Silviculture Guideline for Karri Forest

Sustainable Forest Management Series

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FEM Guideline No. 3

Department of
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This Guideline supersedes:
SFM Guideline 3 2005 Silvicultural Practice in Karri Forest

when applied in conjunction with:
Silvicultural Reference Material for Karri Forest (2014)
Silviculture Manual for Karri Forest (2014).

Cover illustration: Developed by Clare Martin, Strategic Development and Corporate Affairs, Department of Parks and Wildlife

Deirdre Kaye Maher
20 June 1967 - 13 August 2011

Deirdre Kaye Maher was a wife, mother, friend, passionate forester and community member. Deidre began the consultation and development of these guidelines before her illness and contributed a great deal to these guidelines.

Deirdre's career with the Department of Conservation and Land Management (CALM), later the Department of Environment and Conservation (DEC), began in 1990 as a junior officer at Manjimup at a time when women were a rarity in forestry, and District field operations in particular. Deirdre soon became familiar with what was required and quickly gained the respect of contractors and crews by never trying to be "one of the boys", but by being proud to be a woman in a predominantly male workplace.

It was during the early years of her career that Deirdre developed her love of silviculture, especially the intricacy of jarrah forest management. In 2007 Deirdre was appointed Senior Silviculturalist with DEC and worked out of the Bunbury Office for over three years. Her experience and attention to detail earned her great respect and staff soon found out that work completed to Deirdre's satisfaction would stand up to any scrutiny inside or outside the Department.

Deirdre was much loved by her husband Tony, and their children Leah and Michael. Deirdre passed away too young, with so much more to contribute to the science of forest silviculture, a knowledge and skill that will become increasingly important for sound management of the forests of the south-west Western Australia in the face of changes in climate and community expectations.

Table of Contents

1. Framework for this guideline

Purpose

The purpose of this document is to provide guidance on the application of silvicultural practices in those parts of the karri forest that are subject to timber harvesting. Guidelines are generally not prescriptive, but provide the intent and guidance for forest managers.

Scope

This guideline deals with the silvicultural management of the karri forest available for timber harvesting and applies to State forests and timber reserves and freehold land that contains indigenous vegetation and which is vested in the Conservation and Land Management (CALM) Act Executive body. The guideline contains some strategies which may not be strictly silviculture, but are integral to and/or managed as part of the silvicultural system. The guideline does not cover the identification of informal reserves or other areas from which timber harvesting is excluded, as this process occurs prior to the application of silviculture and is referred to in this document as the coupe planning process.

Context

This guideline provides the framework for operational practices which meet those goals and proposed operations of the Forest Management Plan 2014-2023 (FMP) that are implemented through silvicultural practice. Legislative requirements are detailed in Appendix 1. Measures to protect soil, including suitable times to conduct timber harvesting operations, are addressed in Soil and water conservation guideline, Sustainable Forest Management (SFM) Series Guideline No 5 (2009), and subsidiary documents. Current versions of all SFM guidance documents are available at http://www.dpaw.wa.gov.au/management/forests.

This guideline provides guiding principles, rationale and strategies, whereas supporting manuals and procedures are intended to provide detail regarding operational practices (Fig 1).

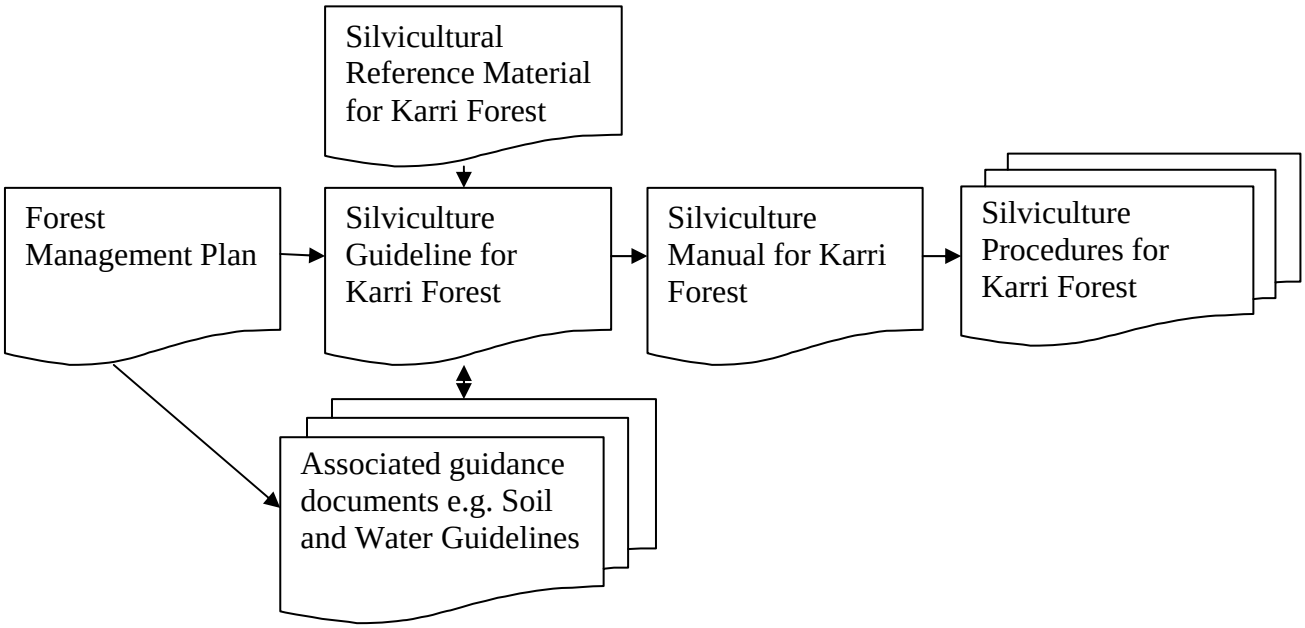


Figure 1. **Diagrammatic representation of the hierarchy of documents to guide the application of silviculture in the karri forest.**

Separate guidelines apply to the jarrah forest and to the wandoo forest. Silvicultural practices for mixed jarrah/karri/marri forest are covered in this guideline.

The manuals and procedures which support the application of this guideline provide instruction on applying silviculture in the jarrah forest. It is important that forest officers are expected to have sufficient training and experience to be competent in applying silviculture in the karri forest, and to facilitate this, training is provided.

Custodianship and management of this guideline

This guideline is a controlled document. The custodian is the Manager, Ecosystem Health Branch, Forests and Ecosystems Management (FEM) Division of the Department of Parks and Wildlife (DPaW).

Application and scale of silviculture

What is silviculture?

Silviculture is the theory and practice of growing and tending forests to achieve management objectives. Historically more associated with timber production, contemporary silviculture encompasses economic, environmental and social objectives to achieve ecologically sustainable forest management. It is applied to achieve a wide variety of outcomes including soil and water protection, wood production, catchment management, habitat for wildlife, maintenance of aesthetics, and provision for recreation.

Objectives may be complementary to, or to some extent, in competition with one another. The silvicultural method(s) applied are therefore designed to achieve a balance between objectives, and those objectives may differ at the local and landscape scale in order to achieve the desired balance of objectives for the whole of forest. The *Silvicultural Reference Material for Jarrah Forest* (Department of Parks and Wildlife 2014), provides a summary of the scientific and observational information that underpins the karri silvicultural system.

In common with other wet sclerophyll eucalypts, karri will not regenerate without the dense understorey first being removed (in natural circumstances by fire) to allow the small seed

be in direct contact with mineral soil to germinate. Fire is important for the natural regeneration and biodiversity of the karri forest. High intensity fires periodically create the conditions required for karri forest to regenerate (large canopy openings and removal of the understorey). Most understorey species found in the karri forest are obligate seeders and require periodic fire for their renewal.

Karri is a relatively intolerant species, meaning it is not tolerant of competition with other trees for growing space, light, nutrients and water. To successfully regenerate karri requires an absence of competition during establishment. Karri is a very large, tall tree growing to 80m with a wide deep crown, so falling mature trees can create damage to other vegetation over a large area. Protecting younger regeneration from felling damage is another reason large canopy gaps are required in karri silviculture. For these reasons karri is regenerated as large patches of even-aged regrowth produced from clearfelling.

Ongoing management of these even-aged stands involves several thinning events before a final felling and regeneration at a rotation age of about 100 years. The decision to regenerate or to thin a stand is based on the structural condition of the stand, together with consideration of the needs of the timber industry. Variation to clearfelling for regeneration is made in mixed jarrah/karri and or marri stands and in uneven aged stands.

Towards the end of the previous FMP (2004-2013) a review of current silvicultural practice (Burrows *et al*. 2011) made a series of recommendations to be considered in the FMP (2014-2023). The primary recommendation was implementation of forest management to achieve a better water balance in a drying climate. Concern was raised over the impacts of human induced climate change, particularly decreased water availability and its effect on forest health and the health of associated ecosystems, especially aquatic ecosystems. This has been addressed within the current guidelines in Guiding principle 10 – *Promote ecosystem health and vitality through silvicultural management*, and Guiding principle 13 – *Silvicultural treatment of native forest may be used to maintain or enhance the flow of water to surface and ground water reserves*. The purpose of Guiding principle 10 is to apply silvicultural management to protect threatened ecological values or communities where the effects of climate change will escalate the threat to the value or community. The purpose of Guiding principle 13 is to increase the flow of water to groundwater and surface reservoirs which will enhance aquatic ecosystems, but also potentially be available for consumptive purposes. In light of declining rainfall leading to reduced risk of salinity associated with rising groundwater the review recommended phased harvesting requirements be revised and this has been addressed in Guiding principle 12 – *Water quality will not decline as a result of silvicultural treatment*. Other changes incorporated into the current silvicultural guideline concern changes to retention of habitat elements (strategies 9, 10, 13, 14, 15 and 17) and thinning (14).

Scales of management

The management of silviculture considers three scales of management which are as follows:

- *Whole of forest* – all karri forest categories that are subject to the FMP.
- *Landscape* – a mosaic where the mix of local ecosystems and landforms is repeated in a similar form over a kilometres-wide area. Several attributes including geology, soil types, vegetation types, local flora and fauna, climate and natural disturbance regimes tend to be similar and repeated across the whole area. It could be a (sub) catchment or, for convenience, an administrative management unit such as a forest block or an aggregation of forest blocks. Landscape scale management could span a few thousand to many tens of thousands of hectares. In this guideline, reference is sometimes made to landscape management units

(LMU's), which are based on mapping of vegetation complexes (see (Mattiske *et al*. 2002).

- *Local* – a discrete area of land to which one or more operations have been or are planned to be applied. It could span tens of hectares to perhaps a few hundred hectares. As a guide, for the purposes of this document, local scale is the average area of the forest blocks in the vicinity subject to, or potentially subject to harvesting in the three year harvest plan.

Silviculture is usually applied at the patch level with a silvicultural objective selected appropriate to the condition of the stand. However, silviculture is also guided by the condition of the forest at the landscape scale and seeks to provide for ecologically sustainable forest management at the whole of the forest scale.

This document includes twenty four guiding principles that provide the framework of silvicultural practice in the karri forest. A guiding principle is a statement that communicates a basis for management decisions. This guideline has been prepared to accompany the FMP and is consistent with the settings adopted for the FMP.

2. Summary of guiding principles for silviculture in the karri forest

Guiding principles for biological diversity	
1.	Knowledge of natural disturbance regimes will be used to guide the size and intensity of silvicultural practices to ensure they contribute to the maintenance of landscape heterogeneity.
2.	Silvicultural practices will contribute to the maintenance of connectivity.
3.	Key structural features will be retained as legacy elements in silviculturally managed forests.
4.	Natural regeneration will be used wherever possible.
5.	Compositional diversity will be maintained in silviculturally managed forests.

Guiding principles for ecosystem health and vitality	
6.	Promote resilient stands on sites with high levels of overstorey mortality or stress through silvicultural management.
7.	Reduce log degrade through silvicultural management.
8.	Prescribed fire will be used to protect fire sensitive regeneration and reduce high fuel loads that may result from silvicultural practices.
9.	Silvicultural management will be used to maintain forest nutrient cycling processes.
10.	Promote ecosystem health and vitality through silvicultural management.

Guiding principles for soil and water	
11.	The extent and severity of harvesting disturbance on soil values will be minimised and damaged soil remediated.
12.	Water quality will not decline as a result of silvicultural treatment.
13.	Silvicultural treatment of native forest may be used to maintain or enhance the flow of water to surface and ground water reserves.

Guiding principles for climate change and carbon cycles	
14.	Forests will be managed to maintain forest carbon stocks, provide forest products and contribute to the mitigation of climate change.

Guiding principles for productive capacity	
15.	The most appropriate silvicultural method will be applied to each stand to support short and long term productivity.
16.	Regeneration and tree growth will be enhanced through action to alleviate competition on regeneration and selected trees.
17.	Silvicultural methods will reflect site productivity and development stage of the stand.
18.	The forest will be regenerated in a timely and effective manner.
19.	Trees to be retained will be marked and protected from damage.
20.	Forest areas that are killed or damaged by fire or other agents may be restored or salvaged.

Guiding principles for heritage	
21.	Harvest disturbance will be managed to avoid adversely affecting Aboriginal cultural heritage values and sites.
22.	Harvest disturbance will be managed to avoid adversely affecting Australian cultural natural heritage values and places.

Guiding principles for socio-economic values	
23.	The capacity of forest areas will contribute to the social and economic sustainability of regional communities.
24.	Visual landscape management will be used to manage potential effects of silvicultural treatments on visual amenity.

