THE NATURE OF THE RESOURCE*

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INTRODUCTION

In general terms, it is not difficult to forecast the nature of the resource coming on stream during the next two decades because its characteristics have already been largely predetermined by past events — by the area we planted (or failed to plant) during the 1940s, '50s, and '60s; by the species we planted; by the class of country we planted and its location; by the planting spacings we adopted and the standards of establishment practice we accepted; by the silvicultural prescriptions we applied or failed to apply; by the wood supply commitments we entered into; and by the rotations we are now obliged to accept as a consequence. These factors in combination have influenced, or will influence the age, dimension, intrinsic properties, and merchantability of our future wood supply. To characterise the quality of the future resource, however, is a more difficult task because quality is determined in respect to a particular product; characteristics that constitute good quality for one product often constitute poor quality for another. Assessing quality, therefore, assumes prejudgement of the type of product or products we are likely to produce. Here we are on much more uncertain ground because it entails prejudgement of markets and future markets could be different from present markets based on the old-growth crop. The old crop, therefore, is the standard against which we should appraise the nature of the new resource that will replace it later this decade.

THE PRESENT RESOURCE

A feature of the resource that we are at present using is its predictability — it has been around a long time, we know what to expect from it, we are familiar with its main characteristics and defects, and we have developed grading rules that define its suitability for specific uses. The stand characteristics are well known. The trees were planted at close spacing and were either

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left untended or tended so belatedly as to have had little effect on their grade outturn. During their life span past attacks by the *Sirex* wood wasp and competition between other trees have thinned them down to between 200 and 400 stems/ha, average tree size has reached up to 65 cm d.b.h., and the volume of harvestable wood in fully stocked stands often exceeds 1000 m³/ha. Mean basic density of the wood and heartwood content have been steadily increasing as the trees age, the average basic density for a 50-year-old tree at Kaingaroa being a respectable 420 kg/m³, an increase of some 30 kg/m³ over an average 25-year-old tree. Although the close initial spacing restricted branch size, the early death of the lower branches has produced bark-encased knots that extend from about the seventh annual ring to the bark, degrading the whole outer wood sheath. The one benefit from having dead branches is that the cost of trimming is reduced because most of them are broken or sloughed off during felling and snigging.

In the forestry literature, the old-crop stands are often labelled as of poor quality, the fact that they were untended being equated with poor quality. It must be emphasised that these are foresters’ assessments of them as stands, rather than an industrialist’s assessment of their quality as raw material for a range of products. As we have seen, the old-crop stands undeniably do have many deficiencies. Some are understocked and their trees are excessively branched, malformation is common, virtually all their timber is knotty, there are many standing dead trees to contend with, and there is a wide range in tree size. Because of their height and stocking, they have become prone to wind damage. Nonetheless, these same “poor quality” stands are the basis for a very diverse industry producing a wide range of timber, pulp, paper, and board products. We have learnt to accommodate their characteristics by channelling particular parts of the trees to an appropriate end-use. When this is done well, we find that the old-crop radiata pine is rated as a good, if not high quality material.

Technically, it will be very difficult to grow radiata pine in a manner that will produce better framing and structural timber or stronger kraft pulps. Another huge plus for the old crop, of course, is that it was concentrated in a few locations on soils of high site index and on country relatively easy to road and log. The influence of these factors combined with large piece size, high volume per hectare, and low stumpages have given our industry relatively low-cost wood. Because the old crop is the standard against which we must judge the new crop, I have felt it necessary to correct or
qualify its "poor quality" image — to establish that in fact it has some very good qualities that we are going to find are difficult to match.

**THE REPLACEMENT RESOURCE**

Inventory of our total resources has revealed that if we are to maintain current levels of production we have to accept one inescapable conclusion — when the old growth stands in our major supply regions cut out towards the end of this decade, the replacement crops will on average be some 20 or more years younger.

The fact that we will be shortening the rotation to this degree in itself will have significant effects because many of the important characteristics that determine quality are age related — tree size, basic density of the wood, knot condition, heartwood and extractives content, tracheid length, and chemical composition of the wood are all influenced by tree age. The resources we shall be utilising after the old crop has cut out are also much more dispersed and cover a much wider geographic range. Apart from the effects this might have on the cost of harvesting and transporting their produce, the latitude and altitude at which the stands are grown will affect intrinsic properties like wood density and heartwood content.

Again, unlike the old crop, the replacement stands have received varying degrees of silvicultural treatment affecting their stocking, tree size, volume production, defect core, branch size, and branch condition so they are much more variable, and their characteristics and values more difficult to predict. This variability and lack of consistency will be apparent not only between stands which have received different treatments, but also between trees and log height classes within stands, dependent upon the degree of pruning they received, the timing of pruning, and their diameter growth since pruning.

**IMPORTANCE OF ROTATION AGE**

Difficulties in forecasting the value outturn of stands that have received varying silvicultural treatments have been magnified by our apparent need to shorten rotations in order to meet our wood supply commitments. When the replacement stands were treated, it was foreseen that the pruned crop trees would be grown to a mean diameter that would ensure they would provide a worthwhile yield of clear veneer or sawn boards. Differences in site
index, stocking, and defect core size can be allowed for by adjusting rotation age but such management flexibility is severely constrained in a tight wood-supply situation.

Rotation age has become a vital factor in many regions and in this situation it is essential that we understand how stand age, location, site index, stocking, and pruning interact to influence wood properties, tree characteristics, and value outturn for different products if we are to succeed in channelling logs to their most appropriate end-use.

Eighteen months ago a Radiata Pine Task Force was formed at FRI with a view to at least clarifying, if not resolving, some of these issues. I can report that the team are hard at work and they have some interim findings but it is a big task and they still have a long way to go. I have drawn fully on their work and that of other FRI personnel in preparing this paper.

AGE EFFECTS ON INTRINSIC WOOD PROPERTIES

Two important wood properties are basic wood density (the amount of dry wood per unit of green volume) and tracheid length. Both these factors vary in a predictable pattern within stems as illustrated in Fig. 1 (Cown, 1980a). Both are static properties — once they have been determined they do not change.

Basic density is probably the single most important intrinsic wood property for most products, particularly if we are contemplating adopting short rotations. It affects the yield of dry wood per tonne, the strength of wood, the tear index of kraft pulps, and other papermaking qualities. It influences transport costs, chemical pulp digester yields, and energy inputs in pulping. Some preliminary work at FRI has indicated that loss of stiffness in 100 × 50 mm timber associated with an increase in knot size might be countered, at least in part, by an increase in density. As it is a highly heritable characteristic we are exploring the prospects of selecting for higher wood density in our radiata pine tree breeding programme. Eliminating very low density corewood would be advantageous for virtually all end-uses.

The predictable pattern for basic density is that it is lowest near the pith, increasing outwards to about the twenty-fifth annual ring, thereafter remaining relatively constant. The pattern is consistent at all levels in the stem. Different trees, however, can have markedly different density gradients across those 25 rings, varying as much as 150 kg/m³ from pith to mature outer wood. For Kaingaroa, wood density adjacent to the pith averages about
340 kg/m$^3$ whereas the outerwood after the twenty-fifth ring averages about 450 kg/m$^3$. Foresters and wood processors are probably more interested in average tree, log, or part-of-log density than patterns within trees. To show how average basic density and tracheid length vary with the age of the stand and for various components of the tree, data are presented in Table 1
for a fast-grown tree, over an age range from 15 to 30 years. Average densities and tracheid lengths are shown also for thinnings at age 11 years, for top logs from 100 to 250 mm diameter, and for slabwood from the four sawlogs (assuming they are all sawn).

### TABLE 1: ESTIMATED WOOD DENSITY AND TRACHEID LENGTH FOR A FAST-GROWN 30-YEAR-OLD TREE

<table>
<thead>
<tr>
<th>Stem Section</th>
<th>Average Wood Density (kg/m³)</th>
<th>Average Tracheid Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(to 100 mm s.e.d.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Total stem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At age 15</td>
<td>367</td>
<td>2.66</td>
</tr>
<tr>
<td>18</td>
<td>373</td>
<td>2.88</td>
</tr>
<tr>
<td>21</td>
<td>379</td>
<td>3.07</td>
</tr>
<tr>
<td>24</td>
<td>386</td>
<td>3.23</td>
</tr>
<tr>
<td>27</td>
<td>393</td>
<td>3.36</td>
</tr>
<tr>
<td>30</td>
<td>400</td>
<td>3.46</td>
</tr>
<tr>
<td>B. Thinnings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At age 11</td>
<td>360</td>
<td>2.40</td>
</tr>
<tr>
<td>C. Top logs (100 to 250 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At age 30</td>
<td>364</td>
<td>2.53</td>
</tr>
<tr>
<td>D. Slabwood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom log</td>
<td>435</td>
<td>4.10</td>
</tr>
<tr>
<td>Second log</td>
<td>420</td>
<td>4.10</td>
</tr>
<tr>
<td>Third log</td>
<td>405</td>
<td>3.8</td>
</tr>
<tr>
<td>Fourth log</td>
<td>390</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Estimates based on average density and tracheid length profiles for Kaingaroa. First ring density 340 kg/m³, first ring fibre length 1.50 mm.

