Alberta-Pacific
Timber Supply Analysis
Yield Curve Development Document

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EXECUTIVE SUMMARY

Alberta-Pacific Forest Industries INC. (Alberta-Pacific) invited Timberline Forest Inventory Consultants Ltd. (Timberline) to develop growth and yield estimates for the Alberta-Pacific Forest Management Area (FMA) located in northeastern Alberta. This information will be used to facilitate the Timber Supply Analysis (TSA) being completed in support of Alberta-Pacific's 2001 Detailed Forest Management Plan (DFMP). This report summarises the procedures used to produce the yield estimates.

The yield curve development process was based on temporary sample plot (TSP) and permanent sample plot (PSP) data collected across the Alberta-Pacific FMA area. After the plot information was linked to Alberta-Pacific's Alberta Vegetation Inventory (AVI), a data conditioning process was conducted to ensure only plots that could be linked to the timber harvesting landbase would be used for developing yield estimates.

Using AVI attributes, the TSP and PSP databases were stratified into 25 yield classes that separate stands or stand groups with different growth characteristics while 22 sets of yield curves were developed after pooling some strata. The key characteristics utilised to stratify the landbase included species composition, crown closure, timber productivity rating, understory occurrence, and geographical location.

Detailed volume compilations were conducted on the stratified TSP and PSP databases. Plots were compiled using a 15 cm stump / 10 cm top diameter deciduous utilisation standard and a 15 cm stump / 11 cm top diameter conifer utilisation standard. Outliers and influential points identified in the volume-age pairs were removed from the analysis based on both statistical procedures and professional judgement. Cull was not account for during the yield curve development process.

Growth and yield modelling was based on stand ages that were calculated as the differences between the plot measurement date and AVI stand origin. A volume-age regression was conducted for total, softwood and hardwood volume against stand age for the individual yield classes. The yield curves were adjusted at old ages, using both statistical procedures and professional judgement, to realistically reflect stand break-up and volume declines.

Overall the analysis, based on the most current inventories available, produced statistically reliable and biologically feasible yield estimates for the FMA area. The resulting curves provide realistic estimates of yield that can be integrated into the current TSA. However, it was realised from early on that the current growth and yield inventory has its limitations; the volume estimates for different yield classes are only as accurate as the current TSP and PSP databases supporting them. Throughout the process breakdowns between the statistical modelling and reality were resolved through manual adjustments that were base on sound biological principles. As additional growth and yield information is collected within the study area, continual adjustments will be required in the future to realign growth and yield estimates.

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1 Introduction

Alberta-Pacific Forest Industries Inc. (Alberta-Pacific) is in the process of completing a Timber Supply Analysis (TSA) in support of the 2001 Detailed Forest Management Plan (DFMP). Timberline Forest Inventory Consultants Ltd. has been contracted by Alberta-Pacific to develop new empirical yield curves to support the current TSA.

The existing empirical yield curves were developed and approved in 1997, in a TSA completed by Alberta-Pacific in support of their 1999 Detailed Forest Management Plan (DFMP). In the 1999 analysis, Alberta-Pacific's Temporary Sample Plot (TSP) data was used and stratified based on Phase 3 Inventory characteristics. Preliminary analysis of the TSP database utilising 1997 stratification rules with the current Alberta Vegetation Inventory (AVI) shows that not all strata (154 strata) had sufficient data to generate reasonable yield estimates. The preliminary analysis also identified several ways to better align growth and yield estimates to the current AVI for use in the 2001 TSA. The results of the preliminary analysis indicated:

- Data stratification should be implemented using current AVI labels. The 1997 stratification criteria should be modified to generate a stratification where each yield class has significant representation across the Forest Management Agreement (FMA) area.

- Explore the feasibility of developing broad landscape divisions that separate areas with significantly different growth and yield characteristics.

- Propose a strategy to focus the future growth and yield sampling program towards any under sampled strata groups on the FMA area.

Currently, AVI exists for more than 80% of the FMA area. The existing yield information (TSP and PSP data), has been successfully linked the new AVI attributes. The results presented in this report also included TSP and PSP data from FMU S14 that is currently not within the FMA. The goal of this analysis was to provide reasonable yield estimates for the upcoming TSA. This report documents the methods and procedures used in data conditioning and analyses for the development of Alberta-Pacific yield curves.

2 Database

This section describes the structure of the current TSP and PSP databases used to develop yield estimates. The section presents details on the design of the sampling programs and the database conditioning applied to both the PSP and TSP databases. Figure 1 presents the spatial distribution of TSP and PSP plots across the Alberta-Pacific FMA area and FMU S14.

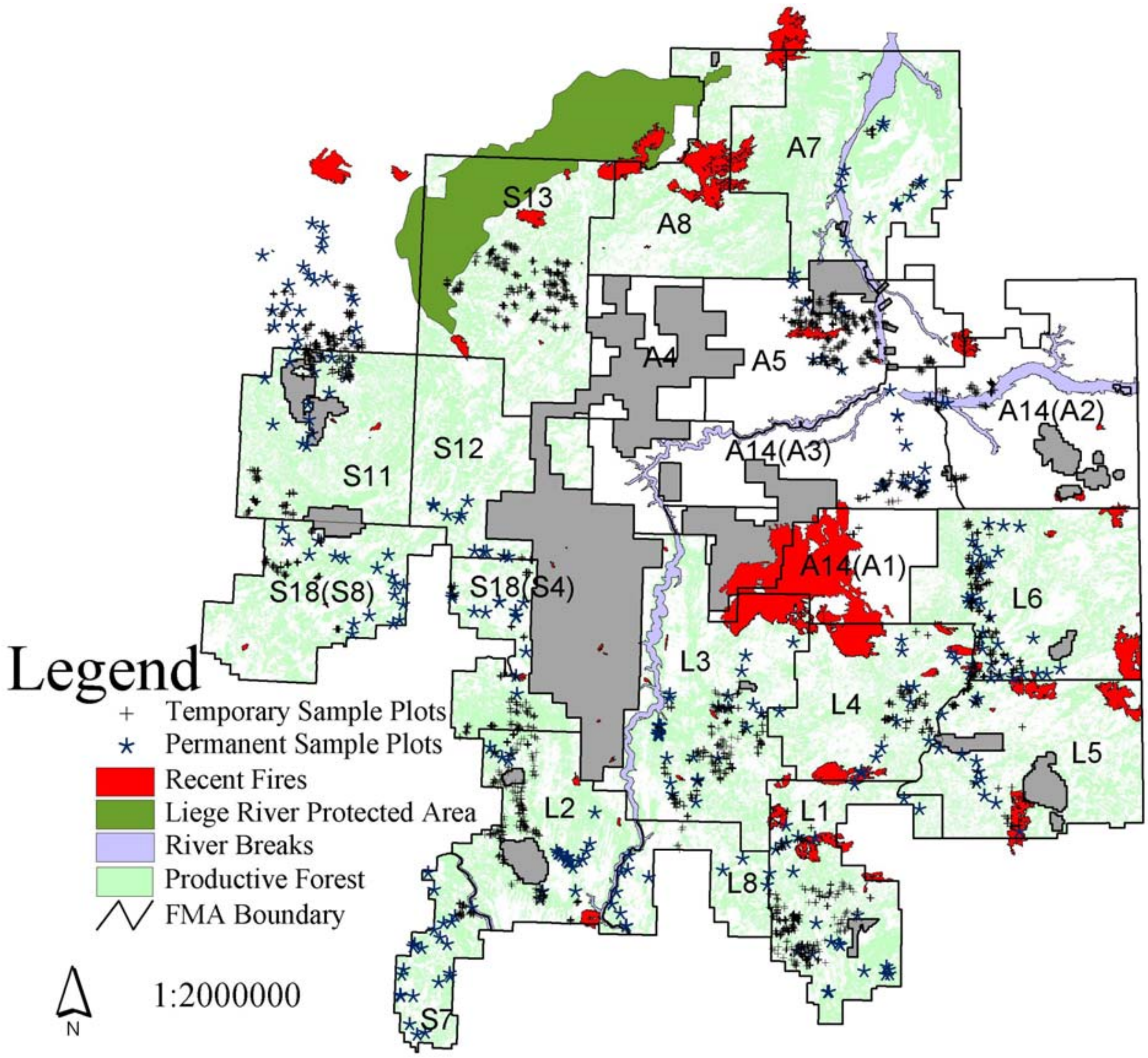

Figure 1. Distribution of sample plot (PSP and TSP) data on Alberta-Pacific FMA area.

