TFL 23 VEGETATION RESOURCES INVENTORY ATTRIBUTE ADJUSTMENT

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Prepared for

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1.0 INTRODUCTION

This document describes the methods used to adjust stand ages, heights, site index, and volumes in the TFL 23 inventory data base, using the results of the 1999 and 2000 field seasons' vegetation resources inventory (VRI). The attribute adjustment procedures used are those described in Volume 8, Chapter 6 of the Ministry of Forests Inventory Manual, October 2001.

As the project progressed interim results were produced and discussed with the Ministry of Sustainable Resource Management staff. This dialogue resulted in changes to the original adjustment process. These changes are described in section 5.0 of the report.

Sections 1.0 to 4.0, and most of section 5.0 were included in the December 2001 TFL VRI Attribute Adjustment report. Section 5.1 was added in March 2002. In May 2002, sections 5.0 and 5.1 were updated and section 5.2 was added. The final attribute adjustment includes adjustments to site index and volume.

2.0 BACKGROUND

During 1999 and 2000, 289 VRI plot clusters were established in productive stands within TFL 23. The 1999 sample included stands between 10 and 80 years old, based on the inventory age. The 2000 sample included stands greater than 80 years old, as well as the second growth samples not completed from the previous year. The compiled plot results from 1999 and 2000 were used to adjust age, height, site index, and volume attributes in the TFL 23 inventory, as described in this report.

Attribute adjustment is the process of analyzing the relationship between existing estimates and ground sampling data; and then adjusting the estimated data. The adjusted attributes form the interim VRI attribute database.

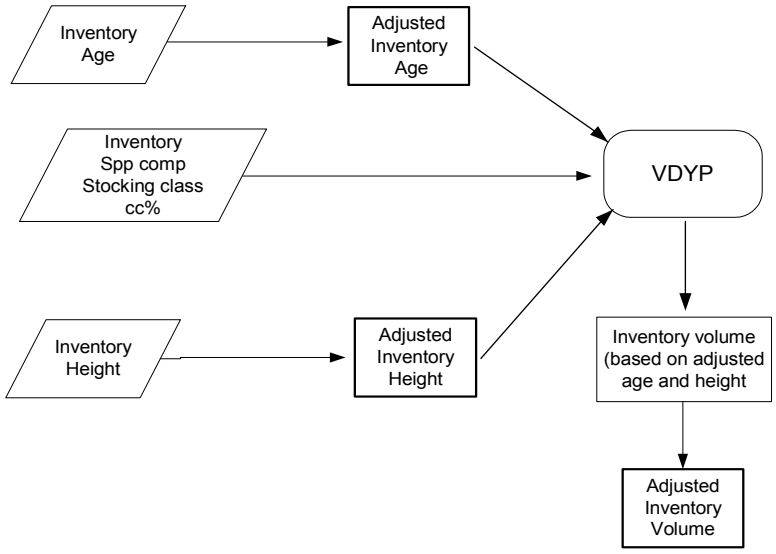
Attribute adjustment has two objectives:

1. to obtain overall averages and totals for an inventory unit that are statistically unbiased;
2. to adjust the existing or new photo-interpreted estimates to obtain individual polygon values.

Height, age, and volume attributes are continuous variables. Site index calculated from height and age is also a continuous variable. Attribute adjustment of these continuous variables for this project is done by ratio technique.

The Fraser Protocol is an interim adjustment process developed by the Ministry of Sustainable Resource Management. Figure 1 outlines this process.

Figure 1: Data and Process Flowchart for the Fraser Protocol



3.0 PROCEDURE

3.1 DATA ASSEMBLY

The inventory data used to determine attribute adjustments were from the original FIP files used in 1999 to determine the VRI sample population. These files were projected to 1999 for age and height comparisons. The original sample population was not pre-stratified, and therefore pre-stratification weights are not required for this data analysis.

The first step was to determine the VRI leading species age and height data to be used to calculate adjustment factors. Leading species is determined by basal area per hectare at the >4.0cm DBH level. The matching of age and height data for each sample is categorized by the following cases as described by the Fraser Protocol:

- Case 1: The Phase II (VRI ground sample) leading species is the same as the Phase I (inventory photo estimated attribute) leading species at the species code level.
- Case 3: The Phase II leading species is the same as the Phase I leading species at the Sp0 code level (genus level, as detailed in Volume 8, Chapter 6 of the Inventory Manual).
- Case 5: The Phase II leading species is matched with Phase I leading species regardless of species, provided that both are hardwood or both are conifer.

- Case 7: None of the above cases apply, and the VRI sample is dropped from the age/height adjustment analysis. These samples, which include the polygons where the Phase II leading species is hardwood and the Phase I leading species is conifer, or vice versa, are considered incompatible for age and height analysis, but are considered useful for volume and basal area attribute analysis.

The Fraser Protocol also documents criteria for Cases 2, 4, and 6, which do not apply to TFL 23 where FIP data are used. The case is identified for each data match used in the adjustment process, as shown in Appendix 1. For TFL 23, 31% of the samples are case 1; 18% are case 3; 48% are case 5; and 3% are case 7. In addition to the 10 VRI samples which are case 7 which are not used for attribute adjustment, a further 24 samples, as documented in Appendix 2, were not used for the following reasons:

- 2 samples are obvious outliers, where data appear to have been taken from veteran trees in young stands. These are evident on scatter plots showing the relationship between the ground attributes and inventory attributes and are further documented in Appendix 2;
- 20 samples did not have age or height data for the matching species;
- 1 sample was the only deciduous match for the entire Phase II VRI.

