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Resource Evaluation for Future Profit:

Part B

Linking Grade Outturn to Wood Properties

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Resource Evaluation for Future Profit:

Part B - Linking grade outturn to wood properties

Prepared for the

Forest & Wood Products
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by

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EXECUTIVE SUMMARY

Objective

The major project objectives were to:

- Demonstrate the value of resource evaluation tools that can predict future trends in structural grade recovery, using the Green Triangle region as the case study.
- Validate the methodology for application to other resources, such as exotic pine in southern Queensland or radiata pine in other areas.

Subsidiary objectives included;

- An increased awareness by the Australian softwood growing and processing industry of the influence of stand, tree and log wood quality characteristics (as influenced by site, silviculture and genotype) on structural grade outturn.
- Benchmarking structural grade outturn in relation to easily measured stand characteristics in the Green Triangle Region.

Key Results

The results of this project are reported in two separate reports. The first report "Resource Evaluation for Future Profit: Wood Properties Survey of the Green Triangle Region, South Australia" outlines the wood quality of the different sampling sites. The second report (this report) "Resource Evaluation for Future Profit: Linking Grade Outturn to Wood Properties" links the results of the batch sawing study to the identified wood properties.

The major results from Linking Grade Outturn to Wood Properties were:

- Rough green sawn recovery ranged from 38.9 to 48.6% across the 10 sites with an average recovery of 44.3%.
- There was no relationship between rough green sawn recovery and small end diameter for the Green Triangle Region. Normally a good relationship exists between rough green sawn recovery and small end diameter.
- Moisture content readings that were randomly taken 9 weeks after drying and prior to machine stress grading were within PTAA's MSG QA limits for timber batches. However, approximately 16% of randomly assessed moisture contents exceeded the upper moisture content limit (15%), but these individual readings were widely distributed between batches.
- Distortion was assessed post planer gauging (approximately 9 weeks post drying), with very little distortion being detected. However sample packs taken to New Zealand for Quality Assurance testing distorted significantly while equilibrating to ambient conditions unrestrained. This subsequent distortion was not measured as it was beyond the scope of this project.
- Quality Assurance destructive testing on four sample packs, undertaken at Forest Research Laboratories in Rotorua, indicated that retrospective adjustment of the grade threshold was needed to achieve actual bending strength and stiffness. All timber was re-graded using the revised grade thresholds based on the Quality Assurance data.
- Log sonic velocity (measured by DIRECTOR) showed a correlation with board average MoE (stiffness), on a site basis, of 0.88 and 0.78 for upper logs and butt logs respectively.
- Log sonic velocity (measured by DIRECTOR) showed no correlation with Branch Index (BIX) on the butt logs and a correlation of 0.46 with BIX on the upper logs.

- Breast height SilviScan site averaged data showed correlations of 0.43 to 0.83 with site average board MoE. The stronger correlations were with SilviScan predicted MoE, and the weaker correlations with SilviScan predicted density.
- Whole tree SilviScan site averaged data showed correlations of 0.49 to 0.87 with site average board MoE. This whole tree data accounted for approximately 2-30% greater variation than SilviScan breast height data alone.
- SAWMOD runs indicated that density accounted for 35% difference in grade recovery, whereas BIX (branch index) accounted for 12%. This may be due to the relatively small branch size in the Green Triangle resource.
- Upper logs had a 0.75 lower MoE compared to butt logs, while butt logs were 29% more variable in MoE than upper logs.
- Outerwood basic density explained 72% of variation in site average MoE, outerwood basic density combined with age explained 79% of variation in site average MoE, DIRECTOR whole stem sonic velocity explained 64% of the variation in site average MoE, DIRECTOR sonic log velocity explained 90% of site average MoE and whole tree SilviScan explained 92% of variation in site average MoE. However the cost of obtaining the information would be ranked from least expensive to most expensive – age, stem sonic velocity, log sonic velocity, outerwood basic density and whole tree SilviScan.
- An analysis of the gross timber value by site indicated a maximum difference of 24% in value. A number of the wood quality assessment tools were quite well correlated with the gross value of timber on a site basis, but these correlations are based only on 10 data points and much more data is needed to develop a robust relationship. Wood quality assessment tools were more weakly correlated with "return to log" values.
- There were significant between-site differences and models could be better fitted on a site, rather than a regional, basis.

Application of Results

The results of this project allow industry in the Green Triangle to predict site average MoE, based on different assessment techniques, to within 64 to 92%. The cost of obtaining this information must be weighed against the value gained from this information.

Participants in this project who are also tree growers can use the density algorithm developed within this project for the green triangle region to assist in evaluating the quality of their timber resources. This will assist in efficient log allocation to appropriate end use.

Outerwood density can be readily obtained from the field, processed through CSIRO's Mt Gambier laboratory and used to drive the density algorithm.

The project research providers would be pleased to work with local industry in the Green Triangle region to further refine the use of these project results in their businesses.

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INTRODUCTION

The Australian radiata pine industry is moving into a new generation of wood supply. Since the 1980's large plantings of radiata pine have been established, with improved genetics and silviculture contributing to trees growing faster. The suitability of the Australian plantation resource for production of structural grade timber is changing as a consequence of growers striving to increase productivity and yield and continued increasing demand by processors for feed stock. Factors such as genetic improvements to promote volume growth and reduction in rotation age all have implications in terms of the impact they have on wood quality and resulting structural grade outturn.

There is a strong perception in the forest products industry that faster growth, however it is achieved, is synonymous with poorer wood quality. Many saw-millers prefer slower-grown older stands. There is a significant need to understand and quantify the potential negative impacts faster growth and shorter rotations have on timber strength. In the longer term, improving wood quality traits through tree breeding has the potential to offset much of the reduction in wood quality. In the short-term there is significant benefit in evaluating the existing resource to quantify variability in wood property characteristics and determine the impacts on structural timber outturn.

This project undertook an initial evaluation of *Pinus radiata* plantations within the Green Triangle Region (GTR) by:

- Stratifying the resource by site-related characteristics and crop types
- Designing a sampling strategy to assess and map regional variability in wood density as a key determinant of potential structural grade outturn.
- Undertaking a wood density survey to map trends in the resource
- Intensively sampling a representative subset of the resource (as determined by the density survey) for detailed wood property assessment and analysis.
- Undertaking a controlled batch sawing study on logs representative of the extrinsic and intrinsic wood properties as determined by the intensive sampling
- Comparing distribution and yield of structural grade outturn from log batches selected and segregated by varying log wood property characteristics.
- Relating structural grade outturn back to known wood quality characteristics in the log batches and the originating stands.

The following diagram summarises the project methodology, approach and expected outcomes.

Resource evaluation for future profit

Staged objective approach to resource evaluation.

Increased knowledge of Wood quality variability

A. To define regional boundaries and forests to be included in study in consultation with participating companies. Confirm regional industry buy in and input to project.

A. Geographic Region

Tasks - Identify companies, consult with Company staff, secure cooperation and in-kind

B. To identify, in consultation with regional industry, resource level site variation indicators know to influence wood properties and stratify resource accordingly

B. Stratification

Tasks - Document site-related characteristics and crop types to determine range of stand variability across the region. Stratify resource into wood quality

C. To determine a representative sample of site related and crop type variability for assessment.

C. Sampling strategy

Tasks - Assessment planning and design, select number of site /crop types, age classes to be sampled.

D. To assess wood properties linked to specific stand characteristics

E. To determine the influence varying stand level wood properties have on structural grade outturn

D. Field Assessment

Tasks - Broad assessment: Undertake outerwood density survey of stands across stratified sites. (not less than 50 stands assessed using outerwood increment cores). Analyse map density variation. Utilise data to select stands for intensive assessment.

Intensive assessment: Destructively sample subset of 6 trees from 10 stands representative of regional density variation. Assessments include

1. Obtaining 5m-log height cross-sectional discs (5 discs per tree) to determine basic wood density by log height class. Utilise data to compare wood density prediction algorithm to NZ derived algorithm.
2. Collecting Breast Height SilviScan cores to assess outer wood and pith to bark density, microfibril angle and stiffness.
3. Measuring spiral grain, documenting branching habit, incidence of compression wood, resin pockets.

E. Sawn outturn study

Tasks - Log segregation: 400 logs (4 logs X 10 trees X 10 stands) 40 logs per stand. Stand batches sorted by 3 stiffness classes within batches.

Sawing study: Batches sawn to nominal 100 x 40 mm, kiln dried, planned and MSG tested. Batch integrity maintained through out entire process

Data analysis: Comparison of average batch outturns linked to stand level resource characteristics.

F. To undertake analyses, report and present findings

F. Outcomes:

- Increased knowledge of fundamental wood properties and their impacts on structural grade outturn
- Increased knowledge of variability in regional resource characteristics in relation to impacts on wood properties and structural grades.
- Effectiveness and usefulness of resource evaluation tools demonstrated and verified.

G. Extension to other regions / species

Use experience gained and lessons learnt to extend and apply refined methodology to other defined regions including exotic pines in southern Queensland

MATERIALS AND METHODS

This project involved an amalgamation of resource evaluation tools and techniques aimed at quantifying variability in wood properties. Stand level wood property characteristics within a geographically distinct region were evaluated and these characteristics were related to structural timber outturn using the Green Triangle region as the case study.

A stand level sampling strategy was developed in consultation with industry participants including defining boundaries and identifying potential key wood quality delineating strata within the region. The sampling strategy encompassed a regional-wide wood density survey of stands with a smaller representative sample of stands selected for intensive wood quality assessment.

Information gained from the regional-wide wood density survey was used to select a representative sub-set of stands, for intensive destructive sampling. The sub-set was used to quantify within and between stand variability, through measurement and assessment of individual tree and log wood property characteristics. This intensive assessment required data to be collected from individual trees and logs. These data were bulked to provide stand level averages.

A batch sawing study was undertaken on logs merchandised as part of destructive sampling process with log batches sawn, kiln dried, dry gauged and MSG tested to determine actual structural timber grade outturn. Results from the sawing study were related back to the varying stand level wood property characteristics assessed in the field.

Techniques used included SilviScan analysis of breast height increment cores and cross-sectional discs, and use of predictive algorithms.

The project was split into three sequential stages as follows;

Stage 1 - Start up and initial wood quality survey (reported in McKinley et al, 2003[1])
Stage 2 - Intensive wood quality assessment (partially in McKinley et al, 2003[1], partially in this report)
Stage 3 - Batch sawing and timber grade study (this report).

A three stage sampling strategy was applied to ensure that the logs finally milled were as representative as possible of the broad range of wood quality variation in the Green Triangle resource.

In stage one the Project Steering Committee stratified the Green Triangle resource into crop types characterised by site quality (South Australian classification system), stocking, thinning history, age, genetics and silviculture.

Stage two involved the selection of a minimum of 50 stands representative of the range of variability in stand characteristics identified in stage one. Selected stands were assessed for their outer-wood density by assessing 30 trees per stand. Cores were uniquely identified and analysed individually with mean and standard deviations in outer-wood density derived for each stand.

Stage three involved intensively sampling 10 trees from within each of 10 stands selected by the Project Steering Committee, that were representative of the surveyed distribution in mean outer-wood density. All ten stems per stand were milled (100 trees x 4 logs per tree = 400 logs) with six of the ten trees from each of the 10 stands were assessed intensively for wood quality characteristics (60 trees).

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[1] McKinley R, R. Ball, A Morrow, D. Fife, D. Gritton, 2004, Resource Evaluation for Future Profit: Wood Properties Survey of the Green Triangle Region, South Australia", FWPRDC final report No 1385

Stage 1 – Start up and Initial Wood Quality Survey & Stage 2 - Intensive Wood Quality Assessment

Detailed methodology for these stages in the project are described in McKinley et al, 2003[1], and are not repeated here.

Stage 3- Batch sawing and timber grade study

The detailed methodology of this part of the project is described below.

Summary of Tree Selection Process for Sawing

For each of the 10 intensively sampled sites chosen by the Project Steering Committee, a sample of trees was selected to broadly represent both the range and average tree (or stem) properties for that site.
Selection criteria used (to try to match as closely as possible) were;

- diameter (breast height)
- outerwood basic density

To achieve this some small, medium and large trees were selected across the density range within the original 30 tree density plot, and this proved reasonably simple in practice (Table 1). Tree selection favoured those trees which could be merchandised into 5m logs (actual log length was 4.9m after discs were sampled) with a minimum of waste, as regular disc sampling at 5m intervals was required for at least 6 stems per site. This meant malformed or strongly swept stems were avoided.

A variable number of stems were selected for logging, and this varied between 9 and 16, due to the large size variation encountered between sites, with some stems on the biggest sites making 5 logs, while some stems on the smallest sites only making 2 or 3 logs. The overall objective was to obtain at least 40 logs per site, which could be subsequently split into 3 sonic sort batches of 13 to 15 logs each. Minimum merchantability limits of 4.9m long, and approximately 20cm small end diameter (sed) were set for the sawlogs. All trees were fully merchandised, to minimise waste and minimise possible biasing of the results.

Table 1: Comparison of harvested tree data to original plot data

SITE	AGE Years	STEMS (#)	Plot Diam Mean (cm)	Harvest Diam Mean (cm)	Plot O/WDensity Mean (kg/m^3)	Harvest O/WDens Mean (kg/m^3)	Height Mean (m)
Byjuke	27	15	31.9	32.9	521.0	521.0	27.3
McGillivrays	32	12	42.7	42.0	534.0	538.0	34.1
Caroline	44	9	50.5	49.5	521.0	526.0	37.7
Nangeela	25	16	30.4	32.1	481.0	482.0	25.3
Kongorong	28	13	37.9	39.5	465.0	470.0	29.4
Kentbruck	31	11	37.8	38.8	480.0	472.0	31.9
Longs	37	10	47.0	46.5	484.0	483.0	35.9
Porters	23	13	34.4	34.7	427.0	428.0	28.9
Emersons	26	11	38.3	38.0	445.0	438.0	33.5
Myora HQ	33	10	52.6	50.6	422.0	418.0	35.0
Averages	31	12	41.3	41.3	473.2	472.8	32.4

Harvesting and log sorting was carried out in May and early June, 2003.

Log Sorting into Batches

Sonic sorting was used to rank the logs from a single site from 1 to 40 (or 43). This ranking was based on sonic speed assessed by the CHH DIRECTOR tool, with the lowest third logs being allocated to the 'low velocity' batch, the middle third to the 'medium velocity' batch, and the highest third to the 'high velocity' batch (Table 2). No fixed batch boundaries were used, and in practice these varied for each site. The butt-logs were simply included in each batch, as per their sonic value. However, they were separately identified as below.

Identification

Each site was allocated a unique base colour for painting log large ends. These were then over-sprayed with black (not a colour used for site I/D) during the sonic sorting procedure, with a template of slots (low velocity), dots (mid velocities) or no overspray (high velocity). The small ends of butt-logs only were over-sprayed with brown (similarly not used as a site I/D colour), to allow later identification of timber from butt-logs (Table 3, Plate 1). Tracking of timber through the sawmill then relied on no end-trimming, so the unique colour identifiers for each batch and butt-log or upper-log were retained. Individual log data is supplied in Appendix A.

Table 2: DIRECTOR data for logs across sites

Sonic Batch Velocity Data				(Data in km/sec)						
Sonic Sort	**H27 Byjuke**	**H32 McGillivrays**	**H44 Caroline**	**M25 Nangeela**	**M28 Kongorong**	**M31 Kentbruck**	**M37 Longs**	**L23 Porters**	**L26 Emersons**	**L33 Myora HQ**
Low (slot)	3.28	3.39	3.40	3.26	3.17	3.32	3.23	2.94	3.15	2.97
Medium(dot)	3.47	3.56	3.63	3.42	3.31	3.47	3.44	3.17	3.36	3.15
High (none)	3.67	3.70	3.79	3.56	3.49	3.62	3.59	3.36	3.53	3.30
Site Average	**3.47**	**3.55**	**3.61**	**3.41**	**3.32**	**3.48**	**3.43**	**3.15**	**3.35**	**3.14**
Min Log	3.13	3.18	3.10	3.11	2.89	3.18	3.05	2.68	2.81	2.86
Max Log	3.89	3.78	3.92	3.67	3.68	3.77	3.73	3.47	3.62	3.43

Table 3: Details of logs selected for sawing study by site and log characteristics*

Sawing Batch Log Data S									
Site I/D	Number of logs	SED (cm)	LED (cm)	Av Log Vol Smalians (m3)	Taper (mm/m)	Internode index	Branch Index (cm)	Sweep (mm/m)	HITMAN velocity km/s (average)
All logs were 4.9m long									
H27 Byjuke	**40**	**22.9**	**26.6**	**0.241**	**7.5**	**0.15**	**2.6**	**3.0**	**3.47**
H32 McGillivray	**43**	**28.2**	**31.9**	**0.359**	**7.5**	**0.20**	**2.8**	**1.6**	**3.55**
H44 Caroline	**40**	**33.0**	**36.5**	**0.478**	**7.2**	**0.03**	**2.9**	**2.4**	**3.61**
M25 Nangeela	**41**	**21.7**	**25.6**	**0.222**	**7.9**	**0.17**	**2.6**	**0.9**	**3.41**
M28 Kongorong	**40**	**27.0**	**31.3**	**0.342**	**8.9**	**0.06**	**3.1**	**3.8**	**3.32**
M31 Kentbruck	**41**	**27.1**	**30.6**	**0.331**	**7.1**	**0.12**	**2.8**	**2.1**	**3.48**
M37 Longs	**41**	**31.9**	**35.6**	**0.456**	**7.6**	**0.15**	**3.2**	**2.9**	**3.43**
L23 Porters	**40**	**24.1**	**28.0**	**0.271**	**8.0**	**0.15**	**2.7**	**3.2**	**3.15**
L26 Emersons	**40**	**26.2**	**29.9**	**0.312**	**7.5**	**0.20**	**2.4**	**1.2**	**3.35**
L33 Myora HQ	**41**	**33.0**	**37.7**	**0.504**	**9.7**	**0.12**	**3.4**	**2.2**	**3.14**

*Internode index – Sum of 600mm increments divided by log length
Branch index – mean branch diameter of largest 4 branches on each quarter

Plate 1: Logs identified by site and sonic batch (H44 – Caroline) at Whiteheads Timber Sales sawmill

Sawmilling

Sawing was carried out on Saturday 14 June 2003 at Whitehead Timber Sales sawmill in Mt Gambier. Logs from all of the 10 sites were pre-sorted in the yard prior to loading on the log chain.

A total of 407 logs totalling 143.3 cubic metres (Smailian's formula) were sawn over a single dayshift with the odd mechanical problem (mainly with the log infeed deck chains), causing minor delays to the proceedings (Plate 2).

Plate 2: Logs at the headrig saw, Whiteheads Timber Sales sawmill (M37 – Longs)

The mill consists of an end-dogging headrig log carriage, and twin circular headrig saws. The logs were centred on the headrig, and one or more wing flitches of 40mm thickness taken simultaneously from either side eventually leaving a single 100mm central cant from each log (Figure 1). The centre-cant was then turned down and passed to a gang edger for reduction into 100x40 boards. The wing flitches were meanwhile passed to a moving saw edger and also sawn into 100x40 boards. A small number of 200x40 boards were produced at the edger, to optimise recovery. Later in the day these were also reduced to 100x40 on the Gray bench, and amalgamated back into the day's cut. The minor recovery size taken at the edger was 75x40mm, but this was minimised as far as possible. Appendix B shows lumber volumes recovered in each sites and sonic sort class, together with grade recovery percentages for each batch.

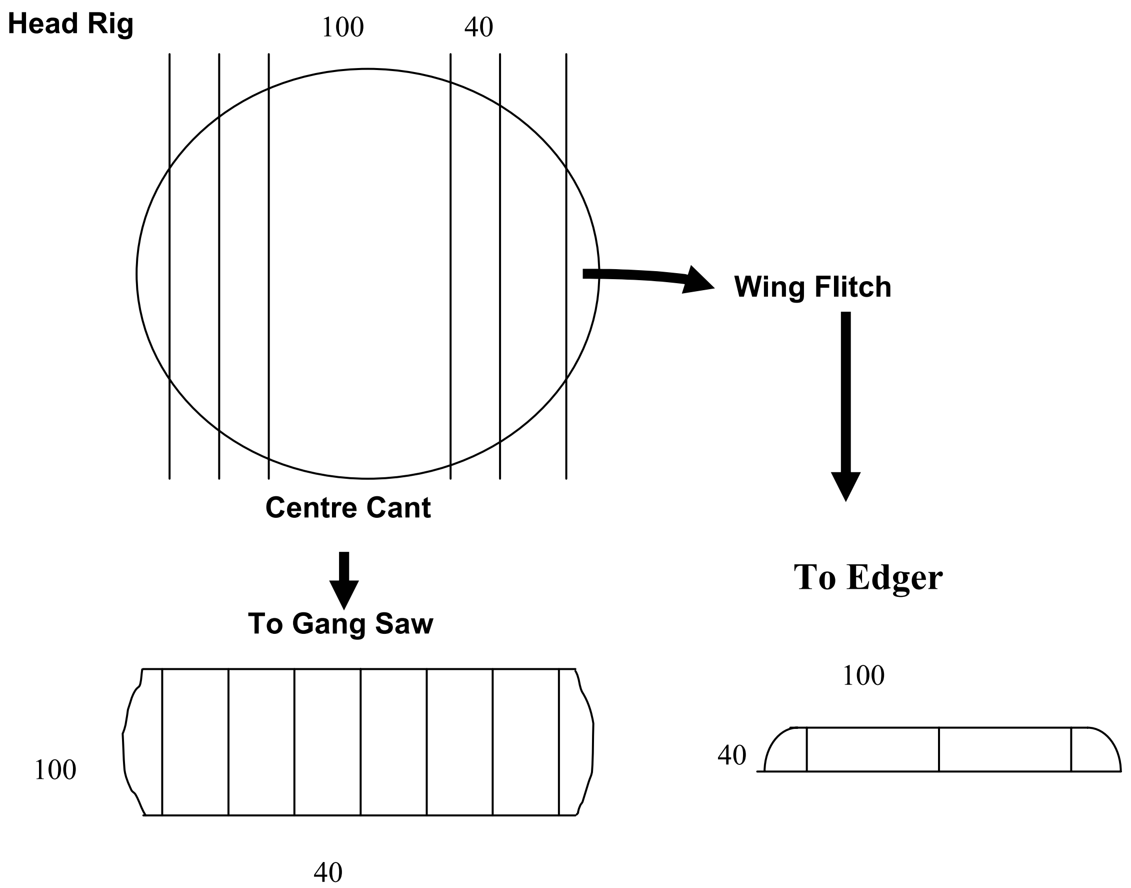

Figure 1: Sawlog cutting pattern at Whitehead Timber Sales Sawmill

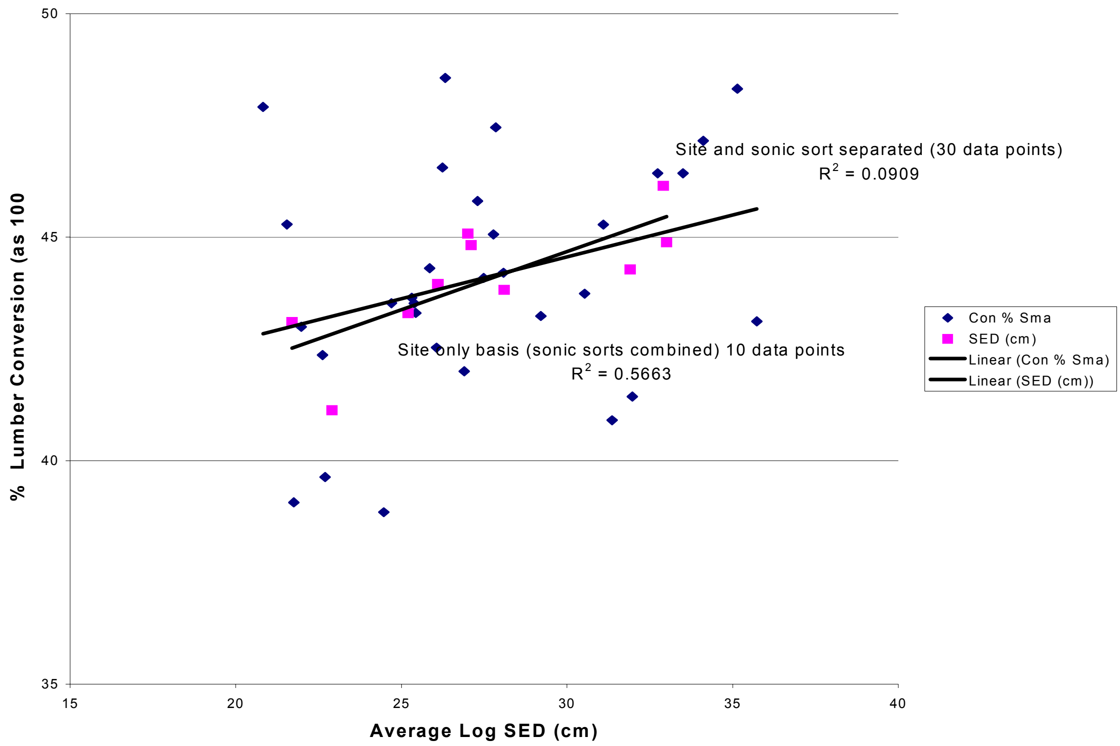

Figure 2: Lumber Conversion % on SED for 30 Batches (Smailian's) and by site only

No strong trend existed for lumber conversion percentage when graphed against batch log small-end diameter (r2 =0.09, Figure 2). This was somewhat surprising, since there is normally a positive correlation expected between these two variables. However when data for all sonic batches (L+M+H) were grouped on a site basis, there was a significant improvement in the relationship between average log SED and lumber conversion percentage with the r2 increasing to 0.57 (Figure 2). Overall lumber conversion was as expected and averaged 44.3% on a green rough-sawn basis with lumber tallied at 100x40mm nominal and log volumes calculated by Smailian's formula (see Appendix B for details).

No end-docking was carried out, and the lumber was segregated visually on the green-chain into heart-in (HI- containing pith) and sapwood (SAP) packets for separate kiln drying schedules, to optimise kiln drying. In all, 71.9% of lumber was segregated into Sapwood for drying, with the Heart-In grades comprising the other 28%. The packets were filleted using best commercial practice during stacking in the green chain, to standard Auspine kiln stack dimensions (Plate 3).

Plate 3: Green 100x40mm timber filleted for kiln drying – John Roper

Kiln Drying

The filleted lumber was transferred to Auspine's Sawmill at Tarpeena for kiln drying. The lumber was dried on 17th and 18th June 2003 in 3 separate kiln charges as follows:

1& 2. Sapwood (SAP as 2 charges)
Drying time approx 13.5 hours @ 135/90 degrees C.
Reconditioning time 4 hours 10 mins @ 95 degrees C & 100% RH

3. Heartwood (Heart-In as 1 charge)
Drying time approx 8.75 hours @ 125/90 degrees C.
Reconditioning time 5.5 hours @ 95 degrees C & 100% RH.

The lumber was then returned to Whiteheads' undercover storage for de-filleting, and resorting back into the 60 batches (30 sonic sort batches consisting of sapwood and heart-in subgroups). It took a significant period of time and effort to reassemble the batches during late June and July. All lumber was stored under cover during this time.

Moisture Content

Random samples of moisture content readings for each of the 60 batches were taken at various stages during de-filleting to ensure the lumber was dried to within specification prior to MSG.

A set of 6 to 8 random board samples from each of the 60 (Sap & Heart) batches (making 440 readings in total) were taken during planer gauging and docking at CHH's sawmill on 27th to 29th August 2003, using a Carrell & Carrell Model 901 moisture meter with a conventional hammer needle probe.

Results from this sample showed very little difference between sapwood batches (average 12.0% m.c. & range from 8.8% to 14.8%) and heartwood batches (average 12.6% m.c. & range from 10.0% to 15.6%, (Figure 3).

