# Review of sustainable sawlog yield :

## Midlands Forest Management Area

Department of Conservation and Natural Resources
Victoria

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# FOREWORD

This report was prepared in response to the requirement of the *Forests Act 1958*, that the sustainable sawlog yield rate of each Forest Management Area (FMA) be reviewed at least once every five years from 1 July 1991.

It was prepared at the same time as the Proposed Forest Management Plan for the Midlands FMA was being finalised. In determining a revised sustainable yield, it therefore takes into account not only new information and analyses about forest growth and yield, but information about the area of forest which should remain available for timber production once important soil, water, flora, fauna and cultural heritage conservation issues have been addressed.

This report and the Proposed Plan have been released together because they have strong links. Sensitivity analyses indicate that minor changes to the land base available for timber production as identified in the Proposed Plan would not require adjustment of the revised sustainable yield. However, major changes would probably require an adjustment, and for this reason the sustainable yield to be incorporated in legislation will not be determined until the Plan is completed.

The revised sustainable yield identified in this report is predicated on a significant program of regrowth management. From 1996-97, approximately $300 000 per year will be available to implement this program.

Over the last year or so a number of exaggerated claims have been made that there has been significant overcutting in the Wombat forest. This report proves that those claims were incorrect, and were based on a lack of understanding of the dynamics of forest growth. While a downward adjustment of sustainable yield will be required, for a range of reasons identified in the report, the reality is that the Midlands' forests will continue to provide a significant and sustainable resource for the region's timber industry.

Richard Rawson
Director, Forests Service

# SUMMARY

The Department of Conservation and Natural Resources (CNR) has reviewed the sustainable sawlog yield rate for the Midlands Forest Management Area (FMA) in conjunction with the development of a Forest Management Plan (FM Plan).

The major elements of the review included:

- Remapping of species composition, management history, age, height and density of eucalypt stands in the State forests.
- Measurement of 467 continuous forest inventory (CFI) plots and temporary sample plots.
- Utilisation studies to compare assessed timber volumes with harvestable timber volumes.
- Extensive analysis of the CFI plot data and the development of growth models for a number of forest management options.
- Forecasts of sustainable yield under a number of management options using CNR's Integrated Forest Planning System, a linear-program based forest modelling system incorporating the FORPLAN system.

An independent evaluation of the methods used in preparing the sustainable yield forecasts concluded that they were appropriate and consistent with best international practice.

The significant outcomes of the review are:

- A recommended sustainable sawlog yield rate, for A, B, C and D grade sawlogs combined, of 58 000 $m^3$ per year compared with the current legislated sustainable yield rate of 70 000 $m^3$ per year for A, B and C grade sawlogs combined. The volume of residual logs and pulpwood available under this level of sawlog output would be 91 000 $m^3$ per year.
- On medium and high productivity sites, use of Shelterwood silviculture in the Wombat forest is a better option than the use of Seed-tree, Clearfelling or Selection silviculture, contributing 3600 $m^3$ per year more to the sustainable yield of 58 000 $m^3$ per year than the next best option.
- A significant increase in sawlog growth rates can be expected on medium and high productivity sites in the Wombat forest following thinning of regrowth at age 10 to 15 years, and a subsequent thinning at age 30 to 50 years. The introduction of such a thinning program would contribute 6900 $m^3$ per year to the sustainable yield rate of 58 000 $m^3$ per year.

- The major reasons for the revised sustainable sawlog yield rate include:

  - changes to the area available for sawlog production as a result of Government land use decisions
  - more accurate estimates of long-term growth rates across the FMA
  - availability and use of more sophisticated tools and modelling techniques which use longer planning horizons, and which recognise the differences between a far greater number of individual forest stands
  - changes in forest structure since 1984, particularly as a consequence of the extensive 1983 wildfire at East Trentham
  - introduction of State-wide sawlog grading standards in 1988
  - sawlog harvesting above the long-term growth rate, as established by this review, since 1984
  - introduction, through the Midlands FM Plan, of a forest management zoning scheme and constraints on harvesting in some domestic water supply catchments.

The revised sustainable sawlog yield rate provides for the probable impact of wildfire on future sawlog growth and is based primarily upon:

- implementation of a young regrowth management program on medium and high productivity sites in the Wombat forest
- continuation of Shelterwood silviculture on medium and high productivity sites in the Wombat forest
- re-treatment of understocked areas in the Wombat forest
- protection of regional biodiversity, domestic water supply catchments and Powerful Owl habitat.

# CONTENTS

# 1 INTRODUCTION

The *Forests Act 1958* requires a review of sustainable sawlog yield rates in each five-year period from 1 July 1991, and this report establishes the sustainable sawlog yield rate which should apply to State forests in the Midlands Forest Management Area (FMA) from 1 July 1996.

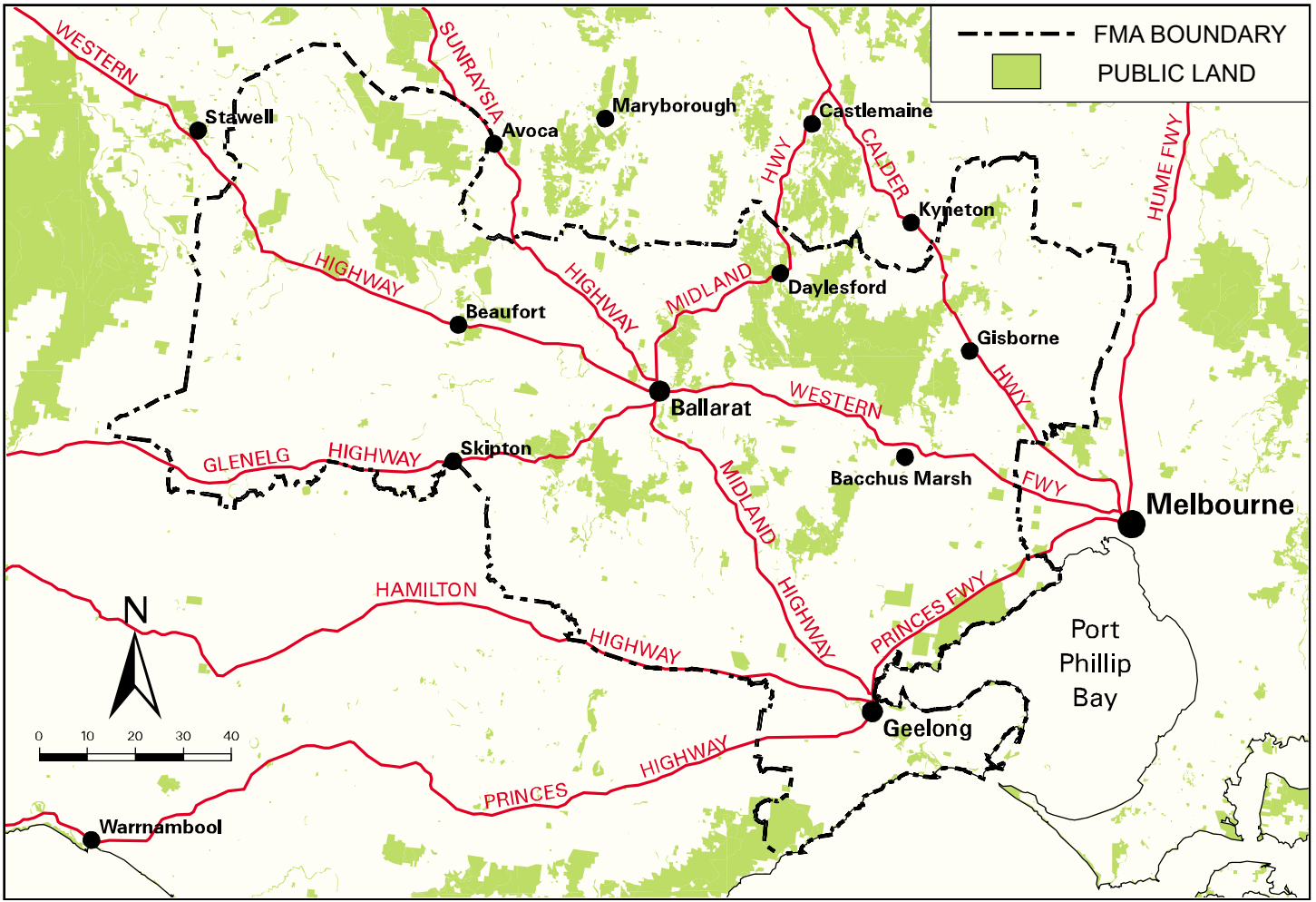
The FMA occupies the central-west part of the State of Victoria and includes the major centres of Ballarat, Ararat, Beaufort, Daylesford and Geelong (Figure 1). It includes the Wombat forest and significant forests at Mount Cole, the Pyrenees, Enfield and the Cobaws. It is one of the 15 areas into which Victoria was divided in 1986 for the purposes of planning the management and utilisation of public native forests.

The review process described in this report was based upon a considerable amount of new information about the land base available for timber production in the Midlands forests, the composition, structure and growth rates of those forests capable of producing sawlogs, and the silvicultural practices which provide optimum conditions for sawlog production.

The process was assisted by the availability of sophisticated computer-based systems capable of completing comprehensive data analyses, and detailed predictions of forest growth and yield.

Figure 1

# MIDLANDS FOREST MANAGEMENT AREA



# 2 FORESTS OF THE AREA

## 2.1 Regional importance

The forests and woodlands of the Midlands, being remnants of much more extensive native vegetation, are particularly important for preserving regional biodiversity. They also contribute significantly to the regional and State economies, and to the protection of water supply catchments for many towns and cities.

The timber industry in the Midlands estimates that it contributes about $30m per year to the region's economy, providing direct employment for more than 450 persons. The sawmills produce about eight per cent of the State's hardwood timber output.

## 2.2 Forest types

Prior to European settlement, the vegetation comprised extensive tall open forests in the higher rainfall areas, woodlands and open forests on the drier foothills and sedimentary plains, and extensive grasslands and open woodlands on the basalt plains in the south.

Much of the original forest cover has been cleared or modified for agricultural and urban uses. The remaining forests and woodlands are generally in the northern part of the FMA, with most of the larger forests straddling the higher rainfall areas on the Great Dividing Range.

The major timber producing species are Messmate Stringybark and Narrow-leaf Peppermint. Others are Broad-leaved Peppermint, Manna Gum, Blue Gum and Candlebark. Appendix 1 provides a description of the forest types within the FMA and indicates their comparative extent.

## 2.3 The State forests

The Midlands FMA includes the Wombat, Mount Cole, Pyrenees, Enfield and Cobaw State forests, and a number of smaller forests.

Timber cutting increased suddenly in 1851 and gathered momentum swiftly as gold mining boomed in several districts. Heavy exploitation continued until the turn of the century. It was not until 1919 that rehabilitation of the cut-over forests was undertaken. Extensive areas of the regrowth stands were thinned during the 1930s. In 1940 timber output was increased to meet demands created by the war, but it was not until the late 1940s that the Mount Cole State Forest was re-opened for timber harvesting.

Selective harvesting of sawlog trees continued generally into the 1960s. In the 1970s Selective harvesting at Mount Cole was abandoned in favour of Clearfelling, and development of Shelterwood silviculture began in the Wombat State Forest.

In 1986 timber harvesting within regional sustainable sawlog yields was introduced for all State forests, and in 1990 these regional limits to sawlog output were prescribed in legislation. For the Midlands FMA, this figure was set at 70 000 m³ of A, B and C grade (C+) sawlogs per year.

Despite improving fire protection, there were many wildfires in the 1950s and major ones in 1962 (at Barkstead), 1983 (East Trentham) and 1995 (Enfield).

A chronology of major events which have influenced the structure and growth of the forests since 1850 is given in Appendix 2.

## 2.4 Current timber production

Twelve sawmills and two residual log and pulpwood conversion centres, located in and around Ballarat, Beaufort, Creswick, Daylesford, Woodend, Bacchus Marsh and Geelong, process hardwood harvested in the FMA.

Current licences for hardwood sawlogs total 70 400 m³ of A, B, C and D grade (D+) sawlogs per year. During the period 1989-90 to 1993-94 the average annual harvest of these sawlog grades was 60 600 m³. Definitions of sawlog grades are provided in Appendix 3.

A hardboard plant owned by CSR Limited commenced production at Bacchus Marsh in 1961. The provisions of the *Forests (Pulpwood Agreement) Act 1959* entitle the company to 70 000 tonnes (approximately 62 300 m³) of pulpwood per year. Supply of this material has been met largely from the Wombat State Forest.

Residual logs are also available under licence and the combined supply of pulpwood and residual logs from the FMA between 1989-90 and 1993-94 averaged 68 000 m³ per year. In 1994-95 the total volume reached about 97 700 m³.

The Midlands forests are important sources of firewood. In 1994 about 25 000 m³ of firewood was cut in State forest, mostly for local use.

# 3 LAND BASE FOR TIMBER PRODUCTION

The land base which remains available for timber production, and is suitable for this activity, is determined by a number of strategic planning, legislative and environmental considerations. The impacts of these factors in the Midlands FMA are described below.

## 3.1 Land use and management planning

Since 1971, Government decisions on public land use have been based largely on recommendations of the Land Conservation Council (LCC). Recommendations which apply to the Midlands FMA have been published during the period 1977 to 1991 (LCC 1977, 1981, 1982a, 1982b, 1987, 1991).

The Wombat, Mount Cole, Pyrenees, Enfield and Cobaw State forests, and a number of smaller forests, are the forests to which the sustainable yield rate recommended in this report applies. In all, they occupy 114 300 ha (half of the public land in the area - see Figure 2).

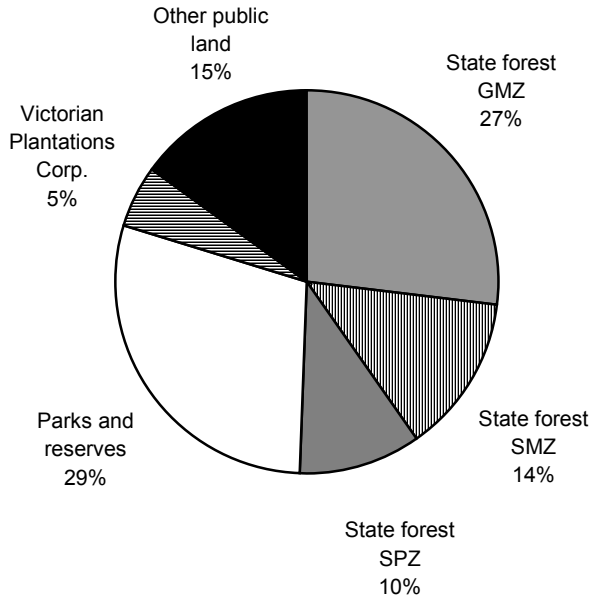
State forest is managed for a range of objectives, including the production of timber. The Proposed Midlands Forest Management Plan (FM Plan) contains detailed information about how the State forests will be managed, and strategies pertinent to this review. The uses of State forest are prescribed for three zones that indicate the special conservation and timber production priorities in different areas of forest. The impacts of this zoning have been taken into account in completing this review.

Zoning incorporates and builds on those areas excluded from timber harvesting by the *Code of Forest Practices for Timber Production* (see Section 3.2) and the provisions of the *Flora and Fauna Guarantee Act* 1988 (Section 3.3). The identification of these zones and the objectives of forest management in them are dealt with in detail in the FM Plan, but a brief description of each follows.

- Special Protection Zone (SPZ), in which conservation of natural values sensitive to disturbance has the highest priority and timber harvesting is excluded
- Special Management Zone (SMZ), in which conservation of a specific feature has a high priority that can be achieved with modified timber production practices
- General Management Zone (GMZ), which is managed for a range of uses but in which timber production has a high priority, with conservation of natural values being a secondary aim.

Figure 2 shows the extent of the broad categories of public land use and of the proposed zoning of State forest in the FMA.

**Figure 2: Public land in the Midlands FMA**




**Note:** 'Other public land' includes the Werribee sewage farm, the Anglesea coal lease area, and land managed by water-supply authorities.

## 3.2 Forest practices

Victoria's *Code of Forest Practices for Timber Production* (CFL 1989) establishes the principles and minimum standards for the conduct of all timber production activities, primarily to protect environmental values. The Code and associated planning procedures protect soil, water, wildlife habitat and rainforest, and exclude some areas of State forest from being harvested for timber.

## 3.3 Flora and fauna

Victoria's *Flora and Fauna Guarantee Act 1988* establishes a framework for protecting the habitats of rare and threatened flora and fauna. Action statements are prepared which identify the processes which threaten a species or community, and the management actions that are required to protect them. These may either modify timber harvesting practices or exclude harvesting in some areas of forest. The requirements of the Act have been taken into account in preparing the FM Plan.

## 3.4 Area for timber production

Within the GMZ and SMZ, only those areas generally capable of growing trees to a height greater than 24 m at maturity are considered to be suitable for growing sawlogs on a sustainable basis. These areas have been mapped, as described in Section 4.

The GMZ is divided into a Timber Production Sub-Zone, which is capable of growing sawlogs on a sustainable basis, and an Other Uses Sub-Zone, for which general conservation and a low level of firewood production are the major management objectives. The SMZ also contributes to the sustainable yield of sawlogs.

The net area of State forest available and suitable for sustainable sawlog production (net productive area) in the Midlands FMA is 50 450 ha. This figure takes into account:

- requirements of the *Code of Forest Practices for Timber Production*
- requirements of action statements under the *Flora and Fauna Guarantee Act* 1988
- the Forest Management Zones proposed in the FM Plan
- revised mapping of those areas capable of producing sawlogs, namely, those in which mature trees grow to heights greater than 24 m.

# 4 TIMBER RESOURCE

Sawlog volumes have been determined from mapping and stratification of State forest, measurement of sample plots in productive forest areas and the results of utilisation studies conducted in mature forests.

## 4.1 Forest mapping and stratification

Tree species, stand densities and height classes of much of the State forest have been re-mapped. In addition, all maps have been updated to 1 July 1994 to show timber utilisation and fire history.

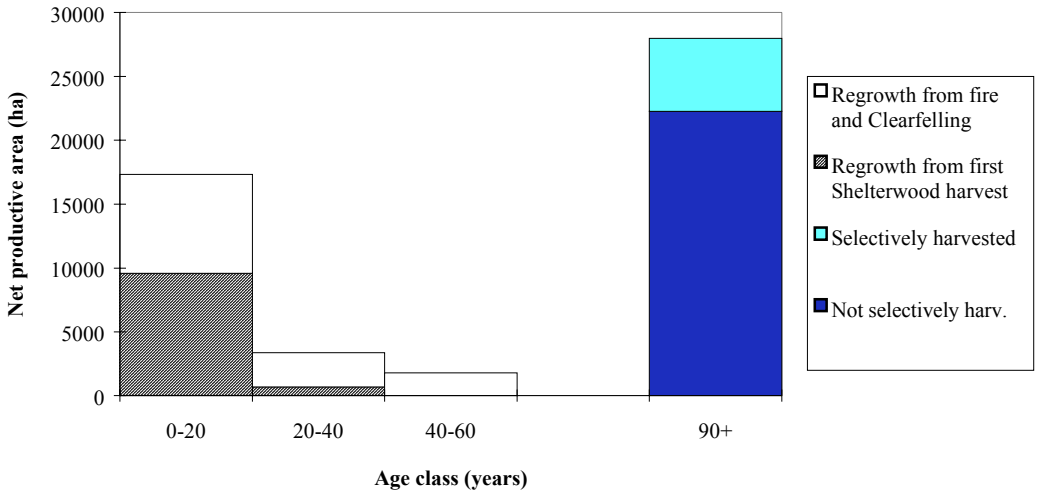
Information interpreted from aerial photographs was verified in the forest. Line work from the photographs was transferred to base maps and then digitised into the Department of Conservation and Natural Resources' (CNR) computerised Geographic Information System (GIS). Information on fire and harvesting history, and the year of origin for regrowth, was then added.

GIS was then used to stratify the map data and to define areas of common forest type, productivity class, utilisation history and age class. The major 1962 and 1983 fire areas in the Wombat State Forest have been identified as separate strata, as the condition of the forest stands in these areas is quite distinct. This stratification provided the basis for forecasts of sustainable sawlog yield.

Appendix 1 describes the stratification of the forests by forest type. Messmate Stringybark/Peppermint/Gum Open Forest is the most extensive forest type in the FMA (59% of public land) and contributes the bulk of the sustainable yield of sawlogs.

Figure 3 shows the distribution of age classes in the net productive area and the history of management of the forests within each age class. A key issue for the future management of the Midlands forests is the need to redress the current imbalance of age classes, which display a predominance of mature forest and young regrowth.

**Figure 3: Age-class distribution and history of management of the Midlands forests**




## 4.2 Forest sampling

Permanent Continuous Forest Inventory (CFI) sample plots were established in the 1960s in the Mount Cole and Wombat State forests. These plots have provided a number of systematic measurements of timber volumes and growth since that time. They are some of the oldest of their type in Australia, and they have proved to be very valuable in monitoring forest growth.

A total of 467 plots was measured to provide data from which present log volumes and periodic annual increments (PAI) could be derived. This total includes an additional 63 CFI plots and 58 temporary plots which were established to provide better sampling of the younger regrowth and the lower-yielding areas of the forest. Species, diameter and lengths of sawlog and residual log in each tree on the plots were recorded.

## 4.3 Assessed and harvestable sawlog volumes

When trees are felled, the volume of sawlogs that can be obtained from the area (harvestable volume) is usually different from the volume that was estimated by assessment of the standing trees. The principal reason is that an assessment cannot determine accurately the impact of internal defect on sawlog volume.

Utilisation studies were carried out for the purposes of this review to determine the relationship between assessed and harvestable sawlog volume.

For these studies, 58 temporary plots were established and the sawlogs in them assessed to both the 1960s standard and the State-wide sawlog standard introduced in 1988. The trees on 22 of these plots were then felled and the sawlogs measured to establish the harvestable volume.

It was necessary to take into account the difference between the 1960s sawlog standard and the State-wide standard because the use of different standards at each remeasure would mean that successive inventories would not be comparable, and estimates of rates of growth would be inaccurate.

Analysis showed:

- the sawlog volume assessed to the 1960s standard is 11 per cent more than the volume assessed to the State-wide standard
- the harvestable sawlog volume is 19 per cent less than the volume assessed to the State-wide sawlog standard (Appendix 4).

The combined effect is that the sawlog volumes assessed to the 1960s standard must be reduced by 27 per cent to obtain an estimate of D+ grade sawlogs harvestable under current sawlog and utilisation standards.

Current harvesting practices are consistent with the State-wide D+ grading of sawlogs although an estimated six per cent of harvestable sawlog volume was not used for these grades of log. However, this was offset somewhat by an additional four per cent in volume recovered from trees or parts of trees not previously considered to be suitable as sawlog.

The results of the recent utilisation studies are consistent with data collected from operational harvesting on more than 20 inventory plots over the past two years.

## 4.4 Current harvestable volume

The CFI data and the results from the utilisation studies were used to calculate the average sawlog yield per hectare for each productivity class in the mature forests. The net productive area of each class was then used to provide an estimate of current sawlog volume (Table 1). Residual log/pulpwood volumes were also determined from the CFI data. The productivity and management history of a forest determines the relative proportions of sawlog to residual log/pulpwood that may be harvested.

**Table 1: Current sawlog volume in the State forests of the Midlands FMA**

| Forests (Productivity class) | Net productive area (ha) | Estimated D+ grade sawlog volume ($m^3$) | Estimated residual log/pulpwood volume ($m^3$) |
|---|---|---|---|
| Wombat State Forest (Medium/High) | 26 140 | 1 340 000 | 2 100 000 |
| Wombat State Forest (Low) | 8 330 | 240 000 | 400 000 |
| Mount Cole State Forest | 4 550 | 148 000 | 200 000 |
| Other forests | 11 430 | 293 000 | 600 000 |
| TOTAL | 50 450 | 2 021 000 | 3 300 000 |
| 95% Confidence limit | | ±431 000 | |

**Note:** The 95% confidence limit represents ± 20% of the total sawlog volume estimate; no limit has been calculated for residual log/pulpwood.

# 5 GROWTH RATES

Knowledge of growth rates in the various types and ages of forest across the range of sites suitable for sawlog production, and how they respond to various management regimes, is essential for making sustainable yield forecasts. CFI plot data have been analysed extensively to determine appropriate growth rates.

## 5.1 Yield curves

A yield curve defines the volumes of logs available (in a particular forest type and productivity class) at different ages for a particular silvicultural regime.

A base yield curve for the Wombat forests was developed as follows.

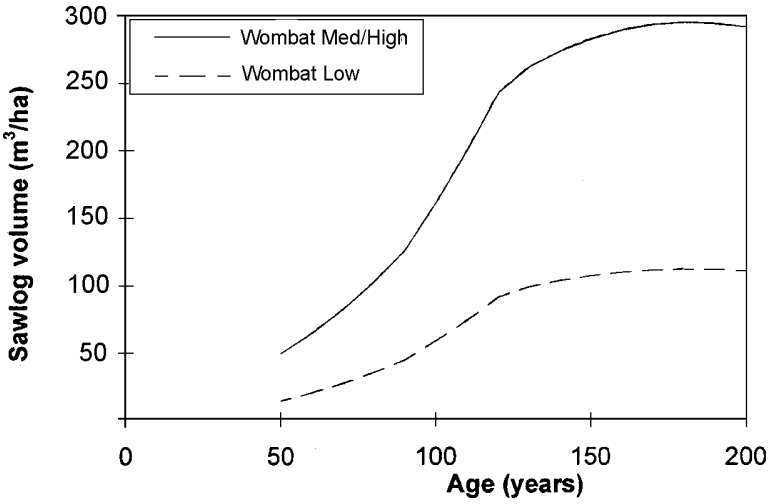
- From the Wombat forest CFI plots a sample was selected to represent stands on medium to high productivity sites with no history of harvesting in the past 35 years.
- The age of the forest on each plot was established from ring counts taken from recent stumps or trees felled outside the plot. Ages ranged from 67 to 104 years (this is less than the average age of the maturing forest which is estimated to be 105 years).
- For each time a plot had been re-measured since 1963, the mean annual increment (MAI) of D+ grade sawlog was plotted against age.
- Growth from ages 105 to 200 years was projected, based upon trends in PAI and MAI combined, because yield estimates were required for ages up to 200 years for the forecast of sustainable yield.

Many of these CFI plots have been thinned by past selective harvesting. Evidence from stumps indicates this occurred when the trees were approximately 30 and 60 years old. The thinning at 60 years in the medium to high productivity stands is estimated to have removed between 10 and 15 $m^3$/ha of D+ sawlog volume. The base yield curve incorporates this silvicultural regime.

Yield curves were then developed for other Midlands forests by adjusting the base yield curve to reflect the difference between the volume of D+ grade sawlog forecast by the base yield curve and the estimated standing volume of the other forests.

Figure 4 shows the base yield curve developed for the medium/high productivity sites and the scaled yield curve for low productivity sites in the Wombat State Forest.

**Figure 4: Yield curves for D+ grade sawlog volume in medium/high and low productivity stands in the Wombat State Forest**




**Note:** From age 105, the base curve is a projection based on trends in PAI and MAI combined.

Estimates of PAI from the base yield curve for medium/high productivity sites have been compared with the PAI between the last two measurements (in about 1975 and 1990) on the Wombat CFI plots. In general the estimates from the yield curve match the measurements from the CFI plots very closely.

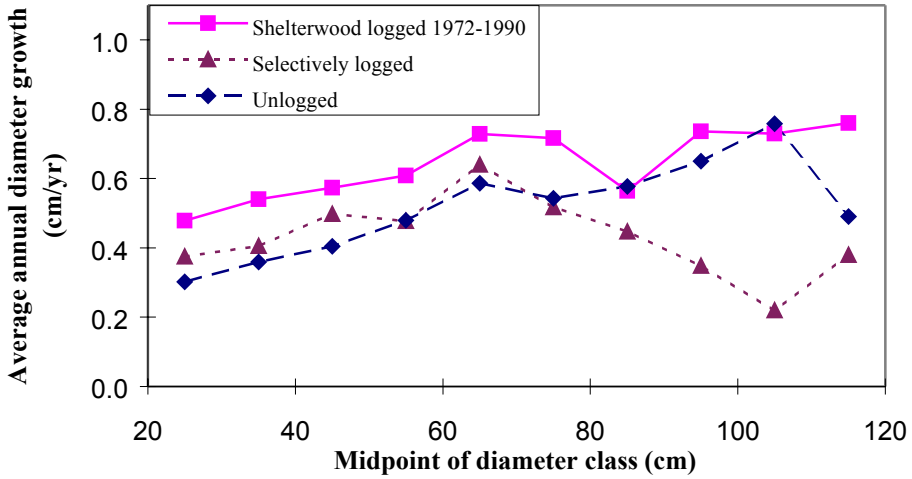
## 5.2 Growth following first Shelterwood cut

Two analyses were done to determine growth on retained trees following the first Shelterwood cut.

- The volume growth on 87 CFI plots which have had a first Shelterwood cut was compared with the predicted growth rate from the medium/high productivity yield curve (Figure 4) for unharvested stands of similar standing volume and age.

- From all CFI plots, the average annual diameter growth in diameter classes, for the period 1975 to 1990, was determined for the three silvicultural treatments that had been applied in the Wombat State Forest (see Figure 5). The basal area growth for the 40 to 80 cm diameter range was then determined for the three silvicultural treatments.

**Figure 5: Average diameter growth from 1975 to 1990 on Wombat State Forest CFI plots under three methods of silviculture**




Both analyses indicated a 30 per cent growth response from the Shelterwood treatment. Some of the indicated response may be due to variations in site quality between samples. This is not thought to be a significant factor, however, given the large sample size and that the two analyses give a similar result.

There are two main reasons for the growth response:

- the trees selected for retention were more vigorous and had higher growth rates than the stand average
- growth rates on the retained trees has increased because of reduced competition.

The magnitude of the increase in growth rates because of reduced competition is indicated by Kellas *et al* 1994 in analysis of CFI plot data from the Wombat State Forest. This analysis shows a 13 per cent increase in basal area growth on retained trees in the 40 to 70 cm diameter range following the first Shelterwood cut.

No analysis has been done to determine the magnitude of growth increase due to the first reason although it is probable that it is also in the order of approximately half of the total growth response.

For the purposes of the forecasts of sustainable yield, the yield from the second Shelterwood cuts incorporates the 30 per cent growth response.

## 5.3 Growth response to thinning

The potential response to thinning has been examined using the STANDSIM growth model (Incoll, 1983). Since STANDSIM does not have functions specific to the Midlands forests, the simulations used Silvertop Ash functions and the results were scaled to calibrate with the base yield curve.

Two silvicultural options were examined closely.

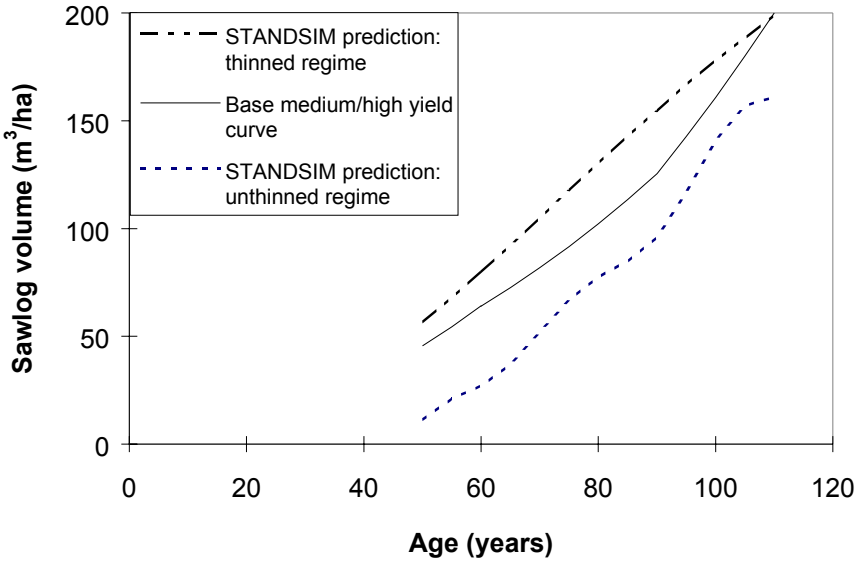
- no thinning
- an early, pre-commercial thinning at 10 to 15 years followed by a commercial thinning at 30 to 50 years.

These options were selected to study the potential of a young regrowth management program to increase sawlog yields. The program is based upon research done by the CSIRO in East Gippsland mixed-species forests. The impacts of these options were compared with the growth understood to have occurred under the silvicultural regime (current regime) applied to the forest up to now and indicated by the base yield curve.

The results of this examination are shown in Figure 6. Sawlog volume at 80 years can be increased by approximately 30 per cent compared to the current regime. This is consistent with work by the CSIRO (West, 1991), which showed that thinning increased sawlog yield of Mountain Ash by 42 per cent.

For use in the sustainable yield forecasts, the volume for the thinned regime was reduced by 10 per cent to account for variations likely to occur in applying the treatments at an operational scale. Such variations would include the impacts of regeneration delay and overwood suppression from the use of the Shelterwood system.

**Figure 6: D+ grade sawlog volume in the medium/high productivity forests in the Wombat State Forest, managed under three silvicultural regimes**



## 5.4 Culmination of mean annual increment

Since the CFI plots were established, the sawlog MAI has been increasing at a constant rate, with no significant indication of reaching a peak. When MAI is examined with PAI, the two trends indicate that culmination of MAI will, under the current silvicultural regime, occur near age 120 years.

It is known that culmination of MAI in slower-growing, mixed-species forests generally occurs later than in faster-growing ash forests. However, it is likely the culmination of MAI in this particular CFI plot sample has been delayed by the relatively late thinning at approximately 60 years.

It is expected that the early thinning regime proposed later in this report will result in culmination of the MAI much earlier than 120 years. However, to confirm this, extensive growth data from across the State needs to be gathered, and variable-density yield functions for mixed-species forests developed.

# 6 SILVICULTURE

Silviculture describes the series of tending operations applied to a forest to promote growth and obtain regeneration following harvesting.

Forest growth varies under different silvicultural regimes. The following sections describe the various options for obtaining regeneration, managing young regrowth and managing the mature stands and which were assessed for their impact on sustainable yield. Appendix 5 summarises and compares this information.

Sustainable yield forecasts must be based on the general application of silvicultural practices, under average forest conditions and assuming average responses in the forest types concerned.

## 6.1 Regeneration

The silvicultural systems used to obtain regeneration were analysed to determine their impacts on sustainable yield. In the Midlands forests, the aim is to establish approximately 2500 healthy seedlings per hectare two years after timber harvesting finishes (Squire *et al* 1991).

The silvicultural systems used to obtain regeneration in the Midlands FMA include:

- Shelterwood, which is applied to well-stocked stands on sites of medium and high site productivity in the Wombat State Forest. This system relies on natural seed-fall from the trees remaining after the first felling, after preparation of the site by burning or soil disturbance (Kellas *et al* 1994). Regeneration burning following the first Shelterwood cut in the Wombat State Forest is now delayed by one year to reduce the adverse impact of fire on retained trees. This results in a one-year regeneration delay. The impact of this has been determined and included in the forecasts of sustainable yield.
- Clearfelling, which is applied in the Mount Cole State Forest because of the presence of an indigenous root disease on many sites which often kills retained trees. This system relies on the collection of seed during harvesting operations, and manual or aerial sowing following site preparation.
- Seed-tree silviculture is applied to the low-productivity sites in the Wombat State Forest and other State forests in the FMA. This system relies on natural seed-fall from retained trees following site preparation by burning or soil disturbance.

A recent review by CNR (not yet published) of regeneration performance for the period 1989-90 to 1992-93 showed that 96 per cent of the harvested areas within the FMA were adequately regenerated at the first attempt. Shelterwood in the Wombat State Forest resulted in a success rate of 92 per cent on 9352 ha surveyed over the period 1976 to 1993 (Kellas *et al* 1994). This information has been used to estimate the area of forest that requires further regeneration treatment, and the impact of the delay in restocking these areas has been taken into account in the forecasts of sustainable yield.

## 6.2 Regrowth stands

The options for thinning regrowth stands, and removing competing mature trees which are not required for wildlife habitat, have been analysed to determine their impact on sustainable yield.

The benefits of thinning regrowth stands have long been recognised and much of the current mature crop has been thinned twice by selective harvesting. At present there is no regular thinning program, primarily because most of the stands are either mature, or comprise regeneration or very young regrowth after first Shelterwood fellings.

Regular second Shelterwood fellings commenced in the early 1990s, and it is timely for a regular young regrowth management program to be considered. CSIRO research (West, 1991), 1960s thinning trials on Mount Cole and STANDSIM analyses all indicate that sawlog growth rates can be significantly improved by thinning regrowth, and reducing competition by felling the remaining unmerchantable mature trees other than those identified as required for habitat purposes.

Current evidence indicates that young, post-harvesting, mixed-species regrowth on sites of medium and high productivity should be thinned to 800 to 1100 evenly-spaced trees per hectare at age 10 to 15 years, and to 250 to 300 trees per hectare at 30 to 50 years. The cost of the first (non-commercial) thinning depends on stand density, ease of access and treatment type. Second thinning would produce small logs suitable mainly for pulpwood. Studies show the first thinning cost can largely be offset from returns from the second thinning.

Over the period 1995 to 2015, 6300 ha are expected to be recruited into the 10 to 15 year age class, and an additional 7500 ha are already in that age class. It is estimated that about half of the area of this regrowth would benefit from early thinning and removal of the unmerchantable mature trees not required for wildlife habitat.

Sustainable yield has been forecast under three thinning schedules applied to stands on all medium and high productivity sites regenerated since 1980. Early thinning at 10 to 15 years was the only thinning considered feasible on sites where the root fungus disease occurs on Mount Cole. Early thinning was not considered economic on poor productivity sites. Table 2 summarises the silvicultural options, including thinning which were analysed for the sustainable yield forecasts.

In the early thinning option the full impact on sustainable yield is not realised until late in the 21st century at which time all mature stands on medium and high productivity sites will have been thinned. However, some benefit is available immediately because it is possible to schedule the final harvesting of thinned stands earlier, and to reschedule the harvesting of existing mature forests.

Regrowth following the 1962 wildfire near Barkstead and the 1983 wildfire near East Trentham has been treated separately in the sustainable yield forecasts. Regeneration following these fires was prolific in most areas and exhibits slow growth as a consequence of overstocking. Most of the 6230 hectares of net productive area of fire regrowth would benefit from thinning, fertilisation and overwood removal.

**Table 2: Silvicultural options for the management of regrowth**

| Forest | Stocking (No. of trees/ha) Age (years) | New regrowth | | | |
|---|---|---|---|---|---|
| | | Early thinning | Mid-age thinning | Late thinning | Final fellings |
| **Wombat State Forest - Medium and high productivity sites** | | | | | |
| a) Early thinning regime | Stocking<br>Age | 800-1100<br>10-15 | 250-300<br>30-50 | -<br>- | Shelterwood<br>70-100 |
| b) Current regime | Stocking<br>Age | -<br>- | 300-400<br>30-50 | 200-250<br>60-80 | Shelterwood<br>80-120 |
| c) Unthinned regime | Stocking<br>Age | -<br>- | -<br>- | -<br>- | Clearfelling<br>80-120 |
| **Wombat State Forest - Low productivity sites** | | | | | |
| Unthinned regime | Stocking<br>Age | -<br>- | -<br>- | | Seed-tree<br>80-120 |
| **Mount Cole State Forest** | | | | | |
| a) Early thinning regime | Stocking<br>Age | 800-1100<br>10-15 | -<br>- | -<br>- | Clearfelling<br>65-100 |
| b) Unthinned regime | Stocking<br>Age | -<br>- | -<br>- | -<br>- | Clearfelling<br>65-100 |
| **Other State forests** | | | | | |
| Unthinned regime | Stocking<br>Age | -<br>- | -<br>- | | Seed-tree<br>80-120 |

Two management options were considered in the sustainable yield forecasts based on the following assumptions:

- all fire regrowth has lost 10 years growth and will remain unthinned
- all fire regrowth has lost 10 years growth but can be put back on a normal growth trend by thinning and fertilising individual trees over the next 10 years.

The second option was incorporated in the sustainable yield forecasts.

On many sites in the FMA, fertilisation of individual crop trees is likely to improve their health and growth, particularly if applied during or immediately after early thinning. However, there are no research data from the Midlands mixed-species forests to indicate what the specific growth responses would be, how long they would last and what impact they would have on long-term sawlog growth. Hence, increase beyond the normal growth trend from the application of fertiliser has not been considered in the sustainable yield forecasts. However, trials have recently been established to investigate various thinning and fertilisation techniques and growth responses.

The impact of competition from habitat trees on the growth of regeneration and new stands has been incorporated into the base yield curve. It is important that the influence of habitat trees is minimised by grouping them and reserving no more than the number prescribed.

## 6.3 Mature stands

The options for managing mature stands were also analysed to determine their impact on sustainable yield.

Half of the net productive area of the Midlands FMA comprises medium and high productivity sites in the Wombat State Forest which, in turn, provide nearly three-quarters of the sustainable yield. Three silvicultural options were considered feasible on these sites, namely, Shelterwood, Clearfelling and Selection. Options for the balance of the FMA were considered limited and were not varied from those described in Table 2.

To provide even flows of sawlogs over the next century, the ages at which the current mature and regrowth stands will be harvested will vary considerably. Some of the existing mature forests will be up to 170 years of age when harvested, for instance, while some current stands of young regrowth treated under the early thinning option may be harvested at 65 years of age. Further research into the growth of mixed-species under various silvicultural treatments is required to guide decisions about optimum harvesting age towards the end of the 21st century.

**Shelterwood and Clearfelling**

Clearfelling results in the removal of all harvestable timber in one operation, with the exception of some timber left in trees retained for habitat purposes. Provision for this loss has been included in the forecast.

Shelterwood results in the removal of all harvestable timber in two operations. Current Shelterwood prescriptions provide for the retention of 7 to 9 square metres of basal area per hectare in better-formed well-spaced trees following the first operation. CFI plot data indicates that this equates to an average of about 34 cubic metres per hectare of D+ grade sawlogs.

CFI and yield model data indicate that the sawlog yield from the second operation will average approximately 47 cubic metres of D+ grade sawlogs per hectare, based on a 10-year period between operations. This is after allowance has been made for windthrow, mortality and additional lag defect following the first operation.

The forecast allows for a one-year longer regeneration period, because burning for site preparation purposes is delayed one year to avoid damage to retained trees.

No studies have been made of the impact on regeneration by mature trees before the second felling. For this review, some analysis was attempted to estimate what the likely range of the impact would be, and an allowance has been included in the forecast. Further, a 10-year period between operations was used in the forecast, instead of the 15 to 20 years currently applied. The assumptions will be tested during the period before the next review is due in 2001.

Shelterwood also results in a greater proportion of wood on high quality sawlogs. The proportion of B grade sawlog volume harvested in the second Shelterwood felling has been approximately double that harvested in the first Shelterwood felling (Kellas *et al* 1994).

**Selection**

Selection silviculture was tested on the basis of a 20-year cutting cycle and one-third basal area removal. It is not considered a viable option because it would not reliably establish and promote the growth of regeneration. Further, it would take a long period to change the Midlands forests to a predominantly un-evenaged structure.

# 7 IMPACT OF WILDFIRE

There has been a major wildfire in the Midlands in nearly every decade since 1950, and this has had a significant impact on stand structure and growth. Appendix 6 indicates the extent of fire-induced regrowth for each decade since the 1920s.

Two potential impacts of fire on sustainable yield were considered. First, a growth loss on burned areas until tree crowns are fully recovered and, second, in the case of a severe wildfire, an alteration to the age class structure of the forest when growing stock is killed or is fit only for salvage, and the burnt stand is replaced by regeneration.

As the yield curves are based upon data from forest which has had wildfires, no additional allowance has been included for growth loss. However, an allowance has been made for the impact of wildfire on forest structure. This was based on the annual probability of severe wildfire in each age and forest type, together with an estimate of how much wood could be salvaged.

Since 1920, approximately 6400 ha have been severely burnt by wildfire and salvaged. On this basis an average of 85 hectares of the net productive area will revert to regeneration each year (Appendix 6).

# 8 MANAGEMENT STRATEGIES

Forest management strategies govern the broad-scale and long-term management of State forest. Those that are specific to the forecast of sustainable yield for the Midlands FMA are as follows.

- **Protection of regional biodiversity.** The forecast excludes timber harvesting from all SPZs and takes into account harvesting constraints in SMZs as prescribed in the Midlands FM Plan.
- **Maintenance of domestic water supply catchments.** The FM Plan identifies a number of catchments where the water being supplied receives minimal treatment. It is believed that a level of management additional to that required under the Code of Forest Practices is warranted, and that the development of a relatively balanced age class distribution should be a priority. The constraint applied in the forecasts is that not more than 30 per cent of the catchment area should be less than 30 years of age at any one time. In addition, a general constraint of limiting harvesting within any 10-year period to within 50 per cent of long-term average harvesting levels was applied to Mount Cole, and other smaller State forests, to protect catchment values.
- **Protection of rare and endangered species.** The forecast is based upon the current conservation guidelines for the protection of these species, including the Powerful Owl. For the Powerful Owl the constraint applied in the forecasts was that more than 70 per cent of the forest in the known range of each pair must be more than 30 years of age at any time.
- **Improvement of forest productivity.** Forecasts have been based on silviculture to maximise sawlog production from existing mature stands, and the use of the three types of silviculture for regrowth on medium and high productivity sites in the Wombat State Forest.
- **Improvement in the age class structure.** The effects of a strategy to maximise sustainable yield under a balanced age-class structure by the year 2100 was built into the forecasts.

# 9 FORECASTING THE SAWLOG YIELD

## 9.1 Integrated Forest Planning System

Sustainable yield has been forecast using CNR's Integrated Forest Planning System (IFPS - Lau *et al* 1994). This system is composed of a number of modules including GIS, the commercial linear programming package LINDO, and the USDA Forests Service's FORPLAN, encased in a shell written in the SIR/DBMS language.

To provide a forecast the IFPS is used to integrate:

- the silvicultural regimes applied to the forest
- the appropriate sawlog and residual log yield tables
- the constraints set by the forest management strategy.

For each forecast, the data used to describe the forest as a whole, when assembled and linked through relationships between components, forms what is termed a FORPLAN model. This process can provide tabular and mapped information which may be used to guide decisions about where, how much and when timber may be harvested for decades ahead.

The smallest land units used in the IFPS are called analysis areas (AA). These have been defined by six separate attributes:

- forest management blocks
- particular domestic water supply catchments (as defined by the Proposed FM Plan)
- current Wood Utilisation Plan
- forest stands
- Forest Management Zones
- Powerful Owl management areas.

The process of defining, collecting and verifying data for each of these attributes has been extensive. All data were entered into the GIS and the six attributes overlayed to produce AAs which are relatively homogeneous. Several small similar AAs were aggregated (less than 150 ha of productive forest was treated in this manner) and areas generated by minor mapping differences were amalgamated with appropriate neighbours. A total of 775 AAs were used in the analysis, the smallest being two ha and the largest 1295 ha.

In the IFPS, the forecasting horizon can be subdivided into 20 separate planning periods. Ten-year planning periods have been used, giving a 200-year planning horizon.

The silvicultural systems were coded into the IFPS, including the age range over which each may be applied, and the AAs to which they apply. The constraints described in Section 8 were also included in the model. Further, the starting point for the forecast has been the Midlands 1995-96 Wood Utilisation Plan which shows the areas and volumes scheduled for harvesting for a three-year period. To achieve a best solution it has been necessary to test a large number of options. Sensitivity analysis has also been carried out on a number of the components.

## 9.2 Evaluation of review procedures

Dr Brian Turner, Department of Forestry, Australian National University, evaluated CNR's methodology in preparing the Midlands sustainable yield. In his report he said:

"My review of the procedures being used to calculate sustainable yields for the Midlands Management Area indicates that an appropriate methodology consistent with best international practices is being used. The FORPLAN model being used to establish the 'best' simulation is a suitable vehicle for this purpose and relevant constraints to protect other forest values are included in the model. Growth models are supported by measurements of permanent plots over the last 30 years, a database superior to that supporting growth estimates of most similar forests in Australia. Correlation of plot measurements with felled plots has been established to ensure that volumes represent current practices. The land area statistics are contained within a GIS, providing flexibility and accuracy."

## 9.3 Future improvements

Dr Turner also indicated several areas where there is room for some improvement, in particular the estimation of future growth, the Shelterwood model and site variation.

In relation to site variation, CNR is already working with the CSIRO on a site productivity study in the Wombat State Forest.

CNR acknowledges there are several areas where work could be carried out which would improve future forecasts of sustainable yield in the FMA. In priority order these are:

- the development of variable density yield tables specific to the mixed-species forests
- further investigation of the suppression of the growth of regeneration by overwood in the Wombat State Forest
- investigation of windthrow, tree mortality and defect associated with Shelterwood.

The sub-sample of CFI plots used to develop the yield curves is exceedingly valuable for obtaining growth data in the future. These plots should be preserved from all timber harvesting until such time as they are no longer useful.

# 10 RESULTS AND RECOMMENDATIONS

## 10.1 Sawlog standards

The utilisation studies carried out for the review indicate that, on balance, current harvesting practices are consistent with the D+ sawlog grading. An estimated six per cent of assessed, potentially recoverable sawlog volume, was not used for sawlog. However, this was largely offset by four per cent recovered from trees or parts of trees assessed as not having sawlog volume. The studies indicate there is room for some improvement in taking sawlogs from near the heads of trees and from small trees.

The utilisation studies also indicated that current State-wide sawlog standards are not as stringent as the sawlog standards applied locally in the 1960s and 1970s, with an estimated six to eight per cent difference in harvestable volume. The six to eight per cent additional wood taken as sawlog in the 1960s and 1970s is taken as residual logs now. The real significance of this change is on the sustainable sawlog yield because the previous sawlog forecast was made prior to the introduction in 1988 of State-wide sawlog grading standards.

Further, sustainable yield rates specified in legislation for all FMAs in 1990 were to a C+ grade standard. However, sawlog volumes were only licensed to the D+ standard in the Midlands FMA in recognition that these were the closest to the standards which applied prior to the introduction of State-wide sawlog grading.

**Recommendation**

**The sustainable sawlog yield rate for the Midlands FMA be set at the A, B, C and D grade sawlog standard.**

## 10.2 Impact of wildfire

The annual loss of sustainable sawlog yield associated with the average annual loss of net productive area due to wildfire (Section 7 and Appendix 6) is 1500 m³ of D+ sawlog.

The two options available for dealing with fire risk are:

- make an annual allowance for future losses, and reduce the sustainable yield by 1500 $m^3$
- make no annual allowance, but reduce the sustainable yield as required following a major wildfire.

The first option is favoured as it should avoid the need for any sudden reduction in sustainable yield associated with a major wildfire.

**Recommendation**

**The sustainable yield rate of the Midlands FMA be based upon provision for the probable impact of wildfire on future sawlog growth.**

## 10.3 Impact of management strategies

The impacts of the forest management strategies outlined earlier in the report are as follows.

- **Maintenance of water catchment values.** The strategy of developing relatively balanced age class distributions in a number of catchments, to limit any potential impacts on catchment flows and water quality, reduces the sustainable yield by approximately 800 $m^3$ per year.
- **Protection of Powerful Owl habitat.** The strategy of maintaining more than 70 per cent of forest older than 30 years of age within the known range of each pair of owls, reduces the sustainable yield by approximately 100 $m^3$ per year.
- **Improved forest productivity.** A number of silvicultural regimes were analysed for their potential to improve sawlog growth and quality as discussed earlier. Table 3 indicates the results in terms of the sustainable yield that would be available from the FMA under various silvicultural options for the medium to high productivity forests in the Wombat State Forest. It also indicates the increase or decrease that would occur compared with the volume available using the current silvicultural practices. These figures take account of all impacts of management strategies as well as the probable impact of wildfire.

**Table 3: Sustained sawlog yield available from the Midlands FMA under various silvicultural options applied in the Wombat State Forest**

| Silviculture | Sustainable sawlog volumes available [ difference from that available under the current regime ] ($m^3$/yr of D+ grade sawlogs) | | |
|---|---|---|---|
| | **Early thinning** | **Current thinning** | **No thinning** |
| **Clearfell** | 54 600 [+3300] | 47 300 [-4000] | 46 900 [-4400] |
| **Shelterwood** | 58 200 [+6900] | Current regime 51 300 | 50 200 [-1100] |
| **Selection** | Not applicable | Not applicable | 34 900 [-16 400] |

**Note:** The options apply only to the treatment of the medium to high productivity sites in the Wombat State Forest.

Sensitivity analysis was carried out on a number of parameters used in the analysis with the following results:

**Table 4: Sensitivity of the sustainable yield calculation to changes in various parameters**

| Parameter | Change | Average proportional change in sustainable yield (per cent) |
|---|---|---|
| Minimum harvesting age | 10 years later<br>10 years earlier | -0.58<br>+0.03 |
| Regrowth yield curve | 10 per cent better growth<br>10 per cent poorer growth | +2.1<br>-10.2 |
| Estimated yield of maturing and regenerating forest | Increase by 10 per cent<br>Decrease by 10 per cent | +11.8<br>-12.0 |
| Estimated yield of existing mature forest | Increase by 10 per cent<br>Decrease by 10 per cent | +7.8<br>-8.3 |

As indicated in the previous discussion, a conservative approach has been taken in the forecasts, particularly as they relate to the most sensitive parameters.

The management strategies are those currently being developed in the Midlands FM Plan. If changes are made to zoning as a result of public comment, they are unlikely to impact significantly on the forecasts, unless they are major changes.

The strategy for improving forest productivity includes the introduction of a management program for young regrowth (arising from both timber harvesting and fire) based on early thinning and overwood removal, which will cost an estimated additional $240 000 to $310 000 per year. No additional funding to that already available is required to implement the other management strategies.

Provided adequate long-term funding for a young regrowth management program can be assured for the Midlands FMA, the sustainable yield can be based upon the management strategies outlined. It should be understood that if the sustainable yield is set on the basis of a young regrowth management program which is not fully implemented, overcutting will occur and the sustainable yield will ultimately fall significantly.

Failure of current first-attempts to obtain regeneration has a negligible impact on the sustainable yield, estimated at 0.2 to 0.3 per cent based on a four to eight per cent failure rate, and an average three-year delay in establishing regeneration on areas requiring retreatment. Nevertheless, it is essential that any areas now unstocked be retreated as soon as possible.

**Recommendation**

**The sustainable sawlog yield of the Midlands FMA be based upon:**

- **full implementation of a young regrowth management program on medium and high productivity sites in the Wombat and Mount Cole State forests**
- **continuation of Shelterwood silviculture on the medium and high productivity sites in the Wombat State Forest**
- **ensuring that all harvested areas are adequately regenerated**
- **continuation of Clearfelling silviculture in the Mount Cole State Forest**
- **continuation of Seed-tree silviculture in low productivity sites in the Wombat State Forest and other State forests**
- **protection of regional biodiversity, domestic water supply catchments and Powerful Owl habitat.**

## 10.4 Forecast sustainable yield rate

Under Section 52B of the *Forests Act 1958,* the Secretary, in determining short-term hardwood sawlog supply levels, must consider:

- the need for significant changes in levels to be implemented over the timber supply period rather than at once, and
- the need to minimise as much as possible any adverse social or economic impact of significant changes in levels.

In view of this requirement, provision was made in the forecasts for the following.

- Maintaining the total licensed volume of D+ grade sawlog at 70 400 m³ per year to 30 June 1996.
- A phase down to the new sustainable yield over a five-year period starting from 1 July 1996.

Based upon the recommended management strategies, methods for treating the probable growth losses from wildfire, adherence to the D+ sawlog standard, and the phase-down of sawlog harvesting over a five-year period from 1 July 1996, the forecast sustainable yield rate is 58 000 m³ per year.

The volume of residual logs/pulpwood available under the above forecast and associated management strategies will be 91 000 m³ per year.

**Recommendation**

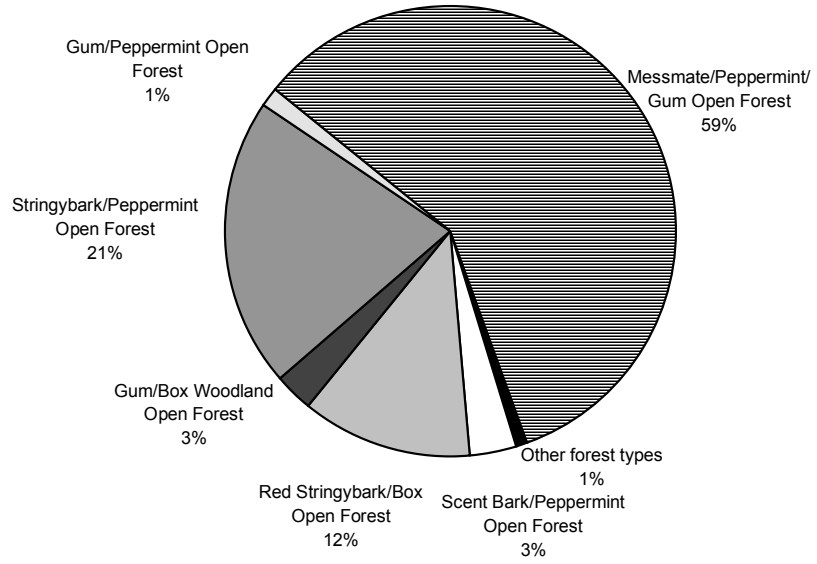
**The Midlands sustainable sawlog yield rate be set at 58 000 $m^3$ per year of A, B, C and D grade sawlogs.**

# APPENDICES

## APPENDIX 1

# FOREST TYPES IN THE MIDLANDS FMA

The comparative extent of forest types in the Midlands FMA is indicated in the following chart.




The variation in forest types results from interaction between site factors such as rainfall, topography, soils and aspect. A very wide range of local variations in understorey vegetation also exists.

Native forests were broadly classified by structure (form, height and projective foliage cover) and dominant tree species, into eleven forest types. The following brief descriptions of the four most extensive forest types in the FMA are derived from Land Conservation Council reports.

***Messmate Stringybark/Peppermint/Gum Open Forest***

This forest type is widely distributed throughout the FMA and is most productive for sawlogs in areas receiving greater than 800 mm of rainfall. It comprises 59 per cent of the public land in the FMA. The dominant eucalypt species include Messmate Stringybark, Narrow-leaf Peppermint, Broad-leaved Peppermint, Manna Gum and Candlebark. In the Mount Cole and Pyrenees State Forests, Blue Gum tends to replace Manna Gum and Candlebark. Mature tree height is between 15 and 40 m.

**APPENDIX 1 (CONT'D)**

### *Stringybark/Peppermint Open Forest*

Covering 21 per cent of public land in the FMA, these forests are mostly limited to low elevation and low rainfall sites in the Wombat State Forest. Usually dominated by Red Stringybark and Broad-leaved Peppermint, mature tree height falls between 5 and 28 m. This forest type provides limited amounts of minor products.

### *Red Stringybark/Box Open Forest*

These forests are restricted to lower rainfall (<700 mm) sites and poor soils. They are dominated by Red Stringybark mixed with a variety of box species and, although of relatively limited occurrence (12 per cent of the total), are widely distributed throughout the FMA. Mature tree height ranges between 5 and 28 m. Although generally not productive for sawlogs, these forests are subject to less intensive harvesting for products such as farm timbers and firewood.

### *Gum/Box Woodland/Open Forest*

Found in the driest parts of the FMA, predominantly in the west. This forest type (three per cent of the total) comprises woodlands of mainly Yellow Gum with a variety of box species. Mature tree heights range between 5 and 15 m. Little to no harvesting of forest products occurs in this forest type.

### *Scent Bark/Peppermint Open Forest*

Found in dry sites around Ballarat, Scent Bark occurs in combination with either Broad-leaved Peppermint or Narrow-leaf Peppermint and Candlebark. This forest type also occupies about three per cent of the total and little to no harvesting of forest products occurs in it.

The other communities listed below total only two per cent of all the vegetation types by area.

- Gum/Peppermint Open Forest - dry sites in the Mount Cole State Forest (one per cent of the total)
- Snow Gum Open Forest/Woodland - isolated patches on Mount Cole and Mount Macedon
- Alpine Ash/Mountain Ash Open Forest - restricted to small areas in the Mount Macedon Regional Park
- Swamp Gum Open Forest - on wet sites in the Enfield State Forest
- Box/Ironbark Open Forest - in the foothills of the Pyrenees State Forest
- River Red Gum Woodland - very few sites on public land

## APPENDIX 2

# MAJOR EVENTS INFLUENCING FOREST GROWTH IN THE MIDLANDS STATE FORESTS

| | |
|---|---|
| 1850 - 1900 | Almost all of the Midlands forests were felled for timber and firewood to supply the needs of gold mining and European settlement. |
| 1898 | A Royal Commission was established which led to controls on harvesting, and to thinning and removal of defective trees to improve timber stands. |
| 1919 | The Forests Commission, Victoria was established and rehabilitation of the cut-over forests commenced. |
| 1920s | Timber harvesting commenced again at a low level. |
| 1930s | Extensive areas of regrowth were thinned for firewood, under unemployment relief schemes, to promote the development of sawlogs. |
| 1940-45 | Timber production increased to meet demands created by the war. |
| Late 1940s | The Mount Cole State Forest was re-opened for timber harvesting on a three-stage cut system. |
| | Selective harvesting increased in the Wombat and other State forests. Estimates of forest growth were made and regulation of levels of annual harvesting based on these estimates was introduced. |
| 1950s | A major wildfire near Barkstead burnt approximately 600 ha of State forest. Selective harvesting was extended in the Wombat State Forest. |
| 1960s | Selective harvesting was introduced in the Mount Cole State Forest. |
| | A major wildfire near Barkstead burnt approximately 1200 ha of forest in 1962, part of which had also been burnt in the 1950s wildfire. |
| | Approximately 500 CFI plots were established in the Mount Cole and Wombat State forests to measure timber volumes and growth. |
| 1970s | Re-measurement of the CFI plots in the Wombat State Forest showed that only the larger trees were growing well, and the trees remaining after selective fellings prevented younger trees from growing satisfactorily. |
| | Selective harvesting was abandoned in the Mount Cole forests in favour of Clearfelling because a root fungus (*Armillaria*) had been found to attack the remaining trees on harvested areas. |
| | Shelterwood silviculture was adopted in the Wombat State Forest. |
| | Periodic reviews of timber harvesting rates were made based on analysis of data from CFI plots. |
| 1980s | The Ash Wednesday wildfire in 1983 burnt approximately 8000 ha of forest near East Trentham. |
| | The Timber Industry Strategy introduced regional sustainable sawlog yields in Victoria. The sustainable yield from the Midlands FMA was set at 70 000 $m^3$ per year of A, B, and C grade sawlogs. |
| 1990 | Regional sustainable yields for the 15 FMAs in the State were scheduled in legislation. |
| 1995 | Much of the Enfield State Forest, and the Enfield State Park, was burnt by wildfire. |

## APPENDIX 3

# DEFINITION OF SAWLOG GRADES

All hardwood sawlogs other than River Red Gum and box-ironbark species must be graded in accordance with hardwood sawlog grading instructions and interpretations.

## Definition of sawlog

Any length of a log of merchantable species which:

- is at least 2.7 m in length
- has a small end diameter (measured under the bark) of 25 cm or greater
- does not have sweep or crook which exceeds one-fifth of the diameter along a 2.4 m straight edge
- is of grade D standard or better.

## Definition of sawlog grade

***A Grade***

Any sawlog with a minimum small end diameter under bark of 50 cm which has no defective quarters and maximum defects on exposed ends of:

- one-quarter diameter lengths of all gum vein or gum pockets
- light stain

**In addition:**

- maximum angle of sloping grain of 1:10 along the length of the sawlog

***B Grade***

Any sawlog with a minimum small end diameter under bark of 35 cm which has maximum allowable defects on exposed ends of:

- one-quarter diameter length of loose gum veins/pockets and shakes
- one diameter length of tight gum vein more than 3 mm in width
- two diameters length of tight gum vein less than 3 mm in width
- light stain

**In addition:**

- 1:10 angle of sloping grain along the sawlog axis.
- a maximum of one defective quarter along the length of the sawlog *
- a maximum of 105 cm squared of pipe in an exposed end *

**APPENDIX 3 (CONT'D)**

### *C Grade*

Any sawlog with a minimum small end diameter under bark of 30 cm which has maximum allowable defects on exposed ends of:

- one diameter length of loose gum veins/pockets and shakes
- seven diameters length of tight gum vein more than 3 mm width
- unlimited lengths of tight gum veins less than 3 mm width
- dark stain

**In addition:**

- maximum sloping grain angle of 1:8 along the length of the sawlog
- maximum of two defective quarters *
- maximum of 112 cm square of pipe in an exposed end *

### *D Grade*

Any sawlog with a minimum small end diameter under bark of 25 cm which has maximum allowable defects on exposed ends of:

- two diameters length of loose gum veins/pockets or shakes
- 10 diameters length of tight gum vein more than 3 mm width
- unlimited length of tight gum vein less than 3 mm width
- dark stain

**In addition:**

- maximum sloping grain angle of 1:8 along the length of the sawlog *
- maximum of three defective quarters *
- maximum of 120 cm square of pipe defect on exposed ends *

* All sawlogs are graded according to a sawlog grading card. This allows grade to change with relative changes between diameter, number of defective quarters and size of pipe defect.

## APPENDIX 4

# UTILISATION STUDIES

Felling trials conducted in the Wombat State Forest in 1995 showed the volume of D+ grade sawlogs actually harvestable to be 19 per cent less than the volume assessed in standing trees to the current D+ sawlog standard. The components of this difference are summarised below in terms of their volume relative to every 100 $m^3$ of assessed sawlog volume.

Data collected from normal harvesting operations on more than 20 CFI plots over the last two years confirms the scale of this difference.

### Difference between assessed and harvestable volumes per 100 $m^3$ assessed

| Components providing the difference | $m^3$ |
|---|---|
| • **Additional sawlog volume assessed in trees producing sawlog** | |
| • Volume function/scaling effect | -1 |
| • Volume in logs cut shorter than assessed | -7 |
| • Volume in defective sections | -3 |
| • Additional volume harvested in stumps | +2 |
| **SUBTOTAL** | **-9** |
| • **Additional sawlog volume assessed in trees not producing sawlog** | |
| • Volume in trees felled to produce pulpwood | |
| - with recorded defect | -7 |
| - without recorded defect | -3 |
| • Volume in cull and retained trees | -2 |
| **SUBTOTAL** | **-12** |
| • **Additional sawlog volume harvested in trees not assessed as producing sawlog** | **+2** |
| **BALANCE** | **-19** |

**The harvestable volume at the D+ standard is 19 per cent less than the assessed volume.**

## APPENDIX 5 SUMMARY OF SILVICULTURAL OPERATIONS USED IN CALCULATING SUSTAINABLE YIELD

| Strata | | | | Next harvest | Future operations | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Current practice | | With thinning | | Without thinning | |
| Forest | Productivity | History | Area (ha) | Relative sawlog volume in current stands [1] | Schedule of operations [2] | Relative sawlog volume in 80 yo stands [1] | Schedule of operations [2] | Relative sawlog volume in 80 yo stands [1] | Schedule of operations [2] | Relative sawlog volume in 80 yo stands [1] |
| Wombat | M / H | MAT | 6472 | 64% | Available for SW1 now, CF 10 yrs later. NCT @30, CT @60, MH @70 | 100% | Available for MH now. NCT @10, NST @40, MH @70 | 128% | Available for MH now. Regrowth MH @70 | 76% |
| | M / H | SEL | 4502 | 46% | Available for MH now. NCT @30, CT @60,MH @70 | 100% | Available for MH now. NCT @10, NST @40, MH @70 | 128% | Available for MH now. Regrowth MH @70 | 76% |
| | M / H | SW1 | 8533 | 26% | Available for MH now. Regrowth NCT @30, CT @60,MH @70 | 100% | Available for MH now. Regrowth NCT @10, NST @40, MH @70 | 128% | Available for MH now. Regrowth MH @70 | 76% |
| | M / H | REG | 6633 | See future operations | Available for NCT @30, CT @60,MH @70 | 100% | Available for NCT @30, CT @60, MH @70 | 128% | Available for MH @70 | 76% |
| Wombat | L | MAT | 4777 | 26% | Available for CF now. Regrowth CF @90 | 40% | Available for CF now. Regrowth CF @90 | 51% | Available for CF now. Regrowth CF @90 | 30% |
| | L | SEL | 1191 | 20% | Available for CF now. Regrowth CF @90 | 40% | Available for CF now. Regrowth CF @90 | 51% | Available for CF now. Regrowth CF @90 | 30% |
| | L | SW1 | 1729 | 20% | Available for CF now. Regrowth CF @90 | 40% | Available for CF now. Regrowth CF @90 | 51% | Available for CF now. Regrowth CF @90 | 30% |
| | L | REG | 637 | See future operations | CF @90 | 40% | Available for CF @90 | 51% | Available for CF @90 | 30% |
| Mt Cole | M / H | MAT | 1737 | 44% | Available for CF now. Regrowth NCT @40, CF @70 | 100% | Available for CF now. Regrowth NCT @10, CF @70 | 128% | Available for CF now. Regrowth CF @70 | 90% |
| | M / H | REG | 2816 | See future operations | Available for NCT @40, CF @70 | 100% | Available for NCT @40, CF @70 | 100% | Available for CF @70 | 90% |
| Other areas | L | MAT | 9292 | 14% | Available for CF now. Regrowth CF @90 | 30% | Available for CF now. Regrowth CF @90 | 30% | Available for CF now. Regrowth CF @90 | 30% |
| | L | REG | 2128 | See future operations | Available for CF @90 | 30% | Available for CF @90 | 30% | Available for CF @90 | 30% |

**Abbreviations:**

**Productivity:** M / H Medium and high
L Low

**History:** MAT Mature
SEL Selection
SW1 Shelterwood 1
REG Regrowth

**Operation Types :** NCT Non-commercial thinning
CT Commercial thinning
NST Non-sawlog thinning
MH Mature harvest: clearfelling, shelterwood or selection

**Operation Timing :** Thinning e.g. NCT @30 NCT will be scheduled at 30 years
Mature harvest e.g. MH @80 First cut of mature harvest can be scheduled at 80 years or later

**Notes:** 1 Relative sawlog volume is expressed as a percentage of average yields in the M/H site class in the Wombat State Forest
2 These are the minimum ages at which the various forests would be available for harvesting; in reality harvesting could be much later

## APPENDIX 6

# ESTIMATION OF PROBABLE IMPACT OF WILDFIRE ON FOREST GROWTH

### (a) Net productive area of wildfire-induced regeneration

| Decade of origin of existing regeneration | Net productive area reverted to age zero classified by site productivity (ha) | | | |
|---|---|---|---|---|
| | Wombat and Mount Cole State forests | Wombat State Forest | Other forests | Total |
| | Medium and high sites | Low sites | Low sites | |
| 1990s | 0 | 0 | 250 [1] | 250 |
| 1980s | 3974 | 89 | 0 | 4063 |
| 1970s | 126 | 53 | 0 | 179 |
| 1960s | 1149 [2] | 24 | 0 | 1173 |
| 1950s | 600 | 115 | 0 | 715 |
| 1940s | - | - | - | - |
| 1930s | 25 | - | - | 25 |
| 1920s [3] | - | - | - | - |
| Total | 5874 | 281 | 250 | 6405 |

**Notes:**

1. Estimate for the 1995 Enfield fire.
2. Approximately 420 ha of 1950s fire regrowth was burnt again in the 1962 fire.
3. Records indicate a large fire in the Wombat State Forest in the 1920s, although no forest of this origin is known.

Average reverted area across the 75 years 1920 to 1995:

(6405 ÷ 75) = 85 ha per year

### (b) Annual probability of a severe wildfire

Annual probability of wildfire severe enough to convert any given hectare of forest back to age zero:

(85 ÷ 50 450 x 100) = 0.17%

**APPENDIX 6 (CONT'D)**

## (c) Loss of growth to wildfire

Potential fire loss is calculated as the difference between the volume from appropriate yield curve and the *pro rata* volume (that is, the volume available at rotation age, proportioned to each age class as if the forest grew at a constant rate). It assumes:

- fires after the rotation age of 80 years (100 years for low productivity sites in the Wombat State Forest and other forest areas) do not result in a loss of production as sawlogs can be salvaged
- standing volumes of D+ sawlog greater than 20 $m^3$/ha can be salvaged.

Different yield curves were applied to each productivity area within the FMA, *viz*.

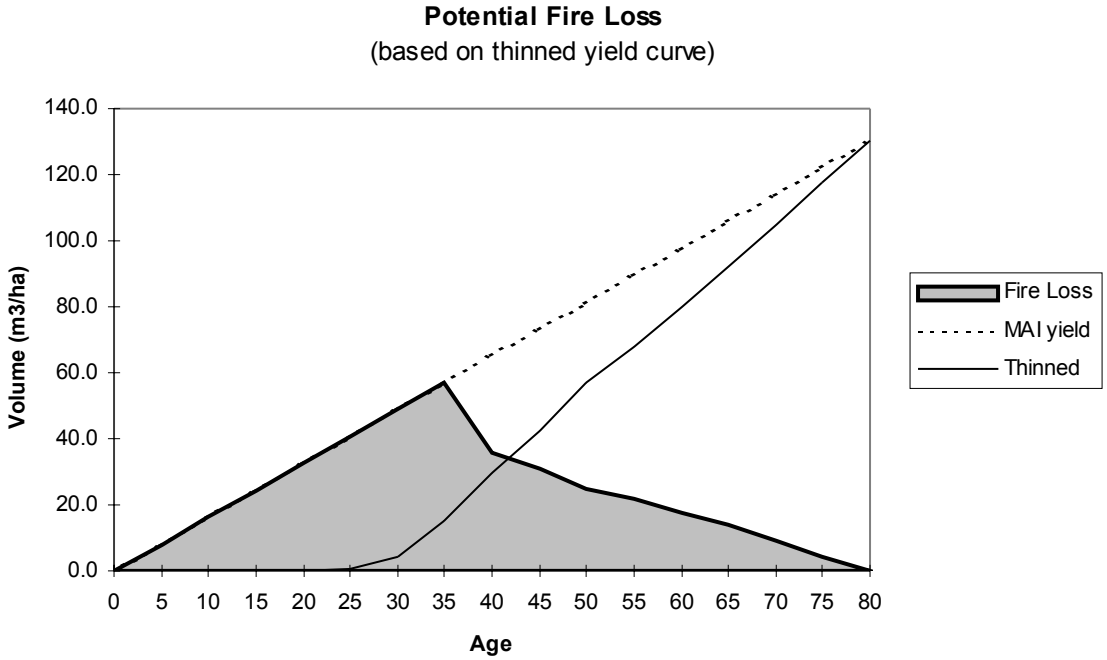
| | |
|---|---|
| Wombat High/Medium productivity | Thinned yield curve |
| Mount Cole | Thinned yield curve |
| Wombat Low productivity | Unthinned yield curve * 40 per cent |
| Other forest areas | Unthinned yield curve * 30 per cent |

**Potential fire loss for Wombat High/Medium Productivity and Mt Cole**

| Age | Thinned Yield Curve | Pro rata volume | Salvage volume | Fire Loss |
|---|---|---|---|---|
| 5 | | 8.2 | | 8.2 |
| 10 | | 16.3 | | 16.3 |
| 15 | | 24.5 | | 24.5 |
| 20 | | 32.6 | | 32.6 |
| 25 | 0.4 | 40.8 | | 40.8 |
| 30 | 4.5 | 48.9 | | 48.9 |
| 35 | 15.3 | 57.1 | | 57.1 |
| 40 | 29.7 | 65.2 | 29.7 | 35.5 |
| 45 | 42.3 | 73.4 | 42.3 | 31.1 |
| 50 | 56.7 | 81.5 | 56.7 | 24.8 |
| 55 | 67.9 | 89.7 | 67.9 | 21.8 |
| 60 | 80.0 | 97.8 | 80.0 | 17.8 |
| 65 | 92.2 | 106.0 | 92.2 | 13.8 |
| 70 | 104.8 | 114.1 | 104.8 | 9.3 |
| 75 | 117.8 | 122.3 | 117.8 | 4.5 |
| 80 | 130.4 | 130.4 | 130.4 | |

**APPENDIX 6 (CONT'D)**

**Graphical representation of the above table**




A similar approach was used for low productivity forests in the Wombat State Forest and the other forest areas.

## (d) Potential volume loss to fire

Using the age class by period information from the IFPS, the potential fire loss was calculated by multiplying the probability of fire (0.17 per cent) by the calculated fire loss and the area for each age class.

The average annual fire loss for the period 2005 to 2104, when the forest age class structure is undergoing considerable change, was calculated to be about 1500 $m^3$. Once the long term sustainable yield has been reached, the data indicates that the average annual loss may exceed 1870 $m^3$.

The potential fire loss for each of the four productivity areas was combined into a table for the FMA. The results are summarised below.

**APPENDIX 6 (CONT'D)**

## Forecast age class distribution for all forest areas in the Midlands FMA

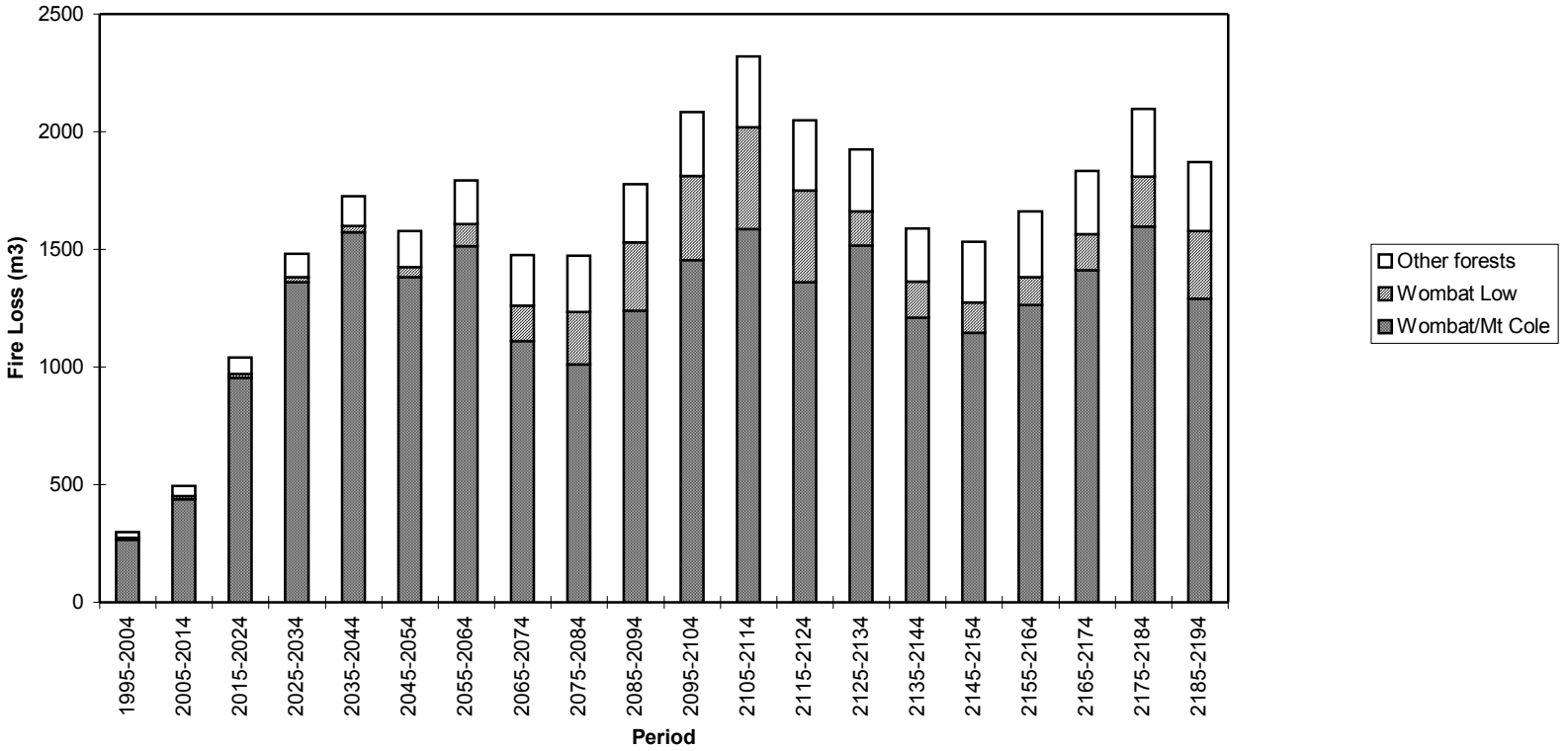
| | Period | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age class | 1995-2004 | 2005-2014 | 2015-2024 | 2025-2034 | 2035-2044 | 2045-2054 | 2055-2064 | 2065-2074 | 2075-2084 | 2085-2094 | 2095-2104 | 2105-2114 | 2115-2124 | 2125-2134 | 2135-2144 | 2145-2154 | 2155-2164 | 2165-2174 | 2175-2184 | 2185-2194 |
| 0-10 | 8664 | 2184 | 1008 | 919 | 862 | 2759 | 4379 | 9020 | 2700 | 1001 | 1920 | 2610 | 2328 | 1555 | 1912 | 1049 | 2849 | 1903 | 3655 | 7360 |
| 11-20 | 934 | 8664 | 9798 | 1008 | 7425 | 2800 | 6208 | 4379 | 9020 | 7273 | 3345 | 4288 | 2610 | 5721 | 3867 | 5205 | 5622 | 3641 | 7047 | 3655 |
| 21-30 | 826 | 934 | 8664 | 9798 | 1008 | 7425 | 2800 | 6208 | 4379 | 9020 | 7273 | 3345 | 4288 | 2610 | 5721 | 3867 | 5205 | 5622 | 3641 | 7047 |
| 31-40 | 1535 | 826 | 934 | 8664 | 9798 | 1008 | 7425 | 2800 | 6208 | 4379 | 9020 | 7273 | 3345 | 4288 | 2610 | 5721 | 3867 | 5205 | 5622 | 3641 |
| 41-50 | 184 | 1535 | 826 | 934 | 8664 | 9798 | 1008 | 7425 | 2800 | 6208 | 4379 | 9020 | 7273 | 3345 | 4288 | 2610 | 5721 | 3867 | 5205 | 5622 |
| 51-60 | 71 | 184 | 1535 | 826 | 934 | 8664 | 9798 | 1008 | 7425 | 2800 | 6208 | 4379 | 9020 | 7273 | 3345 | 4288 | 2610 | 5721 | 3867 | 5205 |
| 61-70 | | 71 | 184 | 1535 | 826 | 934 | 8664 | 9798 | 1008 | 7425 | 2800 | 6208 | 4379 | 9020 | 7273 | 3345 | 4288 | 2610 | 5721 | 3867 |
| 71-80 | | | 71 | 184 | 1535 | 826 | 934 | 7037 | 9798 | 1008 | 7425 | 2800 | 6208 | 4379 | 9020 | 7273 | 3345 | 4288 | 2610 | 5721 |
| 81-90 | | | | 71 | 184 | 1535 | 826 | 934 | 5416 | 5225 | 1008 | 5057 | 2800 | 6208 | 4379 | 9020 | 2700 | 3345 | 1920 | 2610 |
| 91-100 | | | | | 71 | 184 | 1535 | 826 | 934 | 5387 | 2380 | 1008 | 4888 | 2800 | 4895 | 4080 | 7458 | 2700 | 1001 | 1419 |
| 101-110 | 28941 | | | | | 71 | 184 | 909 | 659 | 568 | 4689 | 2380 | 929 | 1495 | 1641 | 2347 | 3655 | 7458 | 2700 | 1001 |
| 111-120 | 9292 | 27732 | | | | | 71 | | 99 | 152 | | 2079 | 2380 | 929 | 1495 | 1641 | 2347 | 3655 | 7458 | 2700 |
| 121-130 | | 8317 | 19932 | | | | | | | | | | | 825 | | | 779 | 432 | | 600 |
| 131-140 | | | 7495 | 19766 | | | | | | | | | | | | | | | | |
| 141-150 | | | | 6743 | 13103 | | | | | | | | | | | | | | | |
| 151-160 | | | | | 6037 | 10428 | | | | | | | | | | | | | | |
| >160 | | | | | | 4014 | 6615 | 103 | | | | | | | | | | | | |
| Total | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 | 50447 |

## Potential fire loss ($m^3$) Midlands FMA - all forest areas

| | Period | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age class | 1995-2004 | 2005-2014 | 2015-2024 | 2025-2034 | 2035-2044 | 2045-2054 | 2055-2064 | 2065-2074 | 2075-2084 | 2085-2094 | 2095-2104 | 2105-2114 | 2115-2124 | 2125-2134 | 2135-2144 | 2145-2154 | 2155-2164 | 2165-2174 | 2175-2184 | 2185-2194 |
| 0-10 | 107 | 9 | 6 | 6 | 7 | 26 | 40 | 95 | 7 | 13 | 16 | 10 | 20 | 32 | 73 | 13 | 15 | 17 | 23 | 29 |
| 11-20 | 19 | 321 | 357 | 17 | 341 | 90 | 160 | 119 | 284 | 352 | 38 | 317 | 85 | 198 | 111 | 219 | 369 | 45 | 319 | 70 |
| 21-30 | 35 | 32 | 534 | 595 | 28 | 568 | 150 | 267 | 199 | 473 | 586 | 64 | 529 | 142 | 330 | 184 | 365 | 615 | 74 | 531 |
| 31-40 | 125 | 48 | 45 | 748 | 832 | 39 | 796 | 210 | 374 | 278 | 662 | 821 | 89 | 740 | 199 | 462 | 258 | 511 | 860 | 104 |
| 41-50 | 10 | 74 | 35 | 37 | 434 | 471 | 36 | 447 | 129 | 306 | 313 | 398 | 458 | 67 | 433 | 123 | 273 | 265 | 320 | 482 |
| 51-60 | 4 | 7 | 57 | 32 | 37 | 329 | 346 | 39 | 326 | 104 | 308 | 366 | 313 | 331 | 64 | 330 | 99 | 211 | 299 | 262 |
| 61-70 | | 4 | 4 | 43 | 30 | 37 | 239 | 240 | 43 | 222 | 83 | 314 | 420 | 242 | 222 | 62 | 243 | 79 | 159 | 335 |
| 71-80 | | | 2 | 1 | 15 | 12 | 15 | 44 | 82 | 18 | 75 | 31 | 127 | 140 | 57 | 75 | 25 | 86 | 29 | 57 |
| 81-90 | | | | 2 | | 6 | 8 | 12 | 26 | | 0 | | 8 | 31 | 87 | 23 | 11 | 1 | 14 | 0 |
| 91-100 | | | | | 1 | | 3 | 4 | 6 | 13 | | | | | 12 | 42 | 4 | 5 | 0 | |
| Total | 299 | 495 | 1040 | 1480 | 1725 | 1578 | 1793 | 1477 | 1474 | 1778 | 2083 | 2321 | 2049 | 1924 | 1588 | 1532 | 1661 | 1834 | 2098 | 1871 |

**APPENDIX 6 (CONT'D)**

**Potential fire loss Midlands FMA – all forest areas**



# GLOSSARY

**Basal area**. The cross-sectional area of a tree at a standard height above ground (1.3 m above mean ground level). Increment of basal area, as used in forest inventory, is a more direct measure than diameter increment or the growth in volume of sawlog in the tree.

**Clearfelling**. Silviculture by which all merchantable trees on a coupe of from five to 40 ha, other than those reserved as habitat trees, are felled so that a new stand of trees becomes established over the area. In eucalypt forests, larger coupes are usually sown with locally collected seed or planted with seedlings to secure regeneration throughout the area.

**Continuous forest inventory plots**. Permanent plots to sample timber volumes and growth throughout a forest, in which the diameter and log length in each tree, and other observations, are recorded. Plots are commonly remeasured every five or 10 years so that forest growth can be estimated, and changes in tree and forest conditions can be recorded.

**Coupe**. An area of forest of variable size, shape and orientation from which logs for sawmilling or other industrial processing are harvested.

**Increment**. The increase in volume, diameter, height or other measure of individual trees or stands during a given period.

**Mature forest**. Older forest stands in which the mean annual increment of sawlog volume is declining or in which the crowns of the dominant trees are fully developed.

**Mean annual increment**. The total increment up to a given age divided by that age; average annual increment to that age.

**Periodic annual increment**. The average annual increment for any short period, such as five years.

**Regeneration**. A new tree crop up to five years old established after wildfire or timber harvesting.

**Regrowth**. Young, rapidly growing forest stands older than five years.

**Residual log**. A log obtained in addition to sawlogs when timber is being harvested which is often unsuitable because it is too small or defective to meet current sawlog specifications, but which can yield low quality products such as pallet wood or pulpwood.

**GLOSSARY (CONT'D)**

**Sawlog**. A log suitable in size and quality for the manufacture of sawn timber. In Victoria there are four grades of hardwood sawlog, called A, B, C and D grade, that are distinguished by specifications for diameter, length and defect in the wood. Grades A and B are processed into higher proportions of furniture and flooring products, and grade D logs typically produce a high proportion of small structural pieces, palings and off-cuts that are chipped for fibre products.

**Seed-tree silviculture**. The practice of felling most trees in coupes up to 40 ha so that a new stand of trees becomes established over the area. Sufficient mature trees are left to provide seed for regeneration and, if required in that area, habitat for wildlife.

**Selection silviculture**. The practice of felling single trees or groups of trees so that new trees become established in the small to medium gaps created.

**Shelterwood**. Silviculture by which timber is harvested by felling trees in two or more stages over a period of up to 20 years. In the Wombat State Forest the trees remaining after the first felling provide seed and shelter for regeneration. The second felling, three to 20 years later, removes all the overwood of mature trees, other than any reserved as habitat trees, before competition from them has seriously impaired the growth of the lower storey of saplings.

**Silviculture**. The theory and practice of establishing and regenerating forest stands, and managing their composition and timber growth.

**Stand**. An aggregation of trees having sufficient uniformity in age, composition and condition to be distinguishable from adjacent parts of the forest.

**Thinning**. A felling of selected trees in an immature stand for the purpose of improving the growth and form of the trees that remain.

**Wood utilisation plan**. A plan covering a three-year period which specifies in detail the volumes and quality of wood to be supplied during the first year and indicative specifications for the following two years. The plan indicates which areas of forest will be harvested, and is updated annually.

**Yield curve**. A graph showing the progressive harvestable volume of sawlog in a stand at periodic intervals on a given site.

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