Silvicultural Practice in the Karri Forest

Sustainable Forest Management Series

Department of Conservation and Land Management
SFM Guideline No.3
2005

GOVERNMENT OF WESTERN AUSTRALIA

DEPARTMENT OF Conservation AND LAND MANAGEMENT
Conserving the nature of WA

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

17 DICK PERRY AV, WESTERN PRECINCT

TECHNOLOGY PARK

KENSINGTON

WESTERN AUSTRALIA 6151

TELEPHONE (08) 9334 0300

FACSIMILE (08) 9334 0498

WEBSITE: WWW.NATUREBASE.NET

EMAIL: INFORMATION@CALM.WA.GOV.AU

Reference details

The recommended reference for this publication is: Department of Conservation and Land Management 2005, Silvicultural Practice in the Karri Forest, Department of Conservation and Land Management, Sustainable Forest Management Series, SFM Guideline No. 3.

This Guideline supersedes Silviculture Specification 2/95 by amending Silviculture Specification 2/95 to include the requirements of Appendix 5 of the Forest Management Plan 2004-2013.

Cover photograph: A stand of immature karri forest (Taken by Chris Garnett)

TABLE OF CONTENTS

1 Introduction

The overall objective of management of the forest, as outlined in the *Forest Management Plan (2004 - 2013),* is for biodiversity to be conserved, the health, vitality and productive capacity of ecosystems to be sustained, and the social, cultural and economic benefits valued by the community to be produced in a manner taking account of the principles of ecologically sustainable forest management. A more specific objective under the productive capacity criterion is to seek to provide for timber production of karri sawlogs on a sustained yield basis. The actions for the sustainable management of the karri forest within areas designated as State forest and timber reserves under the CALM Act are outlined in the *Forest Management Plan (2004 - 2013)*.

Within the forest available for harvesting the specific aim is to develop or maintain a forest structure and composition that will achieve objectives for biodiversity, timber production, water quality, water production, recreation, aesthetics, and other values of local significance.

This document details the silvicultural guidelines for field application in the karri forest, in particular treemarking and silvicultural treatment to achieve the desired forest structure and composition at the coupe level in areas from which timber is harvested.

2 Planning for harvesting

Silviculture plans are prepared for each coupe to be harvested. These are developed from an analysis of the following management information to establish the context for harvesting:

- Forest type and generalised prescription;
- Natural and cultural heritage values;
- Research and inventory plots;
- The salinity risk zone;
- Informal reserves; and
- The Visual Landscape Management zone.

Pre-requisite biological information that can affect the silvicultural method, includes:

- Pre-harvest regeneration survey maps and results (in karri / jarrah stands);
- Dieback occurrence map for the coupe;
- Fauna assessment report; and
- Flora assessment report.

The following management tools are also used:

- Historical records of past cutting and treatments (includes Aerial Photography Interpretation plans);
- Silviculture Recording system (SILREC) information;
- Relevant aerial photography;
- Hygiene plan for the coupe;
- Visual Landscape Management assessment; and
- Roading map.

Prior to harvesting, detailed 'concept' plans will be developed for each coupe. This plan should highlight the zonation relevant to silvicultural practice and any other issues that must be finalised before the harvest pattern in the coupe can be more clearly established.

Coupe concept planning is refined in the field as more accurate and detailed information becomes available through site inspection. It is important to undertake a preliminary field check of those structural and species characteristics that will affect the prescription to be applied early in the plan development stage. Assistance from specialists may be required to assess some values.

2.1 Permanent exclusion zones

2.1.1 Informal reserves

These will generally be identified in the pre-planning phase for harvesting, however treemarkers may find other areas that should be assigned as informal reserves or areas that are incorrectly identified as informal reserves. The types of informal reserves are:

- Old-growth forest;
- Areas previously classified as old growth forest;
- River and stream zones;
- Travel route zones;
- Diverse ecosystem zones;
- Less well reserved vegetation complexes;
- Poorly reserved forest ecosystems; and
- Regional Forest Agreement accredited linkage zones.

The requirements for field confirmation and demarcation of these reserves, is contained in the *Forest Management Plan (2004 – 2013), Appendix 3 – Informal Reserves*, to be superseded by the *Guidelines for the Management of Informal Reserves*, once developed and approved.

2.1.2 Other permanent exclusion zones

Other permanent exclusion zones are:

- Steep slopes - restricted operations;
- Known areas of Declared Rare Flora - include a buffer to ensure they remain undisturbed;
- Areas of high sensitivity or fragility. These may include areas of shallow soil, eagle's nests, caves and other fragile areas;
- Pure marri stands in a mature or senescent growth stage;
- Areas (with appropriate buffer) containing historic, cultural or archaeological sites; and
- Trees in the "Register of Significant Trees".

2.2 Temporary exclusion areas (TEAS)

Maintenance of structural diversity is primarily provided by Permanent Exclusion Areas and the sequencing over time of harvesting in patches of varying size.

A coupe may not be harvested adjacent to its neighbour unless that coupe has at least been regenerated (i.e. a separation of about 3 years) or it is separated by uncut forest, such as a stream reserve.

TEAS are patches of forest temporarily retained to provide protection for a nominated value while the harvested area regenerates. Once a suitable time has elapsed and the TEAS is no longer required, it may be harvested.

3 Silvicultural methods and treemarking for harvesting

Appropriate silvicultural practice in the karri forest varies according to the existing structure of the stand. The structural types available for harvesting are:

- Immature even-aged stands;
- Single-storied mature stands;
- Two-tiered stands; and
- Mixed karri / jarrah stands.

The silvicultural method associated with these structural types, and the requirements for treemarking are outlined below. If, on inspection, the planned silvicultural method appears to be inappropriate the matter should be reviewed. In cases where the CALM Regional Manager has approved the planned silvicultural method, a change to this plan will require review and approval by the Regional Manager before disturbance may take place.

3.1 Retention of habitat

Two types of habitat trees are recognised:

- Primary habitat trees, being habitat trees that have a moderate to high probability of bearing hollows; and
- Secondary habitat trees, being habitat trees that have a lower probability of bearing hollows at the time of treemarking, but provide for the sustained availability of hollows through time. These trees also contribute to structural diversity in the harvested coupe.

In all harvest areas, habitat trees receive priority for marking. Depending on the silvicultural objective of harvesting, both types of habitat tree may need to be retained to ensure the sustained availability of refuges.

Habitat trees need to be retained in single storied mature stands, two-tiered stands and mixed karri / jarrah stands, but not in immature even-aged stands.

3.1.1 Primary habitat trees

Primary habitat trees are those with the physical characteristics to provide a range of habitat niches for fauna. The most important of these are hollows in the branches and bole, which provide refuge and breeding sites for a range of species. Whilst it is important that habitat trees provide a range of sizes of existing and developing hollows, large hollows are least frequently encountered and the retention of trees likely to provide large hollows will also provide a range of hollow sizes. Habitat trees may also provide heavy forks and branches that provide nest construction sites, which may otherwise be limited for many years in a developing regrowth stand. These structural values are especially important for the larger vertebrate fauna.

Priority must be given to trees that show current signs of use by fauna (e.g. possum scratch-tracks), contain visible holes, or broken branch stubs with the potential to develop hollows.

