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Eucalypt Processing

Stockpiling of Regrowth Jarrah and Karri Logs Using Different Watering Schedules

G.K. Brennan, B.R. Glossop and L.R. Mathews

Report No. 16

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Wood Utilisation Research Centre
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This report was part of a program of industrial research and development aimed at establishing techniques and developing equipment to allow processing of small eucalypt regrowth logs in a commercially viable manner, particularly with a view to use in high quality furniture. The research program was funded jointly by the Commonwealth Government under a Public Interest Project, the Department of Conservation and Land Management, and the Western Australian timber industry.

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SUMMARY

Stockpiling of regrowth jarrah (*Eucalyptus marginata* Donn ex Sm.) logs in Western Australian sawmills is essential to minimise the risk of spreading dieback by harvesting operations in the winter months. Logs stored without water sprays degrade through surface checking and end splitting, and are at risk from insect attack. The first part of this study compared water spray schedules ranging from continuous to 1 h on : 3 h off by assessing log degradation and borer infestation in the stockpile, and bow and spring in flitches, wings and sawn boards. The results indicated that the 1 h on : 3 h off schedule did not adversely affect log and timber quality.

The second part of the study was based on Part 1, and used more radical schedules with continuous water sprays used as a control. Regrowth karri (*E. diversicolor* F. Muell.) logs were included with regrowth jarrah. These results indicated that a 15 min on:165 min off schedule gave satisfactory results with minimum log degrade, no apparent borer infestation, and acceptable levels of bow and spring in sawn timber. This schedule gives a 92 per cent saving in water and electricity compared with continuous water spraying.

INTRODUCTION

Jarrah (*Eucalyptus marginata* Donn ex Sm.) forest extends in a long belt 30 km to 50 km wide, along the Darling Range from Mundaring (50 km east of Perth) southward to the vicinity of Albany (Boland *et al.* 1984). Karri (*E. diversicolor* F. Muell.) occurs naturally in areas of the south-west of Western Australia, from Wheatley on the Donnelly River in the north to Walpole in the south. Other occurrences include areas around Margaret River and Karridale to the west of the main forest area. Both forest types are important for water catchments, conservation, and recreation, as well as for timber production.

However, the jarrah forest has been affected by jarrah dieback, a disease caused by the introduced soil-borne fungus *Phytophthora cinnamomi* Rands. During the 1950s and early 1960s, this fungus caused mass destruction of large areas of jarrah forest (Shearer and Tippett 1989).

This disease has forced the Department of Conservation and Land Management to declare disease risk areas, and apply strict hygiene measures in susceptible areas of forest by restricting vehicle and machinery movement, particularly during winter. Sawmillers are required to stockpile logs during the summer months, to avoid logging under the moist soil conditions which occur in winter months.

The impact of dieback on karri trees is low compared with that on jarrah, and there are few restrictions on the time of logging in the karri forest. This results in a steady flow of karri logs to sawmills all year. Stockpiling may be necessary if logging restrictions are enforced because of adverse soil conditions or through unavailability of logging contractors.

Stockpiling may also be desirable as a means for reducing starch contents in *Lyctus*-susceptible species and growth stresses in most. However, the Cerambycid borers such as bardi (*Phoracantha semipunctata* (F.) and *P. recurva* Newm.) are known to infest recently-logged material which has not been debarked.

Prior to milling regrowth sawlogs, it is essential to store them in a way that prevents degradation. The extent to which a log degrades during storage is determined by drying conditions, susceptibility to insect and fungal attack, and the amount of growth stresses present in the log.

Drying degradation results from surface checking and end splitting which can extend well into a log, or from drying stresses, which are additional to growth stresses and result in even greater distortions during sawing than encountered with fresh green logs (Waugh 1986).

Storage of logs under water spray has been recommended as a method to reduce end splitting and surface checking, and it has been demonstrated satisfactorily with *E.grandis* W. Hill ex Maiden and *E.pilularis* Sm. (Hillis 1978) to reduce infestation by *Phoracantha* spp. (Curry, unpublished data). Work carried out by the CSIRO has shown that using water sprays on stockpiled ash-type eucalypt logs over a six-month period, can reduce overall stress levels by as much as 20 per cent. Most of this reduction takes place in the highly stressed logs, in which the stress intensity can be halved (Waugh 1986).

Another factor to be considered was that reducing the amount of water applied to stockpiled logs to a level where log degradation is controlled to within acceptable limits would reduce water and operating costs.

This study was divided into two parts. In Part I, regrowth jarrah logs were stored under watering treatments ranging from continuous to 1 h on : 3 h off. The latter treatment was continued for a second summer. The results of Part I indicated that further reductions in watering schedules were feasible, and were used in designing Part 2, which assessed the effect of reduced watering on regrowth jarrah and karri logs. In both studies, degradation of logs stored under reduced watering regimes was compared with that of logs stored under continuous sprays. The effect of reducing the amount of water was assessed by comparisons of log end splitting, surface checking, and insect damage (particularly attack by bardi). Variation in log moisture contents was also estimated. Bow and spring of the sawn flitches and boards from stockpiled logs were compared with that of flitches and boards sawn from recently harvested logs.

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PART 1

METHODS

The regrowth jarrah logs were extracted from Kent Block in Harvey District during harvesting trials. This area consists of a mixture of mature and regrowth forest and is considered typical of the majority of the forest available for future wood production in Harvey District (Clark and Brennan 1988).

Felling commenced on the 11 November and was completed by 21 November 1985. Sampling for moisture content is described below. Logs were delivered to the Wood Utilisation Research Centre (W.U.R.C.) at Harvey from 21 November to 3 December. Approximately 310 m^3 of regrowth jarrah sawlogs were delivered to the W.U.R.C., and this volume was distributed equally between stockpiling treatments (A to E), which are described below.

At the mill landing, logs were identified, and their small end diameter under bark (s.e.d.u.b.), large end diameter under bark (l.e.d.u.b.) and lengths measured. After measurement, logs were placed in five stockpiling bays (A to E), each with a different watering regime. All logs were stored with bark intact; this is normal practice in timber yards.

Moisture contents

Five regrowth jarrah sample logs were randomly selected in the forest for moisture content assessment, on five separate felling days (ie. a total of 25 sample logs). Sample discs 50 mm thick were cut from both the small and large ends of each sample log immediately after felling, identified by a sample number and felling date, and placed in plastic bags. They were delivered to the W.U.R.C. on the day of felling.

A tag was stapled to the end of each sample log to identify it for further sampling at the mill landing, both before and after stockpiling.

The initial sample data indicates that additional sample logs were required for assessing the variation in moisture content between stockpiling and log conversion. The sample size was increased, therefore, to between 25 and 30 logs in all treatments, with logs being placed randomly in the different log stockpiles.

Moisture contents were assessed by cutting a cross section sample 100 mm wide, along the disc diameter from sapwood to sapwood (including the heartwood centre), and then by taking a sapwood and heartwood sample (20 x 50 mm) from the remainder of the disc. Moisture contents of these three samples were determined using the oven-dried method as outlined by CSIRO Division of Building Research (1974).

Watering schedules

Logs were stacked to a height of between 2.5 and 3 m in the stockpile.

