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EXECUTIVE SUMMARY

SIMULATIONS OF TIMBER GRADE RECOVERY FROM PRUNED DOUGLAS-FIR LOGS USING AUTOSAW

C.L. Todoroki and I. P. McInnes

A sample of seventy pruned Douglas-fir logs were selected from six sites within New Zealand. Logs were cross-cut into discs and detailed measurements of each log, together with internal defects, were made. This enabled the subsequent reconstruction of three dimensional log models which could then be processed in the sawing simulation system, AUTOSAW. Log characteristics varied both between and within each of the sites. SED varied between 188 and 654 mm, logs were 3.2 - 7.2 m in length, and defect cores varied between 165 - 406 mm.

In the simulator, the log models were sawn to two sawing patterns: live sawing and cant sawing, and boards graded using two different methods: one based on the New Zealand Standard timber grading rules, and the other based on the WWPA grading rules for random width factory lumber.

Results of the simulations indicate that, although higher yields (measured in terms of volume) were obtained with live sawing, higher values (measured in terms of the better grades: NZ clears grade or Western Lumber Mouldings grade) were realised with the cant sawing method. Logs from three sites in particular (Golden Downs, Reefton, and Longwood) recorded high conversions to clears grade, indicating timely pruning.

This report discusses the results of sawing simulation runs for the 70 individual logs in the study. The next step is to use the simulation results presented in this report to derive regression equations for predicting timber grade recovery and conversion as a function of log variables such as SED, defect core, etc. Equations will be obtained for predicting both NZ grades and WWPA grades under both live and cant sawing. These equations will be presented in a subsequent report and will ultimately be incorporated into the sawing simulation programme SAWMOD.

Introduction

This paper records work performed as part of the NZ FRI, US Forest Service Pacific Northwest Research Station cooperative research project on Douglas-fir and describes the sawing simulations applied to seventy pruned Douglas-fir logs in the AUTOSAW simulator. The logs were selected from six sites within New Zealand, with fifteen logs being obtained from each of Mamaku, Waiotapu, and Waimihia, five from Golden Downs, and ten each from Longwoods and Reefton.

A summary of the history of the stands from which log samples were taken is given in Table 1.

Table 1: Stand History Summary

Site	Year of Planting	Year of Pruning (@ height)	Year of Pruning (@ height)	Log Age (years)
Mamaku	1966	1975 (2.5m)	1978 (4.0m)	27
Waiotapu	1953	1962 (2.5m)	1968 (6.0m)	41
Waimihia	1943	1958 (5.5 m)		51
Golden Downs	1951	1962 (3.0m)	1965 (5.0m)	43
Longwood	1951	1961 (1.8m)	1968 (5.5m)	44
Reefton*	1949	1957 (2.0 m)	1963 (6.0m)	46

* stand history estimated, age determined by ring count

Data Acquisition

Measurements of individual logs were made to enable the subsequent reconstruction of three dimensional log models. Data was acquired using the method of cross-sectional analysis (Somerville, 1985). This method differs from that used in the previous douglas fir sawing study (Gatenby and Somerville, 1995) as, rather than sawing and then reconstructing the original log from boards, logs are cross-cut into sections or discs in the field. The circumference of each disc, and size and location of individual branch stubs on each cross-section are recorded. This gives a very detailed description of each (reconstructed) log and also serves as input to the sawing simulation system, AUTOSAW.

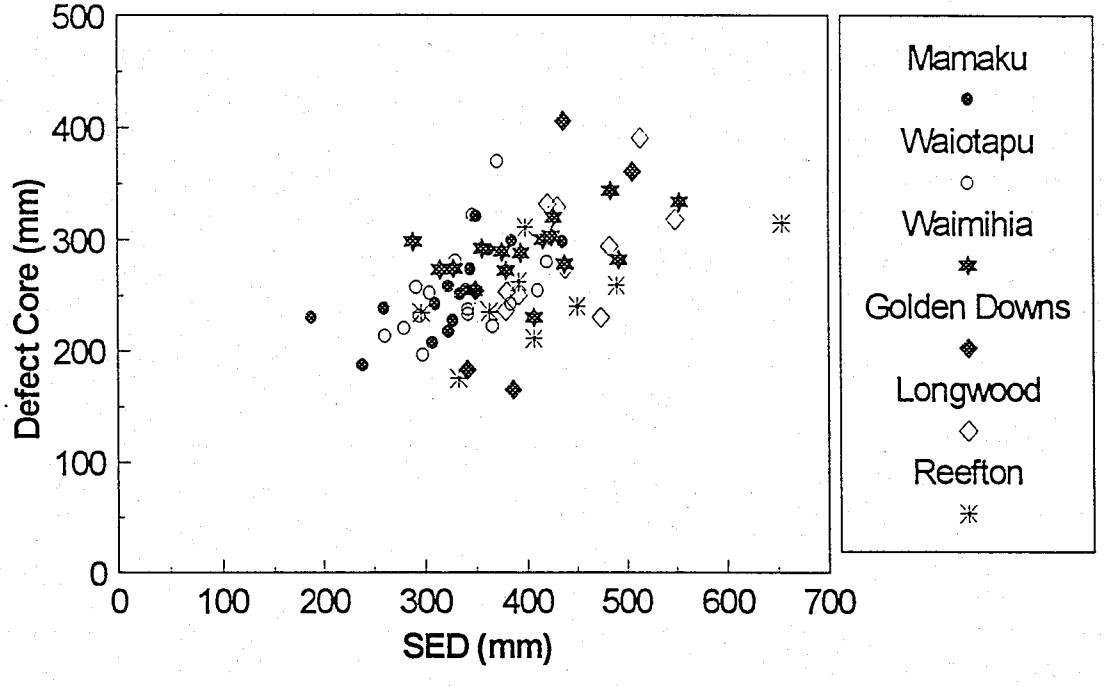
General characteristics of each of the reconstructed logs are shown in Appendix 1. Table 2 shows average characteristics, together with one standard deviation, for each site. It is evident that log characteristics vary greatly both between and within each of the sites. In general, logs taken from

Mamaku are both shorter and smaller than logs from any other site. Although the majority of logs demonstrate moderate sweep, instances of more severely swept logs are also apparent (eg Mamaku log 2, Golden Downs log 3). The recorded log volume measurements are calculated using truncated cones to 1.4m from the butt end and parabaloids thereafter. In determining the defect core size, branch stubs are projected in two planes (ie x and y planes when the log is viewed end-on and the most extreme projections are taken to represent the defect core. A scatter diagram of defect core against SED is shown in Figure 1.