2.1 Temporary Sample Plots

The number and distribution of plots for each cover type were determined according to the distribution of area (Phase 3 Inventory) within the major height, density and leading species classes within the timber harvesting landbase. In addition, the minimum number of plots for each stratum was determined with reference to the statistical requirement of ±10% or ±15% standard error. From 1991 to 1998, 2609 plots were sampled in 68 different strata for the D, DC, CD cover groups and 727 plots for the C cover group. The following section provides an overview of the TSP sampling design. A more detailed description of the sampling design and procedures can be found in Alberta-Pacific's TSP procedure manual[1].

2.1.1 Overview of TSP Sampling Design

TSP locations were determined by a cover group matrix and the number of plots in each cover group by its allowable standard error. The cover group matrix represented the most common cover type combinations by geographic area. To reduce the possibility of bias in the TSP data distribution, the following stratification factors were considered during the design and implementation of the TSP programs on the Alberta-Pacific FMA area.

- Cover groups – D, DC, CD, C
- Height classes – 2 (12.1-18.0 m), 3 (18.1-24.0 m), 4 (24.1-30.0 m)
- Density classes – A, B, C, D
- Geographic areas – South and North Portions of FMA area

The area distribution of target TSP strata was analysed by the stratification factors listed above. Based on this analysis, strata that had insufficient area representation across the FMA were combined at the height and/or density class level. Stands with 'A' and 'B' density classes were combined in all four cover groups and three height classes were deemed as suitable at all densities. Density classes 'C' and 'D' were also combined in cover types with small areas, especially stands with very low or very high heights. However, some strata, including height class 3 (18.1-24.0 m) in C/D density classes, showed high area proportions and therefore 3 height subgroups were maintained. Height classes 2 and 4 in the C/D density classes, also had high area proportions and two height subgroups were used. Therefore, height classes in the sampling design consisted of the following groups and subgroups: 2 (12.1-16.0, 16.1-18.0 m), 3 (18.1-20.0, 20.1-22.0, 22.1-24.0 m), and 4 (24.1-27, 27.1-30.0 m). In addition, sub sample groups were also established in cover groups DC, CD, and C based on the leading conifer species in stands. It was believed that this survey design through the above practices would result in an unbiased sampling program.

[1] Timberline Forest Inventory Consultants. 1994. *Alberta-Pacific Forest Industries INC. Inventory Procedures For Temporary Sample Plot Program.* Edmonton, Alberta, Canada. pp88.

2.1.2 Digital AVI transfer from Phase 3

The original blue line maps had the TSP locations and Phase 3 inventory calls manually plotted on them. In the generation of the GIS coverage containing the TSP locations, the following procedure was used to transfer TSP locations to the AVI maps and assign an AVI stand label for each plot.

For each township, an AVI forest cover mylar was overlaid on its respective Phase 3 blue line map and then the plots, tie points and the cruise lines for each TSP were manually transferred to the mylar. The mylar was then digitised in order to obtain a digital coverage of the TSP locations, tie points and the cruise line locations. In addition, the Forest Management Unit (FMU) was incorporated into the GIS database.

After the cruise lines, plots and tie points had been digitised, check plots were printed and compared against the original blue line maps. Final check plots were printed and included in the project file for each township, along with the tally cards, original blue line map and other applicable plot information.

Throughout the entire transfer process, efforts were directed at quantifying uncertainty introduced in the transfer process. The process only yielded a few plots that fell directly on AVI polygon boundaries. Where these borderline plots did occur, professional judgement by an inventory forester was used to determine which polygon the plot fell in. A distance check was also performed to see where plots were falling in relation to polygon boundaries. Table 1 below summarises the results of the distance check. The results show that less than 8% of all plots fall within 5 meters of a polygon boundary. The analysis lends confidence that through the transfer process the majority of plots were located within their representative polygons[2].

Table 1. Summary of TSP plot distribution in relation to AVI polygon boundaries.

	TSPs	
Distance from AVI Boundary	**Number**	**Percentage of Total**
<5 meters	178	7.8%
>= 5 and < 10 meters	207	9.0%
>= 10 and < 20 meters	363	15.9%
>= 20 and < 30 meters	302	13.2%
>= 30 and < 40 meters	219	9.6%
>= 40 meters	1,020	44.6%
Total**	**2,289**	**100.0%**

** The distance check was based on 2,289 of the 3,336 TSPs. The balances of plots were excluded since they were located in areas where the digital AVI has not been finalized (FMUs S14, A14, A4 and A5).

[2] During the LFS review process some anomalies were identified between plot volumes and AVI calls. Although most of these plots were removed as outliers the LFS concerns were addressed in a letter sent to LFS on Janurary 4th, 2001. A copy of the letter sent is contained in Appendix I.

2.2 Permanent Sample Plot Database

There were 243 PSPs established before 1999 on the Alberta-Pacific FMA area and FMU S14 that were available for growth and yield analysis. The following section provides an overview of the PSP sampling design. A more detailed description of the sampling design and procedures can be found in Alberta-Pacific's PSP procedure manual[3].

2.2.1 Overview of PSP Sampling Design

The populations of interest were commercial deciduous and coniferous forest types within the Alberta-Pacific FMA area. No PSPs were planned at this time for non-commercial forest types. All ages, species compositions, and silvicultural regimes were of interest in this program. All site classes producing or capable of producing commercial timber crops were considered important for the PSP program. Plot selection was therefore loosely based on site classification to obtain reasonable plot distributions across any new classifications, which might arise. The following stratification factors were considered during the design and implementation of the PSP program: cover type, age class, origin, and FMU. The target number of plots for each cover group and age class combination and for each FMU was calculated based on proportional allocation of plots according to the productive and harvestable area (1998 land base net down). These stratification criteria were then applied at the FMU level. Matrices were developed for each FMU based on the cover group and age class. These were considered as the general guides, rather than precise rules. Plot distributions by criteria class is expected to change over time as stands continue to develop.

2.3 TSP and PSP Database Conditioning

Both the TSP and PSP databases required conditioning prior to volume compilation and yield curve regression modelling. The following processes were used to condition the databases:

- Plots located within Non-AVI portions of the FMA and plots with missing locations were not used in the analysis,
- TSP header information was linked with TSP tree measurement information,
- Heights were predicted for trees without height measurements[4],
- Diameters outside bark (DOB) at stump height (30 cm) were calculated, and
- Plots in non-harvestable forest types, according to current landbase Netdown procedures were removed. Forest types excluded are summarized in the following categories:
    - Non-Forest Exclusions
    - Non-commercial Stand Density:
        - Non-commercial Coniferous Stand Densities
        - Non-commercial Deciduous Stand Densities
    - Non-commercial Species

[3] Timberline Forest Inventory Consultants. 1999. *Alberta-Pacific Forest Industries INC. Permanent Sample Plot Program: Procedures manual.* Edmonton, Alberta, Canada.
[4] The predictions of height and stump DOB were based on species specific and natural subregion specific models developed for Alberta (Huang 1994).