Trees should be mature to senescent, > 70 cm dbhob, tall but wind firm with a minimum amount of hollow butt, which must be < 50 % of circumference at ground level. Leaning trees provide better access for fauna but trees with extreme lean are to be avoided because of their instability.

Trees that have major termite infestation should be avoided. Where a choice exists, retain non-sawlog trees as habitat, but do not compromise the quality of the habitat trees to achieve this.

3.1.2 Secondary habitat trees

3.1.2.1 Karri stands

To ensure continued recruitment of habitat trees in karri stands, it is desirable to identify and retain secondary habitat trees of an intermediate age between the generally mature patches and the developing regrowth. This can be done by retaining immature karri trees (about 40-80 years of age) as secondary habitat trees and growing them in a way that will enhance the development of hollows at an earlier age than would normally occur in a closed stand (Appendix 1).

3.1.2.2 Mixed karri / jarrah stands

In mixed karri / jarrah stands, jarrah or marri trees with the following characteristics are to be selected as secondary habitat trees:

- Crowns should show some potential for deterioration and be within crown structure categories 2-4 (Figure 1), but the trees must be healthy and capable of surviving for a very long time;
- Be immature to mature, 30-70 cm dbhob. Some small hollows and/or broken branch stubs with the potential to develop hollows should be visible;
- Be wind firm with a minimum amount of hollow butt, which must be < 50 % of circumference at ground level; and
- Where jarrah trees show signs of apparent field resistance to *Phytophthora cinnamomi* these trees should be preferentially retained.

3.1.3 Rate of retention of habitat trees

3.1.3.1 Karri stands

Primary habitat trees will be provided for by trees in the adjoining informal reserves.

Identify and retain **secondary habitat trees** at the rate of two (2) trees per hectare.

3.1.3.2 Mixed karri / jarrah stands

In mixed karri / jarrah forest, the **primary habitat trees** will be provided in-coupe by identifying and retaining five (5) primary habitat trees per hectare, with jarrah or marri as the preferred species, although the treemarker should be cognisant of the composition of the overstorey and the other elements that are likely to be retained following post-harvest silvicultural treatment. Where suitable primary habitat trees are not present on every hectare, a retention rate of 25 primary habitat trees per 5 hectares must be marked for retention.

Two (2) **secondary habitat trees** per hectare should be retained in clearfell coupes where marri has not been retained. Secondary habitat trees do not need to be retained in clearfell coupes in mixed karri / jarrah forest where marri has been retained.

3.1.4 Pattern of retention

Primary habitat trees must be deliberately marked for retention with a large white "H" and secondary habitat trees marked with a large white "H" (underlined).

Priority should be given to quality over spacing and where possible, habitat trees or small groups of habitat trees should be distributed throughout the coupe. Where post-harvest fuel levels are high, it is preferable to retain habitat trees in groups to facilitate their protection during post-harvest burning, and it is important that tops disposal is carried out to protect these trees or groups from damage that would affect their long-term survival.

Where possible and applicable, secondary habitat trees should be retained in association with primary habitat trees as a small group.

Where the perimeter of a coupe is intended to be a strategic burn boundary then the pattern of retention of habitat trees should recognise the need for subsequent burn security requirements. In this instance trees within the first 100 m of the burn boundary, which catch fire and cannot be extinguished, are likely to be felled as part of the prescribed burn security. Consequently, it is preferable to bias the retention of habitat trees away from the strategic burn boundaries. Where habitat trees are selected close to the boundary bias their selection towards trees with less deterioration in the crown than would otherwise be applicable.

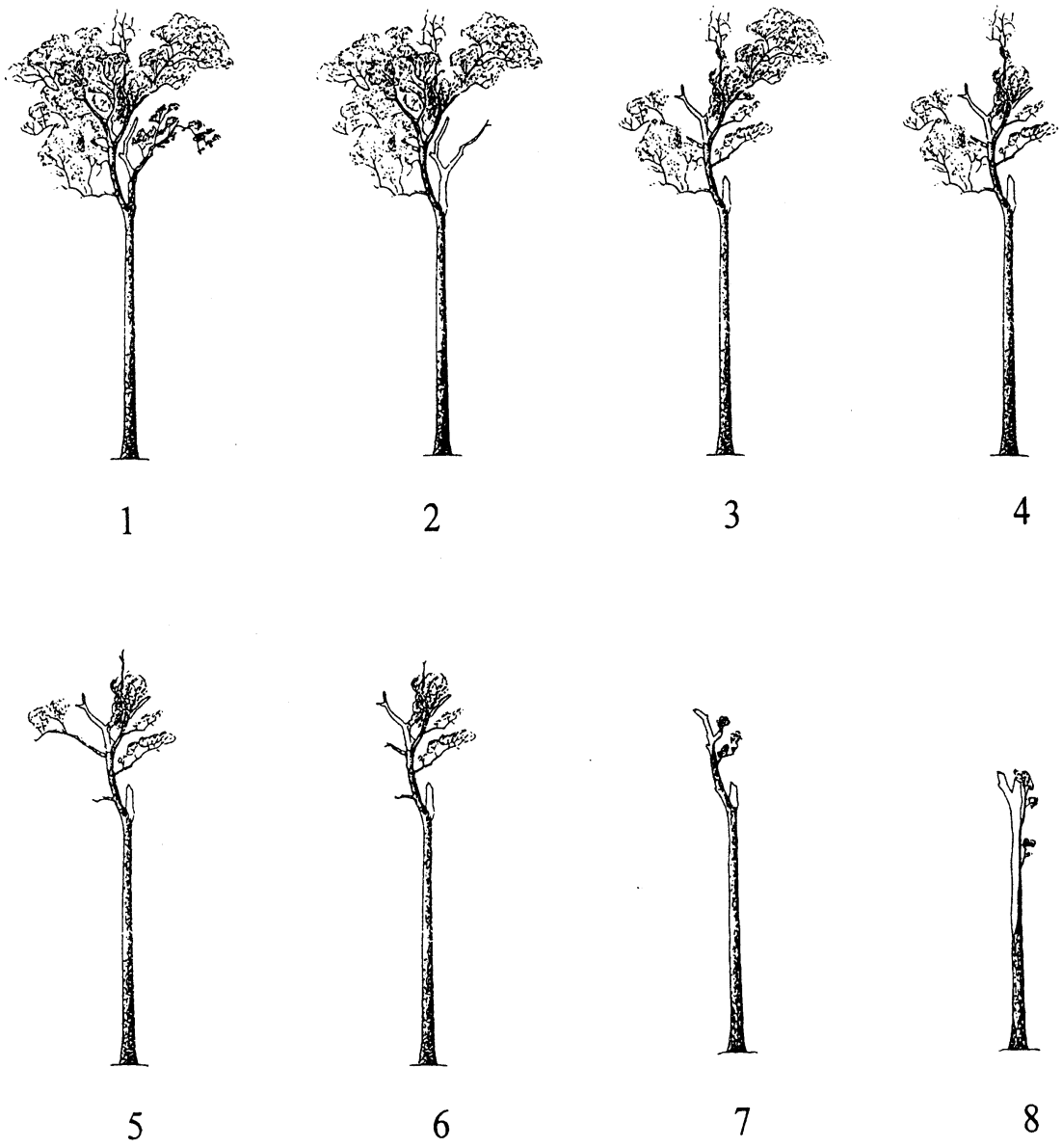

Figure 1: Categories of crown structure and deterioration in jarrah trees (from Whitford and Williams 2001).