For each of the 256 matched samples, the VRI height and age were paired with the existing inventory height and age. For the VRI sample, height was the average height of the T, L and S trees, for the leading species. VRI age was the average age of all T, L and S trees for the leading species. For ten samples, either age or height was missing for the matching species, and in these cases only the available attribute is included in the analysis.

Appendix 1 is a set of tables, by stratum, which identify the VRI and inventory attributes for each matched sample, and the age, height, and volume ratio calculations.

3.2 POST- STRATIFICATION

Post-stratification of the samples was done in an effort to provide more precise adjustment for specific forest types. The strata were determined based on the following criteria:

- biogeoclimatic classification as used in the sample design;
- biological similarity;
- similar relationships in the ratios between VRI and inventory values;
- number of samples available.

Comparison of ratios, plotting of age and height ratios against age, paired t-tests, and the above criteria resulted in the selection of seven strata as shown in Table 1. The seven strata account for 92.5% of the TFL 23 productive landbase.

Table 1: TFL 23 Analysis Strata and Sample Distribution

Stratum	BEC Zone	Subzone/ Variant	Leading Species	Age Range (years)	Number of Samples
1	ESSF	wc1 wc4	B,Cw,H,S	10-39	19
2	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S	10-39	47
3	ESSF	wc1 wc4	B,Cw,H,S	40-140	14
4	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S	40-140	22
5	ESSF	wc1 wc4	Fd, P, L	10-140	90
	ICH	dw mw2 mw3 vk1 wk1			
6	ESSF	wc1 wc4	all conifers	> 140	39
7	ICH	dw mw2 mw3 vk1 wk1	all conifers	> 140	25

3.3 AGE AND HEIGHT ADJUSTMENT RATIO CALCULATIONS

Age and height adjustment factors were calculated for each stratum based on the relationship of the ground attribute to the inventory attribute, using the ratio-of-means approach as described in the Fraser Protocol.

The ratios are calculated for height and age as follows:

$$\text{Ratio} = \frac{\text{weighted mean ground sample attribute}}{\text{weighted mean inventory attribute}}$$

Because pre-stratification was not carried out for this population, the mean attributes all have equal weight. Table 2 identifies the age and height ratios obtained for each stratum.

Table 2: TFL 23 Age and Height Adjustment Ratios

Stratum	BEC Zone	Subzone/ Variant	Leading Species/ Age	Mean Ground Age	Mean Inventory Age	Mean Ground Height	Mean Inventory Height	Age Ratio	Height Ratio
1	ESSF	wc1 wc4	B,Cw,H,S/ 10-39 years	50.44	26.32	9.97	4.22	1.917	2.364
2	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 10-39 years	42.54	26.96	11.73	7.03	1.578	1.669
3	ESSF	wc1 wc4	B,Cw,H,S/ 40-140 years	83.47	66.15	16.06	16.05	1.262	1.000
4	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 40-140 years	79.07	80.64	20.92	20.95	0.981	0.999
5	ESSF	wc1 wc4	Fd, P, L/ 10-140 years	83.31	71.00	21.13	20.64	1.173	1.024
	ICH	dw mw2 mw3 vk1 wk1							
6	ESSF	wc1 wc4	all conifers >140 years	155.99	229.67	22.06	26.32	0.679	0.838
7	ICH	dw mw2 mw3 vk1 wk1	all conifers >140 years	187.82	216.44	32.07	30.76	0.868	1.043

The VRI sample indicates that inventory ages are significantly underestimated in the 10 to 39 year age range for both the ESSF and ICH strata. Inventory ages are also underestimated when compared to ground ages for the older second growth balsam, hemlock stands in the ESSF and the second growth Douglas-fir, pine, larch stands in both the ESSF and ICH. The VRI indicates that inventory ages are overestimated for all sampled stands in the ESSF and ICH greater than 140 years old.

VRI results indicate that inventory heights are significantly underestimated in the 10 to 39 year age range for both the ESSF and ICH strata. Inventory heights in the 40 to 140 year strata for ICH and ESSF balsam, hemlock, cedar and spruce are consistent with the ground samples. Inventory heights appear to be overestimated for old growth in the ESSF and underestimated for old growth in the ICH.

3.4 VOLUME RATIO CALCULATIONS

The volume adjustment was done with a two-step process.

1. The adjusted ages and heights for the samples in each of the seven strata were used along with the original inventory species composition, crown closure, and stocking class to compute the attribute adjusted inventory volumes using VDYP (VDYP Batch ver. 6.6d). Inventory volumes are net decay, waste and breakage.

2. The volume adjustment ratio for each stratum was then calculated by:

$$\text{Ratio} = \frac{\text{mean ground vol / ha}}{\text{mean "attribute adjusted" inventory vol / ha}}$$

The ground volumes were the VRI compiled volumes defined as volume/hectare live top, stump, cruiser decay, waste and breakage (Vha_Nwb) that were updated by the Ministry of Sustainable Resource Management in October 2001. Utilization levels are 12.5 for pine leading stands, and 17.5 for all other conifer species for both ground and attribute adjusted volumes.

For TFL 23, the mean attributes all have a weight of 1 since pre-stratification was not done for the VRI sample. Table 3 shows the volume ratios for the seven TFL 23 strata. These ratios were used in step two to adjust the attribute adjusted inventory volumes derived in the first step of the volume adjustment.

