Review of Fire Operations in Forest Regions managed by the Department of Conservation and Land Management

Report to the Executive Director of the
Department of Conservation and Land Management

Compiled by Chris Muller
December 2001

Currency of Report

This report was compiled during the period July 2001-September 2001, and finalised through to December 2001, and to the best knowledge of the author is correct at that date.

Disclaimer

This report is a review commissioned by the Executive Director of the Department of Conservation and Land Management and considered fire management in the context of the Department's statutory functions and its focus on conservation. The report was compiled by Chris Muller with the assistance of staff of the Department and other agencies.

The document is designed to stimulate discussion and contribute to the broader debate about fire management. The report and its recommendations do not represent the views or policies of the Department or the Minister for the Environment and Heritage.

Acknowledgements

Many people, particularly from the Department's Science Division, Regional Services Division and WA Threatened Species and Communities Unit assisted in the preparation of this report. All the assistance received through information, advice, and review of different sections is greatly appreciated. In particular, I would like to acknowledge Femina Metcalfe and Don Herbertson from Fire Branch for the many long nights they struggled with my requests for information, and for the forbearance they (and my "volunteer" typist and clerical assistant) showed.

I also wish to acknowledge the assistance and advice received from Deputy Crown Solicitor John Young, and the contributions from Forest Products Commission staff.

Chris Muller

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Preface

Fire management is one of the most challenging and one of the most contentious activities undertaken by the Department of Conservation and Land Management. Fire is a natural occurrence, important for the perpetuation of many plant species and ecosystems. Loss of biodiversity may occur as a consequence of inappropriate fire regimes. Inappropriate regimes can include too frequent fires and fire exclusion.

The Department's Corporate Executive initiated a review of fire management operations in the south-west in the context of the change to the Department's statutory functions and the creation of the Forest Products Commission in November 2000. As the Department is no longer responsible for the harvesting and sale of forest products, and has only a limited role in the management of commercial plantations, it is necessary to ensure that the application of fire, the Department's response capability with respect to wildfire suppression, and related resource allocations, remain appropriate and are consistent with the Department's statutory functions.

A project officer, Mr Chris Muller, was appointed to conduct the review which has addressed thirteen terms of reference. It is essential that the Department reviews programs and processes on a regular basis, identifies and debates problems and issues and adapts management and systems in response to the findings of such reviews.

This report makes a timely contribution to a wider review process of fire management in the State's south-west. A symposium is planned for April 2002 and a broader public review is to follow during which the views of stakeholders and the community will be sought.

The conclusions and recommendations contained in the report provide an important basis for constructive dialogue and further debate on key aspects of fire management. The report is openly self-critical in places and this is important so that the Department can learn and progress from errors and missed opportunities.

I would like to encourage departmental staff and others to read the report and participate in a much needed constructive dialogue about how the Department can achieve its fire management goals.

Keiran McNamara
Acting Executive Director

December 2001

Executive Summary

This report was compiled in response to a brief containing thirteen Terms of Reference (see Appendix 1), the last of which: was added after the commencement of the review. The report is structured in line with these Terms of Reference.

Overview

Of the broad range of important issues raised in this review, three key areas identified in the context of the Department's changed statutory functions are:

- A change in the primary focus for fire management planning;
- The need to increase the amount of burning to be undertaken; and
- The need for wider consultation and involvement in fire management.

Historically the primary focus for fire management planning has been protection against wildfire, particularly for life and property, with, in recent years, an increased emphasis on conservation values. This report recommends a fundamental change: that fire management be based primarily on the attainment of the Department's core outputs, supplemented by additional works only as and if necessary to meet the Department's duty of care to in relation to providing community protection.

Legal advice indicates the Department is not bound by the Bush Fires Act, however certain departmental officers have overriding powers under that Act that can be used to take supreme control of wildfire suppression and to prevent others from implementing fire protection activities that may interfere with the management of the land.

The Department has a duty of care under common law that extends to taking reasonable care to prevent loss or injury from fires originating on lands managed by the Department. A risk management approach should be taken in determining the resources to be applied to satisfy a reasonable duty of care. A level of fire management that achieves burning to provide the optimal fire distribution for biodiversity protection would also reduce the risk of fires from lands managed by the Department causing such loss or injury. In some cases additional works may be required to achieve adequate fire protection, but fire management planning should initially be based on achieving the Department's core outputs.

An adaptive management approach to fire planning is advocated, which includes an approach to determining an idealized fire distribution to meet nature conservation outcomes, utilizing bio-indicators.

An analysis of the present situation has identified that insufficient burning is being undertaken to maintain an optimal fire distribution to meet either biodiversity or protection objectives. There is currently potential for large areas to be burnt in wildfires that would be uncontrollable during severe weather conditions. Whilst limited high intensity fires are a desirable component of the overall fire distribution, there is currently a significant risk of loss of biodiversity through extensive high intensity wildfires, particularly in the Southern Forest Region. Such wildfires would also pose a threat to community values.