It is readily apparent from the table that average basic density of the whole tree increases with advancing age at a fairly regular rate. Top logs between 100 and 250 mm s.e.d. have essentially the same basic density and tracheid lengths as 11-year-old thinnings. The data for slabwood emphasise its value as a source of higher density wood for kraft pulping, but slabwood from 30-year-old trees is not as good in this regard as slabwood from 50-year-old trees. Basic density must not be confused with green density; the green density of top logs is higher than that of lower parts of the stem because of their higher sapwood content and thus moisture content. Calculations of yield per green tonne for trees of different basic density have shown that green weight of wood is not a reliable indicator of the yield of dry wood (Cown, 1980b) because of differences in moisture content.
As is apparent from Fig. 1, the pattern of tracheid length variation is similar to that for wood density except that the longest cells occur at about half stem height and the central core zone is more of a core than a cylinder. Tracheid length for Kaingaroa radiata pine is about 1.5 mm adjacent to the pith, increasing to 4.0 mm by the fifteenth growth ring and thereafter increasing only very slowly. The chemical composition of the cell wall follows a similar pattern; lignin decreases from pith to bark, pentosans content decreases over the first 10 to 15 rings from the pith, whilst cellulose increases for the first 10 to 15 rings and then remains fairly constant (Uprichard, 1980).

Heartwood (and extractives which by their nature depend on heartwood content) does not follow the same pattern. Heartwood formation is a dynamic process — it expands with increasing age, altering the extractives content of the corewood in the process. Heartwood first forms in radiata pine when trees are from 12 to 15 years old, and it expands outwards from the pith at a rate of about half a ring per annum in northern districts. At a given age for a given locality, the numbers of heartwood and sapwood rings are predictable from stand age. The heartwood percentage is therefore dependent on relative growth rates in the heartwood and sapwood zones — the wider the outerwood growth rings at a given age, the lower the proportion of heartwood. An average 30-year-old Kaingaroa tree has approximately 20% heartwood, a 50-year-old tree 50% heartwood. When tree age decreases and less heartwood reaches the kraft pulp mill digesters, there will be a decrease in tall oil production and in the resin acid content of tall oil (Uprichard, 1980).

REGIONAL VARIATION IN WOOD PROPERTIES

Although the wood property patterns outlined in the preceding section apply generally, there are some distinct regional variations which also follow a discernible pattern. A recent FRI survey has confirmed that there is a significant decrease in wood density southwards, particularly in the outerwood. Average densities for 30-year-old trees, for instance, drop 20% from Auckland to Canterbury Conservancies (455 to 380 kg/m³). It was found that geographic regions could be grouped into three outerwood density classes (Cown, 1980b):

Canterbury, Westland, and Southland, and inland Wellington Conservancy .... <450 kg/m³
Inland Nelson, coastal Manawatu and
Hawke’s Bay, and inland Rotorua
Conservancy .......................... 450-475 kg/m³

Coastal Nelson, coastal Bay of Plenty
and Gisborne, and Auckland
Conservancy .......................... >475 kg/m³

Corewood densities do not vary regionally to the same extent,
the difference between Auckland and Southland being only
20 kg/m³. The density gradient from pith to periphery is not
so marked in Southland so timber from southern sites has lower
but more uniform density characteristics (Fig. 2). Nelson proved
to be the most variable region, with coastal stands having values
similar to Auckland whilst densities in inland localities are closer
to those in Southland.

The distribution of wood density values is clearly related to
latitude and altitude. Useful rule-of-thumb adjustments for outer-
wood density are:

(a) Outerwood density decreases with increasing latitude at a
rate of 10 kg/m³ per degree of latitude (110 km).
(b) Outerwood density decreases with increasing altitude at a
rate of 10 kg/m³ for each 100 m rise in altitude.

Temperature is clearly implicated as the major factor influenc-
ing wood density, outerwood being more sensitive than corewood.

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**Fig. 2: Regional density trends.**
Tracheid length follows a somewhat similar but less pronounced pattern; there is a decrease from north to south but regional trends are not as regular as for wood density. The age at which heartwood first forms seems to be reasonably constant but its rate of increase is slower in southern districts.

IMPLICATIONS OF VARIATIONS IN WOOD PROPERTIES

Do these variations in wood properties have much significance for our wood processing industries? Wood technologists at FRI believe they do. In the first instance, the 20% difference in density between Auckland and Canterbury/Southland must result in increased handling costs and greater wood consumption per tonne of pulp produced. The variations are such that the wood from the different regions has different potentials for papermaking. Cown and Kibblewhite (1980) in a recent paper have predicted kraft pulp paper properties for slabwood and pulp logs (< 200 mm s.e.d.) produced from 30-year-old trees. Their predictions for average wood density, tear index, and burst index, calculated from regional wood property averages for each Conservancy, are presented in Table 2. Data from several separate pulping studies have supported the trends shown in the table.

It can be seen that both location and wood age (position in the stem) have a significant effect on tear index. Tear index is not a quality that can be changed by beating; it is determined by wood fibre characteristics and is of importance for several grades

<table>
<thead>
<tr>
<th>Conservancy</th>
<th>Average Wood Density (kg/m³)</th>
<th>Tear Index</th>
<th>Burst Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slabwood:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auckland</td>
<td>485</td>
<td>30</td>
<td>5.3</td>
</tr>
<tr>
<td>Rotorua</td>
<td>450</td>
<td>26</td>
<td>6.0</td>
</tr>
<tr>
<td>Wellington</td>
<td>425</td>
<td>23</td>
<td>6.6</td>
</tr>
<tr>
<td>Nelson/Westland</td>
<td>450</td>
<td>26</td>
<td>6.0</td>
</tr>
<tr>
<td>Canterbury</td>
<td>415</td>
<td>22</td>
<td>6.8</td>
</tr>
<tr>
<td>Southland</td>
<td>410</td>
<td>22</td>
<td>6.9</td>
</tr>
<tr>
<td>Pulp logs (to 200 mm s.e.d.):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auckland</td>
<td>420</td>
<td>16</td>
<td>7.2</td>
</tr>
<tr>
<td>Rotorua</td>
<td>400</td>
<td>15</td>
<td>7.6</td>
</tr>
<tr>
<td>Wellington</td>
<td>380</td>
<td>14</td>
<td>8.0</td>
</tr>
<tr>
<td>Nelson/Westland</td>
<td>400</td>
<td>15</td>
<td>7.6</td>
</tr>
<tr>
<td>Canterbury</td>
<td>375</td>
<td>14</td>
<td>8.0</td>
</tr>
<tr>
<td>Southland</td>
<td>365</td>
<td>13</td>
<td>8.2</td>
</tr>
</tbody>
</table>
of paper. Although kraft pulps of high tear index may not be commanding a market premium, it is a factor that helps us to sell them on export markets.

If our pulps fall below an acceptable tear standard we could experience difficulty in selling our exportable surplus. An implication of using younger trees or top logs for kraft pulp is that slabwood becomes of increasing importance as a chip source for our export kraft mills. There is likely to be more segregation of chip material and subsequent blending to produce pulps with the qualities the market demands.

The effects of basic density and tracheid length on the qualities of thermomechanical and refiner mechanical pulps have not been established so clearly. There is some evidence that low density, young, radiata pine wood may consume more power when refined to a low freeness. Long fibre content increases with increasing density, and refiner mill experience in New Zealand is that higher density wood gives superior pulp. Nevertheless, good quality refiner mechanical and thermomechanical pulps have been produced from 9- to 13-year-old thinnings in FRI trials conducted on Aupouri and Tarawera trees (Corson, 1980).