3. Guiding principles for biological diversity

Overall objective

Conserve biodiversity and self–sustaining populations of native species and communities, and facilitate the recovery of biodiversity from harvesting disturbance operations.

Within the area covered by the FMP, biological diversity is conserved through formal reserves, selected to be comprehensive, adequate and representative, the multiple use forest area, informal reserves, temporary exclusion areas (TEAS) and fauna habitat zones (FHZ), which together, represent a significant continuous area of forest cover. Habitat elements are retained in harvested areas through the application of silvicultural guidance. The small proportion subject to harvesting disturbance operations in any one year can re-establish from propagules existing on site and/ or be re-established using seed or seedlings selected for the site. To assist re-establishment, structural complexity and landscape heterogeneity of the forest are maintained at multiple spatial scales, facilitating the movement of genetic material and individuals. Disturbance supports biodiversity so long as the scale and intensity of disturbance are appropriate.

Guiding principle 1

Knowledge of natural disturbance regimes will be used to guide the size and intensity of silvicultural practices to ensure they contribute to the maintenance of landscape heterogeneity.

Rationale

Karri forest undisturbed by timber harvesting occurs as either even or uneven-aged stands, tending to be dominated by one or a few age classes. Stand replacing fire contributed to the pattern of age distribution in karri forests in the past, creating even-aged stands up to, but rarely exceeding 200 hectares. Uneven-aged stands were formed by partial replacement of an age cohort by fire and subsequent regeneration. In karri, uneven-aged stands comprising mature trees intermixed with younger trees are referred to as two-tiered stands. A diversity of structures across the landscape contributes to the biological diversity of the forest, with some species favoured by the habitat of early development structures, others by the later stages and others by a combination of two or more. Providing a mosaic of structural types across the landscape can encourage a wide variety of habitats and plant and animal communities, and thus, enhance ecosystem resilience.

Landscape heterogeneity within the karri forest is retained by limiting clearfell coupe size, dispersing harvest operations throughout the landscape and retaining reserves. This supports the retention of ecological communities associated with particular development stages and the ability of those communities to migrate within the forest. A range of age structures also provides a range of responses to natural disturbance such as fire or storms.

Strategies

1. In clearfell operations, pure karri stands which are predominantly mature or uneven aged forest will have clearfell patch size no more than 40 hectares.

2. In clearfell operations, immature stands of karri will have clearfell patch sizes of no more than 20 hectares (this strategy also contributes to Guiding principle 2).

3. In clearfell coupes, retain or thin all patches of juvenile or immature karri where they can be protected from harvesting and the regeneration burn.

Guiding principle 2

Silvicultural practices will contribute to maintenance of connectivity.

Rationale

Connectivity is the degree to which the landscape facilitates or impedes movement and or exchange of organisms, reproductive material or propagules. Connectivity is achieved by creating functional or structural linkage of habitats, communities and ecological processes. The exchange of individuals or genes among populations in different habitat patches influences both dispersal and genetic diversity and is an important consideration for persistence and resilience of populations, as well as re-colonisation by those species displaced following natural or harvesting disturbance. Connectivity is particularly important in light of human induced climate change, as species or communities may need to reposition themselves in the landscape. Connectivity can be supported in the multiple use forest area through maintaining a variety of habitat at multiple spatial scales. Informal reserves (such as stream zones), and other areas temporarily excluded from operations, such as FHZ, provide areas of forest within which silvicultural treatment is not applied. Heterogeneity at the landscape scale avoids the creation of barriers to biological and ecosystem processes, including the physical movement of species or their propagules within the landscape. Connectivity is also maintained through the imposition of limits to the application of silvicultural treatments. Some species have a preference for particular structural elements, so contemporary silvicultural practices seek to retain a heterogeneous forest structure at the landscape scale. Silvicultural practices seek to mimic the size and intensity of natural disturbances to which native forest ecosystems have evolved (see strategies listed against Guiding principle 1).

The scale and intensity of disturbance that would represent a barrier to biological and ecosystem processes varies from species to species, and the degree to which the disturbance alters the structure of the forest at the local scale. At the local scale, silvicultural treatments retain stand structural complexity to encourage the persistence and re-colonisation of treated forest (for example, the retention TEAS and legacy elements such as mature trees, logs, understorey and overstorey elements see Guiding principle 3). The retention of these elements provides habitat for species which may have limited dispersal, and retains mature forest elements in the regenerating forest.

TEAS are primarily left as a means of ensuring coupe size does not exceed the allowable limits in areas where the previous harvest took place on a broad scale and the nature of the landform meant that the density of informal reserves is relatively low.

Strategies

4. During harvest planning, the application of TEAS will limit clearfell size and provide structural complexity locally and heterogeneity within the landscape.

5. During harvest planning, ensure the maximum size for clearfell patches in immature even-aged karri forest is 20 hectares and the maximum size for clearfell patches in mature and uneven aged forest is 40 hectares.

6. During harvest planning, aim to retain a heterogeneous mix of development stages at the local and landscape scale to provide a variety of structures and habitats (as per Guiding principle 1 and 2).

7. During harvesting operations, legacy elements will be retained in harvested coupes to provide structural complexity and provide connectivity for species which require legacy elements for their life cycle (this strategy also contributes to Guiding principle 3).

8. During regeneration operations, support the rapid development of the karri understorey to provide shelter, food and connectivity within the forest.

Guiding principle 3

Key structural features will be retained as legacy elements in silviculturally managed forests.

Rationale

Forests managed for timber production and other values have significant conservation value and provide habitat for forest dwelling species and support the connectivity of other forest in reserves. The karri forest available for timber production occurs in a matrix alongside forest in formal conservation reserves. Biodiversity conservation is supported through the maintenance of conservation forest spread among the forest for timber harvesting, including that in informal reserves and other areas temporarily excluded from harvesting. The extensive reserve system (formal reserves, fauna conservation areas and informal reserves) accounts for 66 per cent of the area of the main karri forest ecosystem, providing habitat to support the range of karri forest-dependent species. Within the area subject to silvicultural treatment and harvesting additional measures to support connectivity are FHZ and TEAS. FHZs operate at the landscape scale to provide an area from which fauna can recolonise disturbed areas as they regenerate or recover from timber harvesting. *Guidelines for the Selection of Fauna Habitat Zones* Sustainable Forest Management Series Guideline No. 6 (Department of Environment and Conservation 2010) provides more information on the design and function of FHZs. TEAS operate at the local scale as temporarily undisturbed areas during the current harvesting operation. The application of and length of time TEAS are retained is dependent on their purpose. TEAS are primarily a means of limiting clearfell size to below the specified limits. However TEAS may also be imposed where:

- there is a shortage of mature forest elements in the landscape (e.g. informal reserves have not reached maturity or there are few informal reserves at the local scale);
- there is a need to provide a range of development stages, which is beneficial both for wood production and to support the widest range of species or communities.

Legacy elements are structural elements that are long lived or characteristic of mature forests and are considered important in providing diversity of habitat for some species. These elements include mature trees which are likely to contain or develop hollows, structurally rich understorey species; and large coarse woody debris. It is recognised that the number and quality of these can be reduced for periods of time in areas subject to timber harvest. Therefore it is important that some long lived or mature elements are retained and continue to contribute to stand structural complexity, connectivity and landscape heterogeneity at the local scale.

Observation of the development of stands harvested in the 1930s where smaller trees were left and became damaged during the regeneration burn, indicate that some of these younger trees have survived and are now showing signs of developing a range of hollows (Fig 2). Recruitment of legacy elements in this manner is already in place via the retention of secondary habitat trees. However, it is intended to retain mature trees in areas of forest resulting from harvesting prior to 1950. Areas harvested prior to 1950 are recognised as containing fewer mature forest patches than areas harvested subsequently.

Until the end of the immature stage, karri forest supports a dense understorey. The relative species abundance and cover values of the understorey vary with time since fire (part of the natural regeneration of the karri forest as well as the post-harvest regeneration process). After clearfell, the understorey of karri forest regenerates rapidly providing a dense structure which offers food and shelter for particular forest fauna and re-establishes connectivity for those species which dwell in the understorey. Many karri forest species have been shown to re-colonise harvested areas within two to ten years of harvest disturbance. Bird species are known to be quite dependent on forest structure and so bird community composition will vary with development stage.

Logs of various sizes and decay classes provide habitat for a range of species, such as bacteria, fungi, cryptogams, arthropods, which contribute significantly to the overall biodiversity of the karri forest. Log retention can be integrated into regeneration practices to ensure that sufficient logs remain after burning to contribute to habitat diversity.

The fauna distribution information system (FDIS) is used prior to harvesting to identify the likely presence of species in the harvest area and may recommend additional management actions for some species. For example, FDIS may recommend modifications to silviculture such as marking of additional legacy elements. As with all treemarking, retention of these elements requires that they are clearly identified and protected during harvesting and in post-harvest silvicultural treatments.

Strategies

9. Silvicultural treatments will have regard for requirements outlined in FDIS, where the presence of species vulnerable to timber harvesting and/or silvicultural burning is identified.

10. During treemarking and preparation for harvest, give preference for habitat marking to trees that include signs of significant use by, or nests of, threatened fauna species, where these have been identified during pre-harvest checks or observed by the tree-marker or other staff on-site.

11. During clearfell operations in pure karri stands, retain some trees of pole or early mature stage to develop epicormic growth and side branches, which may contribute to hollow development over time.

12. During clearfell operations in mixed stands, retain some mature to over-mature trees.

13. In clearfell or thinning operations, retain some patches of mature karri oak (*Allocasuarina decussata*), or other second-storey species either on their own or in association with retained trees.

14. During thinning operations, retain some remnant mature to over-mature trees where they exist and where it is considered safe to do so. Alternatively where stands are even-aged, heavily thin some small patches to encourage crown development in the retained trees in order to create future habitat trees.

15. In salvage operations following natural disturbance, retain patches of standing dead or damaged trees where they provide habitat value and it is considered safe to do so.

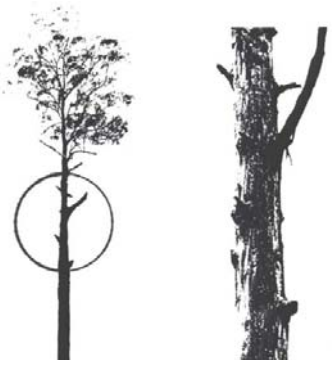
16. In regeneration operations, ensure that retained trees are tops disposed and heaps, if present are located away from retained trees.

17. In regeneration operations, retain some large diameter logs which would otherwise be included in debris heaps, to provide coarse woody debris.

Additional strategies for karri forest resulting from harvesting prior to 1950.

18. Where the silvicultural method is clearfell or thinning, retain mature to senescent trees as well as trees of pole or early mature stage, if available.

Stage 1: Retained karri shortly after the regeneration burn – showing development of epicormic shoots on the bole



Stage 2: 50 years later the epicormic shoots have grown become suppressed, and the lower branches have died and broken off. Hollow formation has been initiated.

Figure 2. Accelerated hollow formation process in young retained karri

Guiding principle 4

Natural regeneration will be used wherever possible.

Rationale

Natural regeneration is the preferred method of regeneration in the karri forest. Natural regeneration is primarily used to restore understorey species, jarrah and marri. For regeneration of karri, limits on coupe size and silvicultural burning restrictions mean that the use of seed trees to provide an on-site source of seed is not generally feasible. Therefore, karri is most often regenerated through the use of planted seedlings. Ripping is undertaken to prepare a receptive seedbed and facilitate planting of seedlings. Fertiliser is

applied to aid regeneration where broadcast burning cannot be carried out. In most cases the aim of regeneration is to eventually restore the area to a self-sustaining ecosystem with a similar species composition to that which existed prior to harvesting disturbance.

Traditionally, regeneration operations requiring the use of supplementary seed or seedlings have strived to use 'local' seed. Where knowledge of the population genetic structure of a species exists or can be reasonably inferred, this should guide seed collection areas. Recently, guidelines for seed collection for regeneration (and rehabilitation) have moved away from the requirement for only using 'local' material as the scientific basis for this has been increasingly questioned, and additional considerations for optimal regeneration outcomes are now recognised. Factors considered important for any seed collection strategy include: matching topographic and edaphic features; allowing for expected changes in climatic conditions between seed collection sites and regeneration sites; and the need to use good quality seed with sufficient genetic variability to help enhance the resilience of regeneration (Millar *et al.* 2007).

Seed collected for regeneration is usually collected from the same LMU as the area to be regenerated. Flexibility is required to facilitate desired outcomes – for example where disease is present, or rainfall has declined, it may be appropriate to consider the use of disease- and/or drought- resistant varieties of those same species. In this case, the best source of seed or seedlings of some species may be from another area. Alternatively, if disease or drought resistant varieties are unavailable or unknown, then using mixed seed sources to maximise genetic diversity might be an appropriate alternative strategy. This would provide a broader source of variation which would allow greater potential to adapt to new perturbations such as disease or environmental change.

Strategies

19. Fire and/or ripping and fertiliser application will be used in regeneration establishment operations to prepare a viable seedbed, and encourage the germination and vigour of seedling regeneration.

20. During harvest planning, aim to use natural regeneration where reasonable and practical. Where natural regeneration is not reasonable and practical, use only species endemic to the area being regenerated.

21. Where there is knowledge of population genetic structure or it can be reasonably inferred from life history traits, use this to guide seed collection areas.