Five separate watering schedules were used, ranging from continuous spraying to 1 h on: 3 h off. Previous trials had indicated that logs which were dry stockpiled were completely useless for milling after a short time in the stockpile, because of excessive end-splitting.

The stockpile design and treatments are shown in Figure 1, and the actual watering schedules in Figure 2.

After assessing Treatments A to E it was subsequently decided to continue storage in Bay D (the most severe treatment) for another summer. Results from this treatment would provide data for any sawmillers having to stockpile logs for more than one year.

Watering periods for all treatments were evenly distributed through the day, which should not bias the assessment of the effect of watering rate on log degradation.

The stockpile operates on a water recycling system, pumping water from a storage dam through irrigation pipes, then spraying it onto the logs. Two Kirloskar DB 32/20 pumps are used to pump water from the dam through a 125 mm aluminium mainline pipe, then 25 mm plastic branch pipes. Bay E was serviced by a 75 mm aluminium pipe then 25 mm plastic pipes. The pumps are powered by 7.5 kW, 3 phase direct coupled electric motors rated at 2900 R.P.M. and a line pressure between 370 kPa and 400 kPa is maintained. During the trial either one or both pumps were operating owing to a requirement to service other log stockpiles.

For the trial, the mainline had a Hardie 'Hydro-rain', series 213, 40 mm constant outlet pressure valve, so each treatment ran on the same pressure, irrespective of how many bays were receiving water. A pressure relief valve was also located in the mainline. When the pressure exceeded 400 kPa the valve opened and water returned to the storage dam.

Naan 3.5 mm, 423 de-luxe part circle, brass knocker sprinklers were used to water the stockpiled logs, with six sprinklers per bay located in identical positions around the bay. Sprinklers were operated by four Arlec PC 737 24 h 240 V timers, which gave a signal to open or close solenoid valves located in the branchlines to all bays except A and F, which operated continuously. Solenoids operated on 24 V current, needing eight transformers to convert 240 V to 24 V.

Direct readings of the volume of water received by each treatment were given by two Andrae Leonberg 25 mm inferential flow meters. In Part 1 one flow meter was permanently attached to the branchline to bay A and the other was moved between the other bays. (As discussed later in Part 2 one flow meter was permanently attached to the

Figure 1. Stockpile design and treatments in Part 1 (Bays A to E).

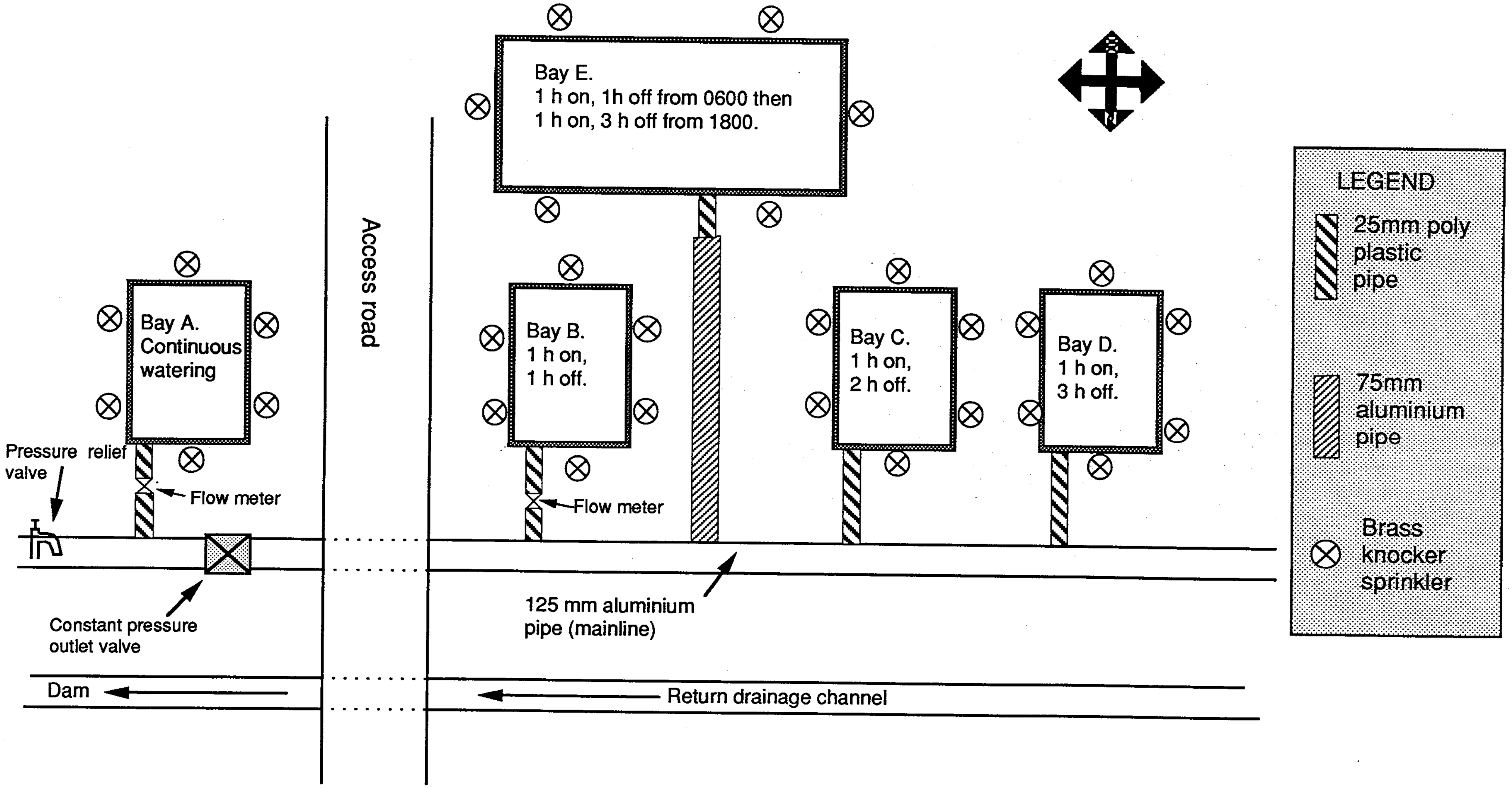
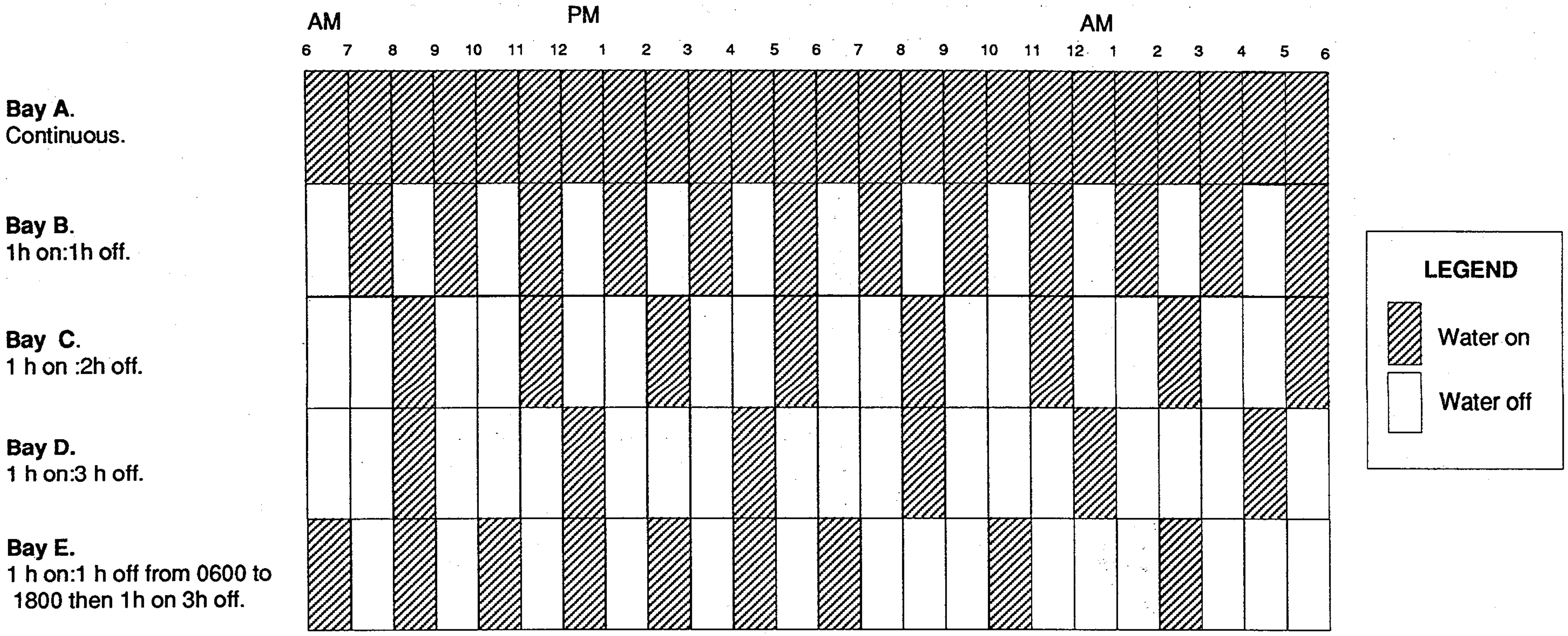


