LOGGING INDUSTRY RESEARCH ASSOCIATION

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PROJECT REPORT

FELLING TECHNIQUES TO MINIMISE BUTT DAMAGE

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AND
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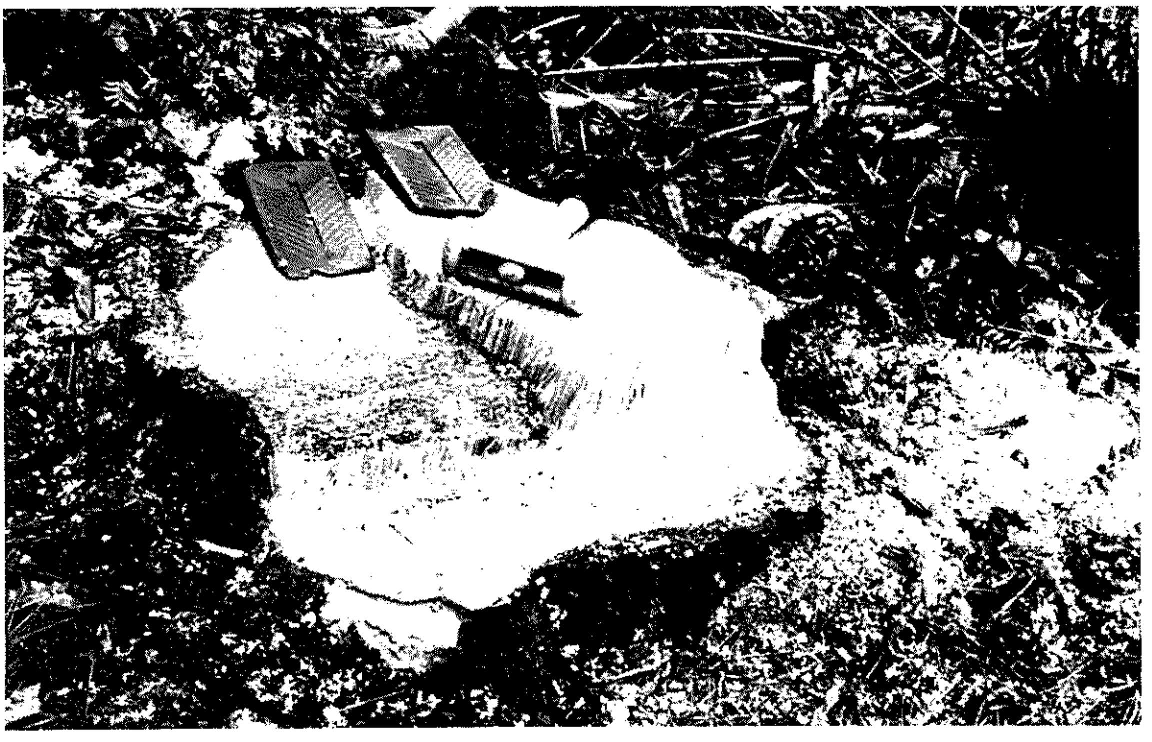

Project Report

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FELLING TECHNIQUES TO MINIMISE BUTT DAMAGE

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EXECUTIVE SUMMARY

The forest industry in the Central North Island is moving into the transition crop stands of radiata pine planted in the 1950's and early 1960's. These stands have been subject to a wide range of pruning and thinning treatments. In the high pruned stands, the butt log will be extremely valuable. Good felling techniques can protect these butt logs by minimising felling damage.

LIRA undertook a major study to identify the techniques that were most effective in controlling felling damage. This is described under four headings below :

- *(i) Felling survey*
- *(ii) Felling trials*
- *(iii) Hinge strength testing*
- *(iv) The effects of winds and side lean.*

Following the Felling Trials, a Felling Working Group was set up to review the work. It included representatives of the major forestry organisations, the Department of Labour, Logging and Forest Industry Training Board, and contractors. Their work is reported under a fifth heading.

1. Felling Survey

Nine fallers on seven forests were studied while each felled twenty trees. Detailed information was collected on each faller, his equipment, techniques used, stump measurements and felling damage from slabbing and draw wood. The most common difficulties were :

- *aligning the bottom cut with the top cut of the scarf;*
- *estimating correct scarf angles;*
- *judging correct back cut height;*
- *judging correct hinge width;*
- *setting up trees to be driven;*
- *using an inappropriate felling technique.*

It was noted that fallers who used good basic practices (as described in Appendix I) generally achieved lower levels of butt damage than those who didn't. Fallers who had undergone some formal training were generally more consistent in their techniques and used a wider range of techniques than those who hadn't. This suggests that forest owners could expect significant benefits from the introduction of formal training schemes such as those advocated by the Logging and Forest Industry Training Board.

Results also indicated a big variation in the incidence of slabbing, between forests in different locations. The incidence and magnitude of slabbing appears to be higher in the transition crop stands than in the old crop stands.

2. Felling Trials

The felling trials examined the effectiveness of good basic techniques and the consequences of making changes to key factors in these techniques in a series of controlled tests. The factors included: scarf type, scarf angle, scarf depth, back cut height, hinge thickness and different side cutting techniques.

Lean was seen to have a major influence on felling damage. A method of lean assessment was used to identify trees with a high risk of butt damage. In general, good basic techniques provided good results in most situations. There were situations, predominantly those involving trees with a significant degree of lean, where alternative back cutting techniques (described in Appendix I) were used to set up the hinge before completing the back cut.

Hinge thickness was considered to be the most important factor that influenced draw wood. Thick hinges (20% to 30% of diameter) consistently produced high values of draw wood. Thin hinges (10% of diameter) minimised draw wood.

Slabbing was recognised as being a major component of felling damage. Analysis of data from 115 trees felled using conventional techniques (no side cutting) suggested the value loss in a pruned stand could be $1400 to $2600/hectare, depending on the sawlog premiums and stocking. A number of different side cutting techniques were tested. Horizontal side cuts and steeply angled wing cuts were found to be equally effective in reducing the incidence of slabbing by over 90%. The Felling Working Group considered that wing cuts were the safest option and subsequently recommended that wing cuts and not side cuts should be used to control slabbing. This technique has the potential to provide major benefits to forest owners in high value stands where slabbing is a problem.

A new technique, vertical under cuts, was developed to control slabbing in heavy side leaners, where the use of wing cuts may cause the tree to fall off-line. The Felling Working Group recommended that this technique should undergo field evaluation but not be promoted for general use at this stage.

3. *Hinge Strength Testing*

As a result of concern over the effect of different side cutting techniques on tree stability, a series of tests were carried out to measure hinge strength. Pilot tests were carried out on standing trees and on 4 m high stumps. A comprehensive study using tree-length logs was then carried out to compare full hinges (no side cutting treatment) with three other hinge types :

- *vertical under cut*
- *side cut*
- *wing cut.*

The results indicated that, on average, vertical under cuts reduced hinge strength by 16%, side cuts by 24% and wing cuts by 25%. This data confirmed the author's impressions that vertical under cuts provided a stronger hinge than side cut or wing cut hinges. It also confirmed that, in a controlled situation, there were no differences between wing cuts and side cuts in their effect on hinge strength.

The data recorded a very wide variation in hinge strength between individual trees. This would help explain why some apparently identical trees behave differently to others when subject to the same felling treatment.

4. *The Effect of Wind and Side Lean*

Some basic modelling was undertaken to estimate the forces generated by wind and by side lean. The results suggested that while these forces would not strongly influence trees of average strength within the range of values tested, they would influence the weaker trees.

For vertical trees, winds up to 50 km/hr would have little effect on trees that had been scarfed and back cut, leaving a full hinge (no side cuts). If wing cuts were applied, the wind would need to exceed 30 km/hr before the weaker trees were affected.

Heavy side leaners are more susceptible to wind. Winds of 30 km/hr would affect side leaners with a full hinge. If wing cuts were applied, some trees (approx. 10%) could be expected to fail under calm conditions. The use of an experimental technique, vertical under cuts, would substantially increase their stability.

In a field situation, the faller would normally increase the thickness of the hinge on the tension side of heavy sideleaners to increase hinge strength and avoid premature failure of the hinge during felling.

5. *The Felling Working Group*

A Felling Working Group was set up in August 1986 to review the felling research and the trial work, and to advise on extension. As a result of their direction, the work on hinge strength testing was undertaken for the different hinge types, as was the basic modelling work on the forces generated by wind and side lean. At the final meeting in July 1987, they made four recommendations to the Department of Labour. These related to :

- *endorsement of the effectiveness of good basic techniques in minimising felling damage in most situations;*
- *the use of wing cuts, but not side cuts, to control slabbing on trees with little or no side lean;*
- *the use of vertical under cuts for the purposes of further evaluation only.*

A brief description of' recommended felling practices is included in the Appendices, along with: a glossary of terms, a bibliography, a list of Felling Working Group members, copies of field forms, an outline of hinge strength calculations, and of the forces generated by wind and side lean.

1. INTRODUCTION

The Forest Industry in the Central North Island is moving out of the "old crop" stands planted before 1940 and into the plantings of the 1950's and early 1960's. These have been described as transition crop stands as they have been subject to a wide range of pruning and thinning treatments. In high pruned stands, the butt log will be extremely valuable. Poor felling techniques can produce significant loss through slabbing and draw wood. Slabbing occurs when a strip of wood tears away from the outside of the log; draw wood occurs when slivers of wood are pulled out from the inner section of the log (Figure 1). These, and other terms, are defined in the Glossary of Terms (Appendix IV).

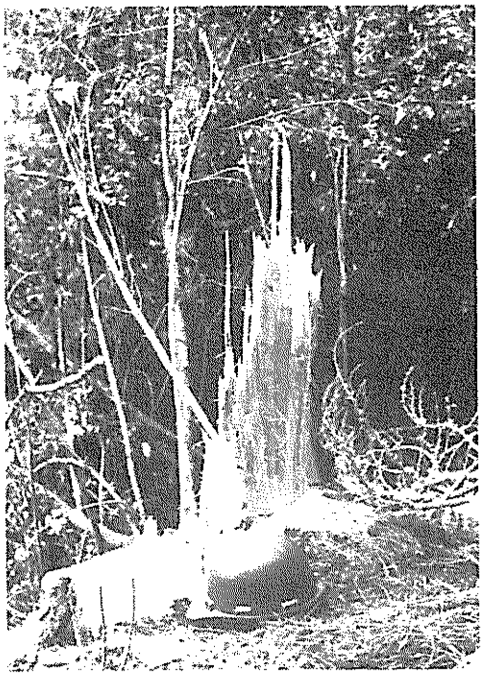


Figure 1 : Butt damage showing slabbing and draw wood

In most situations, the damage occurs along the hinge wood. Both forms of damage can result in substantial volume loss when the end of the log is squared off to remove the damaged section. Slabbing is potentially the more serious form of damage as it can result in losses that exceed 1 metre of log length. Draw wood is usually less than 30 cm in length. The value loss can easily exceed $1,000 per hectare.

It has long been recognised that good felling techniques would be required to protect pruned butt logs by minimising slabbing and draw wood. Major forest organisations are addressing the problem as they become involved in clearfelling of transition crop stands.

In a study of directional felling of transition crop radiata pine on steep terrain (Murphy and Gaskin, 1982), it was found the lowest incidence of butt damage occurred when felling across the slope. However stump height averaged 18 cm, 8 cm higher than when felling down hill. In assessing value savings from the above trial, Murphy (1982) noted that "about 30% of the value loss that occurs during felling can be linked to the loss of pruned log volume in the stump".

The first published work on techniques to reduce felling-related butt damage in radiata pine (Murphy and Buse, 1984) discussed the effect of one side cutting technique. The authors concluded "for trees of about 3 m^3 average stem size, we found that the side cut felling method would help to reduce both the incidence and length of butt damage".

Based on these earlier studies and a strong industry demand for work in developing techniques to reduce the incidence and severity of butt damage caused through felling, LIRA proposed a three-stage approach:

Stage 1 involved a review of relevant literature and a survey of existing techniques and the incidence of butt damage.

Stage 2 suggested the development and testing of the more promising techniques.

Stage 3 involved demonstrating these techniques to the industry.

After the completion of Stage 2, a working group of interested parties was set up under the chairmanship of Mr Kingi Porima (Tasman Forestry Limited) to :

- review the felling research and trial work, and
- consider methods of extension.

The group included representatives from: the major industry groups, the Logging and Forest Industry Training Board, the Department of Labour, and contractors. These are listed in Appendix VIII. The recommendations of the group are included in Section 6 of this report.

2. FELLING SURVEY

The purpose of the survey was to obtain information on the present "state of the art" by studying fallers working in transition crop radiata pine. After discussion with staff from the L & FITB and the major industry organisations, seven exotic forests were selected. These were Matahina, Kinleith, Gwavas, Esk, Tairua and Golden Downs Forests, and Whakarewarewa Forest Park.

2.1 METHOD

A total of nine fallers were chosen at random and the following information was collected :

- logging experience
- chainsaw (make, model and bar length)
- felling pattern
- topography
- stand age.

