Prince George Forest District

Documentation of Analysis for Vegetation Resources Inventory Statistical Adjustment

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EXECUTIVE SUMMARY

Timberline Natural Resource Group recently completed a VDYP6 VRI statistical adjustment analysis of the Prince George TSA. The analysis was done separately for each of the three forest districts within the TSA: Prince George, Vanderhoof and Fort St. James.

The objective of this project was to provide a VDYP7 adjustment for the Prince George Forest District of the Prince George TSA which followed the same approach as the Timberline VDYP6 adjustment for this unit. Hence analysis strata, sampling weights, target population, compiled VRI Phase II data, etc. were provided by Timberline. Although plots were established in the Prince George Forest District under several projects, with the first ground samples being established in 2000, it was agreed that the adjustment analysis would be based solely on the samples established in 2006/2007 (project DPG1). Additional sampling in the deciduous stratum in this management unit is ongoing and was not included in this analysis.

This adjustment was to be carried out according to the interim procedures for a VDYP7 adjustment which allows for adjustment of age, height, basal area/ha at 7.5cm+ dbh utilization, trees/ha at 7.5cm+ dbh utilization and volume/ha net dw2 at 12.5cm+ dbh utilization

Because of the heavy MPB infestation in this area and how MPB mortality is dealt with in a timber supply context, timber supply staff requested that all dead pine be included in the adjustment. Hence the basal area/ha, trees/ha, and volume adjustment factors are all based on live (all species) plus dead lodgepole pine.

Timberline completed the NVAF destructive sampling for this unit in the 2007 field season, compiled this data and provided the NVAF values for the Phase II ground sample compilation. NVAFs were provided on November 29, 2007 in a file that listed the NVAF values for live/dead for each species present within a sample. These NVAFs were then applied as a multiplier to the compiled volumes.

The target population was stratified into 3 groups based on the Pl proportion in the stand and age that were to form the strata for the development of the adjustment factors:

- Polygons containing less than 31% Pl volume and less than 141 years old (Minor-Immature)
- Polygons containing less than 31% Pl volume and 141 years or older (Minor-Immature)
- Polygons containing more than 30% Pl volume (Major)

The resulting VDYP7 adjustment factors for age, height, basal area and trees per hectare are shown in Tables 1.

Timber supply analyses are typically done on a net decay, waste and breakage volume basis. Hence, a special unadjusted run of VDYP7 was done to provide unadjusted volumes net decay, waste & breakage so that the estimated volume impact of the VDYP7 adjustment and its associated sampling error could be computed. The estimated volume impacts of the adjustment were computed as ratios of the ground (Phase II) volume to the unadjusted VDYP7 (Phase I) volume, with appropriate sample weights applied. The results, by stratum, are shown in Table 2.

Table 1: VDYP7 Adjustment Factors for age, height, trees/ha (at 7.5cm+dbh utilization), basal area/ha (at 7.5cm+dbh utilization) and volume/ha (net DW2 at 12.5cm+ dbh utilization). Note that the basal area/ha, trees/ha & volume/ha adjustment factors are based on Phase II per hectare values that include live trees for all species plus dead trees for lodgepole pine.

		VDYP7 Stage 1 Adjustment Factors				***VDYP7 Stage 2 Adjustment Factors***
Stratum	n	Age	Height	Basal area/ha @7.5cm+dbh	Trees/ha @7.5cm+ dbh	Volume/ha net DW2 @12.5cm+ dbh
Pl%<=30% - Immature	32	1.089	1.053	1.045	1.317	1.043
Pl%<=30% - Mature	79	0.827	0.989	1.094	1.470	0.860
Pl%>30%	25	0.964	0.991	0.950	1.442	0.851

Table 2: Volume Impact of VDYP7 adjustment, by stratum

Volume/ha @12.5cm+ dbh utilization net DWB: Estimated VDYP7 Adjustment Impact					
Stratum	n	Wt'd Mean Phase II Vol/ha (LIVE + Dead PL)	Wt'd Mean Phase I Unadjusted vol/ha	Estimated volume impact ratio	SE % for volume impact (at 95%)
Pl%<=30% - Immature	36	236.644	193.011	1.226	21%
Pl%<=30% - Mature	81	255.913	224.948	1.138	13%
Pl%>30%	31	270.489	332.123	0.814	18%

It is estimated that the VDYP7 statistical adjustment based on this sample will increase current VDYP7 volume by about 23% in immature (less than 141 years) stands with less than 31% pine and will increase volume by about 14% in mature (greater than 140 years) stands with less than 31% pine. For stands with greater than 30% pine, it is estimated that the adjustment will decrease VDYP7 volume by nearly 20%. Overall, the adjustment was estimated to increase total VDYP7 volume by about 6.8%. The sampling error for this estimated adjustment impact was ±9.1% (at the 95% confidence level) which met the target specified in the VPIP. When the adjustment was applied to the target population, the calculated impact of the adjustment was about 5.4%, which is reasonably close to what was expected based on the sample.

The Mountain Pine Beetle infestation is widespread in this unit. To facilitate the current TSR approach for representing the effect of Mountain Pine Beetle on the inventory and to ensure consistency with that approach, timber supply requested that dead pine volume be included with live volume in the adjustment. Hence the Phase II compiled values for all per hectare-based adjustments (i.e. basal area/ha, trees/ha, volume/ha) included dead pine. The magnitude of the dead pine component in the resulting total volumes (and basal areas etc.) was significant. In the samples where the inventory indicates greater than 30% pine, dead pine accounts for nearly 40% of the total volume for live trees (all species) plus dead pine. The impact of including dead pine volume in the analysis should be considered in terms of degradation of volume and value in the pine component and therefore pine volumes should not continue to be projected. A process is currently being developed for dealing with the dead pine component of the inventory in a more systematic and consistent manner.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

1.1 Background

Timberline Natural Resource Group recently completed a VDYP6 VRI statistical adjustment analysis of the Prince George TSA. The analysis was done separately for each of the three forest districts within the TSA: Prince George, Vanderhoof and Fort St. James. The Ministry of Forests and Range (MFR) contracted with Churlish Consulting Ltd.[1] to perform a VDYP7 statistical adjustment analysis of the Prince George Forest District, based on the same approach and assumptions used by Timberline in their VDYP6 analysis.

Details of the VRI Phase II ground sampling in the Prince George Forest District can be found in the document: "Prince George Forest District Vegetation Resources Inventory Project Implementation Plan Version 4.0", March 2007, a contract report prepared by Timberline on behalf of Canfor Prince George and the forest licencees in the Prince George TSA. Note that the Phase 1 data in this unit was re-inventoried after sample selection.

An August 24, 2007 memo from Timberline (see Appendix A) described the various VRI Phase II sampling projects completed in Prince George Forest District and their proposed analysis approach:

> "In 2000, 109 VRI Phase II plots were established in the PG Forest District (projects 0241 and 024S). Sixty-six (66) of these plots are in our 2006 target population, in stands less likely to be impacted by Mountain Pine Beetle (MPB). We selected 20 of these plots for re-measurement and 130 new plot locations. Our objective is to use all 196 plots available (20 measured in both 2000 and 2006, 46 measured only in 2000, 130 measured only in 2006) to build the most efficient ratio-of-means estimator possible."

An estimator to use all of the data was proposed. However, the same Timberline memo outlined an alternative approach:

> "The simplest estimator would be to compute the ratio of means based on the 150 plots measured in 2006 and ignore older plots. The advantage of the default position is that it is very simple since it follows all the current standards. The disadvantage however is that it ignores 46 plots that could improve the precision we get for the ratio-of-means."

Largely due to time constraints related to the analysis, the more simple default position was agreed to be used[2].

To ensure that the VDYP6 and VDYP7 adjustments were comparable, strata assignments, sample weights, identification of the target population etc. were provided by Timberline.

1.2 Description of the Inventory Unit

Along with Vanderhoof and Fort St. James, the Prince George Forest District is one of three forest districts that comprise the Prince George TSA (see Figure 1). The following description of the Prince George Forest District is taken from the "Prince George Forest District Vegetation Resources Inventory Project Implementation Plan Version 4.0":

[1] Jahraus &Associates Consulting Inc. was a subcontractor on this project.

[2] As suggested by Sam Otukol.

"The Prince George Forest District covers approximately 3.4 million ha, of which 2.1 million ha (62%) are Vegetated Treed (VT). Most of the Prince George Forest District is located in the Sub-Boreal Spruce (SBS) (65%) or in the Engelmann Spruce-Subalpine Fir (ESSF) (25%) biogeoclimatic zones."

