

Modification of log grading and log segregation strategies for low-quality logs from the East Gippsland FMA of Victoria

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Summary

The potential for segregating higher-quality residual logs at sawmills for the production of sawn timber was investigated in low-quality eucalypt logs from mixed-species forests in the East Gippsland Forest Management Area of Victoria, Australia. Studies were conducted on long-length bush logs that were graded in the forest and were below existing minimum specifications for sawlogs (lower quality than A, B, C or D-grade sawlog).

Following cross-cutting to sawlog length at the sawmills, 15% of logs (82 logs) were found to meet existing sawlog grades, probably because internal defect visible on the ends of logs was less severe than on the full-length bush logs.

Conventional sawing systems and strategies were applied to assess the timber quality from the remaining 85% of the cross-cut logs (449 logs). Multiple regression analysis was used to develop a grading method that could be applied at the sawmill to produce two new residual log grades (Residual grades 1 and 2).

After applying the grading method, Residual grade 1 logs were found to have recoveries similar to those of E-grade logs that are currently milled with higher-quality sawlogs. However, a greater percentage of logs could be selected with the new method. While it was found to be ineffective in low-elevation mixed-species forests where selective logging left a high proportion of large defective trees, the grading method can have broad application across all the other forest types examined.

There are four main differences to the existing log criteria: (i) mean end defect rather than worst-end defect is used as an indicator of log quality; (ii) mean minimum diameter of logs is 25 cm with no small-end restrictions, (iii) the definition of a clear quarter is different; that is, existing rules allow clear quarters to have a defect or combination of defects that have a width no greater than one-third of the surface width of the quarter on which they occur; a clear quarter in the new criteria has no visible defect apart from small epicormics; and (iv) logs with mean diameter >40 cm and end defect <40% are permitted to have four defective quarters.

Keywords: log grade; log size; wood utilization; recovery; *Eucalyptus*; Victoria

Introduction

The native forests of the East Gippsland Forest Management Area (FMA) in Victoria, Australia, have become an important source of sawn wood from native forests over the last 50 y, and sawn wood production has increased rapidly during this period (Morgan 1997). The growth of the industry resulted from the relocation of much of the hardwood sawmilling industry from the Central Highlands following the 1939 wild fires, and from very strong post-war demand for building materials (Woodgate *et al.* 1994). To maintain this, high output harvesting was carried out at well above sustainable levels and, together with about 30% of the resource being allocated to the reserve system during the 1980s, led to a reduction in the availability of high-quality sawlogs (Woodgate *et al.* 1994). More recent assessments have also suggested that sawlog availability has been over-estimated in the past and further reductions in log allocations are currently being implemented (NRE 2002).

To overcome this shortfall in high-quality logs, better utilisation of the available resource is a high priority. The potential to use low-quality roundwood (residual logs) for sawn products has often been considered. Some of this residual resource is currently used for local manufacture of pulp and paper or exported as woodchips for off-shore processing. However, most is left in the forest to be burnt during regeneration burns, or left to decay. It is estimated that the volume of low-quality roundwood that could be available for harvesting, including both logging residue and remaining defective trees, varies from 600 000 to 1 000 000 m³ y⁻¹ (Morgan 1997).

In an attempt to use a small volume of this wood in local sawmills, some modifications to log-grading rules have been introduced. An additional log grade (the E-grade log) that would normally be part of the residual log resource is available to sawmills and limited processing has been attempted. As part of a much broader range of activities the present study was undertaken to evaluate the effectiveness of this grading strategy and if necessary to modify the grading rules.

This study had two aims: (i) to investigate whether log external features might be used to develop a sawlog selection method that can be applied in sawmills after cross-cutting of long-length bush logs, and (ii) to determine whether the major mixed-species forest types within the East Gippsland region have differing potential to produce sawn products from the low-quality residual resource.

Materials and methods

Sampling strategy

The forest strata

The sampling strategy was developed in consultation with the forest managers (at present, the Victorian Department of Sustainability and Environment (DSE)). Bush-log selection was weighted to reflect projected wood flows over the 1997–2002 period from five different forest strata within the East Gippsland FMA. The five forest strata and their identification codes are given in Table 1.

