are considered to be dead when they no longer have any live branches.

All talliable dead trees must be standing, capable of withstanding a firm push, and must have at least 50% of the gross volume as sound wood. Trees with codes “DC” and “DD” are tallied to give the volume and number of stems per hectare for the dead standing timber.

Table 2. Tree Species Recognized in Alberta Vegetation Inventory

Scientific Name	Common Name	Species Code
Picea glauca(Moench) Voss Picea engelmanii Parry Picea mariana (Mill.) B.S.P.	white spruce Engelmann spruce black spruce	SW SE SB
Pinus contorta var. latifolia Dougl. Pinus albicaulis Engelm. Pinus flexilis James Pinus banksiana Lamb.	lodgepole pine white bark pine limber pine jack pine	PL PW PF PJ
Abies balsamea (L.) Mill. Abies lasiocarpa (Hook.) Nutt.	balsam fir alpine fir	FB FA
Pseudotsuga menziesii (Mirb.) Franco	Douglas fir	FD
Larix laricina (Du Roi) K. Koch Larix occidentalis Nutt. Larix lyallii Parl.	tamarack western larch alpine larch	LT LW LA
Populus tremuloides Michx. Populus balsamifera L.	trembling aspen balsam poplar	AW PB
Betula papyrifera Marsh.	white birch	BW

2. Nil Tally Plots

If there are no talliable trees in the plot, “NO” is recorded as the species. The plot information on the tally sheet is completed as usual.

3. Dbh Measurements

Once the “in” trees have been determined, the diameter at breast height (dbh) is measured. It is recommended that the stick marked at the length of 1.3 m with plastic ribbon be used to determine the correct breast height from the point of germination (Figure 2).

Dbh is measured to the nearest 0.1 centimetre with a metal diameter tape. Care should be taken in keeping the tape horizontal to the base of the tree. If calipers are used on an eccentric stem then the mean of two readings, taken at right angles, is recorded. Large branches and swellings right at dbh should be avoided and the measurement is made immediately above or below the distortion. Trees forked below 1.3 m (breast height) are treated as two separate stems and are tallied as such. In summary, talliable trees must be:

a) alive, or dead and standing,
b) a commercial species (as identified in Point 5), and
c) 7.0 cm or larger dbh.

4. Height

In general, on plots where height is fairly uniform, measure at least two healthy trees from each crown class and estimate the remainder. On plots where height is variable, measure 4 to 5 trees across the range of variability and use these measurements as a guide to estimate the heights of the remaining trees on the plot. Trees that have had height measured must have orange flagging tied around them. Paint a blue dot at 1m in the direction the tree height is taken to facilitate quality control checking. Height trees are also to be used for age trees. Leaning trees should be measured perpendicular to the lean and tree height should be the distance from the tip of the tree to the intersection of a vertical line from this tip to the ground.

Record total tree height in metres to the nearest 1/10th of a metre; i.e., xx.x.

Similar to measurement of total tree height, determine the vertical distance from the germination point to the base of the live tree crown (bottom layer of live branches figure 3). Record this height in metres to the nearest 1/10th of a metre, xx.x.

5. Age

In pure conifer or pure deciduous stands, select the largest diameter dominant tree and one other dominant or codominant tree of the leading species to core. These should be healthy trees and should be representative of the larger trees in the stand (i.e., do not select wolf or veteran trees that are not typical of the majority of trees found on the plot). In mixedwood stands, select two trees of the leading conifer species and two trees of the leading deciduous species to core. The selection of trees within each species should be done in the same manner as for pure stands. All trees which are selected for age must also be measured for height.

Use an increment borer to extract a core at breast height from the trees selected for age determination. Ensure that the core extends past the pith and intersects the pith (Figure 4). Place the core in a straw and write the stand number, plot number and tree number on the outside of the straw using tape and a pen in which the ink will not run if it gets wet. At a convenient time, in good lighting, carefully count the number of rings occurring from the pith to the cambium. Record the number of rings on the large tree tally form. Since cores will be taken from trees in the subalpine, it may be necessary to use a microscope to get an accurate age; i.e., 350 years in a 6 cm core has been recorded in the past. Cores should be frozen until counting and should be retained for check cruising.

