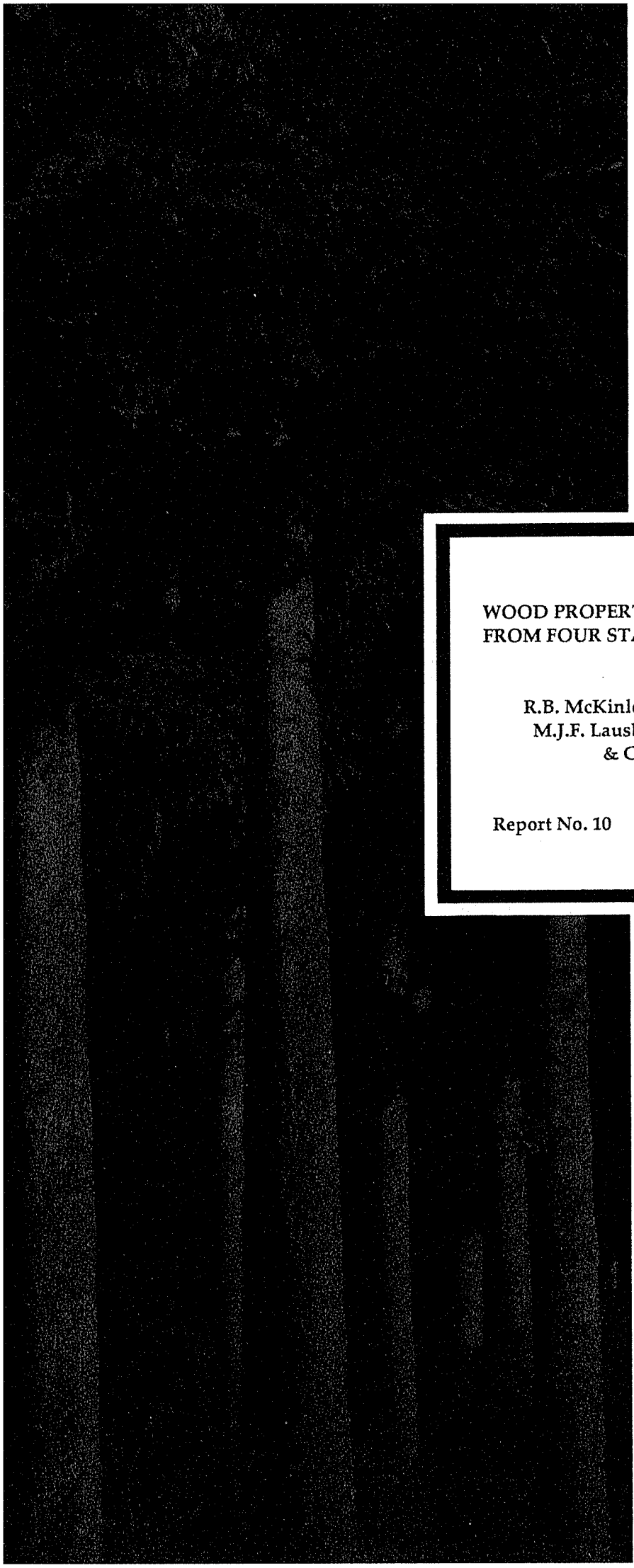

DOUGLAS-FIR

Cooperative

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EXECUTIVE SUMMARY

WOOD PROPERTIES OF DOUGLAS-FIR FROM FOUR STANDS IN KAINGAROA

R.B. McKinley, D.L. McConchie, M.J.F. Lausberg,
K.F. Gilchrist and C.R. Treloar

This report is part of a series carried out with the objective to relate site and silviculture to the yield and value of Douglas-fir. Two managed 33 and 59-year-old stands were selected to provide sawlogs with a wide range of characteristics for subsequent sawing studies.

Standard field and laboratory assessment methods were used to determine the following wood properties:

		33 years	*59 years*
Volume, m^3		1.44	3.13
Heartwood, %		42	56
Corewood, % (inner 10 growth rings)		34	19
Corewood, % (inner 20 growth rings)		84	50
Basic density, kg/m^3		389	437
Green density, kg/m^3		825	783
Moisture content, %		113	80
Shrinkage (%) to Air-dry:	Longitudinal	-0.17	-0.11
	Radial	1.7	1.8
	Tangential	3.4	3.6

Spiral grain patterns within trees were also assessed and although considerable variation within and between trees was noted levels were generally low (below 5°) and deemed unlikely to cause major distortion on drying. The patterns of wood property variation presented in this study are consistent with previous studies of New Zealand grown Douglas-fir.

INTRODUCTION

Douglas-fir is New Zealand's second most important exotic plantation species although the current planted area at about 65,000ha. only equates to approximately 5% of the total exotic plantation resource. The allocation of research effort to this important structural species has been limited and often fragmented when compared to radiata pine. A number of studies however, investigating wood quality aspects in particular wood density and sawing studies, linking log characteristics to timber grade recovery and conversion have been undertaken. A comprehensive review of Douglas-fir in New Zealand was carried out in 1974 culminating in FRI symposium No.15, (James 1975 & 1978). Whiteside *et.al.* 1977 and McConchie *et.al.* 1990 added to the available data linking silviculture to timber quality.

Previous research effort has established a wide range of silvicultural regimes in trials throughout the country. These trials and the older Douglas-fir stands are now reaching maturity and have been or are due to be scheduled for felling in the near future. For this reason there has been a resurgence of interest in Douglas-fir research and the establishment of a Douglas-fir Research Cooperative and the current contract with the U.S. Stand Management Cooperative has provided the opportunity to again review past research and focus current and future research to meet industry requirements.

Old growth Douglas-fir is renowned for the quality of the clear and high strength timber and in the US has been a major source of structural lumber and plywood and also an important source of appearance and finishing grades. However, second-growth stands of Douglas-fir will contain a higher proportion of juvenile wood and yield negligible amounts of clear lumber when harvested at ages below about 150 years (Middleton and Munroe, 1989).

It is already well established that an increase in the juvenile wood content of Douglas-fir logs is undesirable for strength, stiffness and dimensional stability of structural lumber (Barrett & Kellogg, 1989: Senft *et al* 1989). Nevertheless, the control of juvenile wood through inhibition of diameter growth has generally been rejected in New Zealand as an option due to the lengthening of the rotation. On the contrary, forest management practices, including provenance selection, are almost exclusively aimed at increasing stem growth, and where an improvement in wood quality is an objective, thinning and pruning are often recommended. Juvenile wood in North American Douglas-fir has been estimated to extend about 20 growth rings from the pith (Jozsa, 1989: Di Lucca, 1989).

The economic impact of juvenile wood on yield and quality of lumber from young managed plantation stands remains to be evaluated. Previous research in both North America and New Zealand has however shown that young plantation Douglas-fir is likely to be highly variable in quality, (Harris, 1985, Walford, 1985, Smith and Briggs, 1986, Kellogg, 1989).

The purpose of this study is to establish the wood properties of New Zealand plantation-grown Douglas-fir incorporating two ages, 33 and 59 years for comparison with data from New Zealand and North America and to investigate the effect of juvenile wood on some properties. The properties of most interest are stem form, diameter, branching and wood density. Of the wood properties, wood density is considered to be the most important indicator of quality, particularly in a species such as Douglas-fir which has a good reputation as structural lumber. Density is significantly affected by tree age, genotype and site (Harris and Orman, 1958, Walford, 1985; Kellogg, 1989). Other properties of interest in structural lumber are shrinkage and spiral grain, although indications are that these are not serious problems in Douglas-fir (Milota, 1992).

This report forms the basis of a comprehensive series of studies which relate site and silviculture to yield and value of Douglas-fir. The second report provides indicative results of densitometric analysis completed on a sub-sample of trees at the various sampling heights. The third report presents actual grade recoveries and conversion achieved for a wide range of log characteristics sawn to maximise the recovery of structural lumber while the fourth report presents the regression equations relating grade recovery and conversion to log characteristics. To establish the interactions of age and log characteristics on grade recovery and conversion it is important that the wood properties of the stands under investigation be adequately described. In particular wood density, spiral grain and the proportions of juvenile wood are significant variables when interpreting the grade recovery results.

OBJECTIVES

To establish wood properties of New Zealand plantation-grown Douglas-fir for comparison with data from New Zealand and North America by quantification of:

1. Heartwood proportion
2. Heartwood and sapwood moisture content
3. Wood density (basic) - outerwood
   - disc and log averages (green and basic)
   - 5 ring sections
4. Shrinkage characteristics (indicative only)
5. Spiral grain patterns (indicative only)

MATERIALS AND METHODS

Four Douglas-fir stands in Kaingaroa Forest were selected to provide the required study logs from which the wood quality discs were taken. Two of these stands were 33 years old and the other two 59 years old. All stands contained a wide range of log characteristics and had received silvicultural treatments. The stand histories are presented in Table 1.

Table 1. Stand Histories (Kaingaroa Forest).

Compartment/ Stand	Date	Age (yrs)	Operation
1/02	1960	-	Established at 2500 spha
	1977	17	Waste thinned to 625 spha
	1993	33	Fell study logs
2/02	1960	-	Established at 1600 spha
	1977	17	Waste thinned to 640 spha
	1993	33	Fell study logs
688/01	1934	-	Established at 1600 spha
	1951	17	High prune 0-5.8m 284 spha
	1970	36	Production thin to 680 spha
	1993	59	Fell study logs
694/02	1934	-	Established at 1600 spha
	1957	23	High prune 0-5.8m 268 spha
	1967	33	Production thin to 450 spha
	1993	59	Fell study logs

The two younger stands were established at 2500 and 1600spha. and were both waste thinned at age 17 years to 625 and 640spha. respectively. The older stands were both established at 1600spha. and had been high pruned and production thinned to 680 and 450spha.

Prior to final tree selection, a sample of approximately 100 trees for each age class was visually assessed for branching characteristics (large, medium or small), and at breast height, diameter over bark was recorded and two outerwood (outer 50mm) 5mm increment cores were collected to establish outerwood to whole tree density relationships. Increment core densities were established using the maximum moisture content method described by Smith (1954).

From this sample, 60 trees (22 aged 33 years and 38 aged 59 years) were selected to provide the required sawlogs for the sawing study. At the time of felling, one disc was collected from the butt and top of all 4.9m logs down to a small end diameter (SED) of approximately 100mm. Where sawlogs were selected for the subsequent sawing study a second disc was cut from both the large and small end. Table 2 presents the breast height diameter over bark, outerwood density and sampling strategy adopted for all trees.

The complete set of discs were measured to provide data on diameters inside and over bark (dib and dob), and weight including and excluding bark. Further laboratory measurements were made to allow the assessment of:

Bark percentage
Moisture content
Heartwood percentage
Corewood percentage (inner 10 and 20 growth rings)
Green density,
Basic density,
Log volumes,

The second set of discs were sectioned in the laboratory to provide:

i) samples containing 5-growth-rings to give radial trends for basic density, and
ii) separated sapwood and heartwood sections for measurement of moisture content.

From this set of discs a sub-sample of ten trees comprising of a complete set of discs, were selected for measurement of shrinkage to the air-dry (12%) moisture content and oven-dry condition on 5 ring sectors. Spiral grain was measured on the same ten trees using two diametrically opposed radii (Young et al. 1991). Measurements were taken at every alternate ring from the pith up to ring 30 and thereafter in 5-ring increments.

All work was carried out using standard wood quality assessment techniques.

Table 2. Breast Height Diameter, Outerwood Density and Sampling Strategy by Compartment and Tree.

Cpt.	Tree No.	DBHOB (cm)	Basic Density (kg/m³)	Sampled for: Shrinkage and Spiral Grain	Sampled for: Densitometry
Waiotapu					
1	1	55.9	371	No	Yes
1	2	47.6	415	No	Yes
1	3	40.3	371	No	No
1	4	47.5	381	No	Yes
1	5	44.6	373	No	Yes
1	8	44.5	387	No	No
1	11	51.7	395	No	Yes
1	12	36.5	385	No	Yes
1	17	39	435	Yes	No
1	18	49.7	439	No	Yes
1	24	39	426	No	No
Waiotapu					
2	1	33.5	410	No	No
2	2	43.9	358	No	No
2	3	44.1	445	No	No
2	4	35.5	408	No	No
2	8	47.5	392	No	No
2	11	26.2	394	Yes	Yes
2	12	26.6	484	Yes	Yes
2	17	43.5	403	No	No
2	18	48.6	404	No	No
2	22	44.6	422	No	No
2	24	40.5	368	Yes	Yes
2	30	55.7	411	Yes	Yes
Waimahia					
688	8	42.4	562	No	No
688	19	50.8	513	No	Yes
688	20	60.5	548	No	Yes
688	27	65	397	No	No
688	34	70	484	No	No
688	37	53.5	426	Yes	Yes
688	39	51.3	493	No	Yes
688	40	56.8	378	No	No
Waimahia					
688	44	53.5	504	No	No
688	46	68	503	No	Yes
688	47	48	462	No	No
688	52	34.2	456	No	Yes
688	58	51.1	423	No	No
688	68	75.5	455	No	No
688	70	39	443	No	No
688	72	63.5	451	No	No
688	73	47.3	458	No	Yes
688	77	36.6	507	Yes	Yes
688	78	40.4	416	No	Yes
688	80	44.6	545	No	Yes
688	88	44.6	428	No	No
688	91	53.5	573	No	No
688	99	50.2	483	No	Yes
688	100	62	462	No	No
688	103	64	484	Yes	Yes
688	105	77.5	467	No	Yes
688	108	66.5	427	No	No
688	109	57.9	471	No	No
688	110	72	411	Yes	Yes
688	111	57.5	455	No	No
688	113	45.8	453	No	Yes
688	116	46.3	443	Yes	Yes
Waimahia					
694	2	43.9	465	No	Yes
694	3	39.2	460	No	Yes
694	6	32.5	539	No	No
694	8	54.3	425	No	Yes
694	11	72	498	No	No

Note: Complete disc assessments were analysed for all trees. Density by 5 ring groups and heartwood and sapwood moisture contents were only analysed on discs taken from the unpruned sawing study logs.

Outerwood density averaged 403kg/m³ for the Waiotapu 33-year old trees and 469kg/m³ for 59-year-old trees from Compartments 688 and 694 at Waimahia. In a previous study by McConchie et al.(1990) outerwood density from 15 trees at Compartments 731 and 741 Waimahia aged 54-year-old averaged 435kg/m³. The five year age difference and the genetic component would largely explain the slight disparity between the studies.

RESULTS AND DISCUSSION

For many of the properties described below the data for individual disc, log or even tree values are included in the series of Appendices at the end of this report. In general, discussion of results will relate to mean values only. Needless to say, there is wide variation in many properties which is normally due to genetic effect.

Disc Dimensions and Wood Properties

Table 3 details the average values for each age and height class, derived from the individual measurements (Appendix I). Heartwood and corewood (inner 10 and 20 rings) are calculated as the proportion of cross-sectional area of the entire disc.