Each faller was then observed while he felled twenty trees. The trees were randomly selected to cover a range of tree characteristics (size, lean and branching habit). As well as information on felling techniques, the data collected included :

- stump diameter
- stump height
- scarf depth
- scarf height
- side cutting technique used
- back cut height
- hinge wood (size and shape).

A copy of the Felling Survey Form is contained in Appendix VI.

2.2 SURVEY RESULTS

Information on the faller and his chainsaw, along with some stand information, is summarised in Table 1.

2.2.1 Felling Techniques

(a) Scarf Type

All fallers used the conventional scarf; no variations such as Humboldt or Vee scarf were observed (Figures 2, 3, 11). Eight of the nine fallers consistently put in the top cut before the bottom cut of the scarf. Some problems in aligning the two cuts were noted, resulting in over-cutting.

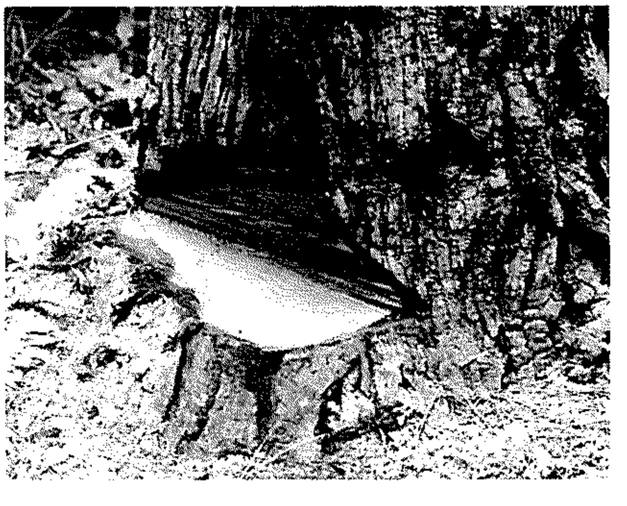


Figure 2 - Conventional Scarf

TABLE 1 : SUMMARY OF FELLING SURVEY DATA

Faller No.	Logging Experience (Yrs)	Chainsaw	Bar Length (cm)	Stand Age (Yrs)	Stump Diameter Mean (Range) cm	
1	9	Husqvarna 181	51 cm	33 yrs	70	(48-91)
2	4	Jonsered 920	51 cm	33 yrs	62	(44-84)
3	30	Stihl 051	66 cm	45 yrs	67	(30-100)
4	15	Husqvarna 181	51 cm	37 yrs	65	(54-79)
5	15	Stihl 048	61 cm	25 yrs	70	(43-89)
6	15	Husqvarna 181	51 cm	27 yrs	61	(48-80)
7	4	Stihl 051	66 cm	35 yrs	57	(42-81)
8	7	Husqvarna 181	51 cm	45 yrs	57	(34-81)
9	10	Husqvarna 266	46 cm	37 yrs	65	(41-111)

(b) Scarf Angle

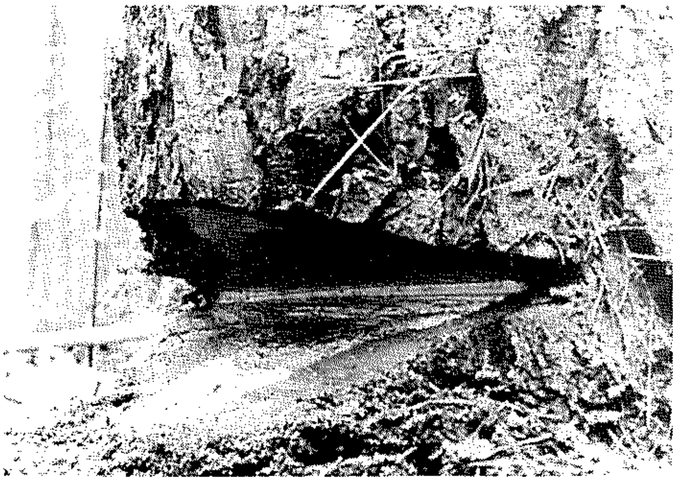


Figure 3 - Humboldt Scarf

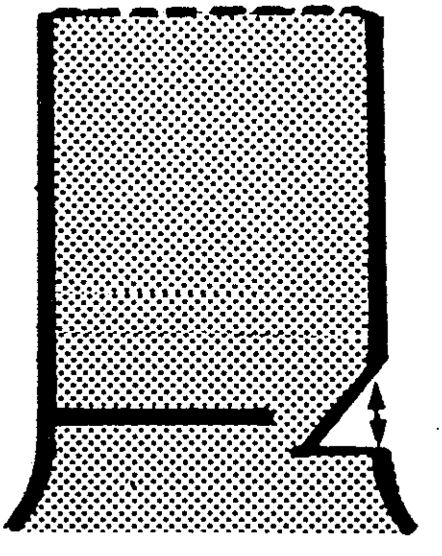


Figure 4 - Measurement of Scarf Angle

Scarf angle (the angle between the top cut and bottom cut) was calculated from scarf height and scarf depth (Figure 4). The results are summarised in Table 2.

The mean scarf angle varied widely from 28° (faller 8) to 49° (faller 3). Conventional scarf angles are normally close to 45°. Several fallers had difficulty in achieving consistency, as shown by a range of more than 20° in their scarf angles.

TABLE 2 : SCARF ANGLES FOR NINE FALLERS

Scarf Angle			Faller No.
Mean	(s.d.)*	Range	
28°	(5°)	20° - 38°	8
30°	(6°)	18° - 44°	6
36°	(6°)	22° - 46°	1
39°	(7°)	24° - 52°	9
42°	(3°)	36° - 46°	4
42°	(5°)	30° - 50°	5
42°	(7°)	30° - 56°	7
45°	(5°)	36° - 52°	2
49°	(5°)	40° - 60°	3

*(s.d.) = standard deviation, a measure of the distribution of data about the mean.

Note : Mean scarf angles differ significantly (at the 99% level) if they are in separate boxes.

(c) Side Cutting Techniques

Side cuts were used by three fallers, two using wing cuts and one using side cuts (Figures 5, 6). These techniques are discussed in Section 4.

Figure 5 - Side Cuts

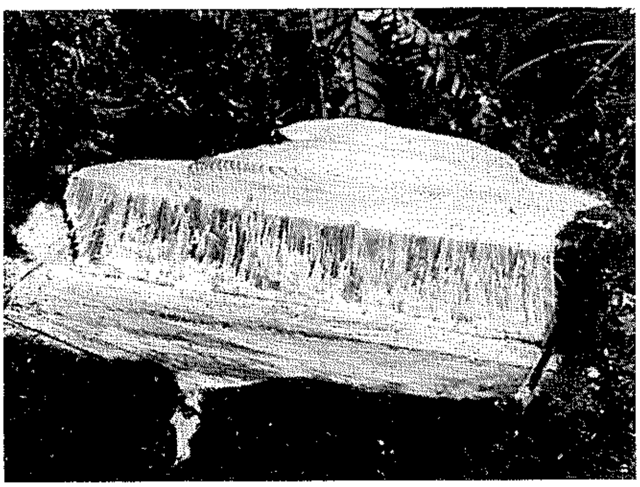


Figure 6 - Wing Cuts

(d) Back Cutting Techniques

Conventional back cutting techniques (i.e. cutting straight through) were used by all fallers (see Appendix I, Figure 2). Four fallers were observed to use alternative techniques (see Appendix I, Figures 3-5).

(e) Back Cut Height

Back cut height was recorded as its height above the bottom cut of the scarf (Figure 7). The results are shown in Table 3.

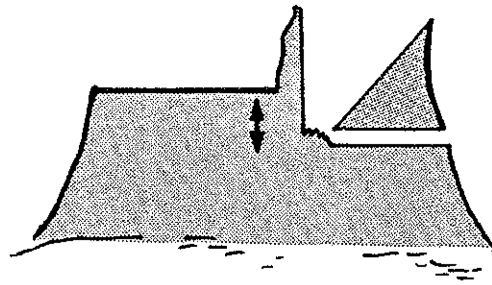


Figure 7 - Measurement of back cut height

In most situations, the fallers followed the conventional practice of having the back cut height of about 10% of stump diameter.

TABLE 3 : BACKCUT HEIGHT FOR NINE FALLERS

Backcut Height (cm)			Faller No.
Mean	*(s.d.)*	*Range*	
0	4	-8 - 8	8
7	5	-2 - 20	5
8	3	4 - 14	7
8	4	2 - 18	9
8	5	-2 - 20	1
8	5	2 - 20	6
9	4	2 - 16	3
11	3	6 - 20	4
11	4	6 - 20	2

Note : Mean backcut heights differ significantly (at the 99% level) if they are in separate boxes.

One faller (No. 8) frequently placed his back cut level with or below the bottom cut, a dangerous practice, in an effort to increase the length of pruned butt log.

(f) Felling Aids

Five of the nine fallers carried wedges and used them regularly. Driving was used at times by most fallers. On one occasion, a skidder was used to push a back leaner.

(g) Hinge Wood

Hinge wood varied in both shape and width, averaging 7 cm (range 1 - 23 cm), with most lying in the 3 - 11 cm range. After allowing for the effect of lean, it was apparent that some fallers had difficulty in estimating hinge width and in achieving a regular hinge shape. On trees with little or no side lean, the hinge wood is usually rectangular in shape (Figure 8).

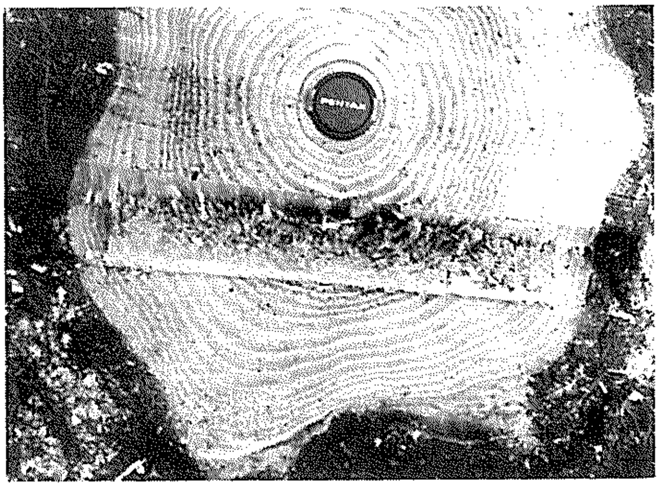


Figure 8 - Well-shaped Hinge Wood

(h) Stump Height

Stump height was recorded as being the height from ground level to the back cut. The data is summarised in Table 4.

TABLE 4 : STUMP HEIGHTS FOR NINE FALLERS

Stump Height (cm)			*Faller No.*
Mean	*(s.d.)*	*Range*	
10	(5)	4 - 20	9
11	(4)	8 - 20	3
12	(4)	4 - 18	2
13	(3)	8 - 20	8
15	(4)	8 - 24	7
17	(8)	8 - 36	5
19	(6)	8 - 32	4
20	(13)	8 - 56	6
26	(10)	10 - 48	1

Note : Mean stump heights differ significantly (at the 99% level) if they are in separate boxes.

Stump heights averaged 16 cm; 15% exceeded 20 cm (the maximum allowable height in Kaingaroa forest) and 8% exceeded 30 cm, mostly from one faller (No. 1).

(i) Butt Damage

Two types of butt damage were recorded, draw wood where damage occurred inside the log, and slab wood where damage occurred to the outside.

(i) Draw wood data is summarised in Table 5.

Draw wood was recorded on 75% of the stumps. It averaged 13 cm in length with a range of 1 - 74 cm. On 15% of all stumps, it exceeded 25 cm in length. One faller (No. 8) had five of the six stumps where draw wood exceeded 40 cm.

TABLE 5 : DRAW WOOD FOR NINE FALLERS

Draw Wood (cm)			Faller No.
Mean	(s.d.)	Range	
3	4	0 - 11	5
9	9	0 - 28	6
9	11	0 - 37	2
10	9	0 - 31	3
13	11	0 - 35	7
13	15	0 - 62	9
15	11	0 - 38	4
16	10	0 - 34	1
26	22	0 - 74	8

Note : Mean draw wood values differ significantly (at the 99% level) if they are in separate boxes

(ii) Slabbing occurred in 12% of all stumps and averaged 55 cm (range 7 to 130 cm). Three fallers used side cutting techniques (No. 3, 7 and 9) and these were generally effective in minimising slabbing (see Figure 9). Three other fallers (2, 5, 6) also achieved very good results, although there is no record of any side cutting technique being applied. Most of the slabbing arises from a single faller (No. 1) with slabbing in almost half his trees. More than one-third exceeded 30 cm in length. The skewed distribution of the data is partly a result of the large number of zero values.