Other forest types that are naturally low-yielding and of low economic value — mainly due to environmental factors — were not considered in the trial. The forest strata, their management history and the major species represented in them are:

- (a) high-elevation mixed-species forests (HEMS). These are the high altitude, cool and generally wet areas of the FMA. The major commercial species are *Eucalyptus denticulata*, *E. cypellocarpa*, *E. dalrympleana*, *E. obliqua*, *E. dives* and *E. sieberi*. These forests are generally located in the northern part of the FMA. This forest type can be further subdivided into two strata: low yielding and high yielding. Most of the high-yielding forests (HEMS/H) have had no previous logging or fire history. Forests that have been harvested previously or have some fire history, particularly in the drier locations where *E. sieberi* is the more predominant species, are usually low yielding (HEMS/L). HEMS/L are often composed of older, highly defective mature trees growing together with younger regrowth. Both the HEMS/H and HEMS/L strata provide large volumes of high-quality sawlogs and significant volumes of low-quality residual roundwood.
- (b) low-elevation foothill forests (LEMS), most of which have a low yield of mostly low-quality logs. Some forests have been subject to periodic fires and as a result carry considerable degrade (LEMS/F). Others have been poorly regenerated, usually because a high proportion of trees has been left standing after logging, which results in suppression of younger regrowth (LEMS/C). The LEMS/F and LEMS/C strata provide the bulk of the residual roundwood from low-elevation forests. The main species are *E. sieberi*, *E. obliqua*, *E. cypellocarpa* and a number of stringybark eucalypt species. Some high-yielding forests also found at low elevation (LEMS/H) have not been harvested or burnt. They were also incorporated in the study, as some low-quality logs are extracted during harvesting operations in this stratum.

Table 1. The five forest strata used for sampling purposes, and identification codes

| Forest type | Yield | Code |
|------------------------------|---------------|--------|
| High-elevation mixed species | High yielding | HEMS/H |
| High-elevation mixed species | Low yielding | HEMS/L |
| Low-elevation mixed species | Cut-over | LEMS/C |
| Low-elevation mixed species | Fire-affected | LEMS/F |
| Low-elevation mixed species | High yielding | LEMS/H |

Table 2. Target log numbers for the various strata

| Log strata defined by log diameter / end defect | Forest strata | | | | |
|--|---------------|-----------|------------|------------|-----------|
| | HEMS | | LEMS | | |
| | H | L | C | F | H |
| <50 cm / <20% | 30 | 20 | 30 | 35 | 15 |
| <50 cm / >20% | 45 | 30 | 40 | 25 | 20 |
| Total logs <50 cm diameter | 75 | 50 | 70 | 60 | 35 |
| >50 cm / <20% | 20 | 12 | 15 | 12 | 8 |
| >50 cm / >20% | 35 | 28 | 35 | 28 | 17 |
| Total log >50 cm diameter | 55 | 40 | 50 | 40 | 25 |
| Total logs all diameters | 130 | 90 | 120 | 100 | 60 |

Log selection

A stratification and accrual sampling strategy was adopted that aimed to collect 500 logs for sawing. This type of strategy has target numbers for various classes of logs, and aims to collect sample logs until the target numbers are obtained. The stratification was based on the forest type and log quality as shown in Table 2. Log selection from each of the five forest strata was undertaken to reflect the range of tree species, log diameter and heart defect. Heart defect included decay, insect attack and pipe defect. Where possible most logs were assigned as a species, or at least assigned to a group of species. While it was important to ensure that all species were represented in the sample, it was not possible to identify species for some logs.

Logs were initially selected in ‘bush log’ lengths (Fig. 1) at log dumps prior to loading and transport. All bush logs had been graded and were of lower quality than D grade. Lengths varied from 3.0 m to 11.0 m, and log cross-cutting strategies at the mill were implemented to maximise the yield of ‘saw-log’ grade wherever possible, while adhering to minimum length requirements. Following cross-cutting, all the logs were graded according to DSE specifications to grades B, C, D and ‘residual’ (listed in order of quality from best to worst). This grading is based on log



Figure 1. Example of low-quality logs at the harvesting coupe

diameter, worst-end defect and log-surface defects. Minimum small-end diameter is 35 cm, 30 cm and 25 cm for B, C and D-grade logs respectively, and there are increasing allowances for end defect and the number of log quarters that have surface defect as log quality declines. In addition, all logs graded 'residual' were regraded under the local unofficial grading rules to E grade and pulp logs, respectively.

The work to assess log grading was confined to logs below the existing D-grade specification. However, the logs that conformed with existing sawlog specifications (B, C or D grade) were retained in the study for comparisons of recovery. An additional constraint to sawlog selection imposed for this project was that an approximate mean of 12 cm of solid wood was required around the defective heart. This approximates existing minimum DSE requirements for sawlogs <50 cm diameter.

Sawing trials

Sawing was conducted in several trials between 1990 and 1997. This allowed sampling across the broad range of wet- and dry-weather coupes over the course of several logging seasons, and made it possible to broadly sample the range of forest strata and to avoid confining sampling to one block and coupe within each stratum. In all trials the following procedures were adopted.