3.2 Immature even-aged stands

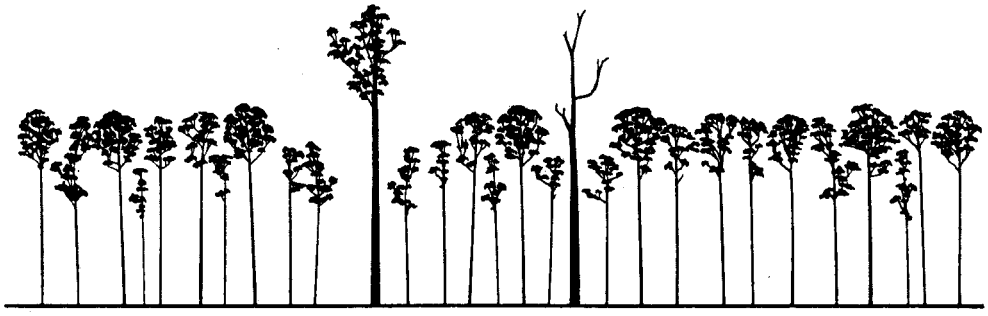

Figure 2: A representation of an even-aged immature stand.

These stands (Figure 2) consist of a predominantly single storey of immature trees of the same age forming a single layered canopy. They generally have 70-80% crown cover that may contain up to 15% overstorey crown cover of mature or senescent trees. They have resulted from the complete, or near complete, removal of the previous mature forest by either harvesting, clearing for agriculture or by high intensity fires. These include the stand development stages of "establishment", "juvenile" and "immature". Commercial operations generally occur in the 'immature', which are nominally those between 25 and 120 years of age. For the purposes of mapping and management planning, this category is restricted to stands exceeding 2 ha in extent, and those stands that contain up to 15% overstorey crown cover.

The silvicultural objective for these stands is to apply one or more thinning operations before harvesting for regeneration at the nominated rotation age. The majority of these stands have a planned rotation age of 100 years, but this may be varied to meet other management objectives.

See Silviculture Specification 1/92 for detailed management of these stands.

In even aged stands where *Armillaria luteobubalina* occurs, stumps left in the ground after thinning increase the substrate for *Armillaria*, which increases the potential for infection and damage or mortality of the retained trees. Infection causes damage to the roots and butt log, and can result in windthrow and mortality. Some losses from the fungus are inevitable but it is important to take whatever practical steps are possible to minimise damage from of the disease.

While *Armillaria* is widespread in the karri forest, the impacts of disease caused by it have been found to be most severe on high site quality sites. The impacts include a high incidence of infected stems, a high percentage of trees with substantial cankers and pockets of overstorey mortality.

The options for ongoing management include:

- Normal harvesting;
- Harvesting with stump removal (stump or whole tree pulling);
- Establishment of a trial and monitoring;
- Impose buffer (no thin) zone;

- Clearfell at age 60-80 and bulldoze stumps (the maximum clearfell patch size in regrowth forest is 20 hectares); or
- Do nothing.

Based on current knowledge of *Armillaria*, the operational practise in first thinning in high site quality sites is to incorporate stump removal, where there is evidence of the fungus infecting live trees. This reduces the potential for a build-up of the fungus inoculum.

First thinning is the best opportunity to minimise future impact from *Armillaria.* The ability to pull stumps at the second thinning will depend on the size of the trees and the equipment available at the time. Trees with evidence of *Armillaria* infection should be preferentially removed.

Evidence of *Armillaria* presence through pre-harvest or post-harvest inspection or machine operators and treemarkers observations will be recorded on coupe prints and forwarded to the Senior Silviculturist for use in adaptive management or research trials.

Where research and adaptive management trials suggest improved management actions for *Armillaria* the Senior Silviculturist will provide appropriate advice for implementation by harvest planners and treemarkers.

3.3 Single storied mature stands

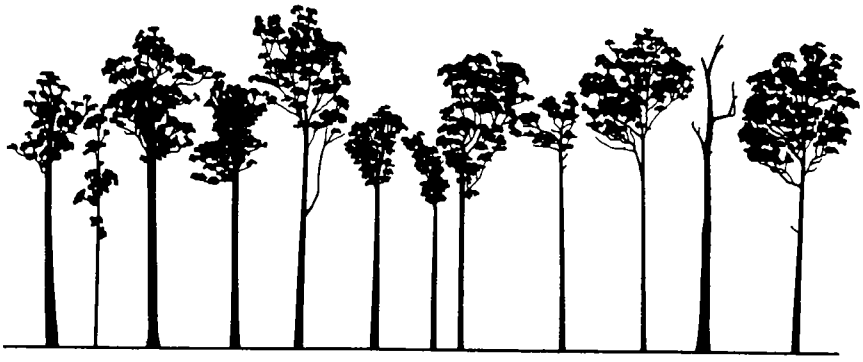

Figure 3: A representation of a single storied mature stand. These stands are not necessarily even-aged, but the majority of the trees are in the mature or senescent stage of development.

These are stands where the forest canopy is predominantly a single layer of mature and senescent trees (Figure 3). They generally have a canopy cover of 70-80 %. In mixed stands of karri and marri, the marri forms a lower layer than the karri but in the context of these guidelines they are considered to be part of the single upper-storey. Although a few smaller or younger stems do occur in these stands they are not a significant component of the overall structure.

Since all old growth karri is excluded from timber harvesting in formal or informal reserves under the Forest Management Plan 2004-2014, there will be few single stories mature stands in the short-term that are available for wood production. However, the current even-aged immature stands will develop into this category, if the rotation length for the particular stands exceeds 120 years.

When these stands are to be harvested, they will be cut to facilitate regeneration. This will involve the remove of all available merchantable trees to create the gap for regeneration, and may also necessitate the removal of a limited number of other cull trees, to create gaps a minimum of 120 metres in diameter. Regeneration may be achieved by retained seed trees, artificial seeding or planted seedlings. Marri regeneration in mixed stands will come from existing lignotubers and advance growth.

The maximum clearfell patch size in mature forest is 40 hectares.

The preferred method of regeneration is by seed trees when there is sufficient seed available to ensure successful regeneration. The seed tree method will not be used when seed availability at the time of the burn will be less than indicated in Appendix 1 or when the seed bed conditions are not conducive to producing acceptable stocking of regeneration (see Silviculture Specification 1/90).

Marri regeneration in mixed stands will come from existing lignotubers.

See Silvicultural Guideline 3/97 for guidelines on establishment of regeneration.

3.3.1 Seed forecasting

An assessment of seed availability is required to determine whether an area of forest can be regenerated using seed trees or whether it will need to be regenerated by seeding or planting.

Each coupe that has been nominated for regeneration by seed trees will be assessed for seed availability and monitored right up until the regeneration burn. The technique for this is the subject of a separate guideline.

Wildfire or prescribed burning is likely to cause abortion or premature seed shed. For that reason areas to be regenerated by the seed tree method should not have been burnt during the previous three years.

3.3.2 Clearfelling with seed trees

Where the planned method of regeneration is by seed trees and seed forecasting shows that there will be sufficient seed available at the anticipated time of the regeneration burn then the area will be marked to retain seed trees.