To achieve sufficient fire diversity, this report recommends that larger (minimum 5-10,000ha) individual burn envelopes be applied where possible, with the objectives of creating mosaics of unburnt and burnt areas within the burn envelope. It is recognized that there are inherent risks associated with such a strategy. For example if conditions are not as predicted, the planned mosaic may not be achieved. It is considered, however, that the potential for extensive high intensity fires through not being able to implement sufficient smaller burns to provide the desired fire distribution carries a much greater risk of loss of biodiversity.

Fire management activities influence and are influenced by factors external to the lands managed by the Department and its core outputs, and should not be viewed in isolation. It is recommended that relevant stakeholders including the Environmental Protection Authority/Department of Environmental Protection and the Department of Health, be involved in fire management decisions to achieve the best overall outcome for the community. Analytical decision support tools such as the Wildfire Threat Analysis, Fire Management Analysis, and Remote Sensing/Geographic Information System (GIS) tools should be used to underpin such decisions.

Expenditure on fire management works undertaken to meet broader community values that are not part of the Department's core outputs, should be separately identified.

Fire management is only one contributor to the attainment of core output goals. A risk management approach is taken for fire management. To enable comparison with other activities and provide an improved basis to optimize the allocation of scarce resources, it is recommended that a similar risk management analysis be undertaken for all other activities that combine to support the Department's outputs.

Fire management activities can be highly dangerous and stressful. It is important that a high level of training and awareness is maintained to reduce the risks. A core experienced workforce should be retained in line with the Standards of Fire Cover model. Fire management is a core activity for attaining outputs and a contribution from all the Department's field based staff is essential. All job descriptions for staff in the South West should recognize such contribution is required and selection criteria should include relevant skills for a role in the fire management organization (be it a primary or support role).

The safety risks associated with the use of fire fighters not experienced with forest fires need to be recognized. The Department should continue to co-operate with the Fire and Emergency Services Authority (FESA) and Local Government to encourage appropriate training for Brigade members where these are likely to be involved in forest fires.

A number of the factors affecting staff in relation to fire activities are identified. Some of these can be addressed through management action. It is recommended that reduction in current inequities between industrial groups be attempted through award realignment.

Brief summary and recommendations for each section

1 Synthesise current research knowledge related to fire.

There is an extensive body of knowledge on fire behaviour and fire effects relevant to the forest regions. More is known about fire in these areas than in other parts of the State. Nevertheless, our knowledge is far from complete, and always will be. Management must be implemented based on the best information available, and research encouraged in order to improve our knowledge base.

To facilitate transfer of knowledge and ensure inclusion of the latest scientific knowledge in the planning process, relevant staff from Science Division should be directly involved in the planning process.

Recent research indicates that fire behaviour models, whilst reliable for low intensity fire, severely under predict rates of spread for higher intensity fires by factors of two or more.

Greatest knowledge of fire effects relates to the vascular flora. Fungi show responses similar to the vascular flora in the same environs. Mammals are the most studied, and invertebrates the largest and least studied fauna group. The responses of many organisms are closely related to the effects on and responses of the vascular flora.

Much of the knowledge has been gained from short term studies. These studies tend to be favoured by grant funding and the requirements for theses. Continued research by institutions should be encouraged.

Whilst there have been a number of studies specific to south west forests, there is a need for greater long term research, in which the Department should take a lead.

There is a range of evidence to suggest historic fire regimes, but many of the factors have changed and past regimes are not necessarily appropriate for the future. Fire management needs to be based on desired future outcomes.

A number of principles are stated, based on existing knowledge, to guide management where more detailed knowledge is lacking:

- Fire is inevitable in the forests of south west Australia;
- Fire is a naturally recurring disturbance that both kills and regenerates vegetation;
- The flora and fauna have evolved with fire;
- Fire is an important determinant of vegetation structure;
- There is no single fire regime that is best suited for all flora, fauna, and ecosystems;
- Environmental heterogeneity is one of the major driving forces in ecological systems;
- Diversity and variability in fire regime at a landscape level help maintain biodiversity;
- Patchiness of burning is an important factor in providing heterogeneity at a local level;
- Fires burning under very dry conditions with moderate to high fuel accumulations leave few unburnt areas;
- Fires burning under severe conditions with moderate to high fuel accumulations cannot be controlled;
- Isolated small fires can result in concentrated grazing of subsequent regeneration;
- Fire regime at a very local scale may be critical for the survival of some threatened species or ecological communities; and
- The ecological impact of fire depends on extrinsic factors as much as fire itself.

Recommendation 1.1: Greater resources be allocated to long term fire effects research.

Recommendation 1.2: Relevant Science Division staff be directly involved in fire planning, including annual burn plan reviews.