Table 3. Average Disc Dimensions and Wood Properties by Sampling Height.

Disc Height (m)	Bark Depth (mm)	Diam. Inside Bark (mm)	Basic Density (kg/m³)	Green Density (kg/m³)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
Waiotapu - Cpts. 1 and 2, Age 33 years								
0	22.0	439	422	816	94	49	16	61
4.9	9.9	350	381	790	108	46	29	78
9.8	8.2	290	377	837	123	37	40	98
14.7	6.9	217	369	905	143	25	60	100
19.6	5.6	148	364	968	167	9	94	100
24.5	4.4	88	357	989	179	1	100	100
Waimahia - Cpts. 688 and 694, Age 59 years								
0	35.4	550	459	771	69	64	9	33
4.9	14.6	442	443	766	73	62	20	47
9.8	11.1	390	431	771	80	59	21	50
14.7	9.8	345	427	794	85	53	22	53
19.6	8.6	289	425	824	94	43	23	59
24.5	7.6	234	418	874	109	32	24	71
29.4	6.4	170	411	932	127	17	40	91
34.3	5.5	125	396	946	146	9	68	98

Bark depth and diameter inside bark show the expected trends from the butt to the top disc within and between the two age classes. Diameter inside bark for the 33 year-old stands averaged 439mm for the butt disc decreasing to 88mm at the 24.5m top height. The older stands were considerably taller and larger in diameter with butt discs averaging 550mm decreasing to 125mm at the 34m height.

Bark depth decreased rapidly from the butt disc, 22mm and 35.4mm for the 33 and 59-year-old stands respectively to the top of the first log (4.9m) where 9.9mm and 14.6mm were recorded. The decrease above the first log was considerably less and for the top disc at 24.5m and 34.3m was 4.4mm and 5.5mm for the younger and older stands respectively.

Disc basic density showed the expected trends of density reduction with increasing height in the stem for the 33 and 59 year-old stands. The younger stands produced a butt disc basic density of 422 kg/m^3 reducing to 357 kg/m^3 at 24.5m. The 59-year-old stands had butt discs averaging 459 kg/m^3 reducing to 396 kg/m^3 at 34.3m. The density reduction between the butt disc and 4.9m disc for the Waiotapu 33-year-old stands was twice that for the Waimahia 59-year-old stands, 422 kg/m^3 to 381 kg/m^3 compared with 459 kg/m^3 to 443 kg/m^3 respectively.

The expected trend of increasing green density with height in the stem was apparent for both stands with the younger stand producing higher values, however the range in green density for both stands were comparable. The differences can be largely attributed to the greater proportions of heartwood in the older trees with correspondingly lower moisture contents.

The values for moisture content and heartwood percent follow the expected trends within and between the two age classes. Moisture content increases with increasing height in the stem, corresponding to the decreasing proportion of the drier heartwood. The higher levels of heartwood in the older stand are also reflected in lower disc moisture contents.

In Table 3 the two methods of corewood definition refect the growth patterns to age 10 and 20 years. The proportions of corewood are also influenced by growth rates in subsequent years. Silvicultural practices which impact on growth rates can therefore be used to manipulate this property. For radiata pine corewood is defined as the inner 10 rings where it encompasses that zone within the tree, near the pith where wood typically has wide growth rings, low percentage of latewood, low density, short tracheids, high spiral grain angles and high longitudinal shrinkage. North American Douglas-fir studies have indicated a zone of relatively low density 15 to 20 growth rings from the pith (Smith and Briggs, 1986; Kellog, 1989). The pith to bark density patterns will be discussed later in this report.

Using the 10 ring definition, corewood development in the 33-year-old stand increases from 16% of the cross-section at the butt to 60% at 14.7m height, and reaching 100% at approximately 20m. The proportion of corewood in the 59-year-old stand was 9% of the cross-section at the butt expanding to 23% at approximately 20m and increasing to 68% at 34.3m.

For the 20 ring definition, corewood in the 33-year-old stands increases from 61% of the butt disc cross-section to 100% at approximately 10m height. For the older stands corewood was 33% of the cross-section at the butt increasing to 98% at 34.3m.

Heartwood and Sapwood Moisture Content

Table 4 presents average moisture content data for heartwood and sapwood sections and the whole disc by position in the tree for the two ages sampled. Values for individual trees are presented in Appendix II. Disc sampling for the various heights was not ideal due to samples being taken only from logs selected for the unpruned sawing study, however the expected pattern of variation was evident.

The moisture content trends within trees for both the 33 and 59-year-old stands are quite different for heartwood and sapwood. Heartwood moisture content varies little within the stem but sapwood moisture content increases with height up the tree. The range of moisture contents for all discs of both ages was greater for the sapwood component. The moisture content levels must be interpreted with regard to wood density and heartwood percent which vary considerably with age and also acknowledging normal genetic variation and discrepancies in identifying break points between heartwood and sapwood boundaries due to the extent of the transition zone.

Table 4. Average Heartwood and Sapwood Moisture Contents by Sampling Height.

Log Height Class	No. of Samples	Heartwood Moisture Content (%)			Sapwood Moisture Content (%)			Whole Disc (%)
		Mean	Min.	Max.	Mean	Min.	Max.	Mean
Waiotapu - Cpts. 1 and 2, Age 33 years								
Butt	23	50	44	58	148	106	178	94
4.9	23	51	47	55	168	140	198	108
9.8	23	51	46	62	175	150	216	123
14.7	11	54	46	65	192	160	212	143
19.6	7	51	38	75	190	171	210	167
Waimahia - Cpts. 688 and 694, Age 59 years								
Butt	38	47	39	52	118	80	166	69
4.9	37	47	39	77	124	70	161	73
9.8	38	46	40	52	132	87	189	80
14.7	21	46	39	51	133	102	162	85
19.6	18	45	39	50	138	95	185	94
24.5	17	45	37	51	142	115	173	109
29.4	8	48	41	57	155	136	176	127

Heartwood moisture contents recorded for the 33-year-old stands were consistently around 50% which was marginally higher than the values for 59-year-old stands. The lower heartwood moisture content in the more mature trees is predominantly due the higher levels of extractives. Sapwood moisture contents for the younger stands increased from 148% at the butt to 190% at 19.6m. On average these levels were approximately 25% higher than the 59-year-old Waimahia stands which ranged from 118% to 155% for the butt and 29.4m discs respectively.

Tree and Log Properties

In Table 5 the values from Table 3 have been used to calculate average results for logs and trees. Values for individual logs and trees are presented in Appendix III. Smalian's formulae was used for calculation of volume which is not as accurate as other methods (e.g 3-D formulae of Ellis, 1988) but does provide a reasonable guide to actual volumes and is more suited to applying weighted wood property values to establish the log and tree estimates.

At 33 years of age, trees sampled in this study were averaging 1.44m^3 of saw logs and pulp logs with over 40% of the volume in the butt log. The 59-year-old trees were producing over 3m^3 of logs with approximately a third of the volume in the butt log. More accurate measures of volume will be provided in the sawing study report (McConchie et al., in press).

The average whole tree basic density for the 33-year-old trees was 389kg/m^3 with individual trees ranging from 360kg/m^3 to 437kg/m^3 compared to the 59-year-old trees at 437kg/m^3 with individual trees ranging from 389kg/m^3 to 496kg/m^3. Basic density from a previous study (McConchie et al., op. cit.) of 15 trees from Compartments 731 and 741 at Waimahia aged 54 years, averaged 408kg/m^3 which relates well with the old stands sampled in this study especially when the age difference is taken into account.

Mean green density averaged 825kg/m^3 for the 33-year-old trees with individual trees ranging from 748kg/m^3 to 912kg/m^3 and the 59-year-old trees averaging 783kg/m^3 with individual trees ranging from 661kg/m^3 to 875kg/m^3.

Average tree moisture content was 113% and 80% for the Waiotapu 33-year-old stands and the Waimahia 59-year-old stands respectively. The normal trend of increasing moisture content with increasing height in the tree is apparent for both ages. These values again reflect the relationship between heartwood volumes and density already alluded to.

Overall 42% of the total volume was heartwood for the 33-year-old trees compared with 56% for the 59-year-old trees. A review of New Zealand grown Douglas-fir wood properties by Cown (1989) found the heartwood volume of 50-year-old trees to be slightly higher at 60%.

Predictably the corewood values are higher for the younger trees. The silvicultural regime prescribed for these stands, using the inner ten ring classification has produced 34% and 19% of the sawlog volume as corewood for the 33 and 59-year-old trees respectively. When the inner 20 ring classification is used the corewood values jump to 84% and 50% of the sawlog volume for the 33 and 59-year-old trees respectively. One must take into account that during the sawing process a large proportion of the denser, more warp resistant outerwood is lost as slabwood thereby increasing the percentage of corewood in sawn timber.

Table 5. Average Log and Tree Values.

Log	Volume (m^3)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core wood 10 rings (%)	Core wood 20 rings (%)
Waiotapu - Cpts. 1 and 2, Age 33 years							
Butt	0.624	406	805	99	48	21	68
2nd	0.411	379	809	114	43	34	93
3rd	0.264	374	860	130	33	47	100
4th	0.157	370	916	147	23	65	100
5th	0.089	369	957	161	11	89	100
Tree	1.442	389	825	113	42	34	84
Waimahia - Cpts. 688 and 694, Age 59 years							
Butt	1.005	453	769	71	63	13	39
2nd	0.705	437	768	76	61	20	48
3rd	0.553	428	781	82	57	22	52
4th	0.426	425	795	87	49	22	55
5th	0.299	422	828	98	39	22	64
6th	0.196	412	885	115	29	26	88
7th	0.133	409	903	123	24	35	97
Tree	3.130	437	783	80	56	19	50

Variation in Basic Density From Pith to Bark

Basic density by 5 ring groups from pith to bark are presented in Table 6. This analysis was carried out on the discs collected from the sawlogs selected for the sawing study, hence not all disc heights were represented in equal numbers. Despite this, the basic density pith to bark trends which are illustrated in Figures 1 and 2 for both the 33 and 59-year-old trees are as expected. The graphs show that the corewood definition using the zone encompassed by the inner 20 growth rings appears to be more appropriate for basic density.

Table 6. Variation in Basic Density From Pith to Bark.

Height (m)	Basic Density (kg/m³) for rings from pith										
	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30	31 - 35	36 - 40	41 - 45	46 - 50	51 - 55
Waiotapu - Cpts. 1 and 2, Age 33 years											
0	401	400	410	409	402	400					
4.9	369	355	374	378	368						
9.8	365	360	367	363							
14.7	365 *	360 *	342 *								
19.6	359 *	359 *									
Waimahia - Cpts. 688 and 694, Age 59 years											
0	383	383	395	411	440	455	486	481	463	461	459
4.9	348	350	397	419	453	467	464	456	457	450	
9.8	358	358	399	418	450	456	450	445	432		
14.7	374	376	419	429	434	438	444	448 *			
19.6	395	395	422	429	433	440	454 *				
24.5	414	414	407	412	425						
29.4	403 *	403 *	406 *	404 *							

* Number in sample less than 10.

Figure 1. Variation from Pith to Bark for Basic Density
Waiotapu Cpts. 1 and 2, Age 33 years.

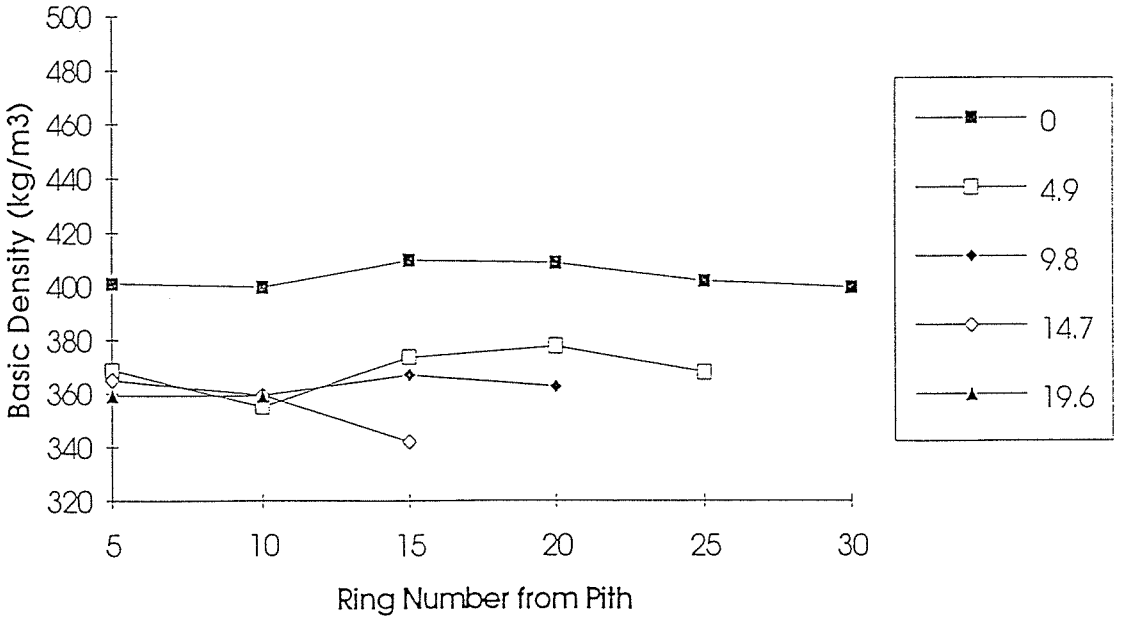
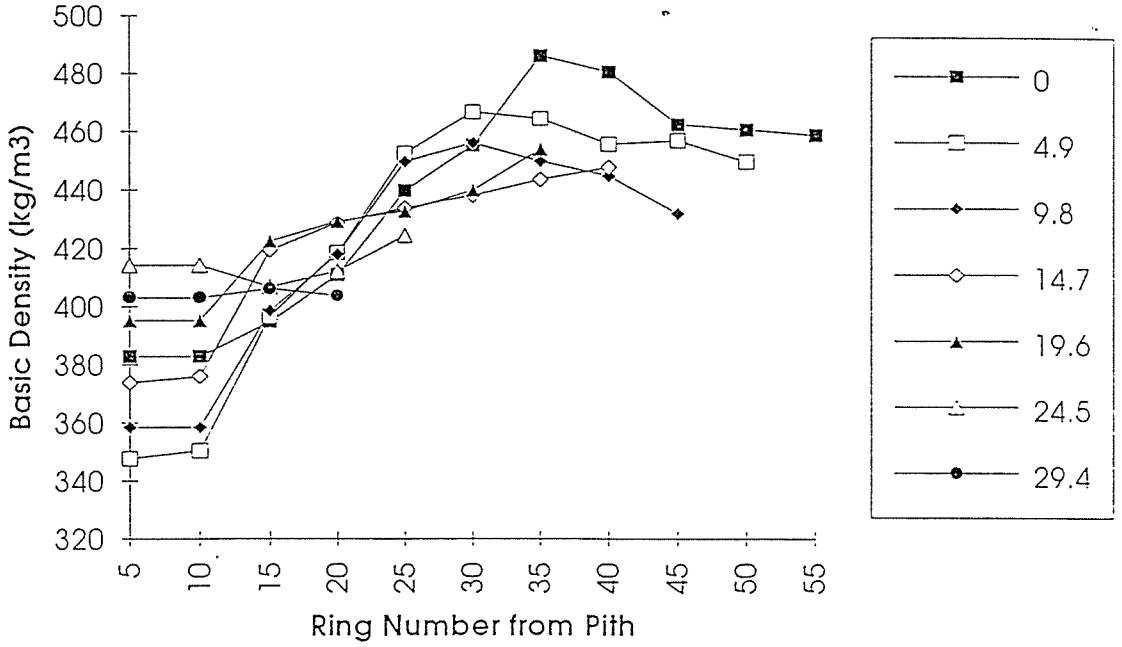


Figure 2. Variation from Pith to Bark for Basic Density
Waimahia Cpts. 688 and 694, Age 59 years.