There are some processes and speciality papers for which young wood is preferred. The slender thinner-walled fibres have more flexibility giving a more compact, smoother, denser sheet with good formation properties and good printability. Experience at Caxton in manufacturing specialty papers has indicated the importance of using fibres with specific characteristics for specific papers. There is undoubtedly a trend towards more "scientific" papermaking. Some see the need for better segregation of the raw material being extended to separation of fibres by fibre fractionation into length and flexibility classes, enabling a whole range of papers to be made to order by recombining fibres in the requisite proportions. One pulp chemist has been heard to say that dealing with the variability encountered in radiata pine is well within the scope of our present technology; he felt we were shying at shadows which lack substance. Perhaps we are, but forewarned is forearmed. We have a much better capability now to predict in advance the properties of the raw material that will be coming on-stream, so we should also be in a much better position to match the processing plants we establish to their raw material resources. It is clear that if we wish to produce strong high-tear pulp, Northland trees are better than those of Southland, but if it is light-weight high-density papers or tissues that are required young Southland trees will be superior to those of Northland.
LOCATION OF THE REPLACEMENT RESOURCE

The absence of an established stand record system foiled my attempts to find where the stands that will be required to replace the old crop are located. Nor was I able to unearth details on their condition or past silvicultural treatment, or the type of country on which they were planted. It is not possible therefore to comment specifically on their likely timber quality. It is likely they may have had a great range of treatments and that they are distributed through many forests throughout New Zealand. This dispersal of the resource and the relatively small areas of radiata pine planted in each forest during the forties, fifties, and early sixties must create difficulties in getting sufficient concentration of material together to establish new industries. Increased harvesting and transport costs can be anticipated if the material has to be moved long distances to keep existing plants functioning efficiently. An increase in lead distance from 10 to 100 km has the effect of increasing the cost of road haulage by up to $8/tonne, more than the grower receives for his wood in some instances. Everything points, therefore, to an increase in the delivered cost of wood at mill door for younger smaller logs. The sawmillers are going to have to look very critically at their log mix and the design of their plant to ensure that they have appropriate equipment for the job.

Profitability studies have revealed how important the location and productivity of planting site are, especially for export material. I fear we have not concentrated the resource as well as we might have. The D.F.C. report (1980) drew attention to the poor cost-effectiveness of some State forests. Where forests are poorly located the very best of silvicultural practices may be unable to offset the disadvantages of remoteness from markets, low productivity, or excessively high roading and transport costs. One objective of having better cost-evaluation and value-prediction procedures is to prevent the planting of plantable country that should not be planted.

In the absence of details on the silvicultural history of the stands we shall be milling 10 to 20 years hence, I can but review the types of silvicultural regime being practised and outline the procedures that are being developed that should enable us to better evaluate their quality and value.

DERIVATION OF SILVICULTURAL REGIMES

Deriving an appropriate silvicultural regime for a region requires the silviculturist to start at the end and work back, because
regimes are designed with an end-product in view. This requires the forester to define the size and quality characteristics of the mean crop tree that will most satisfactorily meet the specifications of the end-product. (That is why foresters want to know so much about other peoples' business!) Having got the image of his target crop tree well defined, he is in a position to calculate the number of crop trees per hectare required to have a fully stocked stand at time of harvest. From this point, it becomes a matter of applying local knowledge of site productivity, growth patterns, and damaging agencies to purpose-grow the specified crop in as short a time as possible. Profitability studies have clearly indicated that the fast-track direct regime without asides or diversions en route yields the best return to the grower. Some foresters, however, like to add another criterion — that of obtaining the maximum volume of merchantable wood per hectare. Unfortunately, this objective conflicts with that of growing the target crop in the shortest time. It requires either diversions into production thinnings which are at the expense of the crop trees (by increasing the time taken for them to reach target size) or the retention of too many crop trees, thereby reducing their mean diameter at their scheduled date for harvest and endangering any investment in diameter in pruning.

A survey conducted by the Radiata Pine Task Force found that currently we are practising about 70 different combinations of initial spacing, pruning, thinning, final-crop stocking, and rotation age. These are the components of a silvicultural regime but it would be misleading to regard each combination prescribed as a separate regime. They fall into three broad categories, “Clearwood”, “Structural”, and “Roundwood”, based on whether their primary objective is to produce: (1) clear boards or veneer, (2) knotty framing timber, or (3) export logs, round produce, or pulpwood. With 33 clearwood and 21 structural schedules being implemented (plus numerous variants that have been practised during the past 20 years), it is obviously not a simple task to predict the future qualities of our stands for sawn timber production.

The Task Force has not seen this as being their responsibility. Their role is to establish relationships between the interacting factors that will enable them to produce means by which foresters can predict the likely outcome of their own prescriptions. Tools of this nature have not been available previously so it is not surprising that silvicultural prescriptions have varied. More thorough evaluation should narrow the range of variation but
it is unlikely that one clearwood or one structural schedule will be found to be universally applicable. The form and growth habit of radiata pine vary significantly over the range of sites on which it is planted and local market circumstances, which decide the merchantability of the end-product, vary markedly from region to region from time to time.

Foresters try to allow for these circumstances when they make their prescriptions. Thus each prescription is in effect an assessment of the future market requirements. The more obscure the market situation, the greater the need to retain flexibility for as long in the rotation as possible. Unfortunately, the decisions that most influence the future quality of the crop for sawn timber or veneer have to be made before age 10 years. The need for early decisions is heightened if the wood supply situation obliges us to adopt short rotations. It has become extremely important, therefore, to develop better prediction methods so that forest managers can more precisely evaluate the consequences of their plans and actions.

INITIAL STOCKING AND ESPACEMENT

The questions of initial stocking and planting espacement immediately raise the issues of end-product and means of controlling defect, so even at this initial stage, the forester is making judgments that affect the quality of the resource and its marketing options. If he opts not to prune, tree espacement is his only recourse for controlling branch size, and thus knot size. Fenton (1967) showed that a relatively small change in initial spacing (1.8 x 1.8 m versus 2.4 x 2.4 m) had a marked influence on the framing grade outturn from 39-year-old unthinned unpruned stands at Kaingaroa.

A decision to control branch defects by pruning provides much more latitude in respect to initial stocking and spatial arrangement. The number of trees planted per hectare need only be sufficient to ensure an even final-crop stocking of straight trees, the number varying according to the exposure and nutrient status of the site. Spatial arrangement can also be varied to accommodate other considerations. For instance, rectangular spacings often reduce land preparation and planting costs. Group plantings and double row configurations have been tested experimentally and could have an application in agro-forestry schemes.
Pruning offers the means for eliminating knot defects in sawn timber and veneer. The presence or absence of knots must rank as the No. 1 quality-determining characteristic in radiata pine sawn timber. We have to accept that, in comparison with other softwood timbers that are traded on world markets, radiata pine has such large knots that it is lowly rated when international grading rules for coniferous timbers are applied. Eliminate the knots and it is a different story; Sutton (1974) pointed out that it lifts radiata pine from being ranked with the poorest grades (Scandinavian fifths or North American lower commons) to amongst the highest softwood grades (Scandinavian firsts or North American B Select). With such scope for improving the grade and value of butt logs by such relatively simple silvicultural means, it is not surprising that some New Zealand foresters became strong advocates for pruning.

Fenton (1972b), after evaluating several alternative regimes for radiata pine, examined the implications of his findings. He assessed the economics of pruning by comparing the best pruned regime (the direct 200 stems/ha peeler/sawlog regime on a 26-year rotation) against the best unpruned regime (the export log regime at 375 stems/ha on a 23-year rotation) he had evaluated. Both had internal rates of return that exceeded 10% so he considered the main question facing New Zealand forest managers was whether or not the extra cost of producing high-quality pruned logs with versatile end-uses was warranted. Whereas the export log regime had lower management risk (as there were fewer operations that could be muffed) but higher marketing risk (export log sales could fluctuate), the direct peeler/sawlog regime had much better marketing versatility but higher management risks because the silvicultural treatments had to be accurately timed and competently executed.

In view of the depth of his analyses and the detailed data he presented in support of them, it is surprising that the reaction to his findings has been so mixed. Many of his concepts have been accepted and acted upon, but the regimes in many instances have been modified. Most foresters have erred towards retaining more trees, on the supposition that as a higher final-crop stocking will yield more wood per hectare, they will obtain a higher financial return.

Recent work by Task Force personnel has emphasised the need for accurate timing of pruning. We know that if we are to ob-
tain a good return on our investment in pruning, the pruned
trees must have an adequate sheath of clearwood over their defect
cores. A lot of effort has been devoted to determining the size
of defect core resulting from present pruning regimes and to
obtaining a suitable measure of the value enhancement resulting
from pruning.