Figure 2. Watering regimes tested in Part 1 of log stockpile trials



	AM						PM												AM					
	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
Bay A. Continuous.	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Bay B. 1h on:1h off.		▨		▨		▨		▨		▨		▨		▨		▨		▨		▨		▨		▨
Bay C. 1 h on :2h off.			▨			▨			▨			▨			▨			▨			▨			▨
Bay D. 1 h on:3 h off.			▨				▨				▨				▨				▨				▨	
Bay E. 1 h on:1 h off from 0600 to 1800 then 1h on 3h off.	▨		▨		▨		▨		▨		▨		▨				▨				▨			

LEGEND

▨ Water on

☐ Water off

branchline to Bay F and the other was moved between the other bays). Comparisons were made between Bays A or F (continuous treatments) and the other bays and the actual flow was compared with an estimated flow. Rain gauges had been found to give substantial errors, and the inferential flow meters were much more accurate.

Water is returned to the dam by draining through the soil profile and running over the ground surface to a drainage channel feeding into the dam. Some water is lost through evaporation and deep leakage.

Evaluation of log degradation

After 12 months storage, end splits were rated from 0 to 5 using a photographic key. Code 0 is no splitting, 1 and 2 minor splits (fissures not extending to the log perimeter), 3 moderate(one or two fissures extending to the log perimeter) and 4 and 5 severe splits (most fissures extending to the log perimeter with splits occurring along the log).

Sawmilling

Sample logs from each bay were sawn using the Waugh (1980) cutting pattern. The pattern initially made two parallel balanced cuts, cut simultaneously on each side of the log by a twin edger with overhead beam feed. The centre cant was squared by making another pass through the twin edger, then cant and wings (if sawn timber could be recovered from the latter) were conveyed to a band resaw. In the study, the centre cant and wings (provided they had two flat edges) were measured for bow and spring before resawing.

The centre cant was cut through the middle with the bandsaw. Bow and spring of the two resulting flitches were measured, and the sections sawn commencing at the sapwood to produce 28 mm thick backsawn boards with widths of 50, 75, 100, 125 or 150 mm. Any pieces with brittle heart were discarded. In most cases the wings were sawn on a two-person circular saw bench, because it was impractical to use the bandsaw, which requires a flat edge for support.

At the docking saw, boards were trimmed to 1.2, 1.5, 1.8, 2.1 or 2.2 m (the last length for seasoning in the tunnel kilns). Board faults e.g. brittle heart, rot, excessive knots, gum and wane were removed in the docking process. Bow or spring, and board length were measured on all boards.

As a control, 28 freshly felled logs were assessed for end splits and then milled as above.

Insect damage

The surface of stockpiled logs was inspected weekly for insect attack, particularly damage by bardi, with any signs of attack to be recorded.

Analysis

A one-way analysis of variance was used to assess any differences between moisture content before and after stockpiling. Regression analysis was used to determine whether the initial moisture content biased any change in moisture content. The effect of different watering rates on the amount of end splitting was analysed using a chi-squared test. Analysis of variance was used to determine the effect of stockpiling treatment on bow and spring.

RESULTS AND DISCUSSION

Initially, log diameter (s.e.d.u.b.) distribution was tested between bays, checking for any bias which would influence other statistical tests e.g. the influence of stockpiling treatment on end splitting or bow and spring. No significant difference was found between the bays in terms of mean log diameter, and log diameter in all bays followed a normal distribution around the mean s.e.d.u.b. (Table 1).

Table 1
Mean log s.e.d.u.b. (mm) distribution in stockpiling treatments of regrowth jarrah logs in Part 1

Bay	Treatment	s.e.d.u.b. (mm) Mean	S.D.
	Sawn fresh	207	43
A	Continuous	188	34
B	1 h on:1 h off	200	47
C	1 h on:2 h off	190	46
D	1 h on:3 h off	201	50
E	1 h on:1h off to 1800 h then 1 h on:3 h off	187	40
D (2 summers)	1 h on:3 h off	202	21

Moisture contents

The large and small end of the logs before and after stockpiling, and the sapwood/ heartwood moisture content ratios are shown in Table 2.

Analysis of variance comparing the moisture contents before and after storage, showed no significant difference for the cross sections, but significant differences for the sapwood, heartwood and the heartwood/sapwood ratios. Sapwood moisture contents showed logs at 1 h on: 1 h off (from 0600 h to 1800 h) then 1 h on: 3 h off (Bay E) had a significantly higher moisture content than those in other bays. For heartwood, continuously watered (Bay A) logs were significantly different to 1 h on: 3 h off (Bay D (2 summers)) and sawn fresh, and for the heartwood/sapwood difference Bay A was significantly different to Bay E, Bay D (2 summers), and sawn fresh.

Analyses of cross section moisture contents showed that logs fresh from the forest or stockpiled for two summers had significantly lower moisture contents than logs under continuous spraying.