Table 3: TFL 23 Initial Volume Adjustment Ratios

Stratum	BEC Zone	Subzone/ Variant	Leading Species/Age	Mean Adjusted VDYP Volume/ha	Mean Ground Volume/ha	Volume Ratio
1	ESSF	wc1 wc4	B,Cw,H,S/ 10-39 years	33.7	34.6	1.028
2	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 10-39 years	49.5	47.9	0.967
3	ESSF	wc1 wc4	B,Cw,H,S/ 40-140 years	119.8	152.0	1.269
4	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 40-140 years	184.6	237.6	1.287
5	ESSF	wc1 wc4	Fd, P, L/ 10-140 years	179.3	196.2	1.094
	ICH	dw mw2 mw3 vk1 wk1				
6	ESSF	wc1 wc4	all conifers >140 years	180.6	228.7	1.266
7	ICH	dw mw2 mw3 vk1 wk1	all conifers >140 years	377.5	498.4	1.320

These VRI results indicate that the attribute adjusted inventory volumes are underestimated for six of the seven strata, with the exception being the ICH hemlock, balsam, cedar, spruce stands aged 10 to 39 years.

3.5 ADJUSTMENT EVALUATION

Residual analysis was used to evaluate potential bias in the attribute adjustments. Scatter plots were produced for each of the strata age, height and volume adjustments as shown in the example in Figure 2. Residual plots for all strata are included in Appendix 3.

The Y axis shows the residual, which is the difference between the ground value and the adjusted inventory value. The X axis shows the adjusted attribute (age, height, or attribute adjusted inventory volume, multiplied by the adjustment ratio).

Figure 2: Age Residuals versus Adjusted Ages, Stratum 5

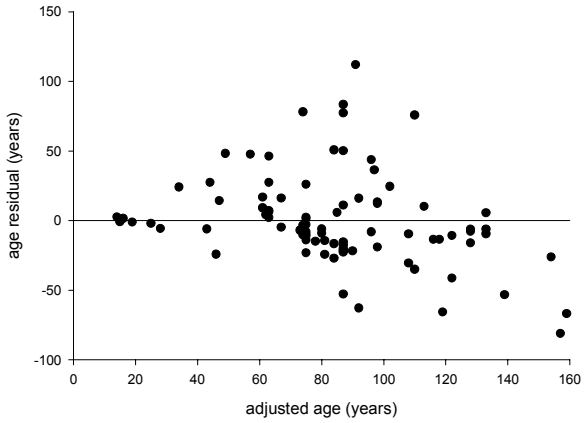
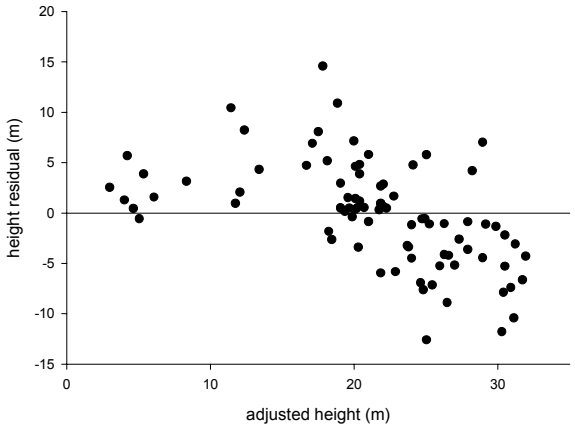


Figure 3 shows the corresponding scatter plot for height.

Figure 3: Height Residuals versus Adjusted Heights, Stratum 5



The downward trend in the height residual plot indicates some bias in the adjustment, namely overestimating the height in taller stands and underestimating the height in the shorter stands for this stratum. The age residual plot also indicates a slight downward trend which suggests there is a trend for adjusted ages to be overestimated for the older stands, and underestimated for the younger stands. One result of this trend is to produce different ratios between VRI and inventory values at different ends of the stratum.

The residual plots showing bias in the adjustment indicate that the ratio of means adjustment methodology is not entirely suitable for all TFL 23 adjustments. A second approach using a moving ratio was tested for height adjustment in stratum 5. The results are shown in Appendix 4. This approach was presented to Ministry of Sustainable Resource Management staff Keith Tudor and Dr. Sam Otukol, who raised the following concerns:

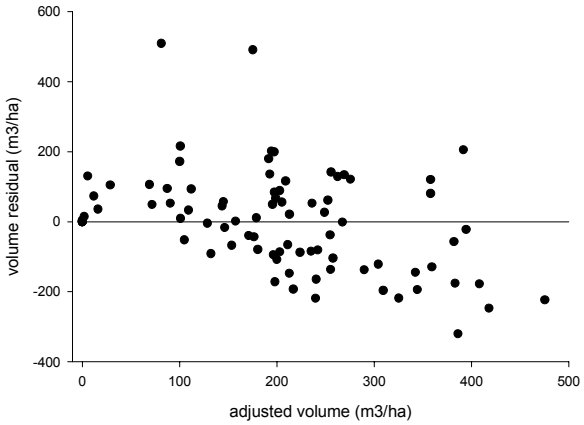
- the method might truncate/ limit height, and therefore site index;

- the method has not been tested or thoroughly peer reviewed and they are unable to endorse it at this time.