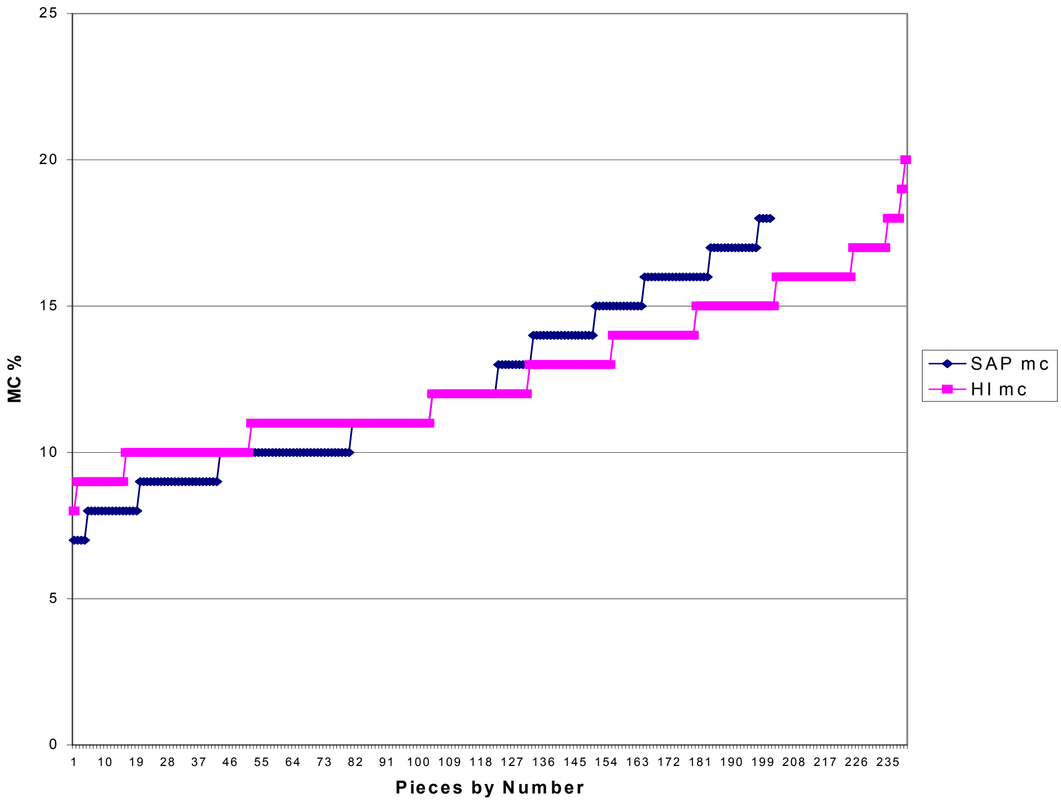

Figure 3 Cumulative moisture content reading –Sapwood (SAP) and Heart-In (HI)

There was still some variability between boards in the same batch, even given that these readings were taken just prior to MSG and nearly 10 weeks after the initial kiln drying. There was thus still some moisture movement and equilibration taking place within and between boards. The PTAA's MSG QA programme as advised by David Syme (pers comm) requires that 90% of samples lie between 8 and 15% moisture content, and our sample meets these requirements on a batch basis. Overall some 72 individual board moisture readings out of 440 exceeded 15% moisture reading - this is 16% of the total sample, but these boards were widely distributed between batches, and unlikely to lead to significant bias in the MoE grading through the MSG. Therefore, no adjustments to the MSG data were considered necessary based on moisture variation.

Planer Gauging, Docking, Distortion Assessment, and Final Tally.

The roughsawn kiln dry lumber was gauged to 90x35mm at CHH's Mt Gambier sawmill on 27th to 29th August, 2003.

Prior to planing, the butt log material was sorted so that it would be first subsequently through the MSG (within the individual batch of the 60 sorts), for data logging purposes.

Planer Gauging and End Docking.
The boards were then planer-gauged through a Weinig planer, and end-docked to standard lengths in 0.3m multiples (4.8m, 4.5m, 4.2m etc. down to 2.1m). This end-docking removed the paint code colours, and batch details were now represented by an alpha-numeric numbering system for the 60 batches written on the end of each board (eg H30b was the Heartwood sort, batch 30, butt-log).

Final Tally
At this stage, full stick tally for sawing recovery purposes was carried out on the 100x40mm, and 75x40mm. Most effort was spent on the 100x40mm (now planer gauged to 90x35mm) as this was the lumber going on to the MSG. A total of 3284 pieces of 100x40 (90x35) were recovered and based on volume, 96.4% of the lumber produced was in this main size.

The remaining 75x40 (2.261 m^3 or 3.6% of the total by volume) was tallied for recovery purposes, but no further grading or machining was carried out.

Distortion Assessment
Distortion was assessed after planer gauging, while the lumber was being stacked and tallied, to pass/fail based on commercially applied distortion limits.
Commercial distortion limits used in a 90x 35mm @ 4.8m length (some 84% of all the 90x35mm produced made this length) were:

- twist 10mm
- crook (spring) 29mm
- bow 45mm

(These limits become lower for shorter lengths.)
The outstanding impression was that all the lumber was impressively straight at the time of gauging, and not one single piece was rejected on this basis.

However, as noted previously there was still considerable moisture variation within and between pieces at this time, being 10 weeks after kiln-drying. Subsequently, during QA testing of 480 pieces (4 packets) in the Forest Research Laboratory in New Zealand, significantly more distortion was noted as the un-strapped packets were allowed to equilibrate to ambient conditions in a relatively unrestrained manner. Unfortunately further assessment of this subsequent distortion was beyond the scope and funding of this study.

RESULTS AND DISCUSSION

MSG Grade Recovery and Quality assurance testing of graded material.

This section deals with the quality assurance testing done on a randomly selected sub-sample of the timber graded. Adjustments were made to the grade recoveries to ensure that they truly represented the likely recoveries from the various sites.

Machine Stress Grading
Machine stress grading (Stiffness) grading provides one of the most economical and reliable methods of sorting timber into different grades for structural purposes. It relies on a relationship between the stiffness of the timber as measured by the machine stress grader and the stiffness and strength properties determined by the Quality Assurance testing. Timber has to be broken to measure its characteristic strength, so only a small (but representative) sample of timber produced is tested. Therefore there is a trade off between the number of samples tested and the accuracy of the estimate of the characteristic strength of the entire production. The method used in this study to evaluate the in-grade bending strength and stiffness of the stress-graded timber is given in AS/NZS 4063:1992.

Colour markings
The mill that conducted the machine stress grading identified the different timber grades by spraying a long tail spray towards the trailing end of the timber being graded. The colour codes were as follows:

- Purple indicated MGP 15 Grade;
- Green indicated MGP 12 grade; and
- Black indicated MGP 10 Grade.

The F4 grade timber was identified by having a few red grade marks sprayed along the length at the lower stiffness points, while the Reject grade material was identified as having a significant number of red colour marks along the length. It was normal mill practice to combine the F4 and Reject material together into packets for further re-working. Also on the timber face was printed text stating the timber grade, timber brand, timber seasoning and the time and date of grading.

A series of grade thresholds are set in the machine stress grader (MSG) and these determine which colour/grade is sprayed. The thresholds set upper and lower limits for the $MoE_{Pmin.}$ The upper limit is equal to the lower limit of the next highest grade. In service, if the quality assurance results show the timber properties to be below that specified for the grade, then usually the lower grade threshold is adjusted upwards. This adjustment should remove some of the poorer timber from that grade and put it into the grade below. Thus two grades are affected. Ideally the on-going quality assurance testing is used to check the effectiveness of this adjustment.

<u>The machine stress grading operation has two basic stages:</u>
First the performance of the machine stress grader must be monitored. This is to ensure that the machine is set-up correctly, to ensure that the Modulus of Elasticity (MoE or stiffness) as a plank (MoE_{Plank}) reading is correct, and to ensure that the machine is spraying the correct grade colour onto the timber. These tests were done just after machine calibration and set up by passing verification sticks through the machine. Verification sticks are lengths of timber (of the same dimension as that to be graded) that have been statically tested for stiffness as a plank (MoEp) independently of the machine stress grader. These sticks, therefore have a known stiffness profile along the length, and are passed through the machine stress grader, and the machine grader's measured stiffness profile is then compared to the sticks known stiffness profile. Usually at least three different verification sticks are passed through the machine, and the results are compared with the known profiles.

Secondly the characteristic stiffness and strength of the material are monitored. This checks whether the properties of the produced material meet the strength and stiffness requirements of the structural grade to which it has been assigned. As the relationship between strength and stiffness changes - due to different log supplies and timber sizes, the machine grade threshold settings should be changed to maintain maximum grade yield while ensuring that the grade stresses are being met.

Visual Override
All machine stress graded timber should have a visual override applied. This override is used to grade the ends of each board as the machine stress grader cannot grade approximately the first and last 650mm at each end. Also the override is used to remove any boards with large strength reducing defects not picked up the MSG.

In this case, the timber was docked after dressing, which was done before machine stress grading, so in effect the visual override was done before machine stress grading.

Test Material
In order to determine the actual grade of timber in this trial a sub-sample of the board material was selected for testing by Forest Research, Rotorua, New Zealand. This sub sample comprised of one packet of each of the four structural grades produced:

- one packet (120 pieces) Reject (35 pieces)/F4 (85 pieces)
- one packet (120 pieces) MGP 10
- one packet (120 pieces) MGP 12
- one packet (120 pieces) MGP 15

These packets were selected on the basis of packets having the greatest cross section of sample sites. These four packets of timber were shipped to the Forest Research, Rotorua, New Zealand for re-machine stress grading (so as to establish the MoEp profile for each piece of timber) and the timber was tested for bending stiffness (MoE_j) and bending strength (MoR_j). Hence, we were able to establish the relationship between the grading parameter ($MoEp_{min}$) and the measured structural parameters (MoEj and MoRj). The method of testing was as follows:

Testing

1. All the timber was tested in the Timber Engineering Laboratory of Forest Research between the 13th October and 11th November 2003.
2. Each length of timber was assigned a unique Forest Research Timber Engineering laboratory number ranging from 212868 to 213367.
3. All the timber was passed twice through the Laboratory's Computermatic Machine Stress Grader (once on each face) to establish the Modulus of Elasticity as a plank (MoEp) profile and minimum MoEp for each piece. The MoEp values for each grade point of each board (as measured by the machine) were then averaged, and the lowest average MoEp value recorded for each stick was used as the $MoEp_{min}$, or grade determining point.
4. All pieces were tested for bending strength and stiffness testing in accordance with AS/NZS 4063:1992. The timber was tested to destruction to determine the bending strength (MoRj) and stiffness as a joist (MoEj). Figure 4 shows the test arrangement with the actual span for the 90x35 being 1620mm. These results were compared against the published design stresses for the grade supplied. This testing simulates the quality assurance testing that is required to be done under AS/NZS1748.
5. The Forest Research Grade 1 Baldwin Universal test machine was used for all the bending tests.

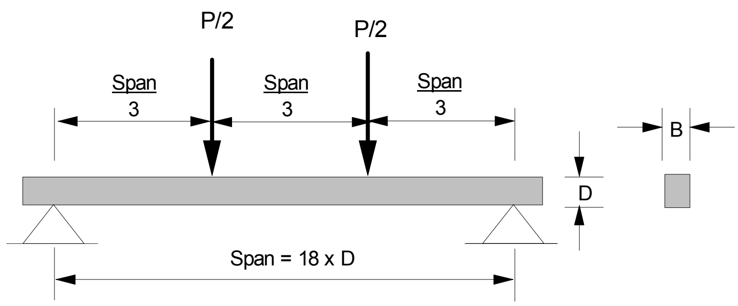

Figure 4*:* Bending test configuration

Verification of Structural (Bending only) Properties

After Machine Stress grading, all of the timber was tested for bending strength and stiffness testing in accordance with AS/NZS 4063:1992. The timber was tested to destruction to determine the bending strength (MoRj) and stiffness as a joist (MoEj). The results for each packet (grade) supplied were then compared against the published design stresses for that grade. This testing simulates the quality assurance testing that is required to be done under AS/NZS1748. Table 4 lists the results of the bending strength and stiffness testing with Appendix C showing the formula used to calculate the characteristic properties.

Table 4 shows:

- In terms of bending stiffness the graded timber did not achieve the required grade characteristic bending stiffness stress (Ek) for any of the structural grades.
- In terms of bending strength the graded timber did not achieve the required characteristic bending strength stress (Rk,norm) for the MGP 12 or MGP 15 grade timber.

Therefore, retrospective adjustment of the grade threshold after the QA on the graded timber was required to achieve the required values. This was trial timber from widely varying stand histories, and no adjustment of the grade thresholds in the MSG could be made prior to running the trial timber through Forest Research's laboratory.

Table 4: Initial AS/NZS 4063 Quality Assurance Bending Stiffness and Strength test results

	Reject		F4		MGP 10		MGP 12		MGP 15	
	MoEj (GPa)	MoRj (MPa)	MoEj (GPa)	MoRj (MPa)	MoEj (GPa)	MoRj (MPa)	MoEj (GPa)	MoRj (MPa)	MoEj (GPa)	MoRj (MPa)
Rk MPa		6.71		12.43		14.37		21.52		28.22
Rbasic, MPa		2.25		4.49		5.17		7.93		10.61
Rk,norm, MPa		**6.66**		**13.25**		**15.28**		**23.43**		**31.32**
Ek(1), GPa	5.19		6.29		8.30		10.73		13.32	
Ek(2), GPa	3.85		5.49		8.16		12.17		15.64	
Ek, GPa.	**3.85**		**5.49**		**8.16**		**10.73**		**13.32**	
Required MoE			6.10		10.00		12.70		15.20	
Required MoR				13.00		16.00		28.00		41.00
Allowable MoE (0.94)			**5.73**		**9.40**		**11.94**		**14.29**	
Allowable MoR (0.91)				**11.83**		**14.56**		**25.48**		**37.31**
Pass/Fail			Fail		Fail		Fail		Fail	
				Pass		Pass		Fail		Fail

Quality Assurance Test Results

To derive the new grade thresholds, all of the test data collected during the quality assurance testing for all of the test pieces (480 individual test samples) were ranked in order of $MoEp_{min.}$ taking an upper and lower MoE_{Pmin}. Thresholds for each grade and the corresponding characteristic bending stiffness and strength were calculated. These calculated values were then compared with required code values for that grade and further adjustments were made to the thresholds (bearing in mind that any adjustment also affected the grades above and below). Table 5 shows the grade thresholds adopted.

Table 5: Estimated Grade thresholds using the QA test data, which were subsequently used to resort lumber.

Timber Size 90 x 35 mm		
	Ep low (GPa)	Ep high (GPa)
Reject	0	4.25
F 4	4.25	7.80
MGP 10	7.80	11.50
MGP 12	11.50	14.80
MGP 15	14.80	18.00

Table 6 shows the results of the bending strength and stiffness testing following the adjustment to the grade thresholds. Figure 5 and Figure 6 show the distribution of the bending stiffness AS/NZS4063 (MoEj) and bending strength AS/NZS4063 (MoRj) for each adjusted grade.

Table 6: Estimated 'True' AS/NZS 4063 Quality Assurance Bending Stiffness and Strength test results based and graded by Laboratory MoE_{Pmin}

	Reject		F4		MGP 10		MGP 12		MGP 15	
	MoEj (GPa)	MoRj (MPa)	MoEj (GPa)	MoRj (MPa)	MoEj (GPa)	MoRj (MPa)	MoEj (GPa)	MoRj (MPa)	MoEj (GPa)	MoRj (MPa)
Rk MPa		6.16		11.71		15.49		24.38		34.78
Rbasic, MPa		2.03		4.25		5.54		8.99		13.36
Rk,norm, MPa		**6.00**		**12.56**		**16.35**		**26.56**		**39.46**
Ek(1), GPa	5.57		6.51		9.23		12.08		14.40	
Ek(2), GPa	3.55		6.05		9.51		13.77		16.80	
Ek, GPa.	**3.55**		**6.05**		**9.23**		**12.08**		**14.40**	
Required MoE			6.10		10.00		12.70		15.20	
Required MoR				13.00		16.00		28.00		41.00
Allowable MoE (0.94)			**5.73**		**9.40**		**11.94**		**14.29**	
Allowable MoR (0.91)				**11.83**		**14.56**		**25.48**		**37.31**
Pass/Fail			Pass		Fail		Pass		Pass	
				Pass		Pass		Pass		Pass

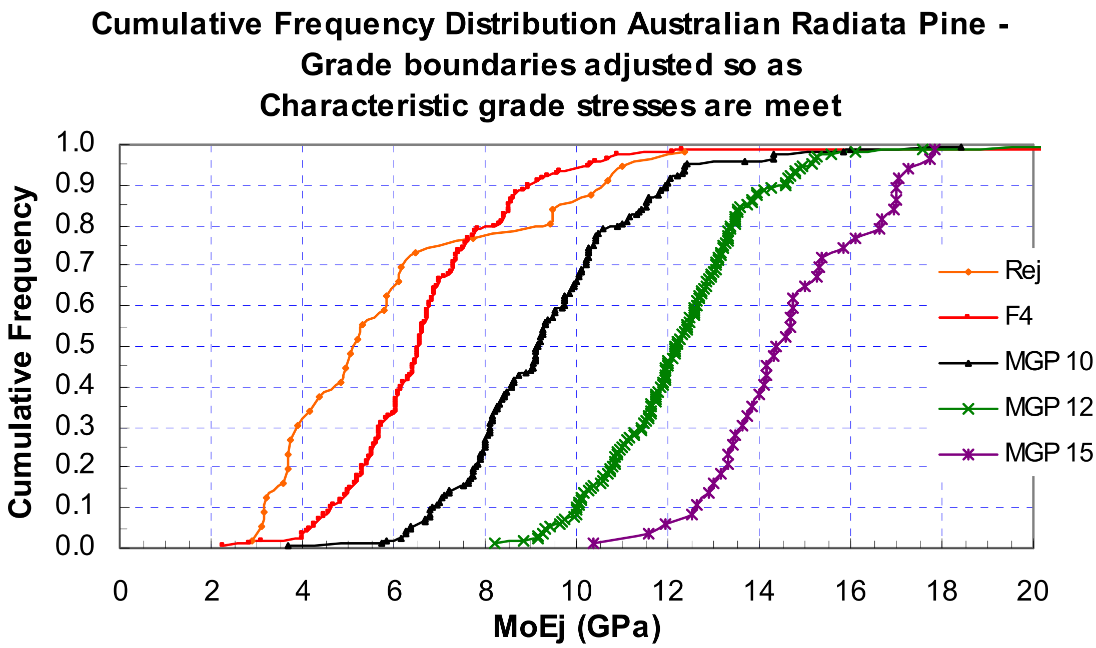

Figure 5: Adjusted distribution of the bending stiffness AS/NZS4063 (MoEj)

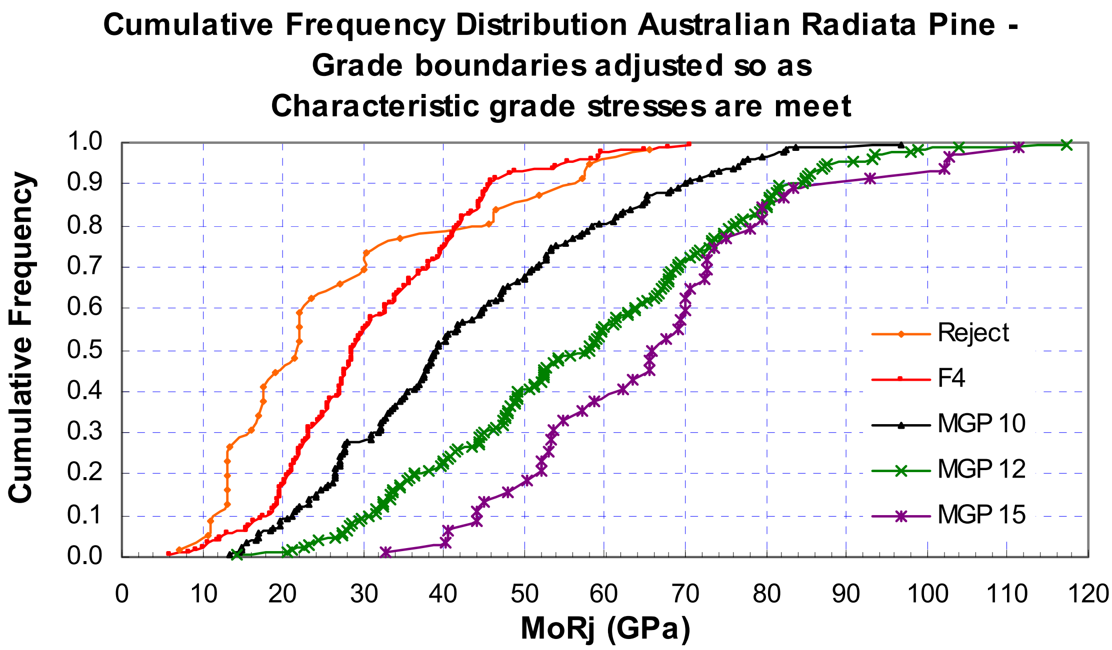

Figure 6: Adjusted distribution of the bending strength AS/NZS4063 (MoRj)

Table 6, Figure 5 and Figure 6 **Error! Reference source not found.**show:

- Bending stiffness for MGP 10 is only just lower than that required. However further increasing the lower grade threshold changed the grade recoveries much more drastically than they improved the characteristic stiffness (Ek) for the grade. Thus the grade thresholds chosen were considered to be a fair estimation considering the limited sample size.
- All other grades meet both bending stiffness and bending strength requirements.

Using the data logged MSG data for the entire study the material was re-graded using the adjusted grade thresholds.

Table 7 shows MSG grade recoveries for Butt log, upper logs and total grade recoveries for each stand density and age class. A more detailed summary of the same ten sites, but sorting by log sonic split is presented in Appendix B. Appendix D lists the raw Quality Assurance test data.

Table 7: Corrected MSG grade recoveries for each stand density and age class.

	Low Density Stand		Age 23 years			
	Site	Porters				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.030	2%	0.008	0%	0.038	1%
MGP 12	0.293	20%	0.102	5%	0.395	11%
MGP 10	0.627	43%	1.065	51%	1.692	48%
F4	0.469	32%	0.879	42%	1.348	38%
Reject	0.024	2%	0.019	1%	0.042	1%
Total	1.443	100%	2.073	100%	3.515	100%
	Low Density Stand		Age 26 years			
	Site	Emersons				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.070	5%	0.193	7%	0.263	6%
MGP 12	0.692	48%	0.888	33%	1.580	38%
MGP 10	0.366	26%	1.072	40%	1.438	35%
F4	0.306	21%	0.558	21%	0.864	21%
Reject	0.000	0%	0.000	0%	0.000	0%
Total	1.434	100%	2.711	100%	4.145	100%
	Low Density Stand		Age 33 years			
	Site	Myora HQ				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.015	1%	0.015	0%	0.030	0%
MGP 12	0.451	18%	0.858	19%	1.310	19%
MGP 10	1.396	57%	2.780	61%	4.176	59%
F4	0.457	19%	0.920	20%	1.377	20%
Reject	0.125	5%	0.021	0%	0.146	2%
Total	2.444	100%	4.594	100%	7.039	100%
	Medium Density Stand		Age 25 years			
	Site	Nangeela				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.119	8%	0.015	1%	0.134	4%
MGP 12	0.469	32%	0.462	29%	0.932	30%
MGP 10	0.433	29%	0.900	57%	1.333	44%
F4	0.468	31%	0.196	12%	0.664	22%
Reject	0.000	0%	0.000	0%	0.000	0%
Total	1.490	100%	1.574	100%	3.064	100%
	Medium Density Stand		Age 28 years			
	Site	Kongorong				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.070	4%	0.082	3%	0.153	3%
MGP 12	0.545	32%	0.747	25%	1.292	28%
MGP 10	0.731	42%	1.624	55%	2.354	50%
F4	0.381	22%	0.501	17%	0.882	19%
Reject	0.000	0%	0.000	0%	0.000	0%
Total	1.726	100%	2.955	100%	4.681	100%

Table 7*(cont)*: *Corrected MSG grade recoveries for each stand density and age class.*

	Medium Density Stand		Age 31 years			
	Site	Kentbruck				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.976	15%	0.357	12%	0.596	13%
MGP 12	0.670	39%	0.983	33%	1.591	35%
MGP 10	0.452	30%	1.434	49%	1.905	42%
F4	0.122	16%	0.183	6%	0.427	9%
Reject	0.000	0%	0.000	0%	0.000	0%
Total	2.220	100%	2.956	100%	4.518	100%
	Medium Density Stand		Age 37 years			
	Site	Longs				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.156	7%	0.073	2%	0.229	4%
MGP 12	0.625	29%	1.455	35%	2.081	33%
MGP 10	0.649	30%	1.620	39%	2.269	36%
F4	0.653	30%	0.960	23%	1.613	26%
Reject	0.095	4%	0.000	0%	0.095	2%
Total	2.179	100%	4.108	100%	6.287	100%
	High Density Stand		Age 27 years			
	Site	Byjuke				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.313	21%	0.061	4%	0.374	12%
MGP 12	0.514	35%	0.494	32%	1.008	33%
MGP 10	0.412	28%	0.862	55%	1.274	42%
F4	0.244	16%	0.138	9%	0.382	13%
Reject	0.000	0%	0.000	0%	0.000	0%
Total	1.483	100%	1.555	100%	3.038	100%
	High Density Stand		Age 32 years			
	Site	MacGillivray				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.428	22%	0.604	18%	1.032	20%
MGP 12	0.787	41%	1.092	33%	1.879	36%
MGP 10	0.374	19%	1.185	36%	1.559	30%
F4	0.270	14%	0.395	12%	0.666	13%
Reject	0.076	4%	0.000	0%	0.076	1%
Total	1.934	100%	3.277	100%	5.212	100%
	High Density Stand		Age 44 years			
	Site	Caroline HQ				
	Butt Logs		Upper Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.976	44%	1.020	23%	1.996	30%
MGP 12	0.670	30%	1.944	43%	2.614	39%
MGP 10	0.452	20%	1.455	32%	1.907	28%
F4	0.122	5%	0.095	2%	0.217	3%
Reject	0.000	0%	0.000	0%	0.000	0%
Total	2.220	100%	4.514	100%	6.734	100%

Determination of Average Stiffness by Site and Sonic Sort

Another method to compare the 10 sites is by using the 'average' stiffness. Only a sub sample of boards was tested for stiffness but all pieces were graded by the machine stress grader and resultant MoE_{Plank} stiffnesses data logged. However the MSG stiffnesses recorded are not always a reflection of the true stiffness i.e. MSG stiffnesses are best useful for comparative purposes and should not be used as absolute values. Thus in order to use these MSG stiffnesses a relationship between the machine stress grader data-logged stiffness and the AS/NZS4063 joist stiffness had to be determined. This was done by averaging the MoE_{Plank} and joist stiffness for all timber from 28 MSG grade/site/sonic sort groups (7-MGP15, 7-MGP12, 7-MGP10 & 7-F4/reject) and plotting the relationship (Figure 7). In this case the average joist stiffnesses are 80% of the average MSG MoE_{Plank} stiffnesses and form a linear relationship.

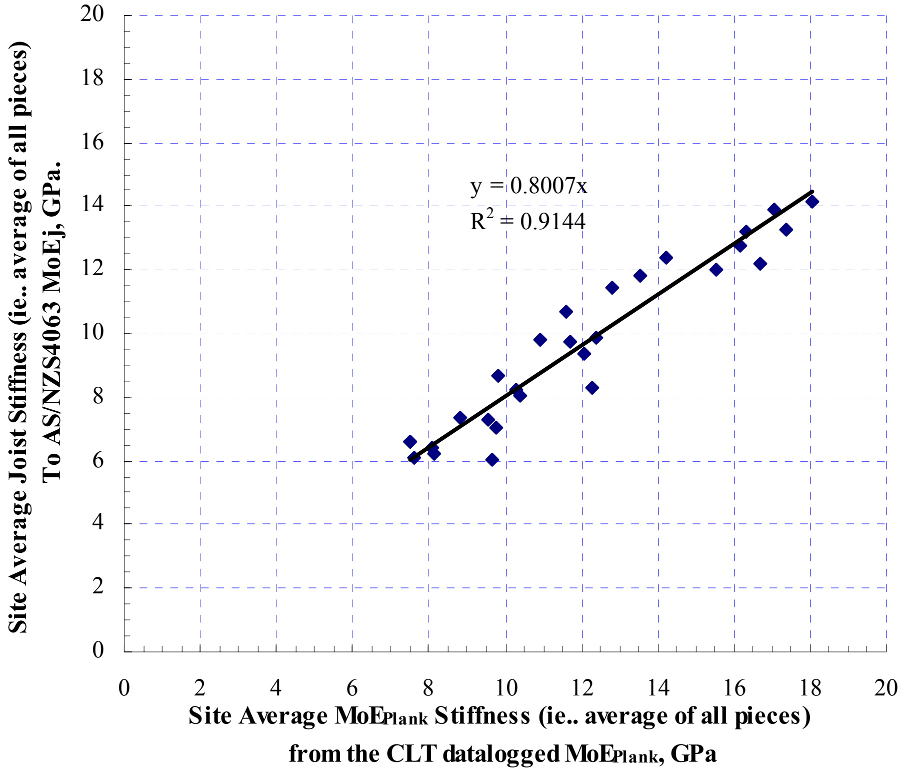

Figure 7: Relationship of CLT MoE_{Plank} stiffness to AS/NZS4063 Joist stiffness by site

The data in Table 8 (Upper logs) and Table 9 (Butt logs) are the average of all MoE_{Plank} stiffnesses recorded by the MSG for all the timber in the ten sites, separated into the three sonic sorts, and multiplied by the 0.8 factor (i.e. the adjusted MoE_{Plank} values). Also shown in these tables is the number of pieces in each log/site/sonic sort group with the maximum and minimum piece stiffnesses.

Less reliability can be placed on data based on just a few pieces of lumber (maybe from only one log). However, the overall trends are clear with site density and sonic sorting showing significant differences in final lumber stiffness.

Table 8: Average upper log MoE_{Plank} (GPa) stiffness 'adjusted' by site and sonic sort with average log DIRECTOR velocities and average Branch Index (BIX).