The 1 h on: 3 h off treatments (Bay D and Bay D (2 summers)) were compared to see whether the second summer of drying would affect log quality and sawing performance, in the event of sawmillers being required to extend stockpiling times. Analysis of variance showed no significant difference for cross section and sapwood moisture contents, but significantly larger heartwood moisture contents and larger sapwood/heartwood ratio after the second summer of storage.

With cross section moisture contents, there is a difference between treatments (Table 2). Logs fresh from the forest or stockpiled for two summers under a one hour on, three hours off regime had significantly lower moisture contents than logs stored under continuous spraying. Moisture was lost from the heartwood, but increased in the sapwood and cross sections. Reducing the volume of water applied to each bay did not significantly affect the moisture content after stockpiling for heartwood and cross sections, but sapwood had a significant difference despite a small mean difference of 6.2 per cent.

The mean moisture contents of regrowth jarrah heartwood in Part I were greater than those of sapwood before stockpiling (99 and 80 per cent respectively), and after stockpiling (108 and 85 per cent respectively), taking the average of large and small end values (Table 2).

Heartwood moisture contents in Bay D (two summers of drying) were less than in Bay D (one summer of drying). The mean difference of 13 per cent indicated that end drying had occurred.

In comparison, Hillis (1978) reported that in a sample of 23-year-old *E. regnans*, the average moisture content of heartwood was 135 per cent and of sapwood 118 per cent, while the heartwood of a 40 - 46-year-old *E. viminalis* sample had a moisture content of 113 per cent, the outermost heartwood 103 per cent and the sapwood 94 per cent. Hillis had reported little relative difference in the ratio of sapwood to heartwood moisture contents between samples of *E. regnans* and *E. viminalis* from two sites.

In general, the large standard deviations in the present trial indicated that the statistical significance has little effect in commercial practice.

Watering schedules

Flow meter readings gave a direct measurement of water received by each bay (Table 3). The actual savings in water for both parts were very close to the estimated savings, except for the Bay A/Bay B comparison (continuous compared with 1 h on: 1 h off), which showed a water saving of 37 per cent when it was expected to be 50 per cent. The problem was subsequently found to be caused by lower water pressure to Bay A than to Bay B at the time of measurement.

Log degradation - end splitting

In Part 1, data for severity classes 0 and 1 (no and minor splitting) and classes 2,3,4 and 5 (moderate and severe splitting) were combined to increase numbers in individual classes, and then a chi-squared test was applied. There was no significant difference between bays (both ends of the log), although logs in Bay D tended to have more severe splitting.

The small sample size required grouping of data from Bays A to E, and comparing these with logs from the fresh and Bay D (2 summers) treatments, which showed the latter had significantly more moderate and severe splitting (codes 2 to 5). Storing for two summers compared with one at the 1 h on: 3 h off schedule, resulted in more splitting. Sawn fresh logs were found to have significantly more splitting than logs stored for two summers in Bay D. This indicates that splits occurring between felling and stockpiling tend to contract during storage. End splits did not present any problem during sawmilling and all logs were cut into 28 mm boards.

The time between felling and stockpiling is very important, as the longer logs remain in the forest, the more they degrade through end splitting. Reducing the time between felling and stockpiling under water spray to a period of two or three days will limit end splitting. The logs which were sawn fresh were in the forest for approximately one week, which is too long if degradation is to be prevented, particularly in the hot summer months.

Bow and spring

Sample logs were all sawn using the Waugh (1980) cutting pattern, to determine the effect of stockpiling treatment on bow and spring.

The highest overall mean values in bow and spring occurred in flitch halves, which was understandable because cutting the centre cant into two pieces releases large growth stresses, resulting in considerable deflection. Large standard deviations were found in bow and spring in flitches, flitch halves, wings and boards (Tables 4 and 5).

Analysis of variance showed no significant difference in bow in timber sawn from logs in different bays for the centre cant, for the two flitch halves, or for the wings (Table 5). There was no significant difference in bow of boards from logs sawn fresh or having one summers storage under any of the five watering regimes, but those cut from logs stored in Bay D (1 h on: 3 h off schedule) for two summers had significantly more bow than the other treatments.

Table 2
Part 1 - Mean log moisture content percentage before and after stockpiling regrowth jarrah logs (standard deviations are in brackets)

	Large end moisture contents								Small end moisture contents							
	Sapwood		Heartwood		Cross section		Ratio of sapwood/ heartwood MC		Sapwood		Heartwood		Cross section		Ratio of sapwood/ heartwood MC	
Bay	B *	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
Fresh		78.8 (9.5)		98.5 (15.3)		88.8 (11.6)		0.80								
A	76.9 (4.9)	85.6 (9.0)	99.6 (21.3)	114.7 (23.6)	85.0 (8.4)	100.0 (15.3)	0.77	0.75	72.0 (2.7)	78.2 (6.5)	89.0 (4.9)	99.7 (6.0)	81.9 (3.4)	86.8 (5.2)	0.81	0.78
B	80.2 (13.2)	84.9 (9.9)	95.2 (17.1)	109.8 (10.5)	89.0 (18.4)	96.4 (12.4)	0.84	0.77	78.0 (11.4)	84.8 (12.1)	91.0 (18.7)	110.8 (17.1)	84.4 (14.8)	93.2 (10.7)	0.85	0.77
C	80.9	82.0	110.1	112.7	92.2	92.7	0.73	0.73	77.2	82.0	91.5	99.7	86.1	88.6	0.84	0.82
	(13.2)	(10.5)	(27.0)	(16.4)	(10.4)	(10.4)			(10.7)	(7.2)	(11.8)	(12.9)	(7.9)	(10.4)		
D	82.3 (9.5)	84.1 (8.9)	107.7 (13.8)	113.0 (20.7)	98.7 (14.6)	95.5 (12.2)	0.76	0.74	79.5 (13.7)	82.9 (10.3)	97.5 (14.0)	103.9 (13.4)	91.3 (14.5)	90.8 (10.6)	0.82	0.80
E	80.2 (8.8)	92.1 (21.0)	100.6 (12.1)	111.3 (21.9)	93.4 (11.2)	98.5 (11.7)	0.80	0.83	78.9 (8.1)	87.8 (11.4)	94.6 (10.6)	105.5 (13.11)	90.6 (10.8)	93.9 (10.0)	0.83	0.81
D 2 summers	83.0 (12.7)		100.4 (16.9)		92.1 (12.2)		0.83									
Mean	80.7 (10.6)	84.4 (13.8)	102.6 (18.3)	108.6 (18.6)	91.7 (13.9)	94.9 (11.8)	0.78	0.77	78.3 (11.2)	84.1 (10.4)	94.2 (13.5)	104.4 (13.9)	88.5 (12.4)	91.4 (10.3)	0.83	0.8

* B = Before stockpiling
A = After stockpiling

Note: Only large ends and after stockpiling moisture contents were taken for sawn fresh and Bay D (2 summers)

Table 3
Readings from 25 mm inferential flow meter in Part 1 of the stockpiling trial

Bay	Treatment	Measurement Time (days)	Actual volume (kL/day)	Target volume (kL/day)	Percentage water saved		Watering time (h/day)
					Actual	Expected	
A	Continuous	5	81.7	40.8	37	50	24
B	1 h on:1 h off		51.5				12
A	Continuous	6	77.9	26.0	67	67	24
C	1 h on:2 h off		25.5				8
A	Continuous	9	80.2	20.2	75	75	24
D	1 h on:3 h off		19.9				6
A	Continuous	47	79.8	30.0	57	62	24
E	1 h on:1 h off to 1800 h then 1 h on:3 h off		34.4				9

The latter result was unexpected, because storing logs under water spray, and then using a cutting pattern that makes simultaneous cuts on both sides of the log, should relieve the growth stresses. The combination of water spray storage and using the Waugh (1980) cutting pattern should reduce the amount of bow and spring in the sawn flitches and boards.