Following further analysis, it was determined that although the height residuals from the moving ratio method show no bias, adjusted heights level off to a common maximum value. Therefore, this moving ratio method has significant consequences with respect to site productivity. Further analysis using a curvilinear function to describe the moving ratio might solve the truncation problem, but is outside the scope of this project. Because a suitable alternative adjustment methodology has not been found to overcome the bias resulting from the ratio of means approach, TFL 23 attributes were adjusted using the ratio of means Fraser Protocol methodology.

Figure 4 shows the volume residual plot that corresponds to the age and height residual plots above. This plot has a similar downward trend that indicates that there is a tendency for the adjusted volumes to be overestimated for the higher volume stands, and underestimated for the lower volume stands.

Figure 4: Volume Residuals versus Adjusted Volumes, Stratum 5



Another check on the reliability of the adjustment is a comparison of the adjusted site index with the VRI site index for the VRI sampled stands. A match between the mean site index values would be one indication of an effective, reliable attribute adjustment. The following table shows the mean site index values by stratum.

Table 4: TFL 23 Mean Site Index Comparison

Stratum	Mean adjusted site index, VRI sampled stands	Area weighted mean adjusted site index, entire inventory	Mean VRI site index, sampled stands
1	13.2	13.9	17.1
2	16.6	16.4	18.7
3	12.3	13.5	13.8
4	17.9	17.1	18.4
5	17.8	17.3	18.7
6	10.6	12.2	12.0
7	16.3	16.3	18.3

These figures show that average adjusted site index is between 3% and 23% lower than the average VRI site index for the sampled stands in all strata. For stratum 6, the sampled stands have a lower mean adjusted site index than the ground measured mean, however when the adjustment is applied to the entire inventory, the area weighted mean adjusted site index is slightly higher than the ground sample mean. For all other strata, the adjusted inventory site index mean is lower than the sampled mean.

These figures suggest that the adjustment methodology does not result in reliable adjusted site index estimation for TFL 23, and that site index is underestimated in the inventory for all strata except stratum 6. Several factors can contribute to the underestimation. Two of these factors are the existing inventory attributes, and the attribute adjustment methodology. There is evidence of inconsistent height and age classification in the TFL 23 inventory. In addition, some large adjustment ratios occurred that may distort the height/age relationship.

A partial reinventory of TFL 23 was completed in 1990. The 1990 project included restratification and classification of age class 2 to age class 6 stands, based on new aerial photography and field sampling, and mapping of new disturbance boundaries. Attributes for age class 1 stands, and mature stands, age classes 7 to 9, were updated based on the shortform labels that had originated from the previous 1974 inventory and had been updated to 1988. For example, the 1974 map label of BS(C) 731-M was converted to a continuous variable format of $B_{60}S_{30}C_{10}$ 130 years, 24.0 m height. Midpoints were used to assign ages and heights to these mature and age class 1 stands. The reinventory procedures are documented in the September 1990, Industrial Forestry Service Ltd. TFL 23 Reinventory Report.

The existing inventory database has been projected and updated from the 1990 reinventory. The age and height ratios shown in Table 2 are an indication of the discrepancy between inventory ages and heights, and the VRI ground sample ages and heights. The ratios are particularly high in the young stands, aged 10 to 39 years, and in the stands older than 140 years. Part of the observed inventory error in these age groups is probably due to the use of midpoints in the 1990 reinventory. The application of these significant ratios to adjust ages and heights can cause pronounced adjustments to the relationships between the ages and heights for individual stands, and thus result in significant changes to the individual site index estimates. The overall effect is a lower site index than that predicted by the VRI data.

The age and height adjustment bias, as shown in some of the residual plots in Appendix 3 may be another factor in the underestimation of adjusted site index. The residual plots that indicate some bias in the age and height adjustments are primarily strata 2 and 5 ages, and strata 1, 2, 4, 5, and 7 heights. This bias could increase the error in the adjusted attributes, with resulting consequences on the site index.

4.0 INVENTORY FILE ADJUSTMENT

The TFL 23 inventory FIP file database was updated to 2001. The population to be adjusted was defined as the 2001 database productive landbase aged 10 or older that is included in the seven described strata.

The productive landbase is defined by npforestdescriptor is null and npforestcode is 0. For TFL 23, 92.5% of the productive landbase is included in the adjustment. The unadjusted productive land has one or more of the following attributes:

- biogeoclimatic classification was not sampled by the VRI, including AT, ATp, IDFunn, ESSFvc, ESSFvcp, and unclassified;
- stand is less than 10 years old, with inventory age projected to 2001;
- deciduous leading stand.

The post-stratification strata criteria used in the development of the adjustment factors were applied to the inventory database. The appropriate age and height adjustments, which are the adjustment ratios identified in Table 2, were then applied to each polygon in each stratum as follows:

- adjusted age = age adjustment ratio x inventory age
- adjusted height = height adjustment ratio x inventory height

Using the adjusted ages and heights and existing inventory attributes of species composition, crown closure, and stocking class from the inventory database, the inventory volume for each polygon is calculated using VDYP. These are the attribute adjusted inventory volumes. The volume adjustment ratios identified in Table 3 are then applied to each polygon in each stratum as follows:

- final adjusted volume = volume adjustment ratio x attribute adjusted inventory volume

An adjusted site index was calculated for each polygon from the adjusted height and adjusted age, using VDYP. The interim VRI attribute file includes columns for adjusted age, adjusted height, adjusted site index, and final adjusted volume.