Relationship between density measurements

The relationship between breast height outerwood density and the density of the whole tree and also the relationships between whole tree density and the density of the individual logs are given in Table 7 for the 33 and 59-year-old stands. These relationships are based on the two age classes and include all trees felled at Compartments 1 and 2 (Waiotapu) and Compartments 688 and 694 (Waimahia) and include the extra trees selected for cross-sectional analysis of pruned butt logs, and those selected as pruned sawlogs from Compartment 23 have also been included with the 33-year-old age class. All relationships were found to be significant at the 99% level.

The following data will be incorporated in the Wood Processing PC based wood density data bank for Douglas-fir. The raw data used to produce the above regressions has been included in this report as Appendix IV.

Table 7. Relationships between breast height outerwood density, whole tree density and the density of individual logs by age class.

Tree Component	Regression Coefficient (b)	Constant (a)	Correlation Coefficient (r)
Waiotapu - Cpts. 1 and 2, Age 33 years			
Butt log	.94	+ 38.0	.96
2nd log	1.19	- 81.3	.97
3rd log	1.09	- 48.1	.96
4th log	0.82	+ 50.9	.84
5th log	0.75	+ 74.6	.78
Whole tree	1.31	- 137.3	.71
Waimahia - Cpts. 688 and 694, Age 59 years			
Butt log	1.00	+ 12.6	.92
2nd log	1.04	- 16.9	.97
3rd log	.96	+ 11.8	.94
4th log	.93	+ 19.0	.90
5th log	.95	+ 5.5	.87
6th log	.95	+ 2.0	.86
7th log	1.10	- 40.5	.89
Whole tree	0.86	+ 30.6	.74

Shrinkage

Due to the high costs and lack of evidence that shrinkage is a problem in Douglas-fir only ten trees were measured for this property to give indicative results and add to existing databases. Individual disc shrinkage results are detailed in Appendix V with a summary of the averages in Table 8. In these data a negative value for longitudinal shrinkage represents expansion. This is a relatively common occurrence particularly to air-dry (12% moisture content) as shown here.

The expected trend of decreasing shrinkage with increasing height in the stem, linked to the decrease in wood density is not clearly apparent. In a practical sense the amount of variation is negligible and the overall average tree values are presented in Table 9. Variation between trees is also minimal although the older more dense trees show marginally higher shrinkage values. The Douglas-fir review completed by Cown (1989) presented average air-dry shrinkage values of 0.2%, 2.8% and 4.9% for longitudinal, radial and tangential shrinkage respectively for New Zealand grown Douglas-fir. The mean values for both stands in this study showed lower shrinkage levels than those presented by Cown.

Table 8. Average Shrinkage by Sample Height.

Height (m)	Shrinkage, %					
	Longitudinal		Radial		Tangential	
	A-dry	O-dry	A-dry	O-dry	A-dry	O-dry
Waiotapu - Cpts. 1 and 2, Age 33 years						
0.0	-0.09	0.17	1.6	3.3	3.2	5.9
4.9	-0.26	-0.01	1.7	3.6	3.6	6.8
9.8	-0.14	0.12	1.7	3.6	3.5	6.4
14.7	-0.24	0.13	1.5	3.2	3.3	6.1
19.6	-0.03	0.26	1.4	3.1	2.9	5.7
Waimahia - Cpts. 688 and 694, Age 59 years						
0.0	0.00	0.26	1.9	3.7	3.5	6.3
4.9	-0.06	0.18	1.8	3.8	3.8	7.1
9.8	-0.15	0.06	1.8	3.7	3.8	6.9
14.7	0.02	0.33	1.8	3.6	3.5	6.6
19.6	0.00	0.13	1.8	3.6	3.4	6.4
24.5	-0.12	0.08	1.8	3.7	3.3	6.2
29.4	-0.02	0.07	1.9	3.3	3.7	6.4

Table 9. Average Tree Shrinkage.

Cpt.	Tree No.	Shrinkage, %					
		Longitudinal		Radial		Tangential	
		A-Dry	O-Dry	A-Dry	O-Dry	A-Dry	O-Dry
Waiotapu - Cpts. 1 and 2, Age 33 years							
1	12	-0.17	0.10	1.6	3.3	3.2	5.9
2	11	-0.17	-0.01	2.0	3.7	3.7	6.8
2	12	-0.21	0.09	1.9	3.6	3.9	6.9
2	24	-0.25	-0.06	1.1	2.6	3.0	6.0
2	30	-0.06	0.28	1.8	4.0	3.2	6.3
	Mean	-0.17	0.08	1.7	3.4	3.4	6.4
Waimahia - Cpts. 688 and 694, Age 59 years							
688	37	-0.08	0.16	1.6	3.5	3.4	6.3
688	77	-0.14	0.07	2.2	4.5	3.7	7.2
688	103	-0.11	0.08	2.0	4.1	3.7	6.7
688	110	0.06	0.33	1.6	3.3	3.8	6.7
688	116	0.01	0.21	1.7	3.1	3.6	6.6
	Mean	-0.05	0.17	1.8	3.7	3.6	6.7
Overall	Mean	-0.11	0.13	1.8	3.6	3.5	6.5

Appendix VI presents the variation in dimensional shrinkage from pith to bark to the air- and oven dry condition. The appendix details the average results for the 33 and 59-year old trees, individually and combined and are available by height in the tree. The combined data for longitudinal, radial and tangential shrinkage are illustrated in Figures 3 to 5. The figures show that radial and tangential shrinkage increase from pith to bark and that the trend is similar to that shown for wood density.

Longitudinal shrinkage showed highest levels of longitudinal shrinkage near the pith with decreasing levels towards the bark. A number of samples showed slight expansion, particularly to the air-dry condition. This feature reflects the sample preparation and measurement techniques adopted for these measurements. Nault (1989) investigated the extent of juvenile wood in fast-growing stands of Douglas-fir in terms of longitudinal shrinkage as an indicator of fibril angle. His results showed a similar pattern of decreasing shrinkage from pith to the bark with no expansion of samples.

With so few samples the longitudinal shrinkage trend does not lend itself to determining whether the inner 10 or 20 growth rings from the pith is more appropriate for corewood definition.

Spiral Grain

As was the case with shrinkage in Douglas-fir the high cost and lack of evidence that spiral grain is linked to processing problems, reduced the requirement to measure this property extensively. Hence the same ten trees selected for the measurement of shrinkage were also assessed for spiral grain. Both ages have been combined and the averages by disc height are presented in Table 10.

Cown et al. (1991) completed an intensive examination of within and between tree variation of spiral grain in 25-year-old radiata pine. Their results showed that for the radiata corewood zone (the inner 10 growth rings) spiral grain angles averaged 4.7° and considerable variation existed between trees. Those trees with levels above 5° are likely to cause significant problems in processing and marketing through drying degrade, strength loss, and movement in service.

Figure 3. Variation in Longitudinal Shrinkage to the Air-dry Condition from Pith to Bark: 33 and 59-year old trees combined. (Note -ve value indicates expansion).

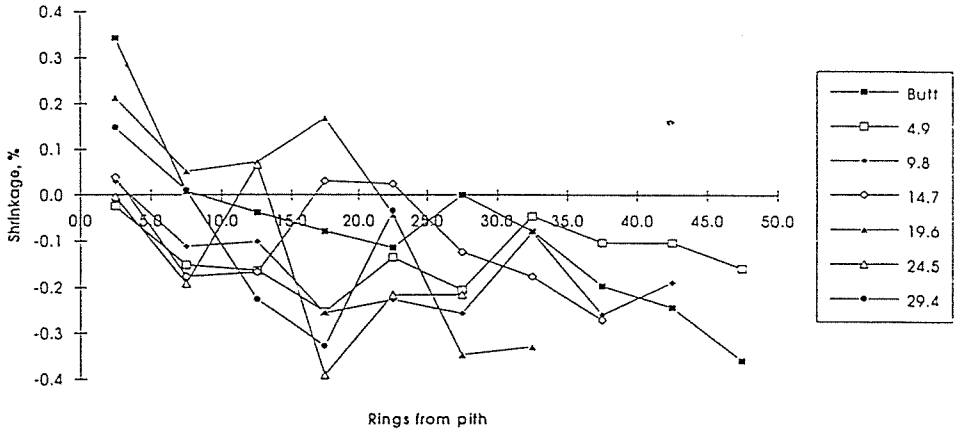


Figure 4. Variation in Radial Shrinkage to the Air-dry Condition from Pith to Bark: 33 and 59-year old trees combined.

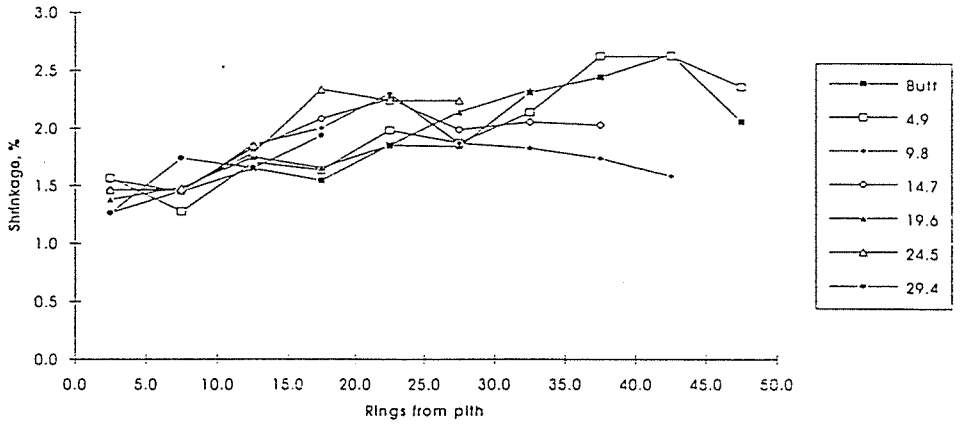
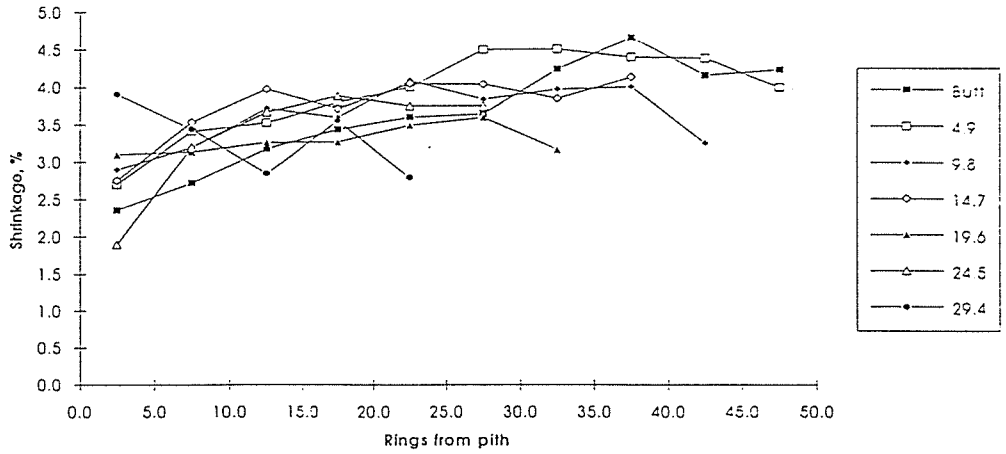


Figure 5. Variation in Tangential Shrinkage to the Air-dry Condition from Pith to Bark: 33 and 59-year old trees combined.



Based on the ten tree sample, this study indicates that on average spiral grain levels are low in comparison to radiata pine, with minimal deviation from pith to bark (Figure 6). The generally low levels indicate that this property is unlikely to have a significant impact when determining the extent of the corewood zone.

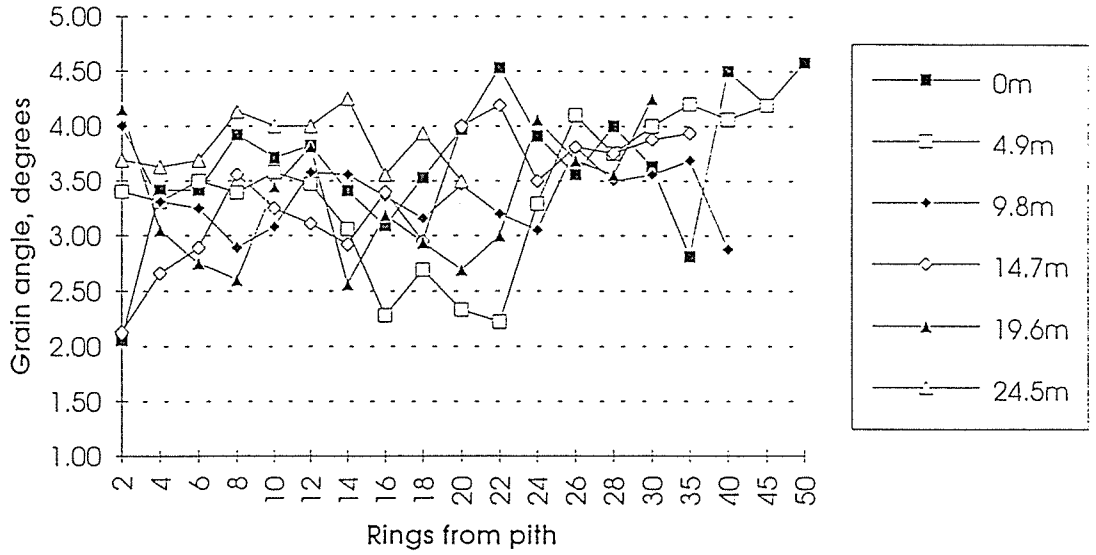
Simpson and Haslett (1994) completed a drying trial on clear boards from the pruned logs selected from Compartment 23 at Waiotapu and Compartment 688 at Waimahia. Levels of distortion were found to be low with no boards rejected for spring or bow.

Table 10. Mean Patterns of Spiral Grain Within Trees.