2 The Department's legal responsibility for fire management and wildfire suppression.

The Department may be liable under common law for damage or injury arising from fire on land that it manages. The extent of this liability depends on the circumstances in each case. However, in relation to government and government entities the Courts have tended to impose very exacting standards when determining whether the care exercised in a particular case was reasonable.

The Conservation and Land Management Act provides powers to certain officers in relation to fire (particularly with respect to forest land), but the Act does not specify any obligations with respect to fire management. Fire management is an implied requirement to meet the objectives of the Act and management plans prepared in accordance with the Act.

The Crown is not bound by the Bush Fires and Fire Brigades Acts, therefore, while certain departmental officers do have powers they may exercise, the Department does not have statutory obligations under these Acts. Actions authorised under these Acts may, however, impact on the Department's management of lands.

The Department should take a risk management approach in discharging its fire control responsibilities to minimise its potential liability. This should include good communications to reduce misleading perceptions and false community expectations.

Recommendation 2.1: The Department develop a consistent approach that complies with both the letter and the spirit of the Bush Fires Act. As the Department is not bound by the Act it should not seek permits or approval, but it should consult with and seek concurrence from FESA and local authorities in situations where private landholders require permits.

Recommendation 2.2: The Department seek amendment to State Emergency Management Committee (SEMC) Policy Statement 7 to properly reflect the Department's statutory powers and responsibilities.

Recommendation 2.3: The Department seek amendments to the Bush Fires Act such that prime responsibility for adequate fire protection clearly rests with the person(s) who establish vulnerable assets in fire prone areas.

Recommendation 2.4: The Department formally respond to all applications for development adjoining lands managed by the Department, outlining the potential fire risks and hazards, and emphasising the responsibility for ensuring adequate fire protection lies with local government.

Recommendation 2.5: The Department regularly communicates to local government the limitations on its contribution to fire protection in the local area, and immediately advises when there is any reduction or other factors that affect the effectiveness of fire protection.

3 Identify values of the south-west forest region land which the Department manages and undertake a consultative risk analysis, with the Output Directors, to determine the risk factors to be applied to the maintenance of those values.

A qualitative risk analysis of the potential impact of fire on values has been undertaken. Fundamental to this is a classification of values that allows comparison between economic and less tangible values. Whilst this classification is the result of consultation with a range of departmental personnel, consultation is required with the wider community to gain acceptance.

Recommendation 3.1: The Department seek wider community input into the classification of values for fire management analysis.

4 Undertake a consultative risk analysis, involving the Forest Products Commission, of the impacts of fire on timber supply, to include advice from the Commission of the level of resource protection it is prepared to fund.

A qualitative risk assessment was undertaken in consultation with Forest Products Commission staff. A more detailed quantitative analysis was beyond the time frame of this review but should be considered in light of both the commercial and social implications of fire.

A number of highly qualified fire control staff have transferred to the Forest Products Commission. It is in the interests of the Department, the Commission and the community that these skilled personnel continue their involvement with fire control. Arrangements should be agreed for recoup of costs for assistance with fire management clearly not associated with State forest or the protection of timber supply, and beyond the scope of the obligations under the Forests Products Act..

Recommendation 4.1: The Forests Products Commission undertake a more detailed quantitative analysis to define the commercial consequences of fire loss.

Recommendation 4.2: Forests Products Commission be requested to ensure its staff maintain and acquire fire skills and experience through training and participation in burning.

5 Provide advice on fire fighter safety as a part of the risk analysis.

Forest fires are potentially lethal. Fireline intensities are much higher than possible in grasslands and can exceed the threshold for survival many times. Most fire crew have gained the majority of their experience on low intensity fires.

Greater fuel accumulations pose increased threats to the safety of fire fighters through higher intensity and less predictable fire behaviour, both reducing the chance of survival and increasing the risk of entrapment.

Knowledge, experience and the ability to recognise and avoid dangerous situations are the most important ways to maintain fire fighter safety. Protective equipment should only be a secondary defence. With increased demands on staff, there is less opportunity for on the job training and mentoring to gain experience. A formal mentoring program should be established.

Recommendation 5.1: The Department ensures all forest fire fighters, controllers and supervisors are trained to understand the potential fire behaviour changes with increased fuel loads, with an emphasis on avoiding entrapment situations.

Recommendation 5.2: Employment contracts for seasonal employees be framed to encourage annual re-employment to increase the experience level and hence safety of seasonal fire crews.

Recommendation 5.3: A level of experienced fire fighters be maintained to enable forest fire crews to include in their total numbers not more than one third inexperienced personnel who in turn must meet the basic fire fighter accreditation standard.

Recommendation 5.4: Increased emphasis be placed on successional planning for key fire control staff.

Recommendation 5.5: The Department cooperate with FESA and local government authorities to encourage a high level of forest fire training for brigades likely to be involved in forest fires.