22. Where population genetic structure is not known, use seed collected from the same LMU or neighbouring LMU as the area to be regenerated.

23. Seed collection for rehabilitation or regeneration should prioritise the matching of climatic, edaphic and other environmental variables of the seed collection area with the area to be regenerated.

24. Seed collection for highly disturbed sites, or sites subject to pest, disease or changed climatic conditions, should be target a genetic material with resistant traits, or alternatively a wide genetic base to facilitate adaptation.

Guiding principle 5

Compositional diversity will be maintained in silviculturally managed forests.

Rationale

Diversity in overstorey composition can be observed throughout the karri forest where karri may occur in pure stands or mixed at various proportions with other species including marri (*Corymbia calophylla*), jarrah (*Eucalyptus marginata*), WA blackbutt (*E. patens*) and bullich (*E. megacarpa*). In some areas, past harvesting and regeneration practices have altered the species mix. Evidence such as old stumps can be used to infer the previous stand composition. This is evident where mature karri overstorey was selectively removed in mixed stands and has not regenerated or where mixed stands were harvested and replaced with karri only. Where mixed stands have or still occur, regeneration to a single species is inappropriate, as it would lead to simplification of species composition and impair ecosystem resilience.

Mixtures of karri and marri or karri, jarrah and marri are common throughout the forest especially where karri is at the limit of its natural range. Some species mixes are less common and can be confined to particular positions in the landscape. Blackbutt occurs on lower slopes in the karri forest, and in some situations may represent a significant proportion of the overstorey. Bullich is usually confined to the stream zone, particularly in the northern karri forest, and doesn't form a substantial part of the overstorey in harvested coupes.

Where artificial regeneration methods such as the planting of seedlings are used, it is important to ensure that all components of the overstorey are represented in the forest that is replaced. Marri advance growth is often present in the karri forest where it exists as an element of the overstorey and it often persists as an element of the regenerating stand without planting. Karri and blackbutt advance growth may be present, but these species generally require planting or seeding in regeneration operations to ensure adequate representation in the regeneration.

Floristic assemblages of the karri forest have been found to demonstrate a general resilience to harvesting and fire disturbance (Inions *et al.* 1990; Wardell-Johnson *et al.* 2004). However, due to restrictions on burning at certain times of year due to the presence of vineyards and smaller coupe sizes, regeneration methods have been adapted. Harvest debris is often pushed into rough heaps and burnt in autumn rather than the traditional high intensity broadcast burns. This may influence the regeneration of karri understory species diversity.

Weed species can establish on recently harvested sites, but are generally excluded as the forest regenerates. However, should there be a delay between harvest and regeneration, weed species may become established.

Strategies

25. Prior to harvesting operations, record the overstorey species distribution and composition. In stands that have been previously harvested, the presence of identifiable stumps can be used to infer the original composition and species distribution of the stand. Use this information to inform the regeneration seed mix.

26. During treemarking, mark for retention some large individuals or thickets second-story species that are slow growing, long-lived and rely on capsule-stored seed for regeneration.

27. In regeneration operations, reflect the composition and distribution of overstorey species in the previous stand and consider the relative competitive ability of each species in the regeneration species mix.

28. During harvest planning, demarcate for exclusion, mapped stands of pure mature marri.

29. After harvesting, avoid delays in regeneration which may allow weeds to establish.

30. During burn planning, consider the importance of fire regimes to regeneration, forest health and species diversity.

4. Guiding principles for ecosystem health and vitality

Overall objective

Use silvicultural management to mitigate the impacts of abiotic, biotic and anthropogenic stressors on the health and vitality of the forest.

Threats to the health and vitality of the forest will be identified and prioritised. Where practicable, threats or damage from stressors will be avoided or mitigated through silvicultural treatment.

Guiding principle 6

Promote resilient stands on sites with high levels of overstorey mortality or stress, through silvicultural management.

Rationale

Climate change has the potential to impact on forest health. Competition for water may lead to drought related deaths of trees and other vegetation, particularly on upper slopes, shallow soils and others with low water holding capacity. The predicted increased incidence of extreme weather events may also lead to an increase in tree deaths from bushfire, storm and frost. Disease and insect attack may also have detrimental impacts on forest health. Water stress may predispose trees to insect attack and compromise their ability to recover from damage. Thinning stands subject to water stress increases the resources available to the retained trees and associated vegetation. This helps improve health and vigour and reduce the potential for drought related deaths, and reduce vulnerability to pest insect and disease attack (Barry *et al.* 2011). Should myrtle rust enter Western Australia, both the increased vigour of trees due to thinning and the effect that a more open canopy has on relative humidity may reduce the incidence or intensity of infections. Thinning may also reduce the incidence of Bullseye borer (*Phoracantha acanthocera*) if it reduces water stress and competition for nutrients. This is likely to be of most benefit on less productive drier sites at the margins of the natural distribution of karri (Abbott *et al.* 1991; Farr *et al.* 2001).

Invasion or expansion of existing pest, weed and disease populations or invasion by pest, weed or disease species favoured by changed climatic conditions can reduce the natural resilience of forest stands. This may impact on the health and biodiversity of forest ecosystems. The application of hygiene is useful to reduce the potential for harvesting activities and/or silvicultural treatments to introduce or exacerbate pests, weeds or diseases.

Browsing by native herbivores can have a detrimental effect on karri regeneration. To avoid browsing damage, regeneration is best timed soon after surrounding areas have had a prescribed burn. Burning stimulates a flush of new growth which can distract herbivores from new growth on regenerated seedlings, avoiding browsing damage.

Strategies

31. During silvicultural treatment, reduce stand density in stands subject to water stress (those that are highly stocked or located on shallow or low water holding soils) to assist

with adaption to a drier climate and prevent stress related susceptibility to pests and diseases.

32. Identify weeds present in coupes and alter management practices where required, to prevent spreading or favouring the spread of the weeds present.

33. When new populations of weeds are identified in coupes, aim to control, quarantine or eradicate populations of these species before they become established.

34. In burn planning, try to schedule prescribed burns, in areas adjacent to regeneration operations to avoid browsing damage to regeneration.

35. Adaptive management trials to investigate the rehabilitation of sites with significant tree deaths may be approved by the Manager, Ecosystem Health.

Guiding principle 7

Reduce log degrade through silvicultural management.

Rationale

Armillaria luteobubalina, the causal agent of Armillaria root disease (ARD), is an endemic pathogen throughout southern Australia. In the south-west of WA, it is widespread through the karri forest resulting in scattered mortality in undisturbed forest and variable levels of disease in undisturbed forest and higher levels in some juvenile / immature stands (Robinson *et al*. 2003).

The production of a high number of stumps by thinning has the potential to increase ARD inoculums. ARD causes root damage making trees more prone to wind-throw and stem defect which degrades log quality. Without effective controls, about one half of the gains in growth attained from thinning may be lost to defect (Robinson, 2005). Infected trees may eventually be killed if infection girdles the root collar. Death and defect in trees within infested stands potentially affects sustained yield.

Log degrade may also be caused by other wood rotting fungi which enter through branch stubs, borer galleries and scars caused by fire or other damage to the cambium. The incidence of fungi entering through branch stubs reduces with branch size. Dense initial plantings can be used to limit branch size on the lower trunk, and so reduce the incidence of fungi entering through branch stubs. However, trees subject to stress are targeted by borers so it is important that stand density is managed to avoid the onset of intense tree competition from the age of about 14 years onward. Minimising damage to the cambium through fire or thinning-related damage should also limit the opportunities for wood rotting fungi to enter the tree and degrade wood.

Strategies

36. Monitor the occurrence of ARD in thinned stands.

37. Where the incidence of ARD is high, consider not thinning or modifications to thinning, to reduce the build-up of ARD inoculums.

38. During thinning operations, manage inter-tree competition to avoid stress which may pre-dispose trees to insect or disease attack (Guiding principle 16).

39. During harvesting operations, protect trees from damage (Guiding principle 19) which may lead to wood degrade or decay.

40. During early regeneration stages, manage fire to avoid damage to regenerating stands which would result in defects, decay or provide and an entry for insects such as borers (Guiding principle 8).

Guiding principle 8

Prescribed fire will be used to protect fire sensitive regeneration and reduce high fuel loads that may result from silvicultural practices.

Rationale

Fire is critical in the regeneration of karri forest. Fire creates a receptive seed bed, temporarily reduces understorey competition (allowing the seedlings to establish) and regenerates nitrogen fixing understorey important to maintain nutrient cycles. The exclusion of fire for long periods, or frequent high intensity fire will degrade the karri forest ecosystem.

After harvesting, fire is used to remove fuels and establish karri regeneration. Fire potential is low for the first five years following regeneration. As understorey and litter accumulate, so does the potential for fire damage in fire sensitive young karri. Fire should be excluded for around 20 years following establishment. The first burn can be undertaken once co-dominant trees are able to withstand a mild prescribed fire.

The primary attributes that affect the timing and application of fire to young karri stands are:

- the height and bark thickness of the co-dominant stems in the stand;
- the homogeneity of site quality and stocking in the stand;
- the understorey composition and structural type; and
- the arrangement of the litter and trash fuels.

The first burn following regeneration must be achieved within specified intensity limits to prevent deformation of the stem from crown scorch or unacceptable damage to the stem. Burning of juvenile/young immature stands prior to thinning is preferred. The window of opportunity for silvicultural burning is widened after thinning as fuels have compacted and the more open canopy allows fuels to dry sufficiently for burning earlier than for un-thinned areas. Caution is required as thinning creates additional fuel. High fuel loads may result in damage to trees, especially woody debris close to retained trees.

Planning and application of silvicultural burns is important to maintain biodiversity and timber values of the stand. However, burns are often planned to achieve multiple objectives within the landscape and it can be necessary to compromise on the timing of

silvicultural burns to achieve targets such as community protection. In managing prescribed fire, the primary objective is reducing bushfire related risk, after which consideration is given to biodiversity conservation, forest silviculture, research and any other land management objectives. Prescribed burning objectives for silviculture include preventing damage to growing stock, promoting regeneration, nutrient cycling and achieving a mosaic of burnt and unburnt patches.

Strategies

41. During burn planning, aim to exclude fire from regeneration until the fire sensitive period has passed (nominally 20 years or until saplings have developed sufficient height and bark thickness). Once this period has passed, aim to re-introduce stands to the burn programme as soon as they have passed the fire sensitive period.

42. During burn planning, if there is a low risk of escape, aim to reduce fuel loads in areas adjacent to fire sensitive regeneration in order to reduce the likelihood of bushfire during the fire sensitive period.

43. During burn planning, aim to burn juvenile stands prior to first thinning.

44. During burn planning, aim to reduce high fuel loads which can result from silvicultural practices, but only where the fuel load and tree age are such that there is little risk to the developing stand.

Guiding principle 9

Silvicultural management will be used to maintain forest nutrient cycling processes.

Rationale

The understorey of the karri forest contains a significant proportion of the available nutrients of the forest. Fire plays a positive role in the nutrient cycling. Fire releases organically-bound nutrients in the litter into available inorganic form and promotes the regeneration of nitrogen-fixing understorey, which not only fix nitrogen from the atmosphere but also help increase the rate of decomposition and mineralisation of the litter.

The removal of nutrients in sawlogs constitutes small losses to the system relative to the stores of readily extractable nutrients in the soil. However, excessive removal of biomass from forest stands has the potential to impact on soil nutrient levels. Proposals that include the removal of fine branch and leaf material have greater potential to impact on soil nutrient and organic matter levels than those only removing only woody material. Similarly the loss of surface soil will also result in loss of nutrients from the system.

The objective of regeneration burning is to burn with sufficient intensity to remove excessive harvesting debris and create a receptive seed bed. In all regeneration burns, harvesting debris is ‘pushed in’ from the burn edge to facilitate burn security and personnel safety. Where rough heaping burns, harvest debris is pushed into piles and burnt. The area where the harvesting debris has been ‘pushed in’ is likely to receive little or no nutrient boost from burning. If left untreated, these areas may suffer significant reductions in growth. The application of fertiliser will reduce this effect.

Strategies

45. Avoid excessive removal of leaf and fine branch material from forest harvesting operations.

46. During regeneration establishment, apply fertiliser to seedlings just prior to their leaving the nursery to promote early growth and survival.

47. During regeneration establishment, apply fertiliser to target seedlings in areas of 'push in' and between heaps, to improve their growth.

48. Minimise the potential of soil erosion by limiting soil disturbance during harvesting and through measures to minimise high intensity fire.

49. After harvesting, where possible or practicable, silvicultural burns should be planned to allow sufficient time for leaching of nutrients from the leaf litter produced by the harvest.

Guiding principle 10

Promote ecosystem health and vitality through silvicultural management.

Rationale

This guiding principle is also referred to as 'silviculture for ecosystem health'.

A key finding of the Review of Silviculture in Forests of South-west Western Australia (Burrows *et al.* 2011) was the opportunity that silviculture provides to assist forest to adapt to climate change. In summary, the report found that "*declining rainfall has significantly impacted water availability in the FMP area and predicted future climate change is likely to lead to further impacts. Further declines in streamflow and impacts on aquatic environments are likely. The impact of climate change needs to be closely monitored with adaptive management strategies*." The purpose of silviculture for ecosystem health is to enhance ecosystem health and function, and biodiversity, through enhanced water availability. Enhanced water availability is achieved by reducing the density of vegetation in the stand (and thus lowering transpiration demand).