- Non-commercial Site Index (Height – Age Relationship)
- Non-commercial Timber Productivity Rating (TPR)

Netdown exclusions are described in the following sections. The results of the data conditioning process are summarized in Table 8. After data conditioning and removing outliers and influential points (detailed in Section 4.5), there were 2244 TSPs and 202 PSPs available for yield curve development.

2.3.1 Non-Forest Exclusions

Non-forest exclusions were used to remove area from the gross landbase that is currently inventoried as non-forested. These exclusion types were defined using the following six classes:

- Natural Non-Vegetated
- Anthropogenic Non-Vegetated
- Anthropogenic Vegetated
- Non-Forest Vegetated
- Potentially Productive Cutblocks
- Natural Disturbances

Definitions used in defining these non-forested classes with AVI attributes are presented in Table 2. Plots located in this exclusion category were result of a post establishment disturbance.

Table 2. Non-forest land classes defined using AVI.

Non-Forest Exclusion	Alberta Vegetation Inventory	
	Attribute	**Value**
Naturally Non-Vegetated	NAT_NON	NWI, NWL, NWR, NWF, NMB, NMC, NMR, NMS
Anthropogenic Non-Vegetated	ANTH_NON	CA, CP, CPR, CIP, CIW
Anthropogenic Vegetated	ANTH_VEG	ASC, ASR, AIH, AIE, AIG, AIF, AIM, AII
Non-Forest Vegetated	NFL	BR, HF, HG, SC, SO
Non-Forested Cutblocks	MOD1	CC without a free to grow forest (i.e. AVI indicates no forest is currently established)
Non-Forested Natural Disturbances	MOD1	BU, WF, DI, IK, UK, WE, DT, BT, SN: without a free to grow forest (i.e. AVI indicates no forest is currently established)

2.3.2 Non-commercial Coniferous Stand Densities

The non-commercial coniferous stand density subjective deletions were used to exclude older conifer stands with insufficient stocking. The AVI definition used to define this exclusion is presented in Table 3.

Table 3. Inventory definition for non-commercial conifer stand density subjective deletion.

Leading Species	Stand Density Class		Stand Origin (year)	Stand Height (meters)
	Overstory	**Understory**		
P, Pl, Pj, Sb, Sw, Fb	A	A or NONE	< 1950	<18

2.3.3 Non-commercial Deciduous Stand Densities

The non-commercial deciduous stand densities subjective deletions excluded deciduous stands with 'A' density of insufficient stocking. 'A' density deciduous stands (6 - 30% Crown Closure) were excluded from the timber harvesting landbase based on the assumption that 'A' density stands will perpetuate throughout time. The AVI definition used to define the exclusion is presented in Table 4.

Table 4. Inventory definition for non-commercial deciduous stand density subjective deletion.

Inventory	Leading Species	Stand Density Class	
		Overstory	Understory
AVI	Aw, Bw, Pb	A	A or NONE

2.3.4 Non-commercial Species

This subjective deletion removed all stands dominated by tree species that currently have no timber value. More specifically it removed all stands with larch assigned as the leading or secondary species. The AVI definition for this exclusion is presented in Table 5.

Table 5. Inventory definition for non-commercial species subjective deletion.

Inventory	Leading Species		Second Leading Species
AVI	Sp1 = Lt	or	Sp2 = Lt

2.3.5 Non-commercial Site Index (Height – Age Relationship)

The non-commercial site index subjective deletion excluded slow growing stands that may never reach merchantable height. The approach is based upon a height-age requirement that states a stand must attain a height of 15 meters by 180 years of age. The AVI rules used to define this deletion are presented below (Table 6).

Table 6. AVI Definition for non-commercial site index.

Table Index	Stand Height (m)	Stand Age Threshold (years) by Leading Species			
		Sb	Pj or Pl	Sw or Fd or Fb	A or Aw or Bw or Pb
1	3	>18	>13	>27	>18
2	4	>28	>22	>38	>26
3	5	>37	>28	>49	>34
4	6	>47	>37	>60	>46
5	7	>57	>47	>72	>53
6	8	>68	>57	>84	>67
7	9	>80	>68	>95	>75
8	10	>93	>80	>107	>86
9	11	>117	>95	>120	>101
10	12	>123	>111	>134	>117
11	13	>140	>130	>148	>136
12	14	>165	>160	>165	>160
13	15	>180	>180	>180	>180

2.3.6 Non-commercial Timber Productivity Rating (TPR)

The AVI definition for this exclusion is presented in Table 7.

Table 7. Inventory definition for non-commercial timber productivity rating.

Inventory	Leading Species	TPR
AVI	Any	U

Table 8. TSP and PSP summary table.

Netdown Criteria	TSP		PSP	
	Number	%	Number	%
Gross Number of Plots	3,336	0	243	0
Plots in Non-AVI FMUs or Missing Locations	613	18.38	17	7.00
Landbase Netdown Exclusions				
Non-Commercial Cover Groups	224	6.71	17	7.00
Non-Commercial Timber Productivity Rating	9	0.27	0	0
Non-Commercial Species	17	0.51	0	0
Non-Commercial Site Index	58	1.74	6	2.47
Non-Commercial Stand Density	95	2.85	0	0
Duplicate Plots	1	0.03	1	0.41
Plots Missing Link to Tree Measurements	28	0.84	0	0
Outliers and Influential Points Deletions*	47	1.41	0	0
Total Usable Plots	2,244	67.27	202	83.13

* Detailed descriptions can be found in Section 4.5

3 Stratification

Stratification of the Alberta-Pacific FMA area was approached with the following objectives in mind:

- The stratification must separate strata with different growth and yield characteristics; key characteristics included species composition, crown closure, timber productivity rating, and understory.
- The stratification would ensure all strata would achieve the minimum area representation. As a guideline, an individual stratum would require at least 2% representation across the FMA area, prior to the south-north splitting exercise.
- The stratification would ensure all strata have a minimum sample plot requirement. To produce reasonable yield estimates each stratum must have adequate sampling, usually 30 plots or more that are well distributed across all age classes.
- The stratification must meet operational and policy requirements of the FMA area.

The following sections describe the methodology for applying the stratification to AVI.

3.1 Yield Class Stratification

Developing yield classes for the FMA area required that each inventory polygon be classified in accordance with characteristics necessary to define the yield classes. Yield class assignments involved the determination of two primary stand characteristics:

- Overstory and understory broad cover types
- Leading conifer species

3.1.1 Determining Overstory and Understory Broad Cover Types

The AVI does not carry a cover group characteristic; it was therefore developed as a function of the tree species and their associated crown closure percentage. Deciduous and coniferous crown closure percentage for both overstory and understory layers was tallied for each AVI polygon. The resulting characteristics were used to assign broad cover groups. The cover group assignment rules are presented in Table 9.

Table 9. Summary of rules used to assign broad cover groups to AVI.

Broad Cover Group	Crown Closure (10% Classes)	
	Deciduous	Conifer
C	0 - 20	80 - 100
CD	30 - 50	50 - 70
DC	60 - 70	30 - 40
D	80 - 100	0 - 20

3.1.2 Determine Leading Conifer Species

The stratification process also required the leading conifer species to be identified in order to facilitate yield class assignment. To do this, the first conifer species as assigned in the AVI attribute species list was selected for each polygon.