To achieve adequate regeneration using seed trees, the predicted minimum viable seed crop present at the time of the burn must be as outlined in Table 1.

Table 1: Seed requirements for seed tree burning

	Minimum seed/ha at time of burn	
Soil type	**Spring burn**	**Autumn burn**
Red "karri" loams (high quality 'pure' karri sites).	120,000	90,000
Podsols (Generally mixed K, M types).	180,000	135,000

Coupes being cut to seed trees will not have the dominant/codominant strata logged until flowering has finished. Cutting to seed trees prior to or during flowering may result in reduced cross-pollination and loss of flowers due to exposure.

Wherever possible, areas suitable for seed tree regeneration should be scheduled for harvesting in summer. Seed trees must not be retained in areas harvested in winter.

3.3.2.1 Seed tree stocking

Seed trees will be retained at a stocking of 3-4 trees/ha. This corresponds to a spacing of about 60 metres between the boles.

This number must be increased to 6 trees/ha (40-50m spacing) in areas with past severe fire damage or stands of less than average height class (commonly MK stands).

Additional seed trees may also be retained to provide for losses due to windthrow or falling damage if there is reason to believe that this will be a problem.

Seed trees must be marked before any harvesting of mature trees has begun.

3.3.2.2 Seed tree specification

The seed tree will be a wind-firm dominant or co-dominant tree with a healthy spreading crown, with good form and free from hereditary defect such as severe sweep and bends, forking or grain deviations. However it is permissible to retain any seed source (i.e. cull tree) if no seed tree meeting the above specification is available at the prescribed spacing. Areas larger than 1ha that are devoid of suitable seed trees will be clearfelled and planted.

3.3.2.3 Seed tree species

Seed trees will be karri. Marri regeneration will come from existing lignotubers. Blackbutt regeneration that may be required for specific sites will be established by planting or broadcast sowing.

3.3.2.4 Seed tree protection

Retain any additional tree which when felled is likely to uproot or damage the crown of a seed tree.

3.3.3 Clearfelling without seed trees

Where an area is unsuitable for seed tree regeneration, it is to be regenerated by hand planting or artificial seeding. Harvesting is to remove all merchantable trees (except retained habitat trees) within the demarcated coupe.

Areas harvested in winter must be clearfelled, ripped and planted. See Silvicultural Guideline 3/97 for guidelines on establishment of regeneration.

3.3.4 Combined regeneration methods

It is not essential that an entire coupe be regenerated by the same method. In sites where there is a patchy distribution of karri, it will not always be possible to obtain a full stocking of seed trees. Where insufficient seed trees occur, the patch (of 1 ha or more) should be clearfelled and

planted. Coupe photos must be examined before the area is prepared for regeneration to highlight these areas. Every location where seed tree stocking falls below that which is specified, and where seed surveys indicate have inadequate seed, must be identified for planting in the first winter following the regeneration burn. See Silvicultural Guideline 3/97 for guidelines on establishment of regeneration.

3.3.5 Diversity

Within patches of forest to be harvested for regeneration, the following will be retained in addition to the permanent exclusion zones and TEAS:

- Small patches of regrowth less than 2ha in size are to be retained if they can reasonably be protected during the regeneration burn; and
- All patches of regrowth over 2ha are to be retained and protected.

3.3.6 Removal of seed trees

The objective of this operation is to remove seed trees after they have shed their seed, with the minimum damage to seedlings and soil.

Sufficient time must elapse after the burn to allow seed to shed prior to seed tree removal. For burns carried out in November to February, allow 5 weeks before removing seed trees. For burns done in March to April, allow 3 weeks. Seed trees must be removed within 2 years of the regeneration burn.

See *Manual of Management Guidelines for Timber Harvesting in Western Australia* for harvesting practices that apply to the removal of seed trees.

3.4 Two-tiered stands

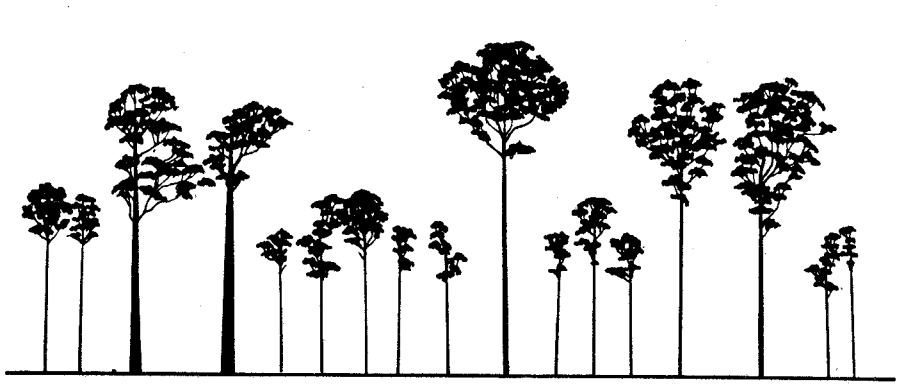

Figure 4: A representation of a two-tiered stand, which is characterised by a two-layered canopy composed of trees that are distinctly different in age or maturity.

Two-tiered stands result from selective logging or the less complete removal of the original overstorey by agricultural clearing or wildfire.

Two-tiered stands are extremely variable in composition. The overstorey may be vigorous or decadent and may vary in crown cover from 15-50%. Patches of regrowth in the lower storey may be distinct or ill defined and may vary in diameter from 40m to 140m. **Patches exceeding**

140m in diameter (2ha) are regarded as even-aged stands. The regrowth in all but the largest patches are under varying degrees of suppression, and selective removal of the larger trees will cause excessive damage to the regrowth if an attempt is made to manage them under a group selection system.

Consequently the silvicultural objective for these stands will be thinning or clearfall according to the size of the lower storey patches, and the composition of the surrounding forest.

The maximum clearfell patch size in two-tiered forest is 40 hectares.

The likely scenarios that are to be considered to define the management extent of the regrowth are:

1 For two-tiered stands that occur in conjunction with, or as an extension of older even-aged stands, the process is to:

- Thin from below incorporating both the even-aged and two-tiered stands. The thinning should be pushed to the practical and economic limit in the field. Regrowth stands may be retained as 'thinned' if they are stocked to half stocking (> 10 m^2/ha);
- Following thinning the quality and shape of the thinned stands should be assessed, and a boundary defined that provides the best practical management boundary for the retained regrowth; and
- The areas not identified for retention as regrowth, should then be scheduled for clearfelling and subsequent regeneration.

2 For two-tiered stands that occur in conjunction with predominantly mature forest, or young even-aged stands the process is to:

- Areas are generally to be clearfelled and prepared for regeneration;
- However in those instances involving small patches of two-tiered forest adjacent to younger regrowth, it is desirable to defer the clearfell until the patch can be managed in conjunction with the regrowth;
- Where small areas are to be retained they may be left uncut, or thinned to a basal area not conducive to the establishment of a regeneration cohort, depending on the particular circumstances; and
- These smaller patches will typically be long narrow strips (<60 m in width), which have resulted from a redefinition of management zonation.