Table 2: Average log characteristics (and one standard deviation) by site

Site	Sample Size	Length (m)	SED (mm)	LED (mm)	Diameter @1.3m (mm)	Sweep (mm/m)	Volume (m3)	Defect Core (mm)
Mamaku	15	4.1±0.5	322±59	428±80	359±69	7.1±3.8	0.41±0.14	253±38
Waiotapu	15	6.2±0.5	336±48	452±64	391±57	7.6±3.1	0.69±0.20	254±45
Waimihia	15	4.8±0.3	405±70	517±93	445±80	7.5±3.0	0.73±0.25	292±28
Golden Downs	5	6.0±0.5	404±69	496±86	440±75	8.5±6.0	0.88±0.35	274±107
Longwood	10	5.3±1.1	446±58	583±78	498±67	8.7±3.9	0.98±0.36	291±52
Reefton	10	6.3±0.7	414±101	545±132	466±98	7.6±3.3	1.02±0.41	249±42

Figure 1: Defect core against SED by site



Sawing Simulations

All simulations were performed using the sawing simulation system, AUTOSAW, with two sawing patterns being applied: live sawing (also known as through and through sawing), and cant sawing. The latter used a three-sided sawing pattern with the cant centred on each log. Figures 2(a) and (b) show examples of the live and cant sawpatterns respectively.

Figure 2(a): Example of live sawing sawpattern

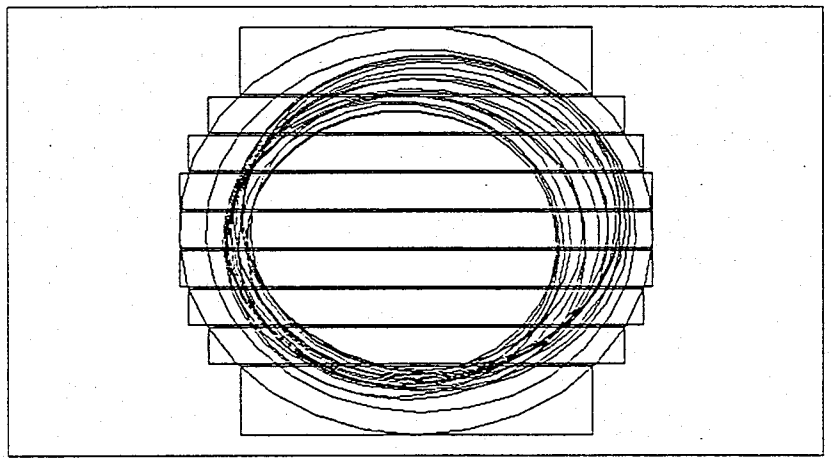
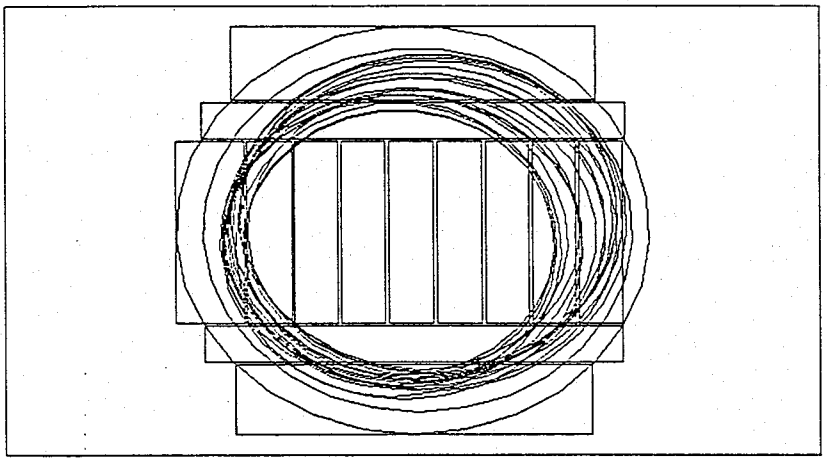


Figure 2(b): Example of cant sawing sawpattern



For each log the cant size was determined according to the small end diameter (SED) of the log. The call (and target) cant sizes were specified as: 200 mm (203 mm) for logs of at least 270 mm SED, 150mm (155mm) for logs of at least 220 mm SED, and, for smaller logs, a 100 mm (103 mm) cant size was cut. For both live sawing and cant sawing simulations the following sawing configuration and strategy was used:

- Half-taper sawing on both log sides
- Number of carriage knees: 3
- Log centred on carriage with second and third knees positioned at 1800 and 4200 mm respectively from front knee
- Flitch thicknesses: 5/4" or the metric equivalent 38.1 mm (40 mm)
- Headrig sawkerf : 3.0 mm

Simulations of the 70 log sample were repeated for two grading practices:

- AUTOSAW appearance and cuttings grades
- Random width factory lumber grades

Each of these methods is briefly described below.

AUTOSAW Appearance and Cuttings Grades

The AUTOSAW appearance and cuttings grades are based on the New Zealand timber grading rules for exotic softwoods (SANZ 1988). Table 3 provides a brief description of each of the grades. These grades were assigned to pieces cut at a (simulated) four saw edger. The following parameters were employed at the edger:

- Edger sawkerf : 5.0 mm
- Widths - call (and target) mm: 75 (77), 100 (103), 150 (153), 200 (203)
- Minimum piece length: 1800 mm
- Docking step: 100 mm

For each flitch, that combination of pieces of the given dimensions which maximised volume were selected.

Table 3: Description of AUTOSAW Appearance and Cuttings Grades

Grade	Code	Description
Clear	c	Piece must be free of defects
No. 1 Cuttings	s	Piece must be capable of yielding clear cuttings which are not less than: a) 1.0 m each b) 2.0 m of total cuttings c) 70 % of the total length of the piece
No. 2 Cuttings	f	Piece must be capable of yielding clear cuttings which are not less than: a) 0.6 m each b) 1.8 m of total cuttings c) 70 % of the total length of the piece
Dressing	d	The following defects are permitted on the better face or edge:
		Knots (other than spike knots) a) 75 mm (singly) b) sum of sizes in any combination half of the width of the piece
		Spike knots a) 50 mm wide b) projected length half of the width of the piece
		Double spike knots a) 25 mm wide b) projected length two-thirds of the piece
		Tight encased knots a) three b) 15 mm
Merchantable	m	The following defects are permitted on the better face or edge:
		Knots (other than spike knots) a) 100 mm (singly) b) sum of sizes in any combination half of the width of the piece
		Spike knots a) 50 mm wide b) projected length two-thirds of the width of the piece
		Double spike knots a) 50 mm wide b) projected length two-thirds of the piece
		Tight encased knots a) four b) 75 mm
Box	p	Any number or combination of defects

Random Width Factory Lumber Grades

A routine for assigning factory lumber grades for random width lumber has recently been incorporated in AUTOSAW (Todoroki, in prep). The factory lumber grades (and AUTOSAW grade codes) considered are: Mouldings (M), Factory Select (F), No. 1 Shop (1), No. 2 Shop (2), No. 3 Shop (3), and Finger Joint Common Shop (J). The grade requirements for these grades are based on those described in the WWPA publication (WWPA, 1992) and are outlined in Table 4(a).