High Sonic Sort, Upper Logs										
	L23	L26	L33	M25	M28	M31	M37	H27	H32	H44
	Porters	Emersons	Myora HQ	Nangeela	Kongorong	Kentbruck	Longs	Byjuke	MacGillivray	Caroline HQ
Average	9.04	11.45	9.71	10.48	10.82	11.95	10.48	11.65	12.10	13.06
Count	47	81	151	46	62	71	115	27	68	115
Max	13.62	14.91	14.52	14.92	14.75	16.31	15.06	15.45	17.44	17.11
Min	5.97	6.88	5.68	6.68	6.77	7.06	5.44	7.42	6.43	6.85
DIRECTOR	3.35	3.54	3.3	3.54	3.48	3.63	3.6	3.63	3.71	3.81
BIX	2.5	2.0	2.7	2.1	3.0	2.5	3.4	2.5	2.5	2.3
Medium Sonic Sort, Upper Logs										
	L23	L26	L33	M25	M28	M31	M37	H27	H32	H44
	Porters	Emersons	Myora HQ	Nangeela	Kongorong	Kentbruck	Longs	Byjuke	MacGillivray	Caroline HQ
Average	8.49	10.08	9.66	9.79	9.77	10.90	10.63	10.54	11.92	12.03
Count	44	58	86	23	71	67	97	37	83	87
Max	10.97	13.68	12.33	12.45	13.81	14.03	14.86	13.50	16.42	15.87
Min	6.14	5.44	6.07	7.03	6.07	6.95	5.80	6.91	6.51	6.42
DIRECTOR	3.17	3.35	3.15	3.41	3.31	3.49	3.44	3.46	3.56	3.64
BIX	2.5	2.5	3.5	2.7	3.3	2.7	3.2	2.7	2.7	2.6
Low Sonic Sort, Upper Logs										
	L23	L26	L33	M25	M28	M31	M37	H27	H32	H44
	Porters	Emersons	Myora HQ	Nangeela	Kongorong	Kentbruck	Longs	Byjuke	MacGillivray	Caroline HQ
Average	7.46	8.62	8.19	9.31	9.13	9.74	9.67	9.58	11.02	10.81
Count	49	43	74	37	67	61	62	41	71	102
Max	11.03	11.09	11.05	13.07	12.12	12.45	12.65	12.95	15.27	16.02
Min	5.43	6.14	5.64	6.89	6.48	6.72	6.00	6.23	6.65	6.55
DIRECTOR	2.92	3.12	2.94	3.25	3.13	3.31	3.23	3.27	3.37	3.40
BIX	3.70	3.00	5.40	3.20	3.90	3.40	3.60	3.30	3.50	3.80

Table 9: Average butt log MoE_{Plank} stiffness (GPa) 'adjusted' by site and sonic sort with average log DIRECTOR velocities and average Branch Index (BIX).

	L23	L26	L33	M25	M28	M31	M37	H27	H32	H44
High Sonic Sort, Butt Logs										
	Porters	**Emersons**	**Myora HQ**	**Nangeela**	**Kongorong**	**Kentbruck**	**Longs**	**Byjuke**	**MacGillivray**	**Caroline HQ**
Average	10.93	11.44	9.47	10.95	11.69	12.64	10.66	12.36	14.40	14.05
Count	18	14	15	16	25	42	33	45	26	74
Max	14.14	14.60	13.15	15.09	17.33	17.73	14.59	17.32	19.54	17.37
Min	7.54	6.71	5.46	6.58	6.68	6.67	4.44	6.74	6.67	6.76
DIRECTOR	3.4	3.51	3.33	3.59	3.52	3.59	3.55	3.71	3.69	3.75
BIX	2.0	1.9	3.0	2.3	2.7	2.6	3.0	1.9	2.4	2.4
Medium Sonic Sort, Butt Logs										
	L23	**L26**	**L33**	**M25**	**M28**	**M31**	**M37**	**H27**	**H32**	**H44**
	Porters	**Emersons**	**Myora HQ**	**Nangeela**	**Kongorong**	**Kentbruck**	**Longs**	**Byjuke**	**MacGillivray**	**Caroline HQ**
Average	9.19	11.44	9.93	10.97	11.01	12.00	10.47	11.73	12.38	12.28
Count	36	40	82	47	42	35	40	26	31	74
Max	12.92	16.38	12.99	14.68	15.32	15.23	14.96	16.10	16.77	16.84
Min	5.24	6.13	5.06	6.44	5.39	5.09	4.92	6.84	6.08	5.94
DIRECTOR	3.18	3.37	3.14	3.42	3.32	3.43	3.43	3.49	3.54	3.57
BIX	1.9	2.3	2.7	2.5	2.8	3.0	2.8	2.2	2.8	2.7
Low Sonic Sort, Butt Logs										
	L23	**L26**	**L33**	**M25**	**M28**	**M31**	**M37**	**H27**	**H32**	**H44**
	Porters	**Emersons**	**Myora HQ**	**Nangeela**	**Kongorong**	**Kentbruck**	**Longs**	**Byjuke**	**MacGillivray**	**Caroline HQ**
Average	8.07	10.10	9.01	9.88	9.85	10.71	10.26	10.52	12.29	
Count	43	43	66	38	50	27	72	29	75	
Max	12.85	12.99	11.63	14.15	13.19	14.17	14.54	14.74	16.83	
Min	2.79	5.35	4.32	5.96	5.03	5.14	2.15	6.07	4.71	
DIRECTOR	2.96	3.2	3.04	3.27	3.23	3.36	3.23	3.31	3.42	
BIX	2.7	2.2	2.0	2.7	2.4	2.6	2.7	2.1	2.9	

Figure 8 (upper logs) and Figure 9 (butt logs) show the relationship between the DIRECTOR sonic velocities for all the logs from a site/sonic sort batch against the average stiffness of the all the timber from the same log batches. As expected a reasonable relationship exists between these two variables.

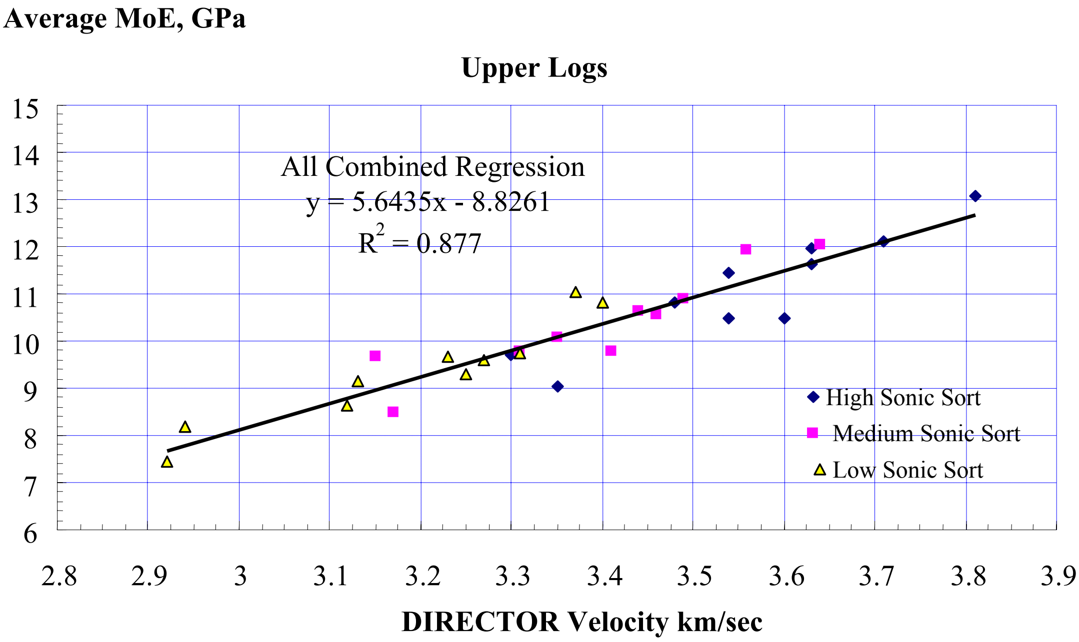

Figure 8: Relationship of Average log DIRECTOR velocities to average CLT MoE_{Plank} stiffness for Upper logs

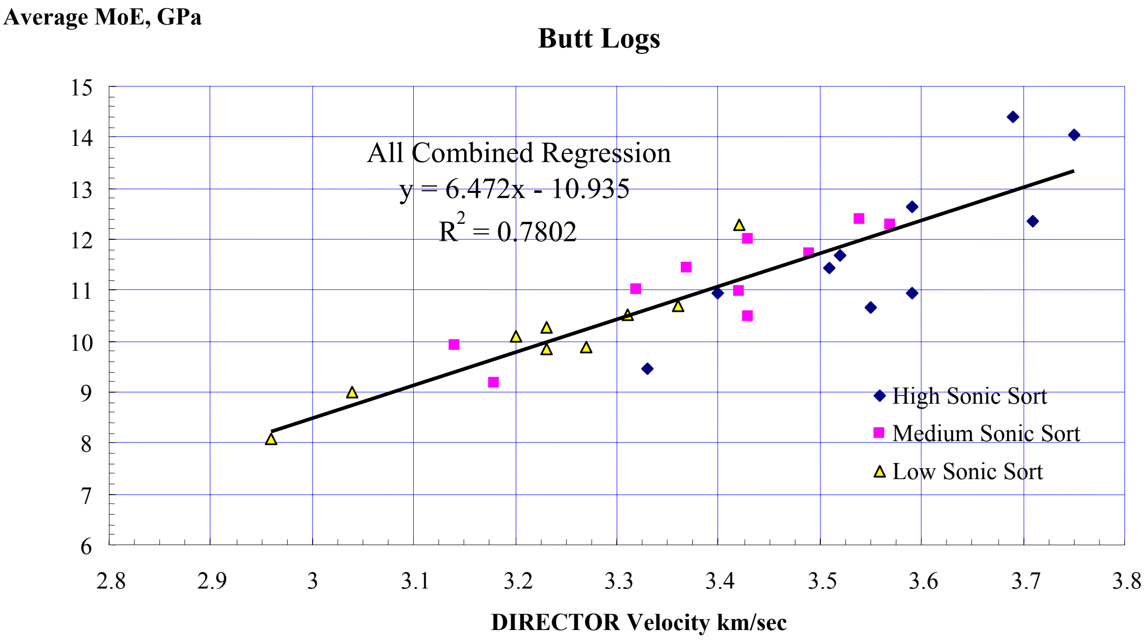

Figure 9: Relationship of Average log DIRECTOR velocities to average CLT MoE_{Plank} stiffness for Butt Logs

Figure 10 (upper logs) and Figure 11 (butt logs) show the relationship between the DIRECTOR sonic velocities for all the logs from a site/sonic sort batch against the average branch index (BIX) for the same log batches. For the upper logs a trend appears to exist showing that with increasing DIRECTOR velocities BIX decreases. This trend however does not exist for the butt logs.

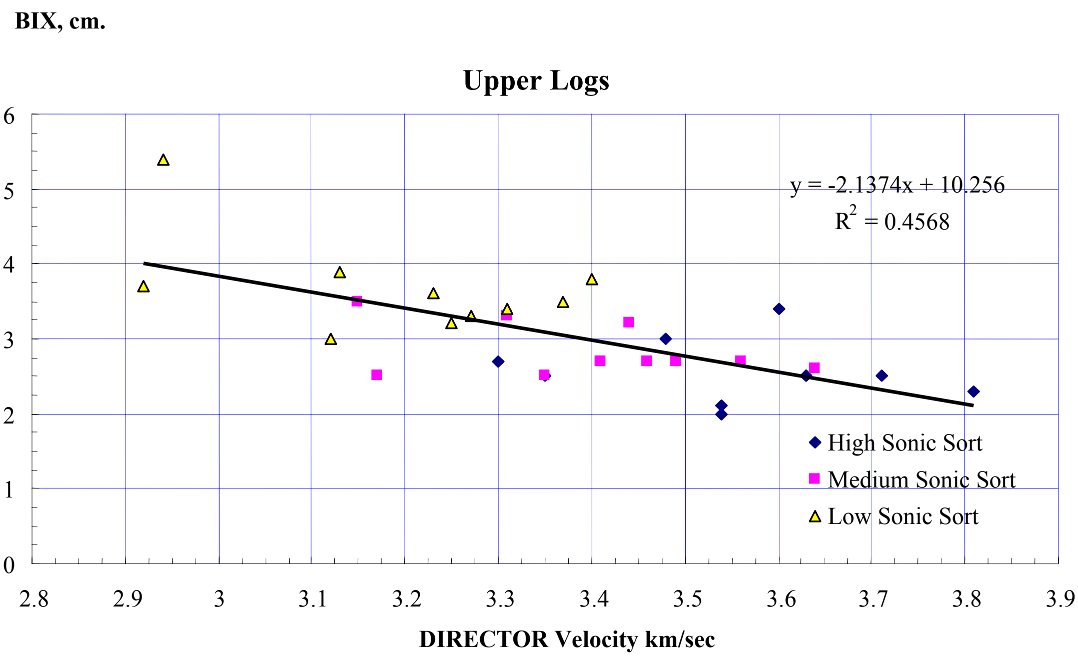

Figure 10: Relationship of Average log DIRECTOR velocities to average Branch Index for Upper logs

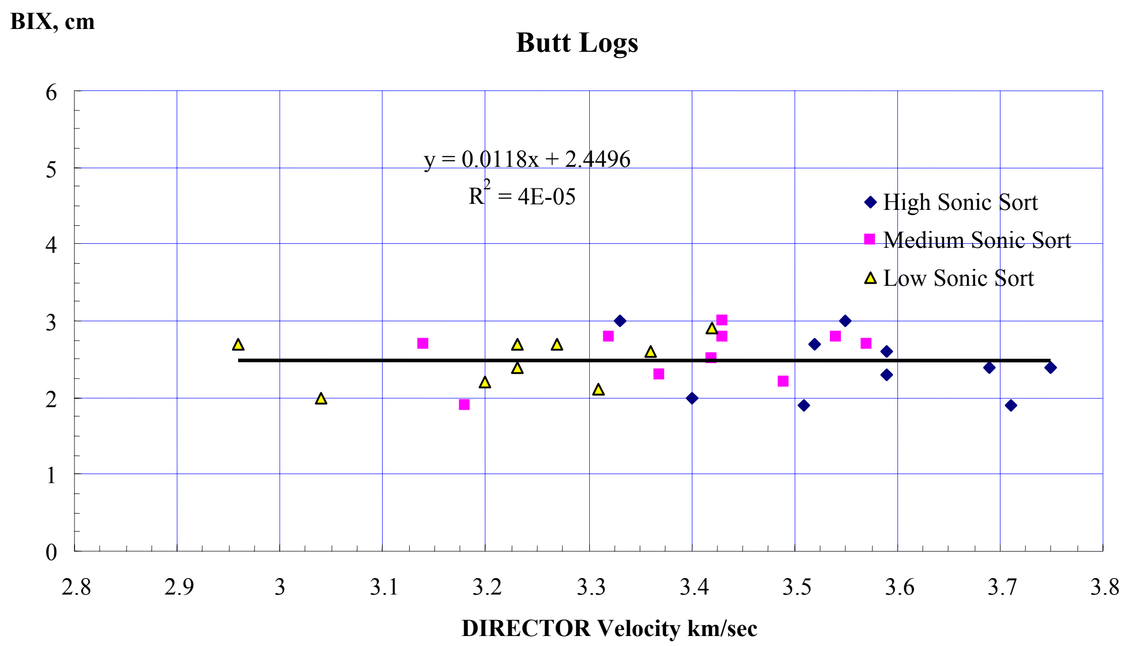

Figure 11*:* Relationship of Average log DIRECTOR velocities to average Branch Index for Butt logs

Linking SilviScan information to timber MOE

As this was a batch sawing study, boards could not be tracked back to individual trees or logs. It was not possible to examine the relationships between SS data from individual trees and the boards produced from them. However site averages of the butt log information was available in terms of the average plank MoE from each log class, classified according to velocity. Breast height SilviScan data expressed as a site average did have a reasonable correlation with average Plank MoE across the sites, with SS_MoE explaining the most variance (Figure 12). In general the variance explained by SilviScan breast height data was greater in the lower velocity (lower stiffness) classes. The correlation between butt log average plank MoE and acoustic velocity for the three sonic sorts, as shown in Figure 9,, was 0.78, which is on par with the variation explained by the SS breast height data (r^2 of 0.64 to 0.83 - Figure 12).

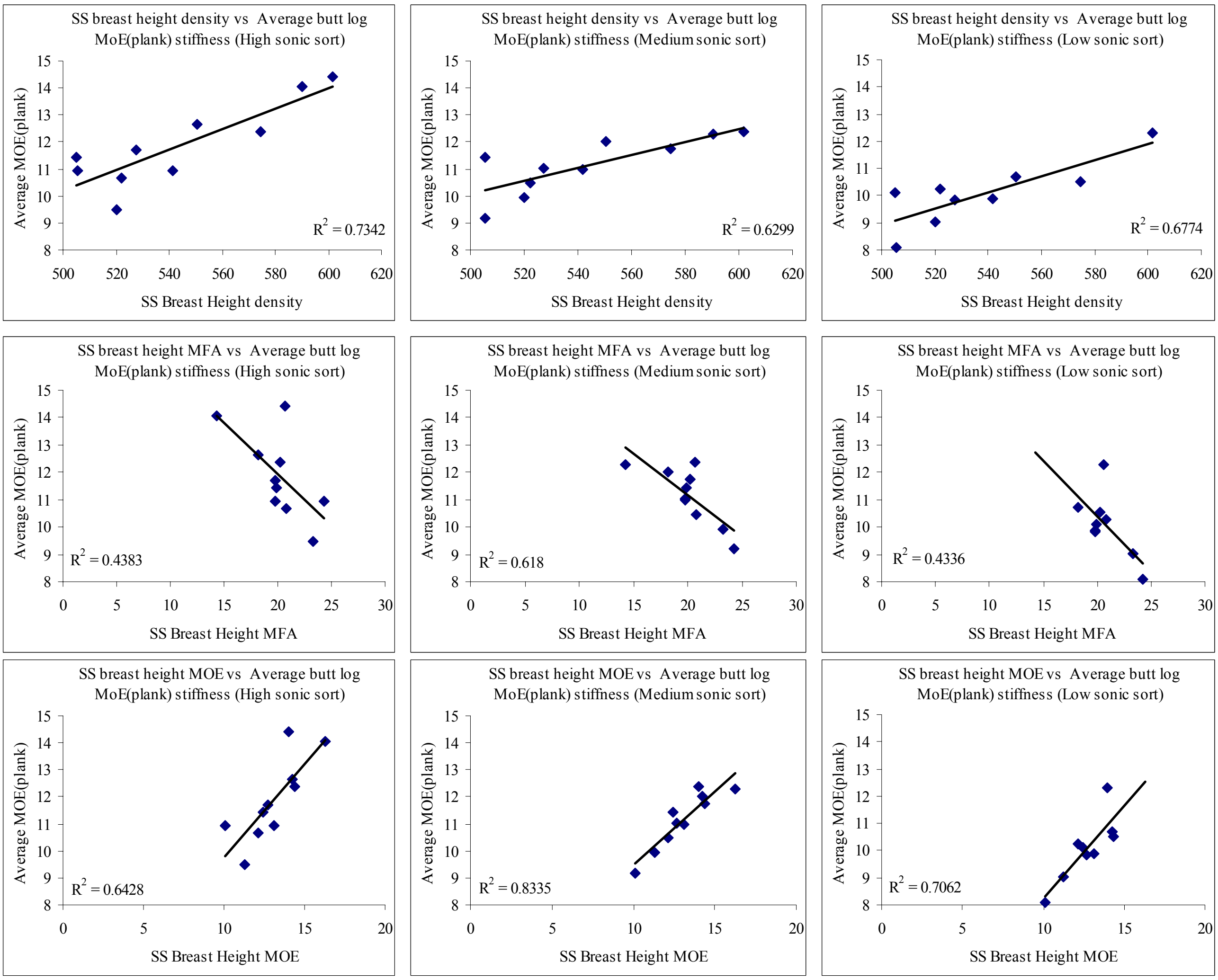

Figure 12: Simple correlation relationships between SilviScan breast height core data (Density, MFA and estimated MoE) expressed as a plot average and the average plank stiffness in the butt log for each sonic sort (Low, Medium, High) for each site.

The use of the SilviScan whole-tree average data to generate site averages increased the variance explained in the average plank MoE's derived from butt logs by several percent (compared to the SilviScan breast height data only) for density and SilviScan_MoE and 20-30% for MFA (Figure 13). Similarly the variance explained by SilviScan whole–tree data improved by a further 5-6% for the upper logs, particularly in the lower acoustic log sort (data not shown). Interestingly the BH SilviScan MoE value gave a stronger correlation with upper log average plank MoE than with the butt logs (data not shown). However the cost and effort required to acquire SilviScan whole-tree data would not warrant its use as a management tool to assess average site board stiffness.

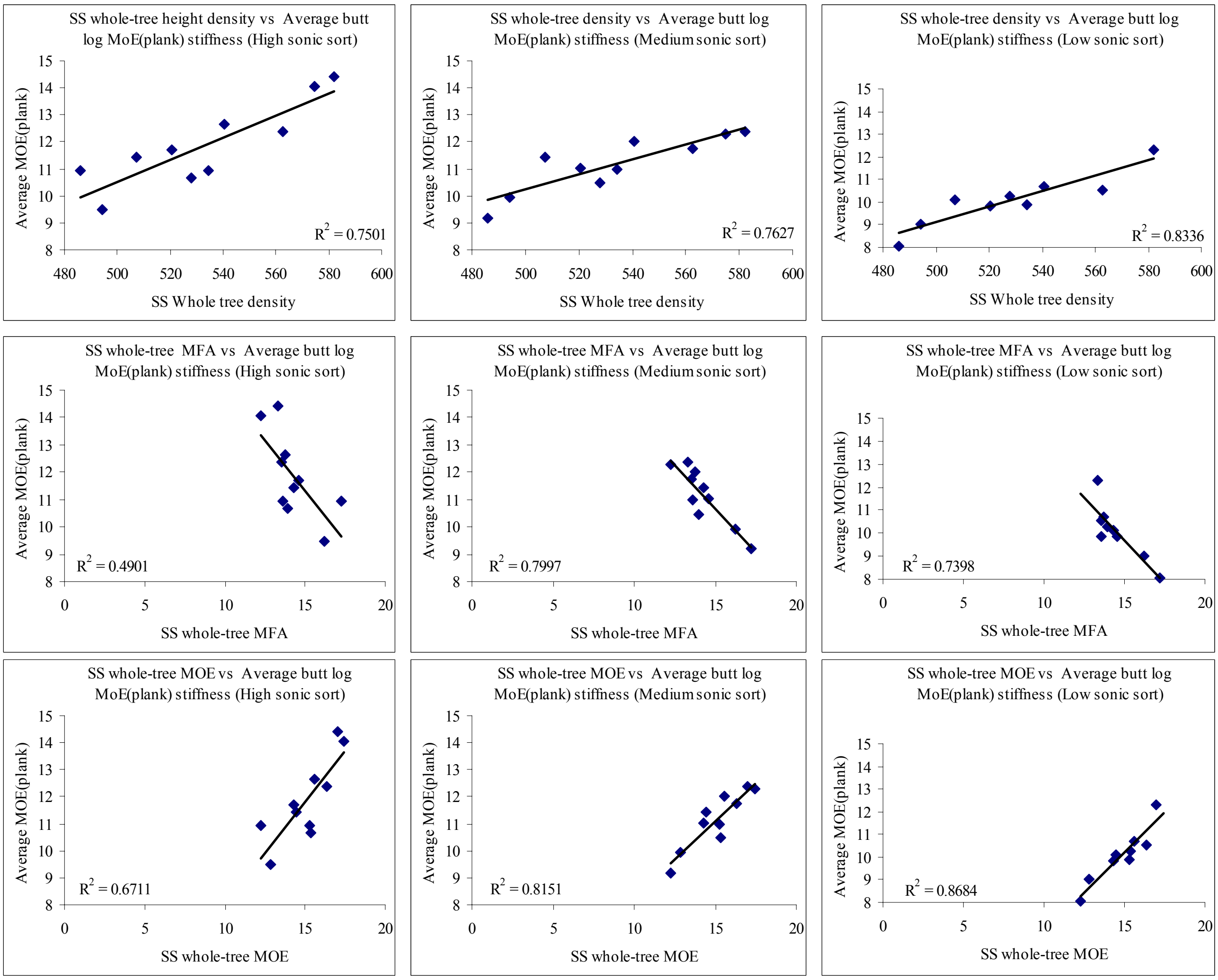

Figure 13: Simple correlation relationships between SilviScan whole-tree values (Density, MFA and estimated MoE) expressed as a plot average and the average plank stiffness in the butt log for each sonic sort (Low, Medium, High) for each site.

Structural timber grade prediction (SAWMOD):

Forest Research has developed a model "SAWMOD" to predict “F” grade recovery. The model is based on a comprehensive data set of detailed individual log characteristics and resultant timber grade recovery for a range of commercial saw patterns. SAWMOD caters for machine grading structural dimensions to Australian standards and allows the impact of individual log characteristics such as branch size or log density to be investigated. SAWMOD inputs are SED, length, taper, sweep, internode index, branch index and basic density.

Log density information was not available for all logs in this study due to the reduced subset of six trees per site sampled for intensive wood quality assessment - 25 of the 30 site/sonic batches had less than 10 logs each with density information. Therefore it was decided to predict grade recovery by site using the outerwood density data from the earlier survey in conjunction with the wood density prediction algorithm, along with average measured log characteristics per batch. Table 10 details site average log characteristics and their respective predicted grade recoveries, while Table 10b details site average butt logs and upper logs separately.

In general, the most important log characteristics for machine stress grade recovery are branch size, assessed as branch index (BIX) and density. However in this study branch sizes were well controlled, averaging approximately 3 cm for the region. Site mean BIX values ranged from 2.4 to 3.4 in Table 10, while site mean density values ranged from 391 to 474. As a result, density was the most important variable in this study. For example, at an average density of around 432, grade recovery was predicted to decrease from 56% to 44% F8 and better as BIX increases from 2.4 to 3.4, i.e. BIX makes about a 12% difference. At an average BIX of around 2.9, grade recovery increases from 32% to 67% as density increases from 391 to 474, i.e. density makes about a 35% difference to grade recovery

Table 10 – Measured log characteristics and predicted "SAWMOD" structural grade recovery by site

Site	No. of Logs	Measured log characteristics						Predicted machine grade recovery %			
		SED (mm)	Taper (mm/m)	Sweep (mm/m)	Int Index	Br. Ind. (cm)	Density* (kg/m^3)	F8+	F5	F4	<F4
L (23)	40	241	8	3	0.1	2.7	399	40	41	12	7
L (26)	40	262	8	1	0.2	2.4	402	45	39	11	5
L (33)	41	333	10	2	0.1	3.4	391	28	45	17	10
M (25)	41	217	8	1	0.2	2.6	445	63	27	6	4
M (28)	40	270	9	4	0.1	3.1	430	50	35	9	6
M (31)	41	271	7	2	0.1	2.8	428	53	34	8	5
M (37)	41	319	8	3	0.1	3.2	427	48	36	10	6
H (27)	40	229	8	3	0.2	2.6	465	72	21	4	3
H (32)	43	282	8	2	0.2	2.8	474	73	20	3	3
H (44)	40	330	7	2	0	2.9	456	65	26	5	4

NB. All 4.9m logs
* Predicted from outerwood density using the wood density algorithm

Table 10b – Measured log characteristics and predicted "SAWMOD" structural grade recovery by site for butt and upper logs (italicized) separately

Site	Log height class	No. of logs	Measured log characteristics*						Predicted machine grade recovery %			
			SED (mm)	Taper (mm/m)	Sweep (mm/m)	Int Index	Br. Ind. (cm)	Density (kg/m^3)	F8+	F5	F4	<F4
L (23)	1	6	272	13	3	0.1	2.1	418	57	32	8	4
L (23)	***3***	***13***	***227***	***7***	***2***	***0.1***	***3***	***386***	***30***	***45***	***16***	***9***
L (26)	1	6	302	12	3	0.2	2.4	435	61	29	6	4
L (26)	***3***	***16***	***247***	***6***	***1***	***0.2***	***2.4***	***406***	***47***	***37***	***10***	***5***
L (33)	1	6	394	13	3	0.1	2.4	417	53	34	9	4
L (33)	***3***	***16***	***316***	***8***	***1***	***0.1***	***3.8***	***396***	***26***	***45***	***17***	***12***
M (25)	1	6	244	8	2	0.1	2.4	471	76	19	3	3
M (25)	***2***	***9***	***209***	***7***	***1***	***0.2***	***2.4***	***428***	***58***	***31***	***7***	***4***
M (28)	1	6	312	12	6	0.1	2.7	460	69	23	4	4
M (28)	***3***	***12***	***261***	***7***	***3***	***0.1***	***3.7***	***415***	***36***	***42***	***13***	***9***
M (31)	1	6	325	11	5	0.2	2.9	463	68	24	4	4
M (31)	***3***	***16***	***263***	***6***	***1***	***0.1***	***3.1***	***432***	***51***	***34***	***8***	***6***
M (37)	1	6	387	10	5	0.1	2.7	457	67	24	5	4
M (37)	***3***	***19***	***307***	***7***	***2***	***0.1***	***3.1***	***423***	***47***	***37***	***10***	***6***
H (27)	1	6	253	9	5	0.1	2	495	85	11	1	2
H (27)	***2***	***8***	***219***	***6***	***3***	***0.2***	***2.8***	***457***	***66***	***25***	***5***	***4***
H (32)	1	6	339	9	3	0.2	2.8	508	83	13	1	3
H (32)	***3***	***15***	***261***	***8***	***1***	***0.3***	***3***	***460***	***65***	***25***	***5***	***4***
H (44)	1	6	397	7	2	0.1	2.4	501	84	12	2	2
H (44)	***3***	***20***	***310***	***7***	***3***	***0***	***2.9***	***458***	***66***	***25***	***5***	***4***

NB. All 4.9m logs
* 6 trees/site subsample used for wood property study

Since SAWMOD predicts F-grades, and the measured grades in this study were MGP grades, a statistical model was used to examine the likely predictions of MGP10 and better using a predictor variable* derived from SAWMOD. This predictor was also used to examine the predictions of MoE and compared with the predictions from sonics.