5.0 IMPACT OF VRI ADJUSTMENT ON TFL 23

The following table shows the impact of using the Fraser Protocol for age, height, and volume adjustments for the adjusted portion of TFL 23 in terms of site index and merchantable volume. The pre-adjustment site index and volumes are generated by VDYP using the current inventory ages and heights. Site index and merchantable volumes are area weighted for the pre- and post adjustment comparisons.

Table 5: TFL 23 Site Index and Merchantable Volume Comparisons – Inventory File

Stratum	BEC zone	Subzone/ variant	Leading species/age	Average original SI	Average adjusted SI	Average original volume	Average adjusted volume
1	ESSF	wc1 wc4	B,Cw,H,S/ 10-39 years	15.3	13.9	2.2	26.9
2	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 10-39 years	17.6	16.4	5.6	34.8
3	ESSF	wc1 wc4	B,Cw,H,S/ 40-140 years	15.7	13.5	184.1	237.6
4	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 40-140 years	17.2	17.1	250.5	321.9
5	ESSF	wc1 wc4	Fd, P, L/ 10-140 years	18.8	17.3	184.0	218.7
	ICH	dw mw2 mw3 vk1 wk1					
6	ESSF	wc1 wc4	all conifers >140 years	11.5	12.2	282.7	299.1
7	ICH	dw mw2 mw3 vk1 wk1	all conifers >140 years	14.7	16.3	401.0	518.2

Note: site index and merchantable volume figures are area weighted

For all strata up to 140 years old, site index is decreased with the adjustment, with the greatest decrease in the ESSF H, B, Cw, S aged 40 to 140 years. Site index is increased with the adjustment for both strata greater than 140 years. However, as shown in section 3.5, the adjusted site index means are poorly correlated with the VRI sample site index figures. All seven strata show a post-adjustment increase in merchantable volume over the pre-adjustment volumes.

This divergence of adjusted site index values and adjusted volumes in the strata that are younger than 40 years, requires some discussion. Taking stratum 5 as an example, table 2 showed that the mean

ground age is 12 years older than the mean inventory age and that mean ground height is about the same as mean inventory height (ground height 0.5 metres lower). The resulting ratio for adjusting inventory age and height attributes were 1.173 and 1.024 respectively. These adjustments will lower site index because each polygon will be made older, but not taller. Mean site index was lowered from 18.8 to 17.3 metres (table 5) for all polygons in stratum 5.

When table 3 is inspected, the mean ground volume generated by these adjusted heights and ages is 179.3 cubic metres per hectare. As expected, increasing ages but not heights caused VDYP to generate a lower volume than that in the unadjusted inventory. In fact, the mean unadjusted inventory volume for stratum 5 was 184 cubic metres per hectare (table 5). Therefore, step 1 of the volume adjustment process lowered site index and lowered the inventory volume.

Step 2 of the volume adjustment process for stratum 5 was to calculate the ratio of the mean ground volume to the figure of 179.3 cubic metres produced from step 1. This ratio was 196.2/179.3, or 1.094 (table 3). When all the polygon volumes in stratum 5 adjusted in step 1 were further adjusted by multiplication by 1.094, the mean adjusted volume increased from 179.3 to 218.7 cubic metres per hectare. Applying step 2 of the volume adjustment procedure to all inventory polygons in stratum 5, using a ratio calculated from the VRI sampled subset, caused the adjusted volume to increase, even though the adjusted site index decreased.

5.1 TFL 23 VRI ATTRIBUTE ADJUSTMENT – MARCH 2002

A meeting was held at Ministry of Sustainable Resource Management in Victoria on February 6, 2002. The intent was to review the inventory attribute adjustments as described in sections 1.0 to 4.0. The following people attended the meeting: Keith Tudor, Sam Otukol, Rob Drummond, and Albert Nussbaum, Chris Mulvihill from the Nelson Region MOF by telephone; Chris Shelley from Pope and Talbot by telephone; and Steve Smith and Ann Donaldson from Sterling Wood Group.

The following concerns were highlighted:

1. The December 2001 report shows that the age and height adjustment ratios for strata 1 and 2 are large, ranging from 1.58 to 2.36.
2. The adjustment evaluation, section 3.5 of the report, shows that residual analysis indicates bias in many of the age and height adjustments, with consequences for adjusted site index.
3. Section 3.5 provides a further check of the reliability of the adjustment with a comparison of the adjusted site index with VRI site index. The conclusion was that the adjustment methodology does not result in reliable adjusted site index estimation for this TFL.
4. It was also noted at this meeting that the volumes used for the VRI volume adjustment should be the new_nwb, not the vha_nwb as was used for the December report.

Following discussion, the consensus was to use VRI data to adjust the inventory site index, with no age or height adjustment. The following procedures were used to adjust site index directly.

Site Index Adjustment

Sterling Wood Group completed the following steps to further check and understand the VRI results, and to produce defensible site index adjustments.

1. For the two young strata (1 and 2), check the source of the inventory information, the history records and the plot photos.
2. If there is no silviculture survey, then accept the inventory information, but note the establishment date from the history record.
3. If there was a silviculture survey, use this inventory label information to provide average height and stand age. This has already been done in the TFL database.
4. Where VRI age is at least 15 years older than the stand disturbance date, assume that the VRI site trees are advanced regeneration. Where plot photos are available use these to check this assumption.
5. Calculate stratum average site index with and without the advanced regeneration for strata 1 and 2.
6. For all strata, calculate the ratio of VRI site index to existing inventory site index. For strata 1 and 2 use the VRI site index calculated from plots that are not considered to be advanced regeneration.
7. Use the site index ratios calculated in (6) to adjust the site index for all inventory polygons except those polygons with silvicultural survey information. The site index for polygons with silvicultural survey information were not be adjusted. Store the results in a new field called 'VRI adjusted site index.'
8. Compare VDYP volumes predicted from the adjusted site index with the VRI compiled volume (new_nwb) for the polygons sampled by the VRI.
9. When the yield analysis is being done, compare the volumes predicted by the yield curves with the VRI compiled volume (new_nwb) for the polygons sampled by the VRI.