Disc Height (m)	Spiral grain (°) by ring number from the pith.																		
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	35	40	45	50
0.0	2.1	3.4	3.4	3.9	3.7	3.8	3.4	3.1	3.5	4.0	4.5	3.9	3.6	4.0	3.6	2.8	4.5	4.2	4.6
4.9	3.4	3.3	3.5	3.4	3.6	3.5	3.1	2.3	2.7	2.3	2.2	3.3	4.1	3.8	4.0	4.2	4.1	4.2	
9.8	4.0	3.3	3.2	2.9	3.1	3.6	3.6	3.4	3.2	3.5	3.2	3.0	3.8	3.5	3.6	3.7	2.9		
14.7	2.1	2.7	2.9	3.6	3.2	3.1	2.9	3.4	3.0	4.0	4.2	3.5	3.8	3.8	3.9	3.9			
19.6	4.2	3.0	2.8	2.6	3.4	3.8	2.6	3.2	2.9	2.7	3.0	4.1	3.7	3.6	4.2				
24.5	3.7	3.6	3.7	4.1	4.0	4.0	4.2	3.6	3.9	3.5									

NB Tree 110 butt sample excluded due to measurement error.

Figure 6. Variation in spiral grain.



CONCLUSIONS

1. The results of this comprehensive study support and extend the current data available for Douglas-fir grown in New Zealand.

2. The data provides a useful base from which comparisons with the wood quality of second growth Douglas-fir grown in North America can be drawn.

3a. The pith to bark density trends suggest that the corewood definition of the inner 20 growth rings is more appropriate than the inner 10 growth rings if a minimum level of 400 kg/m^3 is to be achieved. The extent of the corewood zone can be more accurately defined following densitometric analysis of the pith to bark samples collected during this study.

3b. The establishment of statistically significant relationships between breast height outerwood density and the tree and individual log densities provides a useful tool for predictive purposes.

4. The generally low levels of spiral grain recorded in this study indicate that this property is unlikely to have a significant impact when determining the extent of the corewood zone. It is also unlikely to cause major problems with regard to drying degrade.

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Appendix I: Individual Disc Measurements

Tree No.	Disc Height (m)	Bark Depth (mm)	DIB (mm)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
Waiotapu Cpt. 1									
1	0	22.5	548	387	741	92	59	13	56
1	4.9	8.5	453	344	718	109	58	20	68
1	9.8	8	380	357	746	109	50	31	92
1	14.7	6.5	283	359	838	134	40	43	100
1	19.6	5	170	358	919	157	15	98	100
2	0	21	484	397	806	103	46	13	50
2	4.9	11.5	409	361	798	121	42	30	74
2	9.8	8	338	350	835	138	33	35	100
2	14.7	9.5	283	340	892	134	26	43	100
2	19.6	6	190	331	924	179	14	88	100
2	24.5	4	101	333	982	195	0	100	100
3	0	24	435	413	746	81	61	24	78
3	4.9	9.5	322	366	700	92	58	44	87
3	9.8	8	241	360	756	110	50	50	87
3	14.7	6.5	171	370	870	135	34	60	100
3	19.6	3	98	378	969	156		100	100
4	0	21	483	378	889	135	32	7	45
4	4.9	10.5	394	355	820	131	34	26	81
4	9.8	10.5	339	352	889	153	27	32	100
4	14.7	7	264	355	936	154	21	46	100
4	19.6	8	188	361	986	173	12	82	100
4	24.5	4.5	91	344	1006	192		100	100
5	0	24	453	391	755	93	48	16	60
5	4.9	10.5	342	360	799	122	38	26	81
5	9.8	7.5	275	360	856	138	30	43	100
5	14.7	6	188	353	962	173	12	69	100
5	19.6	4.5	104	359	1006	180		100	100
8	0	25	449	424	799	88	48	19	69
8	4.9	9.5	354	356	768	116	46	27	79
8	9.8	7.5	275	344	810	136	32	34	100
8	14.7	5.5	138	340	925	155	16	59	100
11	0	25	515	450	811	80	52	20	57
11	4.9	12	422	403	827	105	47	20	69
11	9.8	11	364	409	873	113	37	34	92
11	14.7	9.5	285	380	891	135	30	40	100
11	19.6	7	191	402	920	130	8	60	100
11	24.5	4	63	410	964	135	3	100	100
12	0	14.5	383	427	781	83	52	20	57
12	4.9	7	298	373	771	107	50	29	74
12	9.8	6.5	255	347	808	133	37	38	100
12	14.7	5.5	205	353	883	150	26	60	100
12	19.6	4.5	132	340	972	186	5	97	100

Appendix I: Individual Disc Measurements (Contd)

Tree No.	Disc Height (m)	Bark Depth (mm)	DIB (mm)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
17	0	23.5	383	431	811	88	52	26	64
17	4.9	9	321	373	756	103	47	31	54
17	9.8	7.5	272	383	820	114	44	39	95
17	14.7	7.5	218	380	883	123	30	53	100
17	19.6	6.5	149	363	941	159	14	100	100
18	0	24.5	521	413	766	85	53	15	55
18	4.9	11	396	412	805	95	43	27	78
18	9.8	10.5	358	422	863	105	34	34	93
18	14.7	9.5	286	394	907	130	29	49	100
18	19.6	7	204	378	929	146	17	74	100
18	24.5	5	82	350	1009	188		100	100
24	0	23	421	403	810	101	49	25	77
24	4.9	11	302	399	826	107	42	43	88
24	9.8	6.5	212	401	910	127	27	47	100
24	14.7	4.5	149	375	912	143	16	81	100
Waiotapu Cpt. 2									
1	0	15.5	337	460	905	97	37	14	62
1	4.9	6.5	297	384	815	112	39	26	83
1	9.8	7.5	267	397	865	118	36	41	100
1	14.7	4.5	191	387	948	145	18	68	100
1	19.6	5	105	369	1018	176		100	100
2	0	16	459	431	877	103	46	11	52
2	4.9	9	393	363	812	123	49	18	75
2	9.8	8.5	310	343	813	137	42	37	100
2	14.7	6	257	344	855	149	34	47	100
2	19.6	6	140	336	966	188	13	100	100
3	0	31.5	420	468	835	79	53	15	61
3	4.9	12.5	348	428	809	89	52	29	84
3	9.8	10.5	309	434	839	93	48	38	97
3	14.7	8	254	428	896	109	35	48	100
3	19.6	5	155	374	958	156	13	100	100
4	0	16	373	470	931	98	35	11	56
4	4.9	7.5	298	404	877	117	39	29	78
4	9.8	7	256	401	891	122	32	42	95
4	14.7	6	195	392	976	149	17	62	100
4	19.6	4	101	357	1043	192		100	100
8	0	19	482	411	832	103	43	12	58
8	4.9	10.5	389	390	798	105	48	29	86
8	9.8	9	329	388	838	116	41	42	100
8	14.7	7.5	270	370	850	127	35	51	100
8	19.6	6	176	361	915	153	21	100	100

Appendix I: Individual Disc Measurements (Contd)

Tree No.	Disc Height (m)	Bark Depth (mm)	DIB (mm)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
11	0	13	283	418	836	100	38	12	58
11	4.9	6	228	364	770	111	40	33	93
11	9.8	6.5	192	357	833	133	33	55	100
11	14.7	6	124	336	955	184	13	88	100
12	0	10	284	424	874	106	40	18	59
12	4.9	6.5	218	384	829	116	44	32	84
12	9.8	5	181	376	858	128	31	50	100
12	14.7	4.5	131	374	981	162	15	100	100
17	0	25	433	440	817	86	53	18	68
17	4.9	15	375	412	778	89	50	40	92
17	9.8	8.5	298	414	858	107	41	46	100
17	14.7	7	216	378	873	131	28	50	100
17	19.6	4	101	376	1000	166		100	100
18	0	32	478	436	839	92	57	15	65
18	4.9	11.5	385	386	786	103	51	26	84
18	9.8	8.5	328	377	823	119	45	32	100
18	14.7	8	244	382	894	134	33	54	100
18	19.6	7	144	378	981	160	10	100	100
22	0	27.5	465	411	758	85	50	15	63
22	4.9	11	352	379	778	105	45	30	88
22	9.8	9.5	274	366	821	125	34	42	100
22	14.7	9	164	365	891	144	18	100	100
24	0	25	424	416	771	85	64	26	70
24	4.9	9.5	324	357	720	102	55	29	77
24	9.8	7	246	349	790	126	37	49	100
24	14.7	6	177	346	900	160	20	77	100
24	19.6	5	110	338	991	193	1	100	100
30	0	26.5	586	404	771	91	60	12	60
30	4.9	12	438	398	801	101	50	24	42
30	9.8	10	373	381	846	122	40	34	100
30	14.7	8.5	297	387	897	132	33	40	100
30	19.6	6.5	205	388	995	157	17	88	100
30	24.5	4.5	102	346	985	185	1	100	100
Waimahia Cpt. 688									
3	0	52	483	439	753	72	56	14	34
3	4.9	14	354	452	763	69	58	21	42
3	9.8	9.5	305	441	762	73	57	22	47
3	14.7	8	275	450	798	77	56	26	47
3	19.6	7	232	416	822	97	45	24	51
3	24.5	6.5	165	435	903	108	27	21	54
3	29.4	4	75	424	1019	140	2	48	100

Appendix I: Individual Disc Measurements (Contd)

Tree No.	Disc Height (m)	Bark Depth (mm)	DIB (mm)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
8	0	21	451	520	816	57	65	11	31
8	4.9	11	340	508	812	60	35	16	46
8	9.8	7.5	304	490	809	65	35	25	51
8	14.7	7.5	267	475	824	74	43	26	55
8	19.6	7.5	220	471	865	84	35	25	65
8	24.5	6.5	147	451	920	104	14	20	72
19	0	29.5	529	485	762	57	65	11	34
19	4.9	11.5	410	426	702	65	67	19	44
19	9.8	9	377	424	707	67	65	20	46
19	14.7	9.5	343	426	721	69	62	23	49
19	19.6	8	293	418	749	79	54	23	59
19	24.5	6.5	237	395	795	101	43	24	73
19	29.4	5.5	150	399	900	126	25	44	100
19	34.3	3	65	384	1018	165		100	100
20	0	30	665	450	723	65	62	8	34
20	4.9	16	496	464	769	66	63	16	47
20	9.8	12.5	438	457	764	67	62	20	51
20	14.7	12.5	415	461	790	71	58	21	54
20	19.6	11	364	461	807	75	49	19	52
20	24.5	10	316	450	834	86	44	21	61
20	29.4	9.5	241	451	930	106	25	19	67
20	34.3	7	143	420	978	133	6	40	100
27	0	45.5	711	420	753	79	61	5	22
27	4.9	15.5	560	393	739	88	65	14	33
27	9.8	12.5	505	376	718	91	63	15	41
27	14.7	12	472	395	739	87	72	15	43
27	19.6	11	413	388	745	92	58	15	44
27	24.5	9.5	339	381	783	105	52	14	49
27	29.4	8.5	244	384	829	116	49	21	72
27	34.3	5	148	380	840	183	22	46	100
34	0	45	720	447	792	77	51	5	22
34	4.9	14.5	543	446	819	84	57	12	33
34	9.8	12	477	434	827	91	54	14	36
34	14.7	12.5	443	434	806	86	47	15	41
34	19.6	11	397	424	820	93	45	16	47
34	24.5	11	320	404	887	119	33	14	49
34	29.4	7.5	238	424	930	120	21	13	54
34	34.3	7	129	370	976	164	7	55	100
37	0	47.5	630	440	767	74	47	11	25
37	4.9	13	468	392	703	79	63	14	37
37	9.8	11.5	425	381	712	87	60	19	43
37	14.7	11.5	392	405	746	84	51	17	44
37	19.6	10	345	369	722	96	50	15	47
37	24.5	7.5	282	380	819	115	39	21	60
37	29.4	7.5	200	381	884	132	20	21	71
37	34.3	5	92	383	984	157	1	79	100

Appendix I: Individual Disc Measurements (Contd)

Tree No.	Disc Height (m)	Bark Depth (mm)	DIB (mm)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
39	0	33	530	484	818	69	54	10	35
39	4.9	14	404	459	791	72	57	19	41
39	9.8	11	366	455	808	78	49	24	42
39	14.7	8.5	316	435	847	94	40	17	42
39	19.6	8	265	413	860	108	32	14	54
39	24.5	6.5	183	395	925	134	15	19	74
39	29.4	4	78	410	1016	135	0	76	100
40	0	26.5	587	418	739	77	64	10	25
40	4.9	16	478	399	731	83	62	16	34
40	9.8	9.5	413	378	713	89	60	22	32
40	14.7	8.5	374	374	718	92	58	16	35
40	19.6	9.5	323	389	759	95	51	13	36
40	24.5	9	252	358	825	131	38	10	44
40	29.4	6.5	166	393	943	140	15	36	100
44	0	30	575	469	805	72	57	7	28
44	4.9	13.5	458	429	754	76	54	15	38
44	9.8	11	426	429	770	80	60	15	41
44	14.7	8.5	385	417	786	89	59	16	41
44	19.6	10.5	343	388	792	104	51	19	49
44	24.5	7	271	368	843	129	35	18	51
44	29.4	6	172	366	897	145	17	12	57
46	0	47.5	665	480	801	67	67	8	36
46	4.9	20.5	562	432	758	76	66	17	45
46	9.8	14.5	479	423	777	84	55	15	43
46	14.7	15	430	442	846	79	52	18	47
46	19.6	11	360	444	873	96	39	15	53
46	24.5	10	286	442	924	109	31	20	68
46	29.4	6.5	171	425	962	126	12	41	100
47	0	26.5	505	438	763	74	69	9	33
47	4.9	11.5	429	433	756	75	49	17	48
47	9.8	9	369	409	746	82	62	24	55
47	14.7	10.5	352	438	850	76	57	26	55
47	19.6	7	287	427	842	97	44	26	59
47	24.5	5.5	218	419	917	119	30	28	75
47	29.4	4.5	143	430	978	127	12	40	100
52	0	19.5	369	459	748	63	58	15	38
52	4.9	10.5	293	478	804	68	62	27	49
52	9.8	7.5	262	422	750	78	58	25	50
52	14.7	6.5	236	413	755	83	52	24	47
52	19.6	7	204	407	784	92	44	28	54
52	24.5	5	152	391	849	117	21	25	63

Appendix I: Individual Disc Measurements (Contd)