Table 4(a): Grade requirements for 5/4" and thicker factory lumber

Lumber Grade	Grade Requirements *Each board must contain at least...*
Mouldings	2/3 of the surface area in clean cuttings, 10' and longer, 2" and wider. Up to 10% of a consignment may contain 6' to 9' lengths
Factory Select	70% of No. 1 door cuttings. Subject to: a maximum of 2 muntins; no board may contain muntins only; if one No. 1 stile, or two or more No. 1 door cuttings, one No. 2 stile is permitted.
No. 1 Shop	50% of No. 1 door cuttings. Subject to: a maximum of 2 muntins; if one or more No. 1 door cuttings, one No. 2 stile is permitted
No. 2 Shop	25% of No. 1 door cuttings or 33 1/3 % of No. 1 and No. 2 door cuttings or 40% of No. 2 door cuttings
No. 3 Shop	30% of any combination of No. 1 and No. 2 door cuttings, sash cuttings, moulding rips, or jamb and sill cuttings
Finger Joint Common Shop	50% of finger joint cuttings

Cutting dimensions and quality criteria for the cuttings, as required by AUTOSAW, are illustrated in Table 4(b). In general, AUTOSAW, requires defects to be free from defects on both sides. Whilst this requirement may seem more restrictive than necessary, it should be remembered that the only defects considered in the simulator are pith, wane, and knots (dead and alive). It is thus hoped that the more severe grading requirements will compensate for other defects not currently recognised. Those boards which failed to meet the requirements of the above grades and which were also at least 72" long and at least 4" wide were graded as Box grade (P).

Table 4(b): Dimensions and Quality Criteria of Cuttings used in AUTOSAW

Cutting	Length	Width	Quality
Moulding Rips	10' and longer	2" and wider	No. 1 cutting
Stiles	80" to 90"	5" or 6"	No. 1 cutting
Bottom Rails	28" to 36"	9" or 10"	No. 1 cutting
Muntins	42" to 48"	5" or 6"	No. 1 cutting
Top Rails	28" to 36"	5" or 6"	No. 1 cutting counted as No. 2 cutting
Sash	28" and longer	2½", 3½", 4½ and wider	No. 1 cutting
Jamb and Sill	36" and longer	5" and wider	No. 1 cutting
Finger Joint	9" and longer	2½" and wider	No. 1 cutting

Results and Discussion

Upon inspection of the cant sawing patterns of individual logs, it was noted that in many cases the cant was cut after one or more defects had been exposed on the log face. Thus similar results could be expected had the cant size been set from the defect core. Exceptions to this were logs with large SEDs and small defect cores (eg log 4 of Golden Downs — see Appendix 1) which could have attained one more clear board had a smaller cant been cut. Overall, the effect of this is expected to be negligible, thus the results from the cant sawing simulations may be regarded as being indicative of those which would be obtained with the alterative method.

Figure 3(a) shows, for each of the six sites, the average conversions obtained when the log models were sawn using the live sawing method with NZ grades applied to the sawn outturn. Figure 3(b) shows the results obtained for the cant sawing method using the same grading practice. Individual log conversions for these two sawing practices can be found in Appendices 2 and 3 respectively.

Logs from Mamaku recorded both the lowest average log conversions and the lowest proportion of clear recoveries whilst those from Golden Downs recorded the highest average log conversions. On average, overall levels of recovery were slightly higher for live sawing than for cant sawing, however the average percentage recovery of clearwood was higher for the cant sawing method. Clearwood recovery was equivalent to an average of 7% of sawn volume for the Mamaku logs under live sawing. For the other sites clearwood recovery, taken as a percentage of sawn volume, was: Waiotapu (15%), Waimihia (17%), Golden Downs (32%), Longwood (28%), and Reefton (32%). For the cant sawing method the average clearwood conversions at the corresponding sites were: 13%, 18%, 24%, 39%, 33%, and 38% respectively. Thus the greatest proportion of clearwood recovery was from the Golden Downs and Reefton logs — followed closely by those from Longwood.

Average log outturn from the six sites for random width factory lumber (in board feet), obtained under the live and cant sawing patterns, are shown in figures 4(a) and (b) respectively with individual log results given in Appendices 4 and 5. (Average conversion percentages for each site may be calculated using the average log volume measurements given in Table 2 and converting to

the board foot measure.). Logs from Mamaku recorded the lowest lumber outturn whilst those from Reefton recorded the highest average outturn for both live and cant sawing. Live sawing resulted in higher outturn, and hence conversions, than did cant sawing. However, this latter method produced a higher proportion of Mouldings grade lumber than did the former with logs from Golden Downs recording the highest conversion to Mouldings grade — approximately 50% of sawn outturn. Logs from Reefton also showed higher conversion to Mouldings grade with 44% of sawn outturn for the cant sawing method.

Figure 3(a): Live Sawing (appearance and cuttings grades)

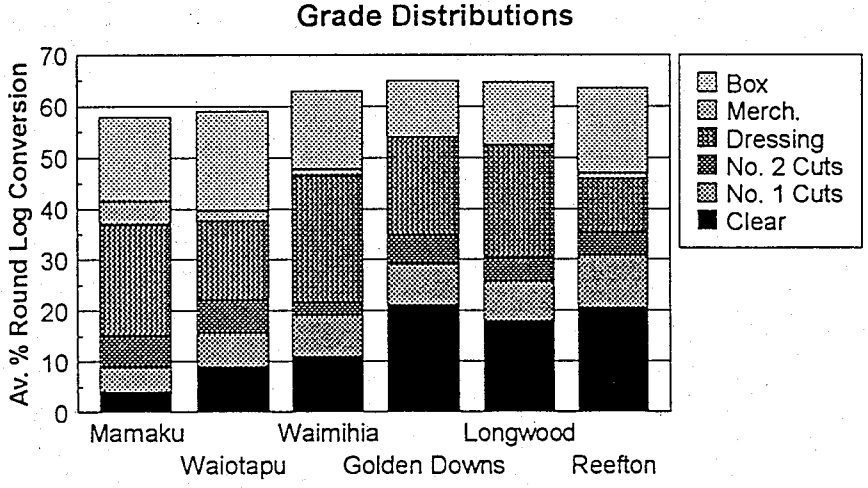


Figure 3(b): Cant sawing (appearance and cuttings grades)