**Prediction of Grade Outturn and Value for Pruned Logs**

Investigations of the timber grade improvement by means of
sawmill studies have resulted in the development of a “grade
index” formula for predicting the value of straight pruned butt
logs (Park, 1980; James, 1980).

\[
\text{Grade Index} = \frac{\text{d.b.h. (o.b.) (mm) } \times \text{ conversion } \% \text{ (decimal)}}{\text{diameter of defect core (mm)}}
\]

This index is closely correlated with value (per cubic metre
log volume) of sawn outturn and can be used to predict the pro-
portions of New Zealand Standard Grades (Fig. 3). A regime
which results in pruned butt logs having a grade index of 0.8
is very poor because (as can be seen from Fig. 3) it yields prac-
tically no long-length clear boards. A grade index of 1.0 is still
unsatisfactory, 1.4 would be good, and 1.7 very good indeed. If
we conservatively give clear boards the same value as finger-
jointed clear boards (a $65/m^3$ premium above Dressing grade,
1978 wholesale price list) a rise in grade index from 1.0 to 1.4
represents a $16/m^3$ increase in the value of the butt log if it is
sawn for timber, or more than $3000/ha on a 28-year-old
direct sawlog regime.

What is required of us to attain a grade index of 1.4 or better?
If we assume an average log conversion factor of 55% and a
20 cm defect core, we need to grow a mean crop tree of 50 cm
d.b.h. However, should we delay our pruning by 9 to 12 months
and thus attain a defect core of 22 cm, the mean final-crop tree
will need to be 55 cm d.b.h. to attain a 1.4 grade index. Obtaining
a 5 cm increase in mean d.b.h. in a fully stocked stand towards
the end of the rotation represents a formidable added cost, all
because old Ranger Z 20 years ago missed out on doing his prun-
ing on time!

**Prediction of Diameter over Pruned Stubs**

How do we ensure that young Ranger Y does not make the
same error, and fully appreciates his responsibilities? Obviously
we must first ensure that the pruning prescription if properly
carried out will achieve defect cores of the desired size. Knowles,
Koehler and West have provided a means of predicting the largest diameter-over-pruned-branch-stubs (hereafter referred to as D.O.S.) obtained for each pruning lift. This prediction tool allows us to do two things:

(a) To calculate the diameter of the defect core likely to result when a specific pruning schedule is applied.

(b) To design a pruning schedule that will confine D.O.S. to a specified diameter.

Suitable D.O.S. models have been developed and tested for the major regions. In Table 3, the predicted D.O.S. for a current pruning regime is compared with that necessary to achieve a 15 cm D.O.S.
TABLE 3: COMPARISON OF PRUNING SCHEDULES FOR CENTRAL NORTH ISLAND FORESTS
(R. L. Knowles and G. G. West, pers. comm.)

<table>
<thead>
<tr>
<th>Regime</th>
<th>Mean Crop Height (m)</th>
<th>Prescribed Pruned Height (m)</th>
<th>Actual Pruned Height (m)</th>
<th>Proportion of stem Pruned (%)</th>
<th>d.b.h.² (cm)</th>
<th>Maximum Branch Pruned (mm)</th>
<th>Predicted D.O.S. (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current regime as prescribed</td>
<td>6</td>
<td>2.2</td>
<td>2.5</td>
<td>42</td>
<td>9.8</td>
<td>35</td>
<td>15.3</td>
</tr>
<tr>
<td>as prescribed</td>
<td>9</td>
<td>4.0</td>
<td>4.4</td>
<td>49</td>
<td>15.3</td>
<td>40</td>
<td>17.5</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>6.0</td>
<td>6.0</td>
<td>50</td>
<td>20.8</td>
<td>45</td>
<td>19.8</td>
</tr>
<tr>
<td>Regime necessary to achieve 15 cm D.O.S. (Annual pruning)</td>
<td>5.6</td>
<td>2.0</td>
<td>2.2</td>
<td>39</td>
<td>9.1</td>
<td>35</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td>7.3</td>
<td>3.2</td>
<td>3.5</td>
<td>48</td>
<td>12.2</td>
<td>35</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td>8.8</td>
<td>4.5</td>
<td>4.8</td>
<td>55</td>
<td>15.0</td>
<td>35</td>
<td>14.9</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>5.8</td>
<td>6.0</td>
<td>60</td>
<td>17.2</td>
<td>35</td>
<td>15.0</td>
</tr>
</tbody>
</table>

¹ Pruned height divided by tree height.
² Central North Island forests have the following relationship of d.b.h. to height: d.b.h. = 1.84 Ht — 1.2.
   (when d.b.h. is in centimetres, and Ht is in metres).
It has been customary to judge the efficiency of a pruning schedule by the proportion of the stem pruned. Pruning beyond half height at any stage has been thought to be too severe because it might reduce diameter growth and induce epicormic branching. However, these effects are insignificant (and can be countered) relative to the effect of large defect cores on value outturn.

For the current regime used in the example above, the proportion of the stem pruned on average remains reasonably constant at around 50%. As the table reveals, an inescapable consequence of using this criterion if the pruned trees are still free-growing is that D.O.S. will increase for each pruning lift. Instead of D.O.S. reducing with increasing height, or at least remaining the same, the defect core has the shape of an inverted cone, the opposite of what we should like. I am sure all foresters present have witnessed that this is, in fact, what is happening in practice.

During our training, we were indoctrinated with the ideal of obtaining a “6 inch knotty core”, but unfortunately we have very rarely achieved it over a 6 m log length. Table 3 indicates the type of schedule necessary to achieve a 15 cm D.O.S. It is immediately apparent that the proportion of the stem pruned at each lift has to increase at each pruning lift, in this instance from about 40% of tree height at the first lift to 60% at the last lift. Also, as both tree diameter and branch size control D.O.S., we simply cannot allow the free-growing branches immediately above the last pruning lift to have unrestricted growth for 2 years before we return.

The simplest means of ensuring smaller defect cores is, once a stand has had its first pruning lift, to schedule pruning of that stand as an annual event until all potential final-crop trees have been pruned to their specified height. The practice of pruning all trees to the same height at each lift requires very close scrutiny because it results in the dominant trees being underpruned (= large D.O.S.) and the smaller trees overpruned (= checked and below average growth). Task Force investigations have revealed that the present practice of pruning to a standard height at each lift increases variability and rarely achieves the small D.O.S. target desired. A programmed annual prune would ensure stands due for pruning would not be overlooked and each tree could be pruned according to its merits. Unskilled men can readily be taught to prune trees in proportion to their height but, as exemplified in the table, that proportion should differ for each pruning lift.
I expect many will think that pruning of this intensity is too difficult, or too costly; my answer would be for them to calculate what they might lose by not improving present standards. Fenton (1972b) was right when he assessed the management risk of the direct peeler/sawlog regime as being high; it has been high but now that we have much better tools to assess our performance, we are in a position to reduce that risk substantially.

One cloud over clearwood predictions from pruned stems is the occurrence of resin pockets. Three types have been identified and their presence in butt logs is quite common in forests as dissimilar in character as Aupouri, Kaingaroa, Golden Downs, and Ashley. Their incidence varies locally with site and is usually highest on ridges. Incidence tends to be greatest in butt logs and there is evidence to suggest that the incidence of one type may be associated with silvicultural treatment. Some trees in a stand are obviously more prone to resin pocket formation than others, and it is believed that resin bleeding could prove to be a useful tool for the early identification of trees that are prone to form resin pockets. They are a degrading feature but their importance for different types of end-product has not as yet been adequately determined.

**THE QUESTION OF FINAL-CROP STOCKING**

Most lay people if asked to identify New Zealand's advantage for production forestry would unhesitatingly reply that it is the fast growth rate of our pine trees. Their concept of fast growth would be our capacity to grow pine trees to large merchantable size quickly, rather than the production of larger volumes or tonnes of wood per hectare per annum. The principles behind the direct peeler/sawlog regime are more in tune with the lay person's concept than with the maximum-total-volume-per-hectare syndrome. The regime is designed to exploit the comparative advantage radiata pine has over the other species — that of producing a useful wood suitable for a wide range of purposes almost regardless of its radial growth rate (width of annual rings). Its objective is to capture the bulk of the stem wood increment that the site can produce on as few trees as possible once the main grade-determining characteristics have been determined for the butt log. It exploits the opportunity of spreading the outerwood increment of mature wood in wide bands over fewer, straight, selected columns of corewood instead of having it dispersed more thinly over many not-so-straight columns of corewood. It incorporates the reasoning that the value per cubic
metre of wood varies markedly within the tree, as well as between trees, dependent on its size, defects, and position in the tree (i.e., butt or upper log). It is based on the confident prediction that fewer large veneer logs or sawlogs from fewer trees per hectare will be cheaper to harvest, transport, and convert than many small logs from many smaller trees. Hence its exponents believe that the number of final-crop trees per hectare and their average diameter at rotation age are vital considerations, especially if rotation age is already constrained by wood supply commitments.