Mean bow of boards from all treatments was very small (4.3 mm/m) and mean spring was even smaller (0.8 mm/m). In comparison, McKimm *et al.* (1985) sawing 20-year-old plantation-grown *E. nitens* Maiden, found the mean bow and spring for backsawn boards were 4 mm/m and 1.7 mm/m, near backsawn boards 3.8 mm/m and 1.7 mm/m and quartersawn 2.2 mm/m and 1.8 mm/m respectively. Figures from the present trial are comparable to the *E. nitens* data, but McKimm *et al.*(1985) used a distortion gauge which presumably had a greater accuracy than the scale measure used in this trial.

Storage in Bay D (two summers) resulted in significantly more bow in boards than Bays A to E and the sawn fresh treatment. No significant difference was found between logs sawn fresh and one summer's storage under any of the five watering regimes. Bay D (two summers) had a mean bow of 5.2 mm/m, which is within the limits given in A.S. 2082-1979.

For spring, the Kruskal-Wallis test showed significant differences between flitch halves and boards cut from logs from different water spray treatments (Table 6). However, the mean ranges for flitch halves and boards were 1.3 mm/m and 0.4 mm/m respectively, which is negligible in commercial operations.

Insect damage

Weekly inspections showed no insect damage (particularly borer infestation) occurred during log storage under any of the waterspray schedules. During milling, no insect damage was observed in these regrowth jarrah logs.

As discussed in the Introduction, the usual recommendation for successful log protection has always been rapid extraction and conversion of logs. To restrict the spread of jarrah dieback, sawmillers using logs from the jarrah forest are required to stockpile logs felled during the summer months to avoid logging under the moist soil conditions in the winter months, when soil can be moved on vehicles and machinery. Regrowth karri can be extracted all year provided logging machines do not cause soil damage.

Continuous water spray storage can be used to reduce the incidence of end splitting and to substantially reduce insect attack. Water is usually supplied from a bore or local Government water supply, but there are advantages in having a water recycling storage system. Reducing the amount of water required to protect logs from degradation, saves both water and energy required to operate water pumps.

Table 4
Distribution of bow (mm/m) of cants, flitches, wings and boards for regrowth jarrah in Part I

		Source of Variation							
		Centre cant		Wings		Flitch halves		Boards	
Bay	Treatment	Mean	S.D.	Mean	S.D	Mean	S.D	Mean	S.D.
	Sawn Fresh	2.6	1.3	7.1	3.6	5.1	3.5	3.9	2.5
A	Continuous	2.0	1.1	6.1	3.6	6.1	2.8	4.5	2.6
B	1 h on:1 h off	2.2	1.3	6.0	3.8	5.4	2.5	4.5	2.6
C	1 h on:2 h off	2.5	1.6	5.1	3.6	6.4	2.9	4.0	2.7
D	1 h on:3h off	2.4	1.9	4.8	2.8	6.1	2.4	4.1	2.4
E	1:1 to 1800 h then 1:3	1.9	1.2	5.6	3.1	6.1	2.9	4.4	2.3
D	(2 summers) 1 h on:3 h off	1.8	0.6	-	-	5.7	2.1	5.2	2.4

* Missing values are where sample size was less than five.

Table 5
Distribution of spring (mm/m) of cants, flitches, wings and boards for regrowth jarrah in Part I

		Source of Variation							
		Centre cants		Wings		Flitch halves		Boards	
Bay	Treatment	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	Sawn Fresh	1.5	1.0	0.6	0.8	2.7	2.5	0.6	0.9
A	Continuous	1.0	0.7	0.7	0.4	1.4	0.8	0.6	0.7
B	1 h on:1 h off	1.2	0.8	0.9	0.6	1.8	1.2	0.9	0.8
C	1 h on:2 h off	1.1	0.7	0.8	0.4	2.3	2.1	0.8	0.7
D	1 h on:3 h off	1.1	0.7	0.7	0.6	2.0	1.3	0.8	0.8
E	1:1 to 1800 h then 1:3	1.0	0.7	0.7	0.4	1.5	1.6	0.6	0.6
D	(2 summers) 1 h on:3 h off	1.1	0.7	-	-	1.5	1.9	1.0	0.9

* Missing values are where sample size was less than five

This study has shown that regrowth jarrah sawlogs can be successfully stored under water spray using a 1 h on: 3 h off (Bay D) watering regime.

Operating pumps on a 1 h on : 3 h off schedule saves 75 per cent of water and electricity compared with continuous watering. In this trial the water pumps operated continuously as different stockpiles required water at different times. A sawmiller designing a stockpile may use a large pump and water the whole stockpile several times per day (depending on the schedule), or operate a small pump continuously, but water different sections several times per day. In either situation the sawmiller will save water and operating costs. The actual cost per cubic metre of logs stockpiled is not given in this report as only a small volume was stored.

Exposed log ends degrade first, therefore sprinklers need to be located to give adequate watering to the log ends and logs should be protected from prevailing winds. The Harvey area is subject to strong hot easterly winds during summer, and for this reason, logs in bays A,B,C, and D were positioned north/south and stored with their insulating bark intact. Bay E had log ends oriented east/west but received some shelter from Bay A (Fig. 1).

Conclusion

The success of this trial suggested that the schedule of 1 h on: 3 h off for water sprays, which used the least water and power without adversely affecting log quality, could be reduced further. The second part of the trial was then commenced, using more radical watering schedules.

PART 2

METHODS

Regrowth jarrah logs for Part 2 of this study were extracted from two areas in Ross Block in Harvey District, one area having dense regrowth and the other groups of regrowth trees. Both areas were selectively cut prior to 1960, then in 1986 crop trees were marked to a retention of between 10 and 12 m^2 /ha, according to Departmental silvicultural prescriptions. All unmarked trees suitable for S.E.C. poles and general purpose sawlogs were extracted before the small regrowth sawlogs, which were stockpiled in treatments F to K (described below).

Regrowth karri logs were extracted from Warren Block in Pemberton District and from Weld Block in Walpole District. The Warren site was regenerated from seed trees in 1972 (i.e.15-years-old) and was burnt operationally under a low fire intensity in 1985, resulting in no crown scorch or butt damage. Logs for this stockpile trial were extracted in a first thinning. Trees from the Weld site were regenerated from seed trees in 1967 <R>(i.e. 20-years-old) and the area had not been burnt or thinned since regeneration. The Warren site is of higher quality than the Weld site, which resulted in the Warren trees having faster growth rates. Logs from both sites were of similar size.