Do not bore the tree at any other height except 1.3 m. Cores that are impossible to count due to rot are recorded at “ROT”. However, if this occurs another sample tree should be bored in order to obtain the correct age of the stand.

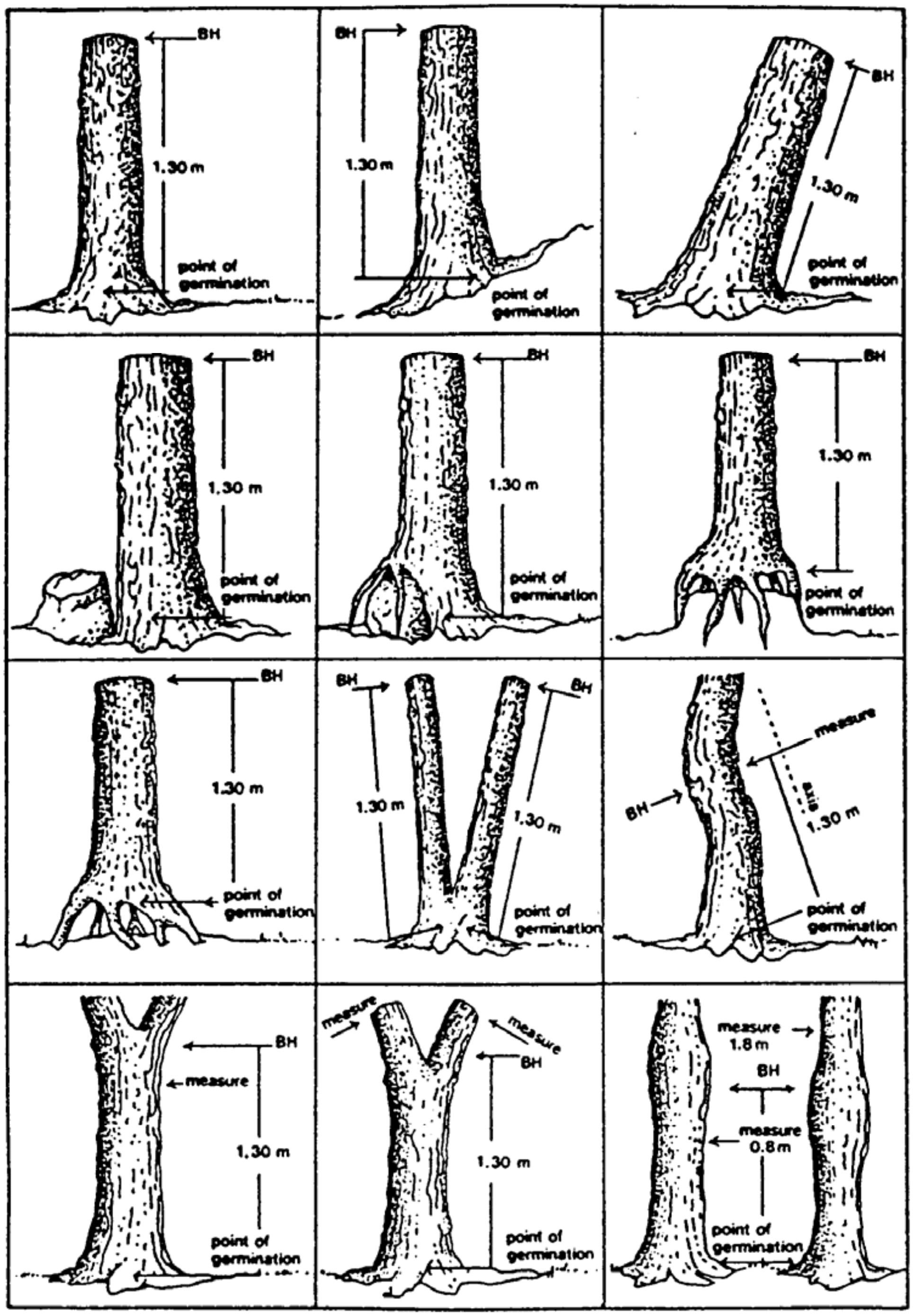

BH
1.30 m
point of germination
measure
axis
measure 1.8 m
measure 0.8 m

Figure 3.

