Growth & Yield of Residual Balsam Stands on TFL 18

Prepared for

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Project: SGV–008

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Executive Summary

The Provincial Chief Forester identified several sources of uncertainty in the growth and yield (G&Y) information for residual balsam (Bl) stands on TFL 18 and potential impacts on timber supply forecasts. The Headwaters Forest District also expressed concern that specific treatments should be evaluated for these stands. Slocan Forest Products Ltd. subsequently designed and implemented a field sampling program to provide better information on these stands and reduce the associated uncertainty in timber supply. Tree measurements were taken from 40 locations in each of 22 polygons randomly selected from the 347 polygons classified as residual Bl stands on the TFL. This sample included 18% of the total area (8,700 ha) of these stands.

The major conclusion from the field sampling is that the current inventory and growth projection systems significantly under-estimate stand volume growth, site index, site productivity, and stand merchantability of these residual Bl stands. Current methods also under-estimate the site quality of area that were previously considered low site stands and that were excluded from the last timber supply analysis. The field sampling also showed that most stands are adequately stocked and growth is not impeded by excessive brush or conifer over-stocking.

The major recommendation from this study is that the new G&Y information be used in the timber supply analysis for the upcoming TFL management plan. The study further recommends that the area of low productivity stands excluded from the last timber supply review be included in the next analysis and any netdowns be based on site index from the site index adjustment (SIA) project. With regards to the District's concern regarding stand treatments, the study suggests that stand-level treatments do not appear warranted at this time.

Specific results from sampling the residual Bl stands include:

- Bl site index is 26% higher than indicated in the inventory (15.4 compared to 13.7 m).
- Sx site index is 17.0 m on average (there was no inventory estimate to compare).
- Species composition is virtually identical to the inventory (Bl 75%, Sx 23%, other species 2%).
- Net merchantable volume is 35% higher than the inventory (155 compared to 115 m^3/ha).
- Most area has stand volume greater than 125 m^3/ha compared to the inventory that shows less.
- About 75% of stand volume is in trees with diameters between 17.5 to 40 cm.
- The potential scaling Grade 6 component is about 25 m^3/ha and is mostly Bl.
- Stand volume growth is about 4.0 m^3/ha/year (twice that indicated by the inventory and VDYP).
- These stands contain about 4,800 trees/ha in the regeneration layer (less than 1.3 m in height).
- About 19% of the stand area is covered by brush with average height of 1-2 m.

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1. INTRODUCTION

1.1 Terms of Reference

We completed this project for Dave Dobi, *RPF* of Slocan Forest Products Ltd., Vavenby Division (Slocan). This project began in spring of 2001 and was completed in the fall of 2003 (Appendix I). The J.S.Thrower & Associates Ltd. team was Jim Thrower *PhD, RPF* (project manager), Dan Turner, *BScF, RPF* (assistant project manager), Mike Ciccotelli, *DoT (For)* (field operations supervisor and field crew leader), Scott MacKinnon, *BNRSc, FIT* (field crew leader), Guillaume Therien, *PhD* (statistical analysis), Gord Lester, *BScF, RPF* (technical support), and Ian Cameron, *MF, RPF* (technical support). We thank Dave Dobi for his endurance in keeping this project *on the rails*, and Keith Tudor, *RPF* (Ministry of Sustainable Resource Management, Victoria, BC) for his support and advice throughout this project.

1.2 The Issue

The issue addressed in this project is the general lack of understanding and information on the growth and yield (G&Y) of the residual balsam (Bl) stands on TFL 18. This issue was identified by the Ministry of Forests (MOF) Chief Forester in the AAC rationale[1] for Management Plan (MP) 9 for TFL 18 where he stated:

> *"There is uncertainty in the future volume projections, site productivity, and merchantability of the residual layer of these stands, particularly those in the low productivity stratum identified in the timber supply analysis."*

The Chief Forester stated in the AAC rationale that during the MP 9 period he expects Slocan to further investigate the G&Y and dynamics of residual Bl stands proposed to be managed as future crops on the TFL.

1.3 Project Goals & Objectives

Slocan's primary goal for this project was to address the Chief Forester's request to investigate the G&Y of residual Bl stands on the TFL for MP 10. The secondary goal was to provide information to help address the concern of the local MOF District staff that Slocan should develop specific treatment plans for these stands. The intent was that new information about the G&Y of these stands would provide clarity to how these stands should be addressed in the next timber supply analysis and what, if any, stand level treatments may be required to improve the growth of these stands.

Slocan's first step to achieve these goals was to complete a problem analysis[2] of the uncertainty related to the inventory and G&Y information for these residual Bl stands. After careful consideration of the issues and alternative approaches to address these concerns, Slocan chose to design and complete field sampling that specifically addressed these G&Y issues.

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[1] Ministry of Forests. 2000. TFL 18 rationale for allowable annual cut (AAC) determination. BC Min. For., Victoria BC. Oct. 25, 2000. 50 pp. + app. http://www.for.gov.bc.ca/tsb/tsr2/tfl/TFL18/18tfl00-Public.pdf

[2] J.S. Thrower and Associates Ltd. 2002. Problem analysis of primary growth & yield issues for residual balsam stands on TFL 18. Contract report to Slocan Forest Products Ltd., Vavenby, BC. March 28, 2002. 13 pp. + app. JST Project SGV-004.

The objectives of the field sampling was to:

1) Describe both stand- and population-level attributes.
2) Use effective and statistically-based sampling methods.
3) Estimate tree and stand attributes for basal area, gross and net volume, volume growth, diameter distribution, species composition, and site index.

Slocan decided not to use the Vegetation Resources Inventory (VRI) methods for this project because it would not reduce costs and would not provide much of the critical information needed to address the Chief Forester's issues. However, in the later stages of this project (after these methods were designed and fieldwork partially completed), the Ministry of Sustainable Resource Management (MSRM) released draft methods for *Within Polygon Variation* (WPV) sampling that were almost identical to the methods we designed and used for this project. The end result is that these methods meet or exceed almost all of the MSRM WPV standards.

1.4 Report Goals

The goals of this report are to give Slocan:

1) A summary of the sampling results.
2) A description of the analytical methods used to compile the results.
3) Interpretations on the inventory, growth, and yield results for these stands.
4) Recommendations on how to proceed with this information to help support the MP 10 timber supply analysis.
5) A technical report to submit to the MOF to support follow up action and use of this information.

2. BACKGROUND

2.1 Location

TFL 18 is located west of the town of Clearwater (about 100 km north of Kamloops) (Figure 1). The TFL is held by Slocan and administered by the Headwaters Forest District in the Southern Interior Forest Region.[3] The TFL is approximately 74,620 ha with elevation ranging from 700–1,800 m. The biogeoclimatic (BGC) zones in the TFL include the SBS, ESSF, and a small portion of ICH.

2.2 Harvesting History

The residual Bl stands on the TFL were created through the partial harvesting of spruce (Sx) leading stands from about 1945 to 1979. Most of the 8,706 ha now considered as residual Bl stands were created under intermediate utilization (IU)[4] standards in effect until the late 1960's (Figure 2). Harvesting under IU removed the larger trees in the Sx overstory leaving an understory of small Bl and Sx trees. These stands were left for natural regeneration that often resulted in a variable spatial and vertical distribution of Bl, Sx, and lodgepole pine (Pl).

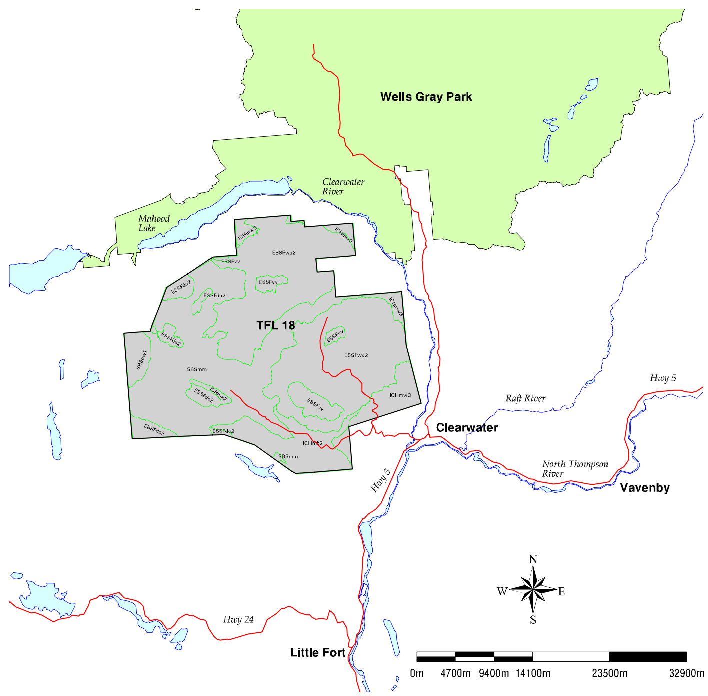

Figure 1. Location of TFL 18 near Clearwater.

Most residual Bl stands on the TFL were created from harvesting in the mid 1940s around the bush mill established near 21 km on Road 1. Some of these earliest residual Bl stands have now been harvested, others are planned for harvesting in the near future, and some are proposed old growth management areas (OGMAs). Consequently, the area of these stands and their management importance on the TFL will diminish over time as the total area of these stands is reduced through harvesting and land withdrawals.

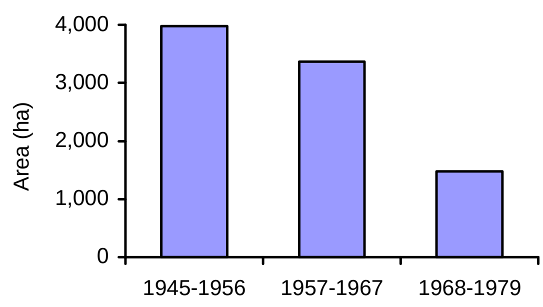

Figure 2. Area of residual Bl stands created on TFL 18 from 1945 to 1979.

2.3 General Perceptions

Many forest managers consider residual Bl stands to have low stocking, patchy spatial distribution, lower than average site productivity, and trees of poor wood quality. This perception could be based on the appearance of patchy and heterogeneous stand structure, and the low site index values on inventory files. However, recent studies show that this is often not true. Most

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[3] Formerly the Clearwater District in the Kamloops TSA within the Kamloops Forest Region.

[4] Minimum utilization specifications were an 18-inch stump, 6-inch top, and 10-inch diameter at breast height.

formal studies and anecdotal observations show that site quality in these residual stands is often higher than average and that residual and regenerating trees are growing well. However, some of these stands are highly variable and may contain under-stocked areas.

For example, preliminary studies[5] on TFL 35 near Kamloops showed the height and diameter growth of trees in residual Bl stands were much higher than expected. A more recent and detailed study on TFL 52 near Quesnel showed similar results where more than 75% of the residual Bl stands had site indices greater than 20 m.[6] The TFL 52 study also showed that most of the 11,000 ha of residual Bl stands were fully stocked and contained trees with no major defects. Field visits to TFL 18 in 2001 suggest that the conditions are similar to TFL 52 in that most residual Bl stands are fully stocked and growing on areas with reasonably high productivity (Figure 3).

Figure 3. Dave Dobi beside an open-grown Bl tree that regenerated after logging in a residual Bl stand logged about 1961. Note the long internodes between branch whorls indicating a high rate of height growth. The growth rate of this tree (site index 23 m) is common in these stands

[5] Willis, R. 1991. Growth characteristics of balsam residual stands: A retrospective study of seven balsam IU Stands on TFL 35. Weyerhaeuser Canada Ltd. Kamloops, BC. 4 pp. + app.

[6] J.S. Thrower & Associates Ltd. 2000. Management options for balsam intermediate utilization stands on TFL 52. Contract report to West Fraser Mills Ltd. Quesnel, BC. January 31, 2000. 21 pp.

3. SAMPLE DESIGN

3.1 Sample Population

The population of residual Bl stands for sampling on the TFL was 8,706 ha. This included the 1,830 ha of residual Bl stands excluded from the timber harvesting landbase (THLB) in the last Rationale for AAC Determination as a proxy for all the uncertainty associated with the residual Bl stands.

The definition[7] of these residual Bl stands was Bl or Sx leading with a history of partial cutting between 1940 and 1979.[8] Most of the area in these stands is in age classes 2, 3, 4, and 8 with most area in volume classes less than 100 m^3/ha (Figure 4).

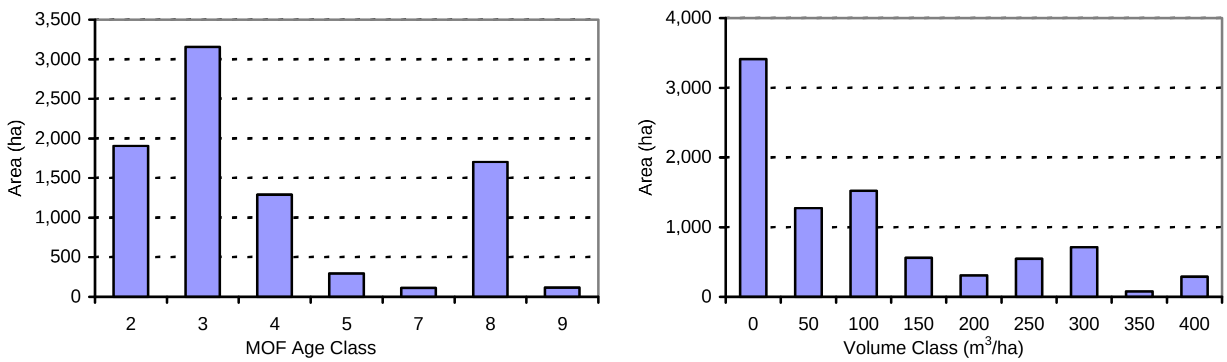

Figure 4. Distribution of residual Bl stand area by MOF age class (left) and volume class (right).

The inventory shows an area-weighted average site index of 13.5 m for these stands (88% Bl leading and 12% Sx leading) (Table 1). The recently completed SIA[9] for the TFL shows the area-weighted average site index for Sx is about 19 m.[10]

3.2 Sample Polygon Selection

We selected and sampled 22 polygons from the 347 residual Bl polygons on the TFL, with probability proportional to size (PPS) without replacement (where size is polygon area). We split the four largest polygons (329, 342, 358, and 669 ha) along forest type lines into 14 smaller polygons (averaging 121 ha) prior to selecting the sample. Four of these reduced polygons were selected in the sample.

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[7] A meeting was held Dec. 12, 2001 to discuss this project and the definition of these residual Bl stands. Attending were Max Tanner, Elia Ganderski, Abby Bates, and Ron Vander Zwan (MOF, Clearwater District), Clark Roadhouse (MOF, Kamloops Region), Dave Poole and Dave Dobi (Slocan), Gord Lester and Dan Turner (JST).

[8] The definition of residual Bl stands in the MP 9 timber supply analysis did not include partially harvested Sx-Bl leading stands from the 1970's (an additional 1,831 ha). After discussions with MOF staff, field tours, and a review of document photos from the late 1970"s, the definition was expanded to include residual Bl areas harvested in the 1970's. This resulted in a 26% more area included in the population of residual Bl stands than was used in MP 9. We believe this is the best possible representation of residual balsam stands on the TFL.

[9] J.S. Thrower & Associates Ltd. 2002. Potential site index estimates for the major commercial tree species on TFL 18. Contract report to Slocan Forest Products Ltd., Vavenby BC. March 13, 2002. 13 pp. + app.

[10] The SIA project developed estimates of potential site index for all areas less than 1,550 m in elevation. Almost 90% of the residual Bl stands (7,872 ha) are in this lower elevation area where the SIA estimates can be used for yield prediction on the TFL.

Table 1. Area (ha) of residual Bl stands by BGC label and inventory site index.

Inventory Site Index Range (m)	BGC Unit						Total	
	ESSFdc2	ESSFvv	ESSFwc2	ICHmk2	ICHmw3	SBSmm	*(ha)*	*%*
<=12			2,118	14	76	150	2,358	27
12.1 – 14	64		2,467	13	224	116	2,884	33
14.1 – 16		107	986	43	74	228	1,438	17
16.1 – 18			1,095	9	29	261	1,393	16
18.1 – 20			199	3	61	134	397	5
20.1+			152			84	236	3
Total Area (ha)	*64*	*107*	*7,017*	*82*	*464*	*972*	*8,706*	
(%)	*<1*	*<1*	*81*	*1*	*5*	*11*		

3.3 Sample Plots

Tree and vegetation attributes were measured from 40 sample points in each sample polygon. The sample plots were located in each polygon on a systematic north-south grid on 25 m intervals (using North American Datum [NAD] 83 Universal Transverse Mercator [UTM] coordinates). The grid interval varied to give the same number of sample points in the polygons of different sizes. Appendix II shows an example of a sample map with plot locations.

The same number of sample plots were established in each polygon using six plot types. Some plots were located at the same points (explained in more detail later). The sample in each of the 22 polygons included:

1) 10 prism full-measure plots.
2) 30 prism count plots.
3) 20 fixed-area site index plots (100 m^2).
4) 20 fixed-area brush plots (100 m^2).
5) 10 fixed-area small tree plots (50 m^2).
6) 10 fixed-area regeneration plots (20 m^2).

3.4 Measurements

3.4.1 Overview

The samples were taken by VRI certified cruisers over a two-year period. Four polygons were sampled in July 2002 and the remaining 18 sampled in June and July 2003 (Appendix IV). Trees were selected and measured in the 22 sampled polygons using prism and fixed-area plots. The same prism angle was used for all plots in a given polygon and was selected with a target to measure 4-6 live trees/plot. Prism plots on stand edges were split using standard MOF procedures.[11] All live and dead standing trees were tallied at full-measure prism plots and live standing trees only were tallied at count plots. More details of the field measurement methods are given in the sample plan[12] and work plan.[13]

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[11] www.for.gov.bc.ca/hva/manuals/cruising

[12] J.S. Thrower and Associates Ltd. 2002. Enhancing the inventory and growth & yield of residual balsam stands on TFL 18. Sample plan. Contract report to Slocan Forest Products Ltd., Vavenby BC. March 28, 2002. 8 pp. + app. JST Contract SGV-004.

3.4.2 Prism full-measure plots

- 10 plots located at every fourth sample point.
- All live and dead standing trees ≥12.5 cm measured.
- Height and diameter at breast height (DBH) measured for of all live and dead trees.
- Pathological indicators recorded for all trees.
- Vegetation Resources Inventory (VRI) net factors recorded for all trees (from a sample of plots located in year 2 of the sampling).
- Diameter growth measured from increment cores taken on all live standing trees.[14]

3.4.3 Prism count plots

- 30 plots located at points where full-measure plots were not located.
- All live standing trees ≥12.5 cm measured (excluding tree class 4 and 6).
- Species recorded and DBH visually estimated.[15]

3.4.4 Site index plots

- 100 m^2 fixed area plot.
- 20 plots located at each full-measure plot, and every other count plot.
- Measured height, DBH, and breast height age of Sx, Bl, and Pl site trees.[16]

3.4.5 Brush plots

- 100 m^2 fixed area plot.
- 20 plots located at each full-measure plot, and every other count plot.
- Visually estimated average height and cover percentage of the three leading brush species over 1.3 m tall.

3.4.6 Small tree plots

- 50 m^2 fixed area plot.
- 10 plots located in each sampled polygon.
- Located at each full-measure plot.
- Recorded species, estimated height, and estimated DBH[17] of trees ≤ 12.5 cm DBH.
- Measurements recorded by plot quadrant in the 2003 samples.

3.4.7 Regeneration plots

- 20 m^2 fixed area plot.
- 10 plots located in each sampled polygon.
- Located at each full-measure plot.
- Visually estimated height of trees ≤ 1.3 m tall (by plot quadrant).

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[13] J.S. Thrower and Associates Ltd. 2002. Growth & yield sampling in residual balsam stands on TFL 18: Work plan. Contract report to Slocan Forest Products Ltd., Vavenby BC. June 26, 2002. 5 pp. + app. JST Contract SGV-005.

[14] Diameter increment was measured in the lab using a Velmex measuring machine (www.velmex.com). The intent was to estimate basal area growth over the last few decades, thus it was not important to hit the tree pith.

[15] Visual estimates of tree diameter were adjusted to remove bias using a ratio developed between measured and estimated diameters taken in the full-measure plots. This is explained in more detail later in this report.

[16] Site trees were defined using the MOF SIBEC definition. We also took measurements for trees that did not meet the MOF definition, but that we considered to provide good estimates of site potential. These trees were noted accordingly.

[17] DBH was adjusted using the correction ratio computed in full-measure plots.

4. COMPILATION

4.1 Species Composition

Species composition was estimated in each polygon using the basal area (BA) of trees from the 40 prism plots in each polygon. The species composition was described using the MOF timber supply analysis merchantability limit of 17.5 cm DBH and to a 12.5 cm DBH limit. The smaller 12.5 cm DBH limit was included to estimate the potential amount of Grade 6 wood[18] that may be in these stands, and to estimate future species composition of these stands after the Bl and Sx trees grow into the 17.5 cm DBH class.

4.2 Height

The height of each polygon was estimated using the average height of the largest diameter tree in each of the 10 full-measure plots. This was used as a reasonable approximation of the height given in the inventory to compare with the sample average.

4.3 Site Index

Polygon site index was estimated as the average of the site trees measured in the 20 site index plots. The site index for each species was estimated using only MOF approved site trees, and using other tree ("O" trees) that we considered to reflect site potential (but that did not meet all MOF criteria).[19]

4.4 Volume Yield

The gross volume of each sample stand was estimated using the basal and VBAR (volume-basal area ratio) from the full-measure and count prism plots. The net merchantable volume was estimated using the MOF appraisal cruising risk groups and loss factors using both 12.5 cm and 17.5 cm DBH limits.[20]

4.5 Volume Growth

The stand periodic annual increment (PAI) for net merchantable volume was estimated in five-year periods for the last 20 years. This was done for each tree in the full-measure prism plots using VBARs and the BA of trees at time of sampling and backdated using the increment cores. The previous years' VBAR was estimated for each sampled polygon using a VBAR – DBH relationship developed from full measured trees.[21] For each year, a polygon-level VBAR was predicted using the estimated quadratic mean diameter and VBAR-DBH relationship. Volume for every tree within a plot was estimated using the backdated basal area of the tree and the polygon-level VBAR.

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[18] Logs scaled as Grade 6 are smaller than the merchantability limit in the cutting authority and are assessed at a lower stumpage rate.

[19] Our criteria for O site trees is less restrictive than the MOF methods thus more trees are sampled. This may give slightly lower estimates than the MOF methods in some stands, but has the advantage of giving "conservative" estimates in stands where the MOF method may not select any trees.

[20] The MSRM raised concerns in the early stages of this project that the net merchantable volume estimated using MOF appraisal cruising loss factors would not be reliable, and would introduce uncertainty in these results and their subsequent use in timber supply analysis. We thus compared the difference in net volume estimated using the loss factors and Vegetation Resources Inventory (VRI) net factor methods. The comparison showed virtually identical estimates of net volume from the two methods, thus we used the loss factor estimates that were available for all sample plots (Appendix III).

[21] The VBAR-DBH model was VBAR = a + b x LOG(DBH) where a and b were estimated for each sample polygon.

We assumed that dead trees standing at the time of our sampling were alive at previous periods, which gives a conservative estimate of stand growth over the period.

We compared the backdated stand volume growth with estimates using the inventory attributes and VDYP, and with growth expected in managed stands. The managed stand comparison used the volume growth from a 1,800 stems/ha planted Sx stand with the measured site index. The managed stand was compared for the time period backdated from a stand of the same age.

4.6 Diameter Distribution

The DBH of each tree was visually estimated in all count and full-measure plots. The DBH was then measured in the full-measure plots to compute a ratio between the estimated and measured diameters (Appendix V). This relationship was used to adjust the DBH estimates in the count plots. The DBH distribution was then compiled using the measured and adjusted DBH from all 40 (10 measured and 30 count) plots in each polygon.

4.7 Small Trees

The DBH of the small trees were adjusted using the adjustment equations developed for the large trees. Number of trees, average DBH, and average height for the main species groups (Bl, Sx, Pl, and others) were compiled by sampled polygon. Number of trees was converted to a per-ha number for reporting purposes.

4.8 Regeneration

The number of trees for the main species groups (Bl, Sx, Pl, and Others) was compiled by sampled polygon. The number of trees was converted to a per-ha number for reporting purposes.

4.9 Brush

The average percent cover of brush species was summarized by polygon. Average height was weighted by the percent cover in each plot.

5. RESULTS

5.1 Species Composition

The species composition in the inventory was very closely matched by the sample. The overall sample average species composition[22] was Bl 75%, Sx 23%, Pl 1%, and Other species 1% (cedar, hemlock, Douglas-fir, and cottonwood) (Figure 6). This species composition was the same when compiled to a 12.5 or 17.5 cm DBH limit. All 22 polygons were Bl-leading in the sample, but three of these were Sx-leading in the inventory (Figure 5). The species composition of individual polygons differed up to 10%.

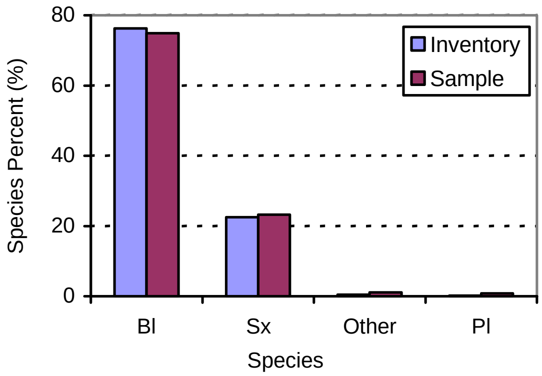

Figure 6. Average species composition of the 22 sampled residual Bl polygons TFL 18.

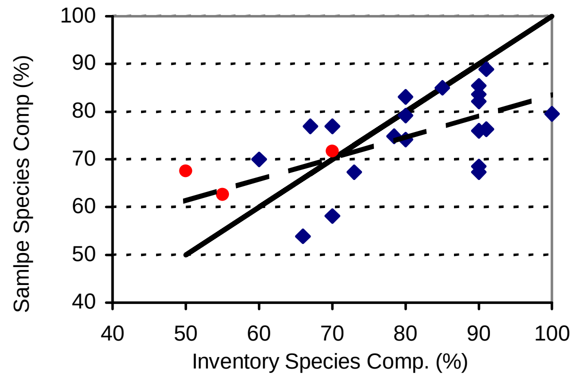

Figure 5. Percent of the leading species in the inventory and sample for the 22 polygons. Red dots indicate Sx-leading polygons in the inventory. Solid line shows perfect relationship between the ground and inventory estimates. Dashed line shows actual relationship.

5.2 Height

The overall average height of the 22 sample polygons was about 25% taller than the inventory (20.4 m [± 13.7 m][23] compared to 15.7 in the inventory), but showed almost no relationship with the inventory estimates (Figure 7).

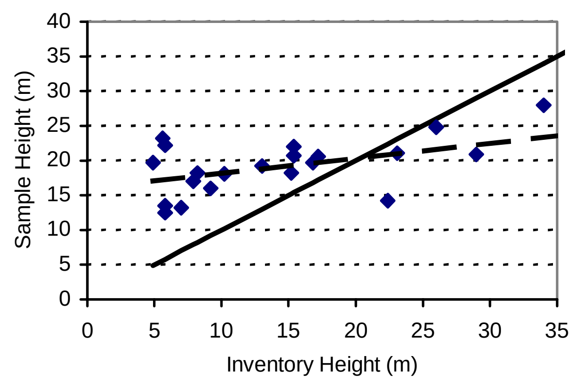

Figure 7. Average polygon height for the sample and the inventory for the 22 residual Pl polygons. Solid line shows perfect relationship between the ground and inventory estimates. Dashed line shows actual relationship.

5.3 Site Index

The average Bl site index increased 1.7 m (14%) to 15.4 m (± 2.5 m) in the sample from 13.7 m in the inventory. The sample estimate decreased to 14.7 m (± 0.9 m) when O trees were included. Suitable MOF site trees were sampled in 13 polygons and in all 22 polygons for O trees.

The average Sx site index was 17.0 m (± 1.4 m) using MOF criteria (estimates in 20 polygons). The estimate decreased to 16.1 m (± 1.1 m) with O trees

[22] The average basal area and 95% confidence interval was 28.2 ± 3.4 m^2/ha for trees larger than 12.5 cm DBH and 24.1 ± 3.5 m^2/ha for trees larger than 17.5 cm DBH.

[23] Indicates 95% confidence interval.

(estimates in all 22 polygons). The SIA project estimated the potential site index for Sx in stands below 1,600 m as 19.0 m; this is probably a better indication of the growth expected after these stands are harvested and replaced with Sx trees. The difference between the sample and inventory estimates of Sx site indices was largest in stands with the lowest inventory site indices, and was similar for stands with the highest indexes (Figure 8). This trend where site index is under-estimated in lower site stands is also common in Pl stands.

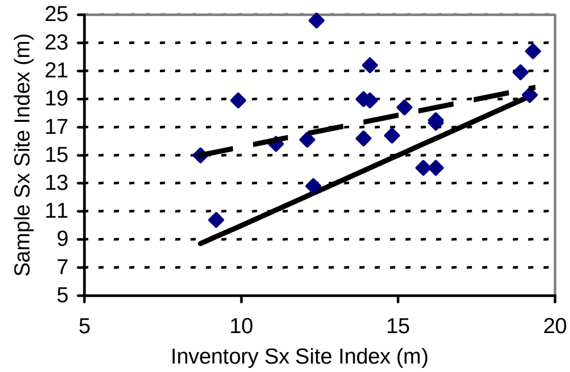

Figure 8. Sample Sx site index versus inventory site index in Bl IU stands on TFL 18. Solid line shows perfect relationship between sample and inventory estimates. Dashed line shows actual relationship.

The Sx site index was always higher in a given polygon than Bl. This could reflect the faster growth for Sx trees, or could result from under-estimating site productivity from the Bl trees selected in these residual stands. Thus, site productivity is probably better characterized by the Sx estimates.

5.4 Volume Yield

The sample showed 163 m^3/ha (± 34 m^3/ha) of gross volume and 155 m^3/ha (± 33 m^3/ha) net merchantable volume (17.5 cm DBH limit) sample compared to 115 m^3/ha of net merchantable volume in the inventory (35% more in the sample). Most of the residual Bl stands are in the 150 m^3/ha class, where the inventory shows most area in lower volume classes (Figure 9).

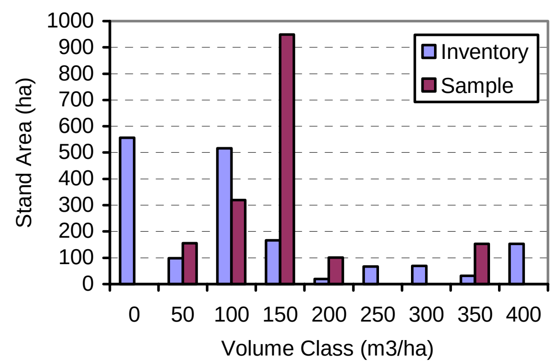

Figure 9. Distribution of stand volume from the inventory and the 22 sampled polygons. Sample area total is 1,678 ha.

Stand volume was in the 20 cm DBH class (Figure 10). The distribution of the volume shows the traditional inverse-J shape where most is in the lower diameter classes. The majority of volume is Bl in

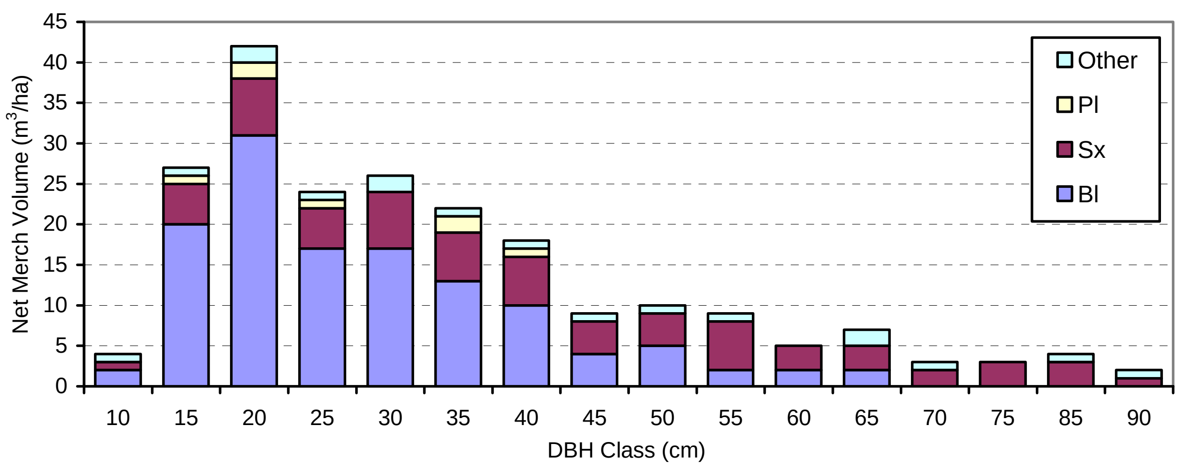

Figure 10. Distribution of net merchantable volume by DBH class for the 22 sample polygons.

DBH classes less than about 40 cm, with the proportion of Sx increasing in larger trees. The largest trees are Sx with no Bl larger than about 65 cm. This distribution shows that the Grade 6 component could be 25 m^3/ha of mostly Bl trees (indicated by the 15 cm DBH class).

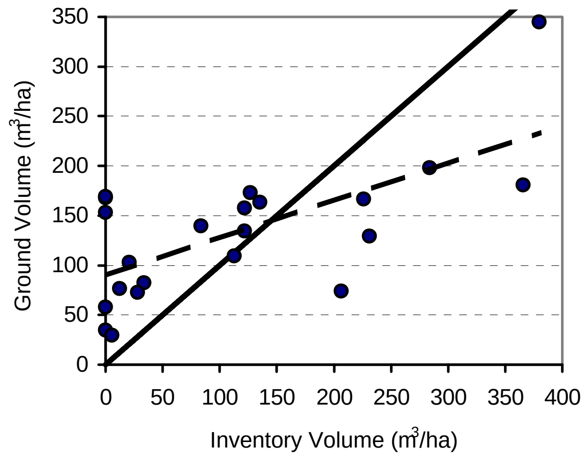

Figure 11. Ground and inventory volume for the 22 sampled polygons. Solid line shows perfect relationship between sample and inventory estimates. Dashed line shows actual relationship.

The sample showed that inventory polygons indicating volumes less than 150 m^3/ha had more volume on the ground (Figure 11). Conversely, inventory polygons with higher volume showed less volume on the ground.

The higher sample volume in stands with the lower inventory volume probably reflects higher growth rates in these stands than predicted with VDYP. Growing space not occupied in these stands when the inventory was done may have subsequently been occupied and are now contributing significantly to stand growth and yield. This additional growth would result from trees regenerating in these stands and the higher growth rates on residual trees. The lower sample volume in stands with higher inventory volumes could reflect mortality that has occurred since the inventory was completed.

5.5 Volume Growth

The sample showed an average volume PAI (net merchantable volume) of 4.2 m^3/ha/yr over the last 20 years. This growth rate is double the average of 1.9 m^3/ha/yr shown by VDYP over the same period (Table 2). The PAI predicted using TIPSY over the same period was similar, but marginally lower than the sample estimate. This suggests that the site indices estimated in these stands is consistent with observed volume growth. The difference between the sample and TIPSY estimates for periods longer than 10 years is expected since the backdating method over-predicts growth (under-estimates volume in trees that do not survive).

Table 2. Sample, VDYP, and TIPSY PAI (m^3/ha/yr) by 5-year periods for the last 20 years.

Backdate Period (yrs)	Calendar Year Period	VDYPI	Sample			TIPSY		
		PAI	PAI	Difference from VDYP		PAI	Difference from Sample	
5	2003-1999	2.1	4.0	1.9	90%	4.1	0.1	5%
10	1998-1994	1.9	4.2	2.3	121%	3.9	-0.3	-15%
15	1993-1989	1.9	4.2	2.3	121%	3.5	-0.7	-35%
20	1988-1984	1.8	4.1	2.3	127%	3.3	-0.8	-42%
Average		1.9	4.2	2.3	121%	3.7	-0.4	-20%

5.6 Diameter Distribution

The overall average density of these stands was 4,012 trees/ha when all trees greater than 1.3 m are included (small tree and prism plots). The species composition of these trees was Bl 82%, Sx 17%, Pl and 1% other species. About 80% of these trees were less than 12.5 cm DBH (almost 50% in the 5 cm

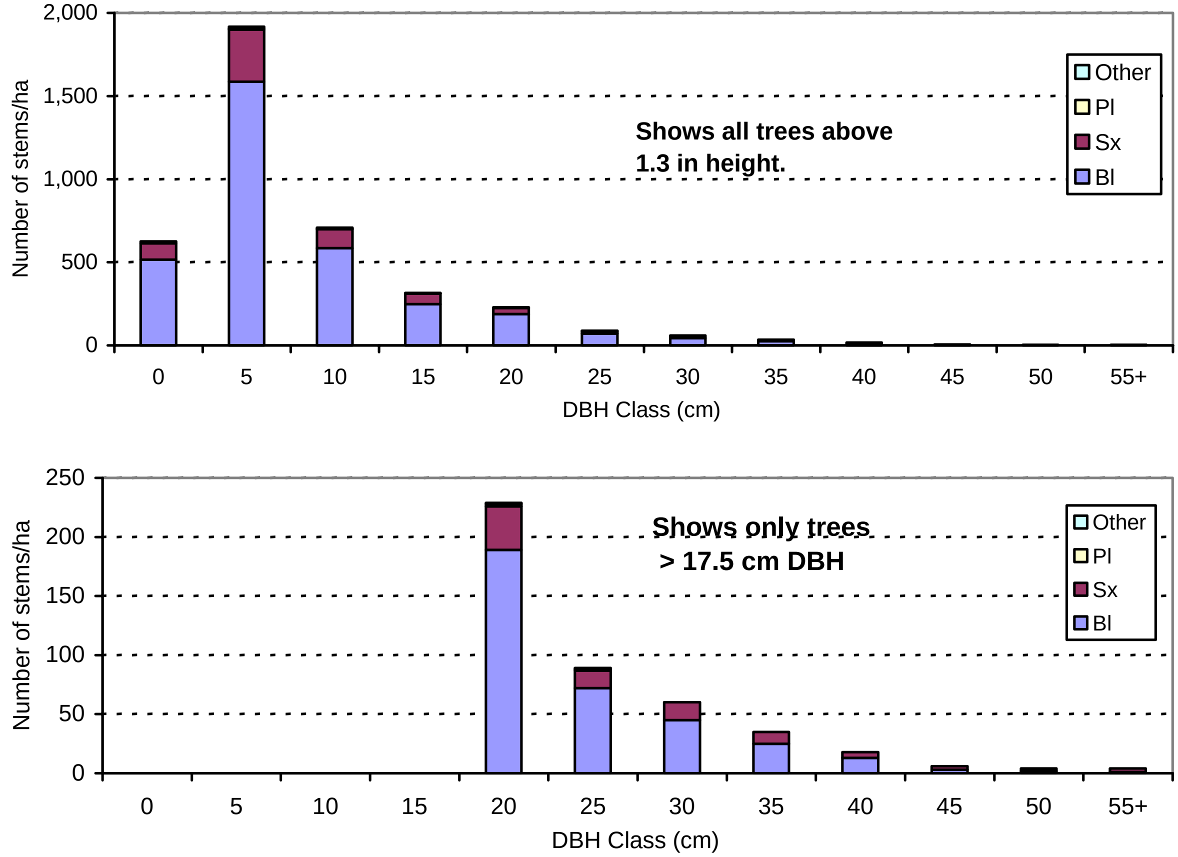

Figure 12. DBH distribution for the 22 sampled residual Bl polygons on TFL 18.

class alone) (Figure 12). About 763 trees/ha were larger than 12.5 cm and 65 trees/ha larger than 32.5 cm. The proportion of Bl trees in each DBH class decreased as diameter increased. Bl trees represent about 80-85% in DBH classes below 27.5 cm and between 50 and 75% for larger DBH classes.

5.7 Small Trees

The sample showed a significant number of small trees in these stands with about 3,250 trees/ha that are above 1.3 m and less than 12.5 cm DBH. The species composition of these trees was 83% Bl, 16% Sx, and 1% minor species.

5.8 Regeneration

The sample also showed a significant amount of smaller natural regeneration in these stands with about 4,810 trees/ha that have not yet reached breast height (1.3 m). The species composition of these trees was 87% Bl, 12% Sx, and 1% minor species.

5.9 Brush

The sample recorded 21 different brush species in the 22 polygons. The overall average brush coverage was 19% for all 22 polygons (Appendix VI). The three most important shrub species were white-flowered rhododendron (*Rhododendron albiflorum*), false azalea (*Menziesia ferruginea*), and Sitka alder (*Alnus viridis ssp. sinuata*). When present, shrub species averaged 1 to 2 m in height.

6. CONCLUSIONS & RECOMMENDATIONS

6.1 MOF Concerns

The primary goal of this project was to address the Chief Forester's request to investigate the G&Y of residual Bl stands on the TFL in preparation for MP 10, particularly related to the future volume projection, site quality, merchantability, and the low productivity stratum in these residual Bl stands. A secondary goal was to provide information to help address the concern of the MOF District staff that specific treatment plans should be developed for these stands.

6.1.1 Future Volume Projection

The primary conclusions relating to future volume projections are:

- Stand volume growth is much higher than indicated in the inventory. The sample estimated overall stand growth (net merchantable volume) at about 4.0 m^3/ha/year. This is twice the rate indicated by VDYP using the inventory attributes. We do not know how long this rate will persist; however, this study clearly shows that stand growth is dramatically higher than projected with current methods.
- Stand growth will be dramatically under-estimated if projected using VDYP and the current inventory attributes.

We therefore recommend that:

- The growth of these residual Bl stands not be projected with VDYP and current inventory attributes.
- New growth curves be developed for these stands for the next timber supply analysis. These curves could be generated with VDYP and inventory attributes modified to better reflect the G&Y results of this study, or with Prognosis and stand and stock tables from this study.

6.1.2 Site Quality

The primary conclusions relating to site quality are:

- The inventory site index under-estimates actual tree and stand growth. For example, the sample showed the Bl site index as 26% higher than the inventory.
- The site quality and site index of these stands is much higher than previously considered. This was also shown in the SIA project.

We therefore recommend that:

- The inventory site index is not used to project the growth of these stands. The site index must be appropriately matched with the yield projection system to give G&Y estimates that are consistent with the result of this study.
- The SIA site index is used for managed stands in the next timber supply analysis.

6.1.3 Merchantability

The primary conclusions relating to stand merchantability are:

- The inventory understates the merchantability of these stands (as indicated by net volume).
- Overall net merchantable volume is 35% higher than the inventory (155 compared to 115 m^3/ha).
- Over 70% of the residual Bl stand area has more than 125 m^3/ha.
- The potential Grade 6 volume (trees between 12.5 and 17. 5cm) is approximately 25 m^3/ha.

- Three-quarters of stand volume is in trees with diameters between 17.5 to 40 cm.
- Decay estimates are about 3% on average.

We therefore recommend that:

- Most of these stands contain enough merchantable volume to be economically harvested (given suitable market conditions).
- A scheduling model be developed to assist in prioritizing these stands for harvesting. This model should use the results of this project and other economic factors related to harvesting and milling.
- Stands be harvested as soon as possible under this scheduling model and stand productivity be increased by converting to managed stands.

6.1.4 Low Productivity Stratum

The primary conclusions relating to the low productivity stratum are:

- The area previously considered low productivity was misclassified because of inadequate inventory information.
- This and the SIA study show that the site index of these stands is much higher than indicated in the inventory.

We therefore recommend that:

- The area previously considered low productivity be included in the next timber supply analysis.
- Future net-downs for low productivity be based on site index from the SIA project.

6.1.5 Treatment Plans

The primary conclusions relating to treatment plans for these stands are:

- These results did not show any evidence that stand-level treatments are required to improve the growth of these stands.
- Most stands have adequate stocking, regeneration, and growth therefore treatments to increase growth probably cannot be justified.
- Excessive brush or stocking does not appear to be inhibiting the growth of these stands.

We therefore recommend that:

- Stand level treatments are not considered for these stands.
- These stands should not be considered differently from other natural stands on the TFL regarding stand level treatments.

6.2 Timber Supply Analysis

The primary conclusions relating to how the next timber supply analysis is conducted are:

- The THLB will be under-estimated if the low site Bl stand area is excluded.
- Overall TFL growth will be under-estimated if the growth of these residual Bl stands is predicted using VDYP and current inventory attributes.

We therefore recommend that:

- The low site area be included in the THLB.
- Further net-down for low site be based on the site index from the SIA project (not from the inventory).
- New yield curves are developed for these residual Bl stands.
- Slocan work with the MOF to consider this information for the timber supply analysis base case.
- An alternate scenario be developed to reflect this improved G&Y information if the MOF will not accept this new information in the base case.

6.3 Inventory

The primary conclusions relating to the inventory are:

- The current inventory does not adequately describe the G&Y of these stands.
- The inventory and G&Y information from this project is much better than the current inventory.

We therefore recommend that:

- The inventory for these residual Bl stands be updated.
- Slocan work with the MSRM to pilot test an adjustment of the inventory using these results.
- This information be used in any future VRI work on the TFL.

APPENDIX I – PROJECT HISTORY

This project began in the spring of 2001 and completed in the fall of 2003. The project was delayed for one full year because of the lack of clarity of the MSRM mandate to approve this project for FIA funding. A chronology of events is given below.

<u>Govt Fiscal Year 2001/02</u> (all work completed under FRBC)

- **May 2001:** Initial discussions between Slocan and JST regarding the general issue. Field trip to TFL 18 to examine some residual Bl stands on the TFL (Dave Dobi, Dave Poole, Jim Thrower, and Gord Lester).
- **Summer 2001:** Slocan awarded JST a contract to complete a problem analysis and sample plan to address the residual Bl issues on the TFL.
- **March 2002:** Problem analysis completed[24] outlining and discussing major issues related to the Chief Forester's comments on the residual Bl stands.
- **March 2002:** JST reviewed options outlined in the problem analysis to address the issue with Dave Dobi. Dave selected the approach to develop an alternate timber supply scenario.
- **March 2002:** Sample plan completed[25] detailing procedures to measure G&Y attributes in the residual Bl stands.
- **March 2002:** Sample plan reviewed by Bob MacDonald, *RPF* of the MOF Kamloops Forest Region.

<u>Govt Fiscal Year 2002/03</u> (transition to FIA from FRBC funding)

- **June 2002:** Work plan completed[26] to address comments of Bob MacDonald.
- **July 2002:** Fieldwork begins. Four polygons sampled according to work plan.
- **August 2002:** Project stopped (August 8) because MSRM would not approve FIA to fund the project. Considerable confusion in MSRM, FIA, and PriceWaterhouseCoopers (PwC) in the transition period between FRBC and FIA funding programs. Considerable confusion in MSRM and MOF mandates, working relationships, etc. in the transition period after Inventory Branch is removed from MOF and placed in MSRM.
- **July 2002 – January 2003:** Negotiations with MSRM (formerly MOF Inventory Branch) to approve field methods.
- **February 2003:** MSRM ultimately did not approve the methods.

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[24] J.S. Thrower and Associates Ltd. 2002. Problem analysis of primary growth & yield issues for residual balsam stands on TFL 18. Contract report to Slocan Forest Products Ltd., Vavenby BC. March 28, 2002. 13 pp. + app. JST project SGV-004.

[25] J.S. Thrower and Associates Ltd. 2002. Enhancing the inventory and growth & yield of residual balsam stands on TFL 18. Sample plan. Contract report to Slocan Forest Products Ltd., Vavenby BC. March 28, 2002. 8 pp. + app. JST project SGV-004.

[26] J.S. Thrower and Associates Ltd. 2002. Growth & yield sampling in residual balsam stands on TFL 18: Work plan. Contract report to Slocan Forest Products Ltd., Vavenby BC. June 26, 2002. 5 pp. + app. JST project SGV-005.

- **March 2003**: Determined by MOF that they should approve the methods for this project as the information is for application in timber supply analysis (which is under MOF mandate), and was not to update the provincial inventory (MSRM mandate).
- **March 2003:** MOF Timber Supply Branch (now Forest Analysis Branch) approved (March 4) methods in the original sample and work plans and PwC subsequently approved for FIA funding.

Govt Fiscal Year 2003/04 *(work completed under FIA)*

- **May 2003:** PwC approved the project for FIA funding based on MOF recommendations.
- **June 2003:** Field crews take EMS training from Slocan in Vavenby and continue field sampling using the methods outlined in the original work plan.
- **July 2003:** Field sampling complete with 22 residual Bl polygons measured.
- **August 2003:** Third-party quality assurance audit completed and all plots pass inspection.[27] Data analysis begins.
- **September 2003:** Analysis and final report complete (reported in this document).

[27] SJW Forestry Consulting Ltd. 2003. TFL 18 Bl IU Field Audit Report. Report prepared for Slocan Forest Products Ltd., Vavenby BC. September 11, 2003. 2 pp.

APPENDIX II – SAMPLE MAP

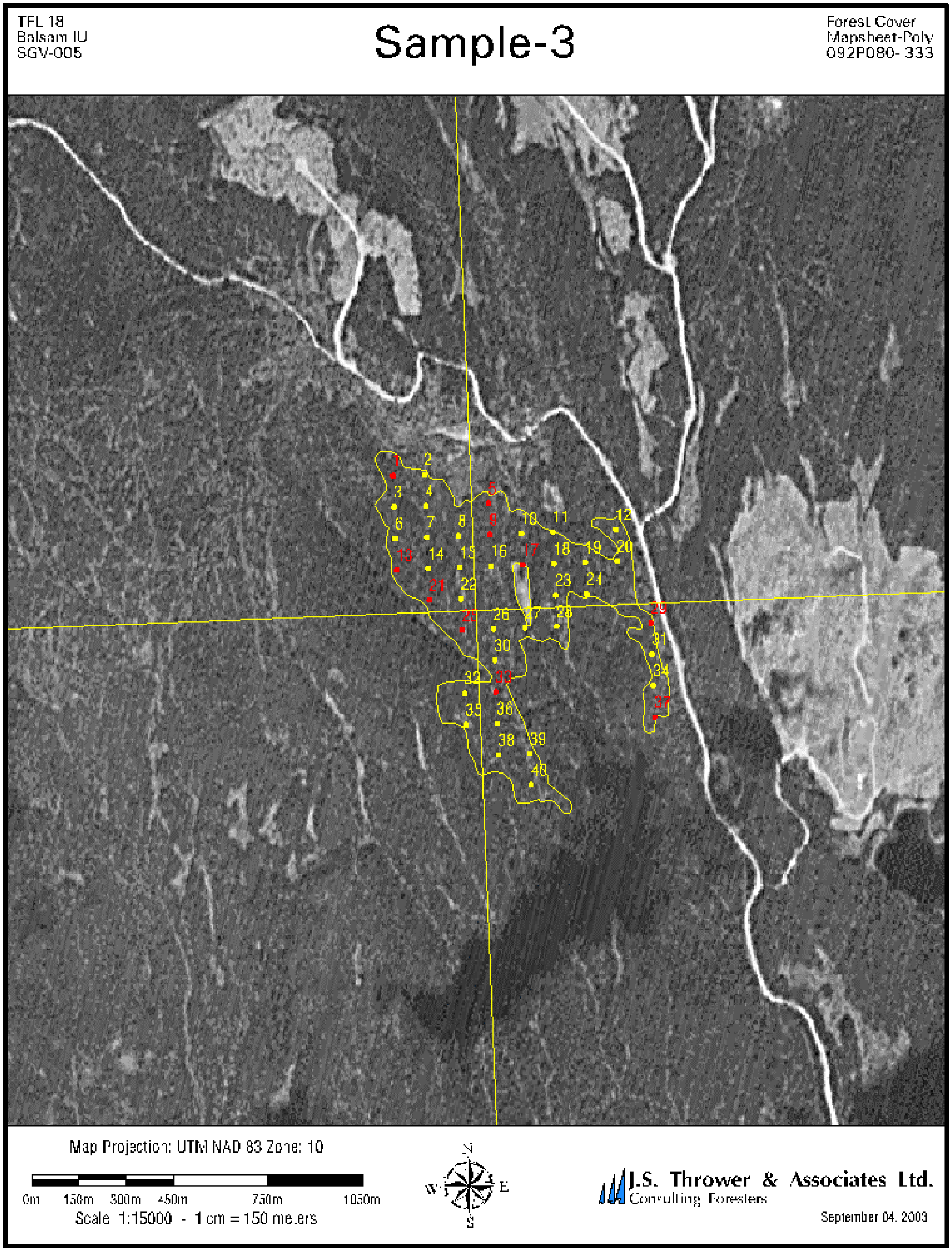

Figure 13. Example of one of the sample maps used by the field crews. Red dots are full-measure plots and yellow are count plots.

APPENDIX III – COMPARISON OF NET VOLUME FROM LOSS & NET FACTORS

We compared the estimates of net merchantable volume computed using MOF appraisal cruising loss factors and Vegetation Resources Inventory (VRI) net factor methods on 24 plots systematically selected from the last 12 polygons sampled in 2003. The net factor volume was on average only 0.6% less than the loss factor volume. The difference between the two estimates is not statistically or practically significant. The same close agreement between these two estimates may not be shown in other stand types and other areas.

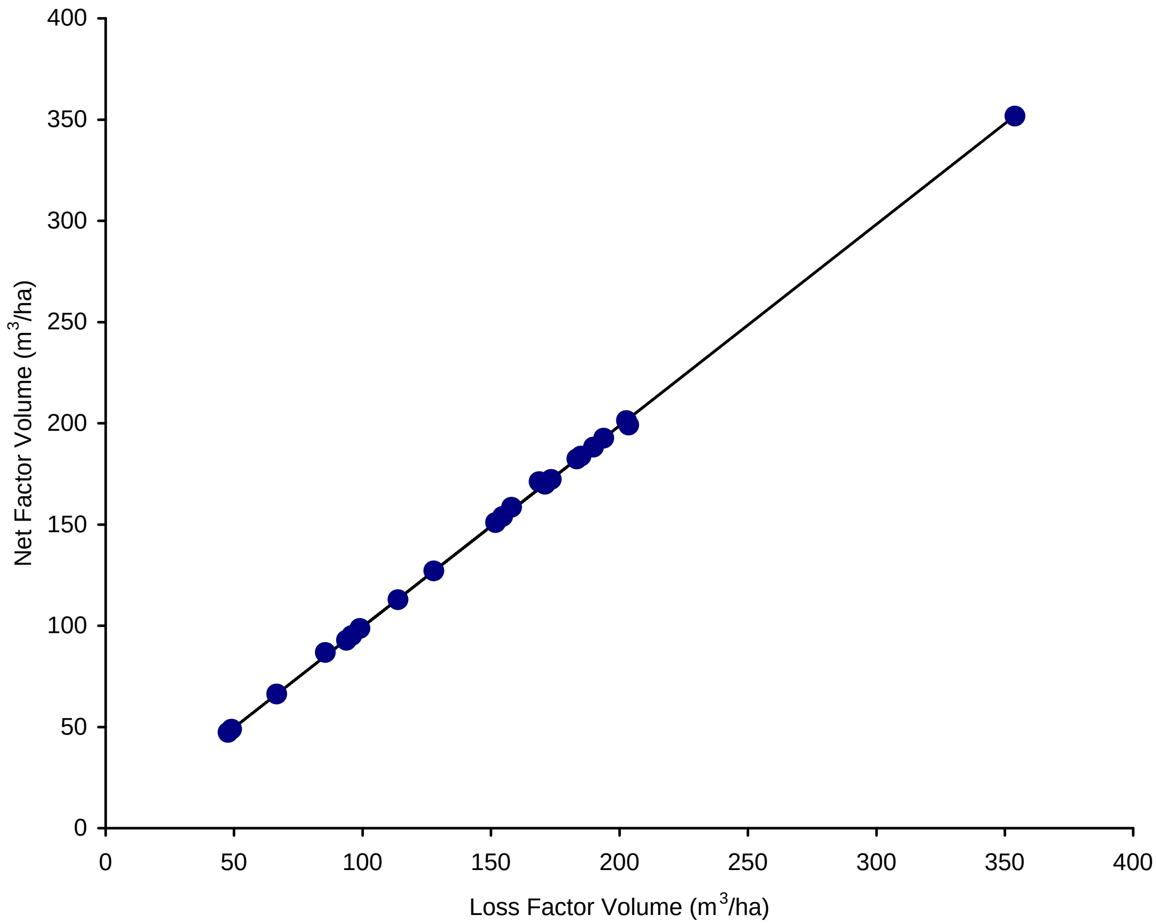

Figure 14. Relationship between net merchantable volume estimated using VRI net factors and MOF appraisal loss factors in 24 plots systematically selected from the last 12 randomly selected polygons sampled in 2003.

APPENDIX IV – SUMMARY OF SAMPLE & INVENTORY ATTRIBUTES

Sample and inventory attributes of the 22 sampled polygons. Merchantability limits for all statistics are 17.5 cm for all species. Overall average at bottom of table is area weighted.

Table 3. Sample and inventory attributes of the 22 sampled polygons.

Sample	Date Sampled	Mapsheet – Polygon	Polygon Area (ha)	Inventory Volume (m^3/ha)	Sample Volume (m^3/ha)	Volume Difference (m^3/ha)	Volume Difference (%)	Sample Basal Area (m^2/ha)	Sample Density (trees/ha)	Quad Mean DBH (cm)	Bl Site Index (m)	Sx Site Index (m)
1	2002-Jul-27	092P080 - 662	148	0	168	168	-	27.1	521	25.7	17.1	15.8
2	2002-Jul-06	092P080 - 562	101	113	109	-4	-3%	21.7	468	24.3	15.0	17.3
3	2002-Jul-23	092P080 - 333	40	127	173	46	37%	31.3	454	29.6	19.1	16.2
4	2003-Jul-10	092P080 - 69	157	84	140	56	67%	23.0	439	25.8	17.1	16.1
5	2003-Jul-17	092P080 - 496a	127	122	158	36	30%	23.3	435	26.1	15.7	17.5
6	2002-Jul-30	092P080 - 686	13	231	129	-102	-44%	22.1	458	24.8		15.0
7	2003-Jul-08	092P080 - 522	32	366	181	-185	-51%	29.4	502	27.3	6.8	21.4
8	2003-Jun-13	092P078 - 475	50	0	35	35	-	7.9	220	21.4	18.0	24.6
9	2003-Jul-08	092P079 - 148	2	0	153	153	-	22.4	451	25.1		
12	2003-Jul-08	092P079 - 1479	54	226	167	-59	-26%	23.6	301	31.6		18.4
11	2003-Jul-08	092P070 - 27	17	0	58	58	-	12.4	250	25.1	20.1	22.4
12	2003-Jul-08	092P079 - 624	20	207	74	-132	-64%	13.8	286	24.8		16.4
13	2003-Jul-10	092P089 - 650	19	6	30	24	438%	6.3	158	22.5	18.2	19.3
14	2003-Jul-10	092P080 - 784	153	380	345	-35	-9%	42.5	647	28.9		
15	2003-Jul-10	092P080 - 956	69	284	198	-86	-30%	29.1	466	28.2		18.9
16	2003-Jul-16	092P080 - 496b	132	122	135	13	11%	20.7	430	24.7		14.1
17	2003-Jul-15	092P080 - 650	150	0	169	169	-	25.0	463	26.2	15.4	18.9
18	2003-Jul-15	092P080 - 750	64	12	77	64	527%	12.4	256	24.8		10.4
19	2003-Jul-16	092P080 - 755	49	33	82	49	147%	13.8	305	24.0	14.5	12.8
20	2003-Jul-17	092P080 - 388	106	21	103	82	391%	22.2	367	27.8	5.0	14.1
21	2003-Jul-16	092P080 - 180	127	135	163	28	21%	27.8	607	24.2	19.5	19.0
22	2003-Jul-15	092P079 - 1260	49	28	73	45	159%	13.3	329	22.6		20.9
	Average		*76*	*115*	*155*	*40*	*34%*	*24.1*	*447*	*26.2*	*15.4*	*17.0*

APPENDIX V – DBH ADJUSTMENT EQUATIONS

The DBH of trees in count plots was visually estimated before being adjusted using a relationship developed from visual estimates and actual measurements obtained from full-measure plots. The adjustment equation is:

$$DBH_M = b_0 + b_1 DBH_E$$

where DBH_M is the measured DBH, DBH_E is the visually estimated DBH and b_0 and b_1 are the model parameters. The root mean square error (RMSE) for the adjustment equations varied between 1.3 and 5.5 cm, and R^2 varied between 80% and 98%.

Table 4. DBH adjustment equations and fit statistics.

Polygon Sample Number	Mapsheet - Polygon	Number of Trees to Fit Equation	b_0	b_1	RMSE (cm)	R^2
1	092P080 - 662	47	3.6	0.885	3.0	94.9%
2	092P080 - 562	46	1.7	0.966	1.7	97.4%
3	092P080 - 333	25	0.3	0.989	3.3	94.6%
4	092P080 - 69	35	-2.1	1.126	2.5	93.3%
5	092P080 - 496a	45	-0.6	1.057	2.3	95.3%
6	092P080 - 686	35	1.9	0.920	2.5	91.4%
7	092P080 - 522	50	0.3	1.027	2.8	92.0%
8	092P078 - 475	26	2.9	0.834	2.5	83.3%
9	092P079 - 148	45	-0.5	1.005	2.5	95.4%
10	092P079 - 1479	41	1.2	0.990	5.5	80.7%
11	092P070 - 27	36	-1.8	1.109	3.6	93.9%
12	092P079 - 624	18	0.6	0.963	1.3	97.4%
13	092P089 - 650	18	-0.4	1.013	1.5	98.4%
14	092P080 - 784	46	2.1	0.921	2.7	97.8%
15	092P080 - 956	38	1.1	1.032	3.6	85.4%
16	092P080 - 496b	38	2.2	0.900	2.8	89.7%
17	092P080 - 650	25	5.5	0.830	4.6	86.8%
18	092P080 - 750	21	1.5	0.938	1.7	96.1%
19	092P080 - 755	30	-0.4	1.040	2.3	93.4%
20	092P080 - 388	49	0.9	0.981	2.4	97.0%
21	092P080 - 180	45	1.9	0.922	2.3	95.1%
22	092P079 - 1260	30	1.1	0.931	1.3	95.0%

APPENDIX VI – BRUSH COVERAGE IN SAMPLED POLYGONS

Table 5. Brush coverage (greater than 1.3 m in height) in the 22 sampled polygons.

	Rhododendron albiflorum		*Menziesia ferruginea*		*Alnus viridis ssp. sinuata*		Other Species		All Species	
Sample	Cover (%)	Avg Ht (m)	Cover (%)	Avg Ht (m)	Cover (%)	Avg Ht (m)	Cover (%)	Avg Ht (m)	Cover (%)	Avg Ht (m)
1	4	1.7	4	1.8	1	2.4	0	2.0	9	1.8
2	16	1.6	0	1.7	0	0	0	1.6	16	1.6
3	9	1.7	4	1.8	3	2.7	0	1.7	16	1.9
4	24	2.0	6	2.0	0	0	0	2.2	30	2.0
5	16	1.5	9	1.5	0	1.8	0	2.8	25	1.5
6	10	1.5	0	0	1	2.3	0	1.6	11	1.6
7	22	1.7	2	1.5	0	0	0	0	24	1.7
8	1	1.6	0	1.4	0	0	0	3.7	2	2.0
9	11	1.7	0	1.5	0	0	0	2.5	11	1.7
10	45	1.6	0	0	0	0	0	0	45	1.6
11	3	1.7	3	1.7	0	0	0	2.7	6	1.8
12	15	1.5	11	1.5	5	3.0	0	1.5	31	1.8
13	2	1.3	3	1.9	3	2.7	0	3.5	8	2.1
14	8	1.6	0	0	0	0	0	2.7	9	1.6
15	19	1.6	0	0	0	0	0	3.3	20	1.6
16	11	1.4	4	1.5	2	3.0	0	1.8	17	1.6
17	4	1.6	2	1.5	0	0	0	2.3	6	1.5
18	14	1.5	8	1.5	0	3.0	0	1.8	22	1.6
19	14	1.7	5	1.6	0	0	0	3.0	19	1.7
20	29	1.5	0	0	0	0	0	0	29	1.5
21	6	1.6	3	1.5	0	0	0	3.0	9	1.5
22	3	1.6	1	1.9	24	4.1	0	0	28	3.8
Total	*13*	*1.6*	*3*	*1.6*	*2*	*2.8*	*0*	*2.4*	*18*	*1.8*