Moisture content sampling

The same method of sampling logs for moisture content (as described in Part 1), was used.

Watering schedules

The watering schedules used in Part 2 ranged from continuous spraying (common to both Parts) to 15 min on: 165 min off. The results from Part 1 had indicated that more radical treatments using less water and power could maintain log quality.

The stockpile design and treatments are shown in Figure 3, and the actual watering schedules in Figure 4. Regrowth jarrah was stored in Bays F to K, and regrowth karri in Bays F, G, I and K. The effect of water duration (15 min spraying at a time compared with 1 h) and intensity (the time interval each bay received water) were assessed.

Insect damage

The extent of borer damage in the log at the time of felling was not examined in this trial. A subsequent trial recorded the amount of borer damage in regrowth karri from different sites, age and dominance class (Brennan, unpublished data).

Figure 3. Stockpile design and treatments in Part 2 (Bays F to K).

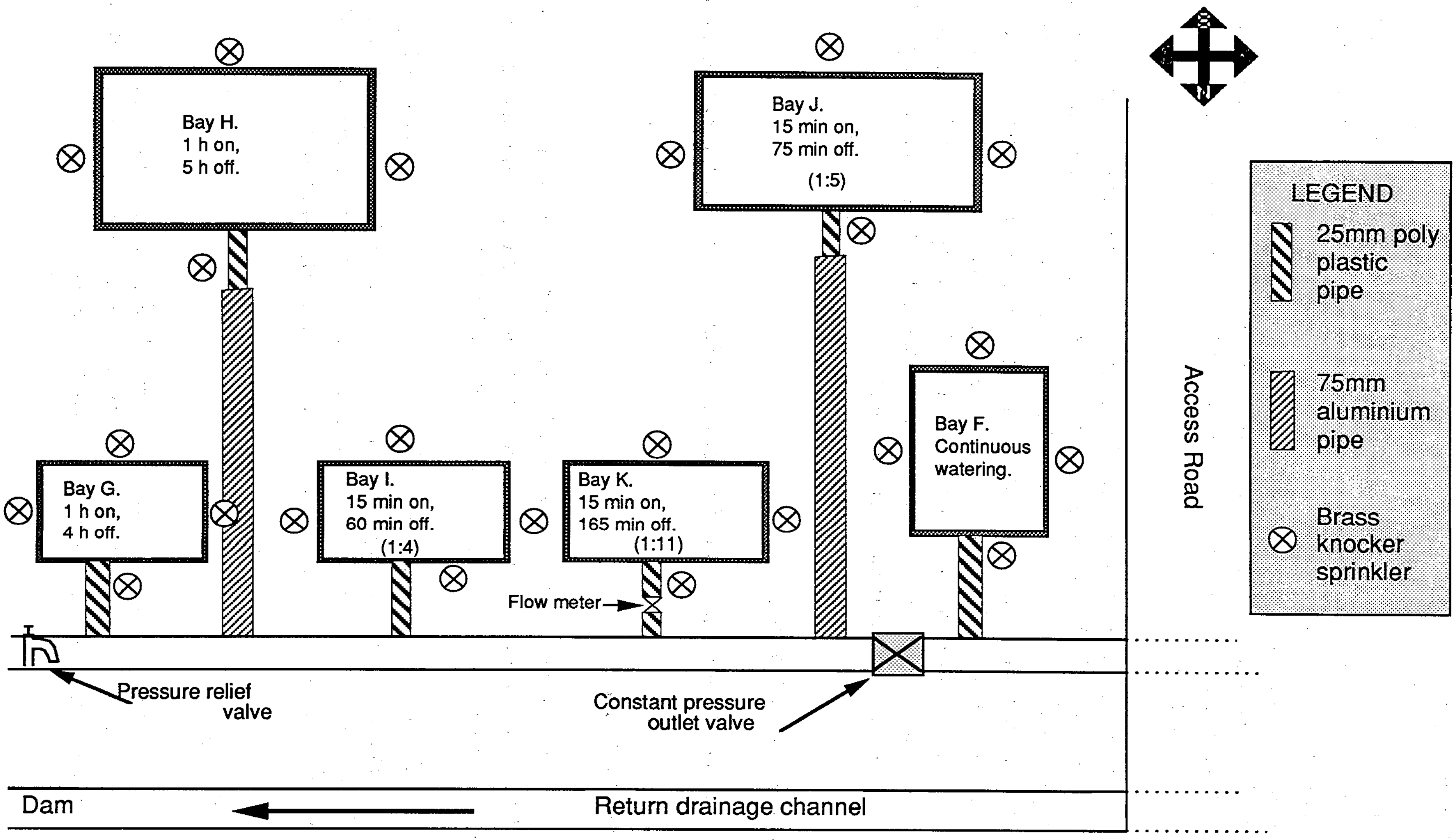
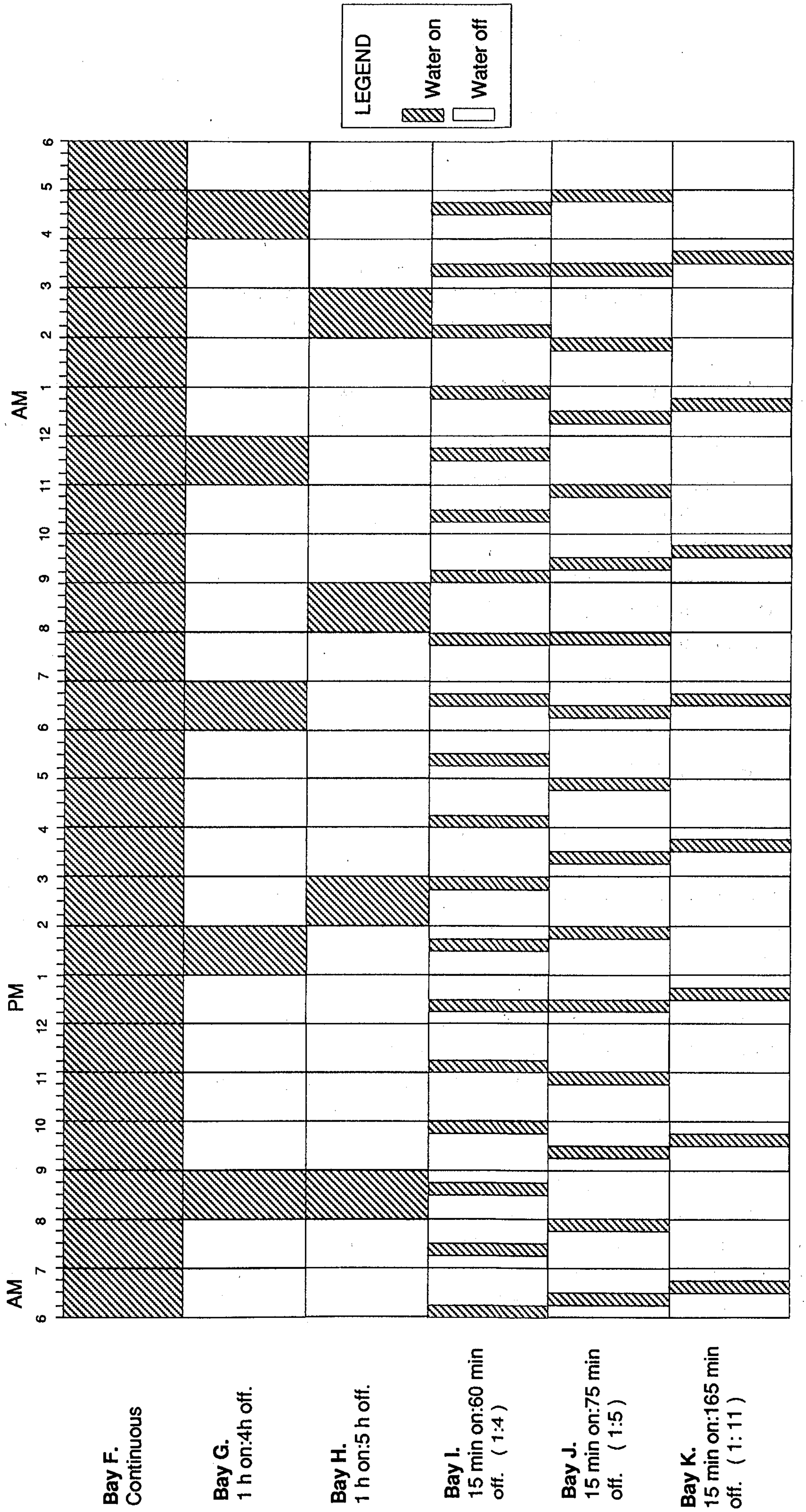