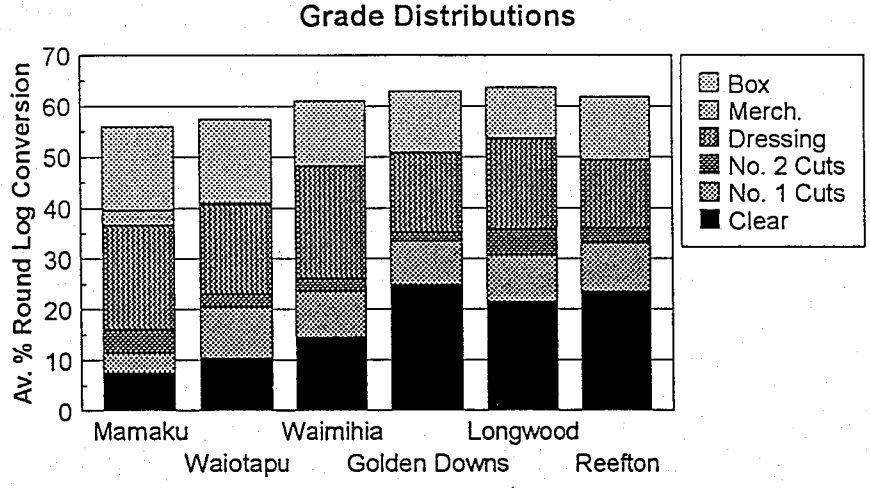


Figure 4(a): Live sawing (random width factory lumber grades) Grade Distributions

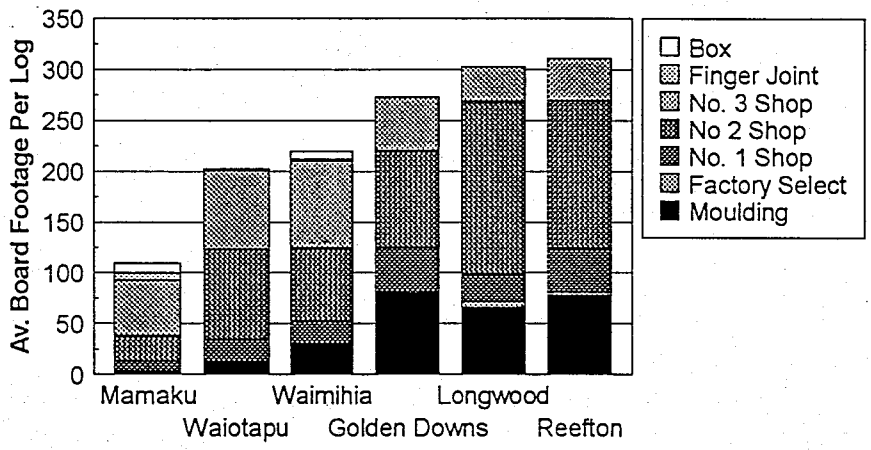
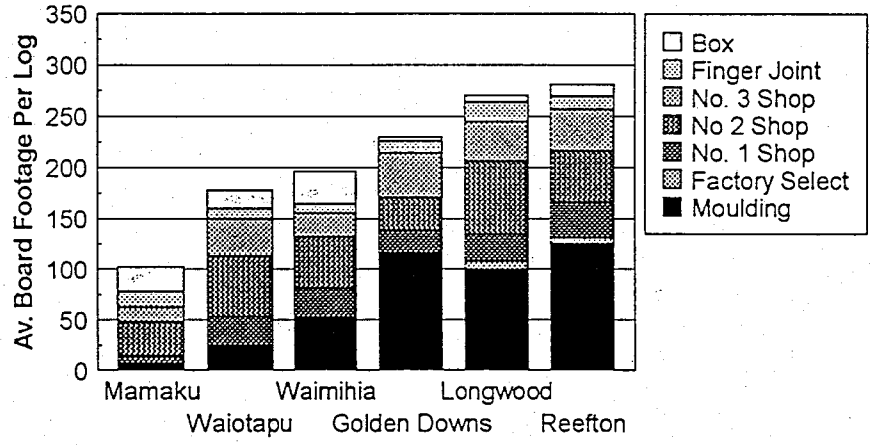


Figure 4(b): Cant sawing (random width factory lumber grades) Grade Distributions



As the simulations had been repeated for two grading practices, a comparison of the two grade sets could be made on a flitch by flitch basis. From identical pairs of flitches a tally of each of the random width factory grades and corresponding* NZ grades was compiled. Where two or more NZ grades were obtained they were proportioned equally between the grades. For example, the grade combinations (cfd), (sf), were encountered for flitches which each obtained No. 1 Shop grade when cut and graded as random width boards. The former combination allocated one-third to the tally of each grade taken to be equivalent to No. 1 Shop, whilst the latter allocated one half to each of those grades.

* corresponding to boards cut from the same flitch

Figures 5(a) and (b) show, for each of the (WWPA) factory grades, the corresponding* proportion of grades obtained under the NZ grading system. The number of random width boards upon which these proportions are based are shown in Table 5.

Table 5: Number of Random Width Boards Obtained in Simulations

Sawing Method	Grade						
	Mouldings	Factory Select	No. 1 Shop	No. 2 Shop	No. 3 Shop	Finger joint	Box
Live	90	10	76	231	162	9	17
Cant	199	18	99	243	167	59	92

This report discusses the results of sawing simulation runs for the 70 individual logs in the study. The next step is to use the simulation results presented in this report to derive regression equations for predicting timber grade recovery and conversion as a function of log variables such as SED, defect core, etc. Equations will be obtained for predicting both NZ grades and WWPA grades under both live and cant sawing. These equations will be presented in a subsequent report and will ultimately be incorporated into the sawing simulation programme SAWMOD.