3.1.3 Assign Yield Classes

With all the necessary inventory characteristics in place, yield classes were assigned according to the rules summarized in Table 10. The assignment was based on stand species composition, leading coniferous species, stand density, timber productivity rating. The occurrence of coniferous understory was considered during the stratification of AVI stands.

The stratification was created independent of the TSP and PSP database. However, there had to be sufficient sample plots in each stratum to develop reasonable yield estimates. In addition, a good distribution of sample plots over stand age classes was also important for a successful yield regression analysis. These resulted in some initial yield classes being dropped or combined with similar strata, which involved:

- Removing the Lt yield class
- Combining the Aw-Pj-O and Aw-Pj-C yield classes due to limited plot data

These changes resulted in 21 yield classes prior to the north-south splitting practice, instead of the original 23 yield classes listed in Table 10.

Table 10. Rules used to define yield classes.

Table Index	Broad Cover Group	Yield Class	Inventory Defining Characteristics (AVI) Cover Group Over	Under	Lead Conifer[5]	Stand Density	Stand Height (m)	TPR
1	Deciduous Types							
1.a	Natural							
1.a.1		1 – Aw-O	D	---	None	B	---	F,M,G
1.a.2		2 – Aw-C-FM	D	---	None	CD	---	F,M
1.a.3		3 – Aw-C-G	D	---	None	CD	---	G
1.a.4		4 – Aw-S-O	D	---	Sw/Sb	B	---	F,M,G
1.a.5		5 – Aw-S-C	D	---	Sw/Sb	CD	---	F,M,G
1.a.6		6 – Aw-Pj-O	D	---	Pj	B	---	F,M,G
1.a.7		7 – Aw-Pj-C	D	---	Pj	CD	---	F,M,G
2	Mixedwood Types – Deciduous Coniferous Types & Coniferous Deciduous Types							
2.a	Natural							
2.a.1		8 – AwS	DC	---	Sw/Sb	BCD	---	F,M,G
2.a.2		9 – PjAw/AwPj	DC/CD	---	Pj	BCD	---	F,M,G
2.a.3		10 – Saw	CD	---	Sw/Sb	BCD	---	F,M,G
3	Coniferous Types							
3.a	Natural							
3.a.1		11 – Lt			Lt	ABCD		F,M,G
3.a.2		12 – Sw-O	C	---	Sw	AB	---	F,M,G
3.a.3		13 – Sw-C-FM	C	---	Sw	CD	---	F,M
3.a.4		14 – Sw-C-G	C	---	Sw	CD	---	G
3.a.5		15 – Sb-O	C	---	Sb	AB	---	F,M,G
3.a.6		16 – Sb-C-FM	C	---	Sb	CD	---	F,M
3.a.7		17 – Sb-C-G	C	---	Sb	CD	---	G
3.a.8		18 – Pj-O	C	---	Pj	AB	---	F,M,G
3.a.9		19 – Pj-C-FM	C	---	Pj	CD	---	F,M
3.a.10		20 – Pj-C-G	C	---	Pj	CD	---	G
4	Deciduous with Understory							
4.a	Natural							
4.a.1		21 – Aw-U-FM	D	C/CD/DC	None/Pj	BCD	---	F,M
4.a.2		22 – Aw-U-G	D	C/CD/DC	None/Pj	BCD	---	G
4.a.3		23 – Aw-S-U	D	C/CD/DC	Sw/Sb	BCD	---	F,M,G
5	Non-Forested Yield Classes							
5.a		200 – CCNF	Cutblock Non Forested			See definitions in:		
5.b		201 – NDNF	Natursl Disturbance Non Forested			Table 2. Non-forest land classes defined		
5.c		300 – NFV	Non-Forested Vegetated			using AVI		
5.d		400 – AV	Anthropogenic-Vegetated					
5.e		500 – ANV	Anthropogenic Non-Vegetated					
5.f		600 – NNV	Naturally Non-Vegetated					

Legend

-O = Open Crown Closure -A&B Density
-C = Closed Crown Closure -C&D Density
-U = Deciduous with Conifer Understory

-F = Fair Site
-M = Medium Site
-G = Good Site

[5] Leading Conifer (as described in section 3.1.2) does not imply conifer dominated stands but is used to identify the leading conifer component within the stand.

3.2 Feasibility of Broad Landscape Divisions

The Alberta-Pacific FMA area covers approximately 5.8 million hectares and spans 17 FMUs. There was an initial concern that FMA area wide yield estimates were not appropriate for some FMUs. An exploratory analysis compared two groups of FMUs – a "northern" set and a "southern" set as designated in Table 6.

Table 11. FMU summary of north/south landscape division.

	South	North
FMUs	L1, L2, L3, L4, L5, L6, L8, S7, S18	S11, S12, S13, S14, A7, A8, A14, A4, A5
There is currently no AVI for shaded FMUs (above) and therefore, the yield information for these areas was not used.		

The exploratory analysis regrouped plots for each stratum, based on the north-south division. Total plot volume from all plots between stand ages of 60 and 120 years were averaged to determine the yield difference between southern and northern divisions for the strata that met the minimum area and number of plot criteria identified in Section 3. Figure 2 shows the results of the comparison between the northern and southern divisions. Of the seven strata that met this criterion, only the Aw-S-C, AwS, SAw and Aw-S-U strata showed a significant difference in yield characteristics. Due to the significant difference in total volumes, these 4 yield classes were split into northern and southern yield divisions. As a result, 25 final yield classes were used in the final yield curve development (Table 12).

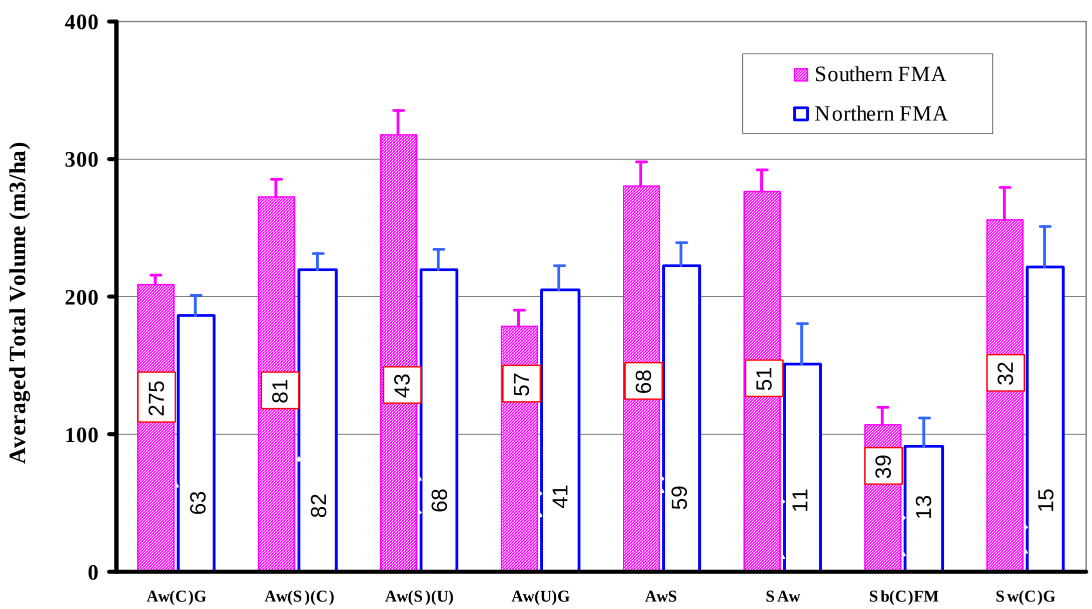

Figure 2. Comparison of average total volume by strata based on a north-south landscape division.