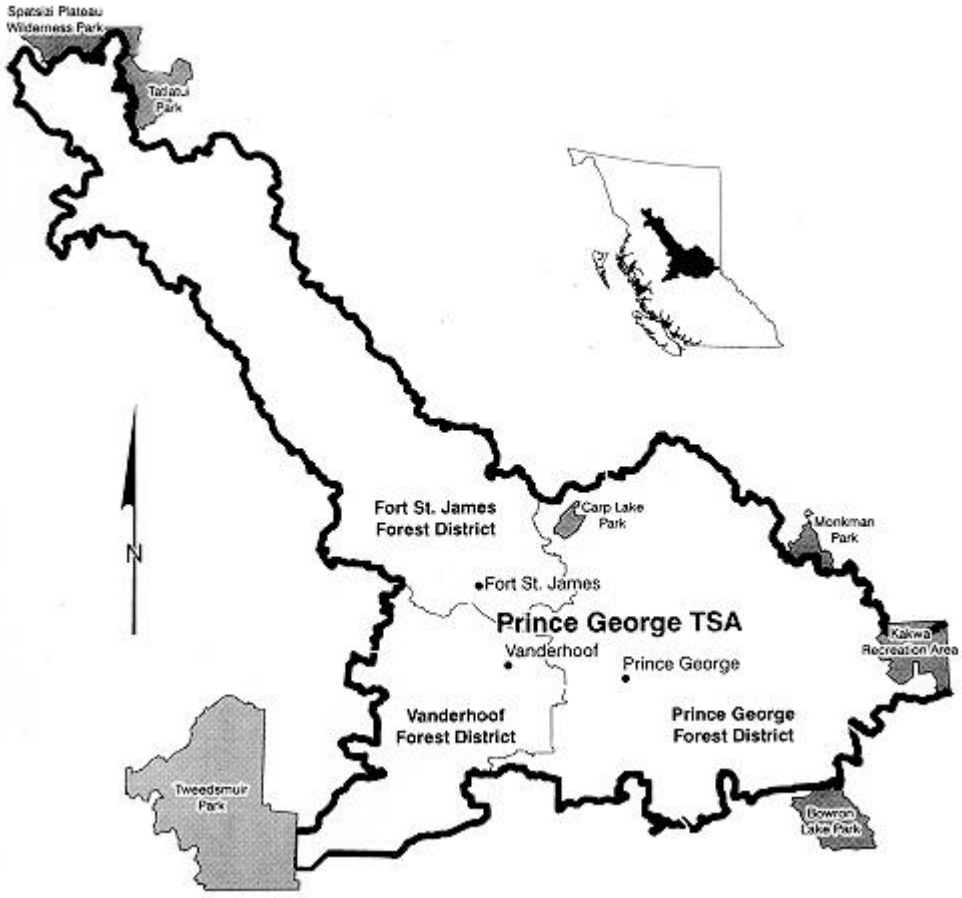

Figure 1: Map of the Prince George TSA showing the Prince George Forest District [3]

1.3 Scope and Objectives

The objective of this project was to provide a VDYP7 adjustment for the Prince George Forest District of the Prince George TSA which followed the same approach as the Timberline VDYP6 adjustment for this unit. Hence analysis strata, sampling weights, target population, compiled VRI Phase II data, etc. were provided by Timberline. Although plots were established in the Prince George Forest District under several projects, with the first ground samples being established in 2000, it was agreed that the adjustment analysis would be based solely on the samples established in 2006/2007 (project DPG1). Additional sampling in the deciduous stratum in this management unit is ongoing and was not included in this analysis.

This adjustment was to be carried out according to the interim procedures for a VDYP7 adjustment which allows for adjustment of age, height, basal area/ha at 7.5cm+ dbh utilization, trees/ha at 7.5cm+ dbh utilization and volume/ha net dw2 at 12.5cm+ dbh utilization. Lorey height was not adjusted (an adjustment

[3] http://www.for.gov.bc.ca/hts/tsa/tsa24/map.gif

factor of 1.0 was applied for this attribute). The single volume adjustment computed was applied to all other volume utilizations.

Because of the heavy MPB infestation in this area and how MPB mortality is dealt with in a timber supply context, timber supply staff requested that all dead pine be included in the adjustment. Hence the basal area/ha, trees/ha, and volume adjustment factors are all based on live (all species) plus dead pine.

2. METHODS

2.1 Overview of NVAF analysis

Timberline completed the NVAF destructive sampling for this unit in the 2007 field season, compiled this data and provided the NVAF values for the Phase II ground sample compilation. NVAFs were provided on November 29, 2007 in a file that listed the NVAF values for live/dead for each species present within a sample. These NVAFs were then applied as a multiplier to the compiled volumes. For further details on the NVAF analysis, please refer to Timberline's report for this project.

2.2 Population for Adjustment

The population of interest for this adjustment, as specified in the VPIP, was:

> "All VT polygons, 30 years of age and older as of 2006."

The target population for adjustment and the stratum assignment for each polygon in the target population for adjustment were specified by the file target_population.csv provided by Timberline[4]. Note that the area in this file represented 93% of the area in the population of interest as defined above. Only polygons listed in the target population file provided by Timberline were adjusted. The remaining 7% of the population of interest area was not adjusted.

The sampling error objective was specified as achieving:

> "…an overall minimum sampling error of ±10% (at a 95% confidence level)".

2.3 Data Sources

The Phase I & II data were largely provided as a series of linked files from Timberline.

2.3.1 Phase I photo-interpreted inventory data

The Phase I attribute files from Timberline represented a subset of the inventory data that was relevant to VDYP6. To enable the analysis based on VDYP7, a more complete set of Phase I data was obtained from FAIB (Tim Salkeld). The Phase I data was projected to the year of ground sampling (i.e. 2006 or 2007).

Timberline supplied several other files that provided the only means of identifying sample status (i.e. established, replaced, etc.), stratum assignments and sampling weights[5]. In some cases, assumptions were required where there was inconsistency among these files. These are documented as Data Issues in Appendix B.

[4] In combination with a file indicating inventory update depleted areas.

[5] PG_plot_location.csv (sampling status); princegeorge_phase2_data.csv (sample weights; sample inclusion); samples.csv (sample identifiers); target_population.csv (stratum assignment) and depleted areas file (population inclusions)

2.3.2 Phase II ground sample data

The Phase II ground sample data was compiled by Timberline based on ascii data. The data had not been loaded onto the Ministry of Forests and Range (MFR) Oracle database and as such it did not go through the MFR error checking process. All samples had a DPG1 project id.

The compiled data (as smy_c and smy_cs files) used in this analysis was received from Timberline[6] at the beginning of November 2007. The Phase II volumes were adjusted with the NVAF values provided by Timberline on November 29, 2007.

Note that after the VDYP7 adjustment analysis was completed, a corrected set of compiled data files was produced by Timberline (December 21, 2007). The differences between the two versions of the compilation were examined and the decision was made by MFR (Sam Otukol) not to re-do the VDYP7 analysis. Details on the differences between the two files and the potential impact are provided in Appendix C.

2.3.3 Data matching

The data matching used to determine the appropriate heights and ages upon which to base the adjustment ratios followed the standard procedures outlined by the MFR. The results have been included in the Appendix D cut of the analysis spreadsheet.

For each VRI sample polygon, the ground sample data was matched with the corresponding inventory data for the same polygon. The ground heights and ages used in the adjustment were based on the average values for the T, S & L[7] trees for the leading species (by basal area at 4cm + dbh utilization) on the ground. Since the Prince George Forest District includes a mix of FIP (F-type) and VRI (V-type) inventory data height and age may or may not have been available for both the leading and second species[8]. The objective in the matching process was to choose an inventory height and age (i.e. for either the leading or second species) so that the ground and inventory species "matched". If a match could not be made at the sp0[9] level, conifer-to-conifer matches were allowed. However, conifer-deciduous matches were not considered acceptable. Note that where second species inventory ages and heights were required and were available, these attributes were also projected to the year of ground sampling.

For 81 of the 148 samples, the inventory leading species matched the ground leading species at 4cm+ dbh utilization. For a further 37 samples, the ground leading species matched the inventory second species. Twenty-seven samples were matched based on conifer-to-conifer or deciduous-to-deciduous. The remaining 3 samples could not be matched and were excluded from the development of the age and height adjustment factors.

2.4 Data issues related to the statistical adjustment

In the course of the analysis, issues and questions arose for some samples. The resolution of these issues or the assumptions that were made is summarized in the Data Issues table in Appendix B.

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[6] Timberline used the VRI compiler distributed by MFR.

[7] T or "top height" tree is the largest DBH in 0.01 ha plot, regardless of species; L or "leading species" tree is the largest DBH in 0.01 ha plot, of leading species; S or "second species" is the largest DBH in 0.01 ha plot, of second species. T and S trees are selected and measured at the IPC only whereas L trees are selected at the IPC and all auxiliary plots. For details, refer to the MFR document "Vegetation Resources Inventory Procedures and Standards for Data Analysis Attribute Adjustment and Implementation of Adjustment in a Corporate Database Version 2.0", March 2004.

[8] Only 3 out of 148 samples in the analysis were from FIP-type inventories.

[9] sp0 refers to the 16 major species codes and is roughly equivalent to the genus level.

2.5 Stratification and weights

This analysis followed the same stratification used by Timberline in their VDYP6 adjustment analysis. All strata assignments and sampling weights were provided by Timberline.

The target population was stratified into 3 groups based on the Pl proportion in the stand and age that were to form the strata for the development of the adjustment factors[10]:

- Polygons containing less than 31% Pl volume and less than 141 years old (Minor-Immature)
- Polygons containing less than 31% Pl volume and 141 years or older (Minor-Immature)
- Polygons containing more than 30% Pl volume (Major)

2.6 Overview of statistical adjustment

The VDYP7 statistical adjustment process is similar to the VDYP6 process in that it is sequential and involves two stages. However, for VDYP7 additional attributes are adjusted at the first stage: age, height, basal area at 7.5cm+ dbh utilization (BA7.5), and trees per hectare at 7.5cm+ dbh utilization (TPH7.5). Although the process has the flexibility to adjust multiple attributes at the second stage, only volume net decay and waste at the 12.5cm+ dbh utilization will be adjusted at the current time. Within the VDYP7 context, various internal modules of VDYP7 are used to project the polygons, generate additional attributes, and adjust attributes. Hence the VDYP7 model itself takes a much larger role in the statistical adjustment process than did VDYP6.