The first eight of these steps were completed. Step nine must wait until the yield analysis. History records and photographs appeared to indicate that advanced regeneration trees were used in some VRI plots for age and height information. This was evident where the age of the stand, as reported in the VRI data, was older than the establishment age in the inventory, or older than the years since harvest. In total, 12 plots were removed from stratum 1, and 18 plots were removed from stratum 2 for site index ratio calculations. This resulted in only seven plots remaining in stratum 1, and since the site index ratio was similar to that for stratum 2, strata 1 and 2 were combined for subsequent site index adjustment.

The site index ratios were calculated for each stratum as: $\frac{\text{mean ground sample attributes}}{\text{mean inventory attribute}}$

The following table identifies the site index ratio obtained for each stratum.

Table 6: TFL 23 Site Index Adjustment Ratios

Stratum	BEC Zone	Subzone/ Variant	Leading Species/Age	Mean Inventory Site Index	Mean Ground Site Index	Site Index Ratio
1 & 2	ESSF	wc1 wc4	B,Cw,H,S/ 10-39 years	17.0	20.6	1.212
	ICH	dw mw2 mw3 vk1 wk1				
3	ESSF	wc1 wc4	B,Cw,H,S/ 40-140 years	16.0	13.8	0.863
4	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 40-140 years	17.7	18.4	1.038
5	ESSF	wc1 wc4	Fd, P, L/ 10-140 years	19.4	18.7	0.962
	ICH	dw mw2 mw3 vk1 wk1				
6	ESSF	wc1 wc4	all conifers >140 years	10.1	12.0	1.189
7	ICH	dw mw2 mw3 vk1 wk1	all conifers >140 years	14.3	18.3	1.275

The site index adjustments were applied to the 2001 TFL 23 inventory database. The population to be adjusted was defined as the 2001 landbase aged 10 or older that was included in the seven described strata. Subsequent to the December 2001 report, it was noted that some records in the database labeled NP or AF have a site index that appears productive, for example, over 500 polygons labeled NP or AF have site index identified greater than 15. For this reason, the site index adjustment was applied regardless of the npforestdescriptor, as long as the polygon met the criteria for one of the above strata.

The adjusted site index was calculated as the site index adjustment ratio * inventory site index, and was applied to each polygon in each of the seven strata. A separate column in the TFL 23 database labeled 'VRI adjusted SI' contains the adjusted site index values.

Volume Adjustment *(updated May 2002)*

The volume adjustment completed per sections 1.0 to 4.0 was replaced with the following.

1. The adjusted site index from table 6 for the samples in each of the strata were used along with the original inventory species composition, age, crown closure, and stocking class to compute the site index adjusted inventory volumes using VDYP (VDYP Batch ver. 6.6d). Inventory volumes were net decay, waste and breakage.
2. The volume adjustment ratio for each stratum was then calculated by:

$$\text{Ratio} = \frac{\text{mean ground vol / ha}}{\text{mean "site index adjusted" inventory vol / ha}}$$

The ground volumes were the VRI compiled volumes new_nwb that were updated by the Ministry of Sustainable Resource Management in October 2001. These are the net factor volumes. The volume adjustment ratios are also calculated for each stratum using the VRI compiled volumes new_dwb. These are the loss factor volumes.

Utilization levels were 12.5 for pine leading stands, and 17.5 for all other conifer species for both ground and attribute adjusted volumes. The volume ratio calculations in spreadsheet format are attached in Appendix V.

The following tables show the volume adjustment ratios obtained from the above calculation.

Table 7: TFL 23 Calculated Volume Adjustment Ratios - Net Factor

Stratum	BEC Zone	Subzone/ Variant	Leading Species/Age	Mean Site Index Adjusted VDYP Volume	Net Factor Mean Ground Volume	Net Factor Volume Ratio
1 & 2	ESSF	wc1 wc4	B,Cw,H,S/ 10-39 years	10.4	48.2	4.635
	ICH	dw mw2 mw3 vk1 wk1				
3	ESSF	wc1 wc4	B,Cw,H,S/ 40-140 years	84.8	173.3	2.044
4	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 40-140 years	195.6	276.5	1.413
5	ESSF	wc1 wc4	Fd, P, L/ 10-140 years	154.9	208.9	1.349
	ICH	dw mw2 mw3 vk1 wk1				
6	ESSF	wc1 wc4	all conifers >140 years	281.1	230.2	0.819
7	ICH	dw mw2 mw3 vk1 wk1	all conifers >140 years	445.2	502.4	1.129