Acknowledgments

We would like to thank the following companies for making available the logs for this study:

Forestry Corporation of NZ Ltd (30 logs)

Rayonier NZ Ltd (10 logs)

Fletcher Challenge Forests (5 logs)

NZ FRI Ltd (25 logs)

Figure 5(a): Grade comparison for live sawn logs

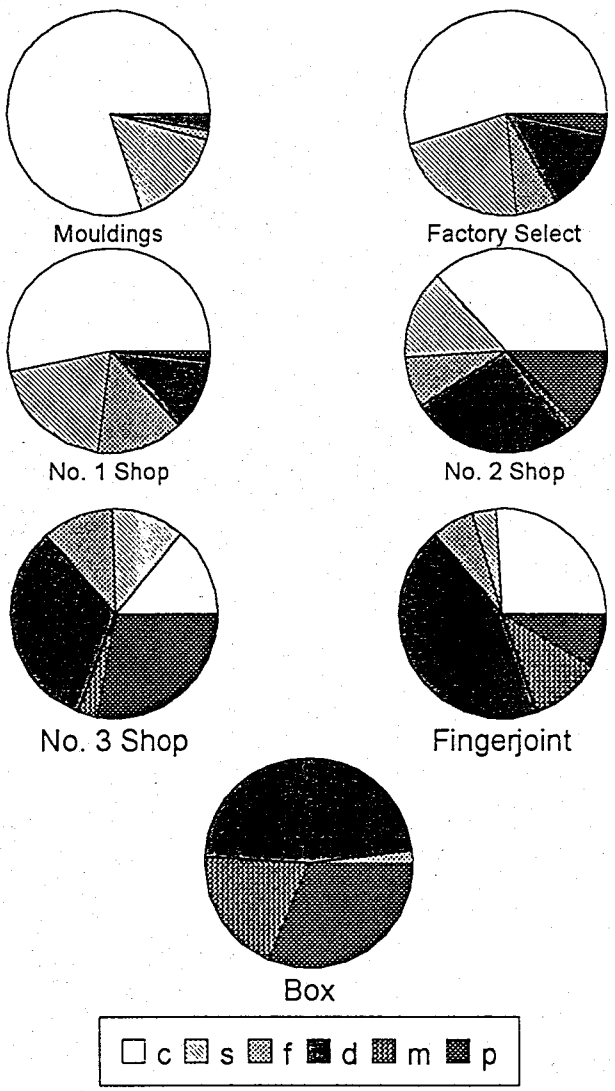
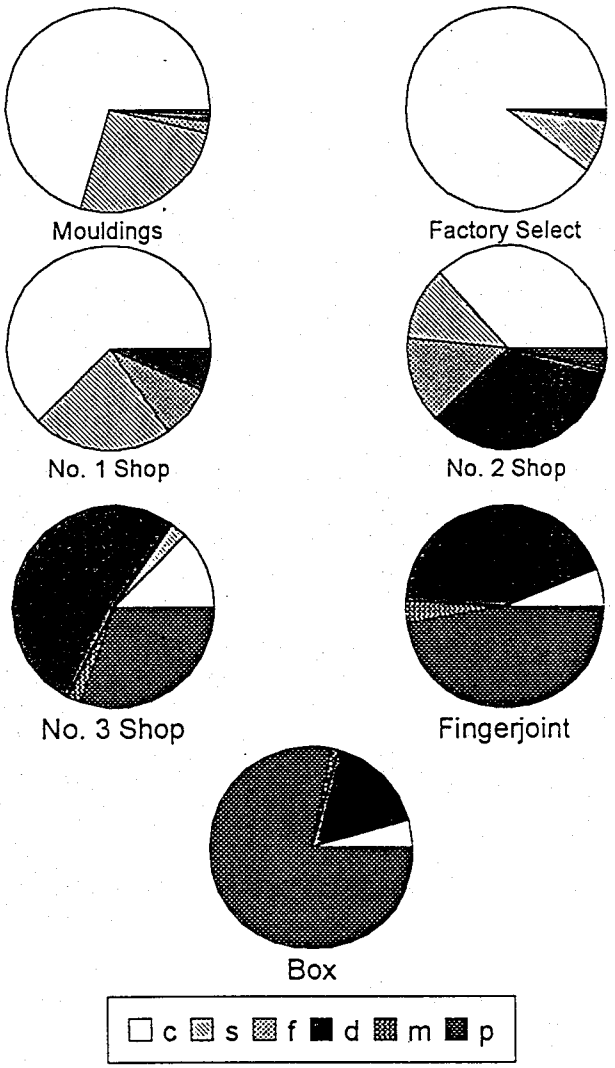


Figure 5(b): Grade comparison for cant sawn logs



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WWPA (1992) Western Lumber Grading Rules 91 Western Wood Products Association

Appendix 1: Log Characteristics

Log	Length (m)	SED (mm)	LED (mm)	Diameter @1.3m (mm)	Sweep (mm/m)	Volume (m3)	Defect Core (mm)
***** Mamaku *****							
1	3.7	307	442	341	5.4	0.33	207
2	3.2	188	256	206	18.4	0.11	230
3	3.8	340	471	398	5.2	0.46	255
4	3.9	323	403	335	5.3	0.34	217
5	3.7	385	527	461	7.3	0.56	299
6	3.9	239	306	259	5.0	0.19	187
7	4.4	327	441	366	8.0	0.43	227
8	3.9	344	426	356	5.1	0.39	273
9	3.6	436	552	455	12.5	0.59	298
10	4.7	362	468	419	5.0	0.55	291
11	5.4	350	459	406	6.3	0.60	321
12	4.3	310	402	329	5.0	0.36	242
13	4.5	260	342	303	4.1	0.30	238
14	4.6	334	507	385	7.8	0.51	251
15	4.2	323	419	363	5.6	0.39	258
***** Waiotapu *****							
1	5.5	298	411	343	5.2	0.48	196
2	5.7	280	368	311	6.1	0.42	220
3	5.7	411	515	461	6.0	0.89	254
4	5.7	384	501	441	9.4	0.79	242
5	5.9	371	481	444	11.7	0.82	370
6	6.8	330	414	372	9.5	0.69	281
7	6.2	342	463	400	5.6	0.71	233
8	6.8	261	376	318	4.3	0.47	213
9	5.9	292	386	338	7.1	0.48	257
10	6.9	366	471	411	8.0	0.84	222
11	6.3	342	509	418	4.4	0.75	237
12	6.5	420	604	507	5.3	1.14	280
13	6.4	347	449	394	15.4	0.68	322
14	6.5	295	403	349	5.2	0.55	231
15	6.3	305	432	357	10.2	0.58	252
***** Waimihia *****							
1	4.6	416	496	445	6.1	0.69	300
2	4.4	315	439	351	14.5	0.39	273
3	4.6	438	539	481	10.3	0.79	278
4	4.8	484	682	571	8.0	1.13	344
5	4.6	553	699	597	10.7	1.21	334
6	4.7	289	343	301	6.2	0.33	298
7	5.2	356	481	381	7.8	0.57	292
8	4.2	492	586	511	8.8	0.85	282
9	5.0	379	467	413	1.9	0.64	272
10	4.6	375	456	407	5.6	0.58	289
11	5.4	425	561	485	7.3	0.91	303
12	5.4	407	519	457	4.7	0.82	230
13	5.0	328	425	370	8.4	0.50	274
14	4.8	394	519	428	5.4	0.67	288
15	4.8	427	546	470	6.4	0.80	320