3 For two-tiered stands that have varied regrowth patch sizes, or are affected by special management requirements such as high scenic value or other VLM issues, a *partial* cut may be appropriate, and the process is to:

- Mark the regrowth and mature components for removal;
- Remove the available sawlog and chipwood;
- Retain as much of the existing regrowth resource as possible where it is healthy and protectable, without compromising sawlog removal (retain chipwood if it would damage regrowth) or the safety of the operation;
- Remove all culls within four metres of a crop tree that are located more than five metres from a habitat tree;

- Carry out tops disposal, and heaping of slash to facilitate burning without damage to any retained regrowth;
- Burn and regenerate; and
- Remove the retained regrowth at the time of the first thinning (at that time a decision will be made whether to continue with a partially stocked thinning or cut to a gap with retained habitat and regenerate).

It is recognised that both the regrowth retained and the regeneration to be established may be well below the standards accepted for even-aged stands, and that felling damage to future regrowth will be high in some places. This is a recognised compromise to the future sawlog supply during a critical period when the wood resource from mature trees is limited and before the time when substantial volumes become available from regrowth forest.

Because of the wide structural and patch size variation that exists and the need for a highly 'customised' approach to fire management of these stands, it is not possible to provide detailed prescriptions for all combinations in these guidelines. However as a general guide:

- Regrowth that can be protected from damage during felling and subsequent burning should be retained;
- Regrowth stands may be retained as 'thinned' if they are stocked to half stocking (> 10 m^2/ha); and
- Remaining areas are to be clearfelled and prepared for regeneration.

Figure 5 illustrates the structure of a two-tiered stand before thinning and Figure 6 illustrates the structure after thinning for both large gaps and small gaps.

Delay the regeneration cut for as long as possible if thinning is proposed.

3.4.1 Coupes containing regrowth patches <140 m in diameter.

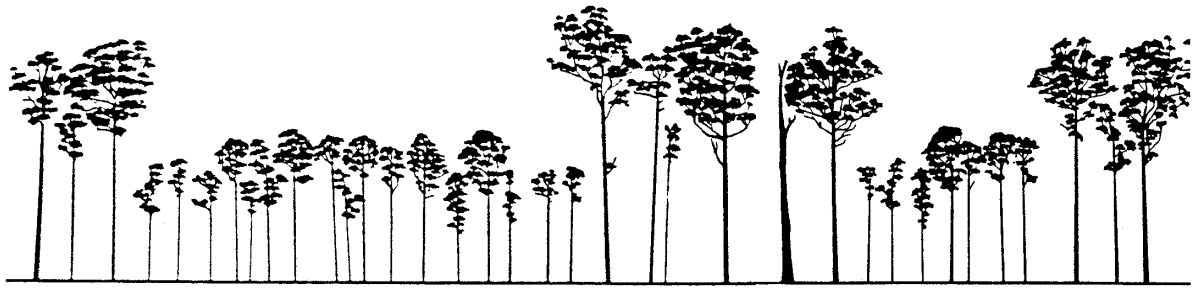

Figure 5: A representation, before thinning, of a stand containing regrowth patches 60 – 140 m in diameter.

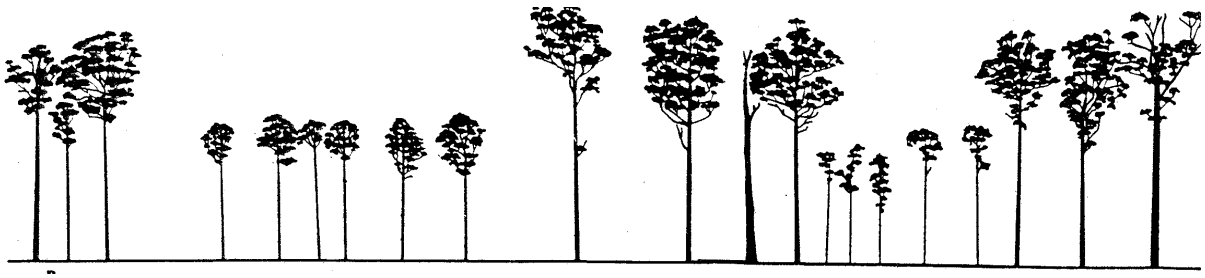

Figure 6: A representation, after thinning, of a stand containing regrowth patches 60 – 140 m in diameter.

Thin large gaps (60 – 140 m diameter) from below in accordance with Silvicultural Specification 1/92. Thinning from below involves removing the poorest and smallest components of the regrowth or lower storey of the stand, whilst retaining the larger trees to grow on.

Thin small gaps (< 60 m diameter) from above if these trees are large enough to provide small sawlogs. Retain a minimum of 20% crown cover within the lower storey patches to inhibit the emergence of young regeneration. Thinning from above involves removing from the lower storey only the larger regrowth stems that are marketable as sawlogs, retaining the smaller and unmarketable stems to be removed at the time of the regeneration harvest.

Figure 7 illustrates the structure of a two-tiered stand where the regrowth patches are all < 60m diameter before thinning, Figure 8 illustrates the structure after thinning and Figure 9 illustrates the structure after a pre-logging operation.

Regenerate the coupe when required by the methods described in Section 3.3.

3.4.2 Coupes containing regrowth patches that are all < 60 m in diameter.

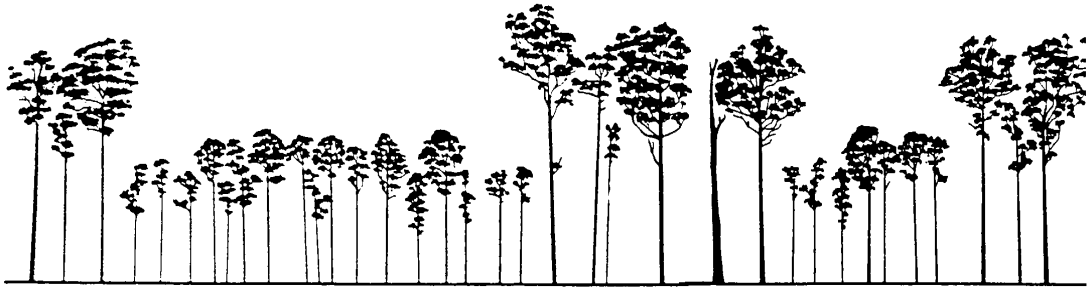

Figure 7: A representation, before thinning, of a stand containing regrowth patches that are all < 60 m diameter.

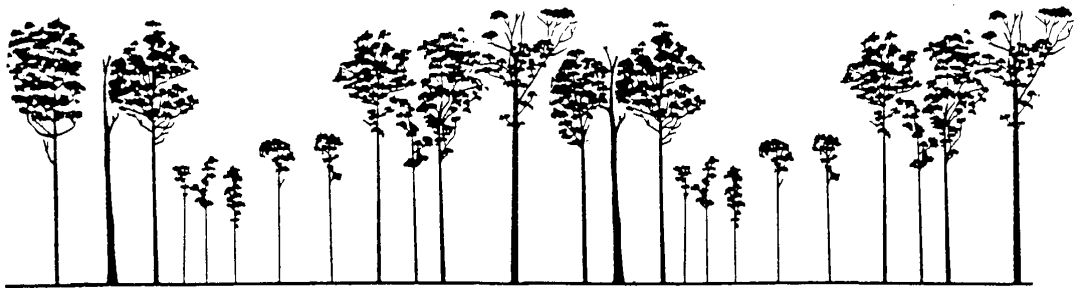

Figure 8: A representation, after thinning, of a stand containing regrowth patches that are all < 60m diameter.