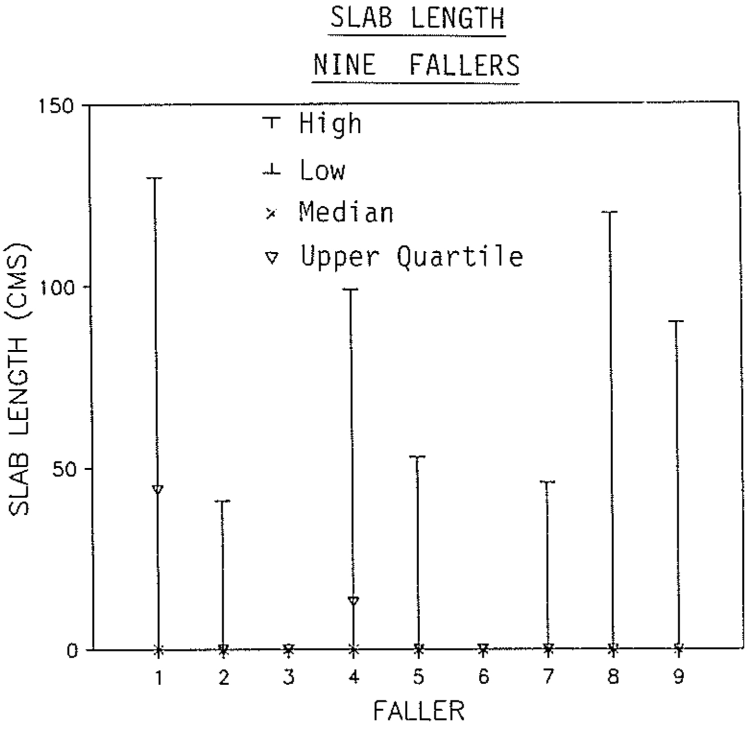


Figure 9 : Slab Wood for Nine Fallers

2.3 DISCUSSION

The main factors arising from the survey were the problems that some operators were experiencing in :

(i) aligning the bottom cut to the top cut of the scarf;
(ii) estimating correct scarf angle;
(iii) judging correct back cut height;
(iv) judging correct hinge width;
(v) setting up trees to be driven;
(vi) using inappropriate felling techniques (e.g. using long bar techniques on large trees while operating a chainsaw with a short bar).

Informal discussions with the fallers identified those who had received some form of formal or systematic training. In general, those fallers were more consistent in their techniques, used safer methods and achieved better results than those who had not. It would suggest that forest owners have a lot to gain from actively promoting basic faller training. However, it has been suggested (W. Blundell, pers. comm.) that some fallers with a high degree of natural ability develop a flair for knowing how and where to cut a tree for a given set of conditions. These fallers can achieve good results (despite a lack of formal training) even if all the aspects of good basic practice are not followed.

The survey results suggest that, in general, the fallers who used good basic practices achieved lower levels of butt damage than those who didn't. (Compare Nos 2 and 5 with Nos 1 and 8 in Table 5 and Figure 9.) However, faller No. 6 achieved good results on all 20 trees, despite narrow scarf angles (20 - 35°) and a wide range of back cut heights (1 to 20 cm). This would appear to support the suggestion of a faller with a high level of natural ability. However, it should be noted that the frequency of slabbing appeared to vary widely from stand to stand. Of the six fallers (on six different forests) who did not use any side cutting techniques, only two had a high incidence of slabbing. The lack of a consistent relationship between the magnitude and frequency of butt damage, and factors such as hinge thickness and back cut height, suggest there were other factors involved in contributing to butt damage.

3. FELLING TRIALS

3.1 INTRODUCTION

Following analysis of the survey data, it was decided to undertake a series of felling trials under controlled conditions to examine their effect on butt damage.

The first phase of the trials involved the testing of key factors. These included :

- Scarf angle
- Scarf depth
- Back cut height
- Hinge thickness
- Side cutting techniques

The second phase involved testing and refinement of the most promising techniques on a range of ages and sizes of trees with varying degrees of lean in different forests, and varying topography.

The number of combinations of key factors required a large sample of trees for testing. A total of 290 trees were assessed after felling to a prescribed method, using unique combinations of factors.

Details of forests, number of trees, stand age and treatment purpose are shown in Table 6.

TABLE 6 : FELLING TRIALS - FORESTS, STAND AGES AND NUMBERS OF TREES ASSESSED

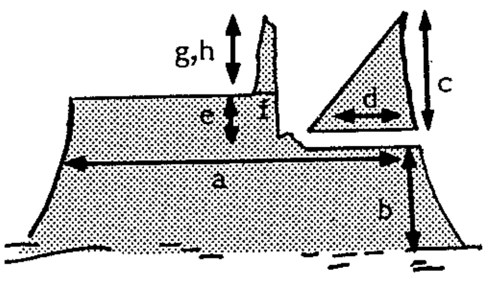
Forest	Stand Age (Years)	No. of Trees	Purpose
Whaka	40	70	Testing of key factors
Whaka	40	77	Testing of treatments and method development
Kinleith	33	64	Testing and refinement of most promising methods
Matahina	27	51	Testing and refinement of most promising methods
Rotoehu	29	28	Testing and refinement of most promising methods

3.2 METHOD

Felling trials were initially carried out in 40 year old radiata pine in Compartment 15, Whakarewarewa State Forest Park. To look at the effect of varying a single factor, a small number of trees (minimum of four) were felled using the same method throughout. This involved using carefully controlled felling techniques, maintaining the same scarf type, scarf angle and keeping scarf depth, back cut height and hinge thickness constant (as a proportion of diameter) as far as possible. The use of a small group of trees made some allowance for the tree-to-tree variation. It had originally been planned to try and match the trees in each group for diameter and lean, but this proved impractical. Instead, each tree was subjectively assessed for lean in two directions - side lean and forward/back lean. Details of the method of assessment are in Appendix V.

A plumbob was used to assist in checking the eyeball assessment, although a considerable degree of interpretation was involved in assessing trees with lean in the lower and upper sections in opposite directions (e.g. S-shaped trees). There was also some allowance made for branching habit in the assessment. This greatly assisted in identifying potential candidates for severe butt damage. Usually, lean is only considered in terms of its effect on the felling direction.

Detailed measurements were carried out on the stump to record the key factors (Figure 10). A copy of the Felling Trials Assessment Form is reproduced in Appendix VII.



a - Stump diameter
b - Stump height
c - Scarf height
d - Scarf depth
e - Backcut height
f - Hinge width
g - Slab
h - Draw

Figure 10 : Measurements Recorded During Felling Trials

3.3 RESULTS

3.3.1 Effect of Scarf Type on Draw Wood

Three scarf types were tested; the conventional, the Humboldt and the Vee. These are shown in Figure 11. Differences existed in the levels of draw wood achieved, but these were not statistically significant, due to the high variability of the data.

SCARF TYPES

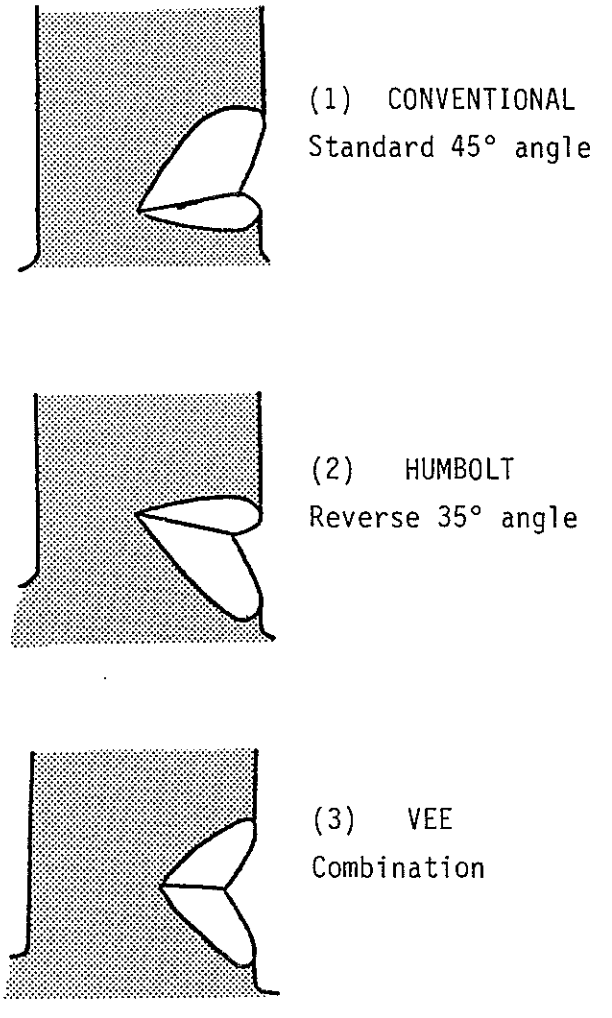


Figure 11 : The three scarf types tested

The results of these tests are summarised in Table 7.

TABLE 7 : EFFECT OF SCARF TYPE ON DRAW WOOD

Scarf Type	Scarf Angle Mean	No. of Trees	Draw Wood Mean	(s.d.)
Conventional	44°	10	12 cm	(10)
Humbolt	34°	7	22 cm	(18)
Vee	40°	5	8 cm	(5)

TABLE 8 : EFFECT OF HINGE THICKNESS AND SCARF ANGLE ON DRAW WOOD

Hinge Thickness (as % of diameter)	Scarf Angle	No. of Trees	Draw Wood Mean	(s.d.)
Thin (5%)	Conventional (45°)	4	4 cm	(6)
	Open (57°)	4	6 cm	(1)
Conventional (10%)	Narrow (28°)	5	7 cm	(7)
	Conventional (45°)	10	12 cm	(10)
Thick (15%)	Conventional (45°)	11	18 cm	(7)
	Open (57°)	8	19 cm	(6)

3.3.2 Effect of Scarf Angle on Draw Wood

Three types of scarf angle were tested with a conventional scarf (one with a horizontal bottom cut).

These were :

- narrow (nominally 30°);
- conventional (nominally 45°); and
- open (nominally 60°).

They were tested in combination with different thicknesses of hinge wood. These were :

- thin (nominally 5 cm);
- conventional (nominally 10 cm); and
- thick (nominally 15 cm).

Three combinations are shown below (Figure 12).

Only six of the nine possible combinations were adequately sampled. The results (Table 8) indicated no significant differences between the three different scarf angles tested, but clearly showed the importance of hinge thickness on draw wood (discussed later in Section 3.3.7).

A further series of trials were conducted in September 1986 at Kaingaroa Forest on new crop radiata pine. One of the paired treatments involved another comparison of the effect of a shallow scarf (30°) and a conventional (45°) scarf on draw wood on 'normal' trees (those with little or no sidelean). The two treatments produced similar results.

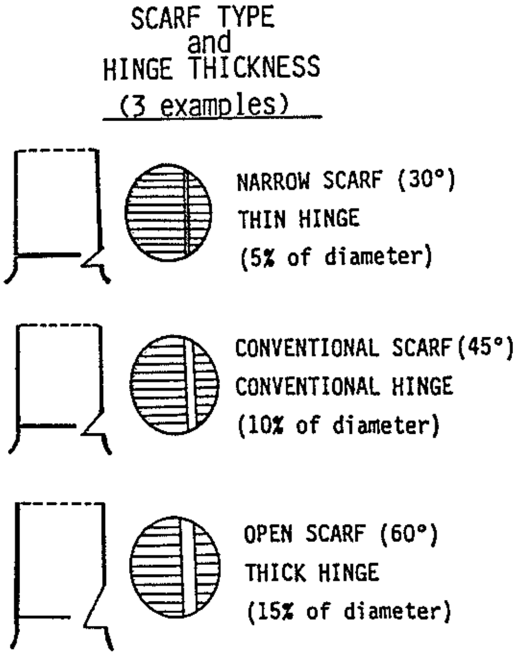


Figure 12 : Three combinations of scarf angle and hinge thickness

3.3.3 Effect of Scarf Depth

Three types of scarf depth were tested with a conventional scarf. These were shallow (nominally 20% of stump diameter), conventional (30%) and deep (40%). Lowest values of draw wood were obtained with a shallow scarf, and then the deep scarf. These differences were not statistically significant as there was a high degree of variability in the data. (Table 9).

TABLE 9 : EFFECT OF SCARF DEPTH ON DRAW WOOD

Scarf Depth	Measured Depth (as % of diameter)	No. of Trees	Draw Wood Mean	(s.d.)
Shallow (15 cm)	22%	4	6 cm	(5)
Conventional (19 cm)	30%	10	12 cm	(10)
Deep (24 cm)	36%	5	17 cm	(12)

3.3.4 Effect of Side Cutting

Two types of side cutting techniques were tested; side cuts (horizontal) and wing cuts (angled). (Figure 13.)

The first series of tests involved side cuts. The use of side cuts was highly effective in reducing slabbing to minimal levels. Analysis data for 252 trees from four forests showed that side cuts reduced slabbing from 37% to 3%, a dramatic reduction. This involved all three types of scarf.

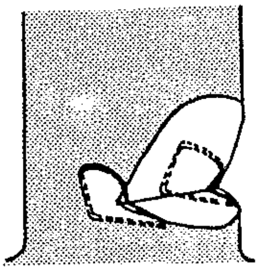
Analysis of data for 40 trees from Kinleith forest showed a reduction in slabbing from 62% to 8%. If four heavy sideleaners are excluded, the reduction is from 47% to 6% (significant at the 95% level). Only the conventional scarf was used. Where slabbing does occur with side cuts, it is of limited significance (Table 10).