SED = Small End Diameter LED = Large End Diameter

Appendix 1: Log Characteristics

Log	Length (m)	SED (mm)	LED (mm)	Diameter @1.3m (mm)	Sweep (mm/m)	Volume (m3)	Defect Core (mm)
***** Golden Downs *****							
1	6.4	349	440	388	7.5	0.70	254
2	6.6	506	628	548	6.9	1.47	361
3	5.5	437	526	483	18.9	0.93	406
4	5.4	386	483	418	5.1	0.72	165
5	5.9	341	405	365	4.2	0.58	183
***** Longwood *****							
1	5.7	392	526	450	9.6	0.83	250
2	5.1	380	520	438	7.2	0.70	253
3	5.1	421	532	465	9.4	0.82	332
4	2.4	439	515	455	11.7	0.41	274
5	5.6	474	619	529	2.5	1.17	230
6	6.1	483	590	500	6.1	1.09	294
7	5.4	379	518	426	6.5	0.71	236
8	5.6	549	743	628	7.8	1.60	318
9	5.4	514	679	587	17.2	1.40	391
10	6.1	431	592	497	8.5	1.04	329
***** Reefton *****							
1	7.0	451	566	514	4.1	1.28	240
2	5.6	392	475	418	7.8	0.74	262
3	7.2	333	445	395	4.7	0.79	175
4	6.7	349	520	416	8.7	0.82	250
5	7.0	363	485	416	10.2	0.87	235
6	5.6	297	382	353	6.4	0.51	234
7	6.6	407	505	442	6.8	0.96	211
8	5.7	399	534	465	15.1	0.87	311
9	5.2	654	837	695	4.6	1.95	315
10	6.1	490	697	543	7.1	1.36	259

SED = Small End Diameter LED = Large End Diameter

Appendix 2: NZ Grade Distributions Obtained under Live Sawing (% Round Log Volume)

Grade\ Log	c	s	f	d	m	p	Total
***** Mamaku *****							
1	5.6	7.8	8.0	18.4	0.0	16.7	56.5
2	0.0	0.0	0.0	9.5	13.5	19.0	41.9
3	16.4	9.3	1.8	18.6	0.0	14.9	61.0
4	2.7	9.7	0.0	32.1	0.0	17.2	61.6
5	3.5	3.6	18.8	18.0	5.0	10.0	58.9
6	0.0	4.4	7.6	17.8	0.0	26.8	56.6
7	7.6	0.0	9.9	15.9	11.7	13.7	58.7
8	0.0	7.4	2.8	35.6	3.8	11.4	60.9
9	8.0	0.0	10.5	21.6	4.7	16.3	61.1
10	2.1	3.6	7.4	27.6	3.2	14.5	58.5
11	0.0	0.0	6.9	25.0	8.6	15.5	56.0
12	0.0	0.0	10.8	31.1	0.0	15.8	57.6
13	0.0	9.5	4.7	18.1	8.6	17.3	58.2
14	10.6	13.3	0.0	15.5	0.0	20.5	59.9
15	0.0	6.7	4.1	23.3	10.1	16.2	60.5
***** Waiotapu *****							
1	12.2	2.8	0.0	15.0	12.0	15.3	57.3
2	2.7	0.0	0.0	31.9	4.6	18.1	57.4
3	13.4	7.4	12.2	9.7	0.0	19.5	62.1
4	16.0	2.7	15.9	2.7	2.1	21.9	61.3
5	8.5	2.2	11.8	17.2	0.0	22.0	61.6
6	8.1	9.3	10.7	9.7	0.0	20.5	58.2
7	6.2	9.1	13.3	12.5	2.5	19.1	62.6
8	0.0	6.7	5.2	23.4	4.2	16.7	56.1
9	1.2	4.4	0.0	25.3	0.0	23.4	54.2
10	17.5	9.5	1.7	10.8	0.0	21.2	60.7
11	14.1	9.4	7.0	18.3	0.0	11.1	59.8
12	14.4	10.3	1.9	17.9	4.3	13.0	61.8
13	7.9	13.4	8.2	6.9	0.0	19.7	56.1
14	2.5	5.3	8.0	15.9	0.0	26.7	58.4
15	7.2	9.3	0.0	17.5	0.0	22.8	56.8
***** Waimihia *****							
1	8.5	13.1	0.0	30.1	2.6	10.2	64.5
2	2.5	9.1	5.6	13.7	0.0	23.4	54.3
3	14.4	4.4	3.0	31.9	0.0	13.3	66.9
4	17.5	1.6	4.8	30.3	0.0	8.9	63.0
5	23.6	14.9	0.0	17.3	0.0	11.5	67.3
6	0.0	0.0	0.0	32.6	7.3	21.4	61.3
7	8.4	4.9	2.5	30.5	0.0	12.2	58.6
8	20.5	9.4	3.8	22.5	0.0	9.4	65.5
9	6.5	9.1	2.0	28.2	4.4	14.8	64.9
10	6.1	5.1	2.3	28.2	0.0	21.1	62.7
11	15.8	3.2	3.4	20.4	2.2	18.0	62.9
12	24.4	7.5	0.0	17.4	0.0	14.9	64.2
13	0.0	18.6	0.0	27.0	0.0	15.2	60.8
14	4.6	15.7	3.4	21.8	0.0	16.2	61.6
15	10.1	9.0	3.4	24.0	0.0	17.1	63.6

Appendix 2: NZ Grade Distributions Obtained under Live Sawing (% Round Log Volume)

Grade\ Log	c	s	f	d	m	p	Total
***** Golden Downs *****							
1	7.9	12.6	13.4	21.0	0.0	8.7	63.6
2	25.8	9.3	6.8	23.0	0.0	3.4	68.4
3	15.2	6.3	4.5	16.4	0.0	20.0	62.4
4	37.2	2.9	0.0	14.2	0.0	11.4	65.7
5	19.1	9.6	3.8	21.1	0.0	11.5	65.1
***** Longwood *****							
1	17.7	10.4	5.2	13.0	0.0	16.9	63.2
2	17.0	10.4	4.9	19.3	0.0	11.1	62.6
3	14.3	0.9	2.4	35.8	0.0	13.0	66.3
4	13.3	4.5	10.6	24.6	0.0	12.3	65.3
5	27.4	16.4	0.0	17.3	0.0	6.4	67.5
6	15.1	11.7	0.0	20.2	0.0	17.0	63.9
7	12.0	4.5	5.8	24.4	0.0	15.8	62.5
8	31.1	2.7	5.3	21.3	0.0	5.3	65.8
9	16.6	5.9	6.5	25.6	0.0	11.8	66.3
10	13.2	11.4	6.7	18.7	0.0	13.4	63.4
***** Reefton *****							
1	22.5	11.8	6.2	12.2	0.0	11.3	64.0
2	29.6	7.7	2.9	10.1	0.0	15.8	66.0
3	18.3	8.6	6.0	9.9	0.0	17.3	60.2
4	17.1	15.2	0.0	16.3	0.0	12.4	60.9
5	20.4	7.4	0.7	6.1	2.3	27.5	64.3
6	6.7	12.6	8.4	6.3	0.0	25.3	59.2
7	17.7	8.5	2.6	12.3	0.0	22.3	63.4
8	9.3	6.7	8.0	12.6	4.3	18.4	59.3
9	36.1	12.2	8.1	2.0	4.1	6.1	68.6
10	26.2	13.7	0.0	18.8	0.0	9.4	68.1

Appendix 3: NZ Grade Distributions Obtained under Cant Sawing (% Round Log Volume)

Grade\ Log	c	s	f	d	m	p	Total
***** Mamaku *****							
1	8.7	7.3	3.6	19.0	0.0	16.7	55.4
2	0.0	0.0	0.0	7.1	0.0	32.2	39.3
3	23.6	4.4	0.0	25.1	0.0	12.6	65.7
4	12.7	3.9	4.3	20.9	0.0	17.2	59.0
5	11.7	1.9	21.3	8.7	5.0	10.0	58.5
6	0.0	5.5	6.5	0.0	0.0	34.4	46.4
7	13.3	2.1	2.2	39.0	0.0	0.0	56.6
8	10.1	3.0	3.8	27.3	0.0	15.2	59.3
9	9.6	2.0	5.5	23.3	9.3	9.3	59.2
10	4.2	0.0	14.6	27.1	0.0	12.9	58.7
11	3.1	2.6	0.0	17.4	18.5	13.8	55.3
12	1.4	6.5	0.0	30.5	0.0	18.3	56.7
13	0.0	5.8	3.7	28.2	0.0	17.3	54.9
14	9.8	10.1	0.0	20.5	3.4	13.7	57.4
15	2.0	5.8	4.7	12.5	8.1	24.4	57.3
***** Waiotapu *****							
1	6.2	13.4	0.0	17.5	0.0	17.5	54.6
2	5.6	0.0	2.3	36.0	0.0	10.3	54.2
3	16.0	9.0	7.3	19.5	0.0	9.7	61.4
4	19.6	13.3	1.3	16.4	0.0	10.9	61.5
5	6.6	7.5	3.4	26.3	0.0	16.5	60.3
6	8.0	8.2	6.0	10.6	0.0	22.3	55.1
7	12.4	15.1	0.0	19.9	0.0	13.3	60.7
8	3.9	7.7	0.0	24.1	0.0	16.7	52.3
9	1.2	10.5	2.9	12.4	0.0	28.0	55.0
10	22.4	11.8	0.0	12.3	0.0	12.3	58.9
11	12.7	11.1	2.1	19.0	0.0	12.7	57.6
12	14.3	13.0	4.3	20.5	0.0	8.6	60.7
13	7.6	9.2	9.2	4.8	0.0	24.6	55.4
14	6.4	11.8	0.0	8.8	4.5	26.7	58.2
15	11.3	9.7	0.0	16.4	0.0	16.6	54.0
***** Waimihia *****							
1	12.6	11.3	0.0	29.3	0.0	10.2	63.4
2	5.8	9.6	0.0	18.7	0.0	17.1	51.1
3	20.4	4.4	4.4	27.0	0.0	8.9	65.1
4	21.3	12.9	0.0	23.3	0.0	6.4	63.9
5	31.5	11.5	2.9	11.5	0.0	8.7	66.1
6	0.0	0.0	0.0	36.3	0.0	21.4	57.6
7	5.3	14.2	1.2	16.3	0.0	20.9	57.8
8	26.7	7.5	7.5	14.1	0.0	7.5	63.3
9	8.0	12.7	0.0	30.2	0.0	11.8	62.7
10	12.4	3.6	0.0	32.9	0.0	12.1	60.9
11	17.5	5.1	11.7	14.6	0.0	13.5	62.3
12	27.4	14.9	0.0	10.0	0.0	10.0	62.2
13	8.5	11.9	0.0	22.8	0.0	15.2	58.5
14	9.6	9.5	7.4	16.2	0.0	16.2	58.8
15	8.5	8.0	4.0	27.4	0.0	13.7	61.5

Appendix 3: NZ Grade Distributions Obtained under Cant Sawing (% Round Log Volume)

Grade\ Log	c	s	f	d	m	p	Total
***** Golden Downs *****							
1	4.3	15.4	6.1	21.0	0.0	14.0	60.8
2	38.0	11.9	0.0	10.2	0.0	6.8	67.0
3	14.6	9.9	2.2	20.4	0.0	13.3	60.4
4	35.6	5.7	0.0	11.4	0.0	11.4	64.1
5	31.4	0.0	0.0	15.3	0.0	15.3	62.0
***** Longwood *****							
1	15.2	15.8	0.0	20.8	0.0	10.4	62.2
2	18.9	4.2	10.4	16.6	0.0	11.1	61.1
3	18.0	4.0	9.4	23.6	0.0	9.4	64.5
4	19.1	4.5	16.8	8.9	0.0	13.4	62.7
5	37.1	10.9	0.0	10.9	0.0	7.3	66.3
6	21.6	8.1	4.3	21.3	0.0	8.5	63.7
7	16.7	10.6	0.0	23.0	0.0	11.5	61.8
8	29.2	10.6	2.7	16.0	0.0	8.0	66.5
9	16.1	14.0	2.9	24.0	0.0	8.8	65.9
10	21.0	10.0	4.5	13.4	0.0	13.4	62.1
***** Reefton *****							
1	21.5	21.0	4.1	4.1	0.0	12.4	63.0
2	26.6	10.3	2.9	11.5	0.0	11.5	62.8
3	17.6	13.8	0.0	13.8	0.0	13.8	59.0
4	20.5	6.0	2.1	12.4	0.0	18.5	59.5
5	19.5	10.5	0.0	18.4	0.0	12.3	60.6
6	8.7	4.1	6.5	20.0	0.0	16.9	56.1
7	19.8	10.5	5.2	15.7	0.0	10.5	61.7
8	14.2	4.0	8.6	18.9	0.0	14.8	60.4
9	46.0	6.1	0.0	8.1	2.0	6.1	68.3
10	39.0	10.0	0.0	10.3	0.0	6.8	66.1