Tree No.	Disc Height (m)	Bark Depth (mm)	DIB (mm)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
58	0	25.5	529	426	732	72	68	10	31
58	4.9	14	434	412	762	85	61	15	37
58	9.8	9.5	399	375	737	97	58	17	41
58	14.7	8	364	367	749	104	55	19	43
58	19.6	8	320	365	771	112	49	20	49
58	24.5	7	258	373	824	121	36	16	58
58	29.4	6.5	182	344	919	167	15	33	100
68	0	32.5	765	428	720	68	67	7	34
68	4.9	20	660	435	727	67	62	16	43
68	9.8	14.5	550	480	708	77	65	20	50
68	14.7	14	520	414	752	81	67	17	47
68	19.6	13	438	418	780	86	57	18	49
68	24.5	9	385	415	827	99	46	18	57
68	29.4	9.5	303	421	851	102	39	17	63
68	34.3	8.5	231	404	820	103	34	34	83
68	39.2	5.5	102	402	904	125	15	68	100
70	0	33	386	486	815	68	67	15	42
70	4.9	12	304	426	750	76	65	20	48
70	9.8	8.5	268	400	751	99	59	23	51
70	14.7	7	241	423	794	88	47	22	52
70	19.6	6	203	453	901	99	38	28	66
70	24.5	7	162	419	898	114	28	23	70
70	29.4	5	85	429	987	130	3	52	100
72	0	67.5	615	482	849	76	69	8	50
72	4.9	22	496	484	883	82	63	22	53
72	9.8	16	437	477	849	78	57	15	46
72	14.7	12	391	476	872	83	57	20	49
72	19.6	10.5	341	489	881	80	45	23	56
72	24.5	9.5	270	489	921	88	35	22	62
72	29.4	7	184	497	988	99	19	24	94
72	34.3	3.5	85	447	1057	137		95	100
73	0	41.5	480	460	752	63	71	14	51
73	4.9	13.5	376	426	732	72	64	26	56
73	9.8	11.5	359	449	773	72	65	32	61
73	14.7	8	289	401	755	88	61	28	59
73	19.6	6.5	245	399	794	99	48	23	63
73	24.5	5.5	198	401	915	128	31	21	69
73	29.4	5.5	116	404	969	140	7	48	100
77	0	19	426	473	729	54	73	13	38
77	4.9	10.5	323	470	773	55	75	21	49
77	9.8	7	284	466	743	59	71	28	59
77	14.7	9.5	259	460	821	60	66	29	59
77	19.6	8	217	455	791	74	51	33	64
77	24.5	6.5	170	459	864	88	38	26	68
77	29.4	4.5	105	448	985	120	11	42	100

Appendix I: Individual Disc Measurements (Contd)

Tree No.	Disc Height (m)	Bark Depth (mm)	DIB (mm)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
78	0	20	400	425	759	79	64	11	38
78	4.9	9.5	317	399	749	88	65	20	48
78	9.8	9.5	269	407	771	89	61	25	51
78	14.7	8	216	413	817	98	55	29	60
78	19.6	6	143	429	886	107	35	23	52
80	0	30	465	523	812	55	62	13	42
80	4.9	11.5	357	506	841	66	64	27	53
80	9.8	6.5	305	456	803	76	59	28	52
80	14.7	7	272	477	835	75	57	26	44
80	19.6	6	225	473	875	85	42	26	62
80	24.5	6	176	457	874	91	32	21	71
88	0	35.5	453	414	698	69	67	16	51
88	4.9	13	360	423	727	72	69	28	59
88	9.8	8.5	311	404	742	84	62	26	60
88	14.7	6.5	265	391	754	93	49	27	63
88	19.6	6	220	379	813	115	35	30	71
88	24.5	6.5	132	390	930	118	17	36	90
91	0	45	560	510	875	60	63	11	34
91	4.9	16.5	450	467	753	61	66	23	49
91	9.8	13.5	414	485	807	67	51	19	47
91	14.7	11.5	376	472	812	72	52	20	49
91	19.6	8	314	443	846	91	43	23	59
91	24.5	7.5	238	439	874	99	28	23	69
91	29.4	6	148	439	940	114	9	50	100
99	0	31	487	476	792	67	61	11	35
99	4.9	21.5	430	491	814	66	64	23	47
99	9.8	14.5	390	475	822	73	57	21	43
99	14.7	10	355	442	814	84	50	18	45
99	19.6	9	301	452	841	86	36	16	53
99	24.5	8	241	436	883	103	29	22	67
99	29.4	6	155	425	959	126	10	43	100
100	0	25	625	441	764	73	60	6	25
100	4.9	16	551	430	738	72	73	16	40
100	9.8	13	495	396	717	81	72	21	49
100	14.7	10	452	382	703	84	67	19	49
100	19.6								
100	24.5	8.5	324	383	809	111	48	21	62
100	29.4	7.5	254	376	845	125	35	31	83
100	34.3	5.5	141	377	916	143	13	51	100
103	0	25	695	436	718	65	68	2	32
103	4.9	15	532	416	729	75	72	17	52
103	9.8	12	464	405	745	84	62	20	57
103	14.7	12.5	412	434	798	84	57	24	61
103	19.6	10.5	325	410	820	100	40	20	65
103	24.5	9.5	252	426	881	107	33	30	88
103	29.4	7.5	145	415	951	129	10	50	100

Appendix I: Individual Disc Measurements (Contd)

Tree No.	Disc Height (m)	Bark Depth (mm)	DIB (mm)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
105	0	45	750	478	843	76	65	5	24
105	4.9	25	645	453	823	82	63	15	40
105	9.8	16	573	428	840	96	54	13	45
105	14.7	14.5	508	468	904	93	42	10	47
105	19.6	11.5	380	396	860	117	37	15	62
105	24.5	9	270	405	913	125	27	25	100
105	29.4	5	148	388	948	144	9	83	100
108	0	42.5	635	426	759	78	63	1	13
108	4.9	15.5	509	420	820	95	56	15	47
108	9.8	13	442	433	862	99	48	17	49
108	14.7	11	377	423	865	105	37	18	59
108	19.6	9.5	311	434	904	108	32	18	72
108	24.5	8	249	417	903	116	27	29	100
108	29.4	6	159	413	898	117	14	69	100
109	0	32.5	585	418	750	79	62	2	19
109	4.9	11.5	490	446	796	79	62	18	52
109	9.8	11.5	405	436	791	82	57	22	57
109	14.7	9.5	344	416	803	93	53	25	66
109	19.6	7	272	444	890	101	37	22	57
109	24.5	6	229	424	882	108	25	24	76
109	29.4	5	151	412	937	127	9	41	100
110	0	45	705	470	775	64	69	7	40
110	4.9	17.5	630	482	794	65	60	18	55
110	9.8	15.5	532	415	740	78	65	14	47
110	14.7	14	460	420	781	86	56	18	51
110	19.6	15.5	389	450	867	84	41	15	51
110	24.5	10	262	432	880	104	25	27	100
110	29.4	6	146	402	945	135	8	68	100
111	0	51	558	438	718	64	71	6	39
111	4.9	18	463	436	725	66	73	32	67
111	9.8	17	410	450	780	65	69	29	63
111	14.7	10.5	338	423	742	76	50	21	59
111	19.6	7.5	251	413	783	90	41	30	84
111	24.5	7	183	404	886	119	22	50	100
113	0	42	483	441	768	74	64	3	33
113	4.9	11.5	350	420	740	76	60	23	65
113	9.8	8	298	433	789	82	52	28	63
113	14.7	6.5	239	451	839	86	34	25	70
113	19.6	5.5	174	465	898	93	21	35	81
113	24.5	5	117	446	968	117	7	50	100
116	0	38.5	444	460	773	97	46	6	31
116	4.9	10	355	438	774	77	52	19	57
116	9.8	7	285	410	814	98	40	21	72
116	14.7	6	208	434	889	105	23	37	100

Appendix I: Individual Disc Measurements (Contd)

Tree No.	Disc Height (m)	Bark Depth (mm)	DIB (mm)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)	Heart-wood (%)	Core-wood 10 rings (%)	Core-wood 20 rings (%)
Waimahia Cpt. 694									
2	0	35	421	442	741	68	67	3	34
2	4.9	10	339	418	698	67	44	26	68
2	9.8	6	273	413	738	79	59	32	75
2	14.7	6	187	405	790	98	41	37	88
2	19.6	4.5	125	395	798	102	31	69	100
3	0	27.5	395	510	786	54	68	13	43
3	4.9	15.5	326	480	748	63	76	29	54
3	9.8	8.5	287	465	782	68	70	26	56
3	14.7	6	243	425	759	79	64	29	62
3	19.6	7	201	423	764	81	56	31	72
3	24.5	5.5	156	447	816	83	50	35	82
6	0	15	332	494	764	55	71	15	44
6	4.9	7.5	263	475	766	61	67	28	59
6	9.8	8.5	241	470	814	57	62	29	63
6	14.7	5.5	203	466	777	67	58	38	70
6	19.6	6	174	475	828	74	44	33	76
6	24.5	5	130	480	956	93	21	26	73
8	0	41.5	562	436	741	70	73	10	33
8	4.9	14	455	398	701	76	72	15	35
8	9.8	13.5	417	392	701	79	70	17	42
8	14.7	9.5	373	384	712	86	67	16	45
8	19.6	8.5	326	403	775	92	59	21	59
8	24.5	8	265	402	825	105	49	24	70
8	29.4	7.5	190	391	888	127	22	35	100
8	34.3	5.5	105	403	949	136	4	84	100
11	0	45	730	491	822	67	64	5	15
11	4.9	22.5	595	458	826	80	56	9	21
11	9.8	16	552	438	811	85	55	11	26
11	14.7	18	518	412	808	96	50	11	36
11	19.6	12	467	434	848	95	44	7	35
11	24.5	11	342	404	835	107	40	15	60
11	29.4	8.5	228	405	881	117	28	34	100
11	34.3	4.5	109	391	924	136	5	100	100

Appendix II: Individual Heart / Sapwood Moisture Contents

Tree No.	Disc Height (m)	Heart M.C. (%)	Sap M.C. (%)
Waiotapu Cpt.1			
1	0	54	162
1	4.9	53	197
1	9.8	49	184
1	14.7	46	195
1	19.6	46	194
2	0	51	170
2	4.9	48	185
2	9.8	50	187
2	14.7	49	194
2	19.6	49	210
3	0	53	169
3	4.9	52	187
3	9.8	49	186
4	0	54	176
4	4.9	55	198
4	9.8	56	207
4	14.7	56	199
4	19.6	53	196
5	0	50	149
5	4.9	48	173
5	9.8	50	193
5	14.7	50	194
8	0	48	142
8	4.9	50	178
8	9.8	49	164
11	0	51	139
11	4.9	50	157
11	9.8	49	181
11	14.7	49	188
11	19.6	38	184
12	0	50	165
12	4.9	53	160
12	9.8	53	182
12	14.7	55	212
12	19.6	75	195

Tree No.	Disc Height (m)	Heart M.C. (%)	Sap M.C. (%)
Waiotapu Cpt.1 contd.			
17	0	47	141
17	4.9	49	172
17	9.8	51	170
18	0	54	143
18	4.9	51	149
18	9.8	53	155
18	14.7	53	160
18	19.6	50	181
24	0	58	150
24	4.9	53	173
24	9.8	49	154
Waiotapu Cpt. 2			
1	0	48	139
1	4.9	48	154
1	9.8	51	177
2	0	54	125
2	4.9	51	179
2	9.8	56	216
3	0	44	130
3	4.9	47	144
3	9.8	48	151
4	0	47	145
4	4.9	49	176
4	9.8	51	168
8	0	53	157
8	4.9	51	172
8	9.8	51	170
11	0	50	175
11	4.9	53	157
11	9.8	62	177
11	14.7	63	211
12	0	47	178
12	4.9	49	173
12	9.8	54	174
12	14.7	65	209

Appendix II: Individual Heart / Sapwood Moisture Contents (Contd.)

Tree No.	Disc Height (m)	Heart M.C. (%)	Sap M.C. (%)
Waiotapu Cpt. 2 contd.			
17	0	49	137
17	4.9	47	140
17	9.8	46	150
18	0	50	138
18	4.9	51	171
18	9.8	53	175
22	0	46	126
22	4.9	47	141
22	9.8	48	166
24	0	53	150
24	4.9	55	167
24	9.8	54	167
24	14.7	56	187
30	0	49	106
30	4.9	52	165
30	9.8	50	173
30	14.7	49	160
30	19.6	47	171
Waimahia Cpt. 688			
3	0	47	119
3	4.9	44	119
3	9.8	43	121
8	0	39	96
8	4.9	39	106
8	9.8	40	106
8	14.7	40	115
8	19.6	39	129
8	24.5	40	134
19	0	42	88
19	4.9	42	111
19	9.8	44	117
19	14.7	42	120
19	19.6	41	125
19	24.5	43	146
19	29.4	44	156

Tree No.	Disc Height (m)	Heart M.C. (%)	Sap M.C. (%)
Waimahia Cpt. 688 contd.			
20	0	45	80
20	4.9	45	100
20	9.8	43	99
20	14.7	42	103
20	19.6	43	95
20	24.5	45	131
20	29.4	43	136
27	0	46	166
27	4.9	42	161
27	9.8	46	189
34	0	50	112
34	4.9	49	124
34	9.8	47	124
37	0	46	130
37	4.9	49	150
37	9.8	48	153
37	14.7	45	154
37	19.6	47	175
37	24.5	46	160
37	29.4	44	168
39	0	48	100
39	4.9	77	79
39	9.8	52	101
39	14.7	46	139
39	19.6	44	151
39	24.5	45	173
40	0	44	160
40	4.9	45	122
40	9.8	47	155
44	0	43	122
44	4.9	47	122
44	9.8	41	125
46	0	48	108
46	4.9	49	129
46	9.8	49	143
46	14.7	48	139
46	19.6	47	143
46	24.5	48	143
46	29.4	41	146

Appendix II: Individual Heart / Sapwood Moisture Contents (Contd.)

Tree No.	Disc Height (m)	Heart M.C. (%)	Sap M.C. (%)
Waimahia Cpt. 688 contd.			
47	0	52	136
47	4.9	52	145
47	9.8	47	121
47	14.7	49	142
47	19.6	48	143
47	24.5	43	132
47	29.4	53	159
52	0	44	116
52	4.9	46	99
52	9.8	46	127
52	14.7	47	125
52	19.6	46	134
52	24.5	40	130
58	0	46	141
58	4.9	43	158
58	9.8	43	170
68	0	50	150
68	4.9	47	151
68	9.8	48	150
70	0	46	114
70	4.9	46	122
70	9.8	48	129
72	0	49	129
72	4.9	47	127
72	9.8	46	122
73	0	49	116
73	4.9	52	114
73	9.8	50	118
73	14.7	51	133
73	19.6	49	137
73	24.5	46	158
77	0	44	95
77	4.9	44	94
77	9.8	42	92
77	14.7	43	102
77	19.6	43	103
77	24.5	43	115

Tree No.	Disc Height (m)	Heart M.C. (%)	Sap M.C. (%)
Waimahia Cpt. 688 contd.			
78	0	49	133
78	4.9	49	156
78	9.8	47	156
78	14.7	50	162
80	0	44	91
80	4.9	47	108
80	9.8	45	112
80	14.7	39	116
80	19.6	42	130
80	24.5	37	125
88	0	50	118
88	4.9	49	121
88	9.8	46	124
91	0	43	86
91	4.9	44	103
91	9.8	46	108
99	0	45	118
99	4.9	45	120
99	9.8	44	132
99	14.7	45	129
99	19.6	43	132
99	24.5	48	127
99	29.4	47	140
100	0	43	112
100	4.9	43	135
100	9.8	46	152
103	0	47	120
103	4.9	47	135
103	9.8	44	147
103	14.7	44	145
103	19.6	46	148
103	24.5	45	157
105	0	52	126
105	4.9	52	150
105	9.8	51	174
105	14.7	51	158
105	19.6	50	185
105	24.5	45	161

Appendix II: Individual Heart / Sapwood Moisture Contents (Contd.)