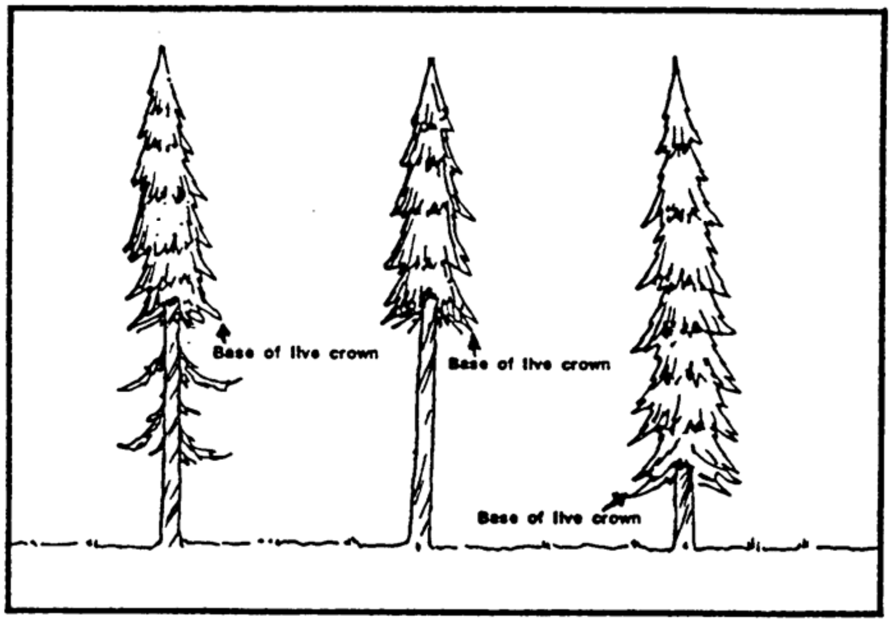


Figure 4. Base of live crown.

6. Crown Class

Crown class refers to the position of an individual tree within the canopy of the stand. Crown class is assessed on a plot-by-plot basis, not for the stand as a whole. For example, an intermediate tree in one plot may be a codominant in the next. Figure 5 shows the types of crown class in a single layer stand.

7. Visual Appearance

Classify the visual appearance of all trees on the plot (live and dead) using the following diagram (taken from B.C., M.O.F. Ground Sampling Procedures) to assign a numerical code:

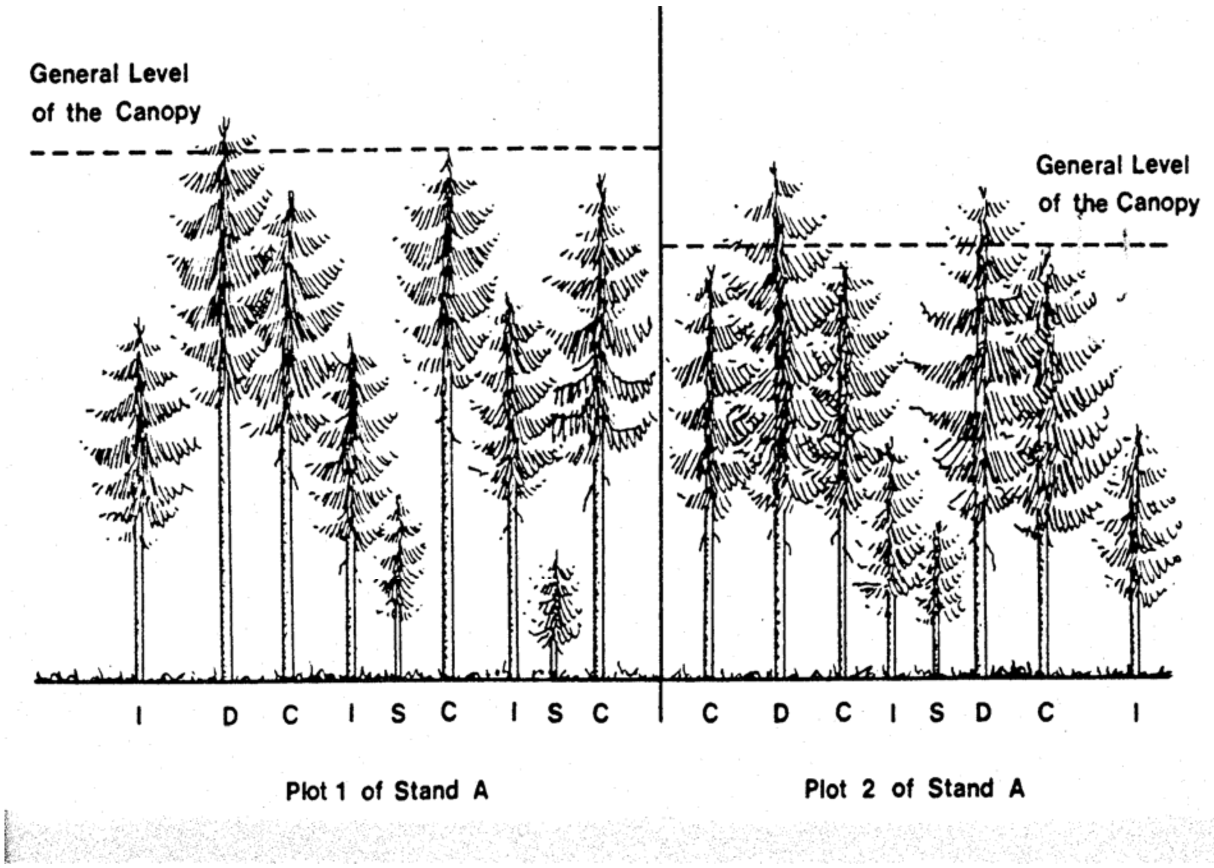


Figure 5. Examples of crown classes.

Symbols used in Figure 5 are as follows:

D	Dominant	—	crowns extend above the general level of the canopy.
C	Codominant	—	crowns form the general level of the canopy.
I	Intermediate	—	crowns below but extending into the bottom of the general level of the canopy.
S	Suppressed	—	crowns entirely below the general level of the canopy.
0	Open-grown	—	used only in special situations for trees in very open stands.

The following descriptions apply to the codes used for visual appearance:

1. All foliage, twigs and branches present.
2. Some foliage and twigs lost, all branches usually present, possible broken top.
3. No foliage, up to 50% of twigs lost, most branches present, possible broken top.
4. No foliage or twigs, up to 50% of branches lost, usually broken top.
5. Most branches gone, some sound branch stubs remain, broken top.
6. No branches left, some sound and rotting branch stubs, top broken.
7. Over 50% loss of tree stem, few rotting branch stubs remaining.
8. Only high stump of tree remains, no branches.
9. Only remnant stump remains.

8. Tree Damage Codes

Visually inspect the tree for presence of damaging agents or wildlife use. If evidence of damage is present, record this in the damage field using the two digit codes given Appendix 3. You may use up to three damage codes.

5.4.2 Tree Stump Tally Form

Stumps are measured on the large tree plot (100 m^2). Stumps are defined for this purpose as being between 0.3 m and 3.2 m in height. Record any tree stumps greater than 18 cm in diameter whose centre point lies on or within the plot boundary. For each stump record species, average diameter outside bark at the top of the stump, stump height and an estimate in percent of the amount of sound, solid wood. Stump diameter is measured at 0.3 m with a metal diameter tape.

Distortions such as root swellings are avoided by measuring the diameter directly above the distortion of tree stump >= 0.3 m in height and >= 5 cm in diameter by species. Record this measurement to the nearest 1/10th of a centimetre (xx.x cm). Record stump height to the nearest 1/10th of a metre (xx.x m). Percent of sound wood should be recorded as a whole number based on estimates to the nearest 10%, i.e., 10, 20, 30 etc. Also record whether the stump is the result of tree harvesting or is a result of natural tree death. Record stump data on the "Stump Tally Form".