3. RESULTS AND DISCUSSION

3.1 First stage VDYP7 adjustment: Height, age, basal area & trees per hectare

When the samples without a suitable inventory species match and/or there were no suitable ground ages or heights were considered, there were 136 samples for age and 134 samples for height that were available for the development of the age and height adjustment factors respectively.

Adjustment factors were computed as the ratio of the weighted mean ground i.e. Phase II (ground) value over the weighted mean inventory i.e. Phase I value, using the sample weights provided by Timberline.

The resulting VDYP7 adjustment factors for age, height, basal area and trees per hectare are shown in Tables 1 through 4 respectively. Scatterplots of the Phase I and II relationships for these attributes are provided in Appendices E & F.

Table 1: Stage 1 VDYP7 Adjustment Factors for age

Age: VDYP7 Adjustment Factors					
Stratum	n	Wt'd Mean Phase II Age	Wt'd Mean Phase I Age	Ratio of Wt'd Means	SE % at 95%
Pl%<=30% - Immature	32	90	82	1.089	13%
Pl%<=30% - Mature	79	171	206	0.827	6%
Pl%>30%	25	109	113	0.964	12%

[10] Plots were allocated proportionally across all strata (for sample allocation purposes only, each stratum was further subdivided into sub-strata – either age class or volume class – to ensure a representative distribution).

Table 2: Stage 1 VDYP7 Adjustment Factors for height

Height: VDYP7 Adjustment Factors					
Stratum	n	Wt'd Mean Phase II Height	Wt'd Mean Phase I Height	Ratio of Wt'd Means	SE % at 95%
Pl%<=30% - Immature	34	20.5	19.5	1.053	9%
Pl%<=30% - Mature	76	24.7	25.0	0.989	5%
Pl%>30%	24	24.7	25.0	0.991	8%

Table 3: Stage 1 VDYP7 Adjustment Factors for basal area/ha at 7.5cm+ dbh utilization (note that the Phase II basal area/ha includes live trees for all species plus dead trees for lodgepole pine only)

Basal Area/ha @7.5cm+ dbh utilization: VDYP7 Adjustment Factors					
Stratum	n	Wt'd Mean Phase II BA/ha (LIVE + Dead PL)	Wt'd Mean Phase I BA/ha	Ratio of Wt'd Means	SE % at 95%
Pl%<=30% - Immature	36	35.175	33.654	1.045	18%
Pl%<=30% - Mature	81	35.912	32.826	1.094	11%
Pl%>30%	31	39.417	41.494	0.950	14%

Table 4: Stage 1 VDYP7 Adjustment Factors for trees/ha at 7.5cm+ dbh utilization (note that the Phase II tree/ha includes live trees for all species plus dead trees for lodgepole pine only).

Trees/ha @7.5cm+ dbh utilization: VDYP7 Adjustment Factors					
Stratum	n	Wt'd Mean Phase II TPH (LIVE + Dead PL)	Wt'd Mean Phase I TPH	Ratio of Wt'd Means	SE % at 95%
Pl%<=30% - Immature	33	1192.61	905.295	1.317	26%
Pl%<=30% - Mature	81	700.675	476.49	1.470	18%
Pl%>30%	31	1325.378	919.23	1.442	25%

The sample suggests that there is little height bias in this unit, with the exception of immature stands where pine is less than 30% of the basal area. In these stands, height is underestimated by about 5%. In general, Phase I basal area/ha is underestimated in stands with less than or equal to 30% pine by basal area but slightly overestimated (by about 5%) where pine comprises more than 30% of the basal area. As is typical with most Phase I photo-inventories, the trees per hectare attribute is underestimated by about 30-45%.

3.2 Second stage VDYP7 adjustment: Volume

The adjustment factors for height, age, BA and TPH were input into the VDYP7 model which then produced an expanded output set of inventory attributes. Only one adjustment factor, for volume net decay & waste2 at the 12.5cm+dbh utilization level, was directly developed from the available attributes produced by VDYP7 at this stage. The ratios developed for this particular volume were applied to volumes at other utilizations[11].

[11] VDYP7 produces volumes at numerous utilization levels. Any adjustments input into VDYP7 must be harmonized, that is, care must be taken to ensure that the utilization relationships (e.g. volume at 12.5cm+

Although the VDYP7 software has been designed to also accept second stage adjustment factors for other attributes, including Lorey height and basal area at 12.5cm+ dbh, adjustment factors for these additional attributes were not computed at this time[12].

Table 5 below shows the VDYP7 volume adjustment factors by strata for the Prince George Forest District population of interest. The ground volumes used to compute the adjustment ratio of means were based on net factored volumes to which the NVAF values had been applied in the compilation. All volumes are net decay and waste2 only, at the 12.5cm+ dbh utilization level for all polygons. The Phase II volumes include dead lodgepole pine. Scatterplots showing the volume relationship and the residuals from the adjustment are provided in Appendix G.

Table 5: Stage 2 VDYP7 Adjustment Factors for volume (note that the Phase II volume includes live volume (all species) plus dead volume for lodgepole pine only).

Volume/ha @12.5cm+ dbh utilization net DW2: VDYP7 Adjustment Factors					
Stratum	n	Wt'd Mean Phase II Vol/ha (LIVE + Dead PL)	Wt'd Mean Phase I Attribute-adjusted vol/ha	Ratio of Wt'd Means	SE % at 95%
Pl%<=30% - Immature	36	242.824	232.825	1.043	20%
Pl%<=30% - Mature	81	263.566	306.514	0.860	13%
Pl%>30%	31	276.902	325.52	0.851	19%

3.3 Estimated volume impact for the VDYP7 statistical adjustment

Timber supply analyses are typically done on a net decay, waste and breakage volume basis. Hence, a special unadjusted run of VDYP7 was done to provide unadjusted volumes net decay, waste & breakage so that the estimated volume impact of the VDYP7 adjustment and its associated sampling error could be computed. The estimated volume impacts of the adjustment were computed as ratios of the ground (Phase II) volume to the unadjusted VDYP7 (Phase I) volume, with appropriate sample weights applied. The results, by stratum, are shown in Table 6.

Table 6: Volume Impact, by stratum

Volume/ha @12.5cm+ dbh utilization net DWB: Estimated VDYP7 Adjustment Impact					
Stratum	n	Wt'd Mean Phase II Vol/ha (LIVE + Dead PL)	Wt'd Mean Phase I Unadjusted vol/ha	Estimated volume impact ratio	SE % for volume impact (at 95%)
Pl%<=30% - Immature	36	236.644	193.011	1.226	21%
Pl%<=30% - Mature	81	255.913	224.948	1.138	13%
Pl%>30%	31	270.489	332.123	0.814	18%

always less than or equal to volume at 7.5cm+) are not contorted by the adjustment ratios. As a simple approach to ensure harmonization, only one volume adjustment factor was computed and this factor was applied to all of the other volumes. This approach was approved by Sam Otukol, Forest Biometrician, MFR.

[12] The VDYP7 adjustment procedures are still under development and are being tested. At the recommendation of Sam Otukol (Forest Biometrician, MFR), Lorey height and BA at 12.5cm+ dbh were assigned an adjustment factor of 1.0. That is, no adjustment was made for these attributes.

This sample suggests that where pine represents more than 30% of the polygon basal area, VDYP7 overestimates volume by nearly 20%. However, in polygons with a smaller pine component (i.e. pine <=30% of the basal area), VDYP7 appears to underestimate volume by roughly 14% for mature stands and about 23% for immature stands. Note that the adjusted VDYP7 volume includes volume associated with dead pine.

The impact of including dead pine in the adjustment is shown for volume in Table 7. In the VT polygons greater than 30 years of age, where the inventory indicates that more than 30% of the polygon is pine, the volume of dead pine comprises over 35% of the total volume for LIVE (all species) + dead pine. Note that the live volume includes non-pine species hence this does NOT suggest that 35% of the pine is dead, rather 35% of the total volume (live all species plus dead pine) is represented by dead pine. The mean volumes are provided so that alternative %'s can be computed.

Table 7: Impact of Dead Pl volume, by stratum

Volume/ha @12.5cm+ dbh utilization net DWB: Estimated VDYP7 Adjustment Impact and Dead Pine %							
Stratum	n	Wt'd Mean Phase II Vol/ha (LIVE + Dead PL)	Wt'd Mean Phase II Vol/ha (LIVE all spp only)	Wt'd Mean Phase II DEAD PL vol/ha	Wt'd Mean Phase I Unadjusted vol/ha	Estimated volume impact ratio based on LIVE all spp volume only	Dead pine vol/ha as a % of LIVE (all spp)+ dead Pl
Pl%<=30% - Immature	36	236.644	212.472	24.172	193.011	1.101	10%
Pl%<=30% - Mature	81	255.913	250.155	5.758	224.948	1.112	2%
Pl%>30%	31	270.489	173.090	97.399	332.123	0.521	36%

3.4 Sampling error

The VPIP for the Prince George Forest District specified a target sampling error of ±10% (at a 95% probability level) for total volume for VT polygons, 30 years of age and older as of 2006 (the target population). To provide an indication of the sampling error achieved in the VDYP7 adjustment process, a comparison of the overall estimated adjusted inventory volume and the overall estimated VDYP7 unadjusted sample inventory volume was made. The overall ratio of these values and its standard error were computed using the formula for a separate ratio estimate after a pre-stratified PPSWR sample.