Recommendation 5.6: The Department consider the changes in the availability and experience of others involved with forest fire fighting when determining its resource and experience requirements for fire management in particular areas.

Recommendation 5.7: The Department provide a formal mentoring program for fire as a requirement of a formal in-service program for all new field personnel.

Recommendation 5.8: Training programs be implemented so as to facilitate both attendance and learning outcomes.

Recommendation 5.9: The Department continue to monitor the development and effectiveness of crew protection systems and ensure best practice is implemented when replacing or upgrading fire fighting units.

6 Identify other outcomes the Department requires from its fire management activity.

Fire management is a highly visible and contentious activity that can have a strong influence on the Department's corporate image. The professionalism of fire suppression activities is widely recognised, but greater efforts are required to gain community support for fire management plans.

The management skills for fire emergencies are equally applicable to other emergency situations and the organisational and leadership skills have many applications in general management.

Recommendation 6.1: Appropriate market research be conducted into what key stakeholders and the wider community know, understand, and perceive concerning fire in the natural environment and fire management practices in Western Australia.

Recommendation 6.2: The Department implement a strategic communication and advocacy program that will develop key stakeholder and community awareness and understanding of the role of fire in the natural environment, and will assist in encouraging informed community discussion concerning fire management in the State's natural environment.

7 Identify short to medium term fire management plans and prescription.

An adaptive approach to fire management planning is proposed, that aims to:

- Maintain seral stages of both overstorey and understorey components based on an idealised distribution for each class at whole of forest, regional and landscape scales. The idealised distribution model proposed to be adopted takes the form of a negative exponential function, with the parameters determined for the key species present.
- Create a mosaic of burn ages from recently burnt to long unburnt, that includes patches burnt at different seasons and at different frequencies. Generally, granite outcrops and more mesic landscape elements, such as riparian zones, wetlands, some swamps, and valley floors, will contain relatively fire sensitive species, so should be burnt less frequently.
- For any given area, vary the interval between fire and the season burnt.
- Protect/enhance threatened species and ecological communities. Localised fire regimes will be applied based on the best available knowledge to protect/enhance these. This will automatically predetermine the seral stages for part of some vegetation units.
- Provide protection for visitors and visitor facilities, and provide for protection against loss or injury on adjoining lands from fires on lands managed by the Department. Just as specific regimes may need to be applied to protect/enhance threatened species and ecological

communities, modified regimes (eg shorter rotation) may need to be applied to provide for an acceptable level of protection in some areas.

A model to determine appropriate fire/structural diversity based on bio-indicators, is suggested. GIS and remote sensing tools are seen as critical for both planning and monitoring the outcomes.

The risks associated with burn size are discussed, and it is concluded that where practicable, burn size should be maximised to improve the ability to implement fire management plans.

Fire management plans must be based on the best knowledge, consider the practicalities of implementation as part of the adaptive process, and must be integrated with other land management activities. Fire management has impacts beyond the Department's lands and responsibilities, and key stakeholders should be involved in fire planning to facilitate both the best overall result for, and the support of, the community.

Recommendation 7.1: The development of remote sensing and GIS tools to support fire management planning is continued.

Recommendation 7.2: An adaptive approach to burn planning is taken, based on fire diversity/structural models for vegetation units.

Recommendation 7.3: Policy Statement 19, Fire Management Policy, be revised to more accurately reflect the values and intended practices of the Department.

Recommendation 7.4: The size of individual burn operations be maximised where possible, with the objectives to provide for diversity and a mosaic of burnt and unburnt patches within the boundaries of the overall burn envelope.

Recommendations 7.5: Prescription objectives clearly identify both the reason(s) and intended outcomes for each burn.

Recommendation 7.6: The Department, the Department of Health and the Department of Environmental Protection/Environmental Protection Authority be involved in determining a fire management strategy that provides for optimal overall outcomes.

Recommendation 7.7: A framework be established to integrate fire management with other plans.

8 Develop a means of separately identifying timber protection, community protection values, and nature conservation values.

Clear identification of values is required to ensure fire management programs are properly targeted and prioritised, and to enable proper financial management and accounting. Current budgeting and accounting practices have contributed to inaccuracies and inconsistent recording of costs. Changes are recommended to increase reliability of financial data.

Many of the fire management activities are undertaken for the benefit of neighbouring communities and not in support of the Department's core outputs, except insofar as such work is required to meet the reasonable duty of care to prevent loss or injury from fires on the lands managed by the Department. Expenditure that is for community protection should be clearly identified.

Recommendation 8.1: Clear objectives for the protection/enhancement of values be agreed between representatives of the purchasers (Forest Products Commission and Output Directors) and providers (Regional Services fire representatives) during the planning process, and these form the basis for cost allocation.

Recommendation 8.2: The budget allocation process be amended to account for annual variations between outputs in fire activities.