5.4.3 Generalized Wildlife Assessment

Visually inspect each tree (live and dead) on the large plot for evidence of nests (Pileated Woodpecker nests or feeding, other cavity nests and open nests). On the Generalized Wildlife Assessment Form, indicate the tree number where this evidence was found and any significant comments, such as size, shape or extent or potential species. Complete the Generalized Wildlife Assessment Form for other evidence of wildlife use.

Based on a general assessment of the vegetation found on the 5x5 m vegetation plot (see Ecological Assessment Form below), estimate the extent of browsing on this vegetation by ungulates and hares. Record this information on the Generalized Wildlife Assessment (browse availability and shrub utilization tally) Form. Ungulate browsing would be indicated if the browsed ends of twigs appeared to be torn, whereas hare browsing would be indicated if the ends appeared to be cut.

Indicate the extent of browsing as light (some minor evidence of browsing), moderate (20-50% of leaders browsed) or heavy (greater than 50% of leaders browsed). Also indicate which plant species were browsed and estimate browse availability (cover %). If twigs have been stripped, indicate as such on the browse tally in the comments section. Ensure that only winter browsing is assessed; do not consider current years leaders in the browse tally.

5.44 Dead and Down Woody Material and Pellet Group Count

Dead and downed woody material is measured on two transects as shown in Figure 1. Dead and down material includes both exposed surface material and material covered by moss. The minimum size that is to be measured is 7.0 cm. On each 30 m line, tally diameter at intersect and species of each piece intersected. Use the "Down and Dead Wood Material" form for data records. Mark the beginning and end of each transect with yellow flagging.

If you encounter a large slash pile on the transect, do not attempt to measure each piece. Instead record the average length, width and height of the slash pile and provide a general description of the piece sizes included in the pile; e.g., 80% of pieces greater than 30 cm diameter, 20% less than 10 cm diameter.

Using the dead and down transect, count the number of winter pellet groups by species occurring within 2 m on each side of the transect. Record this information on Generalized Wildlife Assessment Form.

5.4.5 Small Tree Plot

From the centre of the large tree plot, establish plot centres for two small tree plots. The first plot will be located 15 m north of the plot centre and the second plot will be located 15 m west of the plot centre. Each plot will be a circular with a size of 20 m^2 and a radius of 2.52 m. Complete the tally form for the small tree plots. Flag with blue and orange flagging at plot centre.

For each tree and shrub species whose centre point (estimated mid-point of tree diameter) at breast height is on or within the plot boundary, record the number of stems by 2 cm diameter classes at breast height. Class intervals are:

Diameter Class	Diameter Range cm
1	0 - 1.9
2	2.0 - 3.9
5	4.0 - 5.9
7	6.0 - 7.9
9	8.0 - 9.9.

Estimate the average height of all trees and shrubs by species and diameter class to the nearest 0.5 metres.

5.4.6 Ecological Assessment Form

Fully complete the site, soils, vegetation and site classification portions of the ecological assessment form.

A 5x5 metre vegetation assessment plot is to be established in a representative area near the large tree plot (the soil plot should also be in the same general location). Corners of this plot are to be flagged with blue flagging. This plot will be used for an assessment of the understory vegetation. On the ecological assessment form, record each understory plant species found on the plot and indicate the cover classes for each species. In order to achieve consistency in estimating the understory vegetation, crews must be experienced in performing ecological assessments. Note that total crown closure can exceed 100%, since different vegetation layers are being measured. In the case of shrubs, indicate the average height of each species found on the generalized wildlife assessment form. Note that the decaying wood substrate percentage is only done on downed wood 7.6 cm. Pre-Harvest Ecological Assessment Handbook Version 2.0 is to be used as a reference for the specifications for this form.

5.4.7 Photographs

A total of six photographs are to be taken at each plot. One photo is taken facing north, south, east, and west from the plot centre. One picture is taken straight down from 1.3 m and another straight up from plot centre. Plot number and date should be observed in each photo. **A digital camera is to be used for all photographs**.

5.5 Check Cruising

Check cruising is done to ensure that the standards of measurement for temporary plot sampling are being met. These standards are designed to minimize non-sampling errors that occur in all sampling. The standards given here are for the maximum error allowed before the plot must be remeasured. Check cruising should be viewed as a method of assessing the performance of field crews with the intent of identifying the human errors that can occur due to a lack of care or knowledge in field procedures.