3.3 Final Yield Stratification for Yield Curve Development

The final stratification resulted in 25 yield classes defined using AVI stand labels. The TSP and PSP sample plot distribution indicated a good coverage of plots in most yield classes.

Based on a preliminary review of yield classes 19 and 20 it was obvious the regression modelling would not be able to produce realistic yield estimates. Initial predictions indicated just as much softwood volume in the 'OPEN' strata as was being predicted for the 'CLOSED' strata. Based on a collective decision by Alberta-Pacific and LFS, yield classes 19 (Pj-O) and 20 (Pj-C-FM) were consolidated (Pj-O-C-FM). Some additional combination of yield strata, involving yield class 1-3, was described in the yield modification section. This final stratification resulted in 22 yield classes that were used for yield curve development (Table 12). Therefore, 22 sets of yield curves were developed, in stead of the originally designated 25 yield classes.

Table 12. Final yield classes for Alberta-Pacific FMA area[1].

Yield Class		Area Distribution[3]		TSP and PSP	
No.	**Name**	**Ha**	**%**	**Freq**	**%**
1	Aw-O	63,308	3.2	30	1.23
2	Aw-C-FM	92,495	4.6	96	3.92
3	Aw-C-G	355,219	17.8	594	24.28
1-3	**Aw-composite**	**511,022**	**25.6**	**720**	**29.43**
4	Aw-S-O	37,989	1.9	31	1.27
5	Aw-S-C-S*	82,944	4.1	107	4.37
6	Aw-S-C-N*	39,772	2.0	127	5.19
7	Aw-Pj	46,118	2.3	40	1.64
8[4]	AwS-S	50,051	2.5	87	3.56
9[4]	AwS-N	25,681	1.3	75	3.07
10	MxPj	46,504	2.3	77	3.15
11[4]	Saw-S	61,211	3.1	102	4.17
12[4]	Saw-N	23,511	1.2	28	1.14
13	Sw-O	73,539	3.7	61	2.49
14	Sw-C-FM	46,676	2.3	85	3.48
15	Sw-C-G	58,370	2.9	80	3.27
16	Sb-O	119,862	6.0	40	1.64
17	Sb-C-FM	77,426	3.9	67	2.74
18	Sb-C-G	73,166	3.7	88	3.60
19/20	Pj-O-C-FM	283898	14.2	166	6.79
21	Pj-C-G	81,698	4.1	87	3.56
22	Aw-U-FM	62,302	3.1	84	3.43
23	Aw-U-G	143,081	7.2	155	6.34
24	Aw-S-U-S	18,781	0.9	50	2.04
25	Aw-S-U-N	35,354	1.8	89	3.64
Total	**Total**	**1,998,956**	**100**	**2,446**	**100**

Notes:
1. This reflects AVI for FMUs: L1,L2,L3,L4,L5,L6,A7,A8,S7,S11,S12,S13,S18. AVI has not yet been completed for S14 and is therefore not included in the area distribution summaries.
2. Due to the incompletion of AVI, strata for the northern FMUs showed low area distribution (<2%).
3. This is only an approximation of then net area. The final net area will not be available until netdowns are finalized.
4. Only 0.1% of area was Aw and Sb mixedwood and was combined with Aw and Sw mixedwood.

* S = southern portion of the FMA area, N = northern portion of the FMA area.

The final stratification revealed that a large percentage (> 80%) of the harvestable deciduous was being classified with a 'G' Timber Productivity Rating. The large percentage of 'G' TPRs was additionally highlighted by the fact that the historical Phase 3 Inventory indicated the reverse; where most sites were 'M' rather than 'G'. The following section provides an explanation for the large shift.

3.3.1 Phase 3 and AVI: Shifts Between Productivity Classes

With the inventory transition from Phase 3 to AVI the current TSA procedures have highlighted a shift in the site productivity distributions across the FMA area. As can be seen in Table 12, approximately 80% of the harvestable closed aspen across the FMA area has been assigned 'G' timber productivity rating where the Phase 3 Inventory showed approximately 80% of the same stand group had a 'M' rating. Based on broad knowledge of the FMA area and an understanding of the evolution of the Alberta inventory process, three issues were identified as key contributors to the shift:

1) Changing Site Index Curves
2) Changing Height Class Standards
3) Improved Stand Origin Estimates

The following sections describe how each issue would have contributed to the shift in the distribution of productivity classes across the FMA area.

3.3.1.1 Inventory Site Index Curves

The site index curves used for identifying Phase 3 productivity classes are different than those currently being used in the AVI 2.1 process. For example at reference year 70 a 'G' class occurs at 19 meters for AVI verses 20 meters for Phase 3. Most of the aspen stands across the FMA area are within the 50 to 90 year age range that coincides with significant differences between the site index curves.

3.3.1.2 Inventory Height Standards

Phase 3 used 6-meter height classes as an inventory standard. To determine a productivity class an interpreters would usually use the mid point of the class. Using the mid point of height class 2 with the Phase 3 site index curves would never produce a 'G' class while using the mid point of height class 3 would always produce a 'G' productivity class for stands older than 25 years. The AVI 2.1 standards determine height to the nearest meter. Therefore, if there was a significant amount of area in the high end of Phase 3 height class 2, that area would be classified as 'M' in Phase 3 and would shift to 'G' under AVI 2.1 standards.

3.3.1.3 Inventory Origin Standards

Extensive fieldwork carried out through the AVI process has established that Phase 3 origins are typically one to two decades older than they really are. This will also make a significant contribution to the shift in productivity classes between the inventories.

4 Volume Compilations

Merchantable volumes were calculated for each living and merchantable tree using Alberta-Pacific utilisation standards (Table 8). The volume of each individual tree was calculated according to the procedures presented by Huang (1994). Dead or non-merchantable trees, indicated in TSP or PSP data sets, were assigned a volume of zero.

4.1 Utilization Standards

Prior to the volume calculation, individual tree stump diameter outside bark (DOB) and top diameter inside bark (DIB) were calculated and trees were screened based on the Alberta-Pacific utilization standards (Table 13). Individual trees with a stump DOB smaller than the minimum DOB were assigned volumes of zero.

The minimum stump DOB was predicted for each tree from DBH measurements using species-specific models developed for different species in Alberta (Huang 1994).

Table 13. Utilisation standards for merchantable volume.

Utilization Standards	Top DIB (cm)	Stump ht. (cm)	Min. stump DOB (cm)	Min. Log length (m)
Hardwood	10.0	30.0	15.0	3.66
Softwood	11.0	30.0	15.0	3.66

4.2 Merchantable Length Calculation

Merchantable length was calculated based on the measured or predicted tree height and the utilisation standard according to the established method (Huang, 1994). Minimum log length was also considered in the current analysis.

Each merchantable stem was then divided into ten sections of equal length. Diameters were determined for the top and bottom of each section using Kozak's variable exponent taper equation (eq. 2) (Kozak, 1988) and natural subregion using species specific coefficients for the province of Alberta provided by Huang (1994).