Recommendation 8.3: Accounting procedures be amended to provide for all costs to be debited to a single account for each fire related job, with automatic redistribution on a predetermined basis.

Recommendation 8.4: The fixed costs of specialised equipment such as heavy duties and fire fighting plant be separately identified and debited to wildfire suppression and burning.

Recommendation 8.5: The costs of providing community protection be identified through the creation of a separate program or sub-programs within the core output programs.

9 Review the Wildfire Threat Analysis and provide advice on the incorporation of other values into the WTA or an appropriate similar tool. This review to include the provision of advice on a fire analysis system to identify areas in which fire is required for protection of values

An analytical approach to fire management provides a rational basis for activities. Greater use should be made of the modelling powers of GIS (see also Section 7) and the tools initially introduced for the Wildfire Threat Analysis should be broadened to be used for fire management analysis. The Wildfire Threat Analysis remains appropriate for considering the requirements for protection against wildfires.

For this review, modelling of fire behaviour has been done in an Environmental Systems Research Institute (ESRI) environment (using ArcView and Spatial Analyst) in line with the desk-top GIS being widely used, making it accessible to a range of users. The maps produced and included in this report demonstrate that there is currently significant potential for extensive high intensity fires.

Recommendation 9.1: The Wildfire Threat Analysis be retained as an appropriate means of identifying where additional actions are required to provide fire protection.

Recommendation 9.2: The GIS analytical tools developed for the Wildfire Threat Analysis be maintained and further enhanced to support fire management planning and analysis.

Recommendation 9.3: Science and Nature Conservation Divisions investigate spatial models to incorporate research findings in fire management analyses.

10.Review the appropriateness of the landscape scale of current fire management practices.

The current practices would appear appropriate for the maintenance of biodiversity if sufficiently extensively applied. On available evidence, there appears insufficient fire in many areas, particularly in the southern forests, to maintain an idealised structural/fire diversity model. There is currently potential for the extensive spread of high intensity (uncontrollable) wildfires that potentially threaten biodiversity, life, property and forest values. It is concluded that the scale of current burning undertaken is inadequate to achieve either biodiversity conservation or protection objectives.

Recommendation 10.1: Remote sensing/GIS analysis techniques be further developed and implemented to monitor fire distribution.

Recommendation 10.2: Resources and appropriate techniques be applied to enable sufficient prescribed fire to be applied to maintain an overall fire diversity (including wildfire) as near as practicable to the fire distribution models.

11.Suggest a method of weighting the maintenance of the Department's current fire management program against the implementation of its statutory obligations.

A risk management approach has been developed to assist in determining priorities for fire management. A similar approach is proposed as a rational basis for achieving a balance between fire management and other activities the Department must undertake to meet its statutory obligations.

The current standards of fire cover approach is reviewed and generally supported as an appropriate process and performance measure. Introduction of ISO 14001 is seen as potentially beneficial by providing standards for all processes/outcomes.

Recommendation 11.1: A risk management approach be implemented for all activities to provide weightings for allocation of resources to meet a range of obligations.

12.Implement a Communication Strategy for the Review.

Consultation undertaken for the review included representatives from a wide range of stakeholders within the Department, from fire crew to Directors, and representatives of the Forest Products Commission. Advice was also sought from the Crown Solicitor's office.

A strategy for communicating the findings of this review is suggested.

Recommendation 12.1: This report on the Review of Fire Operations be made widely available to departmental staff, including through publishing on CALMWeb.

13.Identify the human resource issues associated with implementing possible fire management models.

Stress, conflict, and a perceived lack of support are amongst the reasons why many staff are less willing to be involved and are happy to leave the difficult task of fire management to others. There is a need for greater recognition of achievement.

There are inequities in the conditions and remuneration between different industrial groups, between different shifts, and in the different levels of responsibility. Inequities can discourage participation in fire operations.

To maintain sufficient skilled staff for incident management, fireline, and support roles, the selection criteria for field based staff positions in the forest regions should include relevant skills for a role in the fire organisation. Adequate provision needs to be included in works programs and Service Provider Agreements for training to maintain and enhance relevant skills.

Recommendation 13.1: Fire service provisions be given a priority for award alignment, to develop uniform and equitable provisions that reflect the duties performed.

Recommendation 13.2: Fire management be identified as part of the duties of all departmental staff in the forest regions, and relevant skills base be maintained.

14. Miscellaneous

Both operations and accuracy could be streamlined with upgrade of current planning and recording systems making greater use of the Department's intranet. The introduction of technology must be accompanied by adequate training. Improvements are needed in sharing information between different sections of the Department.

Recommendation 14.1: Consideration be given to greater use of the internal web to facilitate operational planning and to improve accuracy of recording data.