The model fit was not ideal with a mean deviance of around 4, compared to an ideal of around 1, indicating that standard errors would be about twice the size expected under binomial sampling. Only when site effects were added was a good model obtained with a mean deviance of around 1. This indicates there were significant differences in grade recovery between sites, after fitting the model.

Model for average stiffness (MoE):

A linear mixed model (LME) was fitted for MoE. These models aimed to show

1. How well the DIRECTOR (or SAWMOD, for comparison) could predict MoE; and
2. If there was a difference between butt logs and upper logs.

There were effects of DIRECTOR (batch mean velocity) and log height class. Random effects of site and sonic sort class within site were fitted.

Upper logs had, on average 0.75 (s.e.=0.09) lower MoE than butt logs, after adjusting for sonic velocity, i.e. upper logs with a given sonic reading are less stiff than butt logs with the same value.

Butt logs were estimated to be 29% (95%ci = 23--36%) more variable in MoE than upper logs.

The random site effects had a standard deviation of 0.41GPa and the random sonic class within site effects had a standard deviation of 0.21 GPa. The residuals (otherwise unexplained errors) had a standard deviation of 2.0 GPa. By comparison a model without sound velocity had random site effects with a standard deviation of 1.2 , meaning that the sound velocity test explained about 66% of the between site variation.

Comparisons with a model using a predictor derived from SAWMOD, which is based on BIX and density, showed that sonics explained a similar proportion of the variance overall, with an estimated 33% lower site and batch level error standard deviations, suggesting that sonics may be more consistent between sites (although the differences are not statistically significant).

With SAWMOD alone, the estimated site, sonics within site, and residual standard deviations were, respectively: 0.66 (0.39—1.10), 0.33 (0.21--0.52), 2.23 (2.18--2.90). The values in brackets are 95% confidence limits. With DIRECTOR alone the estimated site, sonics within site and residual standard deviations were, respectively: 0.42 (0.23--0.74), 0.21(0.12--0.38), 2.23(2.18--2.29).

Note: The site and sonic sort level standard deviations are important because the residual standard deviations reduce when multiple trees are sampled, for example if 100 trees were sampled in a site, the residual standard deviation would reduce by a factor of 10, but the site and sonic class standard deviations would not reduce. The estimated site mean would have a standard deviation of

sqrt(0.42^2 + 0.21^2 + 2.23^2/100)

for DIRECTOR, or

* The model fitted was binomial generalised linear model with logit link. The independent variable was the logit transform of the SAWMOD-predicted proportion of F8 and better. This was fitted to the data in the same way as the other measures such as sound velocity or silviscan, making for a fairer comparison than using a fixed pre-defined model, however in practise, of course a pre-defined model will need to be used.

sqrt(0.66^2 + 0.33^2 +2.23^2/100)

for SAWMOD.

Note: The actual residual standard deviation would be less than 2.23 if MoE data values for individual logs were available.

Predicting Site Average Stiffness - MOEp

This study investigated a number of different tools and techniques that can be applied sequentially in the lead-up to harvest and utilisation of stands.
Briefly these are;

1. Pre-harvest stand **Outer-Wood Breast Height Density** assessment (6mm increment cores each 50mm long with 30 samples per site)
2. **Stem Sonic** assessment at the time of harvest (on whole stems prior to log-making using DIRECTOR tool)
3. **Log Sonic** assessment at the time of harvest (logs as produced from the site using DIRECTOR tool on all suitable logs).
4. **SilviScan** assessment.

Table 11shows the site average data used for these comparisons.

Table 11: Site average data for average MoEplank and MoE predictive tools

Site Rankings & Correlations- All data are Site Averages						
Name	Dens/ Age	O/Wood Dens(Har)	DIRECTOR Stem	DIRECTOR Log Vel	SS MoE whole tree	MoEp(adj) (Gpa)
Byjuke	H27	521	3.42	3.47	16.30	11.04
MacGillivray	H32	538	3.47	3.55	17.00	12.08
Caroline	H44	526	3.47	3.61	17.50	12.392
Nangeela	M25	482	3.32	3.41	15.30	10.232
Kongorong	M28	470	3.23	3.32	14.30	10.168
Kentbruck	M31	472	3.39	3.48	15.60	11.264
Longs	M37	483	3.50	3.43	15.40	10.368
Porters	L23	428	3.13	3.15	12.30	8.6
Emersons	L26	438	3.21	3.35	14.50	10.52
Myora HQ	L33	418	3.07	3.14	12.80	9.4
Average		477.6	3.32	3.39	15.10	10.6064

*Note that using the site average lumber MoEp still has a significant amount of MoE and hence MGP Grade variation around this mean value – however it is useful as a single statistic.

Outerwood Breast Height Density Assessment shows a good predictive ability at the stand average level with an R^2 value of 0.72 (this relationship explained 72% of the variation in mean board MoE at the stand level, Figure 14). Examination of the outliers showed that younger ages tended to be below the trendline, while older stands tended to be above it. Therefore age was added as a second variable improving the R^2 value to 0.79 (data not shown) with age appearing with a positive value (hence older age gives better board MoE, even after taking density into account)

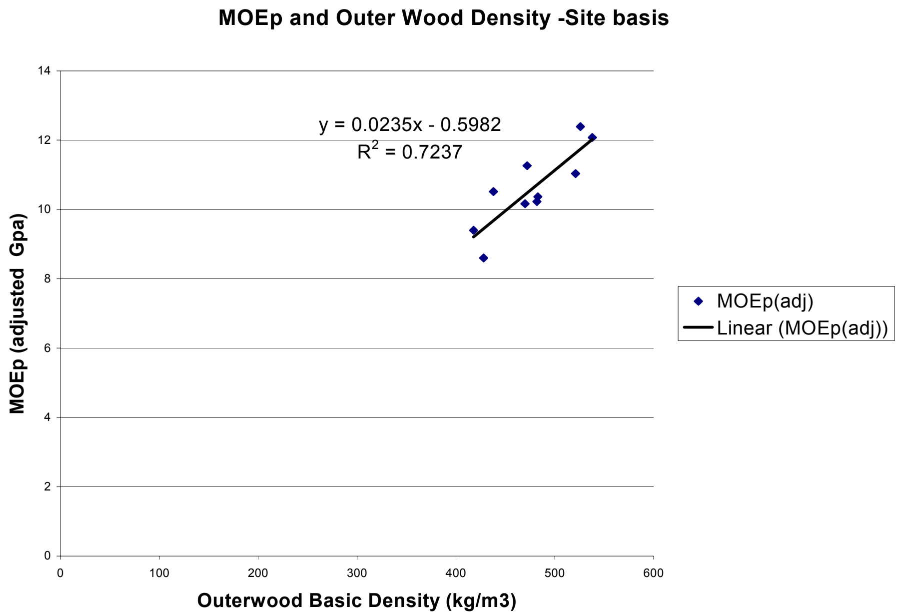

Figure 14: Relationship between site average outerwood basic density and MoEplank

Stem Sonic Assessment at the time of harvest offers another possibility for real time evaluation of the lumber grades likely to come from the site. However, the correlation is less strong than for Outerwood density at R^2 of 0.64 (Figure 15).

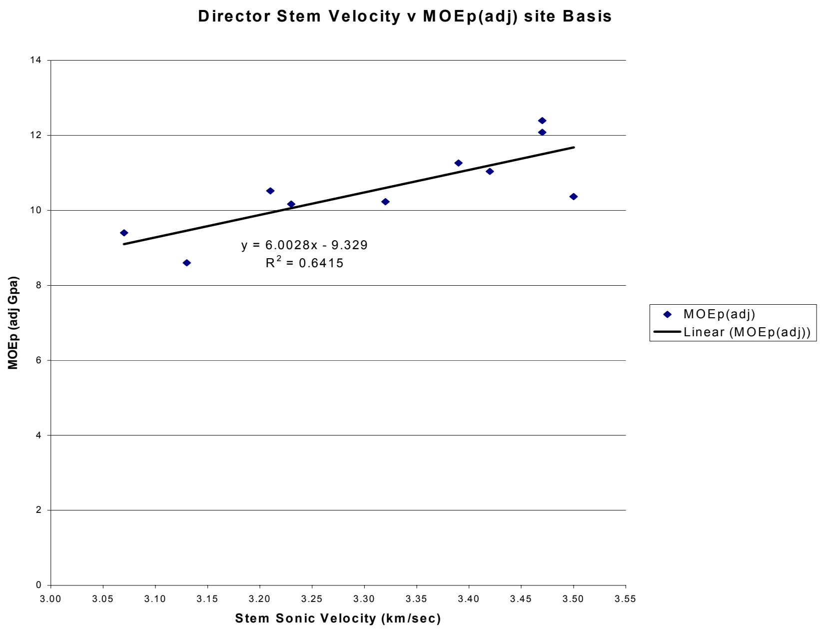

Figure 15: Relationship between site average DIRECTOR stem velocity and MoEplank

Log Sonic Assessment at the time of harvest has already been shown to have useful ability to sort logs into sonic batches with higher lumber MoE within a site (see page 29-30). However, the average log sonic value could also be used as a real time tool to distinguish between sites on a similar basis to the other tools and techniques. Average log sonic velocity as assessed by the DIRECTOR tool, shows excellent ability to distinguish between sites in the prediction of lumber MoE with an R^2 value of 0.90 (or explaining 90% of the between site variation, Figure 16).

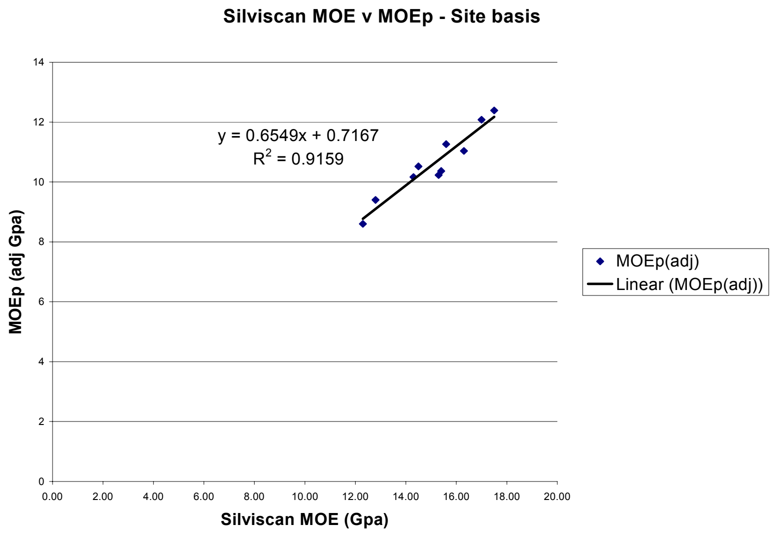

Figure 16: Relationship between site average DIRECTOR sonic velocity and average MoEplank

SilviScan predicted whole tree MoE has been derived and used as a predictive tool. Figure 17 shows SilviScan whole tree MoE has a very strong predictive ability for the final lumber MoE on a site basis with an R^2 value of 0.92.

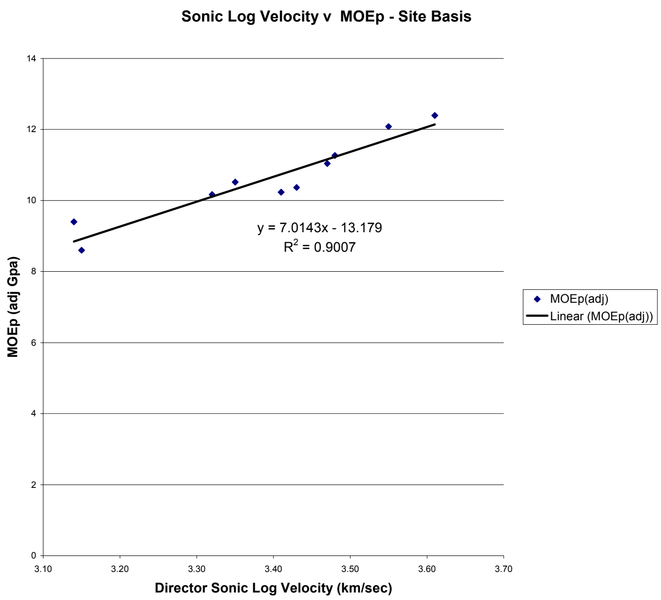

Figure 17: Relationship between site average whole tree SilviScan MoE and MoEplank

Conclusion

On a site average basis, all the tools and techniques show ability to distinguish between sawn lumber average MoE, to varying degrees of precision:

- At the **pre-harvest stage**, Outerwood Density coupled with age predicts at the 79% level.
- Sonic log assessment (DIRECTOR Tool) **at the time of harvest** gives an excellent 90% as an explanatory variable. This also has the added advantage of being able to sort logs within site, into sonic batches, with different resultant lumber average MoEs.
- **SilviScan MoE** shows the highest predictive ability, however the expense and effort required to acquire the SilviScan whole tree MoE average indicates that it is unlikely to be used as a management tool, but will rather retain an important role in further research.

This tool assessment is summarised in Table 11. The correlative relationships shown in Figures 14-17 and Table 11 are based on ten data points ONLY, as these are site based correlations. In all cases the relationship used was a simple linear regression, and a strong correlation does not necessarily indicate a causative relationship between the parameters. Although this analysis is an excellent first indication of possible relationships, many more data points are needed to develop a robust relationship that may be used with confidence.

Table 11: Correlations between assessment tools and site average MOEp

Tool	% R^2	Approximate cost
Outerwood basic density	72	Relatively cheap
Outerwood basic density + age	79	Relatively cheap
Acoustic whole stem velocity	64	Relatively cheap
Acoustic log velocity	90	Relatively cheap
Whole tree SilviScan	92	Expensive

Predicting Site Average Stiffness - MGP10 and better

As the processing industry often markets timber as MGP10 or better (T. Haslett, pers comm[1]) an analysis to determine tools that could predict MGP10 and better from a site was undertaken.

Using stand average values, the ability to predict variation in grade outturn as a function of four wood property measures was undertaken. These measures were SS whole-tree MOE, log acoustic MOE, outerwood density and plantation age. This analysis was preformed at 2 levels. In the first instance the ability to predict cumulative grade recovery starting at MGP15 or better was examined (Figure 18 a-d). In the second the % recovery of each MGP grade was determined (Figure 18 e-f). The predicted % recovery for each grade was determined by subtracting the cumulative grade predictions. Residual analysis indicated this was a valid approach. An alternative approach was investigated that required more complicated models but these were not found to perform any better.

A simple equation (eqn 1) was flexible enough to fit observed relationships and generate acceptable estimates within the data range.

$$\text{Eqn 1:} \quad Y = \exp(a+bX)$$

(Y - % grade outturn, X - wood property measure, a and b are values determined by non-linear regression (Table 12))

[1] Tony Haslett, Technical Manager, Weyerhaeuser Australia, Mt Gambier

Table 12 Model coefficients determined for eqn 1 for each of 4 wood property methods. Nb: Ek(2) values are those defined in table 6.

Model: Y = exp(a+b*x)

Method		MGP15	MGP12	MGP10	F4
	Ek(2)	14.4	12.08	9.23	6.05
SS	a SS	-8.78493	-0.13834	3.46611	4.55321776
	b SS	0.695371	0.247906	0.061089	0.0029746
	R2	0.94	0.88	0.65	0.36
LogVel	a LV	-24.7767	-6.06376	2.159433	4.488775
	b LV	7.81136	2.848644	0.65735	0.03224978
	R2	0.96	0.92	0.62	0.36
Dens	a Dens	-8.193	-0.20805	3.43492	4.549499
	b Dens	0.021155	0.008032	0.002	0.000101839
	R2	0.68	0.63	0.44	0.26
Age	a Age	-0.95896	2.49783	4.057105	4.5963
	b Age	0.096995	0.037612	0.010914	0.000061925
	R2	0.5	0.37	0.32	0

Both acoustic and SS measures of average site stiffness were effective at predicting cumulative grade recovery (Figure 18ab). This was especially so for high grade products (MGP12 and better). In contrast, grade recovery proportions are only weakly correlated with log size (mean log volume) and tree size (plot DBH). Grades were defined by the Ek(2) values rather than MGP values to allow the F4 category to be better integrated into the model. Log size was not a good proxy for log quality. The predictive ability of the 4 independent variables on grade proportions (Table 7) for each site was also examined (Figure 18e-f).

The models related the outturn of product grades to measured wood quality parameters at a stand/site level. As different product grades sell for different prices it should be possible to apply the models to relate differences in measured stiffness to differences in value of the stand. This could be useful in the financial analysis of tree breeding programs (growth vs. wood quality) or silvicultural treatments such as fertilizer, which are known to stimulate tree growth but can also reduce stiffness of the wood formed following treatment.

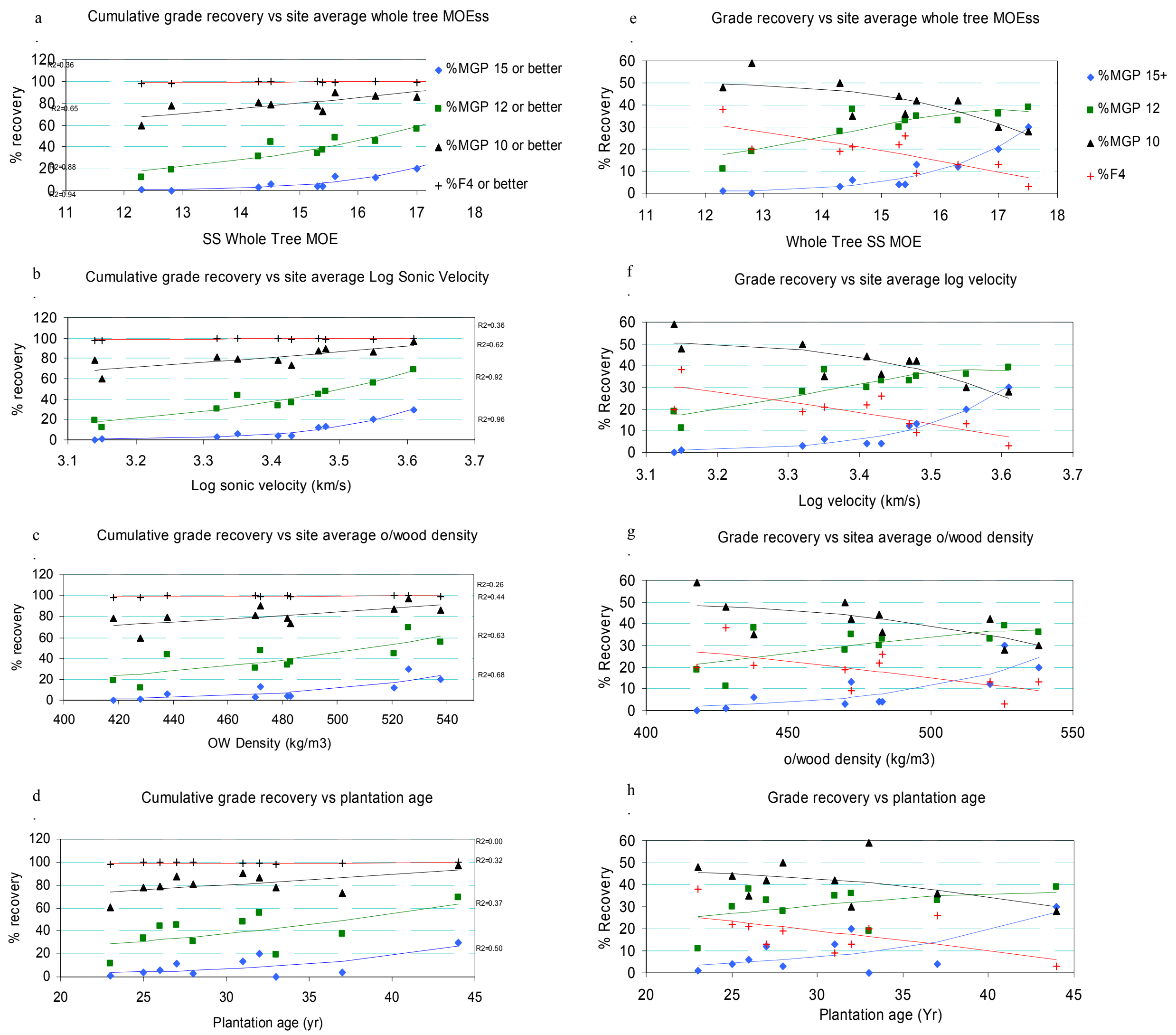

Figure 18 a-d Relationship between cumulative grade outturn and (a) SilviScan MOE, (b) log sonic velocity, (c) outer wood BH density and (d) plantation age; e-f show the relationship between grade recovery in each category and the 4 predictor variables.

Estimation of Timber Value

An alternative to using average MOEp for comparative evaluations between sites (and log sorts) is to use the grade recovery data and estimate the value by grade to include financial returns in the assessment of tools.

The following financial data were used for this purpose based on lumber value per cubic metre on 90x35mm scale basis. (Note that the conversions of logs to lumber previously in this report have used nominal sawn lumber sizes for tally purposes i.e. as 100x40mm). To reduce 110x40 to 90x35 mm is a factor of x 0.7875 (=(90x35)/(100x40)) which was used to convert lumber volumes and hence log/lumber conversions.

Table 13 shows the grade values used in this analysis. While these values may not be strictly accurate the relativity between them will provide a good indication of value by site.

Table 13 Timber values used to calculate gross site timber value (90x35mm basis)

Lumber Grade	Lumber Value ($/m³)
MGP 15	550
MGP 12	500
MGP 10	450
F 4	250
Reject	200

For simplicity, it was assumed that all lumber produced was valued as 90x35 (actually overall 96.4% of the recovered timber was in this size– the balance being 70x35 mm). The weighted average percentage of lumber in each site/sonic sort was valued according to these figures. Table 14 shows the gross average lumber value produced by each site/sonic sort. Note that the value trend from low sonic to high sonic sort is very consistent within sites, with the exception of M37. The maximum difference between the site gross value of timber is 31% between L23 and H44.

Table 14 Timber values per cubic metre by site and sonic sort.

Site	Age	Log Sonic	Tot $/M3	Low Sort	Med Sort	High sort
L23	23	3.15	$377.27	$344.90	$384.32	$413.83
L26	26	3.35	$433.00	$400.68	$430.85	$466.18
L33	33	3.14	$414.50	$384.18	$429.33	$427.16
M25	25	3.41	$425.00	$409.90	$427.15	$444.66
M28	28	3.32	$429.00	$411.76	$431.33	$450.69
M31	31	3.48	$462.63	$431.58	$465.17	$478.29
M37	37	3.43	$413.86	$418.51	$415.52	$411.53
H27	27	3.47	$452.50	$440.05	$451.82	$469.12
H32	32	3.55	$459.50	$441.78	$468.07	$473.01
H44	44	3.61	$493.50	$476.88	$485.88	$508.46
Averages	**30.6**	**3.391**	**$436.08**	**$416.02**	**$438.94**	**$454.29**

Figure 19 shows the relationship between MOEp and gross timber value on a site basis. As expected there is a strong correlation between these two parameters.

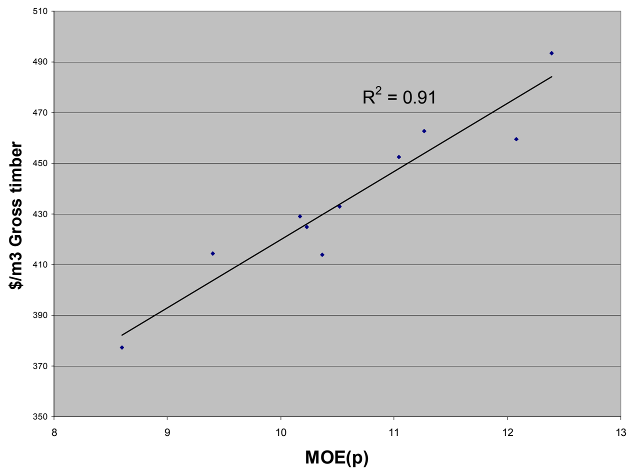

Figure 19 Relationship between MOEp and gross timber value by site

Similar to the analysis show between the wood quality assessment tools and site average MOE, Table 15 shows the correlations between the wood quality assessment tools and site gross timber value. It can be seen from Table 15 that breast height SilviScan shows the strongest correlation with gross timber value, explaining 95% of the variation. Outerwood basic density explained 55% of the variation with site gross timber vale, with acoustic whole stem velocity explaining 75% of the variation. This analysis also showed that whole tree SilviScan, a more intensive wood quality analysis, explained only 77% of the variation compared with breast height SilviScan, a single point wood quality analysis, explained 95% of the variation.

As with the earlier analysis, these correlative relationships are based on ten data points ONLY. In all cases the relationship used was a simple linear regression, and a strong correlation does not necessarily indicate a causative relationship between the parameters. Although this analysis is an excellent first indication of possible relationships, many more data points are needed to develop a robust relationship that may be used with confidence.

Table 15: Correlation between wood quality assessment tools and gross timber value on a site basis

Tool	% R^2	Cost
Outerwood basic density	55	Relatively cheap
Acoustic whole stem velocity	75	Relatively cheap
Whole tree SilviScan	77	Most expensive
Breast height SilviScan	95	Relatively expensive

Estimation of Log Value

An estimate of Log Value at mill for site comparison purposes was derived based on the assumptions listed below:

- **Lumber Values** as previously
- **No account** was take of non-lumber values (e.g. wood chips)
- **Log-to-Lumber conversion factors** (effective mill recovery % - we used the actual mill data)
- **Within-mill processing costs** including
  - Green mill costs
  - Kiln drying costs
  - Site Overheads including handling,
  - Planer gauging and Docking
  - Machine Stress Grading
  - Return on Capital & Depreciation

  Without building a financial model of a mill the approach used was to allocate a fixed cost of $200/m3 to cover these activities. This will vary from actual mill costs, which are unknown in this project.

Table 16 shows the return to log values by site. The maximum difference between any two sites is 76% between L26 and H44, and this difference is largely influenced by the proportion of MGP12 and MGP15 produced from these sites.

Table 16: Return to Log per site

Return to log Calculations

Site	Conv % 90x35	Log Sonic	Grade Recovery % MGP 15	MGP 12	MGP 10	F4	Rej	Gross lumber Val $/m3	Process Cost $/m3	Return to Log $/m3®
L23	34.1	3.15	1	11	48	38	1	377.27	200.00	$60.45
L26	34.6	3.35	6	38	35	21	0	433.00	200.00	$80.65
L33	35.4	3.14	0	19	59	20	2	414.50	200.00	$75.83
M25	33.9	3.41	4	30	44	22	0	425.00	200.00	$76.37
M28	35.5	3.32	3	28	50	19	0	429.00	200.00	$81.30
M31	35.3	3.48	13	35	42	9	0	462.63	200.00	$92.70
M37	34.9	3.43	4	33	36	26	2	413.86	200.00	$74.57
H27	32.4	3.47	12	33	42	13	0	452.50	200.00	$81.78
H32	34.5	3.55	20	36	30	13	1	459.50	200.00	$89.55
H44	36.3	3.61	30	39	28	3	0	493.50	200.00	$106.67
Average	**34.7**	**3.391**	**9.3**	**30.2**	**41.4**	**18.4**	**0.6**	**436.08**	**200.00**	**$81.99**

NB Return-to-Log = (Gross lumber value - Process cost) x (Conv %/100)

Table 17 shows that these'return-to-log' relationship are not quite as strong as with gross lumber value on a site basis for the wood quality tools.