The taper equation is:

$$dib = a_0 DBH^{a_1} * a_2^{DBH} * X^{b_1 Z^2 + b_2 \ln(Z+0.001) + b_3\sqrt{Z} + b_4 e^Z + b_5 (\frac{DBH}{H})} \quad \text{……..eq. 2}$$

where: DIB = upper stem diameter inside bark (cm) at height h (m)
DBH = diameter at breast height (cm)
H = total tree height (m)
X = $\frac{1-\sqrt{h/H}}{1-\sqrt{p}}$
Z = h/H
h = upper stem height (m)
p = relative height of inflection point from the ground
$a_0,a_1,a_2,b_1,b_2,b_3,b_4,b_5$ = coefficients

4.3 Merchantable Volume Calculation

Newton's equation (Equation 3) is an appropriate formula to calculate live tree merchantable volume (Husch et al, 1982). Alberta – Pacific's utilization standards (Table 1) were used to determine volumes from Newton's formula.

$$Vm = ML/10/6(0.00007854)*(d_0^2+4d_1^2+2d_2^2+4d_{2n+1}^2+2d_{2n+2}^2+\ldots+d_{20}^2) \quad \text{………………….eq. 3}$$

Where:
Vm = merchantable volume (m^3)
ML = merchantable height (m)
d_0 = diameter at bottom of merchantable stem (m)
d_1, d_2, …d_{18}, d_{19} = diameters inside bark along the merchantable stem
d_{20} = diameter at top of merchantable stem (cm)

4.4 Stand Volume Calculation

Individual tree volumes were summed to produce plot-level volumes. Softwood and hardwood volumes were aggregated separately to determine total softwood and total hardwood volumes for each plot. These volumes were then converted to a volume per hectare basis, based on plot size or basal area factor where appropriate. Stand ages were calculated as the differences between the plot measurement date (cruise year) and stand origins (AVI attribute). Plots with only dead or non-merchantable trees were assigned a volume of zero.

4.5 Outliers and influential points

Outliers in the volume-age pairs, defined as those observations outside three standard deviations from the mean for each age class in each yield class, were deleted from further analysis. In some age classes, particularly very young and old stands, some plots had volumes, either softwood, hardwood or total volumes (m^3/ha), that were far away from the rest of the population in that age class. These plots were visually analysed and defined as influential points. Their effects on the yield estimates were studied for individual yield classes and plots that showed a significant influence were removed from the yield regression. Influential plots were not only identified through an evaluation of absolute plot volumes but were also examined relative to plot age. For example, a plot with volume of 350 m3/ha may not be considered high at stand age of 100 years but is too high at 30 years. Therefore, the deletion of influential points was applied to yield strata individually and no fixed formula was used. A list of influential points for each yield class can be found in Table 14.

Table 14. Influential points removed prior to the regression analysis.

Yield Class		Problems and solutions
No.	**Name**	
	Deletion by softwood volumes	
1	Aw-O	Sft_vol>350 m^3/ha
2	Aw-C-FM	Sft_vol>350 m^3/ha
5	Aw-S-C-S	Sft_vol>500 m^3/ha
7	Aw-Pj	Sft_vol>350 m^3/ha
10	MxPj	Sft_vol>500 m^3/ha
13	Sw-O	Sft_vol>450 m^3/ha
14	Sw-C-FM	Sft_vol>500 m^3/ha
19/20	Pj-O-C-FM	Sft_vol>350 m^3/ha
	Deletion by deciduous volumes	
2	Aw-C-FM	Hd_vol>600 m^3/ha
3	Aw-C-G	Hd_vol>600 m^3/ha
6	Aw-S-C-N	Hd_vol>400 m^3/ha
7	Aw-Pj	Hd_vol>550 m^3/ha
8	AwS-S	Hd_vol>500 m^3/ha
8	AwS-S	Standage<20 years
9	AwS-N	Hd_vol>450 m^3/ha
13	Sw-O	Hd_vol>450 m^3/ha
14	Sw-C-FM	Hd_vol>600 m^3/ha
16	Sb-O	Hd_vol>350 m^3/ha
18	Sb-C-G	Hd_vol>350 m^3/ha
22	Aw-U-FM	hd_vol>400 m^3/ha or standage>120 years &hd_vol>350 m^3/ha
	Deletion by total volumes	
12	SAw-N	Tot_vol>500 m^3/ha
19/20	Pj-O-C-FM	Tot_vol>500 m^3/ha

The numbers of plots in each yield class that were removed through the above two processes can be found in Table 15.

Table 15. Number of plots removed as outliers or influential points

Yield Class		Deletions		
No.	**Name**	**Outliers**	**Influential points**	**Sub-total**
1	Aw-O	0	1	1
2	Aw-C-FM	1	3	4
3	Aw-C-G	3	1	4
5	Aw-S-C-S*	1	1	2
6	Aw-S-C-N*	0	2	2
7	Aw-Pj	0	2	2
8	AwS-S*	0	2	2
9	AwS-N*	0	1	1
10	MxPj	0	1	1
12	SAw-N*	0	2	2
13	Sw-O	0	6	6
14	Sw-C-FM	0	3	3
16	Sb-O	0	2	2
17	Sb-C-FM	1	0	1
18	Sb-C-G	0	2	2
19/20	Pj-O-C-FM	0	6	6
22	Aw-U-FM	1	4	4*
23	Aw-U-G	2	0	2
Total		9	39	47

*note: Overlapping occurred during deletions

5 Yield Curve Development

5.1 Regression Analysis between Volumes and Stand Age

To select the most suitable mathematical model for volume prediction, an exploratory regression analysis was completed using both the LFS 2-parameter and 3-parameter equations (eq. 4). The exploratory regression was fit to area-weighted average volume observations for both the deciduous and coniferous landbases. The results from the analyses were:

1) Analyses of volume-age relationship in deciduous-leading stands showed no difference in yield projections from these two models.
2) Although the 3-parameter model performed well using averaged data, it failed to converge in most of the coniferous yield strata.
3) In stands with a substantial pine component, including mixed pine-aspen stands, pure open and closed pine stands, a two-parameter model resulted in continuous volume increases through old age where decline would be expected decline. To address the problem, a composite 3-parameter curve was produced using dummy variables that assigned arbitrary scores for all yield stratum cases (detailed below in equation 5).
4) For yield classes without a substantial pine component, a 2-parameter model was fit to the volume-age pairs and the final functions were selected according to the analysis of fitting statistics.

A series of empirical yield curves were constructed based on the TSP and PSP plot data. The plot data was grouped into yield classes before regression analysis. For each yield class, yield curves were fit using a non-linear regression, applied individually to the total, softwood and hardwood volume-age pairs.

- In deciduous leading stands, total and hardwood volumes were modeled with softwood volume determined as the difference between the predicted total volume and hardwood volume.
- Similarly in softwood leading stands, total and softwood volumes were modeled with hardwood volume determined as the difference between the predicted total volume and softwood volume.
- In mixedwood stands, including yield strata AwS-N, AwS-S, SAw-N, and SAw-S, both softwood and hardwood volumes were modeled while total volume was determined as the sum of predicted softwood and hardwood volumes.

The 3-parameter yield curve model is:

$$Volume = a * Age^{b} * e^{-c*Age} \qquad \text{……………eq. 4}$$

where:

Volume = total, softwood or hardwood volume per hectare (m^3/ha)
Age = stand age according to inventory (years)
a, b, c = parameters or coefficients to be estimated (in 2-parameter model: a=c)
e = natural logarithm

The initial values of the estimated parameters were set at 0.01 for coefficient ‘a’ and 2.0 for coefficient ‘b’. Some of the strata required specific starting values. These values were chosen based on past experience with similar data.

The yield curve model chosen for stands with substantial pine component was:

$$Volume = (a_0 + a_1 * dm1 + a_2 * dm2) * Age^{b} * e^{-c*Age}$$

……………eq. 5

where:

Volume = total, softwood or hardwood volume per hectare (m^3/ha)
Age = stand age according to inventory (years)
dm1 and dm2 = dummy variables
a_0, a_1, a_2, b, c = parameters or coefficients to be estimated
e = natural logarithm

The dummy variables were assigned with arbitrary values for each yield class so the yield classes could be distinguished in the regression model. The rules used in assigning dummy variables are listed in Table 16.