A sustained reduction in rainfall in the karri forest will lead to changes to groundwater and flow days. As a result, there may be gradual changes to the health and distribution of ecosystems. More immediate, but localised effects may occur as a result of extreme weather events such as storms and heatwaves, with higher maximum temperatures, more hot days and more intense precipitation events considered very likely as a result of climate change (Arthrington *et al.* 2003).

Mitigating the effects of reduced rainfall and higher temperatures on the forest and associated communities will require adaptive action to help to align density and structure of the forest with current and future climate. Targeted action may protect susceptible ecosystems, retain water availability in some parts of the forest, improve the health of forest and associated ecosystems, reduce susceptibility to high intensity fire and allow for the persistence of ground and surface water dependent ecosystems.

Karri forest vegetation intercepts about 10-20 per cent of rainfall and transpires around 60-70 per cent. A reduction in stand density reduces interception and transpiration and a sufficient reduction in stand density increases the amount of water moving through the soil

profile to groundwater and into streams. Reducing stand density also reduces competition for water and has a positive effect on vegetation health and vitality, increasing resilience to pest and diseases. 'Silviculture for ecosystem health' aims to reduce the impact of declining rainfall on the forest and associated ecosystems. Declines in ecosystem health are associated with:

- loss of free water in the environment
- potential impact on forest health associated with water stress
- reduction in site carrying capacity
- loss of or reduction in riparian and aquatic ecosystems
- increased frequency and intensity of bushfire.

The strategies associated with this principle incorporate a number of management tools able to reduce inter-tree competition, move forests to a more appropriate carrying capacity, slow the loss of and/or maintain current riparian ecosystems and reduce fire intensity.

Areas that could be targeted for treatment are:

- areas with a high stand density that are subject to damage by insects (particularly bullseye borer) or disease (except dieback) and where a reduction in stand density is likely to promote recovery from or reduce susceptibility to damage by insects or disease; and
- catchments where a reduction in stand density is likely to maintain groundwater levels and streamflow so that these catchments can act as refuges from the hydrologic impacts of climate change.

Strategies

50. Identify ecological values or communities where the effects of climate change will escalate the threat to the value or community.

51. Prioritise ecological values or communities in relation to the potential risk associated with the:
    - likelihood and degree to which ground and surface water availability will decline in the areas in which the population or community occurs.
    - likely impact on the community or population of declining ground and surface water availability.
    - feasibility of conducting silvicultural treatment to reduce the potential risk of ground and stream water decline.
    - potential impact on other values of conducting silvicultural treatment to arrest ground and stream water decline.

52. Consider relevant species management plans, species recovery plans or catchment management plans to guide the application of silviculture for ecosystem health treatments, depending on the value being addressed and the scale of the work proposed.

The following strategies are existing practices or modification to existing practices which may be used to enhance water availability

53. Use an adaptive management approach to harvest and culling targets to:
    - arrest or improve groundwater and/or streamflow to threatened communities or ecosystems
    - improve the health and vigour of understorey, second-storey and overstorey
    - reduce water use by reducing basal area (and subsequently leaf area)
    - allow retained trees to develop to maturity at which time they are less water demanding per unit of leaf area

- promote the recovery of trees following severe damage from disease or insect attack.

54. Introduce or modify burn plans to improve the health of and/or reduce the threat to identified values or communities.

5. Guiding principles for soil and water

Overall objective

Protect soil and water resources in order to sustain the foundation for diverse, productive and healthy forest ecosystems, and to provide water for consumptive uses.

The effect of forest cover on soils and water quality is positive. By regenerating forests after harvesting, soils are stabilised, water and wind erosion are prevented and nutrient cycles are maintained. Water quality is maintained and water flow moderated. Disturbance, particularly roading, can be detrimental to soil and water values. Management controls on these operations should limit potential harm.

Guiding principle 11

The extent and severity of harvesting disturbance on soil values will be minimised and damaged soil remediated.

Rationale

Maintaining soil values is one of the most important elements of sustainability since soil health underpins the health of the ecosystem. Potential risks to soil health in association with harvest disturbance activities include:

- changes to soil structure; and
- loss of topsoil (soil erosion).

Soil structure can be adversely affected by soil compaction during timber harvesting and forest management activities, and by mixing of soil profiles particularly when the soil is moist. These types of damage can reduce seed germination, seedling survival and plant growth. Compaction may be alleviated by ripping (Schuster 1979), bur ripping is only of value on soils where soil moisture is at the correct level to provide soil shatter. Profile mixing or topsoil removal cannot be remediated. The effects of compaction and mixing of soil profiles are controlled by restricting machine activity during moist soil conditions (Rab *et al.* 2005; Whitford *et al.* 2012). Compaction can be alleviated by shallow ripping or scarification for surface compaction, and deep ripping for compaction of the lower horizons.

The success of regeneration operations is dependent on having a receptive seedbed to facilitate germination of seedlings, and some soil disturbance contributes to a receptive seedbed. However, soil damage not rehabilitated after timber harvesting can reduce seedbed quality and reduce regeneration. Soil treatments such as scarification and/or ripping with a machine can be used to rehabilitate damaged soils and improve the area of receptive seedbed available for regeneration. However, remediation works need to occur under the correct soil conditions to be effective. For example, ripping to alleviate compaction is of no value unless the soil moisture levels are such that ripping shatters compacted soils and may be detrimental if carried out under moist soil conditions.

Pushing of cull trees can result in soil disturbance where clay is brought to the surface with the root ball of the tree. Where there are a significant number of cull trees to be removed, this method can result in an unacceptable level of soil disturbance and should be avoided.

High intensity bushfire can lead to a loss of nutrients from the system, particularly in erosion events. Prescribed burning should seek to prevent high intensity bushfire. Salvage harvesting operations after bushfire disturbance may require the use of erosion control structures.

Strategies

55. Timber harvesting activities will be managed in accordance with the *Soil and Water Conservation Guidelines*, SFM Series Guideline No 5, (2009).

56. During harvesting operations, use a combination of harvest timing, extraction pattern design and surface water management structures (Department of Environment and Conservation 2009b) to limit erosion and compaction.

57. During post-harvest silvicultural treatments, cull removal will be conducted by felling or notching rather than pushing, to limit soil disturbance.

58. After harvesting is complete, carry out timely remediation of compacted soils, landings, roads and tracks to allow seed fall onto a receptive seed bed or to facilitate planting.

59. During burn planning, aim to ensure burn cycles support nutrient cycling within the forest and prevent high intensity bushfire.

60. During salvage operations post-fire, incorporate erosion control structures.

Guiding principle 12

Water quality will not decline as a result of silvicultural treatment.

Rationale

Historically the main risk to water quality has been from groundwater rise dissolving and transporting salt stored in the unsaturated zone of the soil profile. The potential risk of silvicultural treatment of forested areas leading to a rise in groundwater was limited through phased harvesting requirements in salt sensitivity areas. As a result of reduced rainfall and declining groundwater levels over recent decades, salt sensitivity has been revised in the Swan, South West regions and parts of the Warren region. Accordingly, the measures introduced for the protection of water quality under the previous hydrological regime (mainly higher groundwater levels), are now considered less relevant. Phased harvesting requirements are no longer required in these areas. The phased harvesting requirement for the moderate salt sensitivity part of the Warren Region will be retained as groundwater levels have not fallen to the same extent in this area (see Appendix 2). In addition the planning process for timber harvesting is to ensure that in partially cleared catchments categorised by the Department of Agriculture and Food (DAFWA) as having a high salinity risk (see Appendix 3) there is consideration of the need for modified harvesting requirements. Groundwater monitoring will continue in current and historical salt risk areas in order that management of these areas can change should there be a return to a wetter climate.

All operations conducted during silvicultural treatment must be in accordance with *Soil and Water Conservation Guideline* SFM Series Guideline No 5 (Department of Environment and Conservation 2009c) which guides all aspects of operations associated with silvicultural treatments to avoid or minimise potential effects on water quality.

A number of measures are implemented to control potential impacts on water quality from silvicultural treatments and the operations that accompany them. The river and stream zone informal reserves are excluded from timber harvesting as specified in *Guidelines for protection of the values of Informal Reserves and Fauna Habitat Zones* SFM Series Guideline No 4 (Department of Environment and Conservation 2009a). The width of stream zones is dependent upon the stream order and ranges from 60 m for stream order 1-3 up to 400m for stream orders 5 and greater. River and stream zones provide protection from erosion and sedimentation. Additional guidelines around river and stream zones can be found in *Guidelines for protection of the values of Informal Reserves and Fauna Habitat Zones* SFM Series Guideline No 4 (Department of Environment and Conservation 2009a).

Water quality can also be affected by contamination from chemicals (herbicides and fuel oils) if they are used incorrectly or spilled in the catchment.

Strategies

61. When planning silvicultural treatments, protect water quality from salinity in second order catchments identified as having a high salt risk (see Appendix 3), through increased stream reserve widths, and phased harvesting of the area available to be harvested, which includes i), retaining an unharvested area adjacent the watercourse, equal in area to 30 per cent of the upslope area available to be harvested, and ii), a minimum harvesting interval of 15 years.

62. When planning silvicultural treatments, protect water quality from salinity in second order catchments in the moderate salt sensitivity zone (see Appendix 2), through phased harvesting of the area available to be harvested, which includes i), retaining areas unharvested or at a basal area no less than 15m2/ha, equal in area to 30 per cent of the area of the second order catchment, and ii), a minimum harvesting interval of 15 years.

63. During harvesting or silvicultural treatments, all operations must be in accordance with the *Soil and Water Conservation Guidelines*, Sustainable Forest Management Series Guideline No 5 (2009).

64. Prior to silvicultural treatment, river and stream informal reserves must be demarcated and subsequently protected as specified in Guidelines for the Protection of the Values of Informal Reserves and Fauna Habitat Zones SFM Series Guideline No 4 (Department of Environment and Conservation 2009a).

65. For the period of the FMP, continue ground water level monitoring in areas previously considered to be of low and moderate risk of salinity in order that management of these areas can adapt should there be a return to a wetter climate.

66. If using chemicals during silvicultural treatments, use good practices as guided by regulations and the Code of Practice for the use of agricultural and veterinary chemicals in Western Australia (Department of Agriculture and Food Western Australia 2007).

67. If using herbicides in water catchment areas, use must also be in accordance with the Use of Herbicides in Water Catchment Areas (Department of Health 2007).

68. Pesticides will only be used where there is, in the view of the Department, no practicable alternative.

Guiding principle 13

Silvicultural treatment of native forest may be used to maintain or enhance the flow of water to surface and ground water reserves.

Rationale

This guiding principle is also referred to as 'silviculture for water production'.

The use of silvicultural treatments to increase the flow of water to surface and groundwater reservoirs was foreshadowed in the FMP 2004-2013. Furthermore, the *Soil and Water Conservation Guideline* (Department of Environment and Conservation 2009c) includes a guiding principle that silvicultural treatments and fire regimes may be used to enhance the quantity of water for surface and groundwater reservoirs. While the primary driver may be the maintenance of or increase in water yield, any treatments will first provide an increase in the availability of water to the environment, with benefits for ecosystem health and vitality.

Declines in streamflow have been significantly greater than declines in rainfall in south-western Western Australia. It is thought that prolonged reductions in rainfall have caused groundwater to disconnect from surface water, resulting in significant declines in streamflow (Hughes *et al.* 2012; Kinal *et al.* 2012). The implication is that where disconnection has occurred, the capacity to generate streamflow is greatly reduced. Where disconnection has occurred, groundwater would need to be recharged to the point of connection again before significant improvements in streamflow would be realised. The greater the delay in responding to declining groundwater levels, the less likely it will be that streamflow can be improved in the short term.

The use of silviculture to manage water yield in forested catchments ('silviculture for water production') has been developed from research undertaken locally (Ritson *et al.* 1981; Stoneman 1986; Marshal *et al.* 1992; Stoneman *et al.* 1996; Bari *et al.* 2003; CSIRO 2009), nationally (Vertessy 1998; Erskine 2004; Feikema *et al.* 2006) and internationally (Douglas, 1983; Stednick 1996; Calder 1998; Kaye *et al.* 1999; Brown *et al.* 2004). There is potential to apply 'silviculture for water production' to increase water for consumption or irrigation purposes.

There are some general rules around forest management and water yield. Partially (thinning) or completely removing (gap creation) trees from an area will reduce interception of rainfall allowing additional infiltration and reducing transpiration resulting in increased soil moisture and in some cases a rise in groundwater and streamflow. However, the increases from a single treatment are transient and water yields can quickly decline to pre-treatment levels as the remaining trees and/or regeneration from stump and ground coppice grow. Un-thinned even-aged stands of juvenile and immature regrowth have been demonstrated to use more water than more mature forest development stages. Within a catchment, controlling the amount of younger growth stages may be an option to manage water availability.

Silvicultural thinning of juvenile and immature stands can relieve water stress within the stand, partition a greater amount of water for other ecosystem processes or consumption and accelerate stand development into relatively less water demanding mature stages.

Thinning of both overstorey and mid-storey species may decrease the stand structural complexity of the forest within the catchment. To achieve both increased streamflow and groundwater levels and have the least impact on stand structural complexity, the most intense thinning should be targeted in the areas of the catchment where rainfall can feed

most directly into groundwater. The most beneficial areas to target can be determined by hydrological modelling, groundwater measurements, digital elevation models and professional advice. The beneficial areas will usually be found in the lower to mid slope areas.

In areas where 'silviculture for water production' is intended to be applied the proponent will first develop a catchment management plan. A catchment management plan is a strategic level plan that sets out the extent, intensity, sequencing and return cycle of operations as well as identifying and managing the potential risks associated with applying 'silviculture for water production' along with the potential risks to environmental and social values of not addressing declines in water availability.