All major log characteristics were recorded and their location mapped on log diagram sheets. Characteristics recorded included: (i) log form (sweep and crook); (ii) log-surface defects such as the size and condition of knots (green, dead or decayed branch stubs and surface bumps that indicated over-grown branch stubs or other defects); (iii) log-surface bole damage (both induced during harvest and handling, and natural damage); (iv) spiral grain; and (v) on the log ends, the size of pipe, decay, insect attack, the length of tight and loose kino, and the size and location of kino pockets and log end-splits.

The ends of all logs were colour-coded, using water-soluble paint of eight different colours, to assist the identification of the wood sawn from each log. Log length was also used to assist accurate identification.

The sawing was conducted using conventional sawing systems and strategies in two East Gippsland sawmills. Products were sawn to meet the product requirements of the customers for the respective mills.

Boards were graded while on the green chain. All board dimensions were recorded on product grading sheets. All boards were graded to AS 2082-1979 (Standards Association of Australia 1979) by allocating each to one of the four Structural Grades or rejecting it, and recording the grade on grading sheets. Recoveries were calculated as a percentage of log volume using the recorded nominal green product dimensions, and log volumes calculated in accordance with Victorian Government methods. The recoveries of Structural Grade 3 and better (F8 green structural product for mixed eucalypt species) were calculated for each log (hereafter termed recovery of Structural Grade 3+).

Statistical analysis

From the collected data the relationship between recovery of Structural Grade 3+ and the measured log characteristics was

determined. The statistical methods employed included the calculation of a Spearman correlation matrix (Zar 1996) between individual log characteristics and individual log recovery. Multiple regressions were calculated using two different methods. Firstly, forward stepwise regressions using the most important log quality characteristics (as determined by the Spearman correlations) were calculated using STATISTICA software (Statistica 1994). The regressions were repeated using the predictors selected in the forward stepwise regressions with an analysis of covariance conducted in a multiple regression fashion also using the software.

The analysis of covariance regression results were tested for each stratum by calculating a univariate test for covariate \times stratum interaction. This effectively determined whether the regression model had similar slopes in each of the forest strata.

The regression results were also validated by determining the mean recovery for two new grades of residual logs (Residual grades 1 and 2) that were graded using a method developed from the beta values from the regression models. The mean recovery of Residual grades 1 and 2 was compared between the forest strata.

Results and discussion

Recovery comparisons

The number of residual and 'in-grade' logs and the respective mean recoveries for Structural Grade 3 and better are given in Table 3. In total, 531 logs were processed and, following grading at the respective sawmills, 82 logs (15%) were found to meet existing sawlog grades ranging from a single B-grade log through to D grade. Despite the small number of in-grade logs — which limits the conclusions that can be drawn about the recovery — the recoveries are consistent with expectations from the resource in East Gippsland. There was a general decline in recovery with worsening log quality (26.2% for B grade to 13.0% for residual logs). While there may have been some bias during grading of bush logs, the main reason for the up-grade was an inability to predict the end-defect on cross-cut logs from the defect on the ends of the full-length logs. In some bush logs the diameter of pipe defect, insect/termite damage and/or decay varied rapidly along the length of the log. In some cases the defect was found to be reduced at the point of cross-cutting and in others it was increased (discussed below).

Overall, 449 residual logs were processed — fewer than the target in the sampling strategy (Table 2). Table 4 shows that the number of logs in each of the strata cells also varied from the target figures. The major reason in both cases was our inability to predict the amount of end defect in the sawlogs prior to cross-cutting the

Table 3. Mean recovery of boards of Structural Grade 3 or better for all logs sawn (strata combined)

| Log grade | Number of logs | Recovery of Structural Grade 3+ (% of log volume) |
|-----------|----------------|---|
| B grade | 1 | 26.2 |
| C grade | 17 | 27.5 |
| D grade | 64 | 19.2 |
| Residual | 449 | 13.0 |

Table 4. Number of residual logs selected for sawing trials

| Log strata defined by log diameter / end defect | Forest strata | | | | | Total |
|--|---------------|-----------|------------|------------|-----------|------------|
| | HEMS | | LEMS | | | |
| | H | L | C | F | H | |
| <50 cm / <20% | 31 | 35 | 55 | 54 | 12 | 187 |
| <50 cm / >20% | 0 | 9 | 21 | 26 | 9 | 65 |
| Total logs <50 cm diameter | 31 | 44 | 76 | 80 | 21 | 252 |
| >50 cm / <20% | 25 | 4 | 20 | 17 | 13 | 79 |
| >50 cm / >20% | 22 | 16 | 34 | 26 | 20 | 118 |
| Total log >50 cm diameter | 47 | 20 | 54 | 43 | 33 | 197 |
| Total logs all diameters | 78 | 64 | 130 | 123 | 54 | 449 |

bush logs. It was also difficult to locate, in most strata, small-diameter logs (<50 cm) with large amounts of end defect (>20%) because they were either uncommon in the harvested coupes, or readily split during harvest and handling. Despite these sampling issues, the sample was sufficiently large to allow effective statistical analysis.