Tally sheets should be checked in the office to ensure that all the appropriate columns have been filled (e.g., species, dbh and total height). If the bottom and top slope readings and horizontal distance have been recorded, the total height can be recalculated. Plots that lack certain data or where the data looks “wrong” can be selected for a check cruise.

5.6 Field Inspection

The field inspections will consist of checking all items listed below.

Plot Establishment

1. Major tie point – should be adequately ribboned, marked correctly, and in the right location.

2. Location of Plot Centre – must be correctly marked and within ±2% of the line’s horizontal distance.

Plot Measurement

1. Tree species – all trees checked must be correctly identified by species. Special consideration should be given to confusions with SE, SW and SB or PJ versus PL.

2. Number of trees tallied – all plot trees should be checked to determine if correctly identified as “in” or “out”.

3. Dbh – breast height should be correctly located at 1.3 m ± 6.5 cm from the point of germination. The allowable error for the tree dbh is the greater of ± 0.2 cm or ± 2%.

4. Total height – the allowable error for the estimated and measured heights is ≥ to 90% of the individual stems checked must be ± 5% of the true heights.

5. Crown class – only 10% of all the stems checked may have an incorrect crown class.

6. Total tree age – the allowable error for conifers is ±5%, for deciduous ±10%.

7. Increment width – The allowable error is ±5% for each set of years.

8. Number of stumps – All stumps must be found.

SUMMARY OF ALLOWABLE ERRORS

Item	Allowable Error
Location of Plot Centre Point and Line	±2% of the cruise line horizontal distance (e.g., 3 m of a 150 m cruise line H.D.)
Tree Species	None — except between SE, Sb., Sw and PJ, PL.
Number of trees tallied	±1% of all trees checked (e.g., 3 trees of 300 tallied).
Dbh	Breast height: 1.3 m ±6.5 cm (±5%) diameter — greater of ±0.2 cm or ±2%. (e.g., 31.2 ±0.6 cm).
Total height	Estimated and measured: ≥ 90% of the stems checked must be ±5% of the true heights.
Crown class	10% stems checked may have incorrect crown class (e.g., 10 trees of 100 tallied).
Total tree age	Conifers: ±5% (e.g., SW: 80 ±4 years) Deciduous: ±10% (e.g., AW: 80 ±8 years)
Increment width	±5% for each set of years.

6.0 Completion Schedule

6.1 Plot surveys will begin as soon as possible after the award of the contract and will be completed by no later than October 15, 1997.

6.2 Plot records from stands sampled by each field crew will be submitted for review on request of the contract manager (photocopies acceptable). These will be used for quality audit purposes.

6.3 Computer diskettes containing data as detailed in Section 5 of this Request for Proposal will be submitted no later than October 30, 1997. Original field data collection forms will be submitted along with the electronic data.

7.0 Materials Supplied to the Contractor

The contractor will supply all material and equipment required for the completion of the study with the exception of:

- maps of plot locations which will be supplied by Land and Forest Service,
- field forms for recording plot data.

8.0 Materials Supplied to the Department

The successful completion of the contract will depend upon delivery and departmental approval of the following by the dates specified in Section 6 of this Request for Proposal.

8.1 Completed plot forms for all plots established to the standards specified in Section 5 of this Request for Proposal.

8.2 Computer diskettes containing plot information as specified in Section 5 of this Request for Proposal.

9.0 Liaison

The contractor will maintain close contact with the Contract Manager, and will arrange for the work to be discussed and/or reviewed at critical points in the project. At a minimum, this will include:

9.1 A one or two-day field visit with the Contract Manager near the start of fieldwork to discuss issues. This visit will be arranged at a mutually agreeable date.

9.2 Delivery of completed plot forms from each field crew as discussed in Section 6.2 of this Request for Proposal, for departmental audit.

9.3 Availability to discuss audit results.

10.0 Quality Control

10.1 Contractors should indicate how they intend to monitor data quality, particularly with respect to error-checking electronic databases prepared as specified in Section 5.5 of this Request for Proposal and ensuring the accuracy and legibility of hard-copy plot records.