The best means of examining the effects of final-crop stocking on stand and individual tree characteristics when age is constrained is to compare two stands on the same site that have had identical treatments except that the stocking of final-crop trees differs. The example we shall use is that of two radiata pine stands being grown on a direct peeler/sawlog regime on a 28-year rotation on a good site (Site Index 30 m). Both stands have had the same establishment and early pruning and thinning-to-waste treatments. Upon the completion of high pruning at top height 10.7 m, one stand is reduced to 375 stems/ha, the other to 200 stems/ha and then grown on without further treatment till age 28 years. The Kaingaroa growth model developed from data from young thinned stands has been used to predict the number of live trees, their basal area, and volume at age 28 years, in each instance using actual basal area data (obtained from plots that have had similar thinning treatment at top height 10 to 11 m) as the platform for predicting forward. A stand volume generator, Program PROD, was used to forecast the tree size distribution and log size assortments.

**Influence of Stocking on Stand Characteristics**

The predicted stand parameters for the two stands at age 28 years are as follows:

<table>
<thead>
<tr>
<th>Nominal Stocking (stems/ha)</th>
<th>No. Live Trees</th>
<th>Basal Area (m²/ha)</th>
<th>Mean d.b.h. (cm)</th>
<th>Total Volume (m³)</th>
<th>Volume of Mean Tree (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>375</td>
<td>363</td>
<td>60</td>
<td>46</td>
<td>782</td>
<td>2.15</td>
</tr>
<tr>
<td>200</td>
<td>199</td>
<td>53</td>
<td>58</td>
<td>685</td>
<td>3.44</td>
</tr>
</tbody>
</table>

The growth model predicts a little mortality from competition in the more densely stocked stand but its total volume production is higher by some 12.4%. From what data we have for older stands treated in this way, the forecasts seem reasonable.
Distribution by Tree Volume Classes

Figure 4 shows the number of stems by tree volume classes for the two peeler/sawlog regime stockings and, for added interest, that for a framing regime on the same site, assuming it had been thinned to 600 stems/ha at 6 m top height and given no further treatment. The marked shift in the numbers of trees in the larger volume classes which is associated with reducing stocking from 375 stems/ha to 200 stems/ha when all other factors are similar is very clearly illustrated. So also is the large number of small trees with volumes below 1.5 m$^3$ for 375 stems/ha and 600 stems/ha. An interesting feature is that the number of stems predicted for the higher tree volume classes (2 m$^3$ to 6 m$^3$) for the 600 and 375 stems/ha stands are not markedly different but when stands are thinned heavily to 200 stems/ha, the model predicts a marked shift. This characteristic will be tested against actual stand data to check that Program PROD is predicting the tree size distributions accurately.

The tree size information shown in Fig. 4 will, I am sure, be of interest to any loggers who are present. To remind ourselves where the really high costs of producing wood from plantations occur, I have reproduced as Fig. 5 a graph from Fenton’s 1972a
paper on the economics of growing radiata pine on a direct saw-log regime. Assuming that the same relativity applies today, it emphasises how logging, transport, and sawmilling costs dominate the cost of producing green sawn timber. Harvesting costs are influenced by tree size, number of stems, extracted piece size, and recoverable volume per hectare. The differences between
these 28-year-old stands and the old crop will certainly affect costs markedly if for no other reason than that almost twice the area will be roaded and tracked for extracting an equal volume. We have insufficient data to judge how much the difference in tree numbers and piece size resulting from the three different stockings may affect harvesting and transport costs but most factors point to the lower stocking having a lower cost per cubic metre. This is a factor that requires much closer scrutiny because of the magnitude of the harvesting and transport cost component in relation to the total costs of production.

**Predicted Log Size Distribution**

The differences between the two stands become even more apparent when the trees are cross cut into logs and sorted into likely product categories by small-end-diameter classes. The categories recognised in Table 4 are those used in the National Planning Model except that the small log class has been divided into two sub-classes, 16-25 cm s.e.d. and 26-35 cm s.e.d.

**TABLE 4: PREDICTED LOG SIZE DISTRIBUTION FOR KAINGAROA PEELER/SAWLOG REGIME**

<table>
<thead>
<tr>
<th>Small-End-Diameter Class (cm)</th>
<th>Pulp</th>
<th>Small Sawlogs</th>
<th>Large Sawlogs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-15</td>
<td>11</td>
<td>109</td>
<td>266</td>
<td>244</td>
</tr>
<tr>
<td>16-25</td>
<td>2</td>
<td>17</td>
<td>42</td>
<td>39</td>
</tr>
<tr>
<td>26-35</td>
<td>149</td>
<td>563</td>
<td>677</td>
<td>316</td>
</tr>
<tr>
<td>&gt;35</td>
<td>9</td>
<td>33</td>
<td>40</td>
<td>18</td>
</tr>
</tbody>
</table>

375 stems/ha
(363 live stems/ha)
Mean d.b.h.: 46 cm

375 stems/ha
(363 live stems/ha)
Mean d.b.h.: 46 cm

<table>
<thead>
<tr>
<th>200 stems/ha</th>
<th>(199 live stems/ha)</th>
<th>Mean d.b.h.: 58 cm</th>
<th>Log volume (m³/ha)</th>
<th>150</th>
<th>379</th>
<th>564</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>6</td>
<td>26</td>
<td>67</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of logs/ha</td>
<td>32</td>
<td>146</td>
<td>446</td>
<td>988</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>15</td>
<td>37</td>
<td>45</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sawn volume (m³/ha)</td>
<td>15</td>
<td>79</td>
<td>223</td>
<td>317</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>5</td>
<td>25</td>
<td>70</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
It has been assumed that all the small log class from 16 to 35 cm s.e.d. would be sawn, but should an unsatisfied pulpwood market exist, the 16-25 cm class might more profitably be diverted to a pulpmill. If this is to happen, however, the pulpmills must expect to pay stumpages more in keeping with the costs of production. In a tight wood-supply situation, there could be competition for this class of wood and, although it does not convert into very good sawn timber, at present it is worth much more to the grower as roundwood or sawn timber than it is as pulpwood.

Although there is a predicted 12.4% difference in the total volume of the two stands, when those volumes are extracted, cross cut into logs, and sawn there is little difference in the total output of sawn product per hectare. The difference has become logging waste, sawdust, and slabs. The higher conversion factors obtained from sawing the larger logs from the 200 stems/ha stand virtually compensate for its lower total volume and extracted log volume. The costs of sawing, however, would be substantially less for the lower stocked stand because there would be only 956 logs to saw versus 1556 logs for the 375 stems/ha stand. Figure 5 shows the relative magnitude of the sawmilling cost, so even a small improvement in sawing represents a substantial saving. Good up-to-date data on the sawing costs for log classes of these dimensions and quality are virtually non-existent, so, if all these small young logs are to be sawn, our sawmilling industry will need to very hurriedly start upgrading and extending its technology. The impact of the change from old crop to the younger replacement crops will undoubtedly hit the sawmillers harder than other sectors of the industry unless they prepare for the change in advance. As can be seen from Table 4, the foresters could reduce the impact by adopting silvicultural regimes which produce fewer small logs.

Value of Pruned Butt Logs

Table 5 gives the predicted values of the pruned butt logs when sawn to 25 mm dimension timber. Results are shown for two pruning schedules, one which will give a maximum D.O.S. of 20 cm (approximating current schedules when they are applied on time) and the other a maximum D.O.S. of 16 cm (representing what could be achieved with annual variable-lift pruning, adopting a schedule like that shown in Table 3).
TABLE 5: PREDICTED VALUES FOR PRUNED BUTT LOGS FOR:
A. TWO FINAL-CROP STOCKINGS
B. TWO PRUNING SCHEDULES (see TABLE 3)
(After R. L. Knowles and G. G. West, pers. comm.)