Strategies

69. During harvest planning, develop a catchment management plan to detail the treatments to be applied, the scale of treatment and the controls for potential risks to the environment. These catchment management plans are required where the proposed silvicultural treatments are outside of parameters provided for in the Department's silviculture guidance, or where it is considered by the Department that an excessive proportion of the forest in the catchment may be left in the juvenile and immature stages of development as a result of a proposal.

70. When planning silvicultural treatment of native forest, consider the likely effects on the age structure of forest within the catchment to limit the amount of area in relatively higher water use juvenile and immature development stages at any one time.

71. When planning silvicultural treatment to enhance water availability in areas of native forest in which mining activity is planned, consider the existing and likely future mosaic of developmental stages for both the native forest and mine rehabilitation.

72. Identify the areas of the catchment in which thinning will have the most impact on water yield and target these areas for treatment.

73. Thin young stands (< 30 years old) to reduce water use and to accelerate their development into mature (and more water use efficient) forest.

74. Thin the general forest area to reduce transpiration and interception while taking care to retain enough canopy cover that large scale regeneration is discouraged.

75. Treat coppice and regeneration on an approximate return cycle of five to ten year following thinning to retain gains in water availability.

76. Use prescribed burning to limit understorey development (and so understorey leaf area).

77. Use prescribed burning to prevent the probability that stand-replacing fires will convert large areas of the forest to early developmental stages.

6. Guiding principles for climate change and carbon cycles

Overall objective

Within the constraints of a changing climate and the achievement of other goals of management, seek to adapt forest management to climate change and sustain the contribution of the forest to global carbon cycles.

Native forests contribute to climate change mitigation through storage of carbon in forests. Storage of carbon in forest products harvested from sustainably managed forests and use of those forest products further contribute to mitigation of climate change.

Silvicultural management of the forest to retain its productive capacity in the face of climate change requires addressing potential damage agents such as weeds, pests and diseases, protecting forest soils and adapting silviculture to address changes in water availability. These issues are addressed in Guiding principle for ecosystem health and vitality and Guiding principles for soil and water.

Guiding principle 14

Forests will be managed to maintain forest carbon stocks, provide forest products and contribute to the mitigation of climate change.

Rationale

Forests and forest products have an important role in global carbon cycles, predominantly as sinks. Carbon stocks in forests include biomass (litter, woody debris, stumps, roots, dry standing stems) and soil carbon pools.

Forest products are also part of global carbon cycles. Forest products may reduce carbon emissions if they displace the use of materials which are more carbon-intensive to produce, such as the use of timber rather than steel, concrete or aluminium in construction, or the use of non-sawlog material to replace fossil fuels to produce energy. Forest products store carbon, although the storage time of carbon in forest products varies, and is greatest in products that have a long 'in-service' or 'end-use' life.

Natural disturbances affect the carbon cycle and these disturbances are a major cause of carbon fluxes in forests. Bushfire and damage from insects, diseases and storms may play a large role in the carbon cycling in forests. The aim of forest management practices is to ensure that forests continue to be carbon sinks, sequestering at least as much carbon as they emit at the whole of forest scale. The potential for well managed forests to contribute to climate change mitigation is acknowledged by the Intergovernmental Panel on Climate Change, which states: *In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stock, while producing an annual sustained yield or timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit* (Nabuurs *et al.* 2007).

The cumulative impact of practices implemented at a stand scale contributes to both the rate of accumulation of carbon in forests and the quantity of carbon emitted. In native forests subject to harvest and subsequent regeneration, the impact of practices implemented at a stand scale are related to:

- *Quantity and timing of timber harvests*: the extent to which carbon stocks are modified at a point in time through harvesting practices is related to the proportion

of area harvested, proportion of trees removed and the harvest interval. Effective regeneration and replanting mean that the area of forest available to store carbon is not reduced, and subsequent regeneration restores site carbon stores over time.

- *Low-impact practices*: reducing the harvesting disturbance of soil and remaining vegetation will help conserve soil carbon and the productive capacity and sequestration potential of the site. Soil carbon is mostly held in organic matter and measures to protect soils from disturbance are covered in the Guiding principles for soil and water. However in terms of carbon stocks, as noted Australia's "State of the Forests Report" 2008 (Montreal Process Implementation Group for Australia 2008), in native forests subject to cycles of harvest and subsequent regeneration, change in soil carbon is believed to be insignificant since emissions caused by disturbance of soils during harvesting: *are balanced in a given inventory period by re-accumulation through tree growth*. *This reasoning is also used in accounting rules set out by the UNFCC* (United Nations Framework Convention on Climate Change).

Strategies

78. Protect forest soils during harvesting operations by following the *Soil and Water Conservation Guideline* SFM Series Guideline No 5 (Department of Environment and Conservation 2009c).

79. Use silvicultural treatments to encourage the sustainable production of forest products with a long service life, and those that replace fossil fuels and high-embodied energy alternatives.

80. Ensure effective regeneration and where practicable, carry out rehabilitation of the forest, to maintain productive capacity, maintain the forest area and sustain the pool of carbon stored in the forest.

81. In post-harvest silvicultural treatments, limit culling of trees to a level required to maintain a healthy and productive forest that is actively sequestering carbon.

82. Aim for timely completion of all silvicultural burns, which will also help reduce the potential for frequency of large-scale, high-intensity bushfires.

7. Guiding principles for productive capacity

Overall objective

Silvicultural management will be used to support the capacity of the forest to sustain a supply of goods and services in the long run.

Maintenance of productive capacity provides for the sustainability of the flow of some of the benefits from forests to society. Productive capacity includes both wood and non-wood resources. Maintaining productive capacity of forests available for timber harvesting involves maintaining the area of State forest and timber reserves and the area within State forest and timber reserves where harvest is permitted, and providing for harvesting on a sustained yield basis.

Guiding principle 15

The most appropriate silvicultural method will be applied to each stand to support short and long term productivity.

Rationale

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

- *Immature even-aged stands (regrowth),*
- *Single-storied mature stands (mature),*
- *Uneven-aged stands (two-tiered), and*

Silvicultural methods in all forest types include the retention of habitat, but the types and arrangement of habitat tree retention may vary with stand structure. More details are given on habitat tree retention in Guiding principle 3.

The silvicultural methods employed in karri forest are similar to other tall open forests. Regeneration is established after mature forest is clearfelled, with the regeneration thinned one or more times throughout the rotation. Put simply, regrowth stands and vigorous mature stands should be thinned to promote growth on the retained trees and late mature stands, approaching or beginning to senesce should be clearfelled and the forest regenerated.

After regeneration, as trees expand their crowns and root systems they begin to compete with each other for light, nutrients and water. Thinning should be applied as the competition between trees reaches a level that the annual basal area increment of the stand is reduced. The stand may be thinned a number of times, as long as the trees within it are vigorous enough to take advantage of the additional resources made available to them through thinning. The point at which thinning is no longer of benefit is usually once the trees are well into the mature stage of development and are no longer vigorous enough to expand to further occupy the space created by thinning. At this point, stands should be clearfelled and regenerated.

Some past silvicultural practices have resulted in multi-aged stands and in these stands it is more complex to determine the most appropriate method to apply. The relative proportions and arrangement of the dominant layer and regrowth component should inform the decision. Where the regrowth component can be protected from felling damage and silvicultural burns, it can be retained and grown to maximise the recovery of sawlog

volume. In some cases the removal of the dominant layer in multi-aged stands results in damage to the regrowth component. The decision to remove the dominant layer will depend on patch size and the crown cover of the dominant layer. Accurate assessment of stand structure and the area it covers is essential in applying the correct silvicultural method, in order to maximise the productive capacity of the forest while minimising harvest disturbance and waste.

Strategies

83. When determining stand structure of multi-aged stands, where the upper dominant layer forms less than 15 per cent crown cover, the stand will be managed as regrowth.

84. During harvest planning, stands which are sufficiently vigorous to respond to a reduction in competition should be thinned.

85. During treemarking, where the seed tree method of regeneration is employed, select dominant or co-dominant trees with good form (no hereditary defect) and healthy spreading crowns which will provide seed.

86. During thinning operations, monitor thinning outcomes against standards and undertake remedial action where required.

87. After harvesting, burning and/or planting, monitor regeneration success to target remedial works where required.

Guiding principle 16

Regeneration and tree growth will be enhanced through actions to alleviate competition on regeneration and selected trees.

Rationale

Competition for water, nutrients and light will determine the survival and growth of forest regeneration and the growth rate of established trees. Ultimately competition affects the quantity of wood products that can be produced from a stand. Silvicultural methods for the karri forest have been developed to alleviate competition at various development stages to provide a range of forest values, including sawlog production.

In karri, a high stocking is maintained to encourage height growth and suppress branch growth in the lower crown until a clear bole length of at least 14 – 18m is reached. To achieve sufficient early stand density to maximise clean bole height, seeding or planted seedlings should have a stocking of 2200-3000 stems per hectare (spha) at establishment, depending on site quality.

Due to the size of karri trees, competition from the surrounding overstorey during the regeneration phase can extend for some distance from the edge of gaps. The root system of mature trees will out-compete seedlings for water and nutrients and their canopies will shade seedlings, restricting their access to light. For successful regeneration, the size of the clearfell gap must be sufficiently large to ensure that competition from surrounding trees does not suppress growth on too greater proportion of the gap. Edge effects are lessened by creating rounder and/or larger gaps. Reducing the proportion of gaps in edges and or reducing edge length also aids management.

Silvicultural thinning reduces stand density and inter-tree competition for light, water and nutrients. Thinning shortens the time taken for retained trees to reach maturity and sawlog size by increasing the diameter growth of the retained trees. First thinning usually targets the removal of suppressed or poor form trees and seeks to promote the growth and vigour of the dominant or co-dominant retained trees. A second or even third thinning may be carried out during a rotation. While the main aim of thinning is to reduce competition, thinning regimes may be modified to manage wood flows, but should not be compromised to such an extent that severe competition is induced.

Retained habitat trees also compete with adjacent trees and regeneration and this is influenced by the density and pattern at which they are retained. The footprint of competition is greatest from wide spaced individual trees compared to a clumped distribution for a given stand density.

Strategies

88. During treemarking, retain habitat trees in groups where required to reduce the suppression of regeneration.

89. During thinning operations, the target stand density will be consistent with the development stage and site quality of the stand.

90. Aim to reduce the edge to area ratio of clearfelled areas.

91. During post-harvest silvicultural treatments, optimise regeneration potential by reducing crown cover.

92. Regeneration of karri stands should be at a stocking which is sufficient to promote good form, but not encourage inter-tree competition from an early age.

Guiding principle 17

Silvicultural methods will reflect site productivity and development stage of the stand.

Rationale

The karri forest occurs over a geographically restricted area and site productivity varies across its distribution at a fine scale. Differences in tree height can be observed from valley to ridge and between north and south aspects.

Site index or the top height of a stand at age 50 years is used to categorise the site productivity of a stand in karri forest. It is a useful indicator as it can be derived for any age beyond 20 years. Sites with a higher site index are planted at a higher stocking rate than sites with a lower site index. Sites are also thinned according to their site index. The higher the site index, the higher the number of trees retained at each thinning and so the higher the retained basal area.

The response to thinning is less pronounced as trees age. The older the tree, the less able it is to respond to an increase in resources by expanding its root system and crown. For this reason, thinning becomes more conservative as trees age.

Strategies

93. Regeneration stocking targets will recognise that the forest has areas of high, moderate and low site productivity.

94. Use site index for the application of relevant thinning schedules.

95. Thinning schedules will be more conservative as the stand ages.

96. Periodically review classification of site productivity in light of forest inventory, to ensure the correct stocking and thinning schedules are applied.

Guiding principle 18

The forest will be regenerated in a timely and effective manner.

Rationale

Timely regeneration of harvested coupes in the karri forest is important for,

- sustained yield
- carbon storage and sequestration
- weed suppression
- preventing soil erosion
- successful establishment of overstorey ahead of the rapid development of the understorey
- ongoing provision of habitat for karri forest dwelling species
- visual amenity

Timely regeneration is dependent upon the coordination of harvesting, culling, site preparation, seed crop and silvicultural burns. Scheduling of operations is complex and subject to the availability of resources and suitable weather conditions. This complexity can lead to delays in regeneration.

Good site preparation and scheduling of regeneration operations is important for achieving adequate and vigorous establishment of regeneration. While failed areas of regeneration are remediated, it is better to achieve effective regeneration initially than to remediate and area.

Where regeneration is not achieved in a timely or effective way, the reasons behind this should be recorded. Where possible the information recorded should be used address delays or failure in regeneration to improve regeneration outcomes in the future.

Strategies

97. Post-harvest burns associated with the establishment will be planned to occur as soon as practicable after the cessation of harvesting in that coupe.

98. During regeneration, ensure the site is prepared to a standard that supports the survival and vigour of overstorey seedlings in order that they are able to establish in adequate numbers and ahead of understorey establishment.

99. After regeneration, monitor stocking to determine if and where remedial action is required.

100. Where regeneration is delayed or remedial action is required, document where known the reasons for delay or regeneration failure.

Guiding principle 19

Trees to be retained will be marked and protected from damage.

Rationale

Silviculture practice in the karri forest involves the retention of trees for various purposes depending on the silvicultural method selected e.g. trees may be retained to grow on for future timber values, provide hollows for habitat, seed source or cover to protect water values.