Table 8: TFL 23 Calculated Volume Adjustment Ratios – Loss Factor

Stratum	BEC Zone	Subzone/ Variant	Leading Species/Age	Mean Site Index Adjusted VDYP Volume	Loss Factor Mean Ground Volume	Loss Factor Volume Ratio
1 & 2	ESSF	wc1 wc4	B,Cw,H,S/ 10-39 years	10.4	44.8	4.312
	ICH	dw mw2 mw3 vk1 wk1				
3	ESSF	wc1 wc4	B,Cw,H,S/ 40-140 years	84.8	155.6	1.835
4	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 40-140 years	195.6	264.0	1.349
5	ESSF	wc1 wc4	Fd, P, L/ 10-140 years	154.9	196.2	1.267
	ICH	dw mw2 mw3 vk1 wk1				
6	ESSF	wc1 wc4	all conifers >140 years	281.1	207.4	0.738
7	ICH	dw mw2 mw3 vk1 wk1	all conifers >140 years	445.2	457.7	1.028

Concerns about the application of large calculated volume ratios and their effect on the reported volumes for the TFL landbase, resulted in the following adjustment rule:

1. If the volume adjustment ratio is less than or equal to 1.5, or greater than or equal to 0.67, then the adjustment ratio is the calculated ratio, otherwise the adjustment ratio is set equal to one.

This rule produced a set of final adjustment ratios shown in table 9.

Table 9: TFL 23 Final Volume Adjustment Ratios

Stratum	BEC Zone	Subzone/ Variant	Leading Species/Age	n	Volume Ratio Net Factor	Volume Ratio Loss Factor
1 & 2	ESSF	wc1 wc4	B,Cw,H,S/ 10-39 years	35	1.0	1.0
	ICH	dw mw2 mw3 vk1 wk1				
3	ESSF	wc1 wc4	B,Cw,H,S/ 40-140 years	13	1.0	1.0
4	ICH	dw mw2 mw3 vk1 wk1	B,Cw,H,S/ 40-140 years	22	1.413	1.349
5	ESSF	wc1 wc4	Fd, P, L/ 10-140 years	86	1.349	1.267
	ICH	dw mw2 mw3 vk1 wk1				
6	ESSF	wc1 wc4	all conifers >140 years	38	0.819	0.738
7	ICH	dw mw2 mw3 vk1 wk1	all conifers >140 years	23	1.129	1.028

Based on direction provided by the MOF in February 2002, the volume ratios derived from VRI net factor volumes were used in the database volume adjustments. The volume ratios derived from VRI loss factor volumes are provided in case the MOF chooses this method for adjustment during the timber supply analysis.

For all strata, the use of net factor VRI volumes results in higher adjusted inventory volumes than the use of VRI loss factor volumes.

Final Adjusted Volume File

Two columns have been added to the TFL 23 inventory FIP file database updated in 2001: VRI adjusted SI, and adjusted volume (net factor). This replaces the updated database submitted with the December 2001 report that included new columns for adjusted age, adjusted height, adjusted site index, and final adjusted volume. Note that VRI adjusted SI in the May 2002 version will not match adjusted site index in the December 2001 version because they were calculated differently.

5.2 ADDENDUM – MAY 2002

Section 5.1 was added to the December 2001 report to describe and replace the adjustment methodology. This addendum provides an assessment of the overall volume impact, and the sampling error for the final TFL 23 VRI volume adjustment.

The original strata 1 and 2 were combined for the final volume adjustments as described in Section 5.1, resulting in six final strata rather than the original seven. Section 5.1 outlines the criteria that were used for the application of the final volume adjustments to the six strata.

Target Sampling Error – Age and Height

The ground sampling work plans for both the old growth and the second growth Phase II sampling specified a precision target of ±10% for both age and height attributes. The precision expressed as a proportion of the mean is calculated as:

$$E = \frac{t * cv}{\sqrt{n}}$$

where: n = number of samples
t = students + value with 95% probability
cv = standard deviation expressed as proportion of the mean.

The resulting precision is shown in the following table.

	VRI Age	VRI Height
n	224	218
t	1.96	1.96
cv	0.699	0.419
e	9.2%	5.6%

These values show that the resulting sampling precision is 9.2% for age and 5.6% for height. However, concerns regarding the use of the VRI ages and heights to adjust the TFL 23 inventory are outlined in Sections 5.0 and 5.1, and, as a result the inventory was not adjusted with VRI age and height data.

Overall Volume Impact

Total inventory volumes were calculated for the landbase that falls within the six defined VRI strata. As stated in Section 4.0, this area represents more than 92% of the TFL 23 productive landbase. Volumes were calculated using VDYP bat ver. 6.6d, net decay, waste and breakage. Utilization is 12.5cm+ for pine leading stands, and 17.5cm+ for all other conifer species for both ground and inventory volume estimates.

Within these strata, the total original inventory volume is 79,997,231 cubic metres. Total adjusted volume, based on volume ratios derived from VRI net factor volumes, is 96,463,036 cubic metres. The volume adjustment process is described in Section 5.1.

The volume adjustment therefore increases total volume by 21%.

Summary Statistics

The following calculations were made to compare the overall ground volumes with the overall unadjusted inventory volume, and to determine the standard error for this ratio.