TABLE 10 : EFFECT OF SIDE CUTS - KINLEITH FOREST - NORMAL TREES

Treatment	No. of Trees	Frequency of Slabbing	Slab Size Mean	Slab Size Range
No side cuts	19	47%	24	0 - 120
Two side cuts	17	6%	0.4	0 - 7

Note : Mean values for slab size differ significantly (at the 99% level)

Two comparisons of side cuts and wing cuts were undertaken.



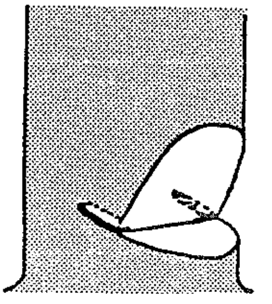


Figure 13 : Two Side Cutting Techniques - Sidecuts and Wingcuts

The first comparison was made using a Humbolt scarf. Both cuts were effective in preventing slabbing. The side cuts also resulted in lower values for draw wood.

The second comparison used a conventional scarf. Again both techniques were effective in reducing slabbing, and this time similar values for draw wood were achieved (Table 11).

A comparison on the effect of side cut angle on slabbing was carried out in September 1986 on new crop trees in Kaingaroa Forest, using a conventional scarf. Only trees with little or no side lean were included (Table 12).

TABLE 11 : EFFECT OF SIDE CUTS AND WING CUTS ON DRAW WOOD AND SLABBING

Treatment	No. of Trees	Draw Wood Mean	(s.d.)	Frequency of Slabbing
Humbolt Scarf				
Side cuts	11	16 cm	(16)	0%
Wing cuts	4	42 cm	(32)	0%
Conventional Scarf				
Side cuts	5	9 cm	(8)	20%
Wing cuts	4	8 cm	(10)	25%

TABLE 12 : EFFECTS OF SIDE CUT ANGLE ON DRAW WOOD AND SLABBING

Treatment	No. of Trees	Slab Size Mean	(Range)	Frequency of Slabbing
Side cuts (Horizontal)	9	0 cm	(0)	0%
Wing cuts (45°)	5	0 cm	(0)	0%
Steeply-angled wing cuts (75°)	5	18 cm	(0 - 92)	20%

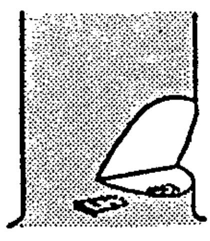
The results confirm the effectiveness of side cuts and (45°) wing cuts in eliminating slabbing in trees without a heavy sidelean.

3.3.5 Effect of Under Cuts

Under cuts are cuts applied underneath the hinge from each end of the hinge and below the level of the bottom cut of the scarf. Under cuts were applied to normal and problem trees to record their effectiveness in controlling draw wood and slab wood. Two types of under cuts were tested - horizontal and vertical (Figure 14).

UNDER CUT TYPES TESTED

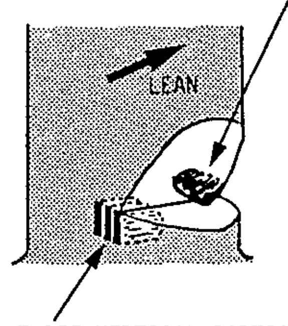
- Normal trees



HORIZONTAL PARTIAL UNDER CUTS

- 25% of diameter on each side
- 10 cm below scarf
- Directly beneath hingewood

- Trees with a heavy side lean



ONE WING CUT

- Compression side of tree
- Level with bottom of scarf
- Finish at right angles to scarf face
- Just inside scarf edge

THREE VERTICAL PARTIAL UNDER CUTS

- Tension side of trees
- 4 cm apart
- 25% of diameter

HINGEWOOD

- Wider on tension side
- Narrow on compression side

Figure 14 : Under Cut Types Tested

TABLE 13 : EFFECT OF UNDERCUTS; WINGCUTS AND SIDECUTS ON DRAW WOOD AND SLABBING

Treatment	No. of Trees	Draw Wood Mean	(s.d.)	Slabbing Frequency	Slab Size Median	Range
Under cuts (Horizontal)	9	10 cm	(8)	89%	18 cm	0 - 120
Wing cuts (45°)	4	8 cm	(10)	25%	0 cm	0 - 3
Side cuts (Horizontal)	5	9 cm	(8)	20%	0 cm	0 - 38

Using a conventional scarf, a comparison was made between wing cuts, side cuts and under cuts (where the horizontal bore cut is about 10 cm below the hinge to a depth of approximately 15 cm on each side of the tree.

Similar values were achieved for draw wood with all three types, but there was a much higher incidence of slabbing in the under cut trees. The size of the slabbing was also greater (Table 13).

The effect of under cut depth was tested for horizontal under cuts using a Humbolt scarf using three groups; shallow (5 cm below hinge wood), intermediate (10 cm) and deep (20 cm). The lowest values for draw wood were achieved by the intermediate level but these were not statistically significant (Table 14).

The end result resembled a dovetail joint on the end of the butt log. However, the results did not justify the considerable effort involved and subsequent studies focussed on the use of a single horizontal side cut and three vertical bore cuts for heavy side leaners.

TABLE 14 : EFFECT OF UNDER CUT DEPTH

Under Cut Depth		No. of Trees	Draw Wood Mean	(s.d.)
Shallow	(5 cm)	5	8 cm	(7)
Intermediate	(10 cm)	8	4 cm	(5)
Deep	(20 cm)	5	14 cm	(17)

A further series of tests in a new crop stand at Kaingaroa compared the effect of different treatments to minimise slabbing on heavy side leaners (Table 15).

For trees with a heavy side lean, the use of two side cuts or wing cuts was effective but not recommended as they may allow the tree to fall off-line. Although a single side cut on the compression side of the tree and 3 vertical under cuts on the tension side did not reduce the frequency of slabbing, it did reduce the size of the slabbing to a maximum of 20 cms. This treatment for side leaners is preferred as there is less chance of the tree falling off-line than with side cuts or wing cuts.

TABLE 15 : EFFECT OF SIDE CUTTING TECHNIQUES ON SLABBING IN SIDE LEANERS

Treatment	No. of Trees	Frequency of Slabbing	Slab Size (Range)
No side cuts	5	40%	0 - 101 cm
Single side cut and 3 vertical under cuts	5	60%	0 - 20 cm
Vertical (75 degree) wing cuts	6	16%	0 - 18 cm

3.3.6 Effect of Back Cut Height

Back cut height was tested at Whaka and at Matahina Forest using conventional felling techniques. At Whaka, three groups were tested; low (nominally 1 cm), conventional (5 cm) and high (10 cm). Lowest values for draw wood were produced by the low (1 cm) back cut and similar values were produced for the conventional and high back cut groups. However, the results were not significant as the conventional and high back cuts produced much more variable results. At Matahina Forest a comparison was carried out between conventional (nominally 5 cm) and high back cuts (15 cm). This time similar values were achieved for draw wood between the two (Table 16).

The very small difference in the data suggest there is little benefit, if any, to be gained by the use of the potentially unsafe practice of very low or level back cuts. Further analysis of the data to determine a relationship between back cut height and draw wood and slab wood was inconclusive. Other factors, such as hinge thickness and side lean, appear to be more important in determining the extent of draw wood and slabbing.

TABLE 16 : EFFECT OF BACK CUT HEIGHT ON DRAW WOOD

Back Cut Height	No. of	Draw Wood Trees Mean	(s.d.)
Whaka Forest			
Low (0.5)	5	8 cm	(3)
Conventional (18)	10	12 cm	(10)
High (11)	5	14 cm	(14)
Matahina Forest			
Conventional (6)	6	11 cm	(6)
High (17)	6	12 cm	(7)

3.3.7 Hinge Thickness

Hinge thickness was assessed in three groups; thin (nominally 5 cm), conventional (10 cm) and thick (15 cm). They were tested with both conventional and Humbolt scarves with normal scarf angles (nominally 45°) and with narrow scarf angles (nominally 30°). In all situations, the lowest values for draw wood were achieved with thin hinges, and the highest values with thick hinges. These differences were not always statistically significant owing to highly variable data, but the effect of a thin hinge in minimising draw wood is widely recognised by experienced fallers (Table 17).

TABLE 17 : EFFECT OF HINGE THICKNESS ON DRAW WOOD FOR THREE SCARF TYPES

Scarf Type (and angle)	Hinge Thickness (% of diameter)	No. of Trees Measured	Draw Wood Mean	(s.d.)
Conventional (30%)	Thin (5%)	4	6 cm	(1)
	Thick (15%)	8	19 cm	(6)
Conventional (45%)	Thin (5%)	4	4 cm	(6)
	Conventional (10%)	10	12 cm	(10)
	Thick (15%)	11	18 cm	(7)
Humbolt (34%)	Thin (5%)	4	10 cm	(9)
	Conventional (10%)	15	23 cm	(23)

Note : Draw Wood means differ significantly (at the 95% level) if they are in separate boxes.

3.3.8 Effect of Side Lean

The effect of side lean was assessed using the data from the September 1986 trials on new crop radiata pine in Kaingaroa forest. Data for draw wood from conventional treatment without side cuts for 'normal' and 'side leaners' is summarised below (Table 18).

This supports the previous work in its emphasis on the role of side lean in butt damage.

TABLE 18 : EFFECT OF SIDE LEAN ON DRAW WOOD

Conventional Techniques No Side Cuts	No. of Trees	Draw Wood Mean	(s.d.)
Normal	5	5 cm	(4)
Sideleaners	6	13 cm	(5)

Note : Draw Wood means differ significantly (at the 99% level)

3.4 DISCUSSION

The highly variable results present in most of these comparisons highlight the complex interactions of many factors, only some of which can be measured. The time required for felling, measuring and recording resulted in relatively small sample sizes. As a consequence, it was not possible to achieve significant results in many of the comparisons. However, the general trends from these tests suggest the following conclusions can be drawn.

The conventional type of scarf achieved results that were as good as, or better than, the Vee scarf or the Humbolt scarf. It is also considered to be the easiest type of scarf to cut and is virtually the only scarf used in New Zealand. These results suggest that fallers should continue to use the conventional scarf. The Humbolt scarf would offer some benefits only in a situation with downhill felling and uphill extraction, by reducing the height of the section of the stump facing downhill.

Within the range of scarf angles tested (30° to 60°), similar results were achieved. There are no benefits to be gained from the use of an open (60°) scarf. A narrower scarf (30°) is more difficult to cut (aligning the bottom and top cuts), but has the advantage of little or no wood loss when the butt log is squared off. The use of a narrower scarf would be an advantage if high value butt logs are being produced and the ends need to be cut flush with the top of the scarf.

The effect of scarf depth suggested that a shallow scarf (one-fifth of diameter) achieved better results than the conventional (between one-third and one-quarter of diameter), or the deep scarf (over one-third of diameter). As well as reducing draw wood, it would also reduce scarf height and wood loss through squaring off.

The back cut is always placed above the horizontal cut of the scarf to produce a "step up" which prevents the tree from jumping backwards off the stump during felling. Although a very low back cut (0.5 cm step) resulted in less draw wood than a conventional (5 cm, 10% of diameter) or high (10 - 15 cm step, 20 - 30% of diameter) back cut, there is little real benefit to be gained by the potentially unsafe practise of very low or level back cuts.

Perhaps surprisingly, increasing back cut height did not consistently reduce the amount of draw wood in trials in two separate forests, although it is a practice widely used amongst experienced fallers to reduce draw wood in forward leaners.

The single most important factor affecting draw wood was hinge thickness. Hinges of 5 cm (10% of diameter) consistently produced less draw wood than 10 cm hinges, (20% of diameter) or 15 cm (30% of diameter) hinges. This is also well known amongst experienced fallers, but difficult to achieve on leaning trees, particularly those with a heavy forward lean, when conventional back cutting techniques are used (where the back cut commences at the back of the tree and proceeds towards the scarf) (Appendix I, Figures 1 and 2).

Alternative back cutting techniques (Appendix I, Figures 3 to 5) require the hinge to be set up first (by boring), before completing the back cut by cutting away from the hinge towards the back of the tree. These techniques achieve a thin hinge and will need to be more widely applied in future with the increasing use of smaller, lighter chainsaws with shorter bars.

Slabbing can cause significant loss of wood volume when the butt log is squared off to exclude the damaged area. An analysis of the data from 115 trees which had been felled using conventional techniques (no side cutting) showed an incidence of slabbing of 37% with an average slab length of 55 cm. After squaring the log with the top of the scarf, the average volume loss was estimated to be .26 m3 for a tree with a 60 cm dbh. With sawlog values of \$60-\$90/m3 on truck, this represents a potential loss of \$15-\$21 per tree, or \$1,400-\$2,600/hectare, depending on stocking and sawlog premiums. Much of this can be saved by the careful use of appropriate side cutting techniques. The incidence of slabbing in 137 trees which had been side cut was only 3%. Similar results were achieved from the Kinleith forest studies on a small number of trees with the incidence of slabbing (for a slab length exceeding 10 cm) reduced from 50% to 4%.

Both side cuts and wing cuts were used and achieved similar results. The authors initially used side cuts as it allowed greater control on the depth and placement of the cut during the trials. Many trainers prefer angled wing cuts because it reduces the risk of fallers in a production situation overcutting the hinge, allowing a sideleaner to fall off-line.