Tree No.	Disc Height (m)	Heart M.C. (%)	Sap M.C. (%)
Waimahia Cpt. 688 contd.			
108	0	48	126
108	4.9	47	149
108	9.8	45	140
109	0	50	123
109	4.9	48	125
109	9.8	47	139
110	0	46	154
110	4.9	45	156
110	9.8	44	147
110	14.7	47	151
110	19.6	45	156
110	24.5	45	151
110	29.4	57	158
111	0	48	127
111	4.9	49	125
111	9.8	48	119
113	0	47	126
113	4.9	47	125
113	9.8	48	123
113	14.7	43	117
113	19.6	40	105
116	0	47	120
116	4.9	47	113
116	9.8	49	130
116	14.7	50	131
Waimahia Cpt. 694			
2	0	45	111
2	4.9	49	70
2	9.8	51	134
2	14.7	50	136
3	0	44	102
3	4.9	44	129
3	9.8	47	142
3	14.7	45	130
3	19.6	46	141
3	24.5	47	118
6	0	45	90
6	4.9	46	90
6	9.8	44	87

Tree No.	Disc Height (m)	Heart M.C. (%)	Sap M.C. (%)
Waimahia Cpt. 694 contd.			
8	0	50	126
8	4.9	48	133
8	9.8	48	150
8	14.7	50	150
8	19.6	49	150
8	24.5	51	157
8	29.4	52	176
11	0	47	106
11	4.9		
11	9.8	46	133

Appendix III. Log and Tree Values

Tree No.	Log Class	Volume (m^3)	Heart-wood (%)	Corewood 10 rings (%)	Corewood 20 rings (%)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)
Waiotapu Cpt. 1								
1	Butt	0.973	58	16	61	369	732	99
1	2nd	0.673	55	24	78	349	729	109
1	3rd	0.432	47	35	95	358	779	118
1	4th	0.210	34	57	100	359	860	140
1	Tree	2.287	53	26	76	360	752	109
2	Butt	0.773	45	20	60	382	803	111
2	2nd	0.542	38	32	85	357	813	128
2	3rd	0.374	30	38	100	346	859	137
2	4th	0.224	22	57	100	337	902	148
2	5th	0.089	11	90	100	331	937	183
2	Tree	2.001	36	34	81	361	833	128
3	Butt	0.564	60	31	81	396	730	84
3	2nd	0.311	55	46	87	364	720	98
3	3rd	0.168	45	53	100	363	794	118
3	4th	0.075	26	70	100	372	894	140
3	Tree	1.118	54	41	87	381	748	97
4	Butt	0.748	33	15	59	369	861	133
4	2nd	0.520	31	29	100	354	849	140
4	3rd	0.355	24	38	100	353	906	153
4	4th	0.202	18	58	100	357	952	161
4	5th	0.084	10	85	100	358	989	177
4	Tree	1.909	28	30	84	360	882	144
5	Butt	0.620	44	20	68	380	771	104
5	2nd	0.371	35	33	100	360	822	128
5	3rd	0.214	24	51	100	358	890	149
5	4th	0.089	9	76	100	354	973	174
5	Tree	1.293	36	32	85	369	819	123
8	Butt	0.629	47	22	73	398	787	99
8	2nd	0.387	41	29	100	351	784	123
8	3rd	0.182	29	39	100	343	833	140
8	Tree	1.198	42	27	86	374	793	113
11	Butt	0.853	50	20	62	431	817	90
11	2nd	0.598	43	26	79	406	846	109
11	3rd	0.411	34	36	100	398	880	121
11	4th	0.226	23	59	100	386	900	133
11	5th	0.078	8	100	100	402	924	130
11	Tree	2.166	41	32	79	412	850	107
12	Butt	0.453	51	23	64	407	777	92
12	2nd	0.296	44	33	85	362	787	118
12	3rd	0.206	33	47	100	349	837	140
12	4th	0.114	20	71	100	349	909	161
12	Tree	1.070	42	36	80	377	805	116

Appendix III. Log and Tree Values (Contd)

Tree No.	Log Class	Volume (m^3)	Heart-wood (%)	Corewood 10 rings (%)	Corewood 20 rings (%)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)
Waiotapu Cpt. 1								
17	Butt	0.481	50	29	60	407	789	94
17	2nd	0.341	46	35	71	377	783	108
17	3rd	0.234	39	44	100	382	845	118
17	4th	0.134	25	68	100	375	902	134
17	Tree	1.189	44	38	75	390	811	107
18	Butt	0.824	50	19	63	413	780	89
18	2nd	0.548	39	30	85	416	831	100
18	3rd	0.404	32	40	100	411	880	115
18	4th	0.237	25	57	100	388	914	136
18	5th	0.093	15	77	100	374	940	152
18	Tree	2.107	39	33	82	409	835	105
24	Butt	0.517	47	31	81	402	815	103
24	2nd	0.262	37	44	100	400	854	113
24	3rd	0.129	23	58	100	392	911	132
24	Tree	0.908	40	39	89	400	840	110
Waiotapu Cpt. 2								
1	Butt	0.388	38	19	71	427	865	103
1	2nd	0.307	38	32	100	390	837	115
1	3rd	0.207	30	50	100	394	893	127
1	4th	0.091	13	75	100	383	964	152
1	Tree	0.994	34	35	89	405	872	116
2	Butt	0.703	47	14	61	403	849	112
2	2nd	0.482	46	25	100	356	812	129
2	3rd	0.312	39	41	100	343	830	142
2	4th	0.165	29	59	100	342	880	158
2	Tree	1.662	43	27	84	372	838	127
3	Butt	0.572	52	21	70	452	825	83
3	2nd	0.417	50	33	90	431	822	91
3	3rd	0.308	43	42	100	432	862	100
3	4th	0.170	29	62	100	413	913	122
3	Tree	1.467	47	33	86	437	842	93
4	Butt	0.439	36	18	64	445	910	105
4	2nd	0.297	36	35	85	403	883	119
4	3rd	0.199	26	49	100	397	922	132
4	4th	0.093	13	70	100	385	991	158
4	Tree	1.028	32	34	81	418	912	119
8	Butt	0.738	45	19	69	403	819	103
8	2nd	0.499	45	34	100	389	815	110
8	3rd	0.349	38	45	100	381	843	121
8	4th	0.200	31	65	100	367	869	135
8	Tree	1.786	42	34	87	391	828	112

Appendix III. Log and Tree Values (Contd)

Tree No.	Log Class	Volume (m^3)	Heart-wood (%)	Corewood 10 rings (%)	Corewood 20 rings (%)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)
Waiotapu Cpt. 2 (contd.)								
11	Butt	0.254	39	20	72	397	810	104
11	2nd	0.171	37	42	100	361	796	121
11	3rd	0.101	27	65	100	351	869	148
11	Tree	0.526	36	36	86	376	817	118
12	Butt	0.247	42	23	68	409	857	110
12	2nd	0.154	39	40	100	381	841	121
12	3rd	0.096	25	69	100	376	900	140
12	Tree	0.497	38	37	84	394	861	119
17	Butt	0.631	52	28	79	428	801	87
17	2nd	0.441	46	43	100	413	809	96
17	3rd	0.261	36	48	100	402	863	115
17	4th	0.109	23	59	100	378	895	137
17	Tree	1.443	45	38	91	415	822	99
18	Butt	0.725	54	19	72	417	818	97
18	2nd	0.492	48	29	100	382	802	110
18	3rd	0.322	41	40	100	379	849	124
18	4th	0.154	27	66	100	381	916	141
18	Tree	1.693	48	30	88	396	828	110
22	Butt	0.654	48	20	72	399	765	92
22	2nd	0.383	41	35	100	374	794	112
22	3rd	0.196	30	57	100	365	840	130
22	Tree	1.234	43	31	85	386	786	104
24	Butt	0.548	61	27	73	394	752	91
24	2nd	0.318	48	37	100	354	746	111
24	3rd	0.177	31	59	100	348	827	138
24	4th	0.084	15	83	100	344	925	170
24	Tree	1.127	49	39	87	372	775	110
30	Butt	1.030	57	16	54	402	782	95
30	2nd	0.637	46	28	100	391	820	110
30	3rd	0.437	37	36	100	384	866	126
30	4th	0.251	28	55	100	387	928	140
30	5th	0.101	14	90	100	379	993	162
30	Tree	2.456	46	30	81	393	830	111
Waimahia Cpt 688								
3	Butt	0.690	56	16	37	444	757	71
3	2nd	0.420	58	21	44	447	763	71
3	3rd	0.325	56	24	47	445	778	75
3	4th	0.249	51	25	49	436	808	86
3	5th	0.156	39	23	52	423	849	101
3	6th	0.063	22	26	100	433	923	113
3	Tree	1.903	53	21	45	442	782	77

Appendix III. Log and Tree Values (Contd)

Tree No.	Log Class	Volume (m^3)	Heart-wood (%)	Corewood 10 rings (%)	Corewood 20 rings (%)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)
Waimahia Cpt. 688 contd.								
8	Butt	0.614	54	13	37	516	814	58
8	2nd	0.400	35	20	48	500	811	62
8	3rd	0.315	38	25	53	483	816	69
8	4th	0.230	40	25	59	473	841	78
8	5th	0.135	28	23	67	465	882	90
8	Tree	1.694	43	19	48	496	823	66
19	Butt	0.862	65	14	38	463	739	60
19	2nd	0.597	66	20	45	425	704	66
19	3rd	0.500	64	22	48	425	714	68
19	4th	0.392	59	23	53	423	733	73
19	5th	0.273	49	23	65	409	767	88
19	6th	0.151	38	30	100	396	825	108
19	7th	0.051	21	53	100	396	918	132
19	Tree	2.826	61	20	50	433	737	71
20	Butt	1.324	63	11	38	461	739	65
20	2nd	0.843	63	18	49	461	767	66
20	3rd	0.701	60	20	52	459	776	69
20	4th	0.586	54	20	53	461	797	73
20	5th	0.447	47	20	56	456	819	80
20	6th	0.304	37	20	63	450	870	93
20	7th	0.151	20	24	100	443	943	113
20	Tree	4.356	56	17	50	459	783	72
27	Butt	1.576	62	8	26	410	748	83
27	2nd	1.094	64	14	37	385	730	90
27	3rd	0.889	67	15	42	384	728	89
27	4th	0.727	66	15	43	392	742	89
27	5th	0.549	56	15	46	385	760	97
27	6th	0.336	51	17	57	382	798	109
27	7th	0.157	42	28	100	383	832	134
27	Tree	5.328	62	13	39	393	747	91
34	Butt	1.565	53	7	26	447	802	80
34	2nd	1.005	56	13	34	440	823	87
34	3rd	0.815	51	14	38	434	817	88
34	4th	0.681	46	15	43	430	812	89
34	5th	0.500	40	15	47	416	846	104
34	6th	0.306	29	14	51	411	902	120
34	7th	0.141	18	23	100	411	941	130
34	Tree	5.014	49	12	38	435	825	90
37	Butt	1.185	52	12	29	423	744	76
37	2nd	0.769	62	16	39	387	707	83
37	3rd	0.643	56	18	43	392	728	85
37	4th	0.525	51	16	45	389	736	89
37	5th	0.382	46	18	52	373	761	104
37	6th	0.230	32	21	63	381	841	121
37	7th	0.093	17	31	100	382	902	136

Appendix III. Log and Tree Values (Contd)

Tree No.	Log Class	Volume (m^3)	Heart-wood (%)	Corewood 10 rings (%)	Corewood 20 rings (%)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)
Waimahia Cpt. 688 contd.								
39	Butt	0.855	55	13	37	475	808	70
39	2nd	0.572	53	21	41	457	799	75
39	3rd	0.450	45	21	42	446	824	85
39	4th	0.327	37	16	47	426	852	100
39	5th	0.200	26	15	60	407	881	117
39	6th	0.076	12	28	100	397	939	134
39	Tree	2.479	47	17	44	451	825	84
40	Butt	1.103	63	12	28	410	736	79
40	2nd	0.768	61	19	33	390	723	85
40	3rd	0.597	59	19	34	376	715	90
40	4th	0.470	55	15	36	380	735	93
40	5th	0.323	46	12	39	377	784	109
40	6th	0.175	31	18	100	368	861	134
40	Tree	3.436	58	15	36	390	740	90
44	Butt	1.040	56	10	32	453	785	73
44	2nd	0.753	57	15	40	429	761	78
44	3rd	0.634	59	16	41	423	777	84
44	4th	0.512	55	18	45	404	789	96
44	5th	0.368	45	19	50	380	811	114
44	6th	0.198	30	16	53	367	858	134
44	Tree	3.505	54	15	40	423	786	87
46	Butt	1.459	66	12	40	460	783	70
46	2nd	1.049	61	16	44	428	766	79
46	3rd	0.797	54	17	45	431	807	82
46	4th	0.605	47	17	49	443	857	86
46	5th	0.407	36	17	59	443	892	101
46	6th	0.214	26	25	100	438	934	114
46	Tree	4.531	56	15	48	443	810	81
47	Butt	0.845	61	12	39	436	760	74
47	2nd	0.616	54	20	51	422	751	78
47	3rd	0.500	59	25	55	423	795	79
47	4th	0.397	52	23	56	433	847	85
47	5th	0.250	39	22	65	424	869	105
47	6th	0.131	25	32	100	422	935	122
47	Tree	2.739	54	20	52	428	795	83
52	Butt	0.427	59	20	42	466	770	65
52	2nd	0.297	60	26	49	453	780	73
52	3rd	0.239	55	24	49	418	752	80
52	4th	0.187	48	26	50	411	767	87
52	5th	0.125	36	24	57	401	807	101
52	Tree	1.276	55	23	48	440	772	76

Appendix III. Log and Tree Values (Contd)