If regeneration cutting is not planned within 3 years, thin from above (if harvesting for small sawlogs) ensuring that a minimum 20% crown cover is retained in the lower storey patches. See Figure 8.

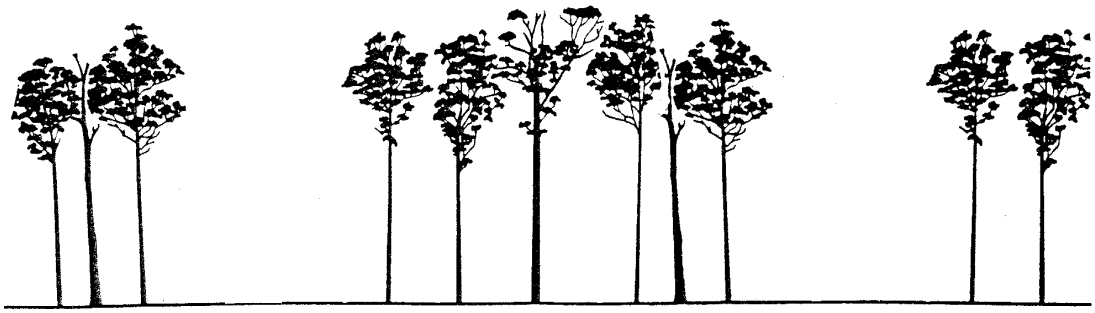

Figure 9: A representation, after a pre-logging operation, of a stand containing regrowth patches that are all < 60m diameter.

If the regeneration harvest is planned to be within 3 years, then undertake a pre-logging harvest as illustrates in Figure 9. Pre-logging is the complete removal of the lower storey prior to the main regeneration harvest.

The proposed management of these stands provides a precautionary process for the retention of areas of two-tiered forest within harvesting constraints, and will allow for patches that do not meet full stocking requirements or minimum patch dimensions, e.g. one to two hectares, to be considered.

3.5 Mixed karri / jarrah stands

Mixed karri/jarrah stands include a range of types within the karri/jarrah ecotone. They include stands with varying proportions of jarrah, karri and marri.

A mixed karri/jarrah stand is defined as one that contains between two and eight overstorey karri trees/ha, (i.e. with 5% to 20% crown cover of karri), within a predominantly jarrah, marri stand; or has contained such a stocking prior to selective logging.

These types occur as:

- Transition zones between karri and jarrah types where soil types change; and
- As substantial stands in their own right, where the site type favours neither the full development of a karri nor jarrah type.

These stands will be managed as mixed types where there are patches of 1ha or more.

The objective is to manage mixed karri/jarrah stands to retain the mixed species forest in the longer term, while acknowledging that the actual mix will vary over time.

3.5.1 Immature Even-aged Stands

These stand types are to be thinned one or more times before regeneration. Patches exceeding 140 m diameter (2 ha) are to be managed as even-aged stands.

Thinnings will be done according to SFM Guideline No 1 (2004) and Silviculture Specification 1/92, depending on the proportion of each species, with the overriding objective of retaining a mixed stand.

3.5.2 Mature and Two-tiered Stands

Pre-harvest surveys may be undertaken prior to treemarking in areas of mixed karri / jarrah forest, so that the most appropriate silvicultural treatment can be determined i.e. whether there is insufficient advance growth requiring planting of seedlings.

Pre-harvest surveys of regeneration should be carried out in any area that:

- Is a site-type likely to have insufficient regeneration (such as areas with ti-tree understorey); or
- Areas that have substantial variation in regeneration status. Visual assessment is not adequate in these situations.

Most of the mixed karri / jarrah forest will be one or other of these types, and pre-harvest regeneration surveys will generally be required, unlike in many areas of the northern jarrah forest.

The stocking of suitable advance growth is more easily assessed following prescribed burning and where possible surveys should be planned accordingly. Where burning is undertaken in autumn, ground coppice may take up to 12 months to develop sufficiently before surveys can occur. Burning in spring will allow surveying to take place in approximately six months, and less on some sites.

Regeneration surveys are best planned well in advance of harvesting to allow the information gathered to be used most effectively in the harvest planning process. Where possible, the timing of surveys should be linked to the prescribed burning program to enable the development over time of a bank of regeneration status information. Surveys may be undertaken well in advance of harvesting following prescribed burning (5-10 years), as regeneration status is unlikely to change significantly in this time.

Where early surveys have not been possible and surveys are planned to be completed closer to the time of harvest, the timing of any advance burning will need to consider the lead time required to allow for ground coppice expression to fully occur. Advance burning should be employed in stands that have a heavy understorey or where ground coppice is difficult to see.

Advance burning should ideally be completed well in advance of harvesting to enable enough time for dieback indicator species to regenerate.

If necessary for reasons of access, the advance burn may be completed prior to harvesting after permanent dieback boundaries have been marked but with sufficient time for lignotubers to reshoot.

Mixed mature and mixed two-tiered stands should be harvested using the silvicultural methods and treemarking as described in Sections 3.3 and 3.4. In patches that contained jarrah:

- Where the advance growth stocking is <25% of the desirable stocking of 1000 spha, plant jarrah at a stocking of 500 spha;
    - In addition to karri seed tree regeneration; or
    - In lieu of 500 karri planted seedlings; and
- Where jarrah advance growth stocking >25% of the desirable stocking of 1000 spha, no further jarrah planting is required.

The objective is to achieve an 85% stocking at the rate of 1666 spha of karri, jarrah or marri when assessed (Silviculture Specification 1/90) the following summer.

4 Control of harvesting

4.1 General

General matters of harvesting control are addressed in *Manual of Management Guidelines for Timber Harvesting in Western Australia.*

4.2 Retention of marri

Where trees cannot be removed as part of the commercial operation, additional work is required to reduce the competition on developing regeneration or retained crop trees to reasonable levels. This is generally referred to as culling or felling to waste and the trees to be removed are referred to as culls. They may be large trees, intermediate trees or small-sized trees depending on the particular situation.

With the reduced market for marri chipwood, there is a requirement to manage marri in harvesting operations. This must balance:

- The cost and waste, and the loss of biodiversity, resulting from culling; and
- The requirement to reduce competition to enable regeneration of karri and jarrah that have been removed as sawlog.

Where the density of marri after harvesting is such that effective regeneration is not possible, limited further removal of marri will be required to enhance the gaps that have been created by harvesting karri. Culling according to the following criteria will maximise the area suitable for regeneration with the minimum amount of felling:

- Where patches of forest have not been disturbed by harvesting consider leaving these in an undisturbed state by not undertaking culling;
- Where the basal area of marri over 50 cm dbhob is > 12 m^2 / ha (i.e. > 30 % crown cover), no further felling is to done;
- Where the basal area of marri trees > 50 cm dbhob is 6 - 12 m^2 / ha, further non-commercial removal of marri is required as follows:
    - Remove all trees < 30 cm dbhob;
    - Remove marri trees > 30 cm dbhob to reduce the basal area to < 6 m^2 / ha (to about 15% crown cover), concentrating on creating gaps > 120 m diameter free of overstorey (1.4 hectares);
    - Retain trees with obvious habitat potential; and
    - Preferences for removal are trees with poor crowns, dying trees, hollow-butts, leaning trees and trees containing ‘widow-makers’ in the crown;
- Where the basal area of marri trees > 50 cm dbhob is < 6 m^2 / ha:
    - Remove all trees < 30 cm dbhob; and
    - Remove trees > 30 cm that have poor crowns, dying trees, hollow-butts, leaning trees and trees containing widow makers in the crown.