The Felling Working Group discussed this topic at length and the consensus was that wing cuts will be used instead of side cuts (see Section 6).

3.5 CONCLUSION

The results highlight the importance of lean assessment as a part of overall tree assessment and the need to match the correct technique to the tree. They confirm that good basic techniques give good results in most situations.

They also show that hinge thickness is closely related to the size of draw wood. Setting up the hinge wood on trees with a substantial forward or back lean involves the use of alternative backcutting techniques (briefly described in Appendix I).

They suggest that draw wood can be minimised by:

- using a conventional type of scarf with an angled top cut of 30° to 40°,
- a horizontal bottom cut to a depth of 20 - 30% of the diameter (depending on lean),
- a back cut of about 10% of diameter (above the bottom cut), and
- a hinge of about 10% of diameter.

They also suggest that slabbing can be minimised by the use of wing cuts or side cuts on trees with little or no sidelean. For heavy sideleaners where wing cuts on each end of the hinge may cause it to fall off-line, slabbing can be controlled by the use of three vertical under cuts on the tension side and a single wing cut on the compression side.

4. THE EFFECT OF SIDE CUTS, WING CUTS AND UNDER CUTS ON HINGE STRENGTH

4.1 INTRODUCTION

During the development and testing of the three side cutting techniques (side cuts, wing cuts and vertical under cuts), concern was expressed over the potential loss of hinge strength. To complete the evaluation of these side cutting techniques, measurement of the effect of these techniques on hinge strength was required.

The testing proved to be more complex than anticipated and three separate tests were undertaken :

- using whole trees
- using 4 m high stumps
- using tree length logs.

These are described below.

Hinge strength is expressed in terms of a "standard force"; this is the force required to break a "standard" hinge (60 x 8 cm) when applied 5 m along the log (or up the stem), across the long axis of the hinge. The formulae are listed in Appendix III. This provides a measure of the strength of the hinge to stop the tree falling sideways after scarfing and back cutting are complete.

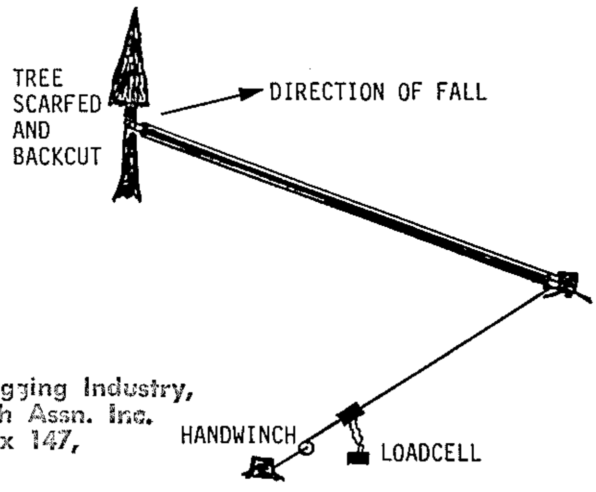


Figure 15 : Hinge strength testing on standing trees

4.2 METHOD

4.2.1 Measurement on Standing Trees

This trial was set up in a 35 year old stand in Kinleith Forest. The objective was to carry out a pilot study to examine the effects of side cuts on the hinge strength of standing trees. This involved recording the response to a sideways force (applied at a height of 8 m) by measuring the lateral movement of the tree at this height with a theodolite. As the force was increased, the movement was measured. Care was taken to remain within the elastic limit of the trees. One tree was pulled over to indicate these limits.

The force was applied using a portable winch and a series of blocks, giving a 4:1 purchase. A load cell was used to measure the applied force. The setup is shown diagrammatically in Figure 15. Measurements were taken at each step in the felling process :

- on the whole tree before scarfing;
- after scarfing;
- after side cutting;
- after back cutting (leaving enough hingewood to support the tree).

All trees tested had a small amount of back lean.

4.2.2 Measurement on High Stumps

Another pilot study was carried out on high stumps to compare the effect of sidecuts on hinge strength. Eleven trees were topped at a height of 4 m. The stumps were pulled sideways after setting up the hinge at the base of the stump and rigging the test equipment. A rubber-tyred skidder was used to provide the lateral force and a series of blocks were used to provide a 4:1 purchase. A load cell was mounted on the skidder (under the arch) and measured the force required to break the hinge. A pen chart recorder was used for recording. The setup is shown below (Figure 16).

Six trees had conventional hinges (without side cuts) and the other five had hinges with horizontal side cuts. The trees were selected from the larger straighter trees (60-70 cm diameter class) in a stand of 40 year old radiata pine in Kaingaroa Forest to minimise the effect of butt sweep.

Figure 16 : Hinge strength testing on high stumps

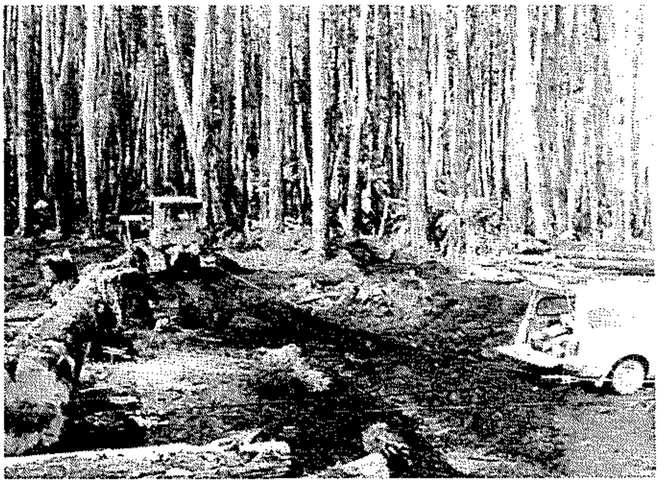


Figure 17 : Hinge strength testing on tree-length logs

4.2.3 Measurement on Tree-Length Logs

Using the data from the high stump pilot study, it was estimated that a sample size of about 20 of each type of hinge (full, side cut, wing cut, under cut) would be needed to obtain significant results in a more comprehensive study. It was not feasible to consider topping a further 80 trees to measure the effects of different side cutting techniques. Further testing would need to be carried out on logs rather than trees. This would involve finding a suitable means of supporting the logs while applying a force to the hinge. Various options were investigated including building a test bed. The method chosen for its simplicity and low cost is described below.

The series of tests were completed on tree-length logs in a 56 year old stand of radiata pine in Kaingaroa Forest. Twenty trees were selected and felled and hauled to a prepared "landing". Two stumps 2.5 m apart, were notched at the base and used to hold each log in a position while a scarf and back cut were cut on a 4 m section at the smaller end of the log. The winch on a Komatsu D65 crawler tractor was used to provide the force to pull the hinge sideways. The mainrope was attached through a system of blocks to a strop connected to the top of the log. A load cell was used to measure the rope tension by fitting it between the cable and the dead-end stump (Figure 17.)

After each 4 m section was broken, it was cross-cut to provide a short sawlog and the log was moved through the notched stumps to provide another 4 m section for testing. In this way, it was possible to cut between 4 and 8 sections per log. By using the smaller end of the log, it was possible to have the 4 m section fully suspended, thus avoiding the problems that arose during some earlier testing when the test section was supported on bedlogs. Friction between the bed and test logs resulted in measured force being substantially higher than that required for breaking the hinge alone.

4.3 RESULTS

4.3.1 Whole Tree Measurements

A typical result is shown in Figure 18. As expected from the reduction in cross-sectional area, there was no measurable effect on stability after cutting the scarf (15% of the area) or from then adding side cuts (a further 2%). However, the tree was less stable after cutting the back cut (removing a further 65%) with only the hinge wood (18%) to support it. It must be emphasised that the trees tested were those with little or no side lean.

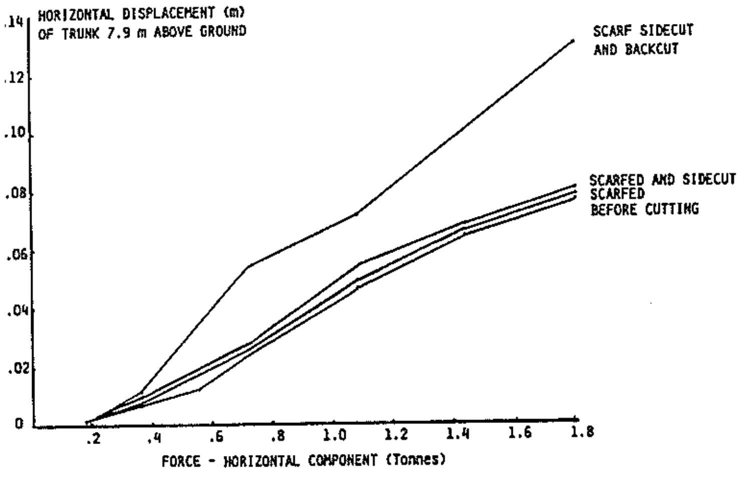


Figure 18 : Results of Standing Tree Tests

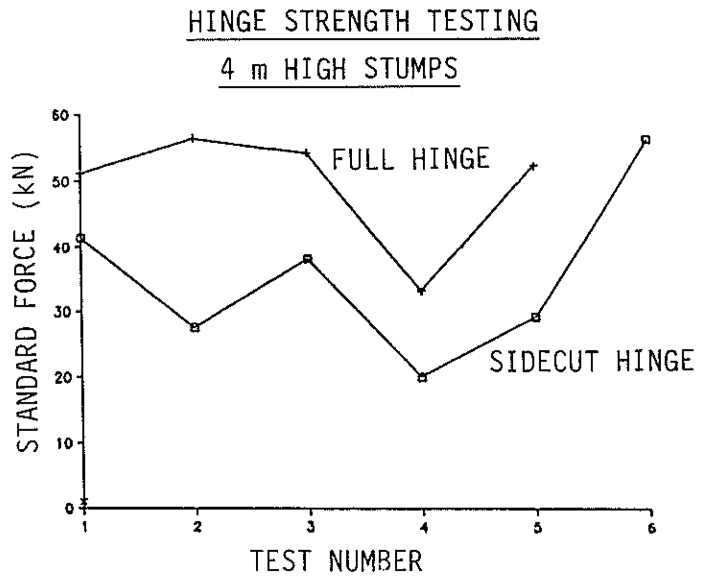


Figure 19 : Results of Hinge Strength Tests on High Stumps

These results suggest that side cuts or wing cuts could be safely applied, after scarfing, to trees with little or no side lean without affecting their stability.

4.3.2 Measurements on High Stumps

The results for the high stumps are illustrated (Figure 19). One notable feature is the wide variation in hinge strength that occurs between individual stumps. One measure of variation is the Co-efficient of Variation which expresses the Standard Deviation as a percentage of the mean. It lies between 30 and 40% for both sets of data. This is similar to the variability that would be expected in the strength of sawn timber (H. Biers, pers. comm.).

Analysis of this data indicated that the difference between the means of the "full" (conventional) hinges and side cut hinges was statistically significant (Table 19).

4.3.3 Measurements on Tree-Length Logs

The results are summarised in Table 20. They show the same variability as previous tests and can be expected to occur as an inherent property of individual trees. To allow for the range of sizes that occurred in the sections tested, the forces were calculated for a standard hinge measuring 60 cm by 8 cm, corresponding to a standard tree with a dbhob of 52 cms. It was assumed that side cuts and wing cuts would remove 5 cm from each end of the hinge; however the side cut at the compression end of the hinge would close once tension was applied. For this reason, force calculations for side cuts and wing cuts assumed a standard hinge measuring 55 cm by 8 cm.

There is a significant difference between full hinges and both side cut and wing cut hinges (a loss of 24-25%). This data suggests that these cuts should not be applied to the end of the hinge under considerable tension (e.g. on heavy side leaners).

TABLE 19 : ESTIMATES OF HINGE STRENGTH DERIVED FROM THE FORCE REQUIRED TO BREAK FULL AND SIDE CUT HINGES USING HIGH STUMPS

Hinge Type	Sample Size	Force (kN) Mean	s.d.
Full	5	49.5	9.3
Side Cut	6	35.5	12.7

Note: Mean values for Force differ significantly (at the 99% level).

TABLE 20 : ESTIMATES OF HINGE STRENGTH, DERIVED FROM THE FORCE REQUIRED TO BREAK FULL, SIDE CUT, WING CUT AND UNDER CUT HINGES - USING TREE LENGTH LOGS

Hinge Type	Sample Size	Force (kN) Mean	s.d.	As Percentage of Full Hinge
Full	24	57.9	17.3	100%
Under Cut	27	48.5	17.2	84%
Side Cut	22	44.2	17.2	76%
Wing Cut	22	43.3	18.6	75%

Note: Mean values for Force differ significantly (at the 99% level) where they are not joined by vertical bars.

The difference between full and under cut hinges is less (a loss of 16%). Although it is not statistically significant owing to the highly variable data, it suggests that under cuts are a more appropriate method than side cuts to apply to heavy sideleaners.