Tree No.	Log Class	Volume (m^3)	Heart-wood (%)	Corewood 10 rings (%)	Corewood 20 rings (%)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)
Waimahia Cpt. 688 contd.								
58	Butt	0.901	65	12	34	420	744	77
58	2nd	0.669	60	16	39	395	751	90
58	3rd	0.561	57	18	42	371	743	100
58	4th	0.452	53	20	46	366	759	107
58	5th	0.325	44	18	52	368	792	115
58	6th	0.192	29	22	100	364	855	136
58	Tree	3.100	56	16	44	389	759	96
68	Butt	1.964	65	11	38	431	723	68
68	2nd	1.420	63	17	46	420	719	71
68	3rd	1.102	66	19	49	407	729	79
68	4th	0.889	63	18	48	416	763	83
68	5th	0.654	52	18	53	417	800	92
68	6th	0.462	43	18	59	417	836	100
68	7th	0.279	37	23	70	415	839	102
68	8th	0.123	31	40	100	404	834	106
68	Tree	6.895	60	16	48	419	750	79
70	Butt	0.465	66	17	44	463	790	71
70	2nd	0.316	62	21	49	424	750	86
70	3rd	0.250	53	22	51	421	770	94
70	4th	0.191	43	24	58	436	838	92
70	5th	0.130	34	26	68	440	900	105
70	6th	0.064	22	29	100	421	917	118
70	Tree	1.416	55	21	53	439	800	86
72	Butt	1.201	67	14	51	483	862	79
72	2nd	0.841	61	19	50	481	868	81
72	3rd	0.662	57	17	48	476	859	80
72	4th	0.518	52	21	52	482	876	82
72	5th	0.364	41	23	58	489	896	83
72	6th	0.205	30	23	72	492	942	92
72	7th	0.079	16	36	100	488	1000	106
72	Tree	3.870	56	18	53	482	875	81
73	Butt	0.715	68	18	53	447	744	67
73	2nd	0.520	64	29	58	437	752	72
73	3rd	0.409	63	30	60	430	766	78
73	4th	0.276	55	26	61	401	771	92
73	5th	0.191	41	22	66	400	842	110
73	6th	0.101	25	28	100	401	929	131
73	Tree	2.213	61	25	60	430	770	80
77	Butt	0.550	74	16	42	472	745	54
77	2nd	0.356	74	24	54	468	760	57
77	3rd	0.284	69	29	59	463	778	60
77	4th	0.220	60	31	61	458	809	66
77	5th	0.146	46	31	66	457	819	79
77	6th	0.077	31	31	100	456	898	97
77	Tree	1.633	67	24	55	466	776	62

Appendix III. Log and Tree Values (Contd)

Tree No.	Log Class	Volume (m^3)	Heart-wood (%)	Corewood 10 rings (%)	Corewood 20 rings (%)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)
Waimahia Cpt. 688 contd.								
78	Butt	0.501	64	15	42	415	755	82
78	2nd	0.333	63	22	49	402	758	88
78	3rd	0.229	59	27	55	409	789	93
78	4th	0.129	49	27	58	418	838	101
78	Tree	1.192	61	20	48	411	771	88
80	Butt	0.661	62	18	46	517	823	59
80	2nd	0.424	62	27	52	485	825	70
80	3rd	0.321	58	27	48	465	817	76
80	4th	0.240	51	26	51	475	851	79
80	5th	0.157	38	24	65	467	875	87
80	Tree	1.804	58	23	50	490	831	70
88	Butt	0.644	68	21	54	417	709	70
88	2nd	0.435	66	27	60	415	734	77
88	3rd	0.321	56	26	61	399	747	87
88	4th	0.228	43	28	66	386	778	102
88	5th	0.127	30	32	76	382	844	115
88	Tree	1.756	59	25	60	407	741	82
91	Butt	0.993	64	15	40	493	827	60
91	2nd	0.719	59	21	48	475	778	64
91	3rd	0.602	51	20	48	479	809	69
91	4th	0.462	48	21	53	460	826	80
91	5th	0.299	37	23	63	441	856	94
91	6th	0.151	22	31	100	439	892	103
91	Tree	3.226	54	20	50	474	818	71
99	Butt	0.812	62	16	40	483	802	66
99	2nd	0.648	61	22	45	484	818	69
99	3rd	0.535	54	20	44	460	819	78
99	4th	0.417	44	17	48	446	825	85
99	5th	0.286	33	18	59	446	857	93
99	6th	0.158	24	28	100	433	905	109
99	Tree	2.857	53	19	48	467	823	77
100	Butt	1.336	66	10	31	436	753	72
100	2nd	1.056	72	18	44	415	728	76
100	3rd	0.865	70	20	49	390	710	82
100	4th	0.671	39	21	51	381	412	49
100	5th	0.480	20	22	58	381	340	47
100	6th	0.326	43	25	70	380	822	116
100	7th	0.162	30	36	100	376	862	129
100	Tree	4.896	57	18	48	405	661	74

Appendix III. Log and Tree Values (Contd)

Tree No.	Log Class	Volume (m^3)	Heart-wood (%)	Corewood 10 rings (%)	Corewood 20 rings (%)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)
Waimahia Cpt. 688 contd.								
103	Butt	1.474	70	8	40	428	722	69
103	2nd	0.959	67	18	54	411	736	79
103	3rd	0.741	60	22	58	417	768	84
103	4th	0.530	50	22	63	425	807	90
103	5th	0.325	37	24	74	416	843	102
103	6th	0.163	27	35	100	423	899	112
103	Tree	4.192	61	17	54	421	760	81
105	Butt	1.883	64	9	31	468	835	79
105	2nd	1.432	59	14	42	442	830	88
105	3rd	1.128	49	12	46	424	868	95
105	4th	0.774	40	12	53	411	888	102
105	5th	0.418	33	18	75	399	878	120
105	6th	0.182	23	38	100	401	921	130
105	Tree	5.819	53	13	45	439	853	92
108	Butt	1.274	60	6	27	424	783	85
108	2nd	0.874	52	16	48	425	838	97
108	3rd	0.649	43	18	53	428	863	102
108	4th	0.460	35	18	64	427	881	106
108	5th	0.305	30	22	100	428	903	111
108	6th	0.168	23	41	100	416	901	117
108	Tree	3.731	48	15	50	425	837	97
109	Butt	1.121	62	9	33	430	769	79
109	2nd	0.778	60	19	54	442	794	80
109	3rd	0.543	55	23	61	427	796	86
109	4th	0.370	47	24	62	427	837	96
109	5th	0.243	32	23	65	436	887	104
109	6th	0.145	20	29	100	420	899	114
109	Tree	3.200	54	17	52	432	802	86
110	Butt	1.720	65	12	47	475	784	64
110	2nd	1.308	63	16	52	454	771	70
110	3rd	0.952	61	16	48	417	757	82
110	4th	0.698	50	17	51	432	817	85
110	5th	0.423	36	19	66	444	871	90
110	6th	0.173	21	36	100	425	896	111
110	Tree	5.275	58	16	52	450	791	75
111	Butt	1.012	72	17	51	437	721	65
111	2nd	0.736	71	31	65	442	749	66
111	3rd	0.543	61	26	61	439	765	70
111	4th	0.341	47	24	68	419	757	81
111	5th	0.186	34	37	100	410	819	100
111	Tree	2.818	64	24	62	435	748	70

Appendix III. Log and Tree Values (Contd)

Tree No.	Log Class	Volume (m^3)	Heart-wood (%)	Corewood 10 rings (%)	Corewood 20 rings (%)	Basic Density (kg/m^3)	Green Density (kg/m^3)	Moisture Content (%)
Waimahia Cpt. 688 contd.								
113	Butt	0.685	62	10	44	434	758	75
113	2nd	0.407	56	25	64	425	761	79
113	3rd	0.281	45	27	66	440	809	84
113	4th	0.168	30	28	74	456	859	88
113	5th	0.085	17	40	100	459	919	100
113	Tree	1.625	52	20	59	436	787	80
116	Butt	0.622	48	11	41	452	773	89
116	2nd	0.399	47	20	62	427	790	85
116	3rd	0.240	34	27	100	419	840	101
116	Tree	1.260	45	17	59	438	791	90
Waimahia Cpt 694								
2	Butt	0.562	58	12	47	433	724	67
2	2nd	0.365	50	28	71	416	714	72
2	3rd	0.211	53	34	79	410	754	85
2	4th	0.097	38	47	100	402	793	99
2	Tree	1.235	53	23	64	422	732	74
3	Butt	0.505	71	20	48	498	771	58
3	2nd	0.363	74	28	55	474	763	65
3	3rd	0.272	68	27	58	448	772	72
3	4th	0.191	61	30	66	424	761	79
3	5th	0.125	53	32	75	432	783	81
3	Tree	1.456	68	25	56	467	769	67
6	Butt	0.345	69	20	50	487	765	57
6	2nd	0.245	65	29	61	473	788	59
6	3rd	0.191	61	33	66	468	799	61
6	4th	0.138	52	36	73	470	798	70
6	5th	0.091	36	30	75	477	874	81
6	Tree	1.009	61	28	61	477	791	62
8	Butt	1.006	72	12	34	421	725	72
8	2nd	0.733	71	16	38	395	701	77
8	3rd	0.602	69	17	43	388	706	82
8	4th	0.472	63	18	51	392	739	88
8	5th	0.340	55	22	63	403	795	97
8	6th	0.205	40	28	100	398	846	113
8	7th	0.091	18	46	100	394	902	129
8	Tree	3.449	65	17	47	402	737	84
11	Butt	1.707	61	7	18	478	824	73
11	2nd	1.268	56	10	24	449	819	83
11	3rd	1.103	53	11	31	426	810	90
11	4th	0.936	47	9	35	422	826	96
11	5th	0.645	42	10	44	424	843	99
11	6th	0.325	36	21	100	405	849	110
11	7th	0.123	24	46	100	403	889	121
11	Tree	6.105	52	10	33	443	825	87

Appendix IV: Basic Density Data for Regression Analyses.

Cpt.	Tree No.	Basic Density, (kg/m³)						
		Outerwood Density	Butt Log	2nd Log	3rd Log	4th Log	5th Log	Whole Tree
1	1	371	369	349	358	359		360
1	2	415	382	357	346	337	331	361
1	3	371	396	364	363	372		381
1	4	381	369	354	353	357	358	360
1	5	373	380	360	358	354		369
1	8	387	398	351	343			374
1	11	395	431	406	398	386	402	412
1	12	385	407	362	349	349		377
1	17	435	407	377	382	375		390
1	18	439	413	416	411	388	374	409
1	24	426	402	400	392			400
2	1	410	427	390	394	383		405
2	2	358	403	356	343	342		372
2	3	445	452	431	432	413		437
2	4	408	445	403	397	385		418
2	8	392	403	389	381	367		391
2	11	394	397	361	351			376
2	12	484	409	381	376			394
2	17	403	428	413	402	378		415
2	18	404	417	382	379	381		396
2	22	422	399	374	365			386
2	24	368	394	354	348	344		372
2	30	411	402	391	384	387	379	393
23*	1	393	410	407	400	391	379	401
23*	2	403	416	402	397	386	362	401
23*	3	404	427	407	386	373		405
23*	4	447	443	436	438	441	429	440
23*	5	444	440	436				439
23*	6	451	486	471	447	415	392	463
23*	8	450	476	465	454	454	452	466
23*	9	429	446	440	419	386	367	424
23*	10	425	437	433	421	399	378	423
23*	6	439	451	425	414	405		430
23*	7	461	443	436	420	390	377	428
23*	8	426	430	428	397	345		422

Appendix IV: Basic Density Data for Regression Analyses. (Contd.)

Cpt.	Tree No.	Basic Density, (kg/m³)								
		Outerwood Density	Butt Log	2nd Log	3rd Log	4th Log	5th Log	6th Log	7th Log	Whole Tree
688	3	485	444	447	445	436	423	433		442
688	8	562	516	500	483	473	465			496
688	19	513	463	425	425	423	409	396	396	433
688	20	548	461	461	459	461	456	450	443	459
688	27	397	410	385	384	392	385	382	383	393
688	34	484	447	440	434	430	416	411	411	435
688	37	426	423	387	392	389	373	381	382	397
688	39	493	475	457	446	426	407	397		451
688	40	378	410	390	376	380	377	368		390
688	44	504	453	429	423	404	380	367		423
688	46	503	460	428	431	443	443	438		443
688	47	462	436	422	423	433	424	422		428
688	52	456	466	453	418	411	401			440
688	58	423	420	395	371	366	368	364		389
688	68	455	431	420	407	416	417	417	415	419
688	70	443	463	424	421	436	440	421		439
688	72	451	483	481	476	482	489	492	488	482
688	73	458	447	437	430	401	400	401		430
688	77	507	472	468	463	458	457	456		466
688	78	416	415	402	409	418				411
688	80	545	517	485	465	475	467			490
688	88	428	417	415	399	386	382			407
688	91	573	493	475	479	460	441	439		474
688	99	483	483	484	460	446	446	433		467
688	100	462	436	415	390	381	381	380	376	405
688	103	484	428	411	417	425	416	423		421
688	105	467	468	442	424	411	399	401		439
688	108	427	424	425	428	427	428	416		425
688	109	471	430	442	427	427	436	420		432
688	110	411	475	454	417	432	444	425		450
688	111	455	437	442	439	419	410			435
688	113	453	434	425	440	456	459			436
688	116	443	452	427	419					438

Appendix IV: Basic Density Data for Regression Analyses. (Contd.)

Cpt.	Tree No.	Basic Density, (kg/m³)								
		Outerwood Density	Butt Log	2nd Log	3rd Log	4th Log	5th Log	6th Log	7th Log	Whole Tree
694	2	465	433	416	410	402				422
694	3	460	498	474	448	424	432			467
694	6	539	487	473	468	470	477			477
694	8	425	421	395	388	392	403	398	394	402
694	11	498	478	449	426	422	424	405	403	443
688*	11	488	431	439	429	419	415	400	390	425
688*	12	458	426	407	416	418	408	409		417
688*	13	494	440	449	455	450	451	449	442	447
688*	14	486	438	430	426	429	426	400		430
688*	15	475	456	423	415	401	387	386	380	422
688*	16	451	461	460	456	457	439	430		456
688*	17	353	365	365	367	364	363	362	364	365
688*	18	447	418	411	410	402	396	381		409
688*	19	462	454	462	467	468	456	431		460
688*	20	410	387	379	390	392	382	358	340	383
688*	6	463	437	410	399	403				416
688*	7	470	430	429	418	407	402			423
688*	8	460	451	425	429	448	432			439
688*	9	457	417	410	408	396	376			409
688*	10	466	465	432	414	414	417			438

* Trees sampled for cross-sectional analysis of pruned butt logs and those selected as pruned sawlogs