Table 16. Dummy variables for pine stands

Yield Class	Dm1	Dm2
MxPj	1	0
Pj-O-C-FM	0	0
PJ-C-G	1	1

5.2 Yield Curve Modifications

Yield curve modifications were done to yield classes 1, 2, 3 and 7. These are the pure deciduous yield strata (Aw-O, Aw-C-FM, and Aw-C-G) and pure deciduous with minor pine component stratum (Aw-Pj).

Compared to the 1997 yield curves, current curves for pure deciduous stands were suggested as too high, especially in yield class 3: Aw-C-G. To ensure the yield estimates are comparable with the current stand conditions, scaling data from recent Alberta-Pacific Forest Industries harvest operations was used to modify the yield curves. The modification was conducted as follows:

- Collecting scaling data, over 480 cutting blocks with over 10,000 hectares in area on deciduous landbase
- Averaging harvested deciduous volumes and stand age, resulted in 215±12 m^3/ha at 90 years of age.
- Modeling deciduous yields by pooling all plots in pure Aw stands together
- Determining the ratio between scaling data and predicted yield at 90 years
- Applying the resulted ratio (0.94076) to reduce deciduous volume projections at every age class
- New total volumes were calculated as the sum of hardwood and softwood volumes. The latter were the modeled softwood yield estimates
- A composite yield class, yield class 1-3, AW-composite was assigned.

Softwood volume projections in yield class 7 (Aw-Pj) was almost 50% of the total volume, however, AVI species composition indicates less than 20% softwood proportion. Therefore, volume projections for incidental conifer volumes needed to be modified. Modifications of yields were done in the following manner:

- Softwood volume in each age class was determined to be 10% of the predicted total volume while the hardwood volume remained as predicted.
- New total volumes were calculated as the sum of hardwood and softwood volume.
- Modifications ensured the incidental conifer volume being less than 20% of total volumes.

5.3 Stand Decline Procedures

Most of the deciduous curves did not show a volume decline at older ages. Even though the yield projections were well supported by the observation prior to 140 years, the pattern could not account for the typical developmental pattern in deciduous stands. Within the eastern boreal region of the province, it is expected that "stand breakup" of deciduous stands likely begins around 100-120 years (LFS letter, Dec. 2000). It was decided that the deciduous curves needed to be modified to produce a realistic yield projection. The modification of the deciduous curves involved setting a maximum volume age at 105 years and implementing a decline to a terminal age of 180 years. The decline rate was determined from the area-weighted deciduous curve and then the rate was applied to all deciduous curves. The decision to modify deciduous curves was made based on:

1) Procedures established in previous Alberta-Pacific TSA (Timberline, 1997)
2) Huang's presentation to 1999 WESBOGY annual meeting
3) Professional judgment

Some of the conifer curves also required modification. To determine the time and rate of conifer volume decline, the softwood volume observations in all coniferous-leading stands were analysed. A 3-parameter model, that usually shows more rapid volume decline at old age than a 2-parameter model, was fit to the volume-age pairs. Based on yield projections, the maximum age was determined as 130 years. The projected rates of volume decline for each age class above 130 years were determined as following:

1) Softwood volume projections at 130 were used as the peak volume.
2) Ratios of decline were calculated as volume projections at 135 years or above over the peak volume.
3) The ratios were applied to each yield stratum to modify softwood volumes.
4) No minimum volumes were determined; this was consistent with the existing yield curve process (Timberline, 1997).

In yield classes that already showed conifer volume declines in old age, no modification was applied. These yield classes (1, 5, 8, 13, 15, 17, 23, 24, and 25) are mostly deciduous-leading stands.

After the above modification, predicted softwood volumes at old age classes in stands with a pine component were still predicting unrealistically high volumes. Compared to the existing pine curves (Timberline, 1997) the volumes in the older age classes were significantly higher. To better predict decline in pine types and to improve congruency with the approved yield curves, it was decided to decline conifer at an earlier age, compared to other conifer types. The age that volume peaks was selected as 110 year and becomes zero at 200 year. The volumes above 110 year will mirror those prior to 110 years. This modification was done in the following yield classes: Aw-Pj, MxPj, Pj-O-C-FM, Pj-C-G.

Table 17 lists the ages for maximum volume and terminal age for the different stand types.

Table 17. Maximum volume and stand break-up ages.

Stand type	Maximum (years)	Stand break-up (years)	Minimum Volume (m^3/ha)
Aw	105	180	0
Pine	110	200	NA
Conifer	130	NA	NA

5.4 Area-Weighted Composite Curves

Area weighted composite curves were produced for both the conifer (C and CD) and deciduous (D and DC) landbases. Yield projections of all yield classes were averaged after weighing the yield projections by the preliminary netdown area of each yield class (Table 12) to produce area-weighted composite curves. These were done for both softwood and hardwood volumes in the deciduous and coniferous leading groups, respectively.

Area weighted composite curves were produced in the following manner.

1) Firstly, for each yield class, the hardwood and softwood volume in each 5-year age class was multiplied by the respective area.
2) After the volumes were multiplied by area, they were divided by the total area within the given group (i.e., conifer or deciduous stands).
3) Lastly, the new coniferous or deciduous volumes within individual age classes were separately summed for all the yield classes within the given group.

This process produced the area weighted predicted volumes for each age class which were combined to produce the area weighted composite yield curves for conifer and deciduous landbases.

The observed volumes for each age class were also area-weighted in a similar manner. The only difference being, the volume observations were averaged into 10-year intervals to increase the number of plots in each age class. The area weighted observed volumes were then plotted with the predicted volume to complete the area weighted composite curves. Because most yield classes have a low number of plots at age classes greater than 100 years and very few plots after 140 years, area-weighted observations and projections showed differences in older stand ages (**Appendix III**).

5.5 Yield Curves and Yield Tables

After modifications, yield curves were produced for each yield stratum as defined by AVI stand attributes including species composition, density, site productivity and location. Coniferous and deciduous curves were generated separately in each yield stratum while total volumes were also produced for a comparison reason. Yield estimates were projected on a five-year interval.

The results of yield projections and yield curves are presented in Appendix II, including the nonlinear model and its coefficients. Plots that were removed as outliers or influential points prior to the regression were also graphed. They were specially labeled with large, black symbols: deciduous volume (❍) and coniferous volume (●).

Graphs and tables in Appendix III contain the area-weighted yield curves. Predictions are also made from a 2-parameter and 3-parameter model using the area-weighted observations. These are also plotted with the area-weighted yield curves.

Based on the suggestion by LFS, yield curves were plotted with averaged volumes in individual age classes (10-year intervals) to show how well the yield regression fit the observation volume-age pairs. These curves are presented in Appendix IV.

6 Future Action Items

6.1 Future Direction

Alberta-Pacific is committed to the long-term enhancement of their growth and yield information database in order to facilitate a better understanding of natural succession patterns occurring within the FMA area's boreal forest region. As boreal mixedwood succession becomes better understood through Alberta-Pacific's cooperative research programs, growth and yield developments can parallel this increased knowledge of stand dynamics. This in-turn will parallel Alberta-Pacific's move towards management of the FMA in the Model II system.

The 2001 FMP will provide a summary of boreal forest succession, ecosystems and how by understanding boreal natural dynamics, we can manage the forest to meet sustainable fibre demands and non-fibre attributes.

The empirical yield curve development is part of Alberta-Pacific's short-term goal that will provide a platform for the 2001 TSA. Long-term growth and yield goals remain focused on migrating towards individual stand-level growth modelling for mixedwood strata in the Model II environment. This is consistent with Alberta-Pacific's mixedwood management program goals, and the Quota Holder's intensive conifer programs. Current modelling tools such as MGM[6] in combination with detailed stand information generated from inventory labels using the TLG[7], can be used to predict how stands will develop over time.