Statistical analysis

Log quality and product recovery relationships (residual logs)

From the log diagram sheets a number of log quality characteristics were calculated for each of the residual logs:

- (i) mean diameter;
- (ii) taper;
- (iii) sweep;
- (iv) ratio of the length of kino rings (tight and loose) on log ends : log diameter;
- (v) percentage end defect (pipe, decay, termite and insect damage);
- (vi) number of bumps, green and dead branch stubs, decayed branch stubs (open) >5 cm diameter — per metre of log length;
- (vii) number of bumps, green and dead branch stubs, decayed branch stubs (open) <5 cm diameter — per metre of log length;
- (viii) felling damage;
- (ix) other bole damage;
- (x) number and width of end splits;
- (xi) number of clear quarters (quarters on the log surface free of defect);
- (xii) number of clear quarters 1.2 m in length as a percentage of the maximum possible.

Using the data from the 449 residual logs only, the Spearman correlation matrix and the forward stepwise regression between the above log characteristics and recovery of boards of Structural Grade 3 or better suggested that the log characteristics of most importance (and significantly correlated with recovery) were: (i) mean log diameter, (v) percentage end defect, (xi) number of clear

Table 5. Results of the analysis of covariance and beta values for each predictor for recovery of boards of Structural Grade 3 or better

| Dependent variable | | <i>F</i> | <i>P</i> value of model |
|---------------------------------|--------------------------|--------------------|-------------------------|
| Recovery of Structural Grade 3+ | | $F(3,441) = 16.18$ | <0.001 |
| Dependent variable | Covariate predictor | Beta | <i>P</i> value |
| Recovery | Mean diameter | 0.227 | <0.001 |
| Structural Grade 3+ | Number of clear quarters | 0.192 | <0.001 |
| | Percentage end defect | -0.311 | <0.001 |

quarters, (vi) number of bumps and green and dead branch stubs >5 cm in diameter, and (xii) number of clear quarters on the log surface 1.2 m in length as a percentage of the maximum possible. None of the other log characteristics was a significant predictor of recovery.

The latter two significant predictors (vi and xii) could be used to substitute for the number of clear quarters in the regression analysis, but this did not improve the results. As both of these characteristics are relatively difficult to measure in comparison with the number of clear quarters, they were left out of the final analysis.

The regressions were repeated with an analysis of covariance in a multiple regression fashion with the three remaining log characteristics (i, v, xi) and the recovery of boards of Structural Grade 3 or better. This analysis specified the forest strata as grouping variables; the dependent variable was the recovery of boards of Structural Grade 3 or better, and the three log characteristics were covariates.

The results of the regression analysis and the beta values for each of the three selected log characteristics are given in Table 5. These results are very similar to those obtained with the initial forward stepwise regression.

Both the recovery of boards of Structural Grade 3 or better, and the selected log characteristics for each forest stratum, are given in Table 6. There were differences in means for each of the forest strata, with the most notable being the larger log diameter and smaller percentage end defect in HEMS/H. This was partly because of the large diameter of logs in the >50 cm diameter groups in this stratum. The result is also partly due to the fact that no logs were obtained for the '<50 cm diameter / >20% end defect' stratum in HEMS/H (Table 4).

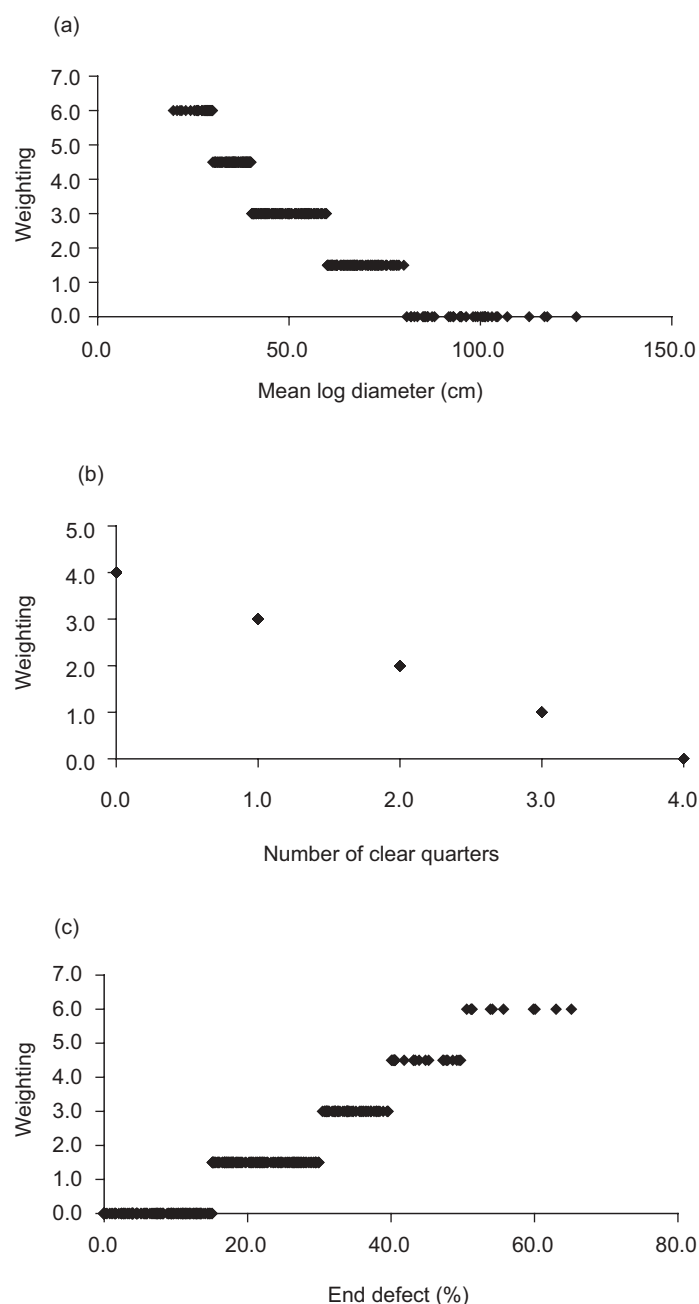
To test for differences between forest strata, a univariate test for covariate x stratum interaction was calculated for the analysis of covariance. Despite the difference in diameter between forest strata, the results were not significant and indicated that the regression planes for the individual forest strata were approximately parallel. This suggests that the model was valid for each forest type.

Table 6. Means for recovery and the selected log characteristics for each forest stratum and all logs

| Forest stratum | Recovery of Structural Grade 3+ (% of log volume) | Mean diameter (cm) | No. of clear quarters | End defect (%) | <i>N</i> |
|-----------------|---|--------------------|-----------------------|----------------|------------|
| HEMS/H | 17.7 | 61.8 | 0.97 | 13.4 | 78 |
| HEMS/L | 10.8 | 47.1 | 1.44 | 16.6 | 64 |
| LEMS/C | 12.3 | 50.3 | 0.91 | 18.5 | 130 |
| LEMS/F | 13.7 | 47.1 | 1.23 | 18.8 | 123 |
| LEMS/H | 9.3 | 54.1 | 0.91 | 24.4 | 54 |
| All logs | 13.0 | 51.4 | 1.08 | 18.1 | 449 |

Table 7. Means for recovery, and the selected log characteristics and number of logs for the two grades of residual logs and the initial grades

| Grade | Recovery of Structural Grade 3+ (% of log volume) | Diameter (cm) | End defect (%) | No. of clear quarters | No. of logs |
|------------------|---|---------------|----------------|-----------------------|-------------|
| Residual grade 1 | 15.7 | 58.0 | 15.1 | 1.5 | 231 |
| Residual grade 2 | 10.2 | 44.4 | 21.3 | 0.6 | 218 |
| All logs | 13.0 | 51.4 | 18.1 | 1.1 | 449 |
| E grade | 16.8 | 51.1 | 12.5 | 2.2 | 96 |
| Pulp | 12.0 | 51.5 | 19.6 | 0.8 | 353 |
| All logs | 13.0 | 51.4 | 18.1 | 1.1 | 449 |

**Figure 2.** Weighting for (a) diameter, (b) number of clear quarters, and (c) end defect

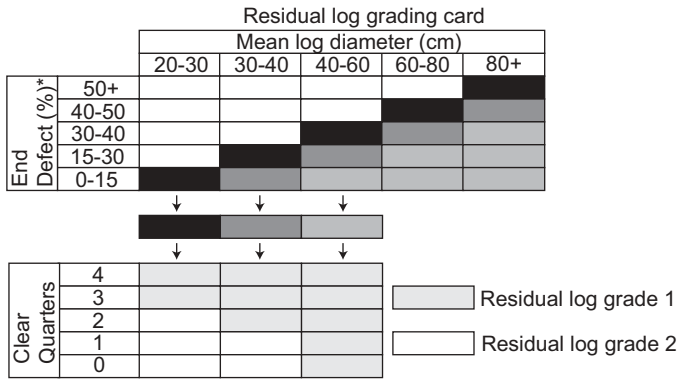
Development of new log grades and comparison with existing local grading rules

To establish a log grading method, a weighting that approximated the beta values was applied to the range of the three log characteristics: mean diameter; number of clear quarters and percentage end defect. Several different weightings that approximated the beta values (Table 5) were applied and tested. The weighting that gave the best differentiation between logs was a weighting for diameter of 0–6, end defect 0–6 and clear quarters 0–4. The ranges in the data are given in Figure 2 a–c.

After calculating the totals for each log, two grades of residual logs were delineated by selecting the approximate mid-point in the weighted totals for the whole log group. The means for the two Residual grades are given in Table 7. To further test the effectiveness of the new log grading method, all logs with significant sweep (between 2.0 cm m⁻¹ and 8.3 cm m⁻¹) and bole damage (both natural and induced with harvesting between 0.3 m² and 1.1 m² on the log surface) were excluded and the means recalculated. The means from this analysis were similar to the means given in Table 7. This result confirms the regression results that these characteristics (sweep and bole damage) were of little importance.

Also given in Table 7 is a comparison with the current local grading rules for E-grade sawlogs and pulp logs (the residual logs of a quality lower than E grade). The results show a slightly higher recovery for the E-grade logs than Residual grade 1. However, there were more logs in the new Residual grade 1 (231 logs) than in the current E grade (96 logs). This shows that the application of the new grading method would improve mill output of high-quality product, while entailing a very small additional cost for regrading. A proposed log-grading card for this purpose is shown in Figure 3. The rules embodied in this card should be applied to logs that fail to meet D-grade sawlog specifications on the existing grading card.

The use of the grading card can be illustrated with an example log with a mean diameter of 70 cm, 45% end defect and three clear quarters. First, in the diagram at the top of the card, locate the 40–50% end-defect row and move along the row to the 60–80 cm diameter cell (the correct cell is shaded black). Then, in the



* End defect is the mean percentage end defect which includes insect damage, decay and pipe. All logs must have a mean minimum of 12 cm of solid wood around the defect core.

Figure 3. Proposed grading card for residual logs developed from the regression analysis. The use of the card is described in the text.

intermediate strip between the upper and lower sections of the card, locate the cell shaded in the same manner, and with the aid of the arrows move to the corresponding column in the diagram at the bottom of the card to account for the number of clear quarters present. Move down the column to the row for three clear quarters. This cell indicates Residual grade 1. If the log had only two clear quarters it would be graded Residual grade 2, indicated by the white cell. Another example is a log with 35% end defect and diameter of 65 cm. This log would align with the dark grey cells, and for it to be graded as Residual grade 1 it would need a minimum of two clear quarters. Similarly a log with 10% end defect and diameter of 45 cm (aligning with light grey cells) would need no clear quarters to be graded as Residual grade 1.

The major differences between this grading procedure and the existing criteria for E-grade logs are that: (i) mean end defect is used as a log quality indicator, rather than worst-end defect; (ii) minimum mean diameter of logs is 25 cm with no small-end restrictions; (iii) the definition of a clear quarter is different. Existing rules allow clear quarters to have a defect or combination of defects that have a width no greater than one-third of the surface width of the quarter on which they occur. A clear quarter in the new criteria has no visible defect apart from small epicormics;

Table 8. Recovery of boards of Structural Grade 3 or better for the two Residual grade log classes and each forest stratum

| Forest stratum | Recovery of Structural Grade 3+ (% of log vol.) | |
|----------------|---|------------------|
| | Residual grade 1 | Residual grade 2 |
| HEMS/H | 20.1 | 12.8 |
| HEMS/L | 13.8 | 7.3 |
| LEMS/C | 12.5 | 12.1 |
| LEMS/F | 17.4 | 10.4 |
| LEMS/H | 13.0 | 6.1 |

and (iv) logs with mean diameter >40 cm and end defect <40% are permitted to have four defective quarters.

The mean recovery of boards of Structural Grade 3 or better for the two residual log grades and forest strata is given in Table 8. This shows that the new grading strategy could be effectively applied in most circumstances to select logs that would be likely to produce higher mean recoveries of material of Structural Grade 3 or better — the only exception is for LEMS/C, where the differentiation between the two log grades was poor (12.5% and 12.1% for Residual grade 1 and 2 respectively).

The recoveries for each of the forest strata and the log classes for the two Residual grades are given in Table 9 and the numbers of logs for each grade given in Table 10. While it is difficult to draw conclusions from these tables because of the small number of logs in some strata cells, the analysis for LEMS/C shows a different trend to the other forest strata. Notably the overall recoveries for the two log grades are similar, and in some log classes the mean recovery is greater for Residual grade 2. The reason for this difference could not be determined because of the small number of logs, but it is probably associated with differences in the management and utilisation of the forest. In this particular forest type, large numbers of highly defective trees have been left standing following earlier harvesting operations. Many of these trees are now being harvested; surface defects on the logs from them may indicate the presence of defects more serious than those found in other forest strata. For example, surface defects such as epicormics in the other strata may have formed only in recent

Table 9. Recovery of boards of Structural Grade 3 or better (% of log volume) using the modified log grading system

| Log criteria | | Strata | | | | | | | | | | Total |
|----------------------|----------|--------------|------|--------------|-----|--------------|------|--------------|------|--------------|------|-------|
| Diameter (cm) | Pipe (%) | HEMS/H Grade | | HEMS/L Grade | | LEMS/C Grade | | LEMS/F Grade | | LEMS/H Grade | | |
| | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | |
| <50 | <20 | 22.4 | 14.8 | 13.2 | 9.5 | 12.5 | 14.2 | 16.9 | 14.7 | 5.7 | 2.2 | 14.0 |
| | >20 | | | 11.9 | 3.8 | 3.3 | 4.5 | 22.0 | 5.5 | 14.3 | 13.0 | |
| Total | | 22.4 | 14.8 | 13.1 | 7.7 | 11.4 | 10.9 | 17.3 | 10.5 | 8.3 | 8.1 | 12.1 |
| >50 | <20 | 22.8 | 10.1 | 12.7 | | 12.5 | | 18.0 | 3.9 | 15.3 | 9.4 | 16.6 |
| | >20 | 14.3 | 7.7 | 16.1 | 6.1 | 14.0 | 15.7 | 16.8 | 10.9 | 18.3 | 4.4 | |
| Total | | 19.3 | 8.3 | 15.0 | 6.1 | 13.2 | 15.8 | 17.4 | 9.8 | 16.1 | 4.9 | 14.2 |
| Overall total | | 20.1 | 12.8 | 13.8 | 7.3 | 12.5 | 12.1 | 17.4 | 10.4 | 13.0 | 6.1 | 13.0 |

Table 10. Grade allocation of residual logs

| Log criteria | | Strata | | | | | | | | | | Total |
|----------------------|----------|--------------|----|--------------|----|--------------|----|--------------|----|--------------|----|-------|
| Diameter (cm) | Pipe (%) | HEMS/H Grade | | HEMS/L Grade | | LEMS/C Grade | | LEMS/F Grade | | LEMS/H Grade | | |
| | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | |
| | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | |
| <50 | <20 | 13 | 18 | 20 | 15 | 21 | 34 | 26 | 28 | 7 | 5 | 187 |
| | >20 | | | 2 | 7 | 3 | 18 | 2 | 24 | 3 | 6 | 65 |
| Total | | 13 | 18 | 22 | 22 | 24 | 52 | 28 | 52 | 10 | 11 | 252 |
| >50 | <20 | 23 | 2 | 4 | | 20 | | 15 | 2 | 11 | 2 | 79 |
| | >20 | 16 | 6 | 9 | 7 | 17 | 17 | 14 | 11 | 4 | 16 | 118 |
| Total | | 39 | 8 | 13 | 7 | 37 | 17 | 30 | 13 | 15 | 18 | 197 |
| Overall total | | 52 | 26 | 35 | 29 | 61 | 69 | 58 | 65 | 25 | 29 | 449 |

years. Even with this exception the grading strategy works well, and had the LEMS/C stratum been eliminated from this assessment the differentiation between Residual grade 1 and 2 would have been even greater.

Recovery distribution and its implications for processing

The previous discussion relates to mean recovery for each log class and forest type. The spread of recoveries must also be considered when examining the effectiveness of a method of log grading. The histogram in Figure 4 presents the distribution of product recovery for the Residual grade 1 (231 logs), showing the number of logs for steps of about 2.5% recovery. Several logs had recoveries of less than 5%. In percentage terms, 22.0% of the logs failed to yield more than 5% recovery of Structural Grade 3. These logs substantially reduced the overall mill outturn of marketable timber from these higher-quality residual logs. Better identification and elimination of low-yielding logs, prior to or during the early stages of processing, may be essential if residual logs are to be processed profitably. Being able to avoid processing low-yielding logs such as these would lift recoveries substantially. The analysis in this study showed that these logs cannot be identified readily using log external surface features or the severity

of log end defects. This problem is not confined to residual logs, but also occurs in logs that make conventional sawlog grades, particularly in the lower-quality D-grade sawlogs where some severe defects may be hidden from view until sawing commences.

One way of approaching this problem may be to identify low-yielding logs during initial log breakdown and then send them to a chipping line soon after they are identified. This would require the development of specialised sawing systems that can efficiently divert defective logs, flitches and residue from the sawing line. These systems would also need efficient chipping equipment and access to viable markets for wood chips or systems for utilization of wood chips and residues. The diversion of logs of Residual grade 2 from sawing, after cross-cutting at the mill, will require the mill to have the ability to readily dispose of wood chips. Economically viable disposal will be especially important if low-quality logs are to be utilised.

Another possible approach may be to develop markets for short-length appearance products. The work described in this paper was concerned with production of F8 structural boards with a minimum length of 2.4 m. Observations made during the later sawing trials suggest that production of both conventional and 'feature grade' appearance products for markets that require shorter lengths would probably increase recovery of high-quality solid wood, thereby improving the viability of processing (Waugh and Washusen 2002).

Conclusions

There is potential to select logs that will produce modest recoveries of high-quality structural products from long-length residual 'bush logs'. The identification of higher-quality candidate logs is probably best done, following cross-cutting of the residual logs to sawlog lengths to expose internal defects on the log ends, by using the modified log grading procedure developed in this study. The grading procedure can identify logs with recoveries similar to those of E-grade logs identified by an unofficial local grading method, and which are currently sawn by industry. However, the proposed procedure can identify a much larger fraction of the residual logs as being of this standard. The contrast between the new grades of Residual grade 1 and Residual grade 2 would have been even greater had the LEMS/C strata not been included in the

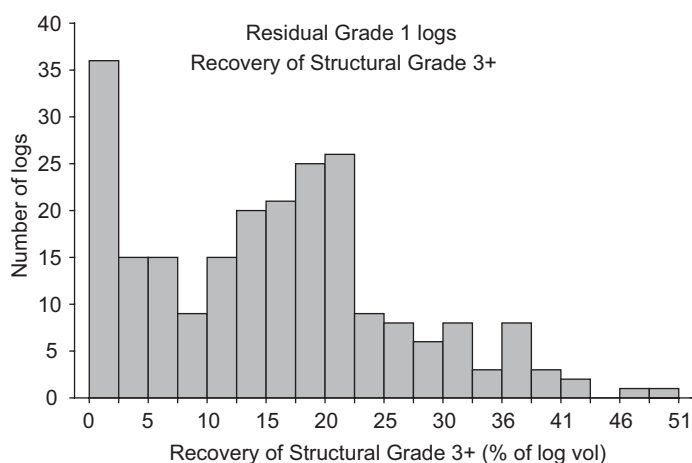


Figure 4. The frequency distribution of logs for classes of recovery of boards of Structural Grade 3 or better

study. This latter point suggests that the grading procedure is best attempted only in logs from the remaining four forest types. The difference between the forest strata is most likely because surface defects on logs in the LEMS/C strata indicate much more serious internal defects than they do on logs from the other forest types, where large epicormic growths appear to be more common.

There are four main differences between the new grading method and existing criteria: (i) mean end defect, rather than worst-end defect, is used as an indicator of log quality; (ii) minimum mean diameter of logs is 25 cm, with no small-end restrictions; and (iii) the definition of a clear quarter is different. Existing rules allow clear quarters to have a defect or combination of defects that have a width no greater than one-third of the surface width of the quarter on which they occur. A clear quarter in the new criteria has no visible defect apart from small epicormics; and (iv) logs with mean diameter >40 cm and end defect <40% are permitted to have four defective quarters.

Following cross-cutting of the residual bush logs it was found that 15% of logs would also meet existing specifications for sawlogs. The reason for this upgrade was probably because the defect core visible on the ends of the long-length bush logs was greater than on the logs following cross-cutting because of rapid changes in the diameter of defect core along the length of the bush log.

The results suggest that grading of logs following cross-cutting and segregation of logs for sawing that meet existing sawlog specifications with those that meet the requirements for the new Residual grade 1 would produce useful recoveries of high-quality solid wood. This type of operation would appear to be best suited to high-elevation mixed-species forests (HEMS/H and HEMS/L) and low-elevation fire-affected and high-yielding mixed-species

forests (LEMS/H and LEMS/F). However, markets for Residual grade 2 logs and for other very defective material would probably be necessary to permit profitable processing of higher-quality logs.

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