Following commercial harvesting, areas with retained marri are to be treemarked for retention, according to the above criteria. Culls are preferably to be removed by falling rather than

pushing, to limit soil disturbance. In moderate to high intensity regeneration burns, where retained marri are surrounded by heavy tops or logs, then this debris is to be pushed away to a distance of at least 5 metres. Where heaps are being created this distance should be a minimum of 10 metres from trees marked for retention. Tops disposal to a minimum distance of 1 metre will be undertaken during burn preparation in areas with retained marri.

4.3 Harvesting and regeneration on steep slopes

These areas will be delineated before logging commences. In general:

- Slopes >20^{o} will not be logged;
- Slopes 14-20^{o} will require the special measures described below. They will:
  - Be burnt for regeneration in spring not autumn;
  - Not be cut to seed trees;
  - Only be logged under dry soil conditions; and
  - Have erosion control measures in place before the end of March or during any temporary cessation of logging.

5 Landing rehabilitation

5.1 Purpose

The purpose of landing and snig track rehabilitation is to provide for the resumption of ecological processes on these areas following harvesting, through the establishment of an indigenous vegetation cover which includes both understorey and overstorey species.

While the return period for the next harvest may be well into the future, many of the landings and snig tracks will remain a part of the infrastructure for future harvesting. For that reason there is no intention to return them to full productivity and stocking from a timber production viewpoint, but to revegetate them to a state where they will contribute a range of the other forest values.

Procedures for the physical rehabilitation of landing sites are described in the *Manual of Management Guidelines for Timber Harvesting in WA.*

5.2 Revegetation

Sow on to recently ripped landings and snig tracks in autumn before the first winter rains, using approximately 1.5kg / hectare of local seed, as outlined below. Simultaneously fertilise with 400 kg/ha of Di-ammonium phosphate (DAP) or an equivalent rate of an approved fertiliser.

Reseeding on landings and snig tracks is aimed at re-establishing the nutrient cycling in the soil by contributing to the carbon and nitrogen cycles. To do this seed should be collected from the local area targeting species with the following attributes:

- Nitrogen fixers;
- Non-mycorrhizal;
- Easy to collect; and
- Likely to accumulate organic matter quickly.

These will include *Allocasuarina*, 4 or 5 *Acacia* species, and 4 or 5 legumes (*Bossiaea*, *Gompholobium*, *Hardenbergia*, *Hovea*, *Kennedia*, etc). The mix will be supplemented with small amounts of jarrah, blackbutt, marri and wandoo seed where the characteristics of particular coupes or landings dictate. It is expected that this sowing will be supplemented by natural seed dispersal from adjacent vegetation to provide establishment of other local species.

The proposed seed mix for all areas to be revegetated is to be approved by the Department's Senior Silviculturalist.

5.3 Monitoring and remediation

Success of revegetation is to be monitored no sooner than the end of the first summer following seeding. Monitoring is based on a stocked quadrat method with samples of each landing.

5.3.1 Method

- Locate 5 sample points on each landing, subjectively chosen to include 1 plot in what is visually the best, 1 in the worst and 3 plots throughout the range. The centre point of each plot must be selected to allow the whole plot to fit within the rehabilitated area;
- Mark the centre point of each plot;
- Search for understorey plants within a radius of 1.13 m (4 m^2) – the plot is stocked if 1 understorey plant occurs within that area (equates to 2500 seedlings/ha); and
- Search for overstorey plants within a radius of 2.26 m (16 m^2) – the plot is stocked if 1 overstorey plant occurs within that area (equates to 625 stems/ha).

5.3.2 Success criteria

The landing can be recorded as successfully regenerated if at least 3 of the 5 sample plots are recorded as stocked with understorey and overstorey seedlings. The same plot does not necessarily need to be stocked with both understorey and overstorey seedlings for this success criterion to be achieved.

This success rate equates to 60 % stocking at the rate of 2500 understorey seedlings/ha and 625 overstorey seedlings/ha.

5.3.3 Remedial action

- If the landing is not stocked with understorey but is stocked with overstorey no remedial action need be taken;
- If the landing is stocked with understorey but not with overstorey, infill planting is to be arranged for the following winter at the rate of 625 overstorey seedlings/ha; and
- If the landing is not stocked with understorey or overstorey seedlings the landing is to be re-scarified, re-sown with understorey seed and planted with overstorey seedlings at the rate of 625 seedlings / ha in the following winter.

6 Fire management

6.1 Tops disposal burning

The objective of tops disposal burning is to reduce fire hazard by the removal of flash fuels and woody material up to 2.5cm in diameter. Tops disposal burning will usually be done after thinning.

Tops disposal burning in thinned stands of karri or karri marri should be carried out according to the criteria in Table 2, Column No. 1, and tops disposal burns in karri / jarrah stands should be carried out according to the criteria in Table 2, Column No. 2. Tops disposal burns are usually low intensity, and to protect the retained trees these burns must also take account of the Soil Dryness Index (SDI) and Profile Moisture Content (PMC) limits which are specified.

Tops disposal burning should be programmed for 2 years after thinning, so that nutrients in the tops can be released, prior to combustion.

The timing and intensity of these burns can be varied to meet a number of objectives such as the regeneration of understorey species, habitat manipulation etc, providing that the intensity of the burn does not compromise the survival or quality of the regrowth.

Post-thinning burns must not be done in autumn. The dry fuel conditions and the long residence time of fire at the base of the trees will cause mortality even under mild conditions. The ignition pattern should take into account aspect, slope and localised patches of heavier fuel. Debris > 75 mm in diameter must be removed at least 1m from the base of the trees.

Table 2: Fire characteristics for post thinning burning in the karri forest.

Column Number	**1**	**2**
Type of burn	**Tops Disposal Karri and karri / marri stands**	**Tops Disposal Mixed karri / jarrah stands**
Silvicultural objective	Post-thinning tops disposal	Post thinning tops disposal
Fuel removal objective	Debris < 2.5 cm	Debris < 2.5 cm
Timing	> 2 yrs after thinning	> 2 yrs after thinning
Season	Spring	Spring
FDI [2]	12-26	12-26
PMC	> 90 %	
SDI Spring	< 500	< 600
SDI Autumn	N/A	N/A
Intensity kW/m	120-250	120-250
Maximum Scorch Ht	6.0 m	6.0 m

[1] Autumn burning may only be considered on a case-by-case basis with approval from the Department's Senior Silviculturalist.

[2] Prescribed FDI (Fire Danger Index) is based on the litter component of available fuels. Use Jarrah FDI for all interpretations.

* refer to *Forest Fire Behaviour Tables for Western Australia 1998* (Red Book)

** may be considered on a case-by-case basis with approval from the Department's Senior Silviculturalist.

6.2 Response to fire damage in karri regrowth

When regrowth forest is damaged by high intensity fire it is often difficult to determine in the short term the long-term extent of the damage and therefore the most appropriate course of action to take. However if the appropriate action is not taken immediately the options for effective action in the future may be severely limited.

The following tables (Tables 3, 4 and 5) have been developed on the basis of experience and observation of previous fire damage events and should be followed until further monitoring provides evidence for amendment.

Due to the different initial establishment targets (1250 spha pre 1992, 1666 spha from 1992 to 1996 and 2200 spha after 1997), and mortality over time it is essential to assess the number of live stems available to coppice after the fire. The objective of the post fire treatment is to ensure that the damaged stand returns to a productive state. It is considered that a stocking of 1000 stems per hectare (representing 85% of the initial minimum stocking) of vigorous coppice will be sufficient to result in reasonable productivity and wood quality. If the stand does not have this stocking, then the damaged stems should be removed through the use of moderate to high intensity fire. Experience has shown that another fire applied to stumps will kill the majority of them, and will also remove debris and provides additional ashbed to facilitate regeneration of the stand. The removal of the existing stand of damaged trees is important because it is unlikely that infill planting will result in effective establishment of the stand, in the presence of coppice.

Table 3: Activities and responsibility for action following fire damage to regrowth

Activity	Responsibility
Notify the Department's Senior Silviculturalist of fire event in regrowth stand	District Fire Co-ordinator
Procure arial photographs of the stand.	Forest Management Branch
Inventory damage and delineate damage classes (unburnt, burnt, scorched, defoliated)	Forest Management Branch
Define site quality, age, top height and stocking level	Forest Management Branch
Define 'manageable units' based on above and damage class. Refer Table 4 & Table 5 for remedial action	Senior silviculturist
Estimate budget for required activities	Forest Products Commission
Schedule operations	Forest Products Commission / CALM
Amend SILREC records	Forest Management Branch
Post regeneration survey (18 months after regeneration treatments)	Forest Management Branch*

* Necessary to confirm the survival and spacing of coppice following remedial action.

Table 4: Follow-up action for stands scorched by high intensity fire

Top height	SDI	Action
<25 m	< 1000	No action required. Expected that stands will fully recover
	> 1000	Inspect for cambium damage and undertake follow-up action as per Table 6
>25 m	< 1000	These stands are to be inspected by the senior silviculturist to determine whether the stand is to be salvaged and planted or grown on. Inspect for likely damage to cambium.
	> 1000	Undertake follow-up action as per Table 5.

Table 5: Follow-up action for karri stands defoliated by high intensity fire.

Stand top height	Stocking level post fire	Site Index θ	Action	
			Immediate	Delayed
< 15 m	Stocked	All	Nil *	Nil
	Understocked (<1000 spha of potential coppice)	> 40	Remove coppice and replant	
		< 40	Replant understocked areas of > 2.0 ha only	Clearfell when economic
15-25 m	Stocked	All	Coppice (salvage if possible)	
	Understocked (< 1000 spha of potential coppice)	>40	Remove coppice and replant (salvage if possible)	
		<40	Coppice (salvage if possible) Replant understocked areas of >2.0 ha only	
> 25 m	All		Salvage, site prep, rip, plant	

* Expected to coppice naturally to a satisfactory stocking standard.

0 Site index is the height of the tallest 25 spha (estimated as the height of the tallest two trees within a 16 m radius) at age 50. See Figure 9 to determine SI from the height at any age.

7 Records

Good silvicultural records are essential for future managers to assess the condition and needs of the forest without having to undertake detailed assessment. The aim is to have an accurate description of the condition of the forest when the operation is completed.

Harvested areas will be photographed in December each year for entry into SILREC and subsequent reporting.

Areas managed as karri, jarrah or mixed stands should be clearly indicated.

8 References

CALM (1990). *Karri regeneration surveys*. Silvicultural Specification 1/90. Department of Conservation and Land Management.

CALM (1992). *Karri thinning*. Silvicultural Specification 1/92. Department of Conservation and Land Management.

CALM (1997). *Establishment guidelines for karri forest regeneration following harvesting*. Silvicultural Guideline 3/97. Department of Conservation and Land Management.

CALM (1999). *Manual of management guidelines for timber harvesting in Western Australia*. Department of Conservation and Land Management.

Conservation Commission (2004). *Forest Management Plan 2004-2013*. Conservation Commission of Western Australia, January 2004.

Whitford, K.R. and M.R. Williams (2001). Survival of jarrah (*Eucalyptus marginata* Sm.) and marri (*Corymbia calophylla* Lindl.) habitat trees retained after logging. *Forest Ecology and Management* **146**: 181-197.

Sneeuwjagt, R.J. and G.B. Peet (1998). *Forest fire behaviour tables for Western Australia*. Third Edition. Department of Conservation and Land Management.

Appendix 1: Growing habitat trees

'Old tree' habitat in State Forest karri is provided for within:

- retained stream zones;
- strips of forest retained along specific roads;
- additional patches of mature forest retained every 400m.

To ensure continued recruitment of habitat trees, however, it is desirable to develop potential habitat trees of an intermediate age between the generally mature patches and the developing regrowth.

This can be done be retaining immature trees (say 40-80 years of age) and growing them in a way that will enhance the development of hollows at an earlier age than would normally occur.

In forest to be harvested for regeneration, potential habitat trees can be grown in the following fashion:

Figure 1: Retained trees shortly after the regeneration burn – showing the development of epicormics on the bole.

Retain two trees per hectare in the 30-50cm dbh range.

- Ensure that the retained trees are not surrounded by heavy tops or logs that may lead to them being killed during the regeneration burn.
- It is preferable to scorch these trees during the regeneration burn. This will stimulate the development of an epicormic crown along the bole.
- In the early years of regrowth development, the retained trees will be open grown allowing the epicormic crown to become established. Growth rate will be rapid.
- By the time the stand is 50 years old, the regrowth will have overtaken the retained trees and be a similar height. The retained trees will be about 100 cm dbh with a deep crown (on about half their total height). The lower epicormic branches will progressively die as light levels below the regrowth canopy are reduced. The dead branch stubs, with a vigorous crown above, then have the potential to begin forming hollows. These trees are capable of living for another 150 years.

Examples of this process can be seen in existing regrowth forests which are now 20 to 60 years old.

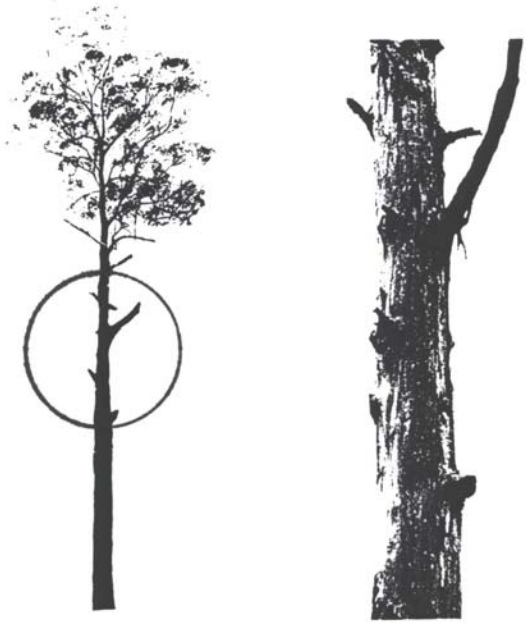

Figure 2: 50 years later the epicormics have grown and become suppressed. Lower branches have died and broken off.

Last updated: 7 January 2005
Custodian: Manager Policy and Practices Branch,
Approved by: Director Sustainable Forest Management