Currently, Alberta-Pacific and Vanderwell are producing a "case-study" in FMU L1J to compare the mixedwood landscape and the MGM modelling approach to the current empirical methodology. This analysis is the first step in the transition to FMA area wide stand-level growth and yield modelling. This analysis is ongoing.

[6] MGM is an acronym for "Mixedwood Growth Model", an individual tree level growth model developed by Morton and Titus (1984).

[7] TLG is an acronym for "Tree List Generator", a model to convert inventory cover-type labels into detailed stand listings, developed by Timberline Forest Inventory Consultants.

6.2 Augment Current TSP Database

Alberta-Pacific recognises weaknesses in their TSP database and is committed to a continuous update program that will further enhance growth and yield information. A future TSP program is one objective of the 2001 FMP. The new program has three priority items:

1. To focus new TSP's on strata containing insufficient data (Pj & Sb in particular) to support pragmatic, accurate yield curve development.
2. To augment TSP samples on the remaining strata where limited sample sizes prevent 'north' and 'south' yield curve comparisons.
3. Continued calibration of MGM and the "Tree List Generator (TLG)."

6.3 Permanent Sample Plot Program

The objective of the PSP program on the FMA is to *monitor and measure* the growth and succession of representative forest types over time. As the PSPs are re-measured, the changes observed with respect to plant species, tree growth, stand development, stand structure and tree mortality contribute to the understanding of the dynamics of the forest. The re-measurement data provides needed information for predicting the growth and succession of forest types through time. The PSP program also contributes to forest management monitoring to assure annual allowable cut (AAC) levels are sustainable.

By 2001, Alberta-Pacific will have established 359 PSPs over the past six years and will continue to re-measure the LFS's 41 PSPs on the FMA area, 16 of which are in deciduous types.

The biological response of the mixedwood forest to an alternative silvicultural treatment (mixedwood management) in targeted stands is an area poorly documented throughout the Western Canadian boreal forest. Thus, similar to the TSP program, the PSP program will assist in the calibration of MGM and provide data for the TLG. Alberta-Pacific, in cooperation with the major Quota Holders, will build upon the 400 PSP database by inputting new PSPs in target stratum. Exact numbers of new PSPs per target area will be delineated in the 2001 FMP. The target areas are as follows:

- regenerating stands (conifer, deciduous, mixedwood) – to meet the 2001 Regeneration Standards and contribute towards "Model II" adjustments;
- operational research trials that address mixedwood challenges;
- enhanced conifer regeneration (in cooperation with the Quota Holders);
- alternative mixedwood silviculture systems (i.e. shelterwoods); and
- recently burned areas.

7 Conclusions and Recommendations

The results of yield curve analyses are presented in Appendix II through IV. For all 22 yield classes, the predicted total, softwood and hardwood volumes are plotted with the observed data.

Despite the success in the yield curve development process, several strata had around 30 plots or less. Although 30 plots are generally considered the minimum number of plots necessary for reasonable yield curve construction, the distribution of plots over age is also important. Alberta-Pacific, through its commitment to mixedwood growth modelling and ecosystem management, is committed to improved growth and yield modelling approaches and to collecting the required supporting data.

Overall the analysis, based on the most current inventories available, produced statistically reliable and biologically feasible yield estimates for the FMA area. The resulting curves provide realistic estimates of yield that can be integrated into the current TSA. However, it was realised from early on that the current growth and yield inventory has its limitations; the volume estimates for different yield classes are only as accurate as the current TSP and PSP databases supporting them. Throughout the process breakdowns between the statistical modelling and reality were resolved through manual adjustments that were base on sound biological principles. As additional growth and yield information is collected within the study area, continual adjustments will be required to realign growth and yield estimates.

8 Literature cited

Gál, J. and I.E. Bella. 1994. New stem taper functions for 12 Saskatchewan timber species. Natural Resources Canada. Canadian Forest Service. Northwest Region. Northern Forestry Centre. Edmonton, Alberta. Information Report NOR-X-338. 25 pp.

Huang S. 1994. Ecologically based individual tree volume estimation for major Alberta tree species. Report #1. Methods of formulation and statistical functions. Alberta Environmental Protection. Land and Forest Services. Forest Management Division. Publication Number T/288. 80 pp.

Husch, B., C.I. Miller and T.W. Beers. 1982. Forest mensuration. John Wiley & Sons, New York. 402 pp.

Kozak, A. 1988. A variable-exponent taper equation. Canadian Journal of Forest Research. 18:1363-1368.

Morton R.T. and S.J. Titus. 1984. The development of a mixedwood stand growth model. Final report to Forest Research Branch, AFS.

Timberline Forest Inventory Consultants. 1997. Alberta-Pacific Forest Industries Inc. Round 8 Timber Supply Analysis: Yield Curve Development. Prepared for Alberta-Pacific Forest Industries Inc. P. O. Box 8000 Boyle, Alberta. pp. 20.

Timberline Forest Inventory Consultants. 1992. Alberta-Pacific Forest Industries Inc. Inventory procedures for temporary sample plot program. Prepared for Alberta-Pacific Forest Industries Inc. P. O. Box 8000 Boyle, Alberta.

Appendix I. Borderline Plot Investigation

Letter sent to LFS on January 4th, 2001 to address anomalies between AVI and TSP linkages established for yield curve development.

Alberta-Pacific Yield Curve Analysis 4/1/01

Borderline Plots issue:

LFS concern #2 (letter from D.Morgan 4/12/00) indicated that spatial errors in plot placement could have resulted from Phase III to AVI transfer of plot location information. This concern arose because of suspposably high hardwood volumes in SB-dominated strata (i.e. 80% or better).

The Timberline method of plot location transfer –Phase III blueline maps with plots located on them were overlaid with mylars of AVI. The points were transferred directly and the decision was made not to move plots from one polygon to another if the plots fell on a border between two AVI plots. An inventory person then analyzed the plot through the photos to determine the proper call.

There were a total of 8 TSP plots where deciduous volumes were suspiciously high and where the stratum was Sb- dominated. Through statistical analysis four of these plots were entirely removed from the analysis. The other 4 were checked by Timberline inventory staff. Results are as follows:

1. Tp 92 Rg 24 w4th, poly 836, plot 44. AVI call=w45-18Sb7Sw2Pb1 87(G) 1200 – deciduous does occur in this stand, therefore the occurrence of deciduous volume is possible.

2. Tp 92 Rg 22 w4th, poly 237, plot 3D. AVI call= w65-14 Sb8Aw2 92G (2100) – again, as deciduous occurs, the occurrence of deciduous volume is possible.

3. Tp 78 rg 7 w4th, poly 741, plot 25. AVI call=Sb9Sw1 1940G (600). There is no deciduous in this label, but poly 742 which contacts poly 741 along about 2/3 of its boundary is Aw10 1940G (1700).

It is possible that a small inclusion of deciduous was not mapped out, or that this plot was incorrectly transferred by field crews from strip information or photos to the blueline map, or subsequently incorrectly transferred during the blueline-to-mylar process. Thus, a “human-error”.

4. Tp 92 R20 w4th, poly 9909, plot 32. AVI class is wC14Sb 9Sw1 1920G. Same possible explanation as provided under (3) above.

Appendix II. Yield Curves

Note: Plots that were removed as outliers or influential points prior to the regression were specially labelled black and with symbols of: deciduous volume (❍) and coniferous volume (●).

Appendix III. Area-Weighted Yield Curves

Appendix IV. Yield Curves with Average Observed Volume in Age-Classes