Appendix 4: WWPA Grade Distributions Obtained under Live Sawing (Board Feet)

Grade\ Log	M	F	1	2	3	J	P
***** Mamaku *****							
1	0	0	19	8	67	0	0
2	0	0	0	0	0	0	21
3	0	15	9	43	40	22	0
4	0	0	23	7	44	7	0
5	0	0	46	44	73	6	0
6	0	0	0	5	6	12	13
7	0	0	0	45	79	0	0
8	0	0	21	6	63	0	0
9	0	0	28	71	67	0	0
10	5	0	0	66	45	23	26
11	0	0	0	10	116	0	27
12	0	0	0	16	57	0	20
13	0	0	0	14	14	18	31
14	0	20	0	18	103	0	0
15	0	0	7	16	45	17	21
***** Waiotapu *****							
1	0	0	0	44	92	0	0
2	0	0	0	48	40	0	0
3	47	0	29	141	36	0	0
4	46	0	30	154	0	0	0
5	0	0	51	26	173	0	0
6	0	0	0	75	138	0	0
7	0	0	51	132	34	0	0
8	0	0	0	14	79	30	0
9	0	0	0	66	64	0	0
10	30	0	65	165	0	0	0
11	22	0	7	65	141	0	0
12	33	0	31	259	47	0	0
13	0	0	28	73	102	0	0
14	0	0	0	52	113	0	0
15	0	0	36	16	110	0	0
***** Waimihia *****							
1	0	22	11	67	117	0	0
2	0	0	0	25	78	0	0
3	31	0	26	31	155	0	0
4	38	0	63	135	117	0	0
5	137	0	74	184	0	0	0
6	0	0	0	0	0	0	89
7	0	0	16	31	114	0	0
8	57	0	64	131	0	0	0
9	20	0	0	91	88	0	0
10	7	0	0	49	57	26	30
11	29	0	11	126	112	0	0
12	100	0	0	119	36	0	0
13	0	0	0	17	118	0	0
14	5	0	41	39	115	0	0
15	0	0	22	41	181	0	0

Appendix 4: WWPA Grade Distributions Obtained under Live Sawing (Board Feet)

Grade\ Log	M	F	1	2	3	J	P
***** Golden Downs *****							
1	17	0	0	39	150	0	0
2	221	0	165	54	20	0	0
3	46	0	35	184	38	0	0
4	71	0	0	150	0	0	0
5	42	0	26	47	60	0	0
***** Longwood *****							
1	49	7	57	136	12	0	0
2	20	0	0	92	96	0	0
3	22	0	20	144	68	0	0
4	0	48	11	46	0	0	0
5	143	0	87	142	0	0	0
6	62	0	16	272	0	0	0
7	21	0	27	123	39	0	0
8	247	0	0	253	0	0	0
9	59	7	24	258	87	0	0
10	27	0	30	233	42	0	0
***** Reefton *****							
1	122	0	74	224	0	0	0
2	58	0	23	139	0	0	0
3	41	0	31	86	76	0	0
4	0	0	59	110	82	0	0
5	48	0	55	111	43	0	0
6	0	0	9	54	83	0	0
7	59	0	7	190	41	0	0
8	0	0	28	164	77	0	0
9	264	44	90	172	0	0	0
10	174	0	55	202	15	0	0

Appendix 5: WWPA Grade Distributions Obtained under Cant Sawing (Board Feet)

Grade\ Log	M	F	1	2	3	J	P
***** Mamaku *****							
1	0	0	0	47	11	18	12
2	0	0	0	0	0	0	18
3	12	0	36	22	9	24	12
4	13	0	0	33	0	36	0
5	0	7	47	56	9	11	24
6	0	0	0	5	4	9	18
7	13	10	0	21	26	28	14
8	0	0	16	19	5	17	36
9	8	0	22	68	14	17	11
10	5	0	0	51	51	0	45
11	0	0	0	31	50	23	51
12	0	0	5	23	12	8	42
13	0	0	0	29	0	20	20
14	0	7	3	68	13	15	30
15	0	0	9	36	11	0	39
***** Waiotapu *****							
1	15	0	0	23	53	18	18
2	0	0	4	35	21	0	23
3	35	0	96	55	31	0	0
4	72	0	27	48	54	0	18
5	0	0	0	140	35	0	57
6	0	0	16	83	73	0	0
7	37	0	41	52	22	20	0
8	14	0	0	33	44	0	16
9	0	0	8	51	27	0	19
10	90	0	29	31	44	44	0
11	33	0	62	20	31	0	49
12	35	0	116	124	12	21	21
13	0	0	17	103	39	0	20
14	0	0	13	53	21	42	21
15	20	15	0	42	48	0	20
***** Waimihia *****							
1	23	4	26	69	10	0	60
2	0	0	13	32	26	0	28
3	74	0	33	44	13	15	45
4	43	7	135	65	13	15	60
5	209	0	48	51	33	0	0
6	0	0	0	0	6	28	37
7	17	0	14	42	30	32	17
8	98	0	55	23	57	0	0
9	36	0	7	74	34	16	0
10	13	0	0	69	15	0	60
11	75	0	8	89	30	0	51
12	134	0	28	0	23	0	34
13	22	0	14	23	3	0	48
14	18	0	27	64	36	15	15
15	0	0	34	115	22	15	30

Appendix 5: WWPA Grade Distributions Obtained under Cant Sawing (Board Feet)

Grade\ Log	M	F	1	2	3	J	P
***** Golden Downs *****							
1	37	0	23	46	35	20	0
2	318	0	0	21	37	21	21
3	62	0	52	61	41	0	0
4	105	0	13	15	69	0	0
5	54	0	23	19	38	18	0
***** Longwood *****							
1	76	5	43	8	81	0	0
2	62	0	0	77	44	0	0
3	30	6	26	72	65	0	32
4	0	16	12	52	3	19	0
5	196	37	29	36	28	0	0
6	88	0	11	133	30	40	5
7	58	0	0	86	0	34	17
8	275	0	29	88	36	36	18
9	99	16	70	94	83	17	0
10	106	6	44	70	19	40	0
***** Reefton *****							
1	195	6	44	43	67	23	0
2	73	0	26	56	45	0	0
3	48	0	64	39	50	3	0
4	40	6	35	85	42	22	0
5	79	0	28	56	5	22	44
6	0	0	15	35	33	18	18
7	89	0	52	58	66	0	0
8	13	0	78	86	34	0	0
9	435	44	0	20	14	17	38
10	272	7	0	29	50	24	20