Table 17: Correlation between wood quality assessment tools and return-to-log value on a site basis

Tool	% R^2	Cost
Age	19	Very cheap
Outerwood basic density	65	Relatively cheap
Acoustic log velocity	47	Relatively cheap
Whole tree SilviScan	50	Most expensive

RECOMMENDATIONS AND CONCLUSIONS

This project has shown the potential of resource evaluation tools to assist in predicting structural grade outturn in order to assist with efficient log allocation to appropriate end uses. This should assist tree growers and timber processors in the Green Triangle to have a better understanding of what quality timber to expect from different sites once the resource evaluation tools/systems are implemented for the estate.

A comparison of the costs of obtaining resource evaluation information, for a given level of accuracy, using the various tools/techniques will assist regional industry to determine what the most appropriate system is for their purposes. This “dollar-o-meter” will be developed for the industry workshops to be held in early 2004.

Further work that might be considered from the results of this project:

- Individually tailoring some of the outputs of this project for individual businesses in the Green Triangle Region;
- Further investigation of the predictive models to determine what increased accuracy could be achieved if working on a site, rather than a regional, basis;
- Replicating this project in other regions to determine whether similar relationships hold true for radiata pine grown elsewhere; and

- Investigating the applicability of this approach for other softwood species such as slash pine or hoop pine in Queensland.

ACKNOWLEDGEMENTS

The authors would like to extend their appreciation to the members of the project steering committee and field staff who assisted in the development and implementation of this project.

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APPENDIX A. INDIVIDUAL LOG DATA

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
1	A	Grey Fog	7	4	28.0	30.5	4.9	0.329	0.330	5	0.00	4.5	3.1		8.2	3.54
1	A	Grey Fog	12	5	28.0	30.5	4.89	0.328	0.329	5	0.00	5.0	4.3		0.0	3.50
1	A	Grey Fog	13	5	22.5	27.5	4.9	0.237	0.243	10	0.00	6.0	4.4		0.0	3.42
1	A	Grey Fog	19	4	28.0	30.5	4.94	0.331	0.333	5	0.00	4.0	3.5		0.0	3.52
1	A	Grey Fog	23	2	34.0	39.0	4.89	0.503	0.514	10	0.00	3.0	2.6		9.2	3.50
1	A	Grey Fog	23	3	31.5	36.0	4.89	0.431	0.439	9	0.00	5.0	3.8		0.0	3.37
1	A	Grey Fog	23	4	26.5	30.5	4.91	0.310	0.315	8	0.00	6.0	4.8		10.2	3.43
1	A	Grey Fog	23	5	21.5	26.0	4.9	0.215	0.219	9	0.00	5.0	3.9		0.0	3.38
1	A	Grey Fog	25	3	35.0	37.0	4.9	0.499	0.499	4	0.00	3.0	2.6		0.0	3.54
1	A	Grey Fog	25	4	30.5	34.0	4.92	0.399	0.403	7	0.14	5.5	4.3		4.1	3.27
1	A	Grey Fog	25	5	26.0	30.0	4.9	0.299	0.303	8	0.00	5.5	4.6		0.0	3.10
1	A	Grey Fog	27	4	28.0	32.0	4.93	0.345	0.350	8	0.00	4.5	4.0		0.0	3.33
1	A	Grey Fog	30	4	22.5	26.5	4.92	0.230	0.233	8	0.00	5.0	3.5		10.2	3.32
1	A	13 logs	Avg	4	27.8	31.5	4.91	0.343	0.347	8	0.01	4.8	3.8		3.2	3.40
2	A	Grey Fog	6	1	41.5	43.0	4.88	0.686	0.684	3	0.00	3.0	2.5		9.2	3.64
2	A	Grey Fog	6	4	29.5	32.2	4.9	0.365	0.367	6	0.00	4.0	2.9		0.0	3.68
2	A	Grey Fog	12	4	31.5	34.5	4.94	0.420	0.423	6	0.12	4.0	3.1		0.0	3.66
2	A	Grey Fog	13	4	26.5	30.0	4.9	0.305	0.308	7	0.00	3.5	2.4		8.2	3.63
2	A	Grey Fog	19	3	31.5	34.5	4.9	0.417	0.420	6	0.00	3.0	2.0		0.0	3.65
2	A	Grey Fog	23	1	39.0	43.5	4.95	0.655	0.663	9	0.00	3.0	2.6		0.0	3.60
2	A	Grey Fog	25	1	42.0	47.0	4.91	0.756	0.766	10	0.00	3.0	3.0		0.0	3.55
2	A	Grey Fog	25	2	36.5	40.0	4.94	0.564	0.569	7	0.00	2.5	2.3		0.0	3.61
2	A	Grey Fog	27	1	45.5	48.0	4.92	0.846	0.845	5	0.12	2.5	2.5		0.0	3.55
2	A	Grey Fog	27	2	41.5	45.0	4.94	0.723	0.727	7	0.14	3.0	2.5		0.0	3.68
2	A	Grey Fog	27	3	38.5	42.5	4.9	0.626	0.633	8	0.00	3.0	2.5		0.0	3.61
2	A	Grey Fog	30	1	34.0	40.0	4.92	0.517	0.532	12	0.20	3.5	2.4		0.0	3.64
2	A	Grey Fog	30	3	27.0	30.5	4.91	0.316	0.320	7	0.00	4.0	3.3		7.1	3.64
2	A	13 logs	Avg	2	35.7	39.3	4.9	0.6	0.6	7.2	0.0	3.2	2.6		1.9	3.63
3	A	Grey Fog	6	2	35.0	39.0	4.89	0.521	0.527	8	0.00	2.5	2.3		9.2	3.83
3	A	Grey Fog	6	3	32.0	36.5	4.89	0.444	0.452	9	0.00	2.0	1.8		0.0	3.80

3	A	Grey Fog	7	1	37.0	39.0	4.9	0.556	0.556	4	0.00	3.0	2.7		0.0	3.70
3	A	Grey Fog	7	2	30.5	33.5	4.93	0.395	0.397	6	0.00	3.5	2.9		0.0	3.79
3	A	Grey Fog	7	2	35.0	37.0	4.91	0.500	0.500	4	0.00	3.0	2.3		5.1	3.82
3	A	Grey Fog	12	1	43.0	44.5	4.94	0.744	0.743	3	0.00	3.0	2.5		9.1	3.71
3	A	Grey Fog	12	2	39.5	42.5	4.92	0.648	0.650	6	0.12	2.5	2.3		0.0	3.81
3	A	Grey Fog	12	3	34.5	37.5	4.92	0.499	0.502	6	0.00	3.0	2.3		0.0	3.83
3	A	Grey Fog	13	1	37.0	42.0	4.89	0.591	0.602	10	0.00	2.0	2.0		0.0	3.87
3	A	Grey Fog	13	2	33.5	37.0	4.89	0.474	0.478	7	0.00	2.5	2.0		0.0	3.92
3	A	Grey Fog	13	3	31.0	34.5	4.89	0.409	0.413	7	0.00	3.0	2.4		0.0	3.76
3	A	Grey Fog	19	1	38.0	44.5	4.9	0.640	0.659	13	0.19	3.0	2.4		5.1	3.70
3	A	Grey Fog	19	2	35.0	39.0	4.92	0.524	0.531	8	0.00	2.5	2.4		0.0	3.74
3	A	Grey Fog	30	2	31.0	33.5	4.91	0.400	0.402	5	0.18	4.0	2.8		0.0	3.80
3	A	14 logs	Avg	2	35.1	38.6	4.9	0.5	0.5	7.0	0.0	2.8	2.3		2.0	3.79
													Site		**min**	**3.10**
															max	**3.92**
															avg	**3.61**
															count	**40**

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
4	B	Scarab Green	8	1	44.5	49.5	4.87	0.838	0.847	10	0.21	4.0	3.0		13	3.24
4	B	Scarab Green	8	4	33	36.5	4.86	0.457	0.462	7	0.00	4.0	2.8		5	3.23
4	B	Scarab Green	8	5	26.5	31.5	4.89	0.317	0.325	10	0.00	5.0	4.0		0	3.09
4	B	Scarab Green	10	1	42.5	49	4.92	0.795	0.813	13	0.15	3.0	2.6		0	3.36
4	B	Scarab Green	10	4	30.5	34	4.89	0.396	0.401	7	0.00	4.0	3.6		0	3.32
4	B	Scarab Green	10	5	22	27.5	4.85	0.229	0.236	11	0.12	7.5	4.5		10	3.05
4	B	Scarab Green	18	4	18.5	21	4.63	0.144	0.142	5	0.00	3.0	2.5		6	3.32
4	B	Scarab Green	26	1	36	44	4.88	0.592	0.619	16	0.13	3.5	3.0		0	3.25
4	B	Scarab	27	5	25.5	31	4.8	0.294	0.304	11	0.00	4.0	3.4		0	3.38

4	B	Green Scarab	30	1	37.5	42.5	4.9	0.607	0.618	10	0.24	2.5	2.1	4	3.05
4	B	Green Scarab	30	2	33.5	37	4.87	0.472	0.476	7	0.27	4.0	3.8	13	3.20
4	B	Green Scarab	30	3	30	32.5	4.89	0.374	0.376	5	0.33	6.0	4.5	10	3.23
4	B	Green Scarab	30	4	24.25	27	4.93	0.254	0.255	6	0.00	4.5	3.3	0	3.21
4	B	Green 13 logs	Avg	3	31.1	35.6	4.86	0.444	0.452	9	0.11	4.2	3.3	4.8	3.23
5	B	Scarab	8	2	42	44.5	4.85	0.712	0.713	5	0.00	4.5	3.8	0	3.39
5	B	Green Scarab	8	3	37	39.5	4.91	0.563	0.565	5	0.15	3.5	3.0	0	3.39
5	B	Green Scarab	10	3	33.5	37	4.94	0.479	0.483	7	0.00	3.0	2.9	0	3.50
5	B	Green Scarab	14	1	34	38.5	4.9	0.499	0.508	9	0.00	2.0	1.6	0	3.42
5	B	Green Scarab	16	1	34.5	41	4.89	0.533	0.551	13	0.12	4.0	3.6	6	3.46
5	B	Green Scarab	16	4	25	27.5	4.91	0.266	0.266	5	0.00	5.5	4.0	0	3.46
5	B	Green Scarab	21	1	40.05	44	4.9	0.675	0.681	8	0.41	3.5	3.1	5	3.42
5	B	Green Scarab	21	3	32.5	35.5	4.89	0.442	0.445	6	0.18	3.5	3.4	0	3.50
5	B	Green Scarab	21	4	28.5	31	4.9	0.340	0.341	5	0.31	4.5	3.9	0	3.42
5	B	Green Scarab	26	2	33.5	36	4.88	0.462	0.463	5	0.29	3.0	2.8	10	3.48
5	B	Green Scarab	26	3	29	32.5	4.85	0.357	0.361	7	0.00	3.5	2.4	0	3.43
5	B	Green Scarab	26	4	23	27.5	4.88	0.242	0.246	9	0.00	3.5	2.6	0	3.41
5	B	Green Scarab	27	4	33	38.5	4.88	0.480	0.493	11	0.00	4.0	3.1	0	3.48
5	B	Green 13 logs	Avg	3	32.7	36.4	4.89	0.465	0.471	7	0.11	3.7	3.1	1.7	3.44
6	B	Scarab	10	2	38	40	4.89	0.584	0.585	4	0.55	4.0	2.9	0	3.53

6	B	Green Scarab	14	2	30.5	33	4.85	0.383	0.385	5	0.15	4.0	3.3	3	3.54
6	B	Green Scarab	14	3	28	30	4.89	0.323	0.323	4	0.00	3.0	2.5	0	3.53
6	B	Green Scarab	15	1	32	36.5	4.87	0.442	0.451	9	0.21	4.0	3.5	3	3.56
6	B	Green Scarab	15	2	26.5	30.5	4.89	0.309	0.313	8	0.42	4.0	3.9	0	3.73
6	B	Green Scarab	15	3	23	26	4.89	0.230	0.231	6	0.32	6.0	4.9	0	3.69
6	B	Green Scarab	16	2	32.5	34	4.88	0.424	0.424	3	0.16	3.5	3.5	0	3.55
6	B	Green Scarab	16	3	28.5	31.5	4.9	0.345	0.347	6	0.00	3.5	3.3	10	3.56
6	B	Green Scarab	18	1	30	36	4.88	0.407	0.421	12	0.12	3.0	2.1	11	3.53
6	B	Green Scarab	18	2	26.5	28	4.87	0.285	0.284	3	0.43	3.5	3.1	0	3.63
6	B	Green Scarab	18	3	23.5	26	4.87	0.235	0.235	5	0.17	3.5	2.4	0	3.61
6	B	Green Scarab	21	2	37	39.5	4.89	0.561	0.563	5	0.51	6.0	4.3	7	3.55
6	B	Green Scarab	27	1	47.5	50.5	4.89	0.923	0.923	6	0.00	3.5	3.5	0	3.55
6	B	Green Scarab	27	2	40	44	4.89	0.673	0.679	8	0.14	3.5	3.1	0	3.64
6	B	Green Scarab	27	3	36	39	4.86	0.535	0.538	6	0.00	4.0	3.5	0	3.58
6	B	Green 15 logs	Avg	2	32.0	35.0	4.9	0.4	0.4	6.1	0.2	3.9	3.3	2.3	3.6
													Site	**min**	**3.05**
														max	**3.73**
														avg	**3.43**
														count	**41**

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
7	C	Blue Chiffon	2	1	39.5	44.3	4.94	0.674	0.683	10	0.18	4.0	3.4		0	3.29
7	C	Blue Chiffon	2	2	36	39	4.89	0.538	0.541	6	0.67	4.5	4.1		0	3.39
7	C	Blue Chiffon	2	3	33	35.5	4.88	0.449	0.450	5	0.51	6.0	4.9		0	3.32
7	C	Blue Chiffon	2	4	29	33	4.91	0.366	0.372	8	0.14	4.5	3.8		4	3.18
7	C	Blue Chiffon	5	1	31	34.5	4.94	0.413	0.417	7	0.16	3.5	3.0		0	3.48
7	C	Blue Chiffon	14	1	37.5	43.5	4.9	0.619	0.635	12	0.29	3.0	2.9		0	3.33
7	C	Blue Chiffon	14	3	31.5	34.5	4.91	0.418	0.421	6	0.26	4.0	2.8		0	3.46
7	C	Blue Chiffon	14	4	28.5	31.5	4.9	0.345	0.347	6	0.12	3.5	3.0		0	3.33
7	C	Blue Chiffon	19	1	28.5	32.5	4.91	0.355	0.360	8	0.00	3.0	2.9		9	3.48
7	C	Blue Chiffon	23	1	32	37	4.91	0.451	0.461	10	0.24	3.0	2.9		0	3.48
7	C	Blue Chiffon	26	1	40.5	44.5	4.96	0.699	0.705	8	0.00	4.0	2.5		0	3.44
7	C	Blue Chiffon	26	3	29.5	34	4.89	0.382	0.389	9	0.00	3.5	2.9		4	3.44
7	C	Blue Chiffon	28	4	20	25	4.9	0.193	0.197	10	0.00	4.0	3.5		0	3.38
7	C	Blue Chiffon	29	4	21.5	25.5	4.92	0.212	0.215	8	0.46	4.0	3.3		0	3.46
7	C	Blue Chiffon	30	4	20	24.5	4.91	0.190	0.193	9	0.00	4.0	3.0		0	3.34
7	C	15 logs	Avg	2	30.5	34.6	4.9	0.4	0.4	8.3	0.2	3.9	3.2		1.2	3.4
8	C	Blue Chiffon	3	4	20	23.5	4.92	0.183	0.184	7	0.00	3.0	2.8		0	3.57
8	C	Blue Chiffon	6	1	26	32	4.92	0.317	0.328	12	0.39	2.5	2.4		9	3.55
8	C	Blue Chiffon	14	2	34	37	4.91	0.484	0.487	6	0.37	4.0	3.6		0	3.55
8	C	Blue Chiffon	19	3	20.5	24.5	4.88	0.194	0.196	8	0.54	3.5	3.0		0	3.57
8	C	Blue Chiffon	23	4	22	24.5	4.91	0.209	0.209	5	0.00	3.0	2.4		0	3.59
8	C	Blue Chiffon	26	2	30.3	37	4.91	0.423	0.441	14	0.29	3.5	3.1		0	3.59
8	C	Blue Chiffon	28	1	34	37.5	4.9	0.488	0.493	7	0.00	3.0	2.8		0	3.49
8	C	Blue Chiffon	28	2	29.5	32.5	4.93	0.370	0.373	6	0.00	3.5	2.9		0	3.56
8	C	Blue Chiffon	28	3	25.5	28.5	4.91	0.280	0.282	6	0.00	4.5	3.3		0	3.50
8	C	Blue Chiffon	29	1	37	39	4.93	0.559	0.560	4	0.26	3.5	3.3		0	3.58
8	C	Blue Chiffon	29	2	30	34	4.92	0.391	0.397	8	0.49	2.5	2.0		9	3.57
8	C	Blue Chiffon	29	3	26	30.5	4.9	0.303	0.309	9	0.63	3.0	2.6		0	3.58
8	C	Blue Chiffon	30	2	28.5	31	4.93	0.342	0.343	5	0.12	2.5	2.4		0	3.60
8	C	Blue Chiffon	30	3	25.5	28.5	4.91	0.280	0.282	6	0.00	2.5	2.1		7	3.50
8	C	14 logs	Avg	2	27.8	31.4	4.9	0.3	0.3	7.4	0.2	3.2	2.8		1.8	3.6
9	C	Blue Chiffon	3	1	31.5	37	4.9	0.442	0.454	11	0.14	3.0	2.5		0	3.72
9	C	Blue Chiffon	3	2	27.5	31.5	4.9	0.331	0.336	8	0.22	2.5	2.3		0	3.77

9	C	Blue Chiffon	3	3	24.5	27	4.92	0.256	0.257	5	0.00	4.0	3.4		0	3.70
9	C	Blue Chiffon	5	2	27.5	29.5	4.89	0.312	0.312	4	0.14	4.0	3.1		12	3.69
9	C	Blue Chiffon	5	3	24.5	27	4.9	0.255	0.256	5	0.12	1.5	1.4		4	3.68
9	C	Blue Chiffon	6	2	20.3	26	4.9	0.203	0.209	12	0.57	3.5	3.1		0	3.74
9	C	Blue Chiffon	6	3	20	23.5	4.89	0.182	0.183	7	0.18	3.0	2.5		0	3.64
9	C	Blue Chiffon	9	1	29.5	32	4.93	0.365	0.367	5	0.14	2.5	2.1		0	3.70
9	C	Blue Chiffon	9	2	26	28	4.92	0.282	0.282	4	0.00	2.5	2.1		0	3.72
9	C	Blue Chiffon	9	3	23.5	26	4.91	0.237	0.237	5	0.26	2.5	2.1		4	3.62
9	C	Blue Chiffon	19	2	24.5	26.5	4.91	0.251	0.251	4	0.47	3.5	3.3		6	3.73
9	C	Blue Chiffon	23	2	29	30.5	4.91	0.342	0.342	3	0.16	2.5	2.3		0	3.78
9	C	Blue Chiffon	23	3	25.5	29.5	4.92	0.289	0.294	8	0.00	2.5	2.3		0	3.72
9	C	Blue Chiffon	30	1	31	38	4.91	0.444	0.464	14	0.13	3.0	2.6		0	3.66
9	C	14 logs	Avg	2	26.1	29.4	4.9	0.3	0.3	6.9	0.2	2.9	2.5		1.9	3.7
													Site		**min**	**3.18**
															max	**3.78**
															avg	**3.55**
															count	**43**

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
10	D	Fire Engine Red	1	1	32	37	4.92	0.452	0.462	10	0.15	2.5	2.4		4	3.27
10	D	Fire Engine Red	1	2	30	31	4.89	0.358	0.357	2	0.00	2.5	2.1		0	3.39
10	D	Fire Engine Red	1	3	26	29.5	4.91	0.295	0.298	7	0.00	3.0	2.8		0	3.29
10	D	Fire Engine Red	1	4	22	25.5	4.89	0.216	0.218	7	0.00	4.0	3.0		0	3.18
10	D	Fire Engine Red	7	4	20.5	25.5	5.03	0.207	0.211	10	0.00	3.0	1.9		0	3.37
10	D	Fire Engine Red	12	4	26	31	4.85	0.304	0.312	10	0.00	6.0	5.0		0	3.28
10	D	Fire Engine Red	15	3	29.5	32.5	4.9	0.368	0.371	6	0.12	5.0	4.0		0	3.33
10	D	Fire Engine Red	18	1	33	41.5	4.9	0.511	0.541	17	0.55	3.5	2.9		0	3.40

10	D	Fire Engine Red	18	3	26	28.5	4.92	0.287	0.288	5	0.14	3.5	3.0	0	3.34
10	D	Fire Engine Red	18	4	23	24.5	4.91	0.219	0.218	3	0.45	4.0	3.9	0	3.20
10	D	Fire Engine Red	23	4	18.5	22.5	4.92	0.163	0.164	8	0.00	5.0	4.5	0	3.39
10	D	Fire Engine Red	25	1	28	32	4.9	0.343	0.348	8	0.12	3.0	2.5	10	3.40
10	D	Fire Engine Red	26	4	21.5	26	4.88	0.214	0.218	9	0.12	4.5	3.8	0	3.30
10	D	13 logs	Avg	3	25.8	29.8	4.91	0.303	0.308	8	0.13	3.8	3.2	1.1	3.32
11	D	Fire Engine Red	7	1	31	34	4.92	0.406	0.409	6	0.00	3.0	2.8	0	3.43
11	D	Fire Engine Red	7	2	28	30	4.92	0.325	0.325	4	0.00	1.5	1.5	0	3.48
11	D	Fire Engine Red	7	3	25	27	4.91	0.261	0.261	4	0.00	1.5	1.5	10	3.52
11	D	Fire Engine Red	12	3	29.5	33	4.88	0.371	0.375	7	0.15	6.5	4.4	0	3.48
11	D	Fire Engine Red	15	1	37	44	4.91	0.616	0.637	14	0.29	5.0	4.0	0	3.43
11	D	Fire Engine Red	15	2	34	36	4.89	0.470	0.471	4	0.18	2.5	2.0	2	3.48
11	D	Fire Engine Red	16	3	21	24	4.88	0.195	0.195	6	0.12	4.0	3.0	0	3.44
11	D	Fire Engine Red	18	2	28.5	32.5	4.91	0.355	0.360	8	0.59	3.0	2.8	0	3.48
11	D	Fire Engine Red	21	4	21	24	4.89	0.195	0.195	6	0.00	3.5	3.1	6	3.48
11	D	Fire Engine Red	25	4	18	21.5	4.89	0.151	0.151	7	0.00	4.0	2.6	4	3.50
11	D	Fire Engine Red	26	1	34.5	40	4.89	0.523	0.536	11	0.00	2.5	2.3	0	3.44
11	D	Fire Engine Red	26	2	31.5	33	4.88	0.399	0.399	3	0.00	3.0	2.8	0	3.53
11	D	Fire Engine Red	26	3	26	29.5	4.89	0.294	0.297	7	0.00	3.0	2.9	0	3.48
11	D	13 logs	Avg	2	28.1	31.4	4.90	0.351	0.355	7	0.10	3.3	2.7	1.7	3.47

12	D	Fire Engine Red	12	1	35.5	40	4.88	0.540	0.548	9	0.45	4.0	3.6	0	3.55
12	D	Fire Engine Red	12	2	33	35	4.86	0.441	0.442	4	0.60	3.5	3.3	9	3.60
12	D	Fire Engine Red	16	1	28	34	4.91	0.361	0.374	12	0.00	2.0	1.9	8	3.55
12	D	Fire Engine Red	16	2	26	28	4.9	0.281	0.281	4	0.00	3.0	2.4	0	3.65
12	D	Fire Engine Red	20	1	28	32	4.91	0.343	0.349	8	0.15	2.5	1.9	8	3.55
12	D	Fire Engine Red	20	2	24	27	4.92	0.251	0.252	6	0.14	2.5	2.1	0	3.64
12	D	Fire Engine Red	20	3	22	23.5	4.9	0.201	0.199	3	0.00	2.5	2.1	0	3.56
12	D	Fire Engine Red	21	1	33	36.5	4.89	0.460	0.465	7	0.14	3.5	3.0	0	3.55
12	D	Fire Engine Red	21	2	29	31	4.87	0.344	0.345	4	0.00	3.0	2.8	0	3.66
12	D	Fire Engine Red	21	3	26.5	29.5	4.88	0.299	0.301	6	0.00	3.5	3.1	0	3.62
12	D	Fire Engine Red	23	1	29.5	35.5	4.91	0.397	0.411	12	0.12	3.0	2.6	16	3.75
12	D	Fire Engine Red	23	2	25.5	28	4.9	0.275	0.276	5	0.00	2.0	1.8	0	3.77
12	D	Fire Engine Red	23	3	22.5	25	4.92	0.219	0.219	5	0.12	3.0	2.6	6	3.64
12	D	Fire Engine Red	25	2	25	28	4.87	0.268	0.269	6	0.00	2.5	2.1	0	3.63
12	D	Fire Engine Red	25	3	22	25	4.87	0.211	0.212	6	0.00	3.0	2.9	0	3.56
12	D	15 logs	Avg	2	27.3	30.5	4.9	0.3	0.3	6.6	0.1	2.9	2.5	3.2	3.6
													Site	**min**	**3.18**
														max	**3.77**
														avg	**3.48**
														count	**41**

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
13	E	Liliac Bud	5	1	47.5	54	4.9	0.981	0.995	13	0.00	2.5	2.0		10	3.05
13	E	Liliac Bud	5	4	34	37.5	4.91	0.489	0.494	7	0.00	7.5	5.6		6	3.00
13	E	Liliac Bud	5	5	29	33.5	4.89	0.370	0.377	9	0.12	7.0	5.3		0	2.86
13	E	Liliac Bud	6	1	40.5	49	4.93	0.752	0.782	17	0.14	2.5	2.0		0	3.05
13	E	Liliac Bud	6	4	29.5	34	4.94	0.385	0.393	9	0.14	6.0	5.1		10	2.94
13	E	Liliac Bud	6	5	19	27	4.87	0.195	0.208	16	0.00	6.5	6.1		0	2.90
13	E	Liliac Bud	15	1	45	52	4.93	0.896	0.916	14	0.14	3.0	2.4		0	3.05
13	E	Liliac Bud	15	4	32.5	35	4.9	0.437	0.439	5	0.00	6.0	4.9		0	2.96
13	E	Liliac Bud	15	5	25	33	4.93	0.311	0.332	16	0.00	6.5	5.1		0	2.94
13	E	Liliac Bud	25	4	26	31	4.91	0.308	0.316	10	0.00	7.0	5.5		0	2.97
13	E	Liliac Bud	26	4	23	28.5	4.93	0.252	0.260	11	0.00	6.5	6.3		6	2.89
13	E	Liliac Bud	27	4	29.5	32.5	4.9	0.368	0.371	6	0.00	5.5	5.1		0	3.05
13	E	Liliac Bud	27	5	24.5	28.5	4.89	0.267	0.271	8	0.14	6.0	5.3		0	2.88
13	E	Liliac Bud	30	1	34	39.5	4.9	0.510	0.523	11	0.00	2.0	1.8		0	3.03
13	E	14 logs	Avg	3	31.4	36.8	4.9	0.5	0.5	11.1	0.0	5.3	4.5		2.3	3.0
14	E	Liliac Bud	1	4	19.5	23.5	4.9	0.178	0.179	8	0.00	4.0	3.4		6	3.17
14	E	Liliac Bud	5	2	42.5	46	4.9	0.751	0.755	7	0.47	3.0	2.1		0	3.17
14	E	Liliac Bud	5	3	38.5	41.5	4.91	0.615	0.618	6	0.00	5.5	3.8		0	3.18
14	E	Liliac Bud	6	3	33	37	4.89	0.466	0.472	8	0.18	3.5	3.1		0	3.16
14	E	Liliac Bud	11	1	35	42	4.93	0.557	0.579	14	0.14	4.0	2.8		9	3.19
14	E	Liliac Bud	11	3	28.5	30	4.93	0.332	0.331	3	0.00	3.0	3.0		0	3.21
14	E	Liliac Bud	13	1	38	45.5	4.95	0.658	0.683	15	0.26	3.0	2.5		0	3.18
14	E	Liliac Bud	13	3	29	32	4.91	0.357	0.360	6	0.12	3.5	3.3		9	3.11
14	E	Liliac Bud	25	1	41.5	50	4.95	0.790	0.821	17	0.14	3.0	2.5		0	3.06
14	E	Liliac Bud	26	1	40.5	47.5	4.92	0.732	0.753	14	0.00	6.0	4.3		0	3.16
14	E	Liliac Bud	26	3	31.5	35.5	4.93	0.430	0.436	8	0.15	6.0	5.6		0	3.10
14	E	Liliac Bud	27	1	41.5	46.5	4.9	0.737	0.747	10	0.20	1.5	1.3		0	3.10
14	E	Liliac Bud	30	3	24.5	28	4.9	0.264	0.266	7	0.00	4.5	3.4		0	3.10
14	E	13 logs	Avg	2	34.1	38.8	4.92	0.528	0.538	10	0.13	3.9	3.2		1.9	3.15
15	E	Liliac Bud	1	1	32.5	39.5	4.9	0.483	0.503	14	0.27	4.0	3.0		15	3.33
15	E	Liliac Bud	1	2	28.5	32	4.91	0.350	0.354	7	0.49	3.5	2.4		0	3.43
15	E	Liliac Bud	1	3	24.5	28.5	4.91	0.268	0.272	8	0.18	2.0	1.9		0	3.39
15	E	Liliac Bud	6	2	37.5	40.5	4.9	0.583	0.586	6	0.40	3.0	2.9		8	3.28