<table>
<thead>
<tr>
<th>Nominal stocking</th>
<th>375</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at felling</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>No. live trees/ha</td>
<td>363</td>
<td>199</td>
</tr>
<tr>
<td>Mean d.b.h. (cm)</td>
<td>46</td>
<td>58</td>
</tr>
<tr>
<td>Butt log vol. (m³/ha)</td>
<td>226</td>
<td>197</td>
</tr>
<tr>
<td>Conversion factor (%)</td>
<td>55</td>
<td>60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assumed D.O.S. (cm)</th>
<th>20</th>
<th>16</th>
<th>20</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defect core (cm)</td>
<td>26</td>
<td>22</td>
<td>26</td>
<td>22</td>
</tr>
<tr>
<td>Grade index</td>
<td>0.97</td>
<td>1.15</td>
<td>1.34</td>
<td>1.58</td>
</tr>
<tr>
<td>% clears/m³ of log</td>
<td>8.20</td>
<td>13.96</td>
<td>20.07</td>
<td>28.01</td>
</tr>
<tr>
<td>Vol. of sawn clears (m³/ha)</td>
<td>18.53</td>
<td>31.55</td>
<td>39.54</td>
<td>54.90</td>
</tr>
<tr>
<td>Value ($/m³ of butt log)*</td>
<td>49.90</td>
<td>57.00</td>
<td>64.50</td>
<td>74.30</td>
</tr>
<tr>
<td>Value/ha ($/ha)</td>
<td>11 300</td>
<td>12 900</td>
<td>12 700</td>
<td>14 600</td>
</tr>
</tbody>
</table>

*Value based on 1978 wholesale price list. Clears valued as equivalent to fingerjointed clears ($65/m³ premium above Dressing grade).

Assuming that the analyses above represent the true situation, the results show:

(1) The stand with a nominal stocking of 375 stems/ha and a maximum D.O.S. of 20 cm at age 28 years is just at the threshold of producing worthwhile volumes of clear timber. Its average grade index of 0.97 would rate it as giving an unsatisfactory return on the investment in pruning. An added value of $1600/ha could have been obtained had medium and high pruning been done about 18 months earlier and annual pruning lifts programmed.

(2) Thinning the stand to 200 stems/ha after high pruning instead of to 375 stems/ha lifts the grade index to 1.34 and improves the value of the butt logs by $1400/ha, even though the total log volume per hectare is lower (197 m³/ha versus 226 m³/ha). The 20% yield of long clear lengths per cubic metre of log (33% of sawn outturn) obtained for the 200 stems/ha stand is regarded as being adequate to give a reasonable return on the investment in pruning.

(3) Pruning the stand earlier in annual lifts to restrain the D.O.S. to 16 cm and thinning after high pruning to 200 stems/ha lifts the grade index to 1.58 and improves the value by a further $1900/ha, a total added value of $3300/ha over the conventionally pruned 375 stems/ha
stand. A return of 28% of total log volume (46% of sawn outturn) is rated as being a good return on the pruning investment. A further increase in mean d.b.h. of 1 cm would increase values by a further $1.50/m^3$, amounting to another $300/ha.

The importance of these results is not the predicted values but relative ranking of the treatments and the magnitude of the differences between them. Using the 1978 wholesale price list for fingerjointed clears as the basis for valuing long-length clears is no doubt being conservative; the actual value enhancements, assuming the prediction functions are correct, could be much higher than those presented. Logs with a 16 cm D.O.S. would be suitable for peeling and slicing, which we expect might be more profitable than sawing. Studies on these aspects are currently in hand.

Unfortunately, the grade and value enhancement obtained from the conventional pruning regime applied to 375 stems/ha appears very marginal for a 28-year rotation. If we aim to maintain the current level of wood supply to the present industry, develop new industries in new localities as the plantings there mature, and progressively cut the oldest stands first, I foresee a lot of belated silvicultural effort giving little return.

Size of Upper Log Branches

Anyone seeing a stand being managed on the direct peeler/sawlog regime for the first time reacts to the fact that not only are the trees of larger diameter than usual but so also are the upper branches. The large branch probably more than any other factor has made foresters demure in adopting the regime. Some have compromised by holding a higher final-crop stocking, partly with a view to restraining the upper log branches a little but, as we have seen, the penalty is that tree diameters are restrained as well. If we are to obtain big boles in a given time, we must accept that we shall have larger branches to contend with, and thus larger knots. The question is — how large can a branch be before it really matters?

The short answer is that we are still not sure but the Task Force is in the process of determining if, to what degree, and in what circumstances large branches do matter.

Log size materially influences their effect so, when they are associated with large logs, their significance may have been overrated. The Task Force has done sufficient work to realise that the influence of branch size on grade returns and timber quality is a
more complex issue than originally envisaged. There are strong interactions and relationships between log size, branch size, and wood density that affect the outcome, especially when stress grading is used. Recently it has been realised that sawing pattern can markedly affect the results, so much so that many earlier studies are now regarded as having doubtful value. Until the significance of some of these variables has been clarified, the researchers are reluctant to make pronouncements.

THE UNPRUNED REPLACEMENT STANDS

A large proportion of the stands that will replace the old crop during the late 1980s and early 1990s will not have been pruned. Today it is customary to describe the management prescriptions for such stands as "Framing" or "Structural" or "Minimum-tending" regimes. As the combinations of initial espacements, thinnings, final-crop stockings, and rotations being practised are so wide, it is simpler for this exercise to categorise them as "unpruned", or perhaps more precisely "thinned unpruned" as most have had a thinning at some stage.

I expect most growers anticipate the grade outturn from their replacement unpruned stands will be similar to that from the untended old crop. They could be in for a surprise, especially if they are expecting to substitute 30-year-old new crop for 50-year-old well-stocked stands of old crop. One similarity between the two will be the distribution of branches and cone holes up the stem but they will differ in most other respects. Of major significance is that the trees will be 20 years younger and thus of much smaller mean diameter. Since the early 1960s, initial espacements have tended to become wider and first thinnings earlier, both factors which will have increased mean maximum branch diameter for the lower height classes. Although most stands have been thinned at least once, final-crop stockings are still at a level that noticeably constrains diameter growth of the crop trees. All these factors in combination — the shorter rotation, wider initial espacement, early thinning, and high final-crop stocking lead me to the conclusion that if their logs are sawn to framing dimension as expected, the grade outturn for the unpruned replacement stands will be notably dissimilar to that of the old growth stands.

The data shown in Table 6 are for a typical "framing" regime being widely practised at present. It has a nominal rotation of 28 years, so the same log size categories that were used in Table
TABLE 6: PREDICTED LOG SIZE DISTRIBUTION FOR FRAMING REGIME

<table>
<thead>
<tr>
<th>Age: 28 years</th>
<th>Site Index 27 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small-End-Diameter Class (cm)</td>
</tr>
<tr>
<td></td>
<td>Pulp 10-15</td>
</tr>
<tr>
<td>Mean d.b.h.: 38 cm</td>
<td>26</td>
</tr>
<tr>
<td>%</td>
<td>4</td>
</tr>
<tr>
<td>No. of logs/ha</td>
<td>361</td>
</tr>
<tr>
<td>%</td>
<td>16</td>
</tr>
<tr>
<td>Sawn volume (m³/ha)</td>
<td>88</td>
</tr>
<tr>
<td>%</td>
<td>28</td>
</tr>
</tbody>
</table>

600 stems/ha
(550 live stems/ha)

-Thinning to 600 stems/ha is prescribed at top height 6 m, with the stand left at that stocking until clearfelled. The regime is being applied to stands that have a Site Index of 27 m or less because these are considered suitable for the production of framing timber.

-It is probable that a stocking of 600 stems/ha since top height 6 m is insufficient to control knot size to a level that will give good yields of No. 1 Framing, especially when 90% of the logs are less than 35 cm s.e.d. In such small logs it is difficult to escape the influence of the pith and low density core. Comparison with the 375 stems/ha and 200 stems/ha log size distributions in Table 4 is revealing, especially the difference in the proportions of large logs for the same rotation.

-It is most doubtful, therefore, that the regime depicted by Table 6 will produce high outturns of strong, stable, readily marketable framing, especially if we wish to market it overseas. Why then label it a “Framing” regime? Fenton (1971) devoted his attention to the problem of designing a suitable silvicultural regime for growing radiata pine framing and concluded that, on other than nutrient-deficient sites, it was technically very difficult to do. He considered the alternative of fingerjointing 50 mm material obtained from the direct sawlog regime might give as good a result if not better.