Harvesting operations involving the removal of mature trees from a stand have the potential to damage retained trees. Damage can result if harvest machinery or falling trees come in contact with retained trees. Damage may result in exposure of the cambium, broken limbs and even accidental falling of the trees marked for retention.

While some damage may be unavoidable, levels of damage should be minimised. Some damage to the bark and cambium or broken limbs is acceptable in retained habitat trees, as it can add to the habitat value over time. However, damage that kills or destabilises a habitat tree should be avoided.

Avoiding damage to crop trees, especially in thinning, requires care as the trees may be closely spaced and machine operators have limited area to manoeuvre. However, damage to the bark or cambium of crop trees can cause wood degrade. Therefore, avoiding damage to crop trees is important if the value of the crop is to be maintained.

Damage to retained trees may also occur during post-harvest burns. The radiant heat generated by the combustion of fine fuel from tree crowns in combination with larger debris has potential to damage or kill trees. The likelihood of damage varies with the amount of heat exposure, the length of time the tree is exposed to the heat and the bark thickness of the tree.

Strategies

101. Treemarking is to be undertaken in advance of harvesting operations and trees are to be marked for retention in accordance with the silviculture manual. In first thinning of regrowth stands, trained machine operators may be used to identify trees for retention without prior marking.

102. During thinning operations, minimise damage to retained crop trees.

103. During harvest operations, monitor the level of damage to retained trees to ensure it does not exceed the allowable level.

104. During harvesting operations, ensure debris is removed from trees selected for retention when the combination and arrangement of fuels is such they would otherwise be potential for damage to wood or other values during post-harvest burns.

Guiding principle 20

Forest areas that are killed or damaged by fire or other agents may be restored or salvaged.

Rationale

Taking measures to bring areas damaged by fire or other agents back to full productive capacity is important to ensure the forest continues to produce timber for future generations, maximise carbon sequestration and visual amenity.

Forest may be damaged by fire, pests, disease or storms. With climate change these sorts of events may become more frequent and there is a need to be able to respond swiftly to restore the damaged areas if required. The quality and quantity of salvageable material declines quickly. Also, conducting fire salvage prior to the release of the seed and lignotubers allows for a faster recovery of the site, than if salvage harvesting occurs after the understorey has regenerated. Fire damaged trees are pre-disposed to insect, fungal and termite attack, which can also lead to mechanical failure in the tree, constituting a safety hazard. Returns from salvage wood can also be used to regenerate areas which have been degraded by fire and no longer support a seed bank or lignotubers to regenerate.

If sizeable patches of forest are killed or degraded, there is often significant benefit to a range of values by regenerating or rehabilitating affected areas. Salvage harvesting of these sites allows for useable wood to be recovered and provides an opportunity to commence the process for regeneration or rehabilitation. However, as the wood of dead trees degrades quite quickly, achieving this requires that the usual assessment, planning and approval processes be undertaken in a timely fashion.

Strategies

105. All stands that are burnt with moderate to high intensity fire, should be assessed for damage.

106. After natural disturbance events which result in tree death or damage, harvesting may be used to salvage forest products and facilitate regeneration and/or rehabilitation of the disturbed areas. Facilitate salvage harvesting as soon as

possible after the disturbance event to reduce log degrade and promote regeneration.

107. Harvesting to salvage forest products in disease or pest killed stands (or other disturbances) may be approved by the Manager, Ecosystem Health on a case by case basis.

108. During salvage operations, retain legacy elements where they exist (see Guiding principle 3).

109. After natural disturbance events and salvage operations, regenerate and/or rehabilitate areas left understocked.

8. Guiding principles for heritage

Overall objective

Protect and maintain Aboriginal and other Australian cultural heritage.

Cultural heritage is a generic term which refers to the qualities and attributes that are present at places which have aesthetic, historic, scientific or social significance for past, present or future generations. These qualities or attributes may be seen in the physical features at a place (such as travel routes, buildings or relics), or can be associated with the intangible qualities such as the association with or feelings for a place by a community. Identifying intangible qualities will require consultation with the people or communities who hold these feelings or associations. The identification and protection of cultural heritage sites is primarily addressed during the harvest planning and approval process.

Section 56 of the CALM Act, prescribes the management objectives for each category of land to which the CALM Act applies, and management plans for lands managed by the Department may enable management activities to conserve, protect, preserve, maintain or restore cultural heritage. The CALM Act requires that the management of lands and waters include the objective to protect and conserve the value of the land to the culture and heritage of Aboriginal persons.

In relation to other Australian heritage, the *Heritage of Western Australia Act 1990* provides the legislative guidance. The crucial factor in applying the requirements of this Act is that there must have been human activity associated with the place.

Heritage issues are addressed in the harvest planning and approvals process, and the strategies listed below are complementary to this.

Guiding principle 21

Harvest disturbance will be managed to avoid adversely affecting Aboriginal cultural heritage values and sites.

Rationale

A large number of Aboriginal sites have been recorded within the FMP area. These are places of importance and significance to Noongar people and to the cultural heritage of Western Australia. They are significant because they link Noongar cultural tradition to place, land and people over time. Noongar people have a rich and intimate connection with the country within the plan area, which includes knowledge of, rights to, and responsibility for these sites and for protecting the culture and heritage values of these sites.

Scarred or modified trees that mark trails or other sites of significance to Noongar people occur throughout the forest. The locations of the trees that exist today are not all known or registered. Staff conducting silvicultural operations should be aware of the need to conserve cultural heritage and be trained to be able to recognise potential cultural heritage sites, report them and take action to avoid disturbing them until they have been assessed. Trees or sites encountered during silvicultural operations that have potential heritage value need to remain undisturbed until their suitability for registration can be formally determined.

Strategies

110. During treemarking, look for and report items that may be evidence of Aboriginal use of a site such as scarred or modified trees, and prevent damage to them until they can be assessed.

111. During rehabilitation planning, consider use of seed from endemic “bush tucker” plants as part of the seed or seedling mix.

Guiding principle 22

Harvest disturbance will be managed to avoid adversely affecting Australian cultural and natural heritage values and places.

Rationale

Throughout the forest there are places providing examples of early settlement and harvesting activity such as remnant tramways, cuttings, old bridges and loading ramps. Pre-harvesting checks of databases are conducted to conserve known cultural heritage sites. However, not all places with other Australian heritage value are currently known and staff conducting silvicultural operations should be able to recognise potential cultural heritage places, report them and take action to avoid disturbing them until they have been assessed. It is important to protect places of significant value that may be encountered in harvesting operations.

The Department maintains a Significant Trees Register. Listed trees can be identified through pre-harvest checks to ensure they are located and protected from harvesting disturbance. Trees encountered during silvicultural operations that have characteristics of significant trees need to remain undisturbed until their suitability for registration can be formally determined.

Strategies

112. During treemarking, ensure the curtilage of registered heritage places is demarcated or the silvicultural method is adapted to conserve heritage values.

113. During treemarking, mark for retention and ensure sufficient protection of trees of cultural significance, and significant trees. Candidate and nominated significant trees should remain undisturbed until they can be formally assessed for registration.

114. Ensure that any proposal to disturb a blazed location reference tree is approved by the Department prior to the disturbance taking place.

9. Guiding principles for socio-economic benefits

Overall objective

Sustain social and economic benefits, through the provision of a range of goods and services valued by the community.

The karri forest provides a range of goods and services including clean and moderated flows of water, clean air, carbon sequestration (in the forest and forest products), minerals and petroleum, wood and non-wood forest produce, basic raw materials, nature based recreation and tourism, apiculture and wildflowers and seeds. Silvicultural treatments are designed to contribute to the provision of a range of goods and services valued by the community.

Guiding principle 23

The capacity of the forest areas will contribute to social and economic sustainability of regional communities.

Rationale

The karri forest forms part of a larger forest matrix that is important to regional communities and industry in Western Australia. Silvicultural management of the forest seeks to balance employment and other benefits of the native forest industry with the ongoing provision of environmental values (Guiding principles for biodiversity, Guiding principles for ecosystem health and vitality, Guiding principles for soil and water, Guiding principles for climate change and carbon cycles) tourism and recreational values. The adaption of silvicultural methods to meet a range of objectives is often at an economic and or efficiency cost to the native forest industry. The development or adaption of silvicultural practices should seek to balance the achievement of environmental outcomes with economic and social outcomes in order to meet the full range of silvicultural objectives.

The application of silviculture can also benefit environmental and social values outside state forests and timber reserves. For example the application of silvicultural principles can be used to rehabilitate cleared or degraded forest, establish new forest areas, mitigate fire risk while maintaining biodiversity, manage water catchments for water and environmental values and manage the impact of clearing for infrastructure on forest values.

Strategies

115. Liaise with companies involved in large scale mining and infrastructure projects to ensure that regeneration strategies and species mixes are able to provide for both natural values and commercial opportunities.

116. When applying an adaptive management approach, balance the delivery of social, economic, and environmental values by evaluating the likely merits of changes to silvicultural methods.

117. Where possible, preference will be given to achieving silvicultural objective through commercial rather than non-commercial means.

Guiding principle 24

Visual landscape management will be used to manage the potential effects of silvicultural treatments on visual amenity.

Rationale

Priorities for management of visual amenity in forest areas are based on the mapping of visual resource values and visitation and/or road usage patterns. Where a landscape has both high visual quality and high visitation, it is assigned a high priority for visual landscape management, and modified practices are used. Higher levels of landscape alteration are permitted where there are reduced visual resource values and lower usage patterns. Silvicultural treatments can alter the landscape in terms of visual amenity. Well planned silvicultural practice can reduce visual impact by introducing variations of gap size, thinning intensity, felling cycle, rotation length and treatment method.

Strategies

118. During harvest planning, manage the visual amenity from major roads and recreation sites by applying the requirements appropriate for the allocated visual management zone.

119. During harvest planning, extend rotation length, where necessary, to allow mature forest characteristic to develop to maintain visual amenity from major travel routes.

120. During harvest planning, extend the cutting cycle adjacent to major travel routes, where necessary, to allow the scenic quality to recover from harvesting disturbance.

121. During treemarking, limit gap size, or where necessary, design the gap shape to reduce the visual impact of harvesting.

122. When conducting post-harvest treatment adjacent to major travel routes, do not create standing dead trees that would reduce the visual quality of the view-shed and that may pose a potential risk to passing traffic in storm or fire events.

10. Appendices

Appendix 1: Legislative requirements

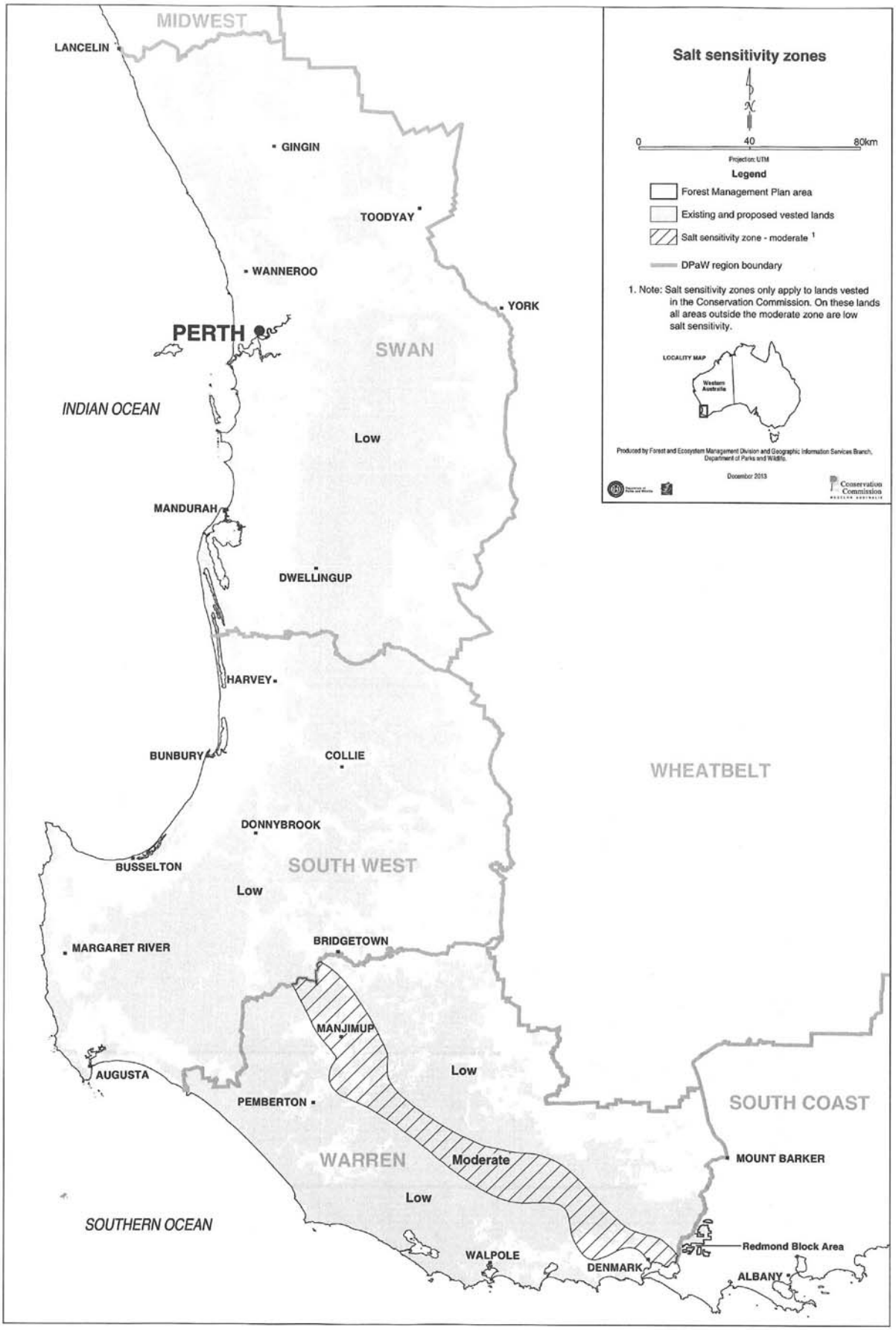
The legislative controls in relation to silviculture in Western Australia are found in the relevant State and Commonwealth Acts and regulations. The following table summarises the relevant government legislation.