The overall impact of a VDYP7 adjustment was estimated to be 1.068 with a 9.1% sampling error (at the 95% confidence level). This sampling error met the target set in the project VPIP.

3.5 Inventory file adjustment for the VDYP7 statistical adjustment

The adjustment was applied to the target population specified by Timberline and the population volume impact was computed. The ratio of adjusted volume to unadjusted volume in the population was 1.054. Impacts on the population by age class and stratum are shown in Appendix I. The actual volume impact on the population was relatively close to the estimated impact (1.054 vs. 1.068). Adjusted yield curves were produced for the target population.

Note that Timberline's target population only covered 93% of the population of interest defined in the VPIP. The remaining 7% of the population of interest was not adjusted but unadjusted yield curves were produced for timber supply purposes. Similarly, unadjusted yield curves were also produced for VT polygons that were outside of the population of interest for the adjustment (i.e. polygons less than 30 years of age).

4. CONCLUSIONS AND RECOMMENDATIONS

The VDYP7 statistical adjustment analysis of the Prince George Forest District was completed as an adjunct to the work done by Timberline in their VDYP6 adjustment analysis of this management unit. The target

population of interest, stratification, sampling weights, sample status, the compilation of the Phase II ground samples and the NVAF values were all provided by Timberline in correspondence with their VDYP6 analysis.

The VDYP7 analysis of this sample suggests that both age and height are underestimated (by 9% and 5% respectively) in immature polygons with less than 31% lodgepole pine. Although the sample suggests that age is overestimated in the stratum with greater than 30% pine and in the mature stratum with less than 31% pine, there appears to be minimal height bias in these strata. The analysis also suggests that basal area/ha is overestimated in stands with greater than 30% pine, but underestimated in stands with less than 31% pine.

After the adjustment of age, height, basal area and trees/ha, the VDYP7 was still overestimating volume in the stratum with greater than 30% pine and in the mature stratum with less than 31% pine, as reflected by the Stage 2 volume adjustment factors of about 0.85 in each of these strata.

When the scatterplots of the data were examined some potential trends in the residuals plots were observed, particularly for the mature stratum with less than 31% pine. These bias trends did not appear to be age-related. *Given the relatively large number of samples in this stratum (n=81) an investigation of post-stratification alternatives may have been able to address some of the bias trend concerns.* However, since the VDYP7 adjustment was intended to directly follow the VDYP6 work done by Timberline, further post-stratification was outside the scope of this analysis.

The VDYP7 statistical adjustment based on this sample will increase current VDYP7 volume by about 23% in immature (less than 141 years) stands with less than 31% pine and 14% in mature (greater than 140 years) stands with less than 31% pine. For stands with greater than 30% pine, the adjustment will decrease VDYP7 volume by nearly 20%. Overall, the adjustment was estimated to increase total VDYP7 volume by about 6.8%. The sampling error for this estimated adjustment impact was ±9.1% (at the 95% confidence level) which met the target specified in the VPIP. When the adjustment was applied to the target population, the calculated impact of the adjustment was about 5.4%, which is reasonably close to what was expected based on the sample.

The Mountain Pine Beetle infestation is widespread in this unit. To facilitate the current TSR approach for representing the effect of Mountain Pine Beetle on the inventory and to ensure consistency with that approach, timber supply requested that dead pine volume be included with live volume in the adjustment. Hence the Phase II compiled values for all per hectare-based adjustments (i.e. basal area/ha, trees/ha, volume/ha) included dead pine. The magnitude of the dead pine component in the resulting total volumes (and basal areas etc.) was significant. In the samples where the inventory indicates greater than 30% pine, dead pine accounts for nearly 40% of the total volume for live trees (all species) plus dead pine. *The impact of including dead pine volume in the analysis should be considered in terms of degradation of volume and value in the pine component and therefore pine volumes should not continue to be projected. A process is currently being developed for dealing with the dead pine component of the inventory in a more systematic and consistent manner.*

This analysis was based on the samples established in 2006 under project DPG1. A more complicated approach that would have incorporated data from samples collected in 2000 (projects 0241 and 024S) was initially proposed by Timberline but was not pursued largely due to time constraints. *It is recommended that advantages and limitations of this and other such approaches be further investigated in order to develop a protocol for dealing with similar situations. For remeasured samples, it is critical that standards for sample identification and numbering be implemented so that corresponding samples from both measurements can be easily linked for future analysis.*

5. APPENDIX A: BACKGROUND DOCUMENTS

The following memo from Guillaume Thérien (Timberline) describes some options that were considered for the analysis of the Prince George District VRI data. Given the time constraints associated with this project, it was decided[13] to adopt the "Default Position".

[13] This approach was agreed to by Sam Otukol, Albert Nussbaum and Barry Snowden in a joint meeting with Guillaume Therien.

Memo

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To: Sam Otukol

From: Guillaume Thérien

cc:

Date: August 24, 2007

Project:

Re: How to maximize efficiency with a mixture of new and remeasured plots

Background

We are currently completing a Vegetation Resources Inventory (VRI) Phase II program in the Prince George (PG) Forest District. In 2000, 109 VRI Phase II plots were established in the PG Forest District (projects 0241 and 024S). Sixty-six (66) of these plots are in our 2006 target population, in stands less likely to be impacted by Mountain Pine Beetle (MPB). We selected 20 of these plots for re-measurement and 130 new plot locations. Our objective is to use all 196 plots available (20 measured in both 2000 and 2006, 46 measured only in 2000, 130 measured only in 2006) to build the most efficient ratio-of-means estimator possible.

The situation in the PG Forest District is not becoming uncommon. In the past, we used VRI plots that had been sampled over two or three years and assumed that they had all been sampled in the same year. A seven-year time span between plots and a major insect infestation make the usual method not appropriate in PG. On the other hand, ignoring the 2000 plots seemed to be a waste of information. The approach we proposed in the sample plan was to re-measure some of the 2000 plots to project the 2000 plots to 2006, and use the augmented pool of plots to compute the adjustment ratios and the associated sampling errors.

This novel approach makes sense only if there is a strong correlation between the 2000 and 2006 measurements. For that reason, only plots in stands with less than 30% of the volume in lodgepole pin (Pl) were re-sampled. Poor correlation was expected in stands with more than 30% Pl, due to the MPB outbreak. The ratio estimator and sampling error in these stands will be estimated using the standard method.

Default Position

The simplest estimator would be the compute the ratio of means based on the 150 plots measured in 2006 and ignore older plots. The advantage of the default position is that it is very simple since it follows all the current standards. The disadvantage however is that it ignores 46 plots that could improve the precision we get for the ratio-of-means.

Proposed Solution

The solution we are proposing is a ratio of means based on all 196 plots. It makes use of the theory on sampling on two occasions as described by Cochran (1977)14 (pages 346 and 347), the total estimator for cluster sampling with unequal probabilities with replacement (Cochran [1977], equation [9A.7] page 252 and equation [9A.16] page 254), and the variance of the combined ratio estimator in the MoFR standards for attribute adjustment (equation [10], page 29).15

Notation

Cochran describes sampling on two occasions based on a simple random sampling (SRS) design. We adapted Cochran's estimator to the random sampling with unequal probability (RSUP) design. We also adapted Cochran's estimator to be used within a ratio-of-means estimator (ROM).

To simplify the notation in this memo, the stratum subscript was eliminated. All variables and estimators are assumed to be within stratum h. The proposed RSUP total estimator applies to Phase II estimates only since Phase I estimates can be obtained from VDYP for both 2000 and 2006.

In these definitions, "type" means either matched (m), first-time only (f), or second-time only (s).

m_j	number of polygons sampled at time 1 and at time 2 in sub-stratum j (matched polygons, 20 in our case)
f_j	number of polygons sampled at time 1 only in sub-stratum j (first time only, 46 in our case)
s_j	number of polygons sampled at time 2 only in sub-stratum j (second time only, 130 in our case)
u_{jl}	number of observations within polygon l in sub-stratum j (usually 1 for VRI)
y_{jtkli}	i^{th} observation in polygon I, type k, in sub-stratum j at time t
Y_{jtkl}	total for polygon l, type k, in sub-stratum j at time t
Y_{jtk}	total for all k polygons in sub-stratum j at time t
Y_{jt}	overall total in sub-stratum j at time t
A_j	area for sub-stratum j
a_{jl}	area of polygon l in sub-stratum j

14 Cochran, W.G. 1977. Sampling Techniques. Third Edition. John Wiley & Sons, New York. 428 pp.

15 BC Ministry of Sustainable Resources Management. Vegetation Resources Inventory – Procedures and standards for data analysis attribute adjustment and implementation of adjustment in a corporate database. Version 2. Victoria, BC, March 2004. 77 pp.

z_{jl} selection probability of the polygon l in the sub-stratum j ($z_{jl} = a_{jl} / A_j$)

J total number of sub-strata

Ratio of Means Estimator

The total for polygon l in sub-stratum j at time t, for any type k, is estimated as:

[1] $$Y_{jtkli} = y_{jtkli} \times a_{jl}$$

Equation [1] is simply the observation times the area of the polygon it comes from.

The point estimate for the polygons sampled at Time 2 only can be expressed as (equation [9A.7] in Cochran):

[2] $$Y_{j2s}' = Y_{j2s} = \frac{1}{s_j} \sum_{l=1}^{s_j} \sum_{i=1}^{u_{jl}} \frac{Y_{j2sli}}{z_{jl}}$$

The variance estimator for Y_{j2s} is based on the variance of all observations at time 2 (equation [9A.16] in Cochran):

[3] $$Y_{j2} = \frac{1}{(s_j + m_j)} \left[\sum_{l=1}^{m_j} \frac{Y_{j2ml}}{z_{jl}} + \sum_{l=1}^{s_j} \frac{Y_{j2sl}}{z_{jl}} \right]$$

[4] $$v(Y_{j2}) = \frac{1}{(m_j + s_j - 1)} \left[\sum_{l=1}^{m_j} \left[\frac{Y_{j2ml}}{z_{jl}} - Y_{j2} \right]^2 + \sum_{l=1}^{s_j} \left[\frac{Y_{j2sl}}{z_{jl}} - Y_{j2} \right]^2 \right]$$

[5] $$v(Y_{j2s}') = \frac{v(Y_{j2})}{s_j}$$

The variable $v(Y_{j2})$ is the same as S_2^2 in Table 12.1 in Cochran (page 346).

The point estimate at time 2 for the polygons sampled at time 1 and time 2 can be derived with the following expression:

[6] $$Y_{j1m} = \frac{1}{m_j} \sum_{l=1}^{m_j} \frac{Y_{j1ml}}{z_{jl}}$$

[7] $$Y_{j2m} = \frac{1}{m_j} \sum_{l=1}^{m_j} \frac{Y_{j2ml}}{z_{jl}}$$

[8]
$$b_{jy} = \frac{\sum_{l=1}^{m_j}\left[\frac{Y_{j1ml}}{z_{jl}} - Y_{j1m}\right]\left[\frac{Y_{j2ml}}{z_{jl}} - Y_{j2m}\right]}{\sum_{l=1}^{m_j}\left[\frac{Y_{j1ml}}{z_{jl}} - Y_{j1m}\right]^2}$$

[9]
$$Y_{j1} = \frac{1}{\left(f_j + m_j\right)}\left[\sum_{l=1}^{m_j}\frac{Y_{j2ml}}{z_{jl}} + \sum_{l=1}^{f_j}\frac{Y_{j2fl}}{z_{jl}}\right]$$

[10]
$$Y_{j2m}{}' = Y_{j2m} + b_{jy}\left[Y_{j1} - Y_{j1m}\right]$$

Equation [8] is the weighted least squares estimates of the slope between the observations at Time 1 and Time 2. It can be derived from Cochran's equation [9A.16]. Equation [10] is similar to the estimate $\bar{y}'_{2m}$ in Table 12.1 in Cochran (page 346). The only minor difference is that Cochran works with averages because he assumes that simple random sampling is used while we are using totals because of our sample selection is based on probability proportional to size with replacement.

The variance estimator for $Y_{j2m}{}'$ is:

[11]
$$\rho_{jy} = \frac{\sum_{l=1}^{m_j}\left[\frac{Y_{j1ml}}{z_{jl}} - Y_{j1m}\right]\left[\frac{Y_{j2ml}}{z_{jl}} - Y_{j2m}\right]}{\sqrt{\sum_{l=1}^{m_j}\left[\frac{Y_{j1ml}}{z_{jl}} - Y_{j1m}\right]^2\sum_{i=1}^{m_j}\left[\frac{Y_{j2ml}}{z_{jl}} - Y_{j2m}\right]^2}}$$

[12]
$$v(Y_{j2m}{}') = \frac{v\left(Y_{j2}\right)\times\left(1-\rho_{jy}^2\right)}{m_j} + \frac{v\left(Y_{j2}\right)\times\rho_{jy}^2}{\left(m_j + f_j\right)}$$

Equation [11] is the weighted coefficient of correlation and can be derived from Cochran's equation [9A.16]. Equation [12] is the variance estimator for the matched samples in Table 12.1 in Cochran (p. 346). Cochran assumes that the same sample size is taken at time 1 and time 2, which he expresses as *n*. It is clear however that, in equation [12], he means the sample size at time 1.

Cochran define the following quantities based on the inverse of the variance (p. 346):

[13]
$$W_{j2s} = \frac{1}{v(Y_{j2s}{}')}$$

[14]
$$W_{j2m} = \frac{1}{v(Y_{j2m}{}')}$$

[15] $$\phi_{j2} = \frac{W_{j2s}}{W_{j2s} + W_{j2m}}$$

We can define the total estimate at time 2 using all samples as well as the variance of this estimator is:

[16] $$Y_{j2}^{'} = \varphi_{j2} Y_{j2s}^{'} + \left(1 - \varphi_{j2}\right) Y_{j2m}^{'}$$

Equation [16] is the same as equation [12.73] in Cochran, page 346.

The overall total at time 2 can then be expressed as:

[17] $$Y_{2}^{'} = \sum_{j=1}^{J} Y_{j2}^{'}$$

The Phase I overall total estimate at time 2 (X_2) can easily be obtained using:

[18] $$X_2 = \sum_{j=1}^{J} \frac{1}{\left(f_j + m_j + s_j\right)} \left[\sum_{l=1}^{f_j} \sum_{i=1}^{u_{jl}} \frac{x_{j2fli} \times a_{jl}}{z_{jl}} + \sum_{l=1}^{m_j} \sum_{i=1}^{u_{jl}} \frac{x_{j2mli} \times a_{jl}}{z_{jl}} + \sum_{l=1}^{s_j} \sum_{i=1}^{u_{jl}} \frac{x_{j2sli} \times a_{jl}}{z_{jl}} \right]$$

The total Phase I at time 2 is therefore easily estimated using the standard formula. The ratio of means estimator when partial replacement is used is then equation [17] divided by equation [18]:

[19] $$R_{2}^{'} = \frac{Y_{2}^{'}}{X_2}$$

Variance of the Ratio-of-Means

Cochran provides the variance of its ratio of means estimator (bottom of page 346) as:

[20] $$v\left(Y_{j2}^{'}\right) = \frac{1}{W_{j2s} + W_{j2n}}$$

Equation [20] can be re-written as:

[21] $$v\left(Y_{j2}^{'}\right) = v\left(Y_{j2}\right) \times \frac{\left(f_j + m_j - f_j \rho_{jy}^2\right)}{\left[f_j s_j + m_j s_j - \rho_{jy}^2 f_j s_j + f_j m_j + m_j^2\right]}$$

This result indicates that the variance of the total estimate when partial replacement is used is the variance of the observations divided by a number of observations varying between $m_j + s_j$ (the number of observations at time

2) when the correlation is 0, and $m_j + f_j + s_j$ (the total number of observations) when the correlation is 1. This result is totally intuitive.

Defining the following variable:

[22] $$c_{jy} = \frac{\left[f_j s_j + m_j s_j - \rho_{jy}^2 f_j s_j + f_j m_j + m_j^2\right]}{\left(f_j + m_j - f_j \rho_{jy}^2\right)}$$

equation [21] can be rewritten in the more familiar form:

[23] $$v\left(Y_{j2}{}'\right) = \frac{v\left(Y_{j2}\right)}{c_{jy}}$$

leading to the variance of total estimate at time 2:

[24] $$v\left(Y_2{}'\right) = \sum_{j=1}^{J} \frac{v\left(Y_{j2}\right)}{c_{jy}}$$

The variance of the ratio of means estimator can be written in a similar form:

[25] $$v\left(R_2{}'\right) = \frac{1}{X_2^2} \times \sum_{j=1}^{J} \frac{v\left(e_{j2}{}'\right)}{c_{jR}}$$

where $e_{j2}{}'$ is the difference between Phase 2 and Phase I multiplied by the ratio of means.

The variable $v\left(R_2{}'\right)$ is the variance of the ratio of means, estimated using all observations at Time 2, multiplied by the number of observations used to calculate that variance. The equation can be written as:

[26] $$e_{j2kl}{}' = Y_{j2kl} - R_2{}' X_{j2kl}$$

[27] $$e_{j2}{}' = \frac{1}{\left(m_j + s_j\right)}\left[\sum_{l=1}^{m_j} \frac{e_{j2ml}{}'}{z_{jl}} + \sum_{l=1}^{s_j} \frac{e_{j2ml}{}'}{z_{jl}}\right]$$

[28] $$v\left(e_{j2}{}'\right) = \frac{1}{\left(m_j + s_j - 1\right)}\left[\sum_{l=1}^{m_j}\left(\frac{e_{j2ml}{}'}{z_{jl}} - e_{j2}{}'\right)^2 + \sum_{l=1}^{s_j}\left(\frac{e_{j2sl}{}'}{z_{jl}} - e_{j2}{}'\right)^2\right]$$

Equation [28] is similar to the term inside the summation of equation [10], page 29 in the MoFR standards. The only difference is the ratio of means estimator presented here in equation [19] was used to define the residuals (in equation [26]) instead of using the combined ratio proposed in the MoFR standards.

A coefficient of correlation needs to be computed to estimate the denominator in equation [25]. In the ratio of means situation, this coefficient of correlation must be computed using the residuals at Time 1 and those at Time 2, based on the matched samples. This means that the coefficients of correlation can be computed using the standard estimators:

[29] $$R_{jt} = \frac{\sum_{l=1}^{m} \frac{Y_{jtml}}{z_{jl}}}{\sum_{l=1}^{m} \frac{X_{jtml}}{z_{jl}}}$$

[30] $$e_{jtml} = Y_{jtml} - R_{jt} X_{jtml}$$

[31] $$\rho_{jR} = \frac{\sum_{i=1}^{m_j} \left[\frac{e_{j1ml}}{z_{ji}} \right] \left[\frac{e_{j2ml}}{z_{ji}} \right]}{\sqrt{\sum_{i=1}^{m_j} \left[\frac{e_{j1ml}}{z_{ji}} \right]^2 \sum_{i=1}^{m_j} \left[\frac{e_{j2ml}}{z_{ji}} \right]^2}}$$

This allows us to write the denominator for the variance estimator as:

[32] $$c_{jR} = \frac{\left[f_j s_j + m_j s_j - \rho_{jR}^2 f_j s_j + f_j m_j + m_j^2 \right]}{\left(f_j + m_j - f_j \rho_{jR}^2 \right)}$$

Using equation [25], [28], and [32], the variance of the ratio of means can be expressed in a form similar to the form used in the MoFR standards:

[33] $$v\left(R_2^{'}\right) = \frac{1}{X_2^2} \times \sum_{j=1}^{J} \left\{ \frac{1}{c_{jR}} \times \frac{1}{\left(m_j + s_j - 1\right)} \left[\sum_{l=1}^{m_j} \left(\frac{e_{j2ml}^{'}}{z_{jl}} - e_{j2}^{'} \right)^2 + \sum_{l=1}^{s_j} \left(\frac{e_{j2sl}^{'}}{z_{jl}} - e_{j2}^{'} \right)^2 \right] \right\}$$

6. APPENDIX B: DATA ISSUES

This table documents questions and responses regarding the Prince George District VRI data that were made during the course of the analysis.

Sample #	***Issue***	***Action/Resolution***
57,149,118,59, 21 etc.	A number of data anomalies related to height and age were noted.	New compiled data was received from Timberline that resolved many of the data discrepancies.
15	Timberline: Sample harvested; replaced by 154	None required
24	Timberline: Sample harvested; replaced by 155	None required
89	Timberline: Sample harvested; replaced by 151	None required
90	Timberline: Sample replaced; replaced by 158	None required
91	Timberline: Sample replaced; replaced by 152	None required
92	Timberline: Sample replaced; replaced by 157	None required
95	Timberline: Status indicated as "sampled". However, not on Timberline's analysis list; no stratum assignment; no weight.	Sample was excluded since it appears that Timberline would be excluding sample as well.
109	Timberline: Sample replaced; replaced by 153 which was in turn replaced by 156.	None required
130	Timberline: Status indicated as "sampled". However, not on Timberline's analysis list; no stratum assignment; no weight.	Sample was excluded since it appears that Timberline would be excluding sample as well.
153	Timberline: Sampled en lieu of 109; replaced by 156	None required
151	Replacement sample; no weight provided. Strata and substrata assignment from population file; but substratum was different from original sample.	Used weight from original sample even though it was in a different substratum. For calculation of SE, this sample was put in the substratum of the original sample.
155	Replacement sample; no weight provided.	Used weight from original sample (replacement and original were in same stratum/substratum).
49	VDYP7 did not produce BA, TPH or volume (sample did not meet minimum ht/QMD)	Assign zero values for BA and volume in adjustment; assign "missing" value for TPH and sample will not contribute

		to TPH adjustment ratio.
143	VDYP7 did not produce BA, TPH or volume (sample did not meet minimum ht/QMD)	Assign zero values for BA and volume in adjustment; assign "missing" value for TPH and sample will not contribute to TPH adjustment ratio.
88	No compiled volume or spp composition at 4cm+ dbh.	Plot card comments were checked; sample appeared to have fallen in a "hole" within the treed polygon. Valid sample. Phase 2 BA/ha and volume will be zero in the adjustment; Phase 2 age, ht & tph will be recorded as "missing" and will not contribute to ratio.

7. APPENDIX C: VOLUME COMPILATION VERSION DIFFERENCES

A revised compilation of the Phase II data was provided by Timberline after the VDYP7 adjustment analysis and population adjustment had already been completed. Differences between the two versions of the compilation and the expected impact on the volume adjustment are provided below. *Note that since the analysis had already been completed and the differences were relatively small, the MFR decided not to re-do the adjustment.*

The main changes were to samples 26 and 36 where the # of plots had decreased from 5 to 4. Sample 26 also contains dead pine in the new compilation. Due to the fact that the compilation relies on a regression based on all samples, changes to these 2 samples resulted in very minor volume changes to all other samples as well.

The top line (red) in the table below shows the revised compilation value. By changing the # of plots from 5 to 4, we have increased the volumes, basal area and stems in samples 26 and 36. The volume changes that resulted in the other samples were typically <0.5 m^3/ha. The dead Pl volume in sample 26 went from 18 m^3/ha to 23 m^3/ha.

Table 1: Compilation difference for samples #26 and 36.

CLSTR_ID	UTIL	NO_PLOTS	PLOT_DED	BA_HA	vht_nw2	STEMS_HA
DPG1-0026-DO1	12.5	4	4	22.75	126.845	936.989
DPG1-0026-DO1	12.5	5	5	18.2	101.48	749.591
DPG1-0026-DO1	12.5	1	1	-4.55	-25.365	-187.398
DPG1-0036-DO1	12.5	4	4	40.5	395.835	421.195
DPG1-0036-DO1	12.5	5	5	32.4	316.668	336.956
DPG1-0036-DO1	12.5	1	1	-8.1	-79.167	-84.239

The difference, in terms of the estimated VDYP7 adjustment impact, between the two versions of the compilation is shown in Table 2.

Table 2: Volume/ha @12.5cm+ dbh utilization net DWB: VYDP7 Adjustment Impact comparison between original and revised compilation.

Original compilation				
Stratum	n	Wt'd Mean Phase 2 Vol/ha (LIVE + Dead PL)	Wt'd Mean Phase 1 Unadjusted vol/ha	Ratio of Weighted Means
Pl%<=30% - Immature	36	236.644	193.011	1.226
Pl%<=30% - Mature	81	255.913	224.948	1.138
Pl%>30%	31	270.489	332.123	0.814
Revised compilation				
Stratum	n	Wt'd Mean Phase 2 Vol/ha (LIVE + Dead PL)	Wt'd Mean Phase 1 Unadjusted vol/ha	Ratio of Weighted Means
Pl%<=30% - Immature	36	236.644	193.011	1.226
Pl%<=30% - Mature	81	256.727	224.948	**1.141**
Pl%>30%	31	271.99	332.123	**0.819**

8. APPENDIX D: INVENTORY AND GROUND ATTRIBUTES USED IN THE ADJUSTMENT

PDF version of spreadsheet to be merged into final PDF of this document

9. APPENDIX E: VDYP7 SCATTERPLOTS & RESIDUALS FOR AGE & HEIGHT (STAGE 1 ADJUSTMENT FOR VDYP7)

Fig. 1: Pl%<=30% - Immature. Phase 1 and Phase 2 age relationship. The line on the graph corresponds to the adjustment ratio.

Fig. 2: Pl%<=30% - Immature. Age residuals (Phase 2 age – adjusted Phase 1 age) vs. unadjusted Phase 1 age.

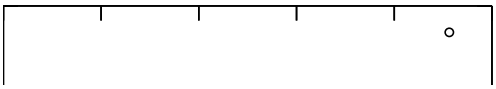


Fig. 3: Pl%<=30% - Mature. Phase 1 and Phase 2 age relationship. The line on the graph corresponds to the adjustment ratio.

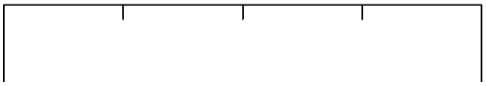


Fig. 4: Pl%<=30% - Mature. Age residuals (Phase 2 age – adjusted Phase 1 age) vs. unadjusted Phase 1 age.

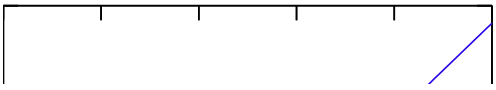


Fig. 5: Pl%>30%. Phase 1 and Phase 2 age relationship. The line on the graph corresponds to the adjustment ratio.

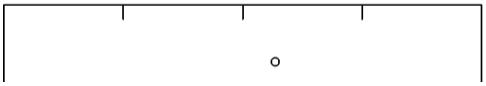


Fig. 6: Pl%>30%. Age residuals (Phase 2 age – adjusted Phase 1 age) vs. unadjusted Phase 1 age.

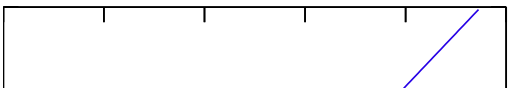


Fig. 7: Pl%<=30% - Immature. Phase 1 and Phase 2 height relationship. The line on the graph corresponds to the adjustment ratio.

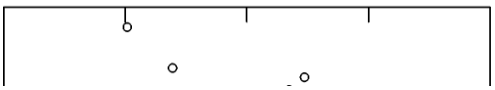


Fig. 8: Pl%<=30% - Immature. Height residuals (Phase 2 height – adjusted Phase 1 height) vs. unadjusted Phase 1 height.

Fig. 9: Pl%<=30% - Mature. Phase 1 and Phase 2 height relationship. The line on the graph corresponds to the adjustment ratio.

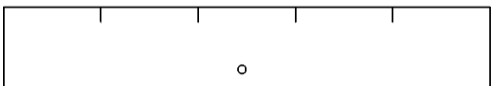


Fig. 10: Pl%<=30% - Mature. Height residuals (Phase 2 height – adjusted Phase 1 height) vs. unadjusted Phase 1 height.

Fig. 11: Pl%>30%. Phase 1 and Phase 2 height relationship. The line on the graph corresponds to the adjustment ratio.

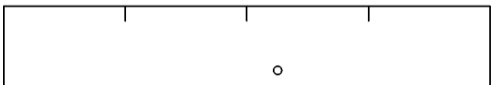


Fig. 12: Pl%>30%. Height residuals (Phase 2 height – adjusted Phase 1 height) vs. unadjusted Phase 1 height.

10. APPENDIX F: VDYP7 SCATTERPLOTS & RESIDUALS FOR BA & TPH (STAGE 1 ADJUSTMENT FOR VDYP7)

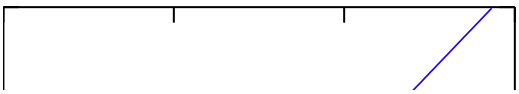


Fig. 1: Pl%<=30% - Immature. Phase 1 and Phase 2 basal area/ha (BA) relationship. The line on the graph corresponds to the adjustment ratio.

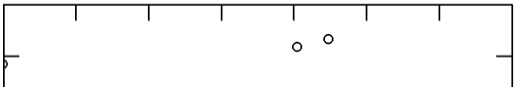


Fig. 2: Pl%<=30% - Immature. Age residuals (Phase 2 BA – adjusted Phase 1 BA) vs. unadjusted Phase 1 BA.

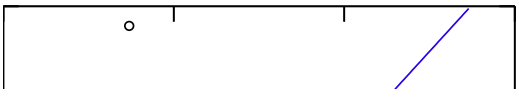


Fig. 3: Pl%<=30% - Mature. Phase 1 and Phase 2 basal area/ha relationship. The line on the graph corresponds to the adjustment ratio.

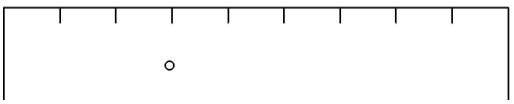


Fig. 4: Pl%<=30% - Mature. Age residuals (Phase 2 BA – adjusted Phase 1 BA) vs. unadjusted Phase 1 BA.

Fig. 5: Pl%>30%. Phase 1 and Phase 2 basal area/ha relationship. The line on the graph corresponds to the adjustment ratio.

Fig. 6: Pl%>30%. Age residuals (Phase 2 BA – adjusted Phase 1 BA) vs. unadjusted Phase 1 BA.

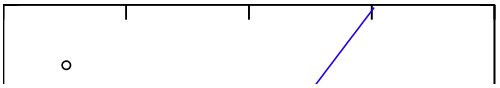


Fig. 7: Pl%<=30% - Immature. Phase 1 and Phase 2 trees/ha (TPH) relationship. The line on the graph corresponds to the adjustment ratio.

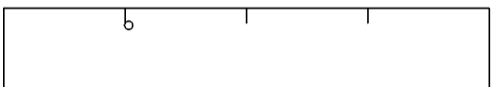


Fig. 8: Pl%<=30% - Immature. TPH residuals (Phase 2 TPH – adjusted Phase 1 TPH) vs. unadjusted Phase 1 TPH.

Fig. 9: Pl%<=30% - Mature. Phase 1 and Phase 2 TPH relationship. The line on the graph corresponds to the adjustment ratio.

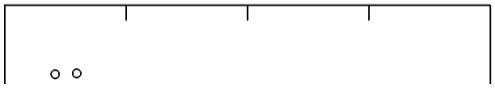


Fig. 10: Pl%<=30% - Mature. TPH residuals (Phase 2 TPH – adjusted Phase 1 TPH) vs. unadjusted Phase 1 TPH.

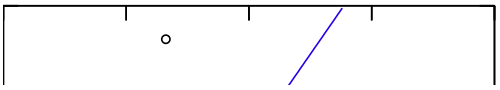


Fig. 11: Pl%>30%. Phase 1 and Phase 2 TPH relationship. The line on the graph corresponds to the adjustment ratio.

Fig. 12: Pl%>30%. TPH residuals (Phase 2 TPH – adjusted Phase 1 TPH) vs. unadjusted Phase 1 TPH.

11. APPENDIX G: VDYP7 STAGE 1 RESIDUALS AS A FUNCTION OF UNADJUSTED INVENTORY AGE

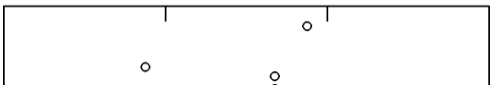


Fig. 1: Pl%<=30% - Immature. Height residuals (Phase 2 height – adjusted Phase 1 height) vs. unadjusted Phase 1 age.

Fig. 2: Pl%<=30% - Immature. BA residuals (Phase 2 BA – adjusted Phase 1 BA) vs. unadjusted Phase 1 age.

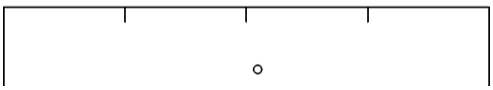


Fig. 3: Pl%<=30% - Mature. Height residuals (Phase 2 height – adjusted Phase 1 height) vs. unadjusted Phase 1 age.

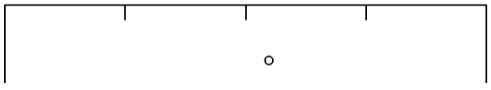


Fig. 4: Pl%<=30% - Mature. BA residuals (Phase 2 BA – adjusted Phase 1 BA) vs. unadjusted Phase 1 age.

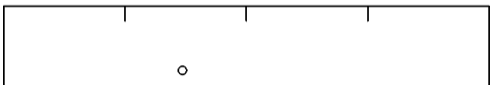


Fig. 5: Pl%>30%. Height residuals (Phase 2 height – adjusted Phase 1 height) vs. unadjusted Phase 1 age.

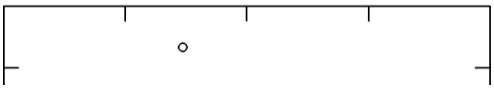


Fig. 6: Pl%>30%. BA residuals (Phase 2 BA – adjusted Phase 1 BA) vs. unadjusted Phase 1 age.

Fig. 7: Pl%<=30% - Immature. TPH residuals (Phase 2 TPH – adjusted Phase 1 TPH) vs. unadjusted Phase 1 age.

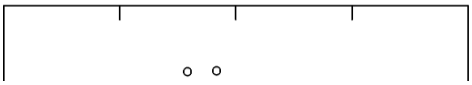


Fig. 8: Pl%<=30% - Mature. TPH residuals (Phase 2 TPH – adjusted Phase 1 TPH) vs. unadjusted Phase 1 age.

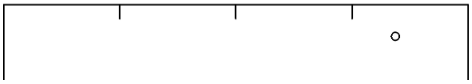


Fig. 9: Pl%>30%. TPH residuals (Phase 2 TPH – adjusted Phase 1 TPH) vs. unadjusted Phase 1 age.

12. APPENDIX H: VDYP7 SCATTERPLOTS & RESIDUALS FOR VOLUME (STAGE 2 ADJUSTMENT)

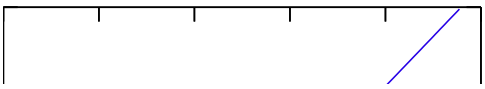


Fig. 1: Pl%<=30% - Immature. Phase 1 and Phase 2 volume relationship. The line on the graph corresponds to the adjustment ratio.

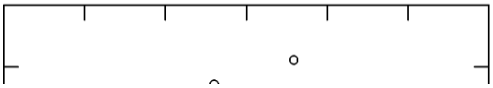


Fig. 2: Pl%<=30% - Immature. Volume residuals (Phase 2 vol/ha – adjusted Phase 1 vol/ha) vs. "attribute-adjusted" Phase 1 vol/ha.

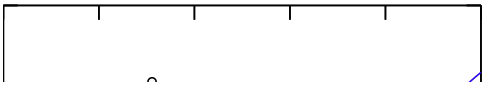


Fig. 3: Pl%<=30% - Mature. Phase 1 and Phase 2 volume relationship. The line on the graph corresponds to the adjustment ratio.

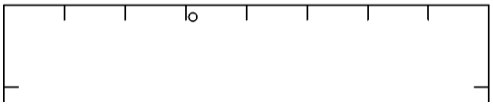


Fig. 4: Pl%<=30% - Mature. Volume residuals (Phase 2 vol/ha – adjusted Phase 1 vol/ha) vs. "attribute-adjusted" Phase 1 vol/ha.

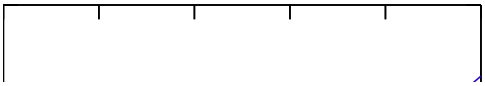


Fig. 5: Pl%>30%. Phase 1 and Phase 2 volume relationship. The line on the graph corresponds to the adjustment ratio.

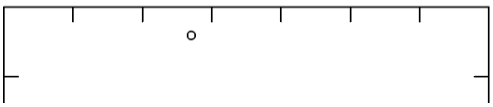


Fig. 6: Pl%>30%. Volume residuals (Phase 2 vol/ha – adjusted Phase 1 vol/ha) vs. "attribute-adjusted" Phase 1 vol/ha.

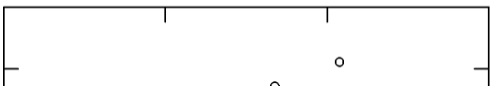


Fig. 7: Pl%<=30% - Immature. Volume residuals (Phase 2 vol/ha – adjusted Phase 1 vol/ha) vs. unadjusted Phase 1 age.

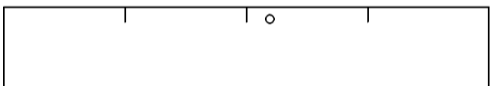


Fig. 8: Pl%<=30% - Mature. Volume residuals (Phase 2 vol/ha – adjusted Phase 1 vol/ha) vs. unadjusted Phase 1 age.

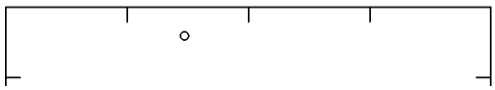


Fig. 9: Pl%>30%. Volume residuals (Phase 2 vol/ha – adjusted Phase 1 vol/ha) vs. unadjusted Phase 1 age.

13. APPENDIX I: POPULATION DISTRIBUTIONS PRE- AND POST-ADJUSTMENT

Figure 1: Age class distribution of Prince George district VT >30 yrs population of interest, pre- and post-adjustment.

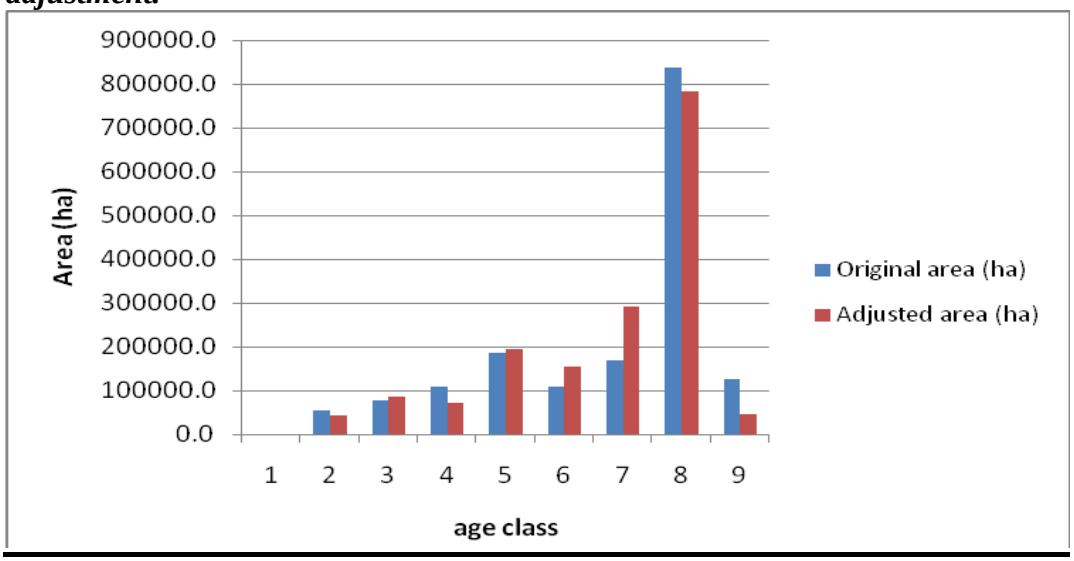


Figure 2: Average vol/ha by age class for population of interest, pre- and post-adjustment.

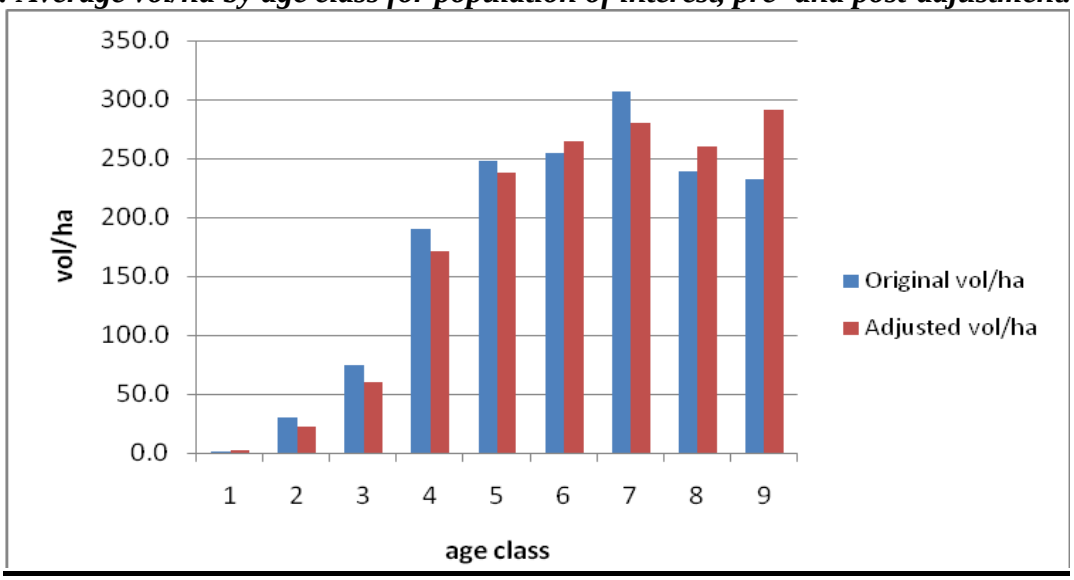


Figure 3: Total volume by age class for population of interest, pre- and post-adjustment.

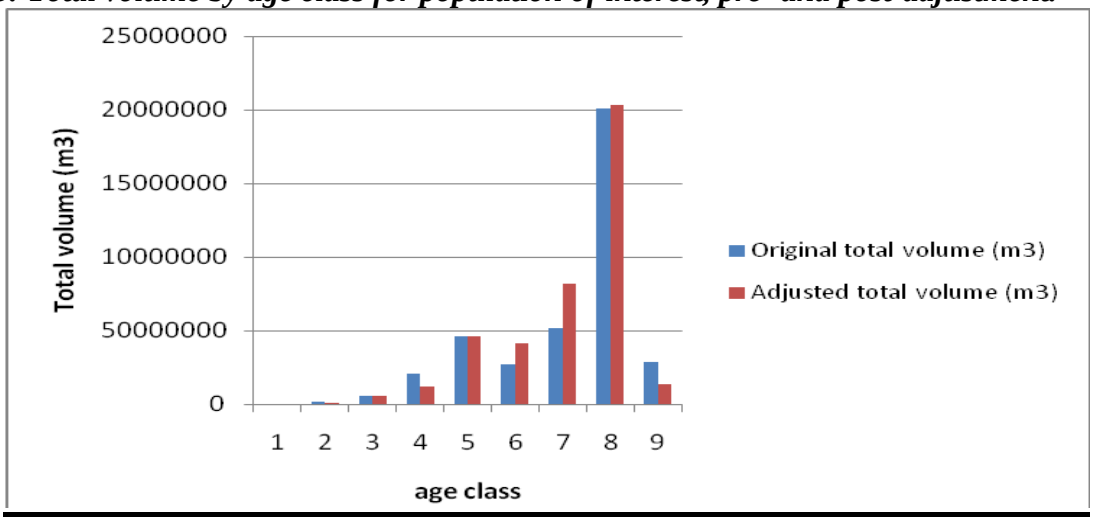
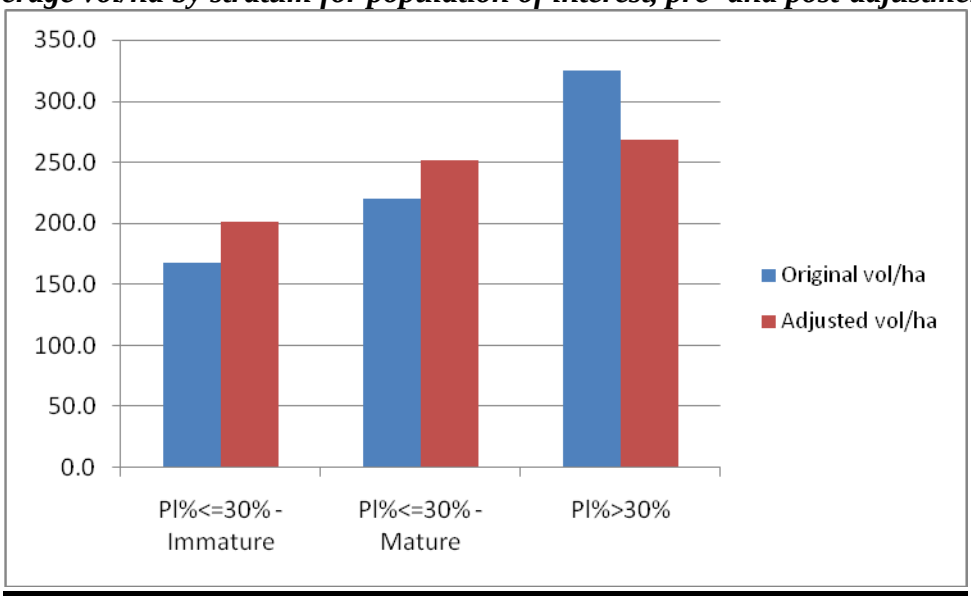


Figure 4: Average vol/ha by stratum for population of interest, pre- and post-adjustment.



14. APPENDIX G: VPIP DOCUMENT

PDF version of VPIP to be merged into final PDF of this document