-I have raised the issue of framing regimes for two reasons. First, it shows that we may have approached the problem from the wrong angle. Rather than severely constrain the diameter...
growth of our trees in the interests of keeping branch size down (in the interests of producing some reasonable framing timber), should we not be considering more direct approaches like Lockwood Homes Ltd — accept that we cannot have the benefits of large trees quickly without some large branches, examine means of neutralising, obscuring, or avoiding knot defects, or make a feature of them. Our dollars may be better spent in researching all possible means of reducing their effect, including lamination, overlays, component sawing, defecting, fingerjointing etc., than in trying to control upper crown branches by manipulating stand density.

Secondly, the Task Force survey of silvicultural regimes revealed that our objectives in many instances are woolly and therefore we are apt to fall between two stools. The constraint that wood supply commitments are placing on rotation age could lead to this happening for many of our stands. We need to be very clear about the potential values we have in our stands, if we are not to allow ourselves to be short-changed. If a rotation is cut short well before the mean target tree has been attained, the return on the money invested in silvicultural treatment with a view to upgrading the quality of the crop trees may amount to naught. It is our responsibility to ensure this does not happen.

OBTAINING MAXIMUM VALUE

If we alter the value of the crop or part of the crop by silvicultural treatment, it is the manager's responsibility to ensure that the added value is realised and that the owner obtains the benefit. The situation for the future stands will be different from the one we have at present. The consistent characteristics of the old crop, the way we have sold it, the surplus supply, and the rather narrow spread of value between products have not encouraged our industry to segregate its material into other than the broadest product classes and/or convenient size classes to handle. The attitude generally throughout the industry has been to maximise throughput at the least possible cost, rather than to sort for value. Before you can do so, you must know with certainty that the value is there in the log for the purpose for which it is to be used. We have not had means for reliably doing this before, so few well-established gradients for size and quality exist. The large price differential and established specifications for export logs to Japan have been an exception, and have provided an opportunity to test methods that focus on "maximum value recovery" rather
than “minimum wood cost”. Elements of a suitable value management package to do this were:

- A preharvest inventory of recoverable volume by log types to establish exactly what the stand contains.
- Matching the forest potential to market demands and product values by computer analysis of alternative cross-cutting patterns.
- Selection of the best log mix to maximise return to the forest.
- Clear precise instructions to the logging gang about the log-marking strategy they are to adopt.
- Generous incentives so that the logging gang benefits from applying the cutting strategy.
- Adoption of felling techniques that will minimise stem breakage.
- A value audit of the logs produced to ensure instructions are understood and mistakes minimised.

A pilot investigation indicated that up to 25% of the potential value of the crop, in this case a mature stand, could be lost through an inappropriate cutting strategy being used. The exercise highlighted the need for a rigorous examination of log segregation and allocation opportunities.

It is the forest owner's responsibility to establish the values his crops possess, to define log types or log grades that operators can readily recognise, and to institute systems and incentives that will ensure the stands are harvested, segregated, and allocated to best advantage. Forest owners have not found it necessary to do much in this line before, but as values for different parts of tended trees widen and are allocated for different products, it will become an increasingly important aspect of their management.

COSTS OF PRODUCTION

A large expanding industry which has several options open to it and in which the public has a stake must be fully aware of all elements of its costs of production, how the various cost elements are interrelated, and how they are influenced by its management decisions. Constantly updated cost-of-production schedules published for selected forests would provide a valuable basis for evaluating options and would clearly demonstrate to the government that growing plantations is expensive.

We must dispel the widely held view that our pine forests are cheap. Because we have to cover the compounded costs of planting and tending, the costs of production of our raw material are high relative to what some competitors are paying for pulpwood
and chips, and there is still a lot of wood that is suitable for these purposes in the world's forests. However, large coniferous logs containing defect-free timber are a very rapidly diminishing world resource (Sutton, 1975) and one sustainable competitive advantage we have is that we can grow that class of log for very little more than the cost of growing smaller knotty logs.

**OPPORTUNITIES FOR SPECIALISATION**

Sir James Doig, speaking on the future development of the forest industry at the 1969 Forestry Development Conference, emphasised that, if a country with only 3½ million people was to succeed in becoming part of a much wider trading community, it had to specialise and become expert in its field of specialisation (Doig, 1969). The vital questions are to pick the right industries and the particular types of processing that best fit the nature of the raw material available and the foreseeable world markets.

The forest industry has already been chosen: it has been selected by the fact that we have established the forests. Our responsibility is to select the best marketing and processing options for the future resource. The order in which I have placed marketing and processing is deliberate. First we have to define the market opportunities where we have a sustainable competitive advantage and then thoroughly evaluate the processing options *before* entering into long-term wood supply commitments. Because our forests provide a sustainable raw material with good general-purpose qualities, and because by world standards we can grow forests efficiently, our forest industry has a sustainable competitive advantage if we select the right options. As I see it, that is what this conference is about.

In the preceding section, I have endeavoured to outline the qualities of the present and future resource, indicate how those qualities will change, define what qualities we should select for, and identify how we could improve our performance and become more expert in managing our forests to ensure that the raw material resource has the qualities we want. Assuming we succeed, what opportunities exist for specialisation within our industry that would take advantage of the properties and qualities of raw material we shall be producing from the 1990s onwards?

*The Pulping Industry*

I separate pulping from papermaking, as the former is essentially a primary conversion process like sawing. It is a mass-producer concerned with converting wood to fibre. To be competitive in selling its product (pulp) on world markets it re-
quires cheap raw material. Present stumpages clearly demonstrate that we cannot afford to grow forests solely for pulp — they would need to increase threefold to cover our costs of production on the best pulpwood regime we have devised. Our planning, therefore, should be on the basis that the pulp mills or chip mills get material that is incidental to or a residue from some other process. I can recall A. R. Entrican stressing that the only way we could provide pulp mills with the cheap raw material they need is to attach it to a more valuable product that can carry the bulk of the harvesting and transport cost. If this viewpoint is accepted, the types of raw material our pulp mills can expect in future are top logs, forest arisings, slabwood from sawmills, and chip and sawdust residues from other wood utilisation plants. These materials will still provide a reasonable blend of thick and thin, long and short fibres suitable for a wide range of papers. If the industry can develop better means of segregating chip inputs or separating the pulp into fibre classes, there are opportunities for producing special-quality pulps which have specific high-value papermaking qualities.

From the raw material viewpoint, the best opportunities for kraft pulping occur where we shall have large concentrations of reasonably dense wood. Expansion of the existing industry at present locations, where large volumes of lower density top-log chips can be blended with slabwood chips, would be logical and it would make good sense to locate future sawmills near existing kraft mills to provide the slabwood the kraft mills need. Northland is the next best prospect for a kraft mill because the wood produced there has higher basic density than elsewhere in New Zealand.

Efficient production of liquid fuels from wood would also require a large concentration of mill and forest residues as its raw material base so the production of ethanol or methanol will need to be thoroughly evaluated as an additional or as an alternative option to expanding pulping in the Rotorua-Taupo-Tokoroa triangle.

The lower density young wood coming on-stream from new forests in new localities from Hawke's Bay southwards is intrinsically more suitable for mechanical pulps than chemical pulps. For all these regions, the level of supply becoming available and the time it becomes available are obviously the major considerations but, within those constraints, we should thoroughly evaluate how the qualities of the raw material affect the qualities of the pulps produced by alternative mechanical, thermo-
mechanical or chemi-thermo-mechanical processes. Pulps made from low-density wood have some papermaking qualities which might favour the establishment of specialist papermaking industries in the southern Conservancies.

**Veneer and Plywood Industries**

Fenton (1972b) in reviewing the implications of his series of profitability studies drew attention to the under-developed potential that existed for veneer and plywood, and van Wyk (1979) put forward the case for plywood as a viable product when sufficient well-pruned logs (of adequate size) become available. Plywood is an established item of international trade, it travels well, world demand in the 1990s is likely to exceed supply, and we can produce a good product. Unfortunately, because of belated pruning and inadequate thinning, the availability of pruned logs for rotary peeling will remain a major constraint in the short term. If we fell all our belatedly tended replacement stands at age 28-35 years to meet our wood supply commitments to existing industries after the old crop cuts out, the supply of pruned peeler logs might continue to constrain the expansion of a promising industry producing a high-value exportable product. A reasonable proportion of clear or near-clear veneer is required if the plywood industry is to produce an internationally competitive product. Serious consideration must be given to this opportunity in the forward planning for the utilisation of our tended forests, because it may require that we extend the rotation of selected stands.