There are many factors which influence hinge strength that are beyond the faller's control. Within the stump, these include the strength of the wood fibres, the proportion and location of juvenile wood (corewood), and the presence of defects like rot, bark pockets or encased branches.

External forces include tree lean, branching distribution and wind force and direction. The interaction of these factors will always make falling an art as much as a science, and one in which training and experience play an important role. Tree assessment must allow for these factors in matching the technique to the tree. The data suggest that carefully applied side cuts or wing cuts achieve similar results; they both reduce the hinge strength by around 25%. On heavy side leaners, the vertical under cuts applied to the tension side appear to be a more appropriate technique to reduce the possibility of the tree falling off-line.

5. MODELLING THE FORCES GENERATED BY SIDE LEAN AND WIND ON DIFFERENT HINGE TYPES

5.1 INTRODUCTION

This work was a follow up to the work on hinge strength where a substantial number of measurements (approximately 25) were carried out on each of the four hinge types (full hinge, under cut, side cut and wing cut). These were intended to give an indication of the effect of different side cutting techniques on hinge strength.

The Felling Working Group suggested further work to investigate the effect of tree lean and wind speed on hinge strength.

The formulae used were taken from Papesch (1974), and are included in Appendix IX. All calculations were based on a large transition crop tree whose dimensions were assumed to be :

- dbh 60 cms
- height 40 m
- volume 3.8 m3

The values used in the calculations for factors such as air density, drag co-efficient and crown area are listed in Table 1, Appendix IX.

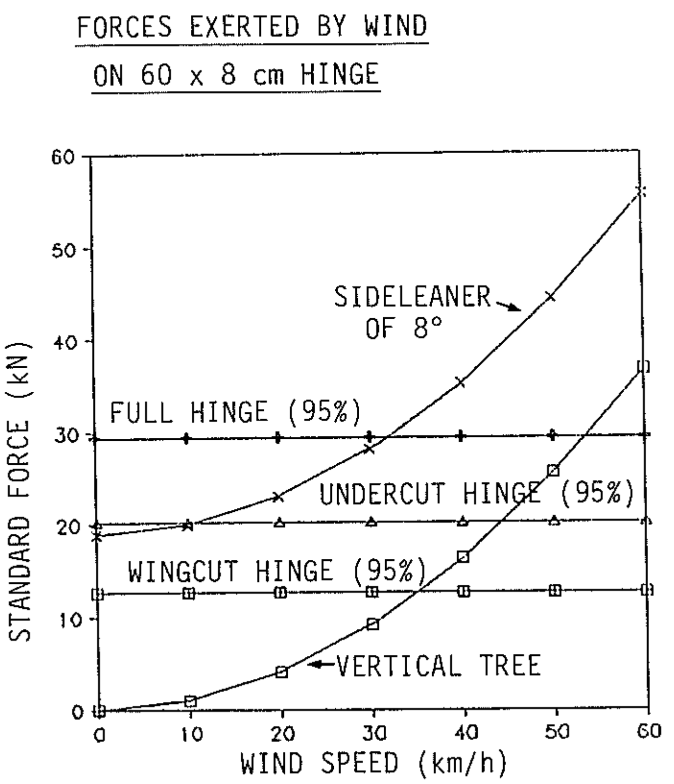


Figure 20 : Effect of Wind Speed on Standard Force

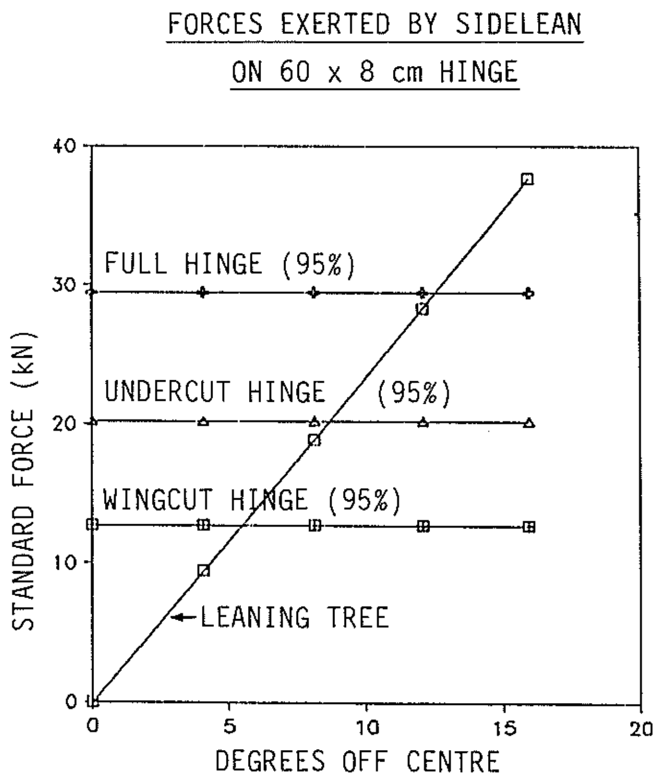


Figure 21 : Effect of Side Lean on Standard Force

As the edge trees in a clearfelling situation are exposed once the stand is opened up, it was treated as a tree in the open and the effect of turbulence generated by the stand canopy was ignored.

Values for hinge strength were those drived from the testing carried out at Kaingaroa Forest on tree-length logs of radiata pine (Section 4.3.3., Table 20). These tests highlighted the highly variable strength of the hinge wood. To allow for this, confidence limits were used which estimated values that would be exceeded by 95% of all trees. This means that only one tree in twenty would be expected to have hinge wood that was weaker than the values indicated by the lines in Figures 13 - 14. Details of these calculations are included in Appendix IX.

5.2 RESULTS AND DISCUSSION

5.2.1 Effect of Wind Speed

Figure 20 shows the forces generated by wind speed on a standard tree (e.g. vertical) and the combined forces exerted by wind and side lean on a side leaner of 8°. The strength of different hinge types (full, under cut and wing cut) is shown for the 95% level. For vertical trees, winds up to 30 km/h create few problems; 5% of the scarfed and back cut trees will have failed as winds rise to 35 km/h for wing cut hinges, 45 km/h for under cut hinges and 55 km/h for full hinges.

For side leaners, a small proportion (about 10%) of wing cut hinges will fail in calm conditions. Five percent of the under cut hinges will fail at about 10 km/h and full hinges at 30 km/h. Mean values for hinge strength are not approached until winds exceed 50 km/h for wing cut hinges, 55 km/h for under cut hinges and 60 km/h for full hinges.

5.2.2 Effect of Side Lean

For trees of average or above-average hinge strength, side lean has limited impact over the range of lean tested (0° - 15° off centre). For the weakest 5%, failure would occur at 5° for a wing cut hinge, 9° for an under cut hinge and 13° for a full hinge. In practice, the faller would cut a trapezoidal hinge (e.g. non-parallel) hinge, increasing the width of hinge wood on the tension side and increasing hinge strength. However this does show that, in a small proportion of cases, side leaners could fall off line through premature failure of the hinge under tension. This is more likely to occur with wing cut than under cut hinges, and with under cut than full hinges. (Figure 21.)

5.2.3 Effect of Other Factors

The effects of varying crown area, tree height, drag coefficient, air density and tree size were examined, but none were as important as side lean or wind speed.

5.3 CONCLUSIONS

This analysis confirms the importance of three factors in terms of determining the susceptibility of trees to falling off-line. These three factors are :

(i) hinge strength
(ii) side lean
(iii) wind velocity.

The only factor that can be influenced by the faller is hinge strength. This is achieved by varying the shape and thickness of the hinge and extent of side cutting.

6. THE FELLING WORKING GROUP

6.1 INTRODUCTION

The Felling Working Group was set up in August 1986 under the chairmanship of Mr Kingi Porima, then Training Manager, Tasman Forestry Limited, Murupara. It included representatives from the major industry groups, the L & FITB, the D.O.L. and contractors. Individual members are listed in Appendix VIII.

It was set up to :

- review the findings of the felling work
- advise on methods of extension.

It met four times between August 1986 and July 1987. The discussion on the major items is summarised in the following section.

6.2 SIDE CUTTING TECHNIQUES

There was concern voiced at the first meeting from some group members over the demonstration of some felling techniques that had been undertaken as part of the extension of the research findings to audiences which included inexperienced fallers. These had shown the use of side cuts and vertical under cuts as means of minimising slabbing. The high turnover rates within the industry meant that many fallers did not have an adequate grasp of the basic techniques. The inappropriate use of techniques such as side cuts and vertical under cuts by these fallers could be dangerous. They also noted that vertical under cuts were not an accepted technique within the industry. It was suggested that future presentations should exclude the contentious techniques and be integrated with formal training on a one-to-one basis.

Otherwise, the presentation was seen to be strongly supportive of the basic techniques included in present training schemes and complementary to these systems.

LIRA was to undertake further testing on the effects of different side cutting techniques on hinge strength and hence, tree stability. The results of this work are described in Section 4 of this Report. The main features include :

(1) A 16% reduction in hinge strength associated with the use of vertical undercuts.

(2) A 25% reduction in hinge strength associated with the use of either side cuts or wing cuts.

(3) A very wide variation in hinge strength between trees of a similar size within a single stand.

(4) Side cuts and wing cuts are equally effective in minimising slabbing.

(5) Vertical under cuts are effective in reducing slab size and are a preferred technique for use on heavy side leaners.

There was some surprise expressed at the similar results achieved by side cuts and wing cuts, but it was emphasised that these were applied in a carefully controlled situation to a prescribed depth. Those in regular contact with operators in the field reported that over cutting of side cuts was common, allowing trees to fall off-line. On this basis, the group reached a consensus that only wing cuts should be used within the industry. N.Z.F.P. Forests Ltd had prepared a video which demonstrated the use of wing cuts to minimise slabbing and this was being used in an operator training programme.

The effect of wind and side lean on hinge strength has been described previously (Section 5). The main points are :

(1) That side lean and wind are the two major factors that affect the forces acting on the hinge.

(2) That faller can influence hinge strength by varying the size and the shape of the hinge.

The group accepted this without further comment.

6.3 TERMINOLOGY

The group agreed there was a need to have a list of standard terms which could be included in an L & FITB publication or possibly the D.O.L. Bush Code. A first draft was prepared by Bryan Vincent (L & FITB) and circulated for comment. It has not been possible to complete this task, largely as a result of industry restructuring.

6.4 RECOMMENDATIONS

The members of the Felling Working Group considered the information presented to them and as a result of their discussions, made the following recommendations to the Chief Bush Inspector of the Department of Labour.

Recommendation 1

That vertical under cuts have the potential to reduce slabbing and butt damage on heavy side leaners, but there are potential dangers in the use of this technique (e.g. incorrect application in over-weakening a heavy side leaner and the risk of saw kickback). The Group does not endorse the general promotion and use of vertical under cuts, but for the purpose of further evaluation the technique may be used only by skilled loggers, equivalent to Logger 1, after proper instruction.

Recommendation 2

That wing cuts become an accepted technique to control slabbing on trees with little or no side lean.

Recommendation 3

That side cuts are not acceptable for controlling slabbing because of the possibility of over cutting the sides of the hinge, allowing the tree to fall off-line.

Recommendation 4

That good basic techniques, as advocated by the Logging and Forest Industry Training Board, will minimise felling damage in most situations.

7. CONCLUSIONS

A survey of nine fallers in seven forests identified a number of problems that some operators were experiencing. These were :

- aligning the bottom cut to the top cut of the scarf;
- estimating correct scarf angles;
- judging correct back cut height;
- judging correct hinge width;
- setting up trees to be driven;
- using inappropriate felling techniques.

Fallers who used good basic techniques generally achieved lower levels of felling damage than those who didn't. Fallers who had undergone formal training of some kind were generally more consistent in their technique and used a wider range of techniques. This suggests that forest owners, especially those involved in clearfelling pruned stands, could expect significant benefits from the introduction of formal training for fallers. This would apply particularly to new fallers.

Felling damage appears to vary widely between forests and different locations. The incidence and magnitude of this damage appears to be higher in transition crop and new crop stands than in the old crop stands of radiata pine. It is of greater economic consequence in the high pruned stands where there is a substantial premium for pruned butt logs.

Lean was identified as having a significant influence on the incidence and magnitude of the slabbing. This reinforces the importance of lean assessment as an integral part of overall tree assessment by the faller and as a major consideration in selecting the appropriate technique to minimise butt damage.

Appropriate felling techniques can do much to minimise felling damage. A series of felling trials were carried out to assess the relationship between felling damage and variations in basic felling techniques. The variables examined included :

- scarf type;
- scarf angle;
- scarf depth;
- back cut height;
- hinge thickness;
- side cutting techniques.

The results strongly supported the effectiveness of good basic techniques, as advocated by the Logging and Forest Industry Training Board, in most situations.

Felling damage is usually due to a combination of draw wood and slabbing. There was a close relationship between the thickness of the hinge and the extent of draw wood. Narrow hinges (10% of tree diameter) consistently produced less draw wood than thicker hinges (20% to 30% of tree diameter). Fallers need to be competent in the use of alternative back cutting techniques to control hinge wood in different situations, particularly for trees with some degree of forward or back lean. These will need to become better known if the smaller, lighter chainsaws, well suited for delimbing, are used for felling.