10.2 All completed work will be subject to inspection by Contract Manager and will be accepted or rejected based on accuracy, clarity, and compliance with specifications stated in Section 5 of this Terms of Reference.

APPENDIX 4. VALIDATION OF FD YIELD CURVE

There were differences in the stratification rules relating to Douglas fir stands. The yield curves were built using only the A+B density montane data, as 49 of 54 plots were from this stratum. The land base was stratified to exclude A+B density stands without an understorey, and included stand types that were not used to fit the curves (C+D density, subalpine Fd if present).

In order to apply the A+B density montane Fd curve to the rest of the land base, some form of validation needed to be performed. As there are only 6 available plots clustered around one age class, most statistical tests would not be conclusive. There was one potential outlier at young ages which would likely cause problems with fitting a non-linear relation if the unused data was pooled with the A+B montane Fd data. Instead, we relied on visual assessment to see if the predictive curve was reasonable. See figure 1 for the comparison.

We concluded that the remaining plots fit well with the predicted volume. The A+B montane curve will be applied to all Fd-leading stands in the C5 FMU.

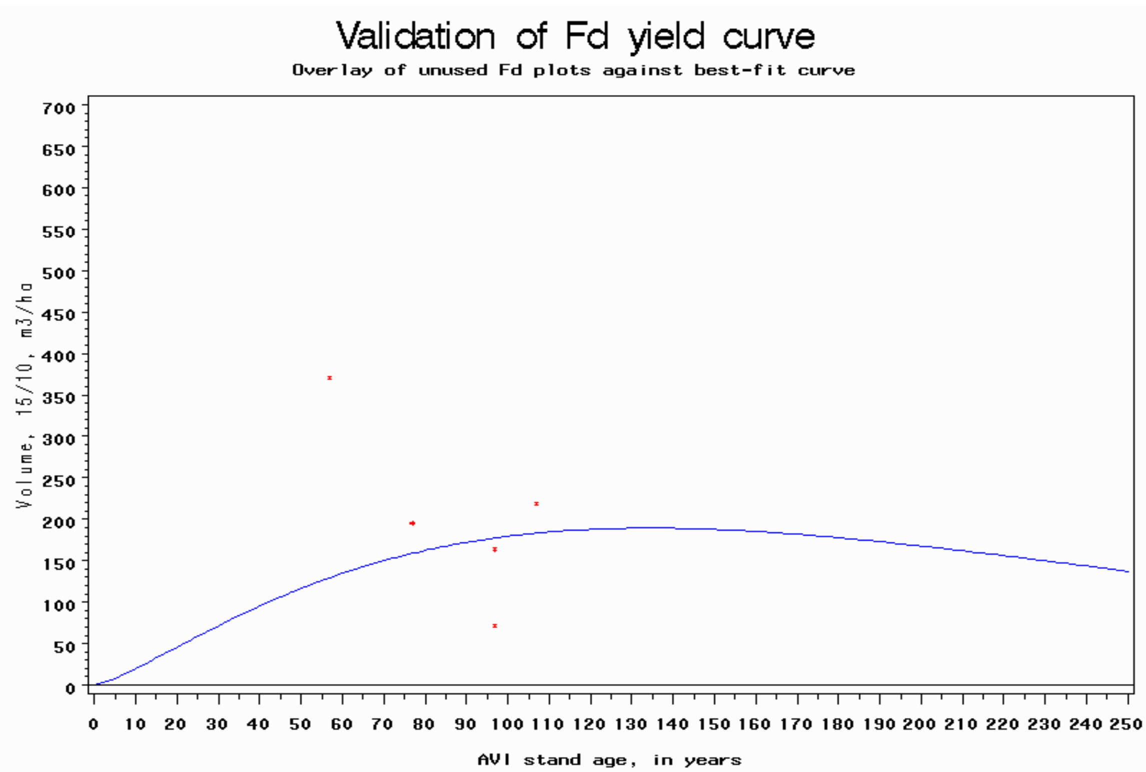


Figure 1. The predictive A+B density Montane Fd yield curve (blue line) against the unused Fd plots (red dots).