Figure 4. Watering regimes tested in Part 2 of log stockpile trials



RESULTS AND DISCUSSION

As in Part 1, the log diameter (s.e.d.u.b.) distribution in different bays was analysed, but no significant differences were found. The log diameter in all bays followed a normal distribution around the mean s.e.d.u.b. (Table 6).

Table 6
Mean log s.e.d.u.b. (mm) distribution in stockpiling treatments in Part 2

Bay	Treatment	Regrowth jarrah		Regrowth karri	
		Mean	S.D.	Mean	S.D.
F	Continuous	223	40	176	31
G	1 h on:4 h off	217	30	181	30
H	1 h on:5 h off	214	26	-	-
I	15 min on:60 min off	227	41	174	27
J	15 min on: 75 min off	217	32	-	-
K	15 min on:165 min off	222	30	173	32

Log moisture content

For Part 2 only large end moisture contents are given (Table 7). The Part 1 data (Table 2) had shown little difference in the ratio of moisture contents in the sapwood/heartwood ratio before and after stockpiling, although the small end ratios were slightly higher than the large end ratios. In all cases the heartwood moisture content was greater than the sapwood.

Statistical comparison between jarrah data in Parts 1 and 2 was not done because logs were from different sources and were stored for different times. The moisture contents for all categories in Part 1 increased, whereas in Part 2 the jarrah heartwood samples showed a decrease after storage.

After stockpiling, the regrowth karri samples showed increases in the sapwood and heartwood moisture contents, and in cross-sectional moisture contents.
Athough analysis of variance indicated significant differences in sapwood, heartwood, and cross-sectional moisture contents between different treatments, this should have no effect on the sawing behaviour of the logs.

Table 7

Part 2 - Mean log moisture content percentage before and after stockpiling regrowth jarrah and karri logs (standard deviations are in brackets)

	Regrowth jarrah								Regrowth karri							
	Sapwood		Heartwood		Cross section		Ratio of sapwood/ heartwood MC		Sapwood		Heartwood		Cross section		Ratio of sapwood/ heartwoodMC	
Bay	B*	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
F	74.6 (8.8)	94.8 (8.7)	96.7 (11.2)	85.6 (13.0)	84.7 (14.9)	94.4 (9.5)	0.77	1.11	75.7 (12.2)	98.7 (12.8)	85.2 (10.4)	101.7 (12.4)	78.2 (8.5)	97.7 (8.7)	0.88	0.97
G	73.1 (17.1)	97.4 (0.9)	92.0 (14.9)	85.0 (9.5)	81.6 (11.7)	93.1 (10.0)	0.79	1.15	81.5 (11.3)	97.1 (16.2)	86.8 (12.6)	96.8 (12.6)	84.0 (10.5)	95.9 (14.7)	0.94	1.00
H	79.3 (6.8)	89.2 (10.7)	99.7 (12.8)	88.7 (11.3)	92.5 (13.7)	94.2 (12.0)	0.80	1.01								
I	77.4 (7.2)	86.5 (13.6)	98.6 (10.5)	86.8 (10.5)	88.3 (8.4)	89.0 (10.2)	0.78	1.00	79.9 (11.3)	82.3 (15.1)	94.6 (13.6)	102.3 (12.9)	86.9 (9.7)	92.5 (10.6)	0.84	0.80
J	78.6 (9.9)	90.8 (12.5)	99.1 (17.9)	84.6 (11.8)	88.7 (12.4)	90.0 (10.6)	0.79	1.07								
K	75.9 (10.6)	97.3 (14.7)	93.8 (15.3)	80.1 (10.4)	86.1 (12.3)	90.3 (13.0)	0.81	1.21	84.3 (14.7)	96.8 (15.6)	99.2 (15.6)	107.9 (11.2)	86.7 (12.7)	100.6 (11.8)	0.85	0.90
Mean	76.5	92.7	96.6	85.1	87.0	91.8	0.79	1.09	80.4	93.7	91.4	102.2	84.0	96.7	0.88	0.92

B* = Before stockpiling
A = After stockpiling

Only large end sample data are given because Part 1 data (Table 2) indicated little variation between large and small end moisture contents.

Log degradation - end splitting

Regrowth jarrah data in Part 2 were combined (severity classes 0 and 1; and 2, 3, 4 and 5), because of insufficient numbers in individual classes. A chi-squared test was then applied (as in Part 1). Logs in Bay F had significantly fewer end splits than the other Bays and there was no significant difference between Bays G to K. Again end splits were not a problem during sawmilling.

For regrowth karri the majority of the logs were classes 1, 2, or 3 with only 7 per cent being 4 or 5. The data for the combined classes of 0, 1, 2 were compared with those for 3, 4, 5 combined, which was necessary owing to low frequencies in individual classes. A chi-squared test indicated a significant difference in the severity of end splits. Logs in Bay F (continuous water spray) had significantly fewer end splits than Bays G and K (1 h on: 4 h off and 15 min on: 165 min off respectively), which had fewer than Bay I (15 min on: 60 min off). Bay K had the least water applied and was expected to have more splitting than Bay I. Bays G, I and K had very few logs in classes 4 and 5 (severe splitting) although Bay I had a higher frequency of class 3 logs (moderate splitting) than the other two. In general, end splitting was not a problem with regrowth karri, and all logs were satisfactorily processed into 28 mm boards.

Watering schedules

The volume of water used in each treatment, and the percentage of water saved compared with continuous spraying, are shown in Table 8.