15	E	Liliac Bud	11	2	31.5	35	4.92	0.424	0.428	7	0.33	3.5	2.8		0	3.32
15	E	Liliac Bud	13	2	33	39.5	4.92	0.494	0.512	13	0.31	4.0	3.1		0	3.29
15	E	Liliac Bud	15	2	42	44.5	4.92	0.723	0.723	5	0.20	2.5	2.1		0	3.27
15	E	Liliac Bud	15	3	36	40	4.94	0.555	0.562	8	0.00	3.0	2.6		8	3.25
15	E	Liliac Bud	25	2	36.5	40.5	4.93	0.569	0.575	8	0.22	2.5	2.1		0	3.30
15	E	Liliac Bud	25	3	32	38	4.92	0.462	0.477	12	0.00	4.0	3.6		0	3.23
15	E	Liliac Bud	26	2	35	39	4.92	0.524	0.531	8	0.00	3.5	3.3		0	3.34
15	E	Liliac Bud	27	2	36	40.5	4.92	0.559	0.567	9	0.21	3.0	2.4		0	3.32
15	E	Liliac Bud	27	3	33	36	4.87	0.453	0.456	6	0.14	4.0	3.1		0	3.22
15	E	Liliac Bud	30	2	31	34	4.9	0.404	0.407	6	0.00	3.5	2.4		0	3.22
15	E	14 logs	Avg	2	33.5	37.7	4.9	0.5	0.5	8.5	0.2	3.3	2.7		2.3	3.3
													Site		**min**	**2.86**
															max	**3.43**
															avg	**3.14**
															count	**41**

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
16	F	Pink	9	1	29	34.5	4.91	0.380	0.392	11	0.00	3.0	2.4		7	3.23
16	F	Pink	9	3	22.5	26	4.9	0.226	0.227	7	0.00	3.0	2.8		0	3.12
16	F	Pink	10	1	42.5	46	4.9	0.751	0.755	7	0.00	2.5	2.1		15	3.19
16	F	Pink	10	3	31.5	36	4.93	0.435	0.443	9	0.00	3.5	3.3		0	3.21
16	F	Pink	10	4	25.5	30.5	4.9	0.296	0.304	10	0.00	8.5	6.9		0	2.89
16	F	Pink	12	1	39	46.5	4.92	0.687	0.712	15	0.30	3.5	3.1		0	3.25
16	F	Pink	12	2	34.5	38.5	4.89	0.507	0.513	8	0.00	4.0	3.8		8	3.11
16	F	Pink	12	3	27.5	33.5	4.93	0.351	0.364	12	0.00	5.5	4.6		0	3.19
16	F	Pink	18	1	32.5	38	4.91	0.469	0.482	11	0.14	3.0	2.5		16	3.23
16	F	Pink	18	3	25	28.5	4.91	0.274	0.277	7	0.00	4.0	3.4		0	3.11
16	F	Pink	21	1	21.2	26	4.92	0.213	0.217	10	0.00	2.5	1.5		5	3.23
16	F	Pink	23	1	31	36.5	4.94	0.433	0.445	11	0.00	3.5	3.0		0	3.25
16	F	Pink	29	3	18	21.5	4.88	0.151	0.151	7	0.00	3.5	2.9		0	3.25
16	F	13 logs	Avg	2	29.2	34.0	4.91	0.398	0.406	10	0.03	3.8	3.2		4.0	3.17
17	F	Pink	3	2	27	29	4.92	0.303	0.303	4	0.24	3.5	3.1		6	3.36
17	F	Pink	3	3	22.5	26.5	4.91	0.230	0.233	8	0.00	6.0	4.0		0	3.29
17	F	Pink	5	1	30	35.5	4.92	0.405	0.417	11	0.00	3.0	2.8		0	3.34
17	F	Pink	9	2	25.5	29	4.91	0.284	0.288	7	0.00	2.5	2.1		0	3.27

17	F	Pink	10	2	37.5	42	4.98	0.611	0.620	9	0.00	3.0	2.9		4	3.31
17	F	Pink	14	1	28	33	4.93	0.354	0.363	10	0.12	3.5	2.9		0	3.28
17	F	Pink	14	3	21.5	24.5	4.91	0.204	0.205	6	0.12	3.5	3.3		0	3.32
17	F	Pink	15	1	31.5	38.5	4.91	0.457	0.477	14	0.13	4.5	3.8		0	3.34
17	F	Pink	15	3	26.5	29	4.87	0.294	0.295	5	0.00	6.5	5.4		0	3.31
17	F	Pink	18	2	29	32.5	4.9	0.361	0.365	7	0.00	4.0	3.0		5	3.31
17	F	Pink	23	3	23.5	27	4.89	0.244	0.246	7	0.00	3.0	2.3		0	3.30
17	F	Pink	28	3	23	27.5	4.92	0.244	0.248	9	0.15	4.0	3.4		6	3.36
17	F	Pink	28	4	18.5	23	4.9	0.166	0.168	9	0.00	4.0	3.8		0	3.26
17	F	Pink	29	1	24.5	31	4.91	0.288	0.301	13	0.00	2.0	1.9		14	3.32
17	F	14 logs	Avg	2	26.3	30.6	4.9	0.3	0.3	8.6	0.1	3.8	3.2		2.5	3.3
18	F	Pink	2	1	29.5	37.5	4.88	0.412	0.436	16	0.39	4.0	3.3		9	3.41
18	F	Pink	2	2	27	29.5	4.9	0.307	0.308	5	0.44	4.5	4.0		7	3.56
18	F	Pink	2	3	22.5	26.5	4.88	0.229	0.232	8	0.00	4.5	4.3		10	3.39
18	F	Pink	5	2	26.5	29	4.91	0.297	0.298	5	0.12	3.0	2.8		0	3.46
18	F	Pink	8	1	24.5	31	4.91	0.288	0.301	13	0.00	3.0	2.5		0	3.62
18	F	Pink	8	2	22	25.5	4.88	0.216	0.217	7	0.00	2.5	2.0		0	3.68
18	F	Pink	14	2	24	28	4.9	0.258	0.262	8	0.00	3.0	2.6		0	3.45
18	F	Pink	15	2	29.5	32	4.91	0.364	0.365	5	0.12	5.5	4.8		7	3.46
18	F	Pink	21	2	18.5	21.5	4.91	0.156	0.155	6	0.00	2.5	2.0		0	3.43
18	F	Pink	23	2	28	31	4.9	0.333	0.336	6	0.14	3.0	3.0		12	3.38
18	F	Pink	28	1	30	36	4.9	0.408	0.423	12	0.12	3.0	2.4		10	3.54
18	F	Pink	28	2	27	30.5	4.89	0.315	0.319	7	0.00	2.5	2.1		5	3.53
18	F	Pink	29	2	21	25	4.88	0.202	0.204	8	0.00	2.5	2.4		4	3.48
18	F	13 logs	Avg	2	25.4	29.5	4.90	0.291	0.297	8	0.10	3.3	2.9		5.0	3.49
													Site		**min**	**2.89**
															max	**3.68**
															avg	**3.32**
															count	**40**

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
19	G	Vivid Orange	1	3	17.5	21	4.91	0.145	0.144	7	0.00	3.0	2.3		0	3.36
19	G	Vivid Orange	2	1	26.5	30	4.93	0.307	0.310	7	0.00	2.5	2.3		7	3.30

19	G	Vivid Orange	2	2	23	26	4.91	0.231	0.232	6	0.18	3.0	2.6	0	3.36
19	G	Vivid Orange	2	3	19	23	4.9	0.170	0.171	8	0.40	6.0	4.4	6	3.15
19	G	Vivid Orange	6	1	23.5	26	4.91	0.237	0.237	5	0.24	2.5	1.8	10	3.29
19	G	Vivid Orange	8	3	20.5	24	4.9	0.191	0.192	7	0.00	4.5	3.0	0	3.33
19	G	Vivid Orange	9	3	21.5	26	4.92	0.216	0.220	9	0.00	6.0	4.4	5	3.36
19	G	Vivid Orange	15	1	26	32.5	4.92	0.321	0.335	13	0.19	3.5	3.0	14	3.32
19	G	Vivid Orange	15	2	23	26	4.9	0.231	0.232	6	0.00	3.5	2.6	0	3.31
19	G	Vivid Orange	15	3	19.5	23	4.92	0.175	0.176	7	0.26	4.0	3.3	0	3.16
19	G	Vivid Orange	18	3	22	25	4.92	0.214	0.214	6	0.00	3.5	3.3	0	3.29
19	G	Vivid Orange	18	4	17	21.5	4.92	0.144	0.145	9	0.00	4.0	3.9	0	3.13
19	G	Vivid Orange	22	3	17.5	21	4.9	0.144	0.144	7	0.00	3.5	3.1	0	3.28
19	G	Vivid Orange	27	1	25	28.5	4.86	0.271	0.274	7	0.00	1.5	1.5	10	3.32
19	G	14 logs	Avg	2	21.5	25.3	4.9	0.2	0.2	7.6	0.1	3.6	2.9	3.8	3.3
20	G	Vivid Orange	4	3	22	25.5	4.92	0.217	0.219	7	0.16	5.0	4.1	7	3.41
20	G	Vivid Orange	6	2	19	23	4.92	0.171	0.172	8	0.00	2.5	2.0	5	3.46
20	G	Vivid Orange	8	1	27	33	4.91	0.338	0.351	12	0.16	2.5	2.3	9	3.46
20	G	Vivid Orange	8	2	23.5	27.5	4.91	0.249	0.252	8	0.16	3.0	2.5	0	3.52
20	G	Vivid Orange	17	3	19.5	22.5	4.9	0.171	0.171	6	0.00	3.5	2.8	0	3.49
20	G	Vivid Orange	18	1	28.5	32.5	4.93	0.356	0.362	8	0.21	3.0	2.3	0	3.42
20	G	Vivid Orange	18	2	25	28	4.91	0.270	0.272	6	0.38	3.0	2.9	0	3.39

20	G	Vivid Orange	20	2	21	24.5	4.89	0.199	0.200	7	0.00	2.0	1.6	0	3.50
20	G	Vivid Orange	22	1	24	28.5	4.9	0.262	0.267	9	0.19	2.0	1.9	0	3.56
20	G	Vivid Orange	22	2	20.5	24	4.9	0.191	0.192	7	0.20	2.5	2.1	7	3.49
20	G	Vivid Orange	27	2	22	24.5	4.9	0.209	0.209	5	0.19	4.5	3.1	10	3.38
20	G	Vivid Orange	28	1	23	29.5	4.89	0.257	0.269	13	0.20	3.5	2.3	0	3.50
20	G	Vivid Orange	28	2	20	23	4.89	0.178	0.178	6	0.41	3.5	2.9	8	3.46
20	G	13 logs	Avg	2	22.7	26.6	4.91	0.236	0.239	8	0.17	3.1	2.5	3.6	3.47
21	G	Vivid Orange	1	1	24	27.5	4.93	0.255	0.258	7	0.00	1.5	1.5	0	3.65
21	G	Vivid Orange	1	2	22.5	23.5	4.9	0.205	0.204	2	0.33	2.5	2.1	0	3.58
21	G	Vivid Orange	3	1	25	32	4.91	0.302	0.318	14	0.18	2.5	1.9	0	3.66
21	G	Vivid Orange	3	2	20.5	24	4.89	0.190	0.191	7	0.00	2.5	2.3	0	3.57
21	G	Vivid Orange	4	1	29.5	33.5	4.9	0.378	0.383	8	0.36	3.0	2.9	8	3.74
21	G	Vivid Orange	4	2	25.5	28	4.89	0.275	0.275	5	0.65	4.5	3.4	0	3.64
21	G	Vivid Orange	9	1	29	34.5	4.89	0.379	0.390	11	0.12	2.0	2.0	0	3.57
21	G	Vivid Orange	9	2	26	29.5	4.9	0.294	0.298	7	0.00	3.5	3.1	0	3.61
21	G	Vivid Orange	17	1	25	28.5	4.91	0.274	0.277	7	0.38	1.5	1.5	8	3.89
21	G	Vivid Orange	17	2	23	24.5	4.91	0.219	0.218	3	0.38	2.5	2.5	0	3.71
21	G	Vivid Orange	20	1	24	27	4.89	0.249	0.251	6	0.12	2.0	1.6	4	3.71
21	G	Vivid Orange	24	1	23.5	27	4.88	0.243	0.246	7	0.00	2.0	1.8	0	3.75
21	G	Vivid Orange	24	2	20.5	23	4.89	0.183	0.182	5	0.00	2.5	1.9	0	3.67

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
21	G	13 logs	Avg	1	24.5	27.9	4.90	0.265	0.269	7	0.20	2.5	2.2		1.6	3.67
													Site		**min**	**3.13**
															max	**3.89**
															avg	**3.47**
															count	**40**
22	H	Pacific Atol Blue	2	3	17	22	4.88	0.146	0.148	10	0.27	6.0	4.1		0	3.25
22	H	Pacific Atol Blue	6	1	25	31	4.96	0.298	0.309	12	0.00	3.0	2.9		9	3.16
22	H	Pacific Atol Blue	6	2	22	26	4.88	0.219	0.222	8	0.18	4.0	3.3		0	3.23
22	H	Pacific Atol Blue	6	3	16	22	4.92	0.140	0.143	12	0.00	5.0	3.8		0	3.11
22	H	Pacific Atol Blue	8	1	24.5	28.5	4.93	0.269	0.273	8	0.12	2.5	2.3		0	3.33
22	H	Pacific Atol Blue	8	3	16.5	21	4.88	0.136	0.137	9	0.29	3.5	3.3		0	3.23
22	H	Pacific Atol Blue	12	3	18.5	23	4.9	0.166	0.168	9	0.00	4.0	2.4		0	3.28
22	H	Pacific Atol Blue	14	3	18	22	4.9	0.155	0.155	8	0.18	4.0	3.4		0	3.33
22	H	Pacific Atol Blue	19	3	16	21	4.91	0.134	0.134	10	0.20	3.5	3.0		0	3.25
22	H	Pacific Atol Blue	25	1	23	26	4.91	0.231	0.232	6	0.18	2.0	1.9		0	3.32
22	H	Pacific Atol Blue	25	2	19.5	22.5	4.9	0.171	0.171	6	0.00	2.0	1.9		6	3.33
22	H	Pacific Atol Blue	28	1	30.5	37	4.91	0.427	0.443	13	0.26	4.0	2.9		0	3.25
22	H	Pacific Atol Blue	28	3	23	26.5	4.91	0.235	0.237	7	0.61	4.5	3.6		0	3.25
22	H	Pacific Atol Blue	30	1	22	24.5	4.91	0.209	0.209	5	0.18	3.5	3.4		4	3.32
22	H	14 logs	Avg	2	20.8	25.2	4.9	0.2	0.2	8.9	0.2	3.7	3.0		1.4	3.3

23	H	Pacific Atol Blue	1	1	24.5	29	4.91	0.272	0.278	9	0.00	5.0	3.3	0	3.48
23	H	Pacific Atol Blue	1	3	17.5	22	4.9	0.151	0.152	9	0.00	3.0	2.6	0	3.35
23	H	Pacific Atol Blue	2	1	25	29.5	4.9	0.282	0.288	9	0.12	5.0	3.8	0	3.40
23	H	Pacific Atol Blue	8	2	20.5	23.5	4.9	0.187	0.187	6	0.49	4.0	2.8	0	3.40
23	H	Pacific Atol Blue	12	1	25	29	4.93	0.280	0.284	8	0.00	2.0	1.6	0	3.49
23	H	Pacific Atol Blue	13	1	25	30	4.93	0.288	0.295	10	0.00	2.0	1.6	0	3.40
23	H	Pacific Atol Blue	14	1	26.5	30	4.94	0.307	0.311	7	0.30	2.5	2.1	0	3.38
23	H	Pacific Atol Blue	17	1	22.5	26.5	4.9	0.229	0.233	8	0.00	3.0	2.6	0	3.45
23	H	Pacific Atol Blue	19	1	23.5	29	4.94	0.262	0.270	11	0.14	3.0	2.4	0	3.34
23	H	Pacific Atol Blue	19	2	20.5	24	4.91	0.191	0.192	7	0.30	3.5	3.0	0	3.39
23	H	Pacific Atol Blue	24	2	18.5	21.5	4.9	0.156	0.155	6	0.33	2.0	1.6	0	3.49
23	H	Pacific Atol Blue	27	3	18.5	22	4.89	0.159	0.159	7	0.00	3.0	2.8	0	3.48
23	H	Pacific Atol Blue	28	2	26.5	30	4.88	0.304	0.307	7	0.32	4.0	3.3	0	3.37
23	H	13 logs	Avg	2	22.6	26.6	4.91	0.236	0.239	8	0.15	3.2	2.6	0.0	3.42
24	H	Pacific Atol Blue	1	2	22	24	4.9	0.205	0.204	4	0.00	2.0	1.9	0	3.51
24	H	Pacific Atol Blue	2	2	24	25.5	4.9	0.237	0.236	3	0.49	2.0	2.0	0	3.54
24	H	Pacific Atol Blue	12	2	23.5	25	4.91	0.228	0.227	3	0.00	2.0	1.9	0	3.50
24	H	Pacific Atol Blue	13	2	21.5	25.5	4.91	0.212	0.215	8	0.12	2.0	1.5	0	3.50
24	H	Pacific Atol Blue	14	2	22.5	26	4.9	0.226	0.227	7	0.47	3.0	2.3	7	3.54
24	H	Pacific Atol	16	1	22	28.5	4.88	0.238	0.248	13	0.20	4.0	3.3	0	3.62

24	H	Blue Pacific Atol	16	2	19	22.5	4.89	0.166	0.167	7	0.00	3.5	3.1		0	3.67
24	H	Blue Pacific Atol	17	2	19	22	4.9	0.163	0.163	6	0.00	2.0	1.9		0	3.51
24	H	Blue Pacific Atol	23	1	23.5	26.5	4.92	0.241	0.242	6	0.00	3.0	2.4		0	3.55
24	H	Blue Pacific Atol	23	2	20	23.5	5.02	0.187	0.188	7	0.12	2.5	2.0		0	3.53
24	H	Blue Pacific Atol	24	1	21	25	4.92	0.204	0.206	8	0.12	2.0	1.8		0	3.55
24	H	Blue Pacific Atol	27	1	25.5	29	4.88	0.283	0.286	7	0.14	2.0	1.9		5	3.64
24	H	Blue Pacific Atol	27	2	22.5	25	4.9	0.218	0.218	5	0.00	2.0	1.9		0	3.63
24	H	Blue Pacific Atol	30	2	18.5	22.5	4.88	0.162	0.163	8	0.92	3.0	2.8		6	3.50
24	H	Blue 14 logs	Avg	2	21.8	25.0	4.9	0.2	0.2	6.7	0.2	2.5	2.2		1.3	3.6
													Site		**min**	**3.11**
															max	**3.67**
															avg	**3.41**
															count	**41**

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
25	I	White	1	1	36.5	45.5	4.92	0.623	0.657	18	0.00	3.0	2.6		0	3.23
25	I	White	1	4	26	30	4.89	0.298	0.303	8	0.17	7.0	5.3		6	3.25
25	I	White	2	1	28.5	32.5	4.89	0.353	0.359	8	0.13	2.0	1.8		0	3.18
25	I	White	2	3	22.5	25.5	4.91	0.222	0.223	6	0.00	3.0	2.4		0	3.04
25	I	White	2	4	18	22	4.86	0.154	0.154	8	0.00	3.0	2.5		0	2.81
25	I	White	3	4	21.5	23	4.93	0.193	0.192	3	0.00	2.5	2.3		0	3.21
25	I	White	4	4	20	22.5	4.91	0.176	0.175	5	0.12	3.5	3.0		0	3.23
25	I	White	12	4	21	24.5	4.89	0.199	0.200	7	0.00	3.5	2.9		0	3.18
25	I	White	15	4	23	26.5	4.91	0.235	0.237	7	0.33	3.0	2.9		5	3.13
25	I	White	25	1	31.5	38	4.9	0.452	0.469	13	0.00	2.0	1.8		0	3.15
25	I	White	25	3	26.5	27.5	4.87	0.280	0.279	2	0.51	3.5	3.1		0	3.17
25	I	White	25	4	21.5	25	5.05	0.214	0.216	7	0.12	3.5	2.9		0	3.08

25	I	White	29	1	32.5	41	4.92	0.500	0.529	17	0.33	3.0	2.5	9	3.23
25	I	13 logs	Avg	3	25.3	29.5	4.91	0.300	0.307	9	0.13	3.3	2.8	1.6	3.15
26	I	White	1	3	30.5	33.5	4.9	0.392	0.395	6	0.00	4.0	3.4	0	3.42
26	I	White	2	2	25	28	4.93	0.271	0.273	6	0.00	2.0	1.8	0	3.26
26	I	White	3	1	29.5	36	4.87	0.398	0.414	13	0.29	4.0	2.6	0	3.38
26	I	White	3	3	23.5	26.5	4.9	0.240	0.241	6	0.14	3.0	2.3	6	3.42
26	I	White	4	1	26	30.5	4.89	0.302	0.308	9	0.36	3.0	2.4	11	3.44
26	I	White	5	3	19.5	21.5	4.89	0.163	0.162	4	0.00	2.5	2.0	0	3.37
26	I	White	12	1	30.5	36	4.88	0.415	0.427	11	0.20	3.5	2.8	0	3.37
26	I	White	12	3	25.5	27.5	4.87	0.269	0.269	4	0.18	4.5	3.4	0	3.36
26	I	White	15	1	32.5	39.5	4.93	0.486	0.507	14	0.41	1.5	1.5	5	3.35
26	I	White	15	3	27	29.5	4.9	0.307	0.308	5	0.49	3.0	2.3	0	3.33
26	I	White	25	2	28.5	32	4.91	0.350	0.354	7	0.37	3.5	2.5	0	3.27
26	I	White	28	1	31	36	4.91	0.425	0.435	10	0.20	2.5	2.2	0	3.32
26	I	White	29	3	26.5	29.5	4.89	0.300	0.302	6	0.56	3.5	2.8	0	3.32
26	I	White	30	3	21	23.5	4.9	0.192	0.191	5	0.00	2.0	1.9	0	3.40
26	I	14 logs	Avg	2	26.9	30.7	4.9	0.3	0.3	7.7	0.2	3.0	2.4	1.6	3.4
27	I	White	1	2	34	36.5	4.9	0.477	0.479	5	0.12	3.0	2.4	0	3.54
27	I	White	3	2	26.5	29.5	4.9	0.301	0.303	6	0.00	2.0	1.6	0	3.49
27	I	White	4	2	24	28	4.88	0.257	0.261	8	0.00	2.0	1.6	0	3.62
27	I	White	4	3	22.5	25.5	4.9	0.222	0.223	6	0.00	2.0	2.0	0	3.51
27	I	White	5	1	24.5	29.5	4.92	0.277	0.284	10	0.00	1.5	1.5	0	3.50
27	I	White	5	2	21.5	24	4.87	0.199	0.199	5	0.12	1.5	1.4	0	3.59
27	I	White	12	2	27.5	30	4.93	0.320	0.321	5	0.12	2.5	2.3	4	3.49
27	I	White	15	2	29.5	33	4.92	0.374	0.379	7	0.51	2.5	2.4	0	3.52
27	I	White	28	2	26.5	29.5	4.91	0.301	0.303	6	0.12	2.0	1.6	0	3.62
27	I	White	28	3	24	27.5	4.92	0.255	0.257	7	0.00	2.5	2.3	0	3.48
27	I	White	29	2	29.5	33	4.87	0.371	0.375	7	0.84	2.5	1.9	0	3.47
27	I	White	30	1	27.5	29	4.9	0.308	0.307	3	0.36	3.0	2.4	0	3.51
27	I	White	30	2	23.5	26	4.9	0.236	0.236	5	0.77	2.5	2.1	0	3.58
27	I	13 logs	Avg	2	26.2	29.3	4.90	0.300	0.302	6	0.23	2.3	2.0	0.3	3.53
													Site	**min**	**2.81**
														max	**3.62**
														avg	**3.35**
														count	**40**

Batch No.	Site	Colour	Tree	LHC	SED (cm)	LED (cm)	Length (m)	Volume 3D (m^3)	Volume Smalians (m^3)	Taper (mm/m)	Internode index	Branch Max (mm)	Branch Index (cm)	Sweep (mm)	Sweep (mm/m)	DIRECTOR velocity km/s
28	J	Dazzle Yellow	5	1	30	38.5	4.91	0.432	0.459	17	0.26	3.0	2.6		0	2.79
28	J	Dazzle Yellow	5	2	29	32.5	4.92	0.363	0.367	7	0.18	4.0	3.5		0	2.97
28	J	Dazzle Yellow	5	3	24.5	29	4.93	0.273	0.279	9	0.12	5.0	4.0		0	2.89
28	J	Dazzle Yellow	5	4	20	24.5	4.93	0.191	0.194	9	0.25	5.5	4.6		0	2.68
28	J	Dazzle Yellow	7	3	26.5	29.5	4.94	0.303	0.305	6	0.19	4.0	3.4		0	3.05
28	J	Dazzle Yellow	7	4	22	25.5	4.9	0.217	0.218	7	0.00	4.0	3.9		0	2.94
28	J	Dazzle Yellow	10	1	25	29	4.92	0.279	0.283	8	0.00	4.0	3.5		14	3.02
28	J	Dazzle Yellow	10	3	18	21	4.9	0.148	0.147	6	0.00	3.0	2.6		6	3.01
28	J	Dazzle Yellow	15	1	31	39	4.94	0.456	0.481	16	0.12	3.0	2.9		7	3.01
28	J	Dazzle Yellow	18	1	34.5	42	4.91	0.546	0.570	15	0.00	2.5	2.3		13	2.95
28	J	Dazzle Yellow	18	3	26.5	30	4.87	0.303	0.306	7	0.00	3.5	3.0		7	2.99
28	J	Dazzle Yellow	18	4	22.5	26.5	4.91	0.230	0.233	8	0.00	6.0	5.5		11	2.81
28	J	Dazzle Yellow	24	1	26.5	31.5	4.93	0.320	0.328	10	0.12	3.0	2.3		0	3.03
28	J	Dazzle Yellow	24	3	20	23	4.92	0.180	0.179	6	0.00	3.0	2.6		0	2.97
28	J	14 logs	Avg	2	25.4	30.1	4.9	0.3	0.3	9.5	0.1	3.8	3.3		4.2	2.9
29	J	Dazzle Yellow	7	1	32.5	37.5	4.9	0.463	0.474	10	0.00	2.5	1.8		0	3.22
29	J	Dazzle Yellow	10	2	24	25.5	4.91	0.237	0.236	3	0.27	3.0	2.8		8	3.23
29	J	Dazzle	11	1	23	28.5	4.92	0.251	0.259	11	0.00	1.5	1.5		0	3.16

29	J	Yellow Dazzle	11	2	20.5	23	4.92	0.184	0.183	5	0.00	2.0	2.0	0	3.23
29	J	Yellow Dazzle	11	3	18	20.5	4.91	0.145	0.144	5	0.00	2.0	1.8	0	3.16
29	J	Yellow Dazzle	12	1	25.5	29.5	4.92	0.289	0.294	8	0.00	1.5	1.5	0	3.11
29	J	Yellow Dazzle	14	1	29	34.5	4.91	0.380	0.392	11	0.37	3.0	2.5	10	3.18
29	J	Yellow Dazzle	15	2	26.5	31	4.92	0.315	0.321	9	0.34	3.5	3.1	0	3.20
29	J	Yellow Dazzle	15	3	22.5	27	4.91	0.234	0.238	9	0.00	4.0	3.4	0	3.11
29	J	Yellow Dazzle	18	2	30.1	33.5	4.91	0.387	0.391	7	0.29	3.0	2.6	0	3.13
29	J	Yellow Dazzle	24	2	24	25.5	4.92	0.238	0.237	3	0.12	2.5	2.1	0	3.13
29	J	Yellow Dazzle	29	1	24.5	31	4.92	0.289	0.302	13	0.00	4.0	2.4	10	3.20
29	J	Yellow Dazzle	29	3	21	21.5	4.9	0.175	0.174	1	0.00	2.5	2.3	8	3.19
29	J	13 logs	Avg	2	24.7	28.3	4.91	0.276	0.280	7	0.11	2.7	2.3	2.8	3.17
30	J	Dazzle	7	2	30	32	4.93	0.372	0.372	4	0.14	3.0	2.6	0	3.24
30	J	Yellow Dazzle	12	2	23	25.5	4.9	0.227	0.227	5	0.00	2.5	2.3	9	3.24
30	J	Yellow Dazzle	14	2	26	28.5	4.9	0.286	0.286	5	0.57	3.5	3.3	0	3.47
30	J	Yellow Dazzle	14	3	23	25.5	4.91	0.227	0.227	5	0.46	4.0	3.6	0	3.25
30	J	Yellow Dazzle	16	1	22	26.5	4.9	0.224	0.228	9	0.18	2.0	1.6	0	3.40
30	J	Yellow Dazzle	16	2	19.5	22.5	4.91	0.171	0.171	6	0.12	2.0	1.9	0	3.46
30	J	Yellow Dazzle	16	3	16.5	19.5	4.9	0.127	0.126	6	0.20	3.0	2.3	5	3.35
30	J	Yellow Dazzle	21	1	23	27.5	4.91	0.243	0.248	9	0.27	2.5	2.0	0	3.46
30	J	Yellow Dazzle	21	2	19.5	22.5	4.92	0.172	0.171	6	0.30	3.0	2.4	0	3.46

30	J	Yellow Dazzle	22	1	23.5	30	4.91	0.268	0.280	13	0.00	3.0	2.3	5	3.36
30	J	Yellow Dazzle	22	2	20.1	23.5	4.91	0.184	0.184	7	0.40	3.0	2.1	0	3.43
30	J	Yellow Dazzle	22	3	17.5	20.5	4.91	0.141	0.140	6	0.00	3.0	2.6	4	3.29
30	J	Yellow Dazzle	29	2	22	25.5	4.91	0.217	0.219	7	0.52	2.5	2.1	9	3.34
30	J	Yellow 13 logs	Avg	2	22.0	25.3	4.91	0.220	0.222	7	0.24	2.8	2.4	2.5	3.36
													Site	**min**	**2.68**
														max	**3.47**
														avg	**3.15**
														count	**40**

APPENDIX B. ADJUSTED GRADE RECOVERIES, BY STAND DENSITY, AGE AND SONIC SORT

Low Density Stand Age 23 years

Porters	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.030	11%	0.038	4%	0.030	2%	0.038	1%
MGP 12	0.034	5%	0.034	2%	0.128	24%	0.150	13%	0.131	49%	0.210	22%	0.293	20%	0.395	11%
MGP 10	0.338	53%	0.622	45%	0.213	40%	0.601	51%	0.076	28%	0.469	49%	0.627	43%	1.692	48%
F4	0.239	38%	0.679	49%	0.197	37%	0.424	36%	0.032	12%	0.246	26%	0.469	32%	1.348	38%
Reject	0.024	4%	0.042	3%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.024	2%	0.042	1%
Total	0.635	100%	1.377	100%	0.538	100%	1.175	100%	0.270	100%	0.963	100%	1.443	100%	3.515	100%

Low Density Stand Age 26 years

Emersons	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.000	0%	0.000	0%	0.039	7%	0.054	4%	0.031	15%	0.209	15%	0.070	5%	0.263	6%
MGP 12	0.296	47%	0.328	26%	0.318	53%	0.607	42%	0.077	38%	0.644	45%	0.692	48%	1.580	38%
MGP 10	0.217	34%	0.544	43%	0.087	15%	0.479	33%	0.063	31%	0.415	29%	0.366	26%	1.438	35%
F4	0.124	19%	0.394	31%	0.151	25%	0.319	22%	0.031	15%	0.151	11%	0.306	21%	0.864	21%
Reject	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%
Total	0.637	100%	1.266	100%	0.595	100%	1.460	100%	0.202	100%	1.419	100%	1.434	100%	4.145	100%

Low Density Stand Age 33 years

Myora HQ	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.000	0%	0.000	0%	0.015	1%	0.015	1%	0.000	0%	0.015	1%	0.015	1%	0.030	0%
MGP 12	0.103	10%	0.103	5%	0.275	22%	0.606	24%	0.074	32%	0.601	24%	0.451	18%	1.310	19%
MGP 10	0.602	61%	1.269	62%	0.733	59%	1.483	59%	0.061	27%	1.425	58%	1.396	57%	4.176	59%
F4	0.182	19%	0.581	28%	0.183	15%	0.381	15%	0.093	41%	0.414	17%	0.457	19%	1.377	20%
Reject	0.094	10%	0.094	5%	0.030	2%	0.030	1%	0.000	0%	0.021	1%	0.125	5%	0.146	2%
Total	0.980	100%	2.048	100%	1.237	100%	2.516	100%	0.227	100%	2.475	100%	2.444	100%	7.039	100%

Medium Density Stand Age 25 years

Nangeela	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.000	0%	0.000	0%	0.061	9%	0.061	6%	0.058	24%	0.073	8%	0.119	8%	0.134	4%
MGP 12	0.166	30%	0.266	24%	0.258	37%	0.316	30%	0.046	19%	0.350	38%	0.469	32%	0.932	30%
MGP 10	0.190	34%	0.549	50%	0.197	28%	0.437	42%	0.046	19%	0.348	38%	0.433	29%	1.333	44%
F4	0.196	36%	0.287	26%	0.183	26%	0.228	22%	0.089	37%	0.149	16%	0.468	31%	0.664	22%
Reject	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%
Total	0.552	100%	1.102	100%	0.699	100%	1.042	100%	0.239	100%	0.920	100%	1.490	100%	3.064	100%

Medium Density Stand Age 28 years

Kongorong	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.000	0%	0.000	0%	0.015	2%	0.015	1%	0.055	15%	0.137	11%	0.070	4%	0.153	3%
MGP 12	0.168	22%	0.249	14%	0.244	40%	0.565	34%	0.132	36%	0.477	37%	0.545	32%	1.292	28%
MGP 10	0.396	53%	1.093	63%	0.230	38%	0.779	47%	0.105	28%	0.482	38%	0.731	42%	2.354	50%
F4	0.183	25%	0.394	23%	0.122	20%	0.304	18%	0.076	21%	0.184	14%	0.381	22%	0.882	19%
Reject	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%

Total	0.747	100%	1.736	100%	0.611	100%	1.664	100%	0.369	100%	1.281	100%	1.726	100%	4.681	100%

APPENDIX A (cont). Adjusted grade recoveries, by stand density, age, and sonic sort.

Medium Density Stand Age 31 years																
Kentbruck	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent		Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.029	7%	0.029	2%	0.076	14%	0.167	11%	0.134	21%	0.400	24%	0.239	15%	0.596	13%
MGP 12	0.161	40%	0.396	30%	0.250	48%	0.612	40%	0.198	31%	0.583	35%	0.608	39%	1.591	35%
MGP 10	0.121	30%	0.688	52%	0.122	23%	0.623	41%	0.228	36%	0.593	35%	0.471	30%	1.905	42%
F4	0.092	23%	0.198	15%	0.076	14%	0.121	8%	0.077	12%	0.107	6%	0.244	16%	0.427	9%
Reject	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%
Total	0.403	100%	1.311	100%	0.523	100%	1.524	100%	0.637	100%	1.683	100%	1.563	100%	4.518	100%

Medium Density Stand Age 37 years																
Longs	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.102	9%	0.102	5%	0.015	2%	0.030	1%	0.039	8%	0.097	4%	0.156	7%	0.229	4%
MGP 12	0.329	31%	0.601	30%	0.136	22%	0.795	38%	0.160	33%	0.685	31%	0.625	29%	2.081	33%
MGP 10	0.299	28%	0.818	40%	0.228	37%	0.672	33%	0.122	25%	0.779	35%	0.649	30%	2.269	36%
F4	0.280	26%	0.439	22%	0.236	38%	0.570	28%	0.137	28%	0.604	28%	0.653	30%	1.613	26%
Reject	0.065	6%	0.065	3%	0.000	0%	0.000	0%	0.030	6%	0.030	1%	0.095	4%	0.095	2%
Total	1.076	100%	2.025	100%	0.615	100%	2.068	100%	0.488	100%	2.195	100%	2.179	100%	6.287	100%

High Density Stand Age 27 years																
Byjuke	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.059	13%	0.059	6%	0.050	13%	0.074	8%	0.204	31%	0.241	23%	0.313	21%	0.374	12%
MGP 12	0.150	34%	0.288	28%	0.182	47%	0.378	40%	0.183	28%	0.342	32%	0.514	35%	1.008	33%
MGP 10	0.137	31%	0.546	52%	0.092	24%	0.364	39%	0.184	28%	0.365	35%	0.412	28%	1.274	42%
F4	0.092	21%	0.153	15%	0.062	16%	0.123	13%	0.090	14%	0.105	10%	0.244	16%	0.382	13%
Reject	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%
Total	0.438	100%	1.046	100%	0.385	100%	0.940	100%	0.660	100%	1.053	100%	1.483	100%	3.038	100%

High Density Stand Age 32 years																
McGillivray's	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.134	12%	0.202	9%	0.098	21%	0.287	17%	0.195	50%	0.542	39%	0.428	22%	1.032	20%
MGP 12	0.485	45%	0.883	41%	0.197	43%	0.694	41%	0.105	27%	0.301	22%	0.787	41%	1.879	36%
MGP 10	0.207	19%	0.652	31%	0.122	26%	0.547	32%	0.045	12%	0.361	26%	0.374	19%	1.559	30%
F4	0.196	18%	0.333	16%	0.043	9%	0.164	10%	0.031	8%	0.169	12%	0.270	14%	0.666	13%
Reject	0.062	6%	0.062	3%	0.000	0%	0.000	0%	0.015	4%	0.015	1%	0.076	4%	0.076	1%
Total	1.084	100%	2.132	100%	0.459	100%	1.693	100%	0.391	100%	1.387	100%	1.934	100%	5.212	100%

High Density Stand Age 44 years																
Caroline HQ	Low Sonic Sort				Medium Sonic Sort				High Sonic Sort				Site Total			
Grade	Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs		Butt Logs		All Logs	
	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent	Volume	Percent
MGP 15	0.090	76%	0.181	11%	0.312	28%	0.599	25%	0.574	59%	1.217	46%	0.976	44%	1.996	30%
MGP 12	0.029	24%	0.644	39%	0.431	38%	1.042	43%	0.210	22%	0.928	35%	0.670	30%	2.614	39%
MGP 10	0.000	0%	0.782	48%	0.300	26%	0.669	27%	0.152	16%	0.456	17%	0.452	20%	1.907	28%
F4	0.000	0%	0.031	2%	0.090	8%	0.123	5%	0.031	3%	0.062	2%	0.122	5%	0.217	3%
Reject	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%
Total	0.119	100%	1.638	100%	1.134	100%	2.433	100%	0.966	100%	2.663	100%	2.220	100%	6.734	100%

APPENDIX C. STRENGTH AND STIFFNESS CALCULATIONS

The following equations have been used to calculate the mechanical properties.
Modulus of rupture (MoRj), modulus of elasticity as a plank (MoEp), modulus of elasticity as a joist (MoEj), were calculated from the formulae:

$$MoRj_{(MPa)} = \frac{PL}{bd^2} \text{ ....[1]}$$

$$MoEp_{(GPa)} = \frac{L^3}{4db^3} X \frac{P}{\Delta} X \frac{1}{1000} \text{ ....[2]}$$

$$MoEj_{(GPa)} = (P/\Delta)\frac{23L^3}{108bd^3} X \frac{1}{1000} \text{ ....[3]}$$

Where:

P = maximum load
(P/ Δ) = slope of the linear portion of the load/deflection graph
b = section thickness
d = section depth
L = test span, for MoEp, 914.4mm,
= test span, for MoRj, MoEj, 1620mm for the 90x45 size

The characteristic normalised stresses have been derived following the procedures of AS/NZS 4063. $R_{k,norm}$ is the characteristic strength value while E_k is the characteristic MoE. The characteristic strength is the fifth percentile value of the measured data estimated with 75% confidence and is given by the following equation:

$$R_k = \left[1 - \left(\frac{2.7V_R}{\sqrt{n}}\right)\right] R_{0.05} \text{ ....[4]}$$

Where:

V_R = coefficient of variation of the measured data
n = sample size
$R_{0.05}$= fifth percentile value of the measured data

The normalised characteristic strength ($R_{k,norm}$) is given by the following equation:

$$R_{k,norm} = \frac{1.35}{\phi} \frac{R_k}{(1.3 + 0.7V_R)} \text{ ....[5]}$$

Where:

ϕ = capacity factor specified in the limit state code, 0.8

The characteristic modulus of elasticity (E_k) is given by the lesser of the values calculated from the following two equations:

$$E_k = \left[1 - \left(\frac{0.7V_E}{\sqrt{n}}\right)\right] E_{Mean} \text{ ....[6]}$$

$$E_k = 1.5\left[1 - \left(\frac{2.7V_E}{\sqrt{n}}\right)\right] E_{0.05} \text{ ....[7]}$$

Where:

E_{mean}, $E_{0.05}$ and V_E refer to the average value, five-percentile value and coefficient of variation of the data.

APPENDIX D. RAW LABORATORY TEST DATA

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
213235	h4b	35.60	90.14	105.99	3.69	3.68	17.49	3123	Reject
213239	h4b	35.37	90.08	110.51	3.84	3.87	19.16	3395	Reject
213244	h4b	35.32	90.16	221.50	4.14	7.75	45.62	8085	Reject
213250	h13b	35.58	90.15	168.08	2.91	5.84	30.37	5421	Reject
213253	h13b	35.50	89.96	144.38	3.81	5.06	23.67	4197	Reject
213254	h13b	35.54	90.01	107.32	4.16	3.75	13.23	2352	Reject
213255	h13b	35.46	90.35	271.45	4.03	9.40	51.95	9283	Reject
213257	h22b	35.31	89.88	90.67	4.09	3.20	13.00	2290	Reject
213258	h22b	35.47	90.03	164.77	3.84	5.76	17.09	3033	Reject
213259	h22b	35.37	90.17	270.62	3.92	9.45	58.16	10325	Reject
213260	h13b	35.37	90.04	88.21	3.87	3.09	22.03	3899	Reject
213261	h22b	35.46	89.93	83.10	3.87	2.92	7.08	1253	Reject
213262	h22b	35.45	89.73	89.28	3.68	3.16	16.05	2828	Reject
213280	h5b	35.05	90.03	147.67	4.13	5.23	21.33	3741	Reject
213282	h14b	35.52	89.98	138.66	3.53	4.85	22.00	3906	Reject
213283	h14b	35.35	90.06	175.95	2.68	6.17	17.53	3102	Reject
213284	h14b	35.42	90.06	151.66	2.99	5.31	12.95	2297	Reject
213285	h14b	34.46	89.93	168.77	4.25	6.10	30.12	5181	Reject
213292	h14b	35.42	90.10	105.95	4.16	3.70	11.14	1978	Reject
213302	h6	35.23	90.16	123.92	4.17	4.35	10.77	1905	Reject
213303	h6b	35.07	90.22	117.59	3.92	4.13	27.23	4797	Reject
213304	h6b	35.09	90.07	100.91	2.59	3.56	13.06	2296	Reject
213305	h6	34.98	90.17	140.66	4.15	4.97	13.54	2377	Reject
213310	h6b	35.33	89.99	304.25	2.59	10.70	46.41	8196	Reject
213317	h15b	34.80	89.90	180.74	4.17	6.47	22.07	3831	Reject
213342	h10b	34.91	89.98	289.96	4.25	10.32	65.42	11414	Reject
213034	s7b	35.37	90.32	316.28	2.40	10.99	34.60	6162	Reject
213228	h17b	34.79	89.79	178.99	5.55	6.43	19.55	3385	F4
213229	h26	34.79	89.74	157.87	4.96	5.68	27.40	4738	F4
213230	h26	34.76	89.88	183.09	5.09	6.57	39.66	6874	F4
213231	h26b	34.76	89.81	268.33	5.46	9.65	37.02	6408	F4
213234	h4b	35.62	90.07	150.36	5.37	5.23	34.03	6070	F4
213236	h2cb	34.91	89.81	154.19	5.68	5.52	20.70	3598	F4
213237	h4b	35.48	90.04	141.37	4.53	4.94	48.79	8662	F4
213238	h4b	35.31	90.46	182.54	4.50	6.32	43.43	7746	F4
213240	h4b	35.65	90.24	134.58	5.00	4.65	30.43	5453	F4
213241	h4b	35.69	89.90	306.29	5.56	10.69	58.31	10383	F4
213242	h4b	35.35	90.17	81.62	6.13	2.85	10.17	1805	F4
213243	h4b	35.54	90.58	127.71	5.45	4.38	41.57	7483	F4
213245	h13	35.24	89.76	175.35	5.11	6.23	28.97	5077	F4
213246	h13	35.40	89.88	161.32	4.74	5.68	35.76	6313	F4
213247	h22	35.47	90.00	179.95	6.79	6.30	22.10	3920	F4
213248	h13	35.32	89.72	173.65	5.82	6.16	19.07	3347	F4
213249	h13b	34.00	89.83	187.99	5.89	6.91	42.26	7157	F4
213251	h27b	35.50	89.95	116.47	5.70	4.08	11.84	2099	F4
213252	h13b	35.58	90.14	245.02	5.14	8.51	59.16	10557	F4
213256	h22	35.84	90.09	199.12	6.06	6.88	37.01	6646	F4
213263	h19b	35.41	89.96	170.47	5.61	5.99	22.13	3915	F4
213264	h22b	35.55	90.02	162.60	4.49	5.68	40.98	7287	F4
213266	h19b	35.42	89.81	243.06	5.58	8.58	41.51	7320	F4

APPENDIX D (cont). Raw Laboratory Test Data.

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
213267	h19b	35.61	89.86	187.25	5.97	6.56	39.67	7042	F4
213268	h16	35.38	89.85	64.29	4.61	2.27	5.85	1031	F4
213269	h16	35.54	89.98	202.69	5.59	7.09	38.23	6791	F4
213270	h16b	35.57	89.88	174.26	5.24	6.11	27.70	4914	F4
213271	h5	35.30	89.98	205.97	5.76	7.25	29.56	5214	F4
213272	h5	35.42	89.99	198.37	5.77	6.96	24.28	4299	F4
213273	h5	35.45	89.82	206.94	4.70	7.29	32.80	5791	F4
213274	h5	35.47	90.06	151.36	4.49	5.29	22.72	4035	F4
213275	h5b	35.32	90.08	88.89	5.11	3.12	12.27	2171	F4
213276	h5b	35.45	89.86	147.82	5.09	5.20	32.69	5777	F4
213277	h5b	35.30	89.79	209.23	5.07	7.41	20.02	3518	F4
213278	h5b	35.03	89.76	111.63	4.51	3.99	28.46	4958	F4
213279	h5b	35.54	90.04	122.88	4.52	4.29	9.19	1634	F4
213281	h14b	33.92	89.38	135.04	5.41	5.05	18.70	3127	F4
213286	h14b	35.37	90.04	294.58	5.86	10.33	46.59	8246	F4
213287	h14b	35.36	89.91	242.16	4.55	8.53	55.29	9757	F4
213288	h11b	35.33	90.20	157.26	5.74	5.49	20.22	3587	F4
213289	h23b	35.46	90.51	129.84	4.33	4.47	22.28	3996	F4
213290	h23b	35.34	90.11	238.17	5.86	8.34	53.99	9564	F4
213291	h27b	35.65	90.12	211.31	5.77	7.33	59.49	10632	F4
213293	h11b	35.48	90.05	243.94	5.79	8.52	43.29	7688	F4
213294	h11b	35.40	90.35	131.61	4.61	4.56	15.36	2740	F4
213295	h6	34.96	89.77	185.95	5.61	6.66	27.42	4768	F4
213296	h6	34.71	90.01	163.55	5.27	5.85	19.66	3413	F4
213297	h6	35.00	89.89	160.57	4.85	5.72	21.23	3706	F4
213298	h6	34.76	89.93	168.56	5.13	6.04	45.72	7934	F4
213299	h6	34.87	89.97	230.90	4.90	8.23	23.72	4132	F4
213300	h11b	35.54	90.06	223.86	5.22	7.81	37.39	6653	F4
213301	h23b	35.45	89.82	254.15	5.51	8.96	40.24	7104	F4
213306	h6	34.84	90.18	190.07	5.83	6.74	30.05	5256	F4
213307	h6b	35.41	89.90	208.19	4.86	7.33	21.41	3783	F4
213308	h6b	35.12	89.90	150.40	5.70	5.34	19.24	3371	F4
213309	h6b	35.09	90.04	244.87	5.44	8.66	41.98	7373	F4
213311	h6b	35.13	90.06	147.24	4.71	5.20	15.68	2758	F4
213312	h15	34.90	90.01	179.67	4.72	6.39	19.75	3447	F4
213314	h15b	34.89	90.00	197.24	6.83	7.02	25.53	4454	F4
213315	h28	34.89	90.03	166.41	4.83	5.92	24.60	4294	F4
213316	h15	33.30	89.88	186.41	7.30	6.98	39.34	6533	F4
213318	h15b	34.60	89.96	125.13	4.61	4.50	15.59	2694	F4
213320	h21b	34.87	89.88	143.56	5.60	5.13	17.24	2998	F4
213321	h28	34.99	90.00	180.35	6.92	6.40	20.65	3613	F4
213322	h28	33.89	89.79	177.85	6.86	6.56	18.42	3106	F4
213323	h28	35.14	90.05	137.72	4.88	4.86	22.97	4041	F4
213324	h28	35.17	90.10	142.42	5.20	5.01	17.57	3097	F4
213325	h28	34.98	90.01	159.38	5.34	5.66	30.75	5379	F4
213326	h28	34.95	90.17	192.53	7.04	6.80	45.32	7950	F4
213327	h28	35.03	89.88	149.58	6.00	5.32	33.24	5806	F4
213328	h28	35.16	90.01	162.74	5.16	5.75	38.25	6726	F4
213329	h28	34.83	89.97	169.42	4.73	6.05	44.28	7707	F4
213330	h28b	35.18	89.94	113.77	5.24	4.02	32.74	5751	F4

APPENDIX D (cont). Raw Laboratory Test Data**.**

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
213331	h28b	35.25	90.02	173.51	5.70	6.11	44.37	7824	F4
213332	h28b	34.99	89.96	160.48	5.48	5.70	34.17	5973	F4
213333	h28b	35.08	90.15	118.47	4.58	4.17	45.61	8027	F4
213334	h28b	35.02	89.95	135.90	4.53	4.83	21.25	3718	F4
213335	h28b	34.97	90.10	131.71	4.60	4.66	27.83	4878	F4
213336	h10b	35.71	90.26	175.13	6.67	6.04	41.07	7375	F4
213338	h22b	35.31	90.03	154.24	5.54	5.42	19.26	3402	F4
213340	h10b	34.88	90.05	193.06	5.64	6.86	25.12	4385	F4
213341	h10b	35.01	90.06	120.36	4.78	4.26	21.62	3790	F4
213343	h10b	34.93	90.15	155.73	5.23	5.51	28.53	4999	F4
213344	h22b	34.71	89.99	185.65	5.49	6.65	16.29	2827	F4
213345	h22b	35.21	89.82	209.21	4.49	7.42	23.28	4082	F4
213346	h22b	34.87	90.05	188.52	6.13	6.70	28.49	4973	F4
213347	h22b	34.94	90.14	182.57	7.74	6.46	35.78	6270	F4
212989	s16	35.19	89.37	284.72	7.27	10.26	27.23	4725	F4
212994	s16	35.21	89.64	183.83	7.73	6.56	19.72	3444	F4
212995	s16	35.47	90.14	190.57	7.30	6.64	28.46	5063	F4
213003	s16b	35.40	90.11	253.64	7.09	8.87	26.90	4773	F4
213004	s16b	35.62	90.24	189.05	6.17	6.54	29.86	5346	F4
213005	s16b	35.54	90.21	217.43	6.89	7.55	21.37	3816	F4
213006	s16b	35.27	90.25	190.53	6.73	6.65	31.02	5501	F4
213009	s12b	35.31	90.15	186.67	7.10	6.53	20.28	3592	F4
213026	s8b	35.14	90.17	246.70	7.26	8.67	25.92	4571	F4
213027	s7	34.85	89.87	303.65	6.59	10.87	45.03	7824	F4
213030	s7	33.74	90.06	329.19	7.53	12.09	53.73	9077	F4
213035	s7b	35.28	90.23	173.70	5.96	6.07	8.47	1502	F4
213037	s14	35.15	90.14	183.16	5.96	6.44	10.86	1914	F4
213038	s14	35.30	90.00	209.03	7.29	7.35	40.63	7172	F4
213049	s14b	35.34	90.20	241.91	6.99	8.45	35.07	6225	F4
213056	h25	35.51	89.93	220.86	7.75	7.74	29.54	5236	F4
213057	h25	35.40	89.92	157.15	5.71	5.53	24.89	4397	F4
213058	h25	35.40	89.99	240.52	7.37	8.44	42.15	7458	F4
213059	h25	35.65	89.87	245.89	6.41	8.60	45.07	8010	F4
213060	h25	35.60	90.11	197.65	7.62	6.87	44.77	7988	F4
213061	h25	35.50	89.93	192.46	7.18	6.75	26.97	4780	F4
213062	h25	35.46	89.99	184.64	7.47	6.47	35.65	6320	F4
213064	h25	35.51	89.93	175.59	6.96	6.16	28.51	5053	F4
213068	h25	35.48	89.90	193.20	6.30	6.79	28.33	5014	F4
213071	h25b	35.49	90.09	187.42	6.96	6.54	31.02	5516	F4
213073	h25b	35.78	90.05	174.84	6.67	6.06	25.50	4567	F4
213074	h25b	35.73	90.09	194.50	6.35	6.74	27.34	4894	F4
213075	h25b	35.53	89.92	267.97	6.25	9.39	39.98	7089	F4
213078	h1	35.37	89.97	215.42	6.19	7.57	32.18	5687	F4
213080	h25b	35.51	90.12	219.06	6.77	7.63	23.29	4145	F4
213084	h1	35.57	90.18	275.65	7.66	9.57	40.76	7279	F4
213093	h30	35.67	90.08	162.05	6.86	5.63	13.03	2329	F4
213094	h30	35.56	90.16	193.83	7.17	6.73	45.85	8181	F4
213097	h30	35.43	89.91	158.36	5.91	5.57	34.54	6107	F4
213098	h30	35.52	90.07	155.63	6.04	5.43	28.25	5026	F4
213101	h30	35.54	90.15	186.98	6.91	6.50	38.61	6885	F4

APPENDIX D (cont). Raw Laboratory Test Data**.**

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
213102	h30	35.27	89.90	216.74	7.41	7.66	29.14	5127	F4
213104	h30	35.56	89.92	210.42	7.65	7.37	21.91	3888	F4
213105	h30	35.61	90.13	144.00	5.93	5.00	25.58	4567	F4
213107	h30b	35.44	89.98	237.90	7.58	8.34	48.17	8532	F4
212915	s13b	35.32	90.27	256.30	4.93	8.93	23.32	4143	F4
212970	S13B	35.47	89.95	261.23	6.24	9.16	44.24	7837	F4
213209	h1	35.52	90.06	365.63	7.80	12.76	70.66	12567	F4
213232	h4	35.36	89.85	256.85	8.05	9.07	49.17	8665	MGP 10
213233	h4	35.57	90.14	233.37	8.00	8.11	62.02	11064	MGP 10
213265		35.70	89.95	237.24	8.05	8.27	37.89	6756	MGP 10
213313	h15	34.11	90.17	175.91	8.23	6.37	20.64	3534	MGP 10
213319	h15b	34.29	89.77	209.08	8.64	7.63	50.17	8557	MGP 10
213337	h22	34.92	89.96	263.68	8.73	9.39	26.41	4608	MGP 10
213339	h22	34.89	89.97	232.12	7.99	8.27	27.14	4732	MGP 10
212990	s16	35.36	89.76	222.68	9.63	7.88	33.63	5914	MGP 10
212991	s16	35.41	90.06	194.11	8.79	6.79	15.49	2746	MGP 10
212992	s16	35.39	89.97	335.52	8.57	11.79	65.17	11524	MGP 10
212993	s16	35.29	89.89	165.31	8.64	5.84	14.99	2639	MGP 10
212996	s16	35.42	89.92	287.42	9.30	10.11	57.90	10236	MGP 10
212997	s16b	35.40	89.97	263.14	8.18	9.24	36.32	6425	MGP 10
212998	s16b	35.38	90.13	235.09	9.86	8.22	24.79	4398	MGP 10
212999	s16b	35.35	90.06	311.19	11.06	10.91	47.00	8318	MGP 10
213000	s16b	35.39	90.22	194.21	8.35	6.77	16.71	2971	MGP 10
213001	s16b	35.48	90.36	345.92	9.85	11.96	44.46	7950	MGP 10
213002	s16b	35.49	90.09	192.24	8.54	6.71	32.71	5816	MGP 10
213007	s9	35.28	90.05	336.77	8.18	11.84	33.03	5833	MGP 10
213008	s12b	35.19	89.85	447.27	8.48	15.87	83.81	14697	MGP 10
213010	s26	35.10	89.95	261.16	7.83	9.26	34.07	5973	MGP 10
213011	s26	34.19	89.96	311.10	9.21	11.32	62.18	10621	MGP 10
213012	s26	35.16	90.09	214.31	8.04	7.55	24.15	4255	MGP 10
213013	s26	35.28	90.18	247.01	8.17	8.64	40.13	7108	MGP 10
213014	s26	35.07	89.53	222.76	8.43	8.01	27.12	4706	MGP 10
213015	s18	35.24	90.11	291.81	8.76	10.25	42.14	7444	MGP 10
213016	s18b	35.19	89.89	283.63	9.11	10.05	37.24	6537	MGP 10
213017	s18b	35.17	90.00	230.71	8.15	8.15	31.02	5455	MGP 10
213018	s8	35.12	90.04	290.47	8.64	10.26	33.29	5852	MGP 10
213019	s8	35.29	90.16	201.84	8.89	7.07	21.21	3757	MGP 10
213020	s7	35.01	80.70	291.15	9.84	14.33	56.73	7984	MGP 10
213021	s18b	35.18	90.27	246.91	9.00	8.64	27.87	4932	MGP 10
213022	s8	35.15	90.13	247.85	9.66	8.72	27.09	4775	MGP 10
213023	s8	35.07	90.27	283.03	8.39	9.93	37.93	6691	MGP 10
213024	s8	35.23	90.24	225.15	8.66	7.87	57.18	10126	MGP 10
213025	s8	34.96	90.18	339.58	9.28	11.99	39.27	6893	MGP 10
213028	s7	35.18	89.82	450.47	8.49	16.00	82.27	14413	MGP 10
213029	s7	35.30	90.03	162.94	8.95	5.73	14.94	2640	MGP 10
213031	s7b	35.28	90.22	175.96	8.01	6.15	16.91	2997	MGP 10
213032	s7b	35.11	90.06	180.82	8.97	6.38	18.38	3230	MGP 10
213033	s7b	35.56	90.00	344.77	9.42	12.04	49.96	8883	MGP 10
213036	s14	35.18	89.89	294.10	9.14	10.42	52.57	9225	MGP 10
213039	s14	35.28	89.99	296.05	7.88	10.43	64.99	11462	MGP 10

APPENDIX D (cont). Raw Laboratory Test Data**.**

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
213040	s14	35.16	90.13	276.08	9.12	9.71	44.62	7867	MGP 10
213041	s14	35.19	90.03	238.64	8.98	8.41	36.99	6513	MGP 10
213042	s14	35.24	90.28	272.98	9.18	9.53	41.64	7383	MGP 10
213043	s14	35.30	89.99	216.68	8.39	7.63	27.74	4895	MGP 10
213044	s14	35.19	89.79	215.73	9.03	7.67	41.45	7259	MGP 10
213045	s14b	35.28	90.11	326.30	7.99	11.44	68.09	12040	MGP 10
213046	s14	35.36	90.05	270.76	8.82	9.49	39.28	6953	MGP 10
213047	s14b	35.41	90.08	288.12	8.37	10.08	45.55	8079	MGP 10
213048	s14b	35.24	90.20	239.61	9.34	8.39	34.99	6192	MGP 10
213050	s14b	34.32	90.15	310.15	8.43	11.17	69.84	12024	MGP 10
213051	s14b	35.27	90.13	178.32	8.92	6.25	24.20	4280	MGP 10
213052	s14b	35.41	89.95	348.13	8.95	12.23	68.96	12196	MGP 10
213053	s14b	35.01	90.21	353.07	8.67	12.44	53.44	9399	MGP 10
213054	s14b	34.44	90.06	270.22	9.27	9.73	64.62	11143	MGP 10
213055	s14b	35.16	90.22	220.13	8.37	7.72	22.14	3911	MGP 10
213063	h25	35.47	89.85	199.20	8.38	7.01	19.68	3479	MGP 10
213065	h25	35.48	90.02	193.38	7.93	6.76	37.44	6644	MGP 10
213066	h25	35.42	89.68	228.24	8.46	8.09	38.09	6697	MGP 10
213067	h25	35.57	89.73	227.41	8.12	8.01	27.51	4864	MGP 10
213069	h25	35.48	89.78	193.53	7.87	6.82	27.17	4797	MGP 10
213070	h25	35.05	89.83	255.07	8.23	9.09	44.57	7781	MGP 10
213072	h25b	35.52	90.23	222.73	8.39	7.73	25.74	4595	MGP 10
213076	h1	35.53	90.23	285.49	9.29	9.90	26.17	4673	MGP 10
213077	h1	35.48	90.06	230.98	8.21	8.07	40.45	7185	MGP 10
213079	h1	35.69	90.17	247.84	9.43	8.58	34.82	6237	MGP 10
213081	h1	35.85	90.11	201.57	8.12	6.96	25.42	4568	MGP 10
213082	h1	35.69	90.08	205.16	8.03	7.12	16.95	3030	MGP 10
213083	h1	35.65	90.13	233.26	8.64	8.09	45.05	8053	MGP 10
213085	h1	35.65	90.20	192.68	8.08	6.67	19.61	3512	MGP 10
213086	h1	35.64	90.02	295.08	7.92	10.28	32.26	5752	MGP 10
213087	h1	35.78	90.10	230.48	9.35	7.97	21.34	3827	MGP 10
213088	h1	35.73	90.00	230.81	8.56	8.02	26.52	4738	MGP 10
213089	h1	35.56	90.18	259.55	8.58	9.01	51.04	9110	MGP 10
213090	h1	35.59	90.15	227.03	7.91	7.88	32.30	5766	MGP 10
213091	h1	35.70	90.05	233.74	8.46	8.12	38.63	6902	MGP 10
213092	h30	35.61	90.14	222.80	8.10	7.73	27.65	4938	MGP 10
213095	h30	35.56	90.10	207.40	7.89	7.22	23.25	4144	MGP 10
213096	h1	35.65	90.28	181.00	8.33	6.25	18.86	3383	MGP 10
213099	h30	35.51	90.01	227.73	8.52	7.96	35.33	6274	MGP 10
213100	h30	35.31	89.35	253.55	9.13	9.11	41.63	7245	MGP 10
213103	h30	35.52	90.18	207.49	7.95	7.21	38.50	6866	MGP 10
213106	h30	35.52	90.05	224.09	7.80	7.82	27.58	4903	MGP 10
212872	s5	35.47	83.01	198.99	9.77	8.88	26.48	3995	MGP 10
212873	s5	35.08	87.44	298.72	11.42	11.53	51.62	8546	MGP 10
212874	s5	35.28	89.92	290.70	10.57	10.26	43.42	7646	MGP 10
212875	s5	35.45	89.77	296.37	10.85	10.46	26.64	4698	MGP 10
212876	s5	35.54	88.25	244.03	11.14	9.05	14.67	2507	MGP 10
212884	s5	35.52	90.02	391.70	11.28	13.69	46.52	8265	MGP 10
212888	s5b	35.29	90.04	260.13	10.58	9.14	23.37	4128	MGP 10
212892	s5b	35.52	90.03	527.03	10.62	18.41	96.81	17204	MGP 10

APPENDIX D (cont). Raw Laboratory Test Data**.**

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
212895	s13	35.29	90.30	279.26	10.77	9.73	31.81	5651	MGP 10
212896	s13	35.39	90.07	317.83	10.83	11.13	52.72	9344	MGP 10
212897	s13	35.14	89.70	290.46	11.14	10.37	37.48	6542	MGP 10
212898	s13	35.18	89.88	320.59	11.50	11.36	70.60	12385	MGP 10
212899	s13	35.26	90.61	284.64	9.84	9.83	53.24	9515	MGP 10
212900	s13	35.25	90.26	233.98	10.01	8.17	38.58	6839	MGP 10
212901	s13	35.25	89.85	234.88	10.31	8.32	21.84	3836	MGP 10
212902	s13	35.30	90.26	263.85	11.00	9.20	61.12	10851	MGP 10
212903	s13	35.28	90.40	280.70	11.35	9.75	47.20	8400	MGP 10
212904	s13b	35.32	90.00	300.70	11.08	10.57	82.62	14590	MGP 10
212905	s13b	35.44	90.06	278.17	10.99	9.73	73.33	13011	MGP 10
212906	s13b	35.36	89.87	269.36	11.05	9.50	38.98	6871	MGP 10
212910	s13b	35.27	90.11	259.46	10.07	9.10	50.61	8947	MGP 10
212912	s13b	35.29	89.99	257.93	10.66	9.08	31.11	5489	MGP 10
212913	s13b	35.44	90.28	287.46	11.35	9.98	79.60	14192	MGP 10
212914	s13b	35.51	90.14	263.80	11.13	9.18	32.55	5797	MGP 10
212916	s13b	35.39	89.85	281.70	11.25	9.94	59.30	10458	MGP 10
212917	s13b	35.30	90.29	298.71	10.87	10.41	74.24	13189	MGP 10
212919	s13b	35.60	90.16	316.72	11.17	10.99	55.01	9827	MGP 10
212921	s13b	35.47	90.19	293.45	10.94	10.21	77.02	13717	MGP 10
212923	s13b	35.39	89.97	264.44	11.28	9.29	46.91	8295	MGP 10
212926	s13b	35.44	90.22	264.79	10.68	9.21	65.13	11597	MGP 10
212930	s13b	35.42	90.14	105.68	10.92	3.69	13.34	2370	MGP 10
212932	s30	35.41	90.51	358.12	10.14	12.35	61.34	10984	MGP 10
212934	s30	35.40	90.10	233.20	10.29	8.15	34.46	6113	MGP 10
212935	s30	35.44	90.16	267.84	11.27	9.34	36.56	6502	MGP 10
212949	s1	35.11	89.50	321.79	10.90	11.57	63.21	10973	MGP 10
212951	s1	35.39	87.86	326.76	7.84	12.33	67.91	11451	MGP 10
212956	s1	34.92	90.01	336.43	10.37	11.96	53.77	9391	MGP 10
212960	s1	35.44	89.85	289.59	11.07	10.20	55.87	9867	MGP 10
212968	s1	35.34	89.72	324.70	11.47	11.52	58.44	10262	MGP 10
212974	S28	35.40	90.16	292.44	11.41	10.21	52.83	9384	MGP 10
212976	S28	35.34	89.94	243.37	11.02	8.57	38.47	6788	MGP 10
212977	S28	35.30	90.32	266.35	10.89	9.27	51.83	9214	MGP 10
212978	S28	35.34	90.01	239.01	9.60	8.40	40.13	7092	MGP 10
212979	S30	35.41	89.80	349.64	10.57	12.35	77.69	13694	MGP 10
212982	S28B	35.33	90.04	222.33	9.27	7.81	47.44	8388	MGP 10
212983	S28B	35.41	89.82	239.49	10.89	8.45	48.06	8475	MGP 10
212984	S28B	35.43	89.82	257.59	11.25	9.08	32.02	5650	MGP 10
212987	S28B	35.39	89.86	286.58	10.87	10.10	71.63	12635	MGP 10
213177	s7	35.27	90.04	407.34	8.20	14.32	75.81	13382	MGP 10
213195	s14	35.17	89.85	325.88	11.15	11.57	76.55	13416	MGP 10
212868	s5	35.29	88.90	369.16	12.50	13.48	97.96	16866	MGP 12
212869	s5	35.40	89.90	424.90	11.78	14.96	59.14	10445	MGP 12
212870	s5	35.68	90.05	350.05	13.28	12.16	49.03	8756	MGP 12
212871	s5	35.30	89.91	260.24	11.82	9.18	26.41	4651	MGP 12
212877	s5	35.50	89.71	304.19	13.09	10.75	55.54	9794	MGP 12
212878	s5	35.41	89.97	406.38	13.49	14.27	51.17	9054	MGP 12
212879	s5	35.37	90.13	374.99	13.77	13.11	59.73	10594	MGP 12
212880	s5	35.14	87.60	310.68	12.88	11.91	47.60	7923	MGP 12

APPENDIX D (cont). Raw Laboratory Test Data.

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
212881	s5	35.47	90.10	382.12	12.93	13.34	67.11	11929	MGP 12
212882	s5	35.36	90.29	358.67	13.43	12.48	73.34	13051	MGP 12
212883	s5	35.37	89.66	337.95	12.81	12.00	62.81	11024	MGP 12
212885	s5	35.38	90.31	337.15	11.85	11.71	27.26	4855	MGP 12
212886	s5b	35.55	90.01	396.79	12.35	13.86	68.68	12210	MGP 12
212887	s5b	35.37	89.73	290.59	13.46	10.30	32.37	5691	MGP 12
212889	s5b	35.41	90.00	402.25	14.65	14.11	51.29	9081	MGP 12
212890	s5b	35.45	90.41	290.75	11.84	10.05	24.29	4345	MGP 12
212891	s5b	35.48	90.20	288.33	13.82	10.03	35.85	6389	MGP 12
212893	s5b	35.41	89.92	365.30	11.82	12.85	40.75	7202	MGP 12
212894	s5b	35.43	90.30	264.41	12.60	9.18	29.50	5261	MGP 12
212907	s13b	35.19	89.30	268.58	12.18	9.70	40.61	7034	MGP 12
212908	s13b	35.36	89.97	321.09	13.72	11.29	71.18	12576	MGP 12
212909	s13b	35.28	89.82	306.23	12.04	10.85	52.80	9277	MGP 12
212911	s13b	35.47	90.44	289.98	11.90	10.01	63.78	11423	MGP 12
212918	s13b	35.57	90.25	291.49	12.31	10.09	68.04	12169	MGP 12
212920	s13b	35.39	90.10	309.41	12.82	10.82	80.26	14234	MGP 12
212922	s13b	35.44	90.24	331.66	11.69	11.53	58.64	10446	MGP 12
212924	s13b	35.45	90.08	309.68	12.61	10.82	68.00	12074	MGP 12
212925	s13b	35.50	90.46	289.53	13.12	9.98	58.04	10408	MGP 12
212927	s13b	34.99	90.08	297.33	11.82	10.53	75.96	13313	MGP 12
212928	s13b	35.32	89.84	337.35	14.05	11.93	84.91	14941	MGP 12
212931	s30	35.31	90.03	268.18	11.60	9.42	39.94	7056	MGP 12
212933	s30	35.44	90.26	366.45	12.18	12.73	59.54	10611	MGP 12
212936	s30b	35.49	90.21	370.74	12.64	12.88	47.26	8426	MGP 12
212937	s30b	35.41	89.86	263.15	12.17	9.27	23.10	4077	MGP 12
212938	s1	35.28	89.70	333.14	11.91	11.85	52.11	9131	MGP 12
212939	s1	34.58	89.40	345.00	12.33	12.64	71.59	12214	MGP 12
212940	s1	35.07	89.85	290.94	11.53	10.36	34.61	6048	MGP 12
212941	s1	35.22	89.96	370.17	14.74	13.07	73.46	12925	MGP 12
212942	s1	35.52	90.13	286.39	11.94	9.97	28.23	5027	MGP 12
212943	s1	35.31	89.99	287.57	13.74	10.12	31.52	5563	MGP 12
212944	s1	35.21	89.87	307.34	13.50	10.89	38.10	6687	MGP 12
212945	s1	35.14	90.30	363.06	11.52	12.70	60.92	10775	MGP 12
212946	s1	35.25	89.66	330.70	13.43	11.78	48.15	8422	MGP 12
212947	s1	35.32	89.72	330.48	13.61	11.73	47.31	8303	MGP 12
212948	s1	33.98	89.67	342.35	13.30	12.65	46.43	7830	MGP 12
212950	s1	35.37	89.76	342.94	12.50	12.14	66.42	11683	MGP 12
212952	s1	35.27	89.82	271.26	13.19	9.61	33.31	5851	MGP 12
212953	s1	35.24	89.78	308.79	13.29	10.96	52.40	9188	MGP 12
212954	s1	33.91	89.90	366.08	12.73	13.45	64.76	10956	MGP 12
212955	s1	35.42	89.62	231.47	11.56	8.22	27.50	4830	MGP 12
212957	s1	35.27	89.77	380.86	14.77	13.52	61.48	10787	MGP 12
212958	s1	35.47	89.68	365.96	11.68	12.95	93.51	16466	MGP 12
212959	s1	34.83	88.74	314.97	13.13	11.72	48.06	8137	MGP 12
212961	s1	35.27	89.89	322.59	12.36	11.40	49.11	8639	MGP 12
212962	s1	35.29	89.72	336.60	14.38	11.96	63.58	11149	MGP 12
212963	s1	35.39	89.88	100.79	12.89	3.55	14.41	2544	MGP 12
212964	s1	35.39	90.07	302.24	12.63	10.58	33.51	5939	MGP 12
212965	s1	35.47	89.80	290.93	11.79	10.26	67.46	11912	MGP 12

APPENDIX D (cont). Raw Laboratory Test Data.

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
212966	s1	35.54	89.99	290.84	13.05	10.17	29.75	5285	MGP 12
212967	s1	35.20	89.34	321.90	12.26	11.61	72.84	12633	MGP 12
212969	S1	35.12	89.72	372.40	13.94	13.29	61.47	10726	MGP 12
212971	S1	35.30	89.59	436.29	14.13	15.56	79.39	13885	MGP 12
212972	S1	35.39	90.04	344.82	14.70	12.09	47.52	8415	MGP 12
212973	S1B	35.53	89.85	305.16	11.95	10.72	36.26	6420	MGP 12
212975	S28	35.40	90.05	348.38	11.67	12.20	52.30	9267	MGP 12
212980	S28	35.22	89.29	367.43	12.11	13.27	74.81	12967	MGP 12
212981	S28B	35.30	89.85	282.28	12.02	9.98	32.56	5728	MGP 12
212985	S28B	35.27	90.21	304.79	12.14	10.66	36.40	6450	MGP 12
212986	S28B	35.31	89.75	306.90	12.97	10.89	44.73	7853	MGP 12
212988	S1	35.25	89.59	365.81	13.72	13.07	44.92	7845	MGP 12
213108	s18	35.18	90.00	383.86	13.42	13.55	78.72	13847	MGP 12
213109	s18	35.29	90.07	384.19	14.18	13.49	80.47	14221	MGP 12
213110	s18	35.51	90.36	336.26	14.08	11.62	30.62	5481	MGP 12
213111	s18	35.17	89.93	412.53	13.30	14.60	69.48	12199	MGP 12
213112	s18	35.52	90.01	425.71	12.77	14.88	93.25	16564	MGP 12
213113	s18	35.32	90.16	362.47	13.30	12.68	76.33	13528	MGP 12
213114	s18	35.11	90.18	276.79	13.17	9.73	20.68	3645	MGP 12
213115	s18b	35.31	90.06	364.81	13.95	12.81	57.95	10244	MGP 12
213116	s18	35.34	90.25	327.70	13.86	11.42	67.21	11942	MGP 12
213121	s18b	35.23	90.02	374.57	12.72	13.20	81.42	14348	MGP 12
213124	s8	35.20	90.02	312.23	13.82	11.01	28.73	5059	MGP 12
213125	s8	35.54	90.16	366.05	14.36	12.72	46.29	8255	MGP 12
213127	s8	35.14	90.18	337.94	13.10	11.87	54.28	9574	MGP 12
213133	s8	35.09	89.52	333.09	14.53	11.98	50.58	8779	MGP 12
213134	s8	35.80	90.10	352.46	14.45	12.19	39.48	7083	MGP 12
213136	s8	35.24	90.00	419.61	14.09	14.79	84.79	14940	MGP 12
213139	s8	35.12	89.91	326.94	11.91	11.60	66.01	11568	MGP 12
213140	s8	35.18	89.80	370.23	13.73	13.16	81.50	14271	MGP 12
213141	s8	35.23	90.02	415.05	14.38	14.62	87.62	15442	MGP 12
213147	s8	35.21	90.06	367.64	12.61	12.94	43.36	7643	MGP 12
213148	s8	35.32	90.27	381.86	14.28	13.31	49.05	8713	MGP 12
213153	s8b	35.09	90.05	312.47	13.31	11.04	44.37	7794	MGP 12
213153	s8b	35.09	90.18	396.39	14.77	13.95	84.57	14897	MGP 12
213156	s8b	35.24	89.71	415.34	13.93	14.78	57.35	10039	MGP 12
213157	s8b	35.18	89.75	303.34	13.63	10.80	41.73	7299	MGP 12
213158	s8b	35.16	89.98	352.40	12.83	12.46	85.51	15026	MGP 12
213161	s8b	35.27	90.12	459.30	13.43	16.11	80.83	14292	MGP 12
213163	s7	35.33	90.11	381.25	14.39	13.35	71.66	12689	MGP 12
213164	s7	35.31	90.37	350.51	12.77	12.18	80.03	14246	MGP 12
213165	s7	35.29	90.07	394.94	13.58	13.87	81.48	14400	MGP 12
213167	s7	35.39	90.15	420.66	14.76	14.69	68.97	12245	MGP 12
213168	s7	35.49	89.97	381.86	12.21	13.38	80.21	14223	MGP 12
213171	s7	35.34	90.14	355.67	13.57	12.44	48.86	8660	MGP 12
213172	s7	35.39	90.12	376.29	14.56	13.15	34.52	6124	MGP 12
213173	s7	35.40	90.24	375.40	12.40	13.07	74.87	13323	MGP 12
213174	s7	35.28	90.08	365.89	12.84	12.85	54.12	9564	MGP 12
213176	s7	34.70	90.15	248.95	13.67	8.87	22.53	3923	MGP 12
213178	s7b	35.21	89.72	408.91	14.46	14.56	103.78	18156	MGP 12

APPENDIX D (cont). Raw Laboratory Test Data**.**

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
213180	s7b	35.25	89.91	313.82	14.48	11.09	39.95	7026	MGP 12
213181	s7b	35.10	89.65	425.12	13.76	15.22	58.72	10225	MGP 12
213183	s7b	35.22	90.09	499.32	13.43	17.56	117.36	20709	MGP 12
213184	s7b	35.32	89.90	318.72	14.48	11.24	59.66	10513	MGP 12
213185	s7b	35.45	90.14	394.49	13.40	13.76	62.82	11170	MGP 12
213186	s7b	35.38	90.14	353.04	13.91	12.34	86.88	15416	MGP 12
213187	s7b	35.24	89.90	338.18	14.66	11.96	32.34	5686	MGP 12
213189	s7b	35.28	90.20	433.33	13.80	15.15	52.29	9265	MGP 12
213191	s7b	35.41	90.02	340.85	13.35	11.95	33.42	5920	MGP 12
213192	s7b	35.44	90.05	347.32	13.68	12.15	33.53	5949	MGP 12
213193	s7b	35.47	90.30	582.76	13.10	20.20	98.91	17659	MGP 12
213194	s7b	35.35	90.07	384.61	13.89	13.48	79.08	13999	MGP 12
213196	s14	35.40	89.95	341.83	13.16	12.01	77.14	13639	MGP 12
213197	s14	35.07	89.84	374.55	13.76	13.34	85.28	14901	MGP 12
213198	s14	35.22	89.87	366.95	13.99	13.00	90.71	15928	MGP 12
213199	s14	35.24	90.11	372.92	12.65	13.10	73.27	12941	MGP 12
213200	s14	35.24	90.23	335.47	13.83	11.73	52.53	9302	MGP 12
213201	s14	35.31	90.15	340.84	12.76	11.93	75.47	13368	MGP 12
213202	s10	35.37	90.10	332.19	12.80	11.63	66.79	11838	MGP 12
213203	s14b	35.50	89.97	350.20	13.05	12.26	67.75	12017	MGP 12
213204	s14b	35.23	90.11	357.96	12.43	12.57	58.88	10397	MGP 12
213205	s14b	35.45	90.10	360.79	13.98	12.60	53.56	9514	MGP 12
213206	s14b	35.39	90.23	320.64	11.73	11.17	67.91	12078	MGP 12
213207	s14b	35.22	90.09	300.60	13.74	10.57	70.43	12427	MGP 12
213210	h8b	35.52	90.60	334.52	13.47	11.47	48.92	8805	MGP 12
213211	h17	34.96	90.02	325.98	12.94	11.57	35.54	6216	MGP 12
213213	h2	35.01	90.08	263.15	12.13	9.31	21.21	3719	MGP 12
213215	h2	35.11	90.16	395.65	14.00	13.92	76.88	13544	MGP 12
213216	h3	35.47	90.10	355.85	14.49	12.42	44.40	7892	MGP 12
213219	h3	35.55	90.26	362.95	12.55	12.57	28.10	5023	MGP 12
213220	h3	35.48	90.08	389.53	13.54	13.60	69.04	12269	MGP 12
213221	h3	35.49	89.93	352.28	12.03	12.36	44.31	7851	MGP 12
213223	h22b	35.01	90.62	356.90	13.04	12.40	41.33	7335	MGP 12
213224	h11	35.37	90.28	361.08	14.60	12.56	65.28	11616	MGP 12
213225	h6	34.63	89.59	320.28	14.15	11.65	31.43	5392	MGP 12
213226	h6b	35.90	90.20	444.13	14.45	15.26	87.27	15734	MGP 12
213227	h21	34.81	89.60	365.58	13.01	13.22	48.06	8291	MGP 12
213212		35.75	90.09	357.51	14.66	12.38	57.11	10228	MGP 12
213117	s18b	35.10	89.75	475.99	15.31	16.98	102.09	17817	MGP 15
213118	s18b	35.29	90.12	435.94	15.46	15.28	83.46	14766	MGP 15
213119	s18b	35.18	90.22	418.89	14.90	14.68	72.32	12783	MGP 15
213120	s18b	35.28	90.12	341.43	15.40	11.97	58.64	10372	MGP 15
213122	s18b	35.33	89.94	472.45	16.15	16.64	69.52	12264	MGP 15
213123	s8	35.26	90.06	435.37	15.81	15.30	82.25	14521	MGP 15
213126	s8	35.32	90.26	487.77	16.23	17.00	92.82	16488	MGP 15
213128	s8	35.17	90.10	369.95	16.06	13.02	70.11	12356	MGP 15
213129	s8	35.26	90.08	356.70	15.04	12.53	40.27	7113	MGP 15
213130	s8	35.20	89.95	389.14	15.23	13.75	40.60	7137	MGP 15
213131	s8	35.20	89.99	417.37	16.38	14.73	65.65	11553	MGP 15
213132	s8	35.22	89.89	454.29	17.66	16.08	77.94	13691	MGP 15

APPENDIX D (cont). Raw Laboratory Test Data**.**

Stick Lab No.	Mill Batch	Low-pt Width (mm)	Depth (mm)	Slope (N/mm)	Average MoEp (GPa)	MoEj (GPa)	MoRj (MPa)	Max (N)	Adjusted Lab MSG Grade
213135	s8	35.17	89.92	415.13	15.87	14.70	74.99	13163	MGP 15
213137	s8	35.17	89.94	503.81	17.71	17.83	102.81	18056	MGP 15
213138	s8	35.02	89.88	393.35	15.02	14.01	63.54	11097	MGP 15
213142	s8	35.29	90.22	410.21	15.22	14.33	52.11	9239	MGP 15
213143	s8	35.19	90.02	418.08	15.42	14.75	70.63	12432	MGP 15
213144	s8	35.24	89.83	398.04	15.46	14.11	70.04	12294	MGP 15
213145	s8	35.09	89.81	408.68	15.24	14.56	57.07	9970	MGP 15
213146	s8	34.77	89.78	479.12	16.32	17.24	62.30	10778	MGP 15
213149	s8	35.06	90.19	328.88	15.72	11.58	44.08	7760	MGP 15
213150	s8b	35.28	89.88	364.20	15.77	12.87	54.89	9657	MGP 15
213151	s8b	35.13	90.17	451.36	16.41	15.87	47.89	8445	MGP 15
213154	s8b	35.25	90.26	297.31	16.01	10.39	44.04	7807	MGP 15
213155	s8b	35.24	90.07	505.04	15.52	17.76	79.40	14011	MGP 15
213159	s8b	35.36	90.15	404.51	15.89	14.14	65.81	11674	MGP 15
213160	s8b	35.37	89.91	402.11	14.97	14.16	69.02	12181	MGP 15
213162	s8b	35.24	89.93	380.96	15.96	13.46	67.52	11878	MGP 15
213166	s7	35.31	90.12	379.48	15.15	13.29	53.25	9426	MGP 15
213169	s7	34.41	90.18	351.59	15.52	12.61	32.67	5644	MGP 15
213170	s7	34.41	90.13	463.89	15.41	16.67	72.53	12515	MGP 15
213175	s7	35.53	90.20	393.21	15.43	13.65	72.53	12943	MGP 15
213179	s7b	35.17	89.89	423.54	17.01	15.01	50.45	8849	MGP 15
213182	s7b	35.33	90.01	485.61	14.89	17.07	111.30	19665	MGP 15
213188	s7b	35.22	89.84	391.08	16.21	13.86	52.25	9168	MGP 15
213190	s7b	35.21	90.01	407.36	15.70	14.36	65.66	11561	MGP 15
213208	s14b	35.42	90.03	379.77	14.83	13.30	73.55	13035	MGP 15
213214	h2	34.86	90.02	377.12	15.32	13.43	53.64	9353	MGP 15
213217	h3	35.58	89.85	438.43	15.37	15.38	52.90	9379	MGP 15
213218	h3	35.39	89.95	373.81	15.85	13.14	44.87	7931	MGP 15
213222	h3b	35.49	89.85	481.15	15.86	16.92	79.55	14069	MGP 15

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