Title of Act or Regulation	Relevance of legislation	Responsible agency
Aboriginal Heritage Act 1972	Under this Act the Department is required to report and protect Aboriginal heritage sites and ensure that sites are protected. This Act is also relevant under section 24 of the Mining Act, the Minister for Mines may consent to mining, including exploration activities, subject to conditions that may be intended to protect environmental and cultural heritage.	Department of Indigenous Affairs
Agricultural and Veterinary Chemicals (Western Australia) Act 1995	Covers the use and control of pesticides, including the requirement to use pesticides in accordance with label requirements or "off label" permits. Regulations related to pesticide application will be covered through compliance with the *Code of Practice for the use of agricultural and veterinary chemicals in Western Australia* (Department of Agriculture and Food Western Australia 2007).	Department of Agriculture and Food WA
Bush Fires Act 1954	Provides regulation of the control of bushfire and the use of prescribed fire.	Department of Fire and Emergency Services
Biosecurity and Agriculture Management Act 2007 **(BAM Act)**	Prescribes certain statutory obligations to the Department concerning biosecurity matters generally, and particularly with respect to the management of pathogens that cause forest diseases, through the CALM Act. The management and control of weeds in Western Australia is guided by the BAM Act and the *Agriculture and Related Resources Protection Act 1976* (it is intended that the BAM Act will replace the Agriculture and Related Resources Protection Act and some other Acts in the near future, which may bring some changes to management requirements).	Department of Agriculture and Food WA
Conservation and Land Management Act *(CALM Act)*	Establishes the Conservation Commission as an independent controlling body and provides for the functions of the Conservation Commission including: to have State forest, timber reserves and conservation reserves vested in it; and to prepare management plans for those lands as prescribed in Part V of the CALM Act, according to certain purposes and objectives. It also provides for the Department to manage land vested in the Conservation Commission according to available resources and management plans.	Department of Parks and Wildlife

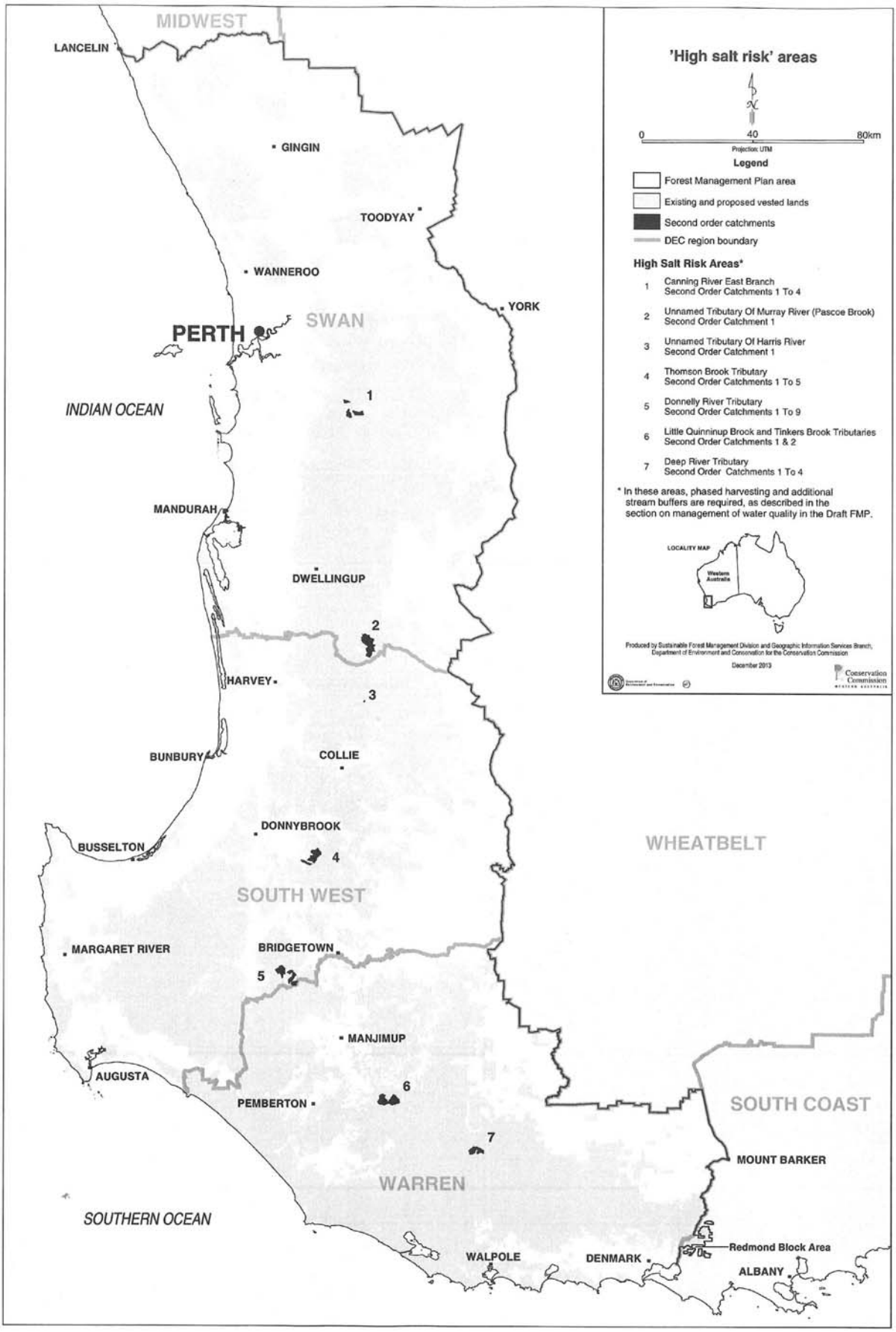
Title of Act or Regulation	Relevance of legislation	Responsible agency
Country Areas Water Supply (CAWS) ***Act 1947***	Governs the construction, maintenance and administration of reticulated supplies of water to country areas, to safeguard water supplies, and influences the Department's activities in gazetted catchments.	Department of Water
Emergency Services Act 2005	Sets out the emergency management arrangements for the State and requires that a number of emergency response plans be maintained. The response plan for bushfire is Westplan Bushfire, which sets out the Department's role in bushfire suppression operations as a 'Controlling Agency'.	Department of Fire and Emergency Services
Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)	Contains provisions relating to the protection of nationally-listed threatened species and ecological communities. In that part of the plan area covered by the Regional Forest Agreement (RFA), the Commonwealth and State governments have agreed that the CAR reserve system and the forest management system, meet the requirements of that Act for the protection of threatened flora and fauna and ecological communities (RFA clause 56). Therefore, the provisions of the EPBC Act for environmental assessment are not triggered for forestry operations.	Department of Sustainability, Environment, Water, Population and Communities (Commonwealth)
Environmental Protection Act 1986 *(EP Act)*	Provides for the protection of the environment across the State. Relates to the prevention, control and abatement of pollution and environmental harm. It is to ensure the conservation, preservation, protection, enhancement and management of the environment, and may relate to any contamination caused by hydrocarbons from machinery and pesticides.	Department of Parks and Wildlife and Environmental Protection Authority
Forest Products Act 2000 *(FP Act)*	Provides for Forest Products Commission with the responsibility for the harvesting and regeneration of native forest and plantations in State forests and timber reserves, and for the sale of forest products (a subset of CALM Act forest produce) and some associated industry development matters.	Forests Products Commission
Health Act 1911	Applicable to pesticide use within a public drinking water source area. The conditions for pesticide use in these areas are specified in the Department of Health *Public Service Circular 88 Use of herbicides in catchment areas*, and also relevant to this is the Department of Water *Statewide Policy 2 Pesticide Use in public drinking water source areas*.	Department of Health
Heritage of Western Australia Act 1990	Provides for the registration and protection of places of historic interest on lands as 'heritage places'. This Act is also relevant under section 24 of the Mining Act, the Minister for Mines may consent to mining, including exploration activities, subject to conditions that may be intended to protect environmental and cultural heritage.	Heritage Council of Western Australia

Title of Act or Regulation	Relevance of legislation	Responsible agency
Metropolitan Water Supply, Sewerage and Drainage Act 1909 (MWSSD Act)	With the CAWS Act (above) and their associated by-laws are used to proclaim Public Drinking Water Source Areas (PDWSA). These may be referred to as water reserves, catchment areas or underground water pollution control areas. There are also requirements that relate to the use of pesticides in PDWSA (see *Health Act*, above). All operations in PDWSA are required to be in accordance with *Statewide Policy No.2 Pesticide use in PDWSA*.	Department of Water
Rights in Water and Irrigation Act 1914	This Act covers the use of water in the plan area, and permits (related to the disturbance of beds and banks) and licences (for the taking and use of water) are required within proclaimed areas.	Department of Water
Soil and Land Conservation Act 1945	This Act provides for the conservation of soil and land resources and provides mechanisms for the mitigation of the effects of erosion, salinity and flooding. This Act covers crown land.	Department of Agriculture and Food
Wildlife Conservation Act 1950	This Act provides for the conservation of native flora and fauna throughout the State.	Department of Parks and Wildlife

Appendix 2: Salt Sensitivity Zones



Appendix 3: High Salt Risk Areas



11. Acronyms

Acronym	Definition
CALM	**Conservation and Land Management**
CWD	**Coarse woody debris.**
Dbhob	**Diameter at breast height over bark.**
DEC	**WA Department of Environment and Conservation (now DPaW)**
DPaW	**WA Department of Parks and Wildlife**
FDIS	**Fauna Distribution Information System**
FHZ	**Fauna Habitat Zone**
FMP	**Forest Management Plan 2014-2023.**
LMU	**Landscape management unit**
TEAS	**Temporary exclusion area.**

12. Glossary

Term	Definition
Adaptive management	A process of responding positively to change. The term adaptive management is used to describe an approach to managing complex natural systems that builds on common sense and learning from experience, experimenting, monitoring, and adjusting practices based on what was learned.
Basal area	The sum of the cross-sectional areas of trees in a given stand measured at 1.3 metres above the ground. It is usually expressed as square metres per hectare.
Biological diversity (Biodiversity) **(described in CALM Act)**	The variability among living biological entities and the ecosystems and ecological complexes of which those entities are a part and includes: (a) diversity within native species and between native species; (b) diversity of ecosystems; and (c) diversity of other biodiversity components.
Biological diversity component **(described in CALM Act)**	Includes habitats, ecological communities, genes and ecological processes.
Bole	The tree trunk from the ground to the crown break. The bole does not include the major branches supporting the crown.
Catchment	The land area drained by a single stream, river, or drainage network.
Clearfell	A silvicultural method in which all, or nearly all trees in a defined area are removed at one time to allow regeneration to establish and develop (note legacy elements are marked for retention, and some non-commercial trees may still remain on site).
Coarse woody debris	Dead woody material such as boles and branches on the ground or in streams.
Coppice (noun)	A shoot (or shoots) arising from adventitious buds at the base of a woody plant that has been cut near the ground or burnt back.
Coppice (verb)	The act of cutting near the ground or burning back a woody plant to encourage a shoot (or shoots) to arise from dormant buds at the base of the plant. Often completed to encourage the development of a new vigorous coppice stem.
Coupe	An area of forest that is planned for timber harvesting as a single unit. It may contain more than one silvicultural objective, such as a number of discrete gaps and areas of thinning.
Crop tree	A tree selected to retain during a harvest operation, to be grown on for many years to become a component of a future commercial harvest
Culling	The reduction in the density of unwanted vegetation, usually to reduce competition to retained crop trees or for establishing or releasing regeneration.
Dbhob	Stem diameter measured at breast height over bark.
Department, or the Department	The Western Australian Department of Parks and Wildlife.