1 Synthesise current research knowledge related to fire.

1.1 Fire Behaviour

There is an extensive body of both Australian and international knowledge on fire behaviour relevant to fires in the forest regions, well beyond the scope of this review. The Department of Conservation and Land Management (and one of its predecessors, the Forests Department) and CSIRO have undertaken a considerable amount of fire behaviour research in south-west forests. Much of this fire behaviour knowledge has been incorporated into fire management practice. This review outlines some of the important areas of knowledge affecting fire management in WA.

The Forest Fire Behaviour Tables (Sneeuwjagt and Peet, 1979, 1985, 1998) are widely used for fire behaviour prediction in south-west forests. These empirical tables are based on a large number of experimental fires, but within a limited range of conditions. The 1985 edition of the tables included a preliminary rate of spread algorithm based on Burrows' more comprehensive range of experiments that included line ignitions (mostly about 50 m line lengths), and dry summer burning conditions. These data have since been analysed comprehensively (Burrows 1984, 1999a & b). Burrows also incorporated some data from wildfires for the revision of the tables, but the paucity of reliable wildfire data limited this analysis.

Early fire behaviour experiments were ignited almost exclusively with individual spot fires or short line fires, which exhibit a delay during an acceleration phase before reaching their "pseudo-steady state" rate of spread for the prevailing conditions. Lines of fire greater than about 200m do not show this delay, but will immediately spread at their pseudo-steady state with a change in wind direction. This has been implicated in the deaths of fire fighters in a number of instances (Cheney et al 2000).

Equations derived from the 1985 Forest Fire Behaviour Tables by Beck (1995), and equations for fire behaviour in grassland (Noble et al, 1980: Cheney et al 1998) and shrubland (McCaw, 1998; Catchpole and McCaw, 1999) have enabled the development of computer modelling of fire spread for use in decision support systems (eg Muller, 1993; Beck & Muller 1991).

The fire behaviour tables provide good prediction within the bounds of the experimental data and for point source ignition fires such as those used during most prescribed burning, but have long been recognised as being deficient in more severe conditions. Experience has demonstrated wildfires in extreme conditions spread much more rapidly than predicted by the Forest Fire Behaviour Tables.

More recent research has shown the Forest Fire behaviour Tables over-predict the rates of spread at low wind speed (Burrows, 1999a) and more importantly, have been shown to consistently under-predict the rates of spread of fires burning faster than 50-60m/hr or on fronts greater than about 100m by a factor of two to three or more (Burrows, 1999b; Gould et al, 2001). Research work as part of Project Vesta (CSIRO/CALM fire behaviour research project) is still in progress and revised fire spread equations from this work are not yet available. Other aspects of Burrows' investigations of summer fires have also been published in relation to crown scorch height (Burrows 1997), bark consumption (Burrows et al 2001), soil heating (Burrows 1999), and flame residence time (Burrows 2001).

The limitations of the tables, particularly in very dry conditions, have been stressed in fire training courses aimed at increasing understanding of the factors that influence fire behaviour, although quantitative predictive modelling data were not available. (eg Burrows, 1984).

Many current forest fire spread models, including the Forest Fire Behaviour Tables, use fuel quantity as an input. Whilst fuel quantity increases with time since last fire, preliminary results from Project Vesta (McCaw, pers. comm.) indicate that other fuel attributes, including time since fire and hazard scores based on height, density and proportion of dead fuel are more strongly correlated with rate of spread than fuel loading is.

The contribution of bark to the fuel load and structure, and consequent development of vertical spread of fire and fire spotting, increases substantially with fuel age (McCaw et al, 2001). This has significant implications for both fire effects and wildfire suppression.

The Project Vesta work is limited to dry sclerophyll forest, and any rate of spread data cannot be directly transferred to other forest types such as karri. Because of the higher fuel loadings, it is possible that the under-prediction of fire behaviour in very dry conditions of current models will be greater for wet sclerophyll forests than for dry sclerophyll forests.

The relationship between fire rate of spread, fuel quantity consumed, and fire line intensity is long established (Byram, 1959). Intensity is used as a measure of suppression difficulty (eg Loane and Gould, 1986, Muller, 1993a; Wilson, 1988) and as a measure of impact on vegetation (eg Cheney, 1981,1990).

1.2 Fire Effects

Because of time and resource limitations, a complete and thorough review of the scientific literature is beyond the scope of this fire review. A brief synthesis of some of the knowledge and references to information available appears below. Presenters to a planned symposium on fire in south west Australian ecosystems have been invited to summarise knowledge across the range of relevant topics, with the intent that the papers be published in a definitive book. Originally planned for September 2001, this has now been deferred to 2002. It is anticipated the outcomes of this symposium will provide a more detailed synthesis of the current state of knowledge in relation to fire in the south west.

Reviews of forest fire ecology have previously been undertaken by Christensen and Abbott (1989), and more recently by various authors for the Comprehensive Regional Assessment (CRA, 1998).

Christensen and Abbott (1989) reviewed the impact of fire on soils, nutrient cycling, micro-organisms, vascular flora, invertebrates, reptiles and amphibians, birds and mammals. They concluded that with regard to the living organisms in the ecosystem a general pattern is apparent. While there are variations on the theme, their broad conclusion was that:

(a) There is a reduction in numbers and sometimes in species of organisms immediately after a fire.
(b) There is recovery in numbers and species of organisms after fire. This recovery is often characterised by the appearance of species which were rare before the fire or were present in the ecosystem only as stored seed in the soil.
(c) Changes may occur in species dominance and relative density after fire. These changes are often spectacular (eg fire weeds) but are almost always transient.
(d) Recovery from fire is achieved almost totally by propagation from within the burnt area, although recovery of vertebrates is often assisted and sometimes is achieved entirely from unburnt areas.
(e) The rate of post-fire recovery of animal species depends largely on vascular plant recovery patterns, which are in turn influenced by the intensity and season of the fire, and by the length of intervals between fires.

(f) Each species of organism has a well-defined response to fire. This response is flexible, allowing organisms to react across a wide range of possible fire regimes. Nevertheless, there are limits to responses, associated with individual life history strategies.

Christensen (1997) updated the Christensen and Abbott 1989 review including a review for fire effects on amphibians. He concluded that the general pattern of impact and recovery following fire described in 1989 for vertebrates is still relevant. He notes that whilst information on reptiles and frogs is limited it appears that frogs recover from fire within the first few years. The Sunset frog may be more permanently affected if its peat habitat is burnt out under dry conditions in a wildfire. He notes the importance of peat areas for relict and threatened species and the vulnerability of swamps to fire. He refers to examples that illustrate the conundrum faced by land managers in that total fire protection is likely to lead ultimately to an intense fire in accumulated fuels resulting in peat loss or alternatively protection using prescribed fire may on occasion also result in some peat damage.

Safstrom and Lemson (1997) reviewed the effect of disturbance on 117 rare and priority 4 listed species. Fire is listed as a threat to 55 of these, but for many the exact nature of the fire threat was not detailed. Fire was noted as enhancing the recruitment for a number of species, and 8 species were identified as disturbance opportunists for which road construction and/or maintenance fire breaks offered significant recruitment opportunities.

Pate and Hopper (1994) outlined the effects of fire on plants in the south west according to the following groups:

- Obligate seeders - destroyed by fire and recruit thereafter solely from seed. Obligate seeders without soil stored seeds are particularly vulnerable to adverse seasonal conditions following a fire, or repeat fires before seedlings reach maturity. Frequent fire will also deplete soil based seed reserves.
- Resprouters – part or all of the above ground parts are killed by fire. New shoots form from fire resistant buds in trunks or root stocks.
- Fire ephemerals – avoid fire in time by germinating exclusively after fire and complete their growth cycle before the likely advent of the next fire.
- Regular ephemerals – mature, reproduce and die within the 6-8 month winter/spring growing seasons when fires are unlikely.
- Geophytes – winter active. Avoid fire in space and time by peronating via various types of underground storage organs.

Obligate seeders without soil stored seeds are particularly vulnerable to adverse seasonal conditions following a fire, or repeat fires before seedlings reach maturity. Frequent fire will also deplete soil based seed reserves.

With facultative resprouters/seeders fire cued or fire obligate germination is common however their seedlings generally grow much less rapidly than those of congeneric seeders. It may take some time to reach sufficient size or establish enough energy reserve to survive a burn following quickly on the fire, which prompted their establishment from seed.

Geophytes include a large number of orchids of limited distribution. While many clearly benefit from, or require fire for reproduction they may be damaged by fire when above ground leaves, shoots and reproductive parts are still present.

Greatest knowledge of fire effects is related to vascular flora and mammalian fauna. Fewer studies have been conducted on other organisms such as fungi and invertebrates.

Australia has a high diversity of fungi, at least equal that of other continents, of which only 5 – 10% have been named (Bougher, 1997). As part of the CRA process Bougher reviewed the effects of key disturbances including fire on the fungi of the forest regions. His report focused on ectomycorrhizal fungi as keystone organisms for plant and community function.

Bougher noted that disturbances are likely to affect fungal fruiting and mycelial activity in ways analogous to the effects on flowering plants, soil invertebrate fauna, and soil micro-organisms. Environmental heterogeneity due in part to disturbance can rejuvenate and benefit forest ecosystems.

Other points in his review included:

- Fire can directly affect fungi by heating/burning/smoke and indirectly by reduction of litter and soil organic matter and altering nutrients.
- Fire may be important for mineralising organically bound phosphorous. Higher intensity fires result in large increases in the extractable concentrations of N,P,K,S in surface soil immediately after fire, though total N,S & K loss may be substantial.
- A specialised group of fungi including many ascomycetes and basidiomycetes often fruit in abundance on many burn sites soon after fire.
- In the same way that fire is an essential disturbance for the perpetuation of some plant species, so too may this be true of some indigenous fungi.
- Some fungi in south-west forests have developed a range of post fire strategies. (eg sclerotia-forming fungi). Fire may be an essential disturbance for some fungi as it is for some plants.
- Long unburnt soils can be inhibitory to plant growth. Ellis and Pennington (1992) showed that the inhibition was alleviated by inoculation with more recently burnt soil, which improved the form and development of mycorrhizal and fine roots.
- Variations in the frequency of burning and the uneven heating of the soil surface, create patchiness and an increase in fungal species richness of some post burn communities.
- Changes in litter quantity and quality may be important for redevelopment of soil fungi after fire. The season and intensity of fire may affect species and in turn litter composition.
- Ectomycorrhizal and other fungi which occur after fire have significant ecological roles including recommencing nutrient cycling activities, establishing mutualistic associations with recolonising plants, and providing food for small marsupials
- Species and populations of fungi vary in ways analogous to those of plants after fire. Various fungal species become prominent and reduced/absent at various times after fire. Long or short fire intervals may favour particular species.

Invertebrates are the largest and least studied fauna group. There has been only one species of over 200,000 for which a population study has been undertaken. In their review of the effects of disturbances on this group of organisms, Majer and Heterick (1997) noted the impact on animals of prescribed burning in dry forests has been the focus of considerable research. The litter invertebrate fauna is radically altered in the short term. Shrub associated invertebrates are eliminated by the burn but recolonise as the vegetation regrows. Colonisation is much slower in large burnt areas where distances to sources of animals are greater.

Other points in their review include:

- Different studies have yielded different results. At an ordinal level, variations in abundances are attributable more to locality, seasonal and annual effects, than fire. In general, fires have little or no effect on soil fauna but litter fauna are substantially affected. Little and Friend (1993) consider that fire does not exert a long term influence but other authors have indicated some studies showing numbers still lower four and five years later.
- Friend (1995) suggested suitable potential indicator groups for invertebrates are Aranaeae and probably Lepidoptera, Isopoda, Blattodea and Thysanura.
- Invertebrate populations are extremely variable in time and space at a very fine scale. This variability is driven by environmental factors (Friend, 1996).
- Whelan et al (1980) reported a richer arthropod fauna in burnt than in unburnt Xanthorrhea, but burnt Banksia yielded much poorer fauna than unburnt.

- Ants show some differences following fire for up to 12 months.
- Spiders with good dispersal mechanisms rapidly recolonise depending on distance from boundaries. Main (1987) has proposed that relict groups and those with poor dispersal cannot readily re-establish and are therefore endangered by fire unless this coincides with dormancy in the taxa.
- Some species of spiders have been shown to survive fire but are subject to predation and death through exposure.
- In a four year study Strehlow (1993) found rapid recolonisation after fire with spider populations returning to pre fire conditions after two years. The arachnid community in both burn and control sites was different to that at the beginning of the study. He suggested that climate was an important factor in influencing spider communities.

There have been very few studies on the effects of fire on aquatic invertebrates and fish. Horwitz et al (1997) state potential impacts include heating (both direct and indirect through loss of cover), exposure and loss of soil moisture. Burning of the dried section of non perennial streams may kill drought resistant eggs/stages which may be over summering.

According to Horwitz et al, longer term effects may include:

- A reduction in the amount of coarse particulate organic matter in the aquatic system.
- Increased water temperature and greater photosynthetic production in aquatic systems through the removal of shading.
- Changes in vegetation with direct impacts on fish habitat.
- Changes in soil moisture regimes with removal of litter and/or foliage.

Peat swamps (organosol terrains) are of high importance, containing many significant flora and fauna. These areas may be highly susceptible to fires during dry seasons, particularly high intensity fires.

Lamont et al (1997) reviewed the impacts of disturbances on processes. They did not locate any literature that examines the hydrological consequences of fire. They note fires can have conflicting effects on nutrient status. Fire increases the availability of scarce nutrients, and results in losses through volatilisation. Considerable nitrogen in particular can be lost through volatilisation, but fires can also stimulate nitrogen fixation by plants. Modelling of nitrogen fluxes in a karri forest subject to regular fire has shown both depletion and net additions depending on assumptions made.

Fires reduce biomass in the short term but the net effect (if any) on the carbon balance is unclear. Lamont et al note many species respond with faster growth after fire. There have been some individual comparisons on implications for biomass accumulation but this has not been done at an ecosystem level or over a fire cycle.

By comparison with other ecosystems there is good knowledge of fire effects in south west forests, particularly Jarrah, however knowledge remains far from complete. Much of the research has been focussed on individual species and/or short-term studies, partly as a result of meeting funding or other objectives. This has resulted in the relatively good knowledge base for the effects of a single fire event, but there are few published data on long term cumulative effects of fire regimes on forest ecosystems. Such studies specific to south west forests undