Potential Site Index Estimates for the Major Commercial Tree Species on TFL 8

FINAL REPORT

Prepared for

Pope & Talbot Ltd.
Boundary Timber Division
Midway, B.C.

Project: PTM-051-011

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Executive Summary

A site index adjustment project was completed on TFL 8 to provide reliable estimates of potential site index (PSI) for post-harvest regenerated (PHR) stands. The intent is to use these statistically-based estimates of PSI to generate Managed Stand Yield Tables (MSYTs) for the upcoming timber supply analysis for Management Plan 10.

Preliminary PSI estimates were developed for the target species and site series on the TFL to provide a basis for subsequent adjustments. Plot locations were then randomly selected from stands likely to express PSI, and field estimates of PSI were calculated from measurements of height and age. The ground-based estimates were compared to the preliminary estimates and the ratio of the two was used to adjust the remainder of the area in the TFL.

Final PSI estimates were developed using three different methods:

1) Statistical adjustment for Pl and Lw in the IDFdm1, ICHmk1, ICHmw2, and MSdm1 subzones.
2) An elevation model for Pl in the ESSFdc1.
3) Ministry of Forests (MOF) site index conversion equations for Bl, Sx, and Fd.

The statistical adjustments in the IDFdm1, ICHmk1, ICHmw2, and MSdm1 subzones decreased the preliminary PSI of Pl by 0.1% and increased the preliminary PSI of Lw by 6.5%. The adjusted estimates resulted in an area-weighted average PSI of 20.8 m for Pl and 21.9 m for Lw on the productive forest landbase. The MOF site index conversion equations resulted in area-weighted averages of 20.2 m for Fd, 19.7 m for Sx, and 19.0 m for Bl.

In the ESSFdc1, the final PSI estimates were based on the unadjusted preliminary estimates and the elevation model. The area-weighted average site index for Pl was 15.6 m. Using the MOF site index conversion equations resulted in area-weighted averages for Sx and Bl of 14.9 m and 14.8 m, respectively.

We recommend that these estimates be used to generate MSYTs for the upcoming timber supply analysis because they better reflect the growth rates observed in PHR stands than site index estimates from the current forest cover inventory. However, these estimates should be monitored and updated as additional information from new PHR stands becomes available. In particular, additional work is required in the ESSF.

Acknowledgements

We are grateful to all who contributed to the success of this project. We thank Geoff Bekker, *RPF* (Pope & Talbot Ltd.) and Chris Mulvihill, *RPF* (Ministry of Forests, Nelson Region) for their involvement in the management of the project. We thank Karel Klinka, *PhD RPF* (University of British Columbia) for sharing his expertise and his forest productivity data for the development of the preliminary site index estimates. We thank Albert Nussbaum, *RPF* (Ministry of Forests, Research Branch) for his review and suggestions for the sample plan. We also thank Tom Braumandl, *RPF* (Ministry of Forests, Nelson Region) for his review of the preliminary site index estimates and for the time he spent training the field staff on the use and interpretation of the Field Guide for Site Identification and Interpretation for the Nelson Region.

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1. INTRODUCTION

1.1 BACKGROUND

Pope & Talbot Ltd. completed this Site Index Adjustment (SIA) on Tree Farm Licence (TFL) 8 in response to the Chief Forester's recommendation[1] that more reliable site index estimates be developed for the timber supply analysis in Management Plan 10. As in many areas of B.C., the site index estimates recorded in the forest cover inventory for TFL 8 tend to underestimate the expected growth of post-harvest regenerated stands (PHR) (Figure 1). The explanation for this underestimation is that the height of older stands frequently reflects factors other than site productivity. Top damage, suppression, and repression[2] are common in older stands, but may be controlled to some extent in PHR stands. Furthermore, the equations used to estimate site index were developed with data from stands less than 150 years old, and may produce biased estimates for older stands.

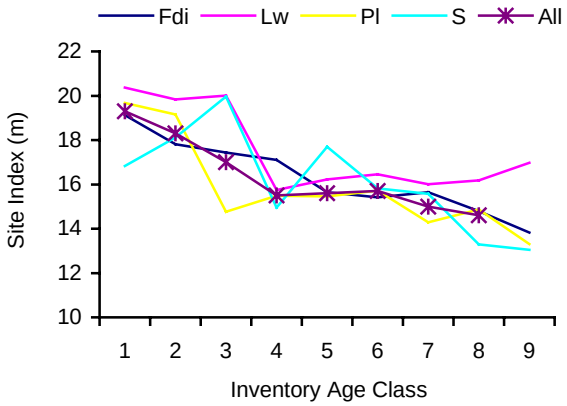

Figure 1. Trends in site index across inventory age classes for the major species.

Site index is a critical input variable in the models used to predict the growth and future yield of forest stands. Underestimates of site index can have powerful effects in timber supply analysis. Large errors in growth predictions can occur if site indices do not accurately represent the growth of actual trees and stands. When a mature stand is harvested in the timber supply simulation, the site index of the mature stand is typically assigned to the PHR stand that replaces it. In TFL 8, approximately 44% of the area is occupied by stands in age classes 6, 7, 8, and 9 (Figure 2, Appendix I), where the likelihood of underestimating site index is high.

Figure 2. Area distribution by age class on TFL 8.

[1] Ministry of Forests. 1997. Tree Farm Licence 8: Rationale for allowable annual cut (AAC) determination. L. Pedersen, Chief Forester.

[2] Repression is a reduction in the height growth of dominant trees due to very high stand densities, such as those found in fire-origin stands of lodgepole pine.

1.2 PROJECT OBJECTIVES

The objective of the SIA project was to develop reliable estimates of PSI for the main commercial species growing on the major ecosystems within the productive forest landbase[3] (PFLB) of TFL 8.[4] The species addressed in this project were lodgepole pine (Pl), western larch (Lw), interior Douglas-fir (Fd), hybrid spruce (Sx), and subalpine fir (Bl). The intent was to use these estimates of PSI with other inventory and silviculture information to develop managed stand yield tables for the timber supply analysis that will be prepared in support of Management Plan 10.

Figure 3. SIA field work on TFL 8.

1.3 TERMS OF REFERENCE

This project was completed by J.S. Thrower & Associates Ltd. (JST) for Pope & Talbot Ltd. The company contact was Geoff Bekker, *RPF*. The JST team included Ian Cameron, *MF RPF*, (project manager), Mike Ciccotelli, *For Tech* (field operations manager), David Affleck, *BScF* (data analyst), and Tara McCormick, *BSc* (report writer). Field crews were provided by JST. This project was funded through Forest Renewal B.C.

2. METHODS

2.1 SIA OVERVIEW

This SIA project was completed in five stages:

1) *Preliminary PSI estimates*. Preliminary estimates of PSI were developed for the target tree species on the forested site series on TFL 8. These site series estimates were used to derive the preliminary PSI estimates for eco-polygons that served as the basis for statistical adjustment. The target tree species were Pl and Lw in the ICH, IDF, and MS subzones, and Pl in the ESSFdc1.[5]

2) *Elevation model.* An elevation model was derived from previous forest productivity research to account for the impact of elevation on PSI in the ESSFdc1.

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[3] This definition of PFLB may vary slightly from the one ultimately used in the timber supply analysis. Basing the sampling on the PFLB ensures that all of the eventual THLB will be within the sample population.

[4] The PFLB includes polygons with inventory type identities 1, 2, or 3 and with ownership codes 72 or 76.

[5] Fd was initially a target species but was dropped due to limited sampling opportunities. More details are given in section 2.4.2.

3) *Field sampling.* Site index data were collected for the target tree species within a sample population of stands where they were most likely to express PSI.

4) *Statistical analysis.* A relationship between field and preliminary PSI was developed for the target species in the sample population.

5) *Final PSI estimates.* Relationships developed from the sample population were applied to target species on the remainder of the landbase through the Terrestrial Ecosystem Mapping (TEM).[6] Results were expanded to other species through site index conversion equations.

2.2 PRELIMINARY PSI ESTIMATES

In December 1999, Dr. Karel Klinka of UBC, Tara McCormick, and Ian Cameron developed preliminary PSI estimates[7] for the target species growing on all the forested site series.[8] The objective was to use available information and expertise to develop localized estimates of PSI for TFL 8. Data sources examined included reconnaissance-level field sampling on TFL 8 (completed by JST), existing Site Index Biogeoclimatic Ecosystem Classification (SIBEC) data, permanent sample plot data from TFL 8 and the Boundary Forest District, and the stem analysis data collected over the past several years by Dr. Klinka and his students. Expert opinion was used to estimate site index for site series with little data. The SIBEC estimates were not used directly because they were not specific to TFL 8 and were generally too coarse to reflect the relative differences in productivity between site series and across subzones.

2.3 ELEVATION MODEL

On TFL 8, the harvest history in the ESSFdc1 has been relatively short and concentrated in the lower elevations. This created an elevation bias in potential sampling locations. Experience in other SIA projects and recent research has shown that PSI for Bl and Sx at high elevation declines approximately 1 m per every 100 m increase in elevation.[9] Consequently, we incorporated elevation effects into the estimation of PSI by assuming that Pl would experience the same rate of change in PSI as had been observed for Bl and Sx. The sampling undertaken in the ESSFdc1 was designed to test the validity of that assumption.

2.4 FIELD SAMPLING

2.4.1 Objectives

The objectives of the field sampling were to:

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[6] Oikos Ecological Services. 2000. Ecosystem Mapping Pope & Talbot, TFL 8. Final report, 30 pp.
[7] J.S. Thrower and Associates Ltd. 2000. Preliminary Estimates of Potential Site Index for TFL 8. Contract report for Pope & Talbot Ltd., 12 pp.
[8] The preliminary estimates were subsequently reviewed by Tom Braumandl (Nelson Forest Region).
[9] Klinka, K., Q. Wang, R.E. Carter and H.Y.H. Chen. 1996. Height growth-elevation relationships in subalpine forests of interior British Columbia. For. Chron. 72(2):193-198.

1) Collect height and age data for Pl and Lw at randomly chosen locations in the ICH, IDF, and MS subzones to provide field estimates of PSI for comparison with preliminary PSI estimates.

2) Collect height and age data for Pl in plots subjectively located across the elevation gradient in the ESSFdc1 to test an elevation model for site index.

2.4.2 Sampling Specifications for the ICH, IDF and MS Subzones

The sample population for the ICH, IDF, and MS subzones included all stands in the PFLB between 15 and 80 years and with more than 35% by volume of Lw or Pl. Polygons with a leading broadleaf species were not included.

Preliminary sampling indicated that many natural stands in age classes 3 and 4 (ages 41-80) would express PSI, hence these age classes were included in the sample population to increase the proportion of the PFLB available for sampling from 17% to 34%. To avoid repressed stands, all polygons in age classes 3 and 4 with more than 70% Pl composition were not included in the sample list.

The sample population for the ICH, IDF, and MS subzones was divided into two lists[10] based on target species (Pl and Lw). Polygons with greater than 35% Pl composition were included in the Pl list while polygons with greater than 35% Lw were included in the Lw list. Polygons with greater than 35% composition of both species were included in both lists. Preliminary PSI values for Pl were assigned to each polygon and both lists were sorted by PSI. One hundred fifty (150) polygons were drawn with probability proportional to area by systematic selection from the sorted list. The samples drawn generally represented the distribution of area by elevation (Figure 4), subzone, and leading species (Figure 5) in the target population.

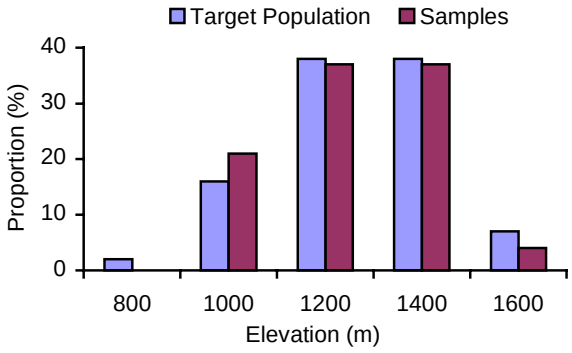

Figure 4. Distribution of samples and target population by elevation class.

For each selected polygon, a sample point was randomly chosen from a 100 m grid generated in a Geographic Information System. Sample locations were transferred to air photos and ortho-photos, and field crews navigated to the intended locations using conventional field surveying techniques.

[10] Initially Fd was considered a target species. However, the Fd-leading stands were unsuitable for site index sampling and 72% of the first plots established were rejected. After consulting with the Ministry of Forests, Research Branch, sampling for Fd was dropped.

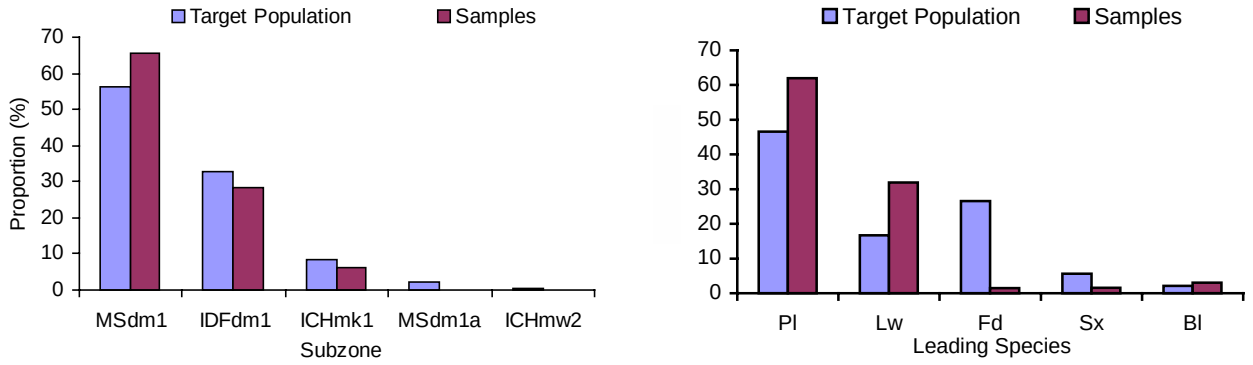

Figure 5. Distribution of samples, sample population, and target populations by subzone and leading species.[11]

2.4.3 Sampling Specifications for the ESSFdc1 Subzone

The sample population for the ESSFdc1 subzone included all Pl-leading stands in the PFLB between 16 and 40 years, and stands between 41 and 60 years where the Pl composition was less than 70% by volume. The sample population totaled only 28 polygons, so all were selected for sampling.

Plot locations for ESSFdc1 samples were determined through a combination of subjective and systematic methods. The intent was to establish samples every 50 m in elevation along the elevation gradient within a selected polygon. Field crews identified suitable transects using maps and a brief reconnaissance of the site. From an arbitrary starting point near the lowest elevation of the polygon, crews surveyed the transect, and checked the elevation with an altimeter at every 50 m of horizontal distance. When the elevation gain exceeded 50 m from the previous plot, a new plot was established. As expected, the samples were biased in their distribution by elevation relative to the PFLB (Figure 6).

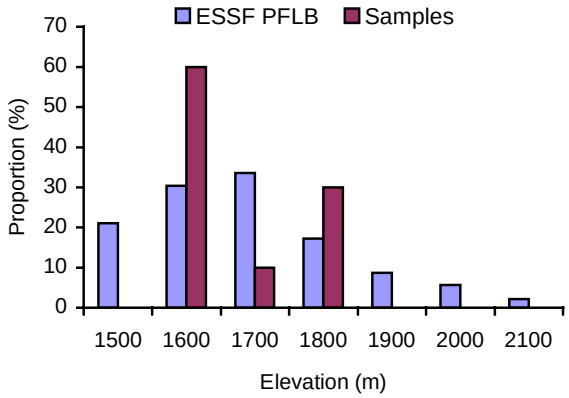

Figure 6. Distribution of samples and target population by elevation.

[11] Figure 5 represents the distribution of the populations after the Fd list was dropped. Data for the ESSFdc1 is not included.

2.4.4 Field Measurements

Complete details of the field measurements are documented in the Sample Plan[12] for this project. The most relevant details were that measurements of total height and breast-height age were collected for site trees[13] of the target species in each quadrant of each plot. One hundred and twenty-four (124) plots were visited between August 1st and November 2nd, 2000. Forty-two (42) of the 124 plots (i.e., 34%) were rejected because they did not contain suitable site trees. The most common reasons for rejection were the proximity of veterans and evidence of suppression.

Sixty-seven (67) plots were installed in the ICH, IDF and MS biogeoclimatic (BGC) zones producing 54 Pl and 36 Lw observations (Table 1). Twenty-three (23) of these plots had observations for both species. In the ESSFdc1, 15 plots were established and 15 observations of PSI for Pl were obtained.

2.4.5 Compilation of Field Data

Site index was calculated for each site tree from measurements of height and breast-height age using *Site Tools Version 3.2I*. An average field site index was determined by plot for each species using all valid site trees within the plot. In the IDF, ICH, and MS BGC zones, the average field site index for Pl was 21.1 m while the average field site index for Lw was 22.2 m (Table 1).

Table 1. Summary of field site index for ICH, IDF, and MS subzones.

Spp	Subzone	Area (ha) in PFLB	No of obs	Field Site Index (m)		
				Avg.	Min.	Max.
Pl	MSdm1	34,086	35	20.6	11.7	24.8
	MSdm1a	1,255	-	-	-	-
	IDFdm1	19,626	16	21.6	17.2	27.7
	ICHmk1	5,098	3	23.5	21.0	25.4
	ICHmw2	279	-	-	-	-
Total	*Target Pop*	*60,344*	*54*	*21.1*	*11.7*	*27.7*
Lw	MSdm1	34,086	24	21.7	13.1	26.7
	MSdm1a	1,255	-	-	-	-
	IDFdm1	19,626	9	22.6	17.1	26.4
	ICHmk1	5,098	3	24.5	24.1	25.2
	ICHmw2	279	-	-	-	-
Total	*Target Pop*	*60,344*	*36*	*22.2*	*13.1*	*26.7*

In the ESSFdc1, some of the selected polygons spanned the ESSFdc1 boundary. According to the Global Positioning System (GPS) data, six of the 15 plots were established outside the ESSFdc1 (4 in the MSdm1, 2 in the ICHmw2). For those within the ESSFdc1, the average site index for Pl was 18.3 m with a range of 15.9 m to 20.8 m. The average plot elevation, as determined from Terrain Resource Inventory Maps (TRIM) was 1,664 m with a range of 1,445 m to 1,798 m.

[12] J.S. Thrower and Associates. 2000. TFL 8 Site Index Adjustment Project Sample Plan. Contract report for Pope & Talbot Ltd., 12 pp.

[13] Site trees for this project included Top Height Trees and Site Trees as defined by the Forest Productivity Council of BC (Top Height Definition, June 1998).

2.5 ANALYSIS

2.5.1 Statistical Adjustment in the ICH, IDF, and MS Subzones

Plot-level estimates of preliminary PSI were calculated for the target species in each plot as the weighted average of the preliminary PSIs (Appendix II) for the different site series in each eco-polygon. Different models were evaluated for describing the relationship between field PSI and preliminary PSI, and the most appropriate model was selected for adjustment of each species.

2.5.2 Elevation Model for Preliminary PSI in the ESSF

As in the other subzones, plot-level preliminary PSI was calculated as the weighted average of the preliminary PSIs for the different site series in each plot. In addition, an elevation model (Equation 1) was used to account for the influence of elevation on PSI. Elevation was calculated from TRIM data as the centroid of the eco-polygon.

Elevation Adjusted PSI_{Pl} =	Preliminary PSI – 0.01 * (Elevation – 1700) [Equation 1]

The elevation model embodied three assumptions.

1) Preliminary PSI values (Appendix II) were referenced to 1,700 m, the area-weighted average elevation for the ESSFdc1 subzone in TFL 8.
2) The slope of the relationship observed by Klinka[9] for Sx and Bl was approximately correct for Pl in TFL 8.
3) The increase in PSI below 1,700 m implied by the elevation model would be limited to areas above 1,500 m elevation. This effectively capped PSI estimates for the lower elevations of the ESSFdc1 so they would not exceed those in adjacent subzones. For example, at 1,500 m, the elevation model predicted a PSI of 19 m for Pl on the 01 site series. That became the maximum value for PSI for all 01 site series in the ESSFdc1 at or below 1,500 m.

3. RESULTS

3.1 SUMMARY

Final PSI estimates were produced through a combination of methods (Table 2). In the ICH, IDF, and MS subzones, final PSI estimates for Pl and Lw were derived by statistically adjusting preliminary estimates. PSI estimates for Fd, Sx, and Bl were calculated from the final Pl estimates using the Ministry of Forests (MOF) conversion equations. In the ESSFdc1, final PSI estimates for Pl were developed from an elevation model. Estimates for Lw, Sx, and Bl were subsequently calculated from final Pl estimates using the MOF conversion equations.

Table 2. Summary of methods used to estimate final PSI.

Subzone	PFLB	Method	Species				
			Pl	Lw	Fd	Sx	Bl
ICHmk1, ICHmw2, IDFdm1, MSdm1, MSdm1a	85.7%	Statistical adjustment	Y	Y			
		Conversion Equation			Y	Y	Y
ESSFdc1	14.3%	Elevation Model	Y				
		Conversion Equation		Y		Y	Y

3.2 STATISTICAL ADJUSTMENT FOR ICH, IDF, AND MS SUBZONES

The ratio of means estimator was used to adjust preliminary estimates of PSI for Pl and Lw for the ICH, IDF, and MS subzones based on the results of the random ground sampling. The adjustment ratio was defined as the ratio of mean field PSI to mean preliminary PSI (Table 3). The targeted sampling error of ± 1.5 m (95% confidence level) was achieved for both species (Table 3). The adjustments resulted in a 0.1% decrease in preliminary PSIs for Pl (Equation 2) and a 6.5% increase in preliminary PSIs for Lw (Equation 3). After adjustment, the area-weighted average PSI was 20.8 m for Pl and 21.9 m for Lw. There was considerable variability in field estimates of PSI for both species (Figure 7) and for individual sample plots (Figure 8).

Table 3. Sample size and adjustment statistics for PSI in ICH, IDF, and MS subzones.

Spp	No. of samples	Ratio Statistics			Adjusted PSI Statistics (m)		
		Mean	SE[a]	CI[b]	Mean	SE[a]	CI[b]
Pl	54	0.999	0.018	0.962 – 1.035	20.8	0.38	20.1 – 21.6
Lw	36	1.065	0.032	0.999 – 1.131	21.9	0.67	20.6 – 23.3

[a] standard error [b] 95% confidence interval

Adjusted PSI_{Pl}	=	0.999	*	Preliminary PSI_{Pl}	[Equation 2]
Adjusted PSI_{Lw}	=	1.065	*	Preliminary PSI_{Lw}	[Equation 3]

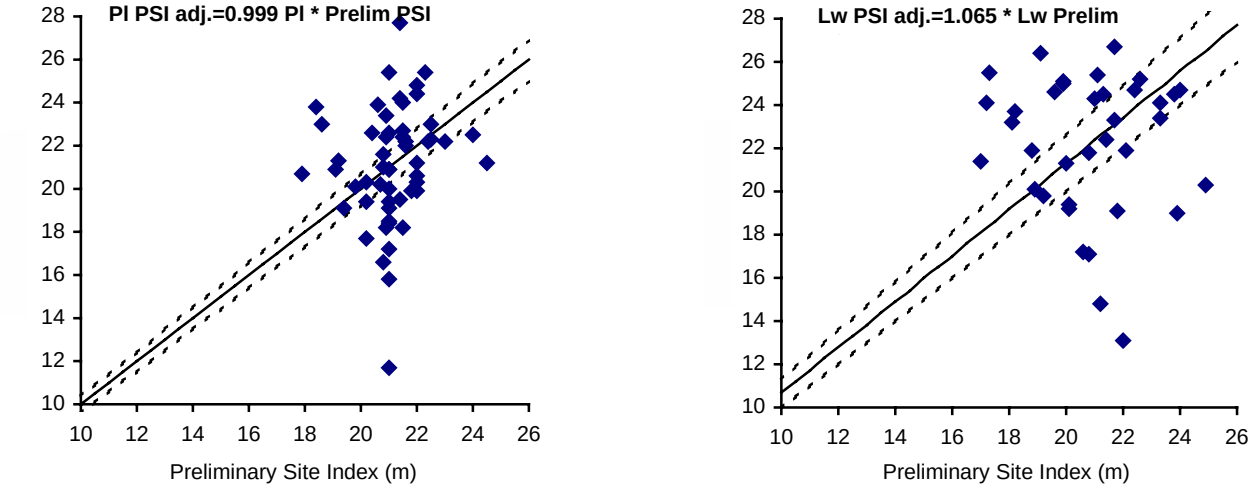

Figure 7. Field and preliminary PSI data with 95% confidence interval of the adjustment ratio.

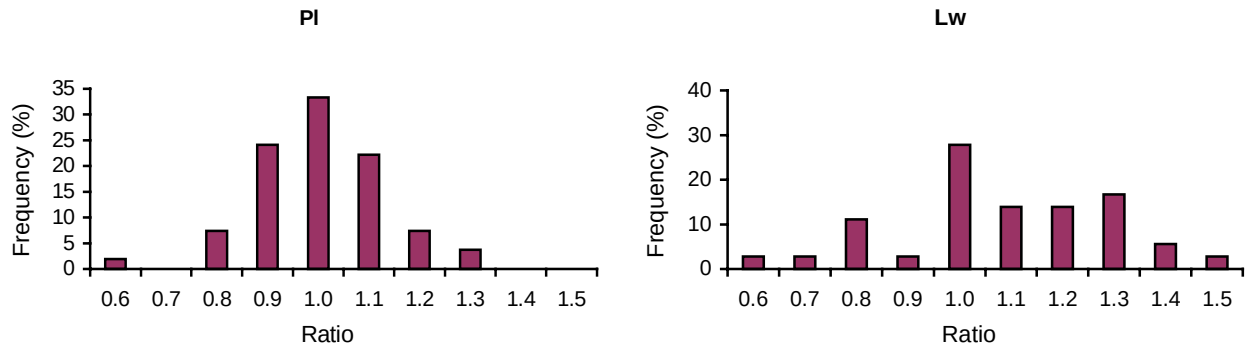

Figure 8. Distribution of individual-plot ratios (Field PSI / Preliminary PSI) for Pl and Lw.

The adjustment ratio for Pl resulted in a slight decrease (0.1%) in preliminary PSIs, and did not result in a noticeable change in the distribution of the target population by site index (Figure 9). The upward adjustment of 6.5% for Lw shifted the distribution towards the higher site index classes.

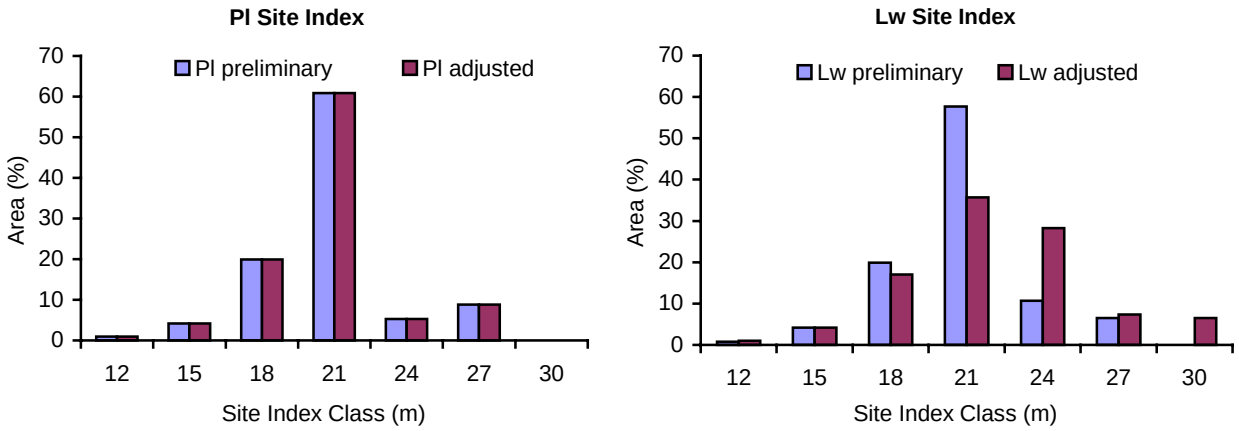

Figure 9. Target population area distribution by 3 m site index class before and after adjustment.

3.3 ELEVATION MODEL FOR PL IN THE ESSF

Some of the polygons selected for sampling the ESSFdc1 spanned the subzone boundary defined in the TEM. Plots outside the ESSFdc1 were actually located on the same transects as plots determined to be within the ESSFdc1. Using only the plots in the ESSFdc1, the relationship between field estimates of PSI for Pl and elevation was described by an ordinary least squares regression line with slope of -0.013 m/m (Figure 10). The 95% confidence interval [-0.002, -0.028] spanned the assumed slope of -0.01 m/m. The PSI for Pl in the plots outside the ESSFdc1 subzone all had PSI estimates greater than 19 m, which suggested that the PSI cap imposed on the elevation model was probably conservative.

There was some evidence in the data that the true slope of the elevation model might be steeper than the -0.013 m/m estimated above. The point with 19.1 field SI and 1,798 m elevation exerted a strong positive influence on the slope of the regression line. When this point was excluded from the analysis, the estimated slope of the regression line decreased to -0.02, but was still within the 95% confidence interval of the previous estimate.

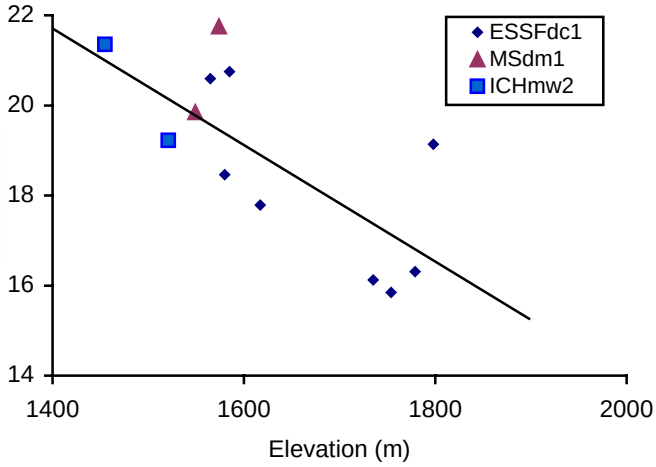

Figure 10. Pl site index versus elevation for high elevation samples on mesic sites.

We calculated the adjustment ratio for Pl in the ESSFdc1 even though the ESSFdc1 samples were not randomly located and the sample size was very small. The intent was to compare the ratio results with those from the elevation model and this adjustment ratio was not used in the preparation of final PSI estimates. With the elevation model incorporated into the plot-level preliminary PSI estimates, the ratio of mean field PSI to mean preliminary PSI was 1.12, indicating that within our samples the field PSI for Pl was underestimated by about 12%. This implied that the preliminary PSI estimates corrected for elevation were probably conservative.

The final PSI estimates for Pl in the ESSFdc1 were based on preliminary PSI values (Appendix II) and the elevation model (slope = -0.01m/m; elevation limit = 1,500 m). The resulting area-weighted average for final PSI for Pl was 15.6 m. The distribution of final Pl PSI by elevation is shown in Figure 11.

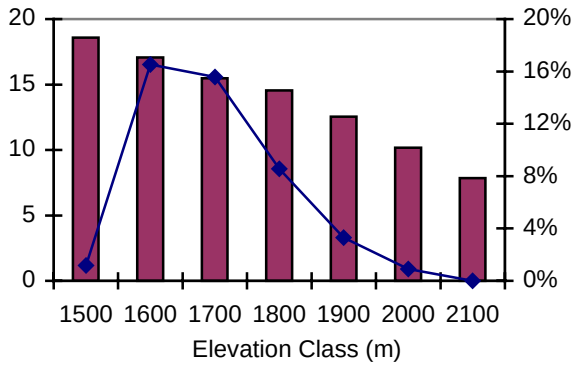

Figure 11. Mean PSI and area proportion by elevation class for Pl in the ESSFdc1.

3.4 SITE INDEX CONVERSION EQUATIONS

3.4.1 ICH, IDF, and MS Subzones

The MOF site index conversion equations (Equations 4, 5, and 6)[14] were used with the final PSIs for Pl to develop PSI estimates for Fd, Sx, and Bl in the ICH, IDF, and MS subzones. The conversions resulted in an area-weighted average final PSI of 20.2 m for Fd, 19.7 m for Sx, and 19.0 m for Bl.

PSI_{Fd}	=	0.709	+	0.935	*	Adjusted PSI_{Pl}	[Equation 4]
PSI_{Sx}	=	-2.150	+	1.090	*	Adjusted PSI_{Pl}	[Equation 5]
PSI_{Bl}	=	0.475	+	0.920	*	Adjusted PSI_{Pl}	[Equation 6]

3.4.2 ESSFdc1 Subzone

Equations 5 and 6 were also used to calculate the final PSIs for Sx and Bl in the ESSFdc1 from the final PSI for Pl. Similarly, the Lw-Pl conversion equation (Equation 7) provided final PSI estimates for the small number of Lw-leading stands in the ESSFdc1. Area-weighted averages for Sx and Bl in the ESSFdc1 were 14.9 m and 14.8 m, respectively.

PSI_{Lw}	=	1.920	+	0.960	*	Adjusted PSI_{Pl}	[Equation 7]

4. DISCUSSION

4.1 ADJUSTMENT METHODS

The ratio of means was selected from several alternative adjustment methods because of the variability in field estimates of PSI (Figure 7) for ICH, IDF, and MS subzones. Given the variability, it is difficult to justify the model assumptions of any other adjustment method. The ratio of means estimator is appropriate when there is a linear relationship between the two variables, the intercept is 0, and the variability in field PSI increases in proportion to preliminary PSI. On average, the ratio of means adjustment is a better reflection of the theoretical relationship between preliminary and field estimates of PSI.

Adjustment ratios for preliminary PSI estimates were developed independently for Pl and Lw. Simultaneous adjustment methods were proposed in the sample plan and considered in the analysis, but adjustment by species was deemed more appropriate because field data indicated a larger adjustment for Lw than Pl. The relationship between Lw and Pl site implied by the separate adjustments was very similar to the relationship derived from field estimates (Figure 12).

[14] Nigh, G.D. 1995. Site index conversion equations for mixed species stands. Research Report 01, BC Ministry of Forests, Research Branch.

The elevation model developed for predicting PSI for Pl was supported by the data collected in the ESSFdc1 (Figure 10). As a result, the elevation model was used to develop final PSI estimates for Pl and indirectly for Sx, and Bl.[15] However, the relationship between PSI and elevation was derived from a small number of subjectively located plots. The accuracy and precision of this model needs further study.

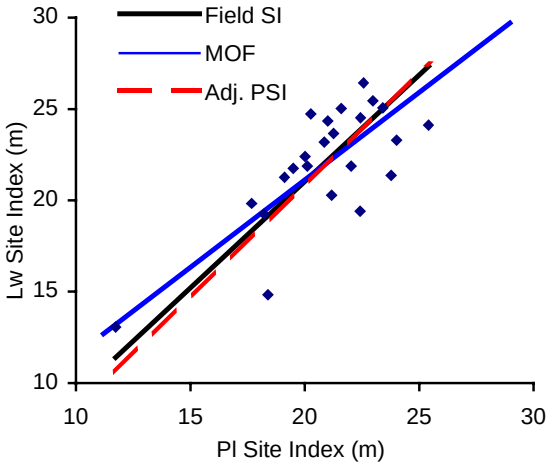

Figure 12. Comparison of field data with alternative site index conversion equations for Lw-Pl.

4.2 Variation Between Preliminary and Field Estimates

There was considerable variation between the field estimates of PSI and the corresponding preliminary estimates for both Pl and Lw (Figure 7). Several sources of variability must be considered when interpreting the results. These include:

1) **Within-polygon variation**. There can be significant variation between average polygon site index and the field estimate of site index at any point within the polygon. This pattern is expected since eco-polygons can contain considerable variation in attributes and site productivity, and small sample plots will only capture a portion of this variability. Approximately 62,441 ha (88% of the PFLB) in the TFL are mapped as eco-polygons with a complex of site series, but 86% of the random plots were classified as a single site series in the field.

2) **Within-site-series variation**. Natural variation in PSI within a site series is a major source of variation. The site series classification is imposed on a continuum of ecological conditions; hence productivity can vary within a given site series. For example, the MSdm1/01 site series has ranges in field estimates of PSI of 12.3 m for Pl and 13.7 m for Lw.

3) **Mapping error**. Mapping error also contributes to the variation in the observed relationship between preliminary and field estimates of PSI. Ecosystem mapping is based on air photo interpretation with some ground verification. Eco-polygon labels will not always reflect the actual distribution of site series on the ground.

4) **Differential bias in preliminary PSI by site series and subzones**. The assumption was made that the direction and the magnitude of bias in the preliminary estimates were consistent across subzones and site series. Different biases may exist in different

[15] The elevation model was directly applied to Pl estimates, but only indirectly applied to Sx and Bl through conversion of final Pl PSIs.

subzones, but this sample was not large enough to allow for post-stratification of results. The issue of local bias could be addressed in the future using a larger sample.

The SIA methodology was developed with full recognition of these sources of error. The errors influence the plot-level preliminary PSI that form the basis for adjustment. The adjustment process, therefore, compensates for the net impact of these sources of error. The key assumption, then, is that the net effect of these errors in the sample population is an appropriate approximation of their impact on the target population. We believe that this is a reasonable assumption.

4.3 TARGET AND SAMPLE POPULATIONS

One difficulty faced in the statistical adjustment of preliminary PSI estimates was that PSI could be reliably measured in a portion of the target population. Inference from the sample to the target population is conditional on the assumption that the relationships between field estimates and preliminary PSI estimates are consistent among eco-polygons in the sample and target populations. Such inference also assumes that the TEM and the Biogeoclimatic Ecosystem Classification are credible representations of the landbase. We believe that these are reasonable assumptions.

4.4 APPLICATION IN TIMBER SUPPLY ANALYSIS

Preliminary estimates of PSI were applied to the PFLB[16] using the weighted proportion of site series in each TEM eco-polygon. This application of the preliminary estimates resulted in an average preliminary PSI of 20.1 m for Pl and 20.6 m for Lw (Table 4).

Table 4. Preliminary PSI statistics (m) for the PFLB.

Subzone	Area (ha)	Pl			Lw		
		Avg	Min	Max	Avg	Min	Max
MSdm1	34,086	21.4	12.0	26.0	21.4	10.0	27.0
MSdm1a	1,255	22.2	17.8	25.4	22.8	17.4	26.1
IDFdm1	19,626	19.8	12.0	24.0	18.8	10.0	24.0
ICHmk1	5,098	20.9	12.0	26.0	21.2	10.0	27.0
ICHmw2	279	23.2	19.0	25.0	23.7	18.0	25.0
ESSFdc1	9,917	15.6	4.9	21.0	-	-	-
Total	*70,261*	*20.1*	*4.9*	*26.0*	*20.6*	*10.0*	*27.0*

Following adjustment, the final PSI estimates are 3 to 6 m higher than the inventory estimates of site index for all species in the non-ESSFdc1 area of the PFLB (Table 5). In the ESSF portion of the PFLB, the final PSI estimates are greater than the inventory estimates for all species except Lw (Table 6).