Table 8
Readings from 25 mm inferential flow meter in Part 2 of the stockpiling trial

Bay	Treatment	Measurement time (days)	Actual volume (kL/day) * See notes on p. 12	Target volume (kL/day)	Percentage water saved		Watering time (h/day)
					Actual	Expected	
F	Continuous	11	46.9	9.8	83	79	24
G	1 h on:4 h off		8.1				5
F	Continuous	8	57.0	9.5	88	83	24
H	1h on:5 h off		6.7				4
F	Continuous	12	49.9	9.3	78	80	24
I	15 min on:60 min off		10.1				4.75
F	Continuous	7	55.4	9.2	81	79	24
J	15 min on: 75 min off		10.5				4
F	Continuous	9	53.1	4.4	89	92	24
K	15 min on:165 min off		5.9				2

Moisture contents

The initial moisture contents of regrowth jarrah heartwood were greater than those of sapwood before stockpiling (97 and 76 per cent respectively). However, after stockpiling heartwood moisture contents were less than sapwood (85 and 93 per cent respectively), presumably because of some end drying. This was a different result to Part 1 where logs were stockpiled for approximately 6 months less.

Moisture from the heartwood can be restricted from moving to the surface by tyloses concentrated around the heartwood/sapwood boundary, but moisture can readily move along the grain and out of log ends. End drying of regrowth jarrah logs in all bays resulted in heartwood moisture contents decreasing. Sapwood moisture contents still increased as in Part 1, owing to diffusion of water through the bark and sapwood cells. Heartwood moisture contents for regrowth karri were greater than those of sapwood before stockpiling (91 and 80 per cent respectively), and after stockpiling (102 and 94 per cent respectively).

Moisture content ratios before and after stockpiling for regrowth jarrah in Part I and regrowth karri were similar, indicating the uptake of water was equally proportioned between the sapwood and heartwood (Tables 2 and 7 respectively).

For regrowth jarrah in Part 2, the moisture content ratios after stockpiling were greater than those before stockpiling, owing to the increase in sapwood moisture and the decrease in heartwood moisture through end drying.

Sawmilling

Generally the bow and spring measurements in boards in Part 2 (Tables 9 and 10) were larger than those in Part 1 (Tables 4 and 5) even though the latter logs were stockpiled for 6 months less. This result was not expected.

Mean bow of regrowth karri boards in Part 2 was 6.1 mm/m (Table 9). This amount of bow is unacceptable in AS2082-1979 (Standards Association of Australia 1979) for Structural Grades 1, 2 and 3. Drying of the boards subsequently reduced bow to limits acceptable to AS2082-1979.

For spring in boards, a significant difference was found between bays (Table 12). However, the mean difference between bays was only 0.6 mm/m, which is not of practical importance.

Table 9
Distribution of bow (mm/m) of cants, flitches, wings and boards for regrowth jarrah in Part 2

		Source of Variation							
Stockpile Bay	**Treatment**	**Centre cants**		**Wings**		**Flitch halves**		**Boards**	
		Mean	**S.D.**	**Mean**	**S.D**	**Mean**	**S.D.**	**Mean**	**S.D.**
F	Continuous	2.0	0.9	6.9	4.6	6.9	2.5	6.1	2.8
G	1 h on:4 h off	1.6	1.0	5.0	2.9	5.4	2.4	4.5	2.4
H	1 h on:5 h off	1.8	1.0	4.7	2.9	6.0	2.6	5.0	2.9
I	15 min on:60 min off	2.2	1.1	5.2	3.7	5.7	2.3	5.0	2.9
J	15 min on:75 min off	1.9	1.4	4.7	3.8	5.9	2.9	4.5	2.9
K	15 min on:165 min off	1.8	1.1	4.5	3.4	5.6	2.6	5.0	3.1

Table 10
Distribution of spring (mm/m) of cants, flitches, wings and boards for regrowth jarrah in Part 2

		Source of Variation							
Stockpile Bay	**Treatment**	**Centre cants**		**Wings**		**Flitch halves**		**Boards**	
		Mean	**S.D.**	**Mean**	**S.D**	**Mean**	**S.D.**	**Mean**	**S.D.**
F	Continuous	1.2	0.7	0.3	0.4	2.0	1.2	1.7	1.0
G	1 h on:4 h off	1.1	0.6	0.3	0.6	1.7	1.2	1.1	0.8
H	1 h on:5 h off	1.0	0.7	0.3	0.6	1.8	1.6	1.2	1.3
I	15 min on:60 min off	1.2	0.8	0.2	0.3	2.0	1.6	1.3	1.2
J	15 min on:75 min off	1.0	0.7	0.2	0.7	1.8	1.7	1.1	0.8
K	15 min on:165 min off	0.8	0.8	0.1	0.3	1.5	1.1	4.0	1.0

Table 11
Distribution of bow (mm/m) of flitches, wings and boards for regrowth karri in Part 2

Stockpile Bay Treatment	Source of Variation Centre cants		Wings		Flitch halves		Boards	
	Mean	S.D.	Mean	S.D	Mean	S.D.	Mean	S.D.
F Continuous	1.8	1.6	6.1	3.3	6.3	2.5	5.9	2.5
G 1 h on:4h off	2.3	1.2	7.9	5.3	6.2	2.5	6.8	3.6
I 15 min on:60 min off	1.4	0.8	5.7	3.4	5.5	2.4	5.8	1.4
K 15 min on:165 min off	2.0	2.0	5.3	4.2	5.6	2.3	5.8	2.8

Table 12
Distribution of spring (mm/m) of flitches, wings and boards for regrowth karri in Part 2

Stockpile Bay Treatment	Source of Variation Centre cants		Wings		Flitch halves		Boards	
	Mean	S.D.	Mean	S.D	Mean	S.D.	Mean	S.D.
F Continuous	0.8	0.7	0.1	0.1	1.5	1.2	0.8	0.6
G 1 h on:4 h off	1.1	0.7	0.5	2.0	2.4	1.8	1.0	0.8
I 15 min on:60 min off	1.0	0.8	0.1	0.3	1.5	0.9	1.2	1.0
K 15 min on:165 min off	0.8	0.7	0.2	0.8	1.5	1.3	1.4	1.3

According to AS2796-1985 (Standards Association of Australia 1985), the amount of bow and spring measured in this trial would be acceptable in select grade dressed boards, and a large proportion would make clear grade. From past seasoning experiments, drying 25 mm regrowth jarrah from green to below fibre saturation point in a tunnel kiln under mild winter conditions will reduce the amount of bow (Brennan 1990). Therefore the bow of boards in the green state can be reduced to a level acceptable in both select and clear grades in AS2796-1985. McKimm *et al.* (1985) found the amount of spring and bow of 25 mm and 50 mm material of *E. nitens* decreased with drying, with bow reducing between 7 mm and 9 mm. Their results also show that the distortion after seasoning in these products is well within the permissible limit for spring, twist and bow described in AS2082-1979 (Standards Association of Australia 1979).

In summary, regrowth jarrah and karri can be successfully stored under a 15 min on, 165 min off watering schedule. Comparison of reduced watering regimes with continuous spraying show no problems with the amount of end splitting and bow and spring of milled boards. Sawmills using water sprays to protect stockpiled logs, based on this trial, need to determine the watering regime most suited to their water supply, pump capacity and stockpile design. The principles outlined in this paper should apply to stockpiling under high pressure water sprays of any regrowth eucalypt logs.

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