Slabbing can be a major component of felling damage.

An analysis of data from 115 trees which had been felled using conventional techniques (no side cutting) suggested a value loss from slabbing of $1,4000 - $2,600/hectare, depending on stocking and sawlog premiums.

Results from the Felling Trials suggest this loss can be reduced by over 90% through the use of appropriate side cutting techniques. A number of side cutting techniques were tested and most were effective in controlling slabbing. One of the most effective techniques was wing cuts, steeply-angled side cuts applied at each end of the hinge wood. This was considered by the Felling Working Group to be the safest technique for general use.

On some heavy side leaners, the use of wing cuts could weaken the hinge sufficiently and allow the tree to fall off-line. An alternative technique, vertical under cuts, which could be used by experienced fallers, has been developed for heavy side leaners. This technique controls slabbing and gives a stronger hinge than wing cuts. This technique was considered by the Felling Working Group to have promise, but field evaluation was necessary.

Extensive tests were conducted to measure the effect of different side cutting techniques on hinge strength. These showed that, on average, vertical under cuts resulted in a 16% reduction in hinge strength, and wing cuts and horizontal side cuts in a 25% reduction. For each hinge type tested, there were wide differences in strength between similar trees within a stand. This variation would help explain why seemingly identical trees receiving identical treatments behave differently.

A mathematical model was used to estimate the forces generated by side lean and wind. These were compared with the strengths of hinge wood (measuring 60 cm by 8 cm) for three major hinge types (full, vertical under cuts and wing cuts). The results indicated that winds up to 30 km/h would have virtually no influence on vertical trees which were scarfed and back cut.

For trees with a heavy side lean, winds of this speed could have some effect on the weaker trees. Full hinges would be least affected, followed by vertical under cuts and then wing cuts. Even under calm conditions, wing cuts could allow a small proportion of heavy side leaners (about 10%) to fall off-line.

A Felling Working Group met to review the findings of the initial felling work. As a result of this, and subsequent work on hinge strength and the effect of wind and side lean, the Group made four recommendations to the Department of Labour. These related to the acceptance of wing cuts (but not side cuts) as the safest technique for controlling slabbing; to the need for field evaluation of vertical under cuts; and to the effectiveness of good basic techniques in minimising felling damage.

This Project confirms that felling is as much an art as a science. While there are a number of factors that can be assessed by the faller (lean, branch distribution, wind force, wind direction), there are also influences on hinge strength that he is unable to assess (fibre strength, proportion of juvenile wood, pith location, presence of defects such as rot, bark pockets, knots). Nevertheless, there are a range of techniques available that allow felling to be carried out safely and efficiently with a minimum of felling damage. The main ones are described in Appendix 1.

APPENDIX I : RECOMMENDED TECHNIQUES

These recommended techniques are based on the use of techniques that are, by and large, known and taught within some of the larger organisations, but not widely practised outside them. They are supported by the results of the felling studies which have examined the effect of key factors on butt damage and documented the means of controlling it. They are not intended to be a detailed training manual, but to provide information for managers, supervisors, trainers and operators. Many of these techniques are mentioned in the L&FITB Tree Felling guides.

1. BASIC TECHNIQUES

Competence in tree assessment (including lean) and in the use of felling aids, such as the wedge and felling lever, is an integral part of basic techniques.

The conventional scarf can be used in nearly all situations, on easy and steep terrain, on normal and problem trees. The correct cutting sequence (Figure I-1) involves cutting :

(1) The angled (45 degrees) top cut to a depth of 1/4 to 1/3 of the tree diameter.

(2) The horizontal bottom cut to meet the top cut so the hinge face is at 90 degrees to the intended felling direction, i.e. scarf opening faces the felling direction.

(3) The conventional back cut commencing at the back of the tree with the back cut height (at 10% of the tree diameter) above the bottom of the scarf and finishing with a rectangular hinge (See Figure I-2). This is best lined up by sighting along the guide bar and the bottom cut.

2. ADVANCED TECHNIQUES

Advanced techniques should only be used by experienced operators who have received proper instruction. These involve variations in basic techniques or the use of new techniques in situations where these give better results.

(1) The conventional scarf can have the depth reduced to 1/6 to 1/4 of the tree diameter on trees with a heavy forward or back lean, or on high value trees to lower scarf height.

(2) Scarf angle can often be reduced to 30 degrees to further lower scarf height so the top is level with the back cut.

(3) The Humbolt scarf can be used in downhill felling to lower the height of the stump, thus facilitating uphill extraction. The cutting sequence that makes it easier to align the cuts is :

- angled (35 degrees) bottom cut first to 1/4 to 1/3 of diameter;
- horizontal top cut next.

(4) The range of alternative back cut types can be used, as appropriate, to deal with problem trees (Figures I-3 to I-5). They can also be applied to normal trees where a thin hinge is required.

3. TECHNIQUES FOR DIFFERENT TYPES OF TREES

(1) Normal trees :

- Basic practice
- Advanced techniques (where appropriate)
- Wing cuts (if slabbing is a problem)

(2) Back leaners :

- Shallower scarf (1/4 to 1/6 of diameter)
- Conventional back cut (wedged)
- Alternative back cuts
  - 3/4 bore (wedged) (Figure I-3)
  - 2-stage split level (wedged) (Figure I-4)
- Heavy back leaners may require driving if wedging fails to tip the tree
- Wing cuts (if slabbing is a problem)

(3) Forward leaners :

- Shallower scarf
- Bore and back cut (a heavy forward leaner may require releasing from the back) (Figure I-5).
- Wing cuts (if slabbing is a problem)

(4) Side leaners :

- Conventional depth of scarf (1/4 - 1/3)
- Uneven hinge wood, wider on the tension side
- 3 vertical under cuts on the tension side under the hinge or single vertical - wing cut if buttress present
- Conventional back cut; or 3/4 bore; or 2-stage back cut, at 10% of diameter above bottom of scarf

(5) Combination leaners (side leaners with forward lean)

- As for (4) above, but may require a higher back cut.

BASIC FELLING TECHNIQUE

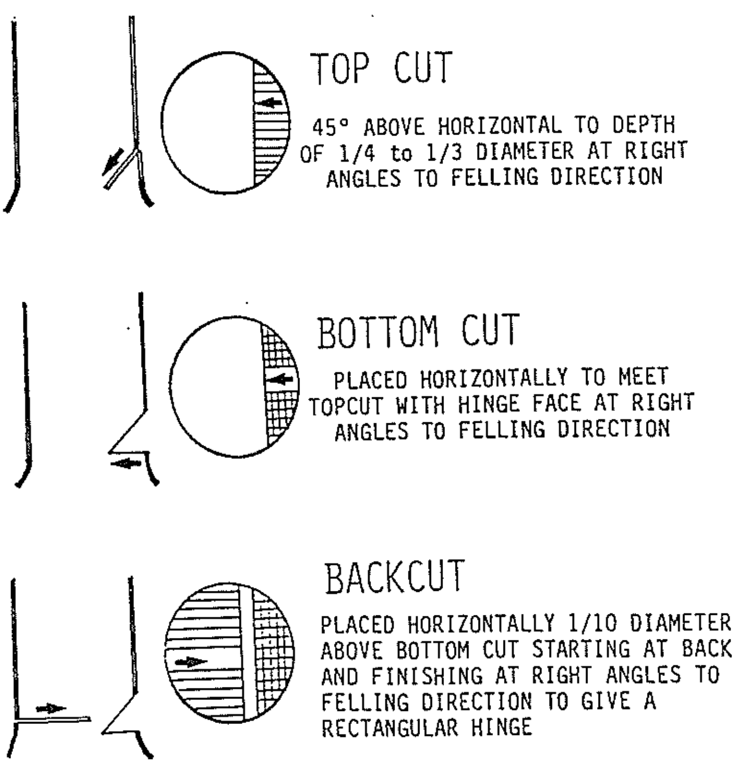


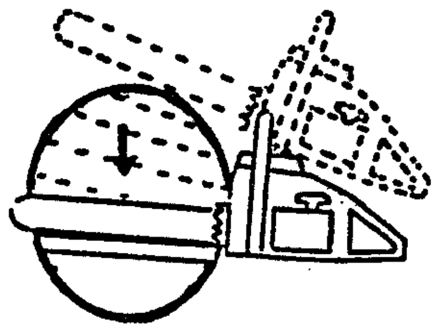
Figure I-1 : Basic Technique - Conventional Cutting Sequence

BACKCUT TECHNIQUES
- LONG GUIDE BAR

(when bar length exceeds tree diameter)

Conventional No.1

"From the back"



BACKCUT TECHNIQUES
- LONG GUIDE BAR

(when tree diameter exceeds bar length)

Conventional No. 2

"1/4 far side, then swing around to the back".

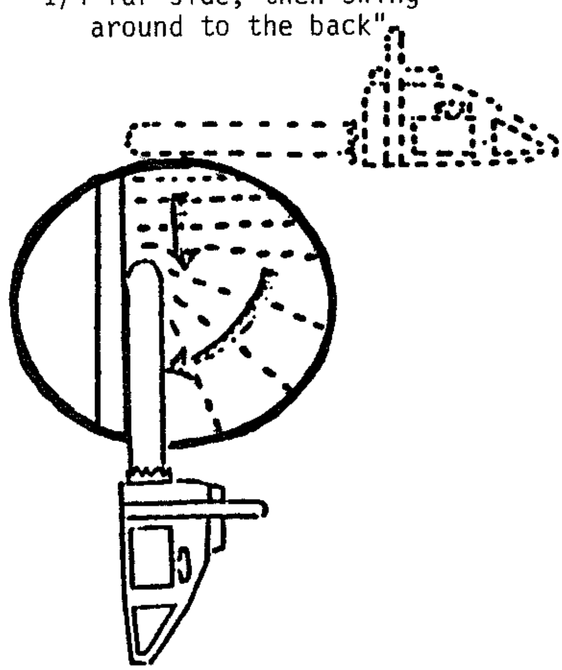


Figure I-2 : Two conventional back cut techniques for long guide bar

APPENDIX II : BIBLIOGRAPHY

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APPENDIX III : CALCULATION OF HINGE STRENGTH

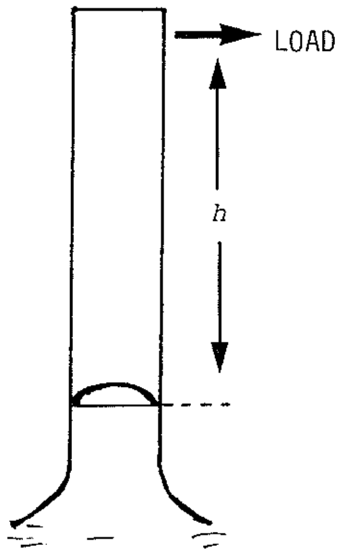


Figure III-1 : Elevation of High Stump

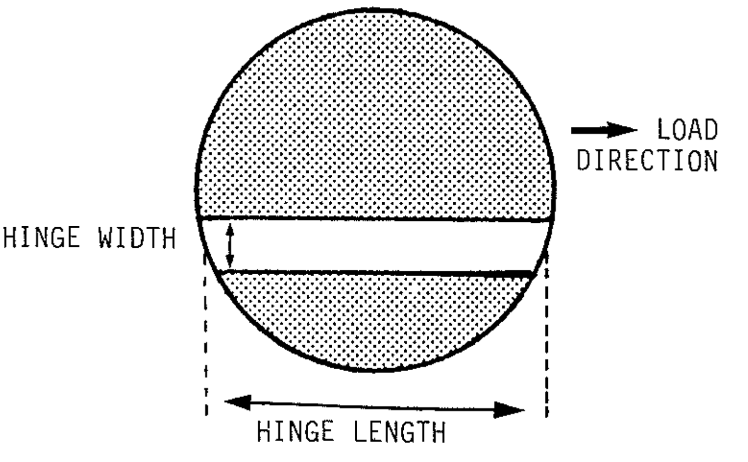


Figure III-2 : Plan View of Hinge

where a = *hinge width (cm)*
b = *hinge length (cm)*
h = *height of load application point above back cut (m)*
L = *load applied across the hinge to break the hinge (tonnes)*

The stress required to break the hinge is calculated from :

$$\text{Stress } (s) = \frac{\text{Applied moment } (M)}{\text{Section modulus of hinge } (Z)} \quad N/m2$$

where $\text{Moment } (M) = L \times h \times 10^{4}$ N-m (*assumes gravitational force of* $10 m/sec^{2}$)

$$\text{Modulus } (Z) = \frac{a \times b^{2} \times 10^{-6}}{6} \quad m^{3}$$

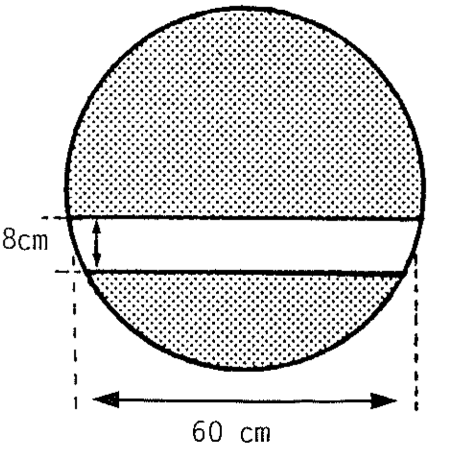


Figure III-3 : Standard Hinge

To standardise the results, a standard hinge size was used, based on the average hinge size recorded during the Felling Trials.

The moment (M std) required to break the standard hinge is calculated by :

$$\text{Moment (std)} = Z\ (std) \times S$$

$$M\ (std) = \frac{(.60) \times (.08)^2}{6} \times 10^{-6} \times S$$

$$= 4.8\ .\ 10^{-3} \times S \quad N\text{-}m$$

The force (F std) required to break the standard hinge can be calculated from the standard moment by using a standard height (taken as being 5 m).

$$F\ (std) = \frac{M}{5}\ .\ 10^{-4}\ \text{tonnes}$$

APPENDIX IV : GLOSSARY OF TERMS

This is intended to provide a definition of the terms used in this report.

BACK CUT - The last cut made through the back section of the tree opposite the scarf and above the junction of the top and bottom scarf cut. It is the last cut made before felling.

BACK LEANER - A tree leaning away from the intended falling direction.

BORE CUT - A cut made using the tip of the chainsaw to bore into the tree.

BOTTOM CUT - The lower cut of a scarf, horizontal for a conventional scarf, angled upwards for Humbolt and Vee scarves.

BUTT DAMAGE - Damage to the butt log from draw wood or slabbing.

BUTT LOG - The first or bottom log to be cut from a fallen tree.

COMPRESSION SIDE - The side of a heavy side leaner which is under the lean and whose fibres are under compression.

CONVENTIONAL SCARF - A scarf where the top cut is put in at 45° to the horizontal bottom cut. (See Figure 4).

DRAW (WOOD) - Slivers of wood attached to the stump that are pulled from inside the butt of the tree during felling.

DRIVING - Directional falling of a tree so it falls against one or more trees which have been scarfed and partially back cut to fell them in a particular direction.

FORWARD LEANER - A tree leaning towards the intended falling direction.

HINGE (WOOD) - The strip of uncut wood between the scarf and back cut on which the tree hinges as it falls.

HUMBOLT SCARF - A scarf where the top cut is horizontal and the bottom cut is angled upwards at approximately 35°. (See Figure 4).

JUVENILE WOOD - Low density, low strength wood laid down within the first 15 growth rings for radiata pine.

NORMAL TREE - A tree whose natural lean will have little or no effect on the direction of felling.

PROBLEM TREE - A tree whose lean is heavy enough to sustantially affect falling direction and may require the use of advanced falling techniques.

SCARF - The wedge-shaped section cut out of the front of the tree to control its direction of fall. (See Figure 4).

SIDE CUT - A shallow horizontal cut on each side of the scarf (i.e. into the ends of the hinge wood), applied prior to back cutting to reduce slabbing. (Figure 6.)

SIDE LEANER - a tree leaning at right angles to the intended felling direction.

SLAB - A large strip of wood torn from the outside edge of the tree during felling.

TENSION SIDE - The side of a heavy side leaner which is away from the lean, whose fibres are under tension.

TOP CUT - The upper cut of a scarf, angled downwards at 45° for a conventional scarf, horizontal for a Humbolt scarf.

UNDER CUT - A special technique involving boring under the hinge on the tension side of heavy side leaners to minimise slabbing. (Figure 7.)

VEE SCARF - A scarf where the top cut is angled downwards at 20 to 25° above the horizontal, and the bottom cut is angled upwards at a similar angle. (See Figure 4.)

WEDGE - A tapered plastic or metal felling aid that is driven into the back cut to prevent a tree from sitting back when felling.

WING CUT - A shallow steeply-angled cut on each side of the scarf, (i.e. into the ends of the hinge wood) going down into the stump, applied prior to back cutting, to reduce slabbing. (Figure 6.)

APPENDIX V : METHOD OF TREE LEAN ASSESSMENT

Each tree was assessed for lean in two directions :

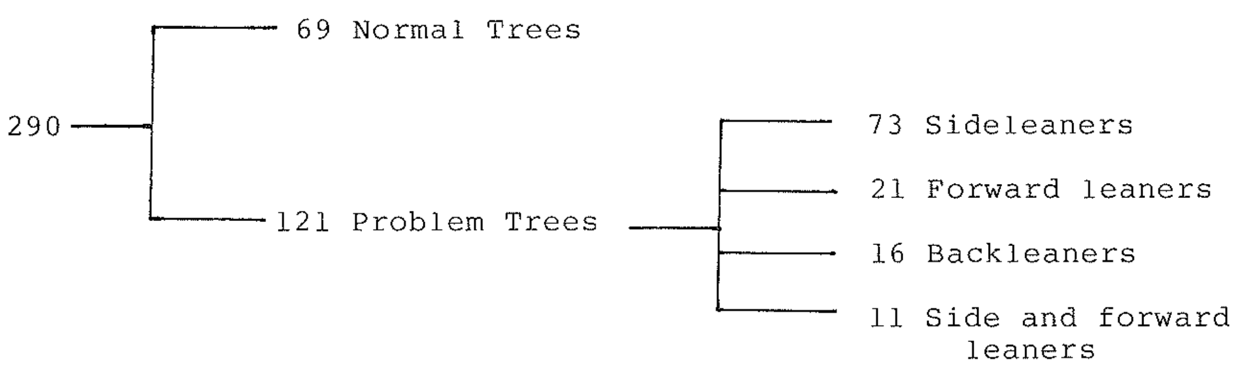
- side lean
- forwards/back lean.

Each was expressed on a scale of 0 to 2 where :

0 = lean having little or no effect on falling;
1 = lean having some effect on falling (forward and side leaners);
2 = lean having a major effect on falling (forward and side leaners);
-1 = lean having some effect on falling (back leaners);
-2 = lean having a major effect on falling (back leaners).

A plumbob was used to assist in checking the eyeball assessment, although a considerable degree of interpretation was involved in assessing trees with lean in the lower and upper sections in opposite directions (e.g. S-shaped trees). There was also some allowance made for branching habit in the assessment.

The results of lean classification of the 290 trees assessed during the felling trials is summarised below :



APPENDIX VI : FELLING SURVEY FORM

LOG BREAKAGE AND BUTT DAMAGE REPORT

FOREST ______________________ DATE ______________________

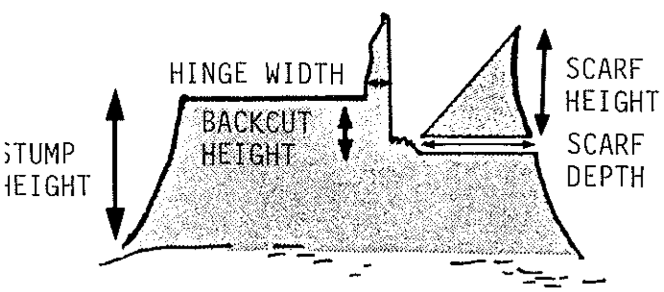
REFERENCE NO. ______________ EXPERIENCE ______________

CHAINSAW ____________________ BAR ______________________

SPECIES _____________________ AGE ______________________

FELLING PATTERN _____________ CONTOUR __________________

TREE NO. ____________________



S.E.D. ______________________

LENGTH ______________________

TRIM TIME ___________________

CAUSE - BREAK _______________

BRANCHES ____________________

STANDARD - TRIM _____________

STUMP HEIGHT ________________

FELL TIME ___________________

SCARF _______________________

SIDECUTS ____________________

BACKCUT _____________________

TECHNIQUE ___________________

SLAB ________________________

DRAW ________________________

APPENDIX VII : FELLING TRIALS ASSESSMENT FORM

Forest ________________________ Date ____________

Faller ________________________ Tree No. ____________

Lean classification ____________________

Stump diameter ________________ cms

Stump height ________________ cms

Scarf height ________________ cms

Scarf depth ________________ cms

Hinge width ________________ cms

Hinge length ________________ cms

Backcut height ________________ cms

Draw __________ cms

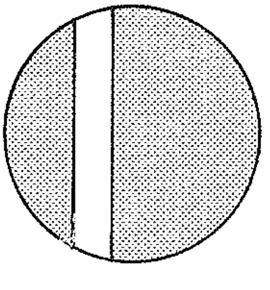
Slab __________ cms

Felling technique ____

____

Sidecuts (type/no.) ______________________________________

Sketch of hinge shape



Comments : ____________________________________

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APPENDIX VIII : MEMBERS OF THE FELLING WORKING GROUP

Chairman :

Kingi Porima	Tasman Forestry Limited

Secretary :

Lindsay Vaughan	Logging Industry Research Association

Members :

Brian Vincent	Logging and Forest Industry Training Board
Sonny Grant	Logging and Forest Industry Training Board
Bernie Collings	Department of Labour
Dando Fraser	N.Z. Forest Service
Pat Dunn	N.Z. Forest Products Ltd
Bill Newton	Logging Contractor
Boy Biddle	Tasman Forestry Limited
Gary Higgins	Tasman Forestry Limited
Fraser Field	Carter Holt Harvey Industries
John Galbraith	Logging Industry Research Association

MODELLING THE FORCES GENERATED BY SIDE LEAN AND WIND ON DIFFERENT HINGE TYPES

Work by Papesch (1974) and others provided a starting point using the following formula to estimate the force produced by the wind on the crowns of trees in the open.

$$F = .5\ p.C_d.V^2.A$$

where F = *force*
p = *air density*
C_d = *drag coefficient*
V = *wind velocity*
A = *crown area*

The moment at the base of the tree generated by this force is calculated by :

$$M = F.C_p.H$$

where M = *moment*
C_p = *centre of pressure (as a proportion of tree height)*
H = *tree height*

Hinge strength was expressed in terms of a "standard force" applied 5 m above (or along from) the scarf (Appendix III). This can be calculated from the moment by :

$$SF = M/5$$

A spreadsheet (Super Calc 4 ©) was used to calculate standard forces under a range of conditions. A set of standard values were used as a basis for calculation (Table 1).

Air density, drag coefficient and centre of pressure were all taken from Papesch (1974). The tree dimensions were selected for a large transition crop tree, and crown area was estimated using an ellipsoid shape, following discussions with FRI staff. The selection of a whole-tree centre-of-gravity of 0.35 of tree height was based on work done by Wells (1982) on radiata pine, by Adamovitch (1970) and Guimier (1980) on North American conifers, and from the standard c.o.g. formula by treating the stem as a uniformly tapering beam and the crown as an ellipsoid.

TABLE IX -1 : STANDARD VALUES USED FOR CALCULATING FORCED GENERATED BY WIND AND SIDE LEAN

Factor	*Standard Values*
Air Density (kg/m3)	*1.226*
Drag Coeff.	*.3*
Wind Speed (km/h)	*20*
Wind Speed (m/sec)	*5.56*
Crown Area (m2)	*150*
Centre of Pressure	*.6*
Tree DBH (cm)	*60*
Tree Height (m)	*40*
Tree Volume (m3)	*3.85*
Wind Force (kN)	*.85*
Moment (kN-m)	*20*
Standard Force (kN)	*4.09*
Sidelean Force (kN)	*18.87*
Std Force and Side Lean (kN)	*22.96*

Values for hinge strength were those derived from the testing carried out at Kaingaroa on tree-length logs, described in Section 4.3.3 (Table 2).

TABLE IX -2 : AVERAGE HINGE STRENGTH EXPRESSED IN TERMS OF STANDARD FORCE FOR A STANDARD (60 x 8 CM) HINGE

	Mean	*(s.d.)*
Full Hinge (kN)	*57.9*	*(17.3)*
Under Cut Hinge (kN)	*48.5*	*(17.2)*
Wing Cut Hinge (kN)	*43.3*	*(18.6)*

This data highlights one of the characteristics of radiata pine - its highly variable hinge strength. In examining the effects of factors such as wind and side lean, it was necessary to consider their effect on the weaker trees.

This was done by using confidence limits to estimate the values of hinge strength for different hinge types.

Confidence limits are estimated from the formula :

$$\bar{x} \pm d.(s.d.)$$

where $\bar{x}$ *= mean*
s.d. = standard deviation
d = a value, selected from the appropriate column of a normal distribution table

For a confidence limit which is exceeded by 95% of the population :

d = 1.645

For a full hinge (60 x 8 cm) :

$\bar{x}$ = 57.9 kN
s.d. = 17.3

The lower 95% level is calculated by

57.9 - (1.645 x 17.3)
= 29.4

Hinge strength data for the three hinge types is listed in Table 3; both mean values and the lower 95% level are shown.

TABLE IX-3 : AVERAGE AND THE 95% LEVEL OF HINGE STRENGTH, EXPRESSED IN TERMS OF STANDARD FORCE FOR A STANDARD (60 x 8 CM) HINGE

	Mean	95% Level
Full hinge (kN)	57.9	29.4
Under Cut Hinge (kN)	48.5	20.2
Wing Cut Hinge (kN)	43.3	12.7

Note : The 95% level is the level exceeded by 95% of the trees. One tree in 20 is expected to have a weaker hinge than the value shown.