Appendix V. Individual Disc Shrinkage

Cpt.	Tree No.	Height (m)	Shrinkage, %					
			Longitudinal		Radial		Tangential	
			A-dry	O-dry	A-dry	O-dry	A-dry	O-dry
Waiotapu								
1	12	Butt	-0.25	0.10	1.9	3.6	3.6	6.2
1	12	4.9	-0.10	0.04	1.3	2.9	2.6	5.1
1	12	9.8	-0.04	0.28	1.6	3.5	3.4	6.4
1	12	14.7	-0.55	-0.02	1.4	3.2	4.0	7.1
1	12	19.6	-0.40	0.19	1.5	3.1	3.5	6.4
2	11	Butt	0.10	0.13	2.1	3.9	3.6	6.4
2	11	4.9	-0.32	-0.11	1.7	3.6	3.8	7.1
2	11	9.8	-0.23	-0.04	2.3	3.9	3.7	6.8
2	11	14.7	-0.55	-0.20	1.7	2.5	2.9	5.7
2	12	Butt	-0.08	0.14	1.8	3.3	3.9	6.8
2	12	4.9	-0.24	0.08	1.9	3.7	4.1	7.5
2	12	9.8	-0.40	0.07	1.9	3.8	3.3	5.8
2	12	14.7	0.02	0.08	1.8	3.4	3.3	5.4
2	24	Butt	-0.17	-0.06	0.4	1.4	1.8	4.0
2	24	4.9	-0.45	-0.23	1.7	3.6	3.9	7.5
2	24	9.8	0.02	0.26	1.2	3.0	3.8	7.1
2	24	14.7	-0.32	0.45	1.1	3.1	3.1	6.5
2	30	Butt	-0.07	0.51	1.9	4.2	3.3	6.1
2	30	4.9	-0.16	0.16	1.9	4.3	3.4	6.9
2	30	9.8	-0.04	0.06	1.5	3.6	3.0	6.2
2	30	14.7	0.21	0.31	1.6	3.5	3.0	5.6
2	30	19.6	0.34	0.34	1.2	3.1	2.4	5.0
Waimahia								
688	37	Butt	0.11	0.35	1.8	3.4	3.3	5.9
688	37	4.9	-0.14	0.03	1.8	3.9	3.9	7.1
688	37	9.8	-0.14	0.30	1.4	3.1	3.1	5.7
688	37	14.7	-0.17	0.16	1.9	3.8	4.1	7.3
688	37	19.6	-0.06	0.01	1.3	2.9	2.5	5.0
688	37	24.5	-0.21	-0.12	1.4	3.2	3.2	5.8

Appendix V. Individual Disc Shrinkage (Contd)

Cpt.	Tree No.	Height (m)	Shrinkage, %					
			Longitudinal		Radial		Tangential	
			A-dry	O-dry	A-dry	O-dry	A-dry	O-dry
Waimahia contd.								
688	77	Butt	-0.28	0.03	2.3	4.5	3.9	6.8
688	77	4.9	-0.17	0.02	2.4	4.9	4.2	8.0
688	77	9.8	-0.26	0.08	1.6	3.7	2.6	6.2
688	77	14.7	0.01	0.25	2.3	4.9	4.3	8.0
688	77	19.6	0.21	0.02	2.3	4.5	3.7	7.2
688	77	24.5	-0.27	0.11	2.5	4.6	3.5	6.7
688	77	29.4	-0.06	-0.05	1.9	3.1	3.1	5.5
688	103	Butt	0.05	0.22	2.2	4.2	3.6	6.1
688	103	4.9	-0.24	0.09	2.0	4.1	3.7	6.9
688	103	9.8	-0.25	-0.21	2.0	4.0	4.0	7.2
688	103	14.7	-0.02	0.30	2.1	4.1	3.7	6.8
688	103	19.6	-0.03	0.12	2.0	3.9	3.7	6.7
688	103	24.5	-0.15	-0.12	1.8	3.7	3.2	5.9
688	103	29.4	0.02	0.19	1.9	3.5	4.2	7.2
688	110	Butt	0.10	0.53	1.8	3.5	3.9	6.4
688	110	4.9	0.12	0.44	1.7	3.6	4.2	7.4
688	110	9.8	0.11	0.14	1.5	3.3	4.0	7.2
688	110	14.7	-0.03	0.28	1.2	2.7	2.8	5.4
688	110	19.6	-0.14	0.18	1.5	3.3	3.7	6.7
688	110	24.5	0.15	0.44	1.5	3.1	3.0	6.2
688	116	Butt	0.02	0.16	1.6	2.9	3.1	6.0
688	116	4.9	0.11	0.32	1.2	2.7	3.2	6.2
688	116	9.8	-0.22	0.01	2.5	4.3	5.1	8.4
688	116	14.7	0.32	0.64	1.5	2.5	2.7	5.4

Appendix VI. Variation in Dimensional Shrinkage from Pith to Bark.

Disc Height (m)	Ring Number from the Pith									
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	45-50
a) Longitudinal shrinkage to air-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years										
Butt	0.09	-0.20	-0.11	-0.16	-0.21	0.03				
4.9	-0.42	-0.28	-0.28	-0.13	-0.13					
9.8	-0.08	-0.14	-0.17	-0.11						
14.7	-0.10	-0.28	-0.41							
19.6	0.15	0.15								
Waimahia - Cpts. 688 and 694, Age 59 years										
Butt	0.60	0.22	0.03	0.00	-0.01	-0.03	-0.08	-0.20	-0.24	-0.36
4.9	0.37	-0.02	-0.05	-0.38	-0.14	-0.21	-0.05	-0.10	-0.10	-0.16
9.8	0.13	-0.08	-0.03	-0.41	-0.23	-0.26	-0.08	-0.26	-0.19	
14.7	0.18	-0.07	0.07	0.03	0.02	-0.12	-0.18	-0.27		
19.6	0.28	-0.04	0.07	0.17	-0.04	-0.35	-0.33			
24.5	0.00	-0.19	0.07	-0.39	-0.22	-0.22				
29.4	0.15	0.01	-0.23	-0.33	-0.03					
b) Longitudinal shrinkage to oven-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years										
Butt	0.47	0.18	0.03	0.09	0.10	0.12				
4.9	0.15	-0.25	0.06	0.02	-0.02					
9.8	0.08	0.09	0.19	0.22						
14.7	0.27	0.00	0.11							
19.6	0.37	0.16								
Waimahia - Cpts. 688 and 694, Age 59 years										
Butt	1.03	0.56	0.31	0.33	0.08	0.16	0.07	0.03	-0.03	0.01
4.9	0.72	0.38	0.06	-0.08	0.03	0.04	0.09	0.15	0.15	0.09
9.8	0.37	0.07	0.13	0.04	0.20	-0.14	-0.10	-0.11	0.12	
14.7	0.49	0.18	0.29	0.33	0.23	0.12	0.29	0.31		
19.6	0.23	0.20	0.20	0.05	0.02	-0.06	-0.28			
24.5	0.37	0.09	0.14	-0.22	-0.07	-0.07				
29.4	0.45	-0.02	0.28	-0.18	-0.10					
c) Radial shrinkage to air-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years										
Butt	1.4	1.3	1.6	1.5	2.0	2.0				
4.9	1.3	1.4	1.7	1.9	2.4					
9.8	1.0	1.6	2.2	2.3						
14.7	1.3	1.6	1.9							
19.6	1.3	1.4								

Appendix VI. Variation in Dimensional Shrinkage from Pith to Bark (Contd)

Disc Height (m)	Ring Number from the Pith									
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	45-50
c) Radial shrinkage to air-dry % contd.										
Waimahia - Cpts. 688 and 694, Age 59 years										
Butt	1.7	1.6	1.7	1.6	1.7	1.7	2.3	2.4	2.6	2.1
4.9	1.8	1.2	1.7	1.4	1.6	1.9	2.1	2.6	2.6	2.4
9.8	1.5	1.3	1.5	1.7	2.3	1.9	1.8	1.7	1.6	
14.7	1.6	1.3	1.8	2.1	2.3	2.0	2.1	2.0		
19.6	1.5	1.6	1.7	1.7	1.9	2.1	2.3			
24.5	1.5	1.5	1.8	2.3	2.2	2.2				
29.4	1.3	1.7	1.7	1.9	3.8					
d) Radial shrinkage to oven-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years										
Butt	2.8	2.8	3.4	3.4	3.8	3.6				
4.9	2.9	3.3	3.6	4.1	4.5					
9.8	2.8	3.4	4.2	4.3						
14.7	2.7	3.4	3.8							
19.6	2.9	3.3								
Waimahia - Cpts. 688 and 694, Age 59 years										
Butt	3.0	3.0	3.1	3.2	3.4	3.6	4.4	4.7	4.6	4.6
4.9	3.0	2.4	3.3	3.1	3.5	4.5	4.7	5.4	5.4	5.3
9.8	2.7	2.8	3.1	3.5	4.5	4.2	4.2	4.2	4.2	
14.7	2.7	2.8	3.4	4.3	4.5	4.4	4.4	4.7		
19.6	3.0	3.1	3.6	3.7	4.0	4.2	4.4			
24.5	2.9	3.0	3.7	4.4	4.5	4.5				
29.4	2.8	3.3								
e) Tangential shrinkage to air-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years										
Butt	2.2	2.6	3.2	3.5	4.0	3.9				
4.9	2.5	3.7	3.3	4.2	4.0					
9.8	3.0	3.3	3.9	3.4						
14.7	2.4	3.7	4.4							
19.6	3.1	2.7								
Waimahia - Cpts. 688 and 694, Age 59 years										
Butt	2.5	2.8	3.2	3.3	3.2	3.4	4.3	4.7	4.2	4.3
4.9	2.9	3.1	3.7	3.4	4.0	4.5	4.5	4.4	4.4	4.0
9.8	2.8	3.1	3.5	3.8	4.1	3.8	4.0	4.0	3.3	
14.7	3.1	3.3	3.6	3.7	4.1	4.1	3.9	4.2		
19.6	3.1	3.6	3.3	3.3	3.5	3.6	3.2			
24.5	1.9	3.2	3.7	3.9	3.8	3.8				
29.4	3.9	3.4	2.9	3.6	2.8					

Appendix VI. Variation in Dimensional Shrinkage from Pith to Bark (Contd)

Disc Height (m)	Ring Number from the Pith									
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	45-50
f) Tangential shrinkage to oven-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years										
Butt	4.8	4.9	5.8	6.4	6.8	6.7				
4.9	5.5	6.9	6.7	7.6	7.5					
9.8	5.6	6.1	7.4	6.9						
14.7	4.7	6.9	7.5							
19.6	5.9	5.5								
Waimahia - Cpts. 688 and 694, Age 59 years										
Butt	4.5	5.4	5.4	5.7	5.9	6.3	7.5	7.9	7.3	7.6
4.9	5.3	5.5	6.9	6.4	7.4	8.4	8.4	8.2	8.2	7.8
9.8	5.1	5.8	6.3	7.2	7.6	7.3	7.4	7.7	6.9	
14.7	5.6	6.1	6.6	7.1	7.5	7.4	7.3	7.9		
19.6	5.5	6.4	6.2	6.5	6.8	6.9	6.4			
24.5	4.6	5.6	6.6	7.0	7.2	7.2				
29.4	6.2	6.0	5.5	6.6	5.4					
g) Longitudinal shrinkage to air-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years and Waimahia - Cpts. 688 and 694, Age 59 years combined										
Butt	0.3	0.0	0.0	-0.1	-0.1	0.0	-0.08	-0.20	-0.24	-0.36
4.9	0.0	-0.2	-0.2	-0.3	-0.1	-0.21	-0.05	-0.10	-0.10	-0.16
9.8	0.0	-0.1	-0.1	-0.3	-0.23	-0.26	-0.08	-0.26	-0.19	
14.7	0.0	-0.2	-0.2	0.03	0.02	-0.12	-0.18	-0.27		
19.6	0.2	0.1	0.07	0.17	-0.04	-0.35	-0.33			
24.5	0.00	-0.19	0.07	-0.39	-0.22	-0.22				
29.4	0.15	0.01	-0.23	-0.33	-0.03					
h) Longitudinal shrinkage to oven-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years and Waimahia - Cpts. 688 and 694, Age 59 years combined										
Butt	0.7	0.4	0.2	0.2	0.1	0.1	0.07	0.03	-0.03	0.01
4.9	0.4	0.1	0.1	0.0	0.0	0.04	0.09	0.15	0.15	0.09
9.8	0.2	0.1	0.2	0.1	0.20	-0.14	-0.10	-0.11	0.12	
14.7	0.4	0.1	0.2	0.33	0.23	0.12	0.29	0.31		
19.6	0.3	0.2	0.20	0.05	0.02	-0.06	-0.28			
24.5	0.37	0.09	0.14	-0.22	-0.07	-0.07				
29.4	0.45	-0.02	0.28	-0.18	-0.10					

Appendix VI. Variation in Dimensional Shrinkage from Pith to Bark (Contd)

Disc Height (m)	Ring Number from the Pith									
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	45-50
i) Radial Shrinkage to air-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years and Waimahia - Cpts. 688 and 694, Age 59 years combined										
Butt	1.6	1.4	1.7	1.5	1.9	1.8	2.3	2.4	2.6	2.1
4.9	1.6	1.3	1.7	1.6	2.0	1.9	2.1	2.6	2.6	2.4
9.8	1.3	1.5	1.9	2.0	2.3	1.9	1.8	1.7	1.6	
14.7	1.5	1.5	1.8	2.1	2.3	2.0	2.1	2.0		
19.6	1.4	1.5	1.7	1.7	1.9	2.1	2.3			
24.5	1.5	1.5	1.8	2.3	2.2	2.2				
29.4	1.3	1.7	1.7	1.9	3.8					
j) Radial Shrinkage to oven-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years and Waimahia - Cpts. 688 and 694, Age 59 years combined										
Butt	2.9	2.9	3.2	3.3	3.6	3.6	4.4	4.7	4.6	4.6
4.9	3.0	2.9	3.4	3.6	4.0	4.5	4.7	5.4	5.4	5.3
9.8	2.8	3.1	3.6	3.9	4.5	4.2	4.2	4.2	4.2	
14.7	2.7	3.1	3.6	4.3	4.5	4.4	4.4	4.7		
19.6	3.0	3.2	3.6	3.7	4.0	4.2	4.4			
24.5	2.9	3.0	3.7	4.4	4.5	4.5				
29.4	2.8	3.3	3.3	3.9	3.3					
k) Tangential Shrinkage to air-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years and Waimahia - Cpts. 688 and 694, Age 59 years combined										
Butt	2.4	2.7	3.2	3.4	3.6	3.7	4.3	4.7	4.2	4.3
4.9	2.7	3.4	3.5	3.8	4.0	4.5	4.5	4.4	4.4	4.0
9.8	2.9	3.2	3.7	3.6	4.1	3.8	4.0	4.0	3.3	
14.7	2.8	3.5	4.0	3.7	4.1	4.1	3.9	4.2		
19.6	3.1	3.1	3.3	3.3	3.5	3.6	3.2			
24.5	1.9	3.2	3.7	3.9	3.8	3.8				
29.4	3.9	3.4	2.9	3.6	2.8					
l) Tangential Shrinkage to oven-dry %										
Waiotapu - Cpts. 1 and 2, Age 33 years and Waimahia - Cpts. 688 and 694, Age 59 years combined										
Butt	4.6	5.2	5.6	6.0	6.4	6.5	7.5	7.9	7.3	7.6
4.9	5.4	6.2	6.8	7.0	7.4	8.4	8.4	8.2	8.2	7.8
9.8	5.4	6.0	6.9	7.0	7.6	7.3	7.4	7.7	6.9	
14.7	5.2	6.5	7.0	7.1	7.5	7.4	7.3	7.9		
19.6	5.7	6.0	6.2	6.5	6.8	6.9	6.4			
24.5	4.6	5.6	6.6	7.0	7.2	7.2				
29.4	6.2	6.0	5.5	6.6	5.4					