A veneer option for smaller pruned logs that has not been adequately explored is slicing. I have seen a Tasmanian mill slicing small pruned radiata logs through and through, producing a very acceptable and readily salable product. They had bought their slicer in New Zealand! It is one possible opportunity for salvaging some of that belated silviculture that should be explored.

**Sawmilling and Timber Industries**

Our radiata pine stands are being managed to produce sawlogs and veneer logs as their primary product and there seems no valid reason why the forestry sector should depart radically from this strategy. However, as has been pointed out in the preceding sections, the future stands will be producing smaller logs with different characteristics and with a much wider range in value than at present. If we are to be efficient users, the differences in the value of log types must be identified in the
forest before the stands are felled, the high-value material must be segregated, and particular log classes must be allocated to sawmills that are appropriately equipped to saw, season, and market them properly. Better appreciation of different log values leading to better segregation I see as being a key feature; log segregation is the grower's responsibility because he is selling the wood. Farmers draft their sheep prior to selling so why do not foresters identify and segregate their log types so that sawmillers know what they are bidding for? Too often in the past we have left it to the sawmiller to assess the qualities of the stands we sell.

Because the old crop has produced large logs with predictable grade outturns for given sawing patterns, our sawmills have become large production-oriented units. Mills of this type will not be the most efficient units for cutting the high-quality pruned logs which will require special sawing methods for obtaining optimum production of clears. Smaller more flexible mills which can taper saw and afford to turn the log as needed are more suitable for such quality maximisation. The technology is known and mills of this type exist in the south-eastern United States. As a very large proportion of clears used by the furniture industry are in short lengths, opportunities exist for designing small sawmills that are specially equipped to saw short clears from second-log internodes (J. D. van Wyk, pers. comm.). The longest internodes in radiata pine usually occur in the second log and it would not be difficult to select trees that have this characteristic. Short clears produced in this way would supplement the restricted volume of long length clears produced from pruned butt logs and would be one solution to any restriction imposed by the large knots of second logs. In addition, the industry should now be looking for profitable export markets for large-dimension knotty timber produced initially from the old crop but ultimately from second and third logs; items like treated sleepers have been suggested.

The technology for neutralising, obscuring, and defecting radiata pine has already been well developed by firms specialising in lamination, overlay, fingerjointing, and end-matching. There will be continuing scope for their initiative and enterprise. The same applies to firms specialising in precutting, prefabrication, and modular construction, all useful means of reducing the significance of scattered defects. Distortion during seasoning of low-density material cut from corewood near the pith is liable to cause problems if the industry does not introduce new methods of drying or improve its drying standards. A visit across the Tasman
to see how some Australian sawmillers are drying low-density corewood material of radiata and Caribbean pine might be informative for those concerned with marketing this class of wood.

Export Logs and Roundwood

The export of logs has a very favourable export-income/import-expenditure ratio and it has been one of the few markets where the grower has received a good profit from trees. Although it fluctuates, the export market is likely to remain large and profitable. Fenton (1972a) put forward a "minimum-tending" silvicultural regime suitable for growing export logs which from his analyses was the most profitable management option. It makes more sense to be adopting a short-rotation export log regime (which maximises the production of export log lengths in the shortest time) for unpruned stands than to opt for higher-stocked framing regimes which have the vague objective of controlling branch size (but do not necessarily succeed). It would be a sound move to budget for the first sales from all suitably located new forests to be export log sales and to treat the first plantings on export log regimes. It would be the quickest way of generating income for the forest, reduce expenditure on silvicultural treatment when the forest was not earning income, establish the true market price for wood in the district, avoid the mill wood waste problem where there were no chipwood outlets, and enable the establishment of a locally based industry to be delayed until a large output of good logs based on clearfellings could be assured. All too often new mills in new localities have had to subsist on a diet of thinnings, virtually ensuring that both the forest and the mill will be losers. There is nothing disloyal or "un-New-Zealand" in advocating the continuation of the export log trade if it is highly profitable and suits the circumstances. It is an excellent stand-by market to have on tap to cope with the occasional disaster or mistake.

Rot is an international phenomenon, especially so in tropical and subtropical countries, and New Zealand must have one of the most technically efficient, well-organised, timber-preservation industries in the Pacific region. The round wooden pole or member is a simple constructional unit, so one could reason that there might be an unexploited opportunity for the export of treated roundwood. It may need to be a package deal linked to some form of construction that requires treated roundwood. Our forests should have sufficient small roundwood to satisfy the anticipated demand if the importing authorities are not too unreason-
able about strength requirements and standards of straightness and taper.

Management of our Forests

I have already touched on some modifications to our management that would be desirable if we are to exploit some of the opportunities outlined above but they will bear reiteration. The evidence I have presented endorses the present policy of aiming for peeler/sawlog production as our principal target but it has revealed we must become more expert in implementing our silviculture to attain that objective. We are at the threshold of having suitable tools for monitoring how well we have applied our prescriptions, and of predicting the likely grade outturn we shall achieve, both for timely treated stands and belatedly treated stands. Some steps I foresee we need to take immediately are to:

- Disseminate our predictive tools to forest growers as soon as they have been adequately validated.
- Implement an efficient stand record system as soon as possible so that pertinent stand data and treatment histories can be extracted.
- Identify all well-pruned “middle-aged” stands with a view to prescribing a suitable treatment and rotation for them that will ensure a worthwhile clearwood yield as peeler logs or sawlogs. Treatment prescriptions should include consideration of further thinning and fertiliser treatment as a means of improving the diameter increment of the final-crop trees.
- Explore possible ways (commencing with slicing) of utilising small pruned trees that have a shallow clearwood sheath over an intergrown knotty core that could ensure some benefit and value are obtained from the pruning.
- Carry out a preharvest inventory and determine the grade index of all tended stands before they are scheduled for felling, to determine whether it might not be a better option to production thin with a view to growing on the best crop trees to a dimension that will provide reasonable returns of clearwood.
- Explore the prospects of component sawing from unpruned logs, and research means of converting pruned logs for maximum value recovery.
- Review critically all unpruned silvicultural regimes with a view to clarifying objectives, validating likely grade outturn, and determining the best future management strategy for unpruned stands.
The object of these measures would be to provide an adequate clearwood resource from our silviculturally treated stands for establishing and sustaining viable export markets for clear radiata pine products. It requires that we take every opportunity to exploit radiata pine’s fast diameter growth rather than restrict its radial growth rate by retaining unnecessarily high final-crop stockings. It may mean we have to come to terms with the “big second-log branch”, accepting it as a necessary evil until means of eliminating or reducing its effect are developed. It is doubtful that we have any sustainable competitive advantage on international markets for growing radiata pine on pulpwood or framing regime prescriptions, so proposals to manage stands on these bases should in future be accompanied by a value outturn forecast and detailed cost-of-production analysis (as has been done for the peeler/sawlog and export log regimes). Without such scrutiny, they could become a convenient excuse for doing as little as possible. Radiata pine afforestation in New Zealand has the capacity to be profitable in its own right and we should be taking all possible measures to ensure it is.

CONCLUSIONS

The nature of the present old-crop resource upon which the exotic forest industry has been established has been briefly reviewed and the main characteristics of the replacement crops defined. Reducing rotation age to 28-30 years, as has been proposed in the National Planning Model, will have a marked impact on the intrinsic and timber qualities of the future resource and the grade enhancement likely to be obtained from present silvicultural prescriptions is likely to be marginal. There is thus an urgent need to review our silvicultural regimes, with a view to capitalising more on radiata pine’s fast diameter growth rate so that we can supply an export-oriented sawmilling and plywood industry with adequate quantities of clear timber or veneer for them to be economically viable.

Although the marked change in log size and type will increase wood costs and cause some disruptions to established plants, the industry is sufficiently vigorous and diversified to meet the challenges posed by the changed nature of the raw material. The fact that it will be different, and that we are going to have increased quantities to export, will require that we match the nature of our future industries to the nature of the future resource. It will require that we specialise more and that we become expert in our fields of specialisation, including forest management. Being fore-
warned is being forearmed, and there are ample opportunities and scope for the industry to adjust and develop in ways that would enable it to utilise to good advantage the additional volumes becoming available for export towards the turn of the century.

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