Volume	Combined total volume ratio	95% confidence interval for ratio	Sampling error as % of ratio	n	se
net factor	1.214	1.114 – 1.314	4.2%	217	0.0508
loss factor	1.115	1.024 – 1.206	4.1%	217	0.0460

Dr. Peter Ott's (Ministry of Forests, Research Branch) formulae, taken from the January 2002 TFL 3 Documentation of Analysis for Vegetation Resources Inventory Statistical Adjustment, for the combined overall volume ratio estimates and variance were used as follows:

Notation

n_h – number of samples in h^{th} stratum, $h = 1,2,\ldots,H$

Z_h – area within h^{th} stratum (hectares)

$\hat{y}_{hj}$ – ground volume per hectare of j^{th} observation in h^{th} stratum, $j = 1,2,\ldots,n_h$

x_{hj} – photo-interpreted volume per hectare of j^{th} observation in h^{th} stratum

$\bar{y}_h$ – estimated mean ground volume per hectare in h^{th} stratum $= \frac{1}{n_h}\sum_{j=1}^{n_h}\hat{y}_{hj}$

$\bar{x}_h$ – estimated mean photo-interpreted volume per hectare in h^{th} stratum $= \frac{1}{n_h}\sum_{j=1}^{n_h}x_{hj}$

$\hat{y}_h$ – estimated total ground volume in h^{th} stratum $= Z_h \cdot \bar{y}_h$

$\hat{x}_h$ – estimated total photo-interpreted volume in h^{th} stratum $= Z_h \cdot \bar{x}_h$

$\hat{y}$ – estimated total ground volume for entire unit $= \sum_{h=1}^{H} \hat{y}_h$

$\hat{x}$ – estimated total photo-interpreted volume for entire unit $= \sum_{h=1}^{H} \hat{x}_h$

X – total photo-interpreted volume of entire population $= \sum_{h=1}^{H} \sum_{j=1}^{N_h} x_{hj}$

Combined Ratio Estimator	Its Standard Error
$\hat{R} = \frac{\hat{y}}{\hat{x}} = \frac{\sum_{h=1}^{H} Z_h \cdot \bar{y}_h}{\sum_{h=1}^{H} Z_h \cdot \bar{x}_h}$	$s.e.(\hat{R}) = \sqrt{\frac{1}{X^2} \sum_{h=1}^{H} \frac{Z_h^2}{n_h} s_h^2}$, where $s_h^2 = \frac{1}{n_h - 1} \sum_{j=1}^{n_h} (e_{hj} - \bar{e}_h)^2$, $e_{hj} = \hat{y}_{hj} - \hat{R} x_{hj}$, and $\bar{e}_h = \frac{1}{n_h} \sum_{j=1}^{n_h} e_{hj}$

1. Combined Total Volume Ratio Estimates

For this ratio, ground and inventory volumes are area weighted for the 6 strata, using mean volumes per strata derived from the sampled polygons. Ground volumes used were the new_nwb for net factor volumes and new_dwb for loss factor volumes. The mean inventory volume is the unadjusted, original inventory volume calculated by VDYP, net decay, waste and breakage, for the polygons sampled by the VRI.

The combined overall volume ratio 1.214 includes strata 1, 2, and 3. However, the final volume ratio adjustments were not applied to these strata for reasons described in Section 5.1. The final reported volumes for these strata are the site index adjusted VDYP volumes. The ratio of actual adjusted volumes (net factor) to unadjusted volumes is 1.206, showing that the impact of the volume adjustment in strata 1, 2 and 3 is minimal.

2. Combined Volume Ratio

The sampling error of 4.2% of the combined total volume ratio (net factor) is equivalent to a sampling error of 0.0508. The sampling error of 4.1% of the combined total volume ratio (loss factor) is equivalent to a sampling error of 0.0460.

3. *Confidence Interval*

The sample size of 217 is large enough to support the use of the normal approximation to calculate the confidence interval for the combined ratio. The 95% confidence interval was calculated from:

$$\hat{R}_c = \pm t_{0.05} S_{\hat{R}_c}$$

For this sample, $t_{0.05}$ = 1.97 with 200 degrees of freedom and the standard errors are 0.0508 and 0.0460.

Discussion

Our concerns regarding age and height adjustments are outlined in Section 5.1. Following discussion of these concerns with MSRM staff, the decision was made to adjust site index and volume only, without age or height adjustment. Subsequently, our concerns regarding volume adjustment in strata 1&2, and 3 are outlined in Section 5.1. For these two strata, the adjusted site index was added to the database, and final volume adjustment is based on the original inventory projected age and adjusted site index. The final strata specific volume adjustment ratios were not applied to strata 1 & 2 and 3.

For strata 4 to 7, adjusted site index and final adjusted volumes are added to the database. This included the application of the volume ratios generated from the VRI net factor ground volumes compared to the site index adjusted volumes.

A review of the appropriate volume adjustment ratios must be determined for the timber supply analysis. At some point in the timber supply analysis the MOF will have to choose between the net factor and the loss factor adjustment ratios.

Although the sampling error for the combined volume ratio appears satisfactory, the consultants have noted classification inconsistencies in the inventory that were brought to light by the VRI. The large age and height ratios identified by the VRI adjustment methodology show evidence of inconsistent inventory age and height information. Possible causes are:

- classification procedures in the original inventory;
- mid pointing of height and age classes together with repeated later adjustments;
- updating inventory attributes for young stands from silvicultural surveys;
- the possible presence of residual trees in stands for which there is no silvicultural record available.

If these inconsistencies are not addressed, project results and information derived from inventory height and age attributes may lose credibility in future field checks.

APPENDIX I

VRI Attribute Adjustment
Strata 1 – 7

APPENDIX II

Documentation of Unused Plots

APPENDIX III

Residual Plots – Age, Height and Volume

APPENDIX IV

Moving Ratio Method for Attribute Adjustment

APPENDIX V

TFL 23 VRI Adjustment for Site Index,
Net Factor Volume and Loss Factor Volume