[16] Preliminary PSIs are only applied to forested eco-polygons for which preliminary PSI estimates were developed (i.e., excluding wetlands, non-vegetated, sparsely vegetated, anthropogenic sites, or rare combinations of tree species and site series).

The final PSI estimates reflect the potential productivity of PHR stands on TFL 8. These estimates are not subject to the various sources of bias associated with estimating site index in older or repressed stands. The final PSI estimates are only applicable to PHR stands because which many of the sources of bias are controlled to some extent by management.

Table 5. Comparison of inventory site index and final PSI estimates (excluding ESSFdc1).

Ldg Spp	Area (ha)	Inventory SI (m)	Final PSI (m)	Difference	
				(m)	%
Pl	28,157	17.7	21.1	3.3	18.9
Fd	16,005	15.3	19.3	3.9	25.4
Lw	10,064	16.8	22.0	5.2	31.1
Sx	3,370	16.2	22.1	6.0	36.9
Bl	2,049	15.9	20.4	4.5	28.0
All	*59,646*	*16.8*	*20.8*	*4.0*	*24.0*

The SIA project has improved the spatial resolution of PSI estimates for TFL 8. Each eco-polygon now has an estimate of PSI and corresponding yield based on its individual TEM attributes. This will enhance the spatial component of the timber supply analysis for the next management plan.

Table 6. Comparison of inventory site index and final PSI estimates in the ESSF.

Ldg Spp	Area (ha)	Inventory SI (m)	Final PSI (m)	Difference	
				(m)	%
Pl	4,636	14.3	15.6	1.3	9.3
Lw	137	18.7	17.4	-1.3	-7.1
Sx	2,680	11.8	15.6	3.8	31.8
Bl	2,404	11.5	14.2	2.7	23.0
All	*9,856*	*13.0*	*15.3*	*2.3*	*17.5*

4.5 MONITORING OF PHR STANDS

The estimates of potential site index developed in this study could possibly have a large impact when applied in timber supply analysis. These estimates were based on sound sampling principles, a new terrestrial ecosystem map and the most up-to-date methods for estimating site index. Nevertheless, the actual growth of PHR stands must be carefully monitored so that any deviation—high or low—will be detected as soon as possible and any necessary corrections applied in subsequent timber supply analyses. Monitoring of PHR stands can be accomplished with modified silviculture surveys, special surveys that focus on site index or through a comprehensive growth and yield monitoring program.

5. RECOMMENDATIONS

The following are the main recommendations from this report:

1) We recommend that final PSI estimates be used with other silviculture and growth and yield information to build managed stand yield tables for application in timber supply analysis for TFL 8.
2) We recommend that a monitoring program be established to collect information on the actual growth of stands for comparison with predictions based on PSI.
3) We recommend that there be additional studies on the effect of elevation on PSI within the ESSF and MS subzones.

APPENDIX I – LANDBASE CHARACTERISTICS

Table 7. Area (ha) of productive forest by BEC subzone and leading species.

	Leading Species						*Total*	
Subzone	Pl	Fd	Lw	Sx	Bl	Other[a]	*ha*	*%*
MSdm1	21,497	3,071	5,820	2,140	1,463	166	*34,157*	*48.4*
IDFdm1	5,296	10,798	2,692	641	87	208	*19,722*	*27.9*
ESSFdc1	4,716	17	138	2,709	2,446	45	*10,071*	*14.3*
ICHmk1	957	2,016	1,201	290	346	300	*5,110*	*7.2*
MSdm1a	432	203	380	218	1	24	*1,259*	*1.8*
ICHmw2	35		0	88	154	3	*280*	*0.4*
Total (ha)	*32,932*	*16,105*	*10,232*	*6,086*	*4,497*	*747*	*70,599*	
Total (%)	*46.6*	*22.8*	*14.5*	*8.6*	*6.4*	*1.1*		*100*

[a] Other species include At, Ac, Ep, Cw, Pa, and Py.

Table 8. Area (ha) of productive forest by BEC subzone and age class.

	Age Class									*Total*	
Subzone	1	2	3	4	5	6	7	8	9	*ha*	*%*
MSdm1	10,291	2,240	849	8,585	2,390	1,721	847	5,888	1,348	*34,157*	*48.4*
IDFdm1	2,889	1,760	610	1,301	1,189	1,845	1,090	8,625	413	19,722	27.9
ESSFdc1	1,184	476	425	1,709	407	496	444	3,976	953	*10,071*	*14.3*
ICHmk1	385	607	383	649	578	614	281	1,212	402	*5,110*	*7.2*
MSdm1a	153	1	6	92	236	31	11	543	187	*1,259*	*1.8*
ICHmw2	144	63	8	11		3	0	38	13	*280*	*0.4*
Total (ha)	*15,046*	*5,147*	*2,281*	*12,347*	*4,801*	*4,710*	*2,672*	*20,281*	*3,316*	*70,599*	
Total (%)	*21.3*	*7.3*	*3.2*	*17.5*	*6.8*	*6.7*	*3.8*	*28.7*	*4.7*		*100*

APPENDIX II – PRELIMINARY SITE INDEX ESTIMATES

Table 9. Preliminary PSI estimates for the forested site series on TFL 8.

Site Series	MSdm1		IDFdm1		ESSFdc1	ICHmk1		ICHmw2*	
	Pl	Lw	Pl	Lw	Pl	Pl	Lw	Pl	Lw
01	21	22	21	20	17	22	23	23	24
02	15	14	12	12	10	16	15	n/a	n/a
03	19	18	14	14	15	19	19	21	20
04	21	20	19	17	19	21	21	n/a	n/a
05	23	23	23	24	19	24	24	25	25
06	26	27	24	24	15	26	27	n/a	n/a
07	19	18	22	21	8	21	20	19	18
08	26	25				12	10		
09	12	10							

*Estimates for ICHmw2 were also used for the MSdm1a.