Term	Definition
Dieback (Phytophthora dieback)	In the south-west of Western Australia a disease of plants caused by infection by the soil-borne organisms of the genus Phytophthora, of which P. cinnamomi is the most widespread.
Disturbance	Any relatively discrete event in time that disrupts ecosystems, communities, or population structure and changes resource availability or the physical environment. Disturbance may be natural (e.g. lightning caused fire) or human induced (e.g. timber harvesting).
Ecologically sustainable forest management	Forest management and use consistent with the principles described in section 19(2) of the CALM Act.
Ecosystem	A community or an assemblage of communities of organisms, interacting with one another and the environment in which they live.
Endemic	Flora or fauna that is confined in its natural occurrence to a particular region.
Evapotranspiration	Loss of water from an area of land through the transpiration of plants and evaporation from the soil.
Even-aged stand	A forest stand dominated by trees of a similar age. In native forests, this includes stands where the non-dominant age classes comprise less than 15 per cent crown cover.
Exotic species	Any species growing or living outside its natural range of occurrence. Normally this refers to species purposely or accidentally introduced into countries or regions where they do not historically occur.
Fauna	The animals inhabiting an area; including mammals, birds, reptiles, amphibians and invertebrates. Usually restricted to animals occurring naturally and excluding feral or introduced animals. With respect to the Wildlife Conservation Act(Section 6), fauna is: (a) any animal indigenous to any State or Territory of the Commonwealth or the territorial waters of the Commonwealth; (b) any animal that periodically migrates to and lives in any State or Territory of the Commonwealth or the territorial waters of the Commonwealth; and (c) any animal declared as fauna pursuant to subsection (2), and includes in relation to any such animal – (d) any class or individual member thereof; (e) the eggs, larvae or semen; (f) the carcass, skin, plumage or fur thereof, but does not include any prescribed animal or prescribed class of animal.
Fauna Distribution Information System	Departmental database of taxonomy, conservation status of fauna species and advice on management practices.
Fauna Habitat Zone	Patches of forest systematically distributed across the landscape which are excluded from timber harvesting in the mid-term.
First and second grade sawlog karri	A log cut from the bole of a karri tree that is a minimum of 2.4 metres in length, has a minimum under bark diameter of 200 mm and has a minimum of 30 per cent millable timber on the worst end face.

Term	Definition
Fire regime	The history of fire use in a particular vegetation type or area including the frequency, intensity, season and scale of burning over a period of time. It may also refer to proposals for use of fire.
Flora	The plants growing in an area; including flowering and non-flowering plants, ferns, mosses, lichens, algae and fungi. Usually restricted to species occurring naturally and excluding weeds. With respect to the Wildlife Conservation Act (Section 6), flora is any plant (including any wildflower, palm, shrub, tree, fern, creeper or vine) which is: (a) native to the State or (b) declared to be flora pursuant to subsection (4), and includes any part of flora and all seeds and spores thereof.
FMP	The Forest Management Plan 2014-2023.
Forest	An area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding two metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20 per cent.
Forest block	A named administrative subdivision of the forest, varying in size from about 3,000 to 8,000 hectares.
Forest ecosystem	An indigenous ecosystem with an overstorey of trees of more than 20 per cent crown cover. These ecosystems should normally be discriminated at a resolution requiring a map-standard scale of 1:100,000. Preferably these units should be defined in terms of floristic composition in combination with substrate and position within the landscape.
Forest products	As for the purposes of both the CALM Act and the Forest Products Act: trees or parts of trees: timber, sawdust or chips; charcoal, gum, resin, kino or sap; and firewood, located on public land or sharefarmed land.
Forest regeneration	The renewal of a forest arising from planting or from seed or the young plants on a site. The process by which a forest is renewed.
Formal reserve	See 'Reserve – Formal'
Global carbon cycles	The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of the Earth.
Guideline	A document type that guides and directs actions for achieving consistency and required standards. Guidelines permit some flexibility in their application.
Habitat	A component of an ecosystem providing food and shelter to a particular organism.
Habitat tree	A tree selected to be retained in a coupe because it has features attractive to wildlife particularly for hollow nesting birds and animals.
Heritage	Something inherited from a past generation that is valued.
Hybrid	The progeny produced from a cross between two genetically different plants, usually different species.

Term	Definition
High salt risk	Refers to certain river systems within the historic intermediate rainfall zone (based on data up to 1978) that are least disturbed and as such, are presumed to have the most intact aquatic ecosystems and consequently are the most environmentally sensitive to rises in saline groundwater.
Immature stand	The stand development stage beginning with the main lateral spread of tree crowns and finishing with the start of a mature stand.
Impact - dieback	The effect on vegetation from the presence of *Phytophthora* species, referred to as either predicted or current impact.
Indicator	A measure (measurement) of an aspect of a criterion. A quantitative or qualitative variable that can be measured or described and that, when observed periodically, may demonstrate trends.
Informal Reserve	See 'Reserve – Informal'.
Land category	Section 5 of the CALM Act specifies the categories of land to which the Act applies and section 6 defines those land categories. For the purposes of the plan the land categories are; State forest, timber reserves, national parks, conservation parks, nature reserves, any other land reserved under the Land Act 1933 and vested by order under that Act in the Conservation Commission and any other land other than excluded waters, reserved under Part 4 of the Land Administration Act 1997, the care control and management of which are placed by order under that Part with the Conservation Commission.
Landform	All the physical, recognisable, naturally formed features of land having a characteristic shape. Includes major forms such as a plain, mountain or plateau, and minor forms such as a hill, valley or alluvial fan.
Landscape Management Unit	An agglomeration of vegetation complexes and ecological vegetation systems, as defined and mapped by Mattiske and Havel (2002), to form more compact management units that recognise the underlying ecological characteristics.
Landscape scale	A mosaic where the mix of local ecosystems and landforms is repeated in a similar form over a kilometres-wide area. Several attributes including geology, soil types, vegetation types, local flora and fauna, climate and natural disturbance regimes tend to be similar and repeated across the whole area. It could be a (sub) catchment or, for convenience, an administrative management unit such as a forest block or an aggregation of forest blocks. Landscape scale is usually tens of thousands to a few thousand hectares.
Legacy elements Also Legacy habitat elements	Refers to existing key habitat features, such as hollow bearing trees and logs which may take many decades to replace and which are retained after harvesting or remain after natural disturbance, which provide refugia and enrich the structural complexity of the new stand.
Lignotuber	A woody swelling formed at the base of some eucalypts that has the ability to produce new shoots when the existing ones are destroyed.
Local scale	A discrete area of land to which one or more operations have been or are planned to be applied. For the purposes of this guideline – the average area of a forest blocks in the vicinity.

Term	Definition
Mature stand	The stand development stage beginning with the formation of large persistent branches forming the outline of the crown as the crown reaches its maximum size, and finishing with the commencement of a senescent stand.
Monitoring	A process of repeated measurement or observation, for specified purposes of one or more elements, usually according to prearranged schedules in space and time, using comparable data collection methods. Often used to assess a management program, condition of the environment and/or resources being managed, to help determine if desired activities, processes, outputs and outcomes are being achieved.
Patch	A group of trees resulting from a natural regeneration event or a past management activity such as gap creation and regeneration. May also refer to a particular, relatively small area of forest and/or other vegetation type(s).
Pest	Troublesome or destructive animals including insects, either introduced or native.
Pesticides	Includes herbicides, insecticides, fungicides and related products registered for use in pest control.
Phytophthora cinnamomi,* or *P. cinnamomi	Water mould. The pathogen that causes most *Phytophthora* dieback disease.
Policy	A document containing principles and rules that outline an organisation's position and which guides decisions and actions taken in the conduct of its activities.
Prescribed burning	The controlled application of fire under specified environmental conditions to a predetermined area and at the time, intensity and rate of spread required to attain planned resource management objectives.
Regrowth forest	Native forest which is dominated by similar aged stems that have not reached the mature growth stage, originating from previous harvest events, such as gap creation, or other disturbances, such as bushfire.
Rehabilitation	The process necessary to return disturbed land to a predetermined surface, vegetation cover, land-use or productivity.
Reserve – conservation	An area set aside primarily for the conservation of natural ecosystems but which may allow a level of recreation consistent with the proper maintenance and restoration of the natural environment.
Reserve – formal	One of the land category categories of national park, nature reserve, conservation park, or CALM Act sections 5(1)(g) or 5(1)(h) reserves for the purpose of conservation.
Reserve – informal	An area set aside for conservation under an approved management plan; has had opportunity for the public to comment on changes to reserve boundaries; able to be accurately defined on a map; and is of an area and design sufficient to sustain the values it seeks to protect.

Term	Definition
Resilience	the capacity of an ecosystem to withstand external pressures and, over time, return to its prior condition, including its ability to maintain its essential characteristics such as taxonomic composition, structural forms, ecosystem functions and processes (adapted from Thompson *et al*. 2009, who cite Holling 1973).
Riparian	Pertaining to the banks of streams, rivers or lakes.
Rotation	The period between regeneration establishment and the final harvest.
Salt sensitivity zone	The Swan and South West regions and parts of the Warren Region are classified as low salt sensitivity and other parts of the Warren Region are classified as moderate salt sensitivity (see Appendix 2).
Salvage harvest	The removal of forest produce and/or forest products following an unplanned disturbance event to recover economic value that would otherwise be lost. Salvage operations require approval by the Department. By their nature, salvage harvest areas may not appear on the three or one year harvest plan(s) that pre-date operation.
Saproxylic	Saproxylic organisms are those which are dependent on dead or decaying wood (or dependent on other organisms that are themselves dependent on dead wood). They may be dependent on dead or decaying wood for part of or the entirety of their life cycle.
Second-storey	The structural layer between the shrub and herb storey and the overstorey (canopy). In the karri forest, this layer may include species such as *Agonis fluxuosa, Allocasuarina decussata, Chlorilaena quercifolia*, B*anksia grandis, Xylomelum occidentale,* and *Persoonia longifolia.*
Seed tree	A tree left standing for the purpose of providing seed for the regeneration.
Senescent Crown (for selecting trees bearing hollows)	The development stage that follows the mature tree stage and precedes natural death, usually involving a decreased ability to repair damage and degradation. Characterised by a dominance of dead branches in the tree crown together with the formation of new branches from epicormic buds. Senescent crowns in large trees are likely to bear usable hollows for large hollow dependent fauna. They are found in trees 50 – 70cm, but more often ≥ 70 cm, dbhob, with a crown senescence rating greater ≥ 4 (Whitford *et al.* 2001), and with highest likelihood at a crown senescence rating of 7. Likelihood of bearing usable hollows is reasonable with higher dead branch order scores (≥ 4 and increases with a dead branch order 7 to 9; (Whitford *et al.* 2001)), and crowns with evidence of hollow entrances (smallest entry dimension >10cm in diameter) into low order branches (orders 1, 2 & 3 - branches leading to, or close to the bole).
Senescent stand	The development stage that follows the mature stand and precedes natural death, usually involving a decreased ability to repair damage and degradation. Characterised by a dominance of dead branches in the tree crown, together with the formation of new branches from dormant buds.

Term	Definition
Silviculture	The theory and practice (silvicultural practices) of managing the establishment, composition, health, quality and growth of forests and woodlands to achieve specified management objectives.
Silviculture for ecosystem health	The application of silvicultural management to protect threatened ecological values or communities where the effects of climate change will escalate the threat to the value or community.
Silviculture for water production	The application of silvicultural management to increase the flow of water to surface and groundwater reservoirs which will support aquatic ecosystems, but also be available for consumptive purposes.
Site productivity	The inherent capacity of forest land to grow woody biomass of a particular species.
Stand	A group of trees or patch of forest that can be distinguished from other groups on the basis of size, age, species composition, structural condition or other attribute.
Structure	When applied to a forest, is the horizontal and vertical distribution of the alive and dead vegetation.
Stool coppice	A growth stage where shoots have developed from a stump cut off at ground level.
Suppression	The process whereby a tree or other vegetation loses vigour and may die when growing space is not sufficient to provide photosynthate or moisture to support adequate growth
Sustained yield, or Sustained timber yield	The first and second grade sawlog yield that a forest can produce for an extended period (to at least the year 2070) at a given intensity of management.
Taxa (taxon)	A defined unit (for example, species or genus) in the classification of plants and animals.
Temporary exclusion area (TEAS)	An area that is excluded from timber harvesting for a particular period of time.
Thinning	A felling made to reduce the density of trees within a stand. Usually undertaken to improve the growth of trees that remain by reducing competition, without either permanently breaking the canopy or encouraging regeneration. May also be undertaken to enhance forest health, water production or achieve another objective.
Threatening process	Those processes which may result in the long-term reduction of biodiversity. Examples include predation and habitat change by introduced animals; competition and displacement by introduced plants and destruction and modification of habitat.
Timber	Sawn or other products derived from first and second grade jarrah and karri sawlogs.
Timber harvesting	The cutting, felling, and gathering of forest products undertaken as part of a planned sequence of silvicultural activities including the regeneration of the forest.
Treemarking	The procedure in which trees are marked for retention (or removal) prior to timber harvesting or other operations in a forest.

Term	Definition
Two-tiered forest (uneven aged)	Native forest stands of mixed age and structure, comprising mature trees intermixed with younger regrowth trees arising from regeneration following the death or removal of mature trees by previous harvests or other disturbances. Also referred to as 'mixed aged forest' or 'uneven-aged forest'.
Understorey	Herb and shrub layer. This vegetation layers occurs beneath both the overstorey and second-storey.
Vegetation complex	A combination of distinct site vegetation types, usually associated with a particular geomorphic, climatic, floristic and vegetation structural association.
Variable density thinning	Type of thinning used to introduce structural complexity into even-aged regrowth stands by for example, leaving un-thinned patches, retaining older trees and understorey elements, creating small gaps and varying the spacing of trees in thinned areas. In stands containing a range of size classes it can also be used to vary the spacing of trees and the retained basal area in response to variations in trees sizes.
Weed	A plant, often a self-sown exotic, growing where it is not wanted.
Weed – environmental	A naturalised non-indigenous plant species outside the agricultural context that adversely affects the health, survival or regeneration of indigenous species in natural vegetation communities.
Whole of forest scale	All land categories that are subject to the plan.
Wood	The material produced in the stems and branches of trees and other woody plants.
Wood products	All timber and other wood products, inclusive of sawlogs, firewood, chiplogs and other log products supplied to the wood products industry.
Yield	The amount of product produced from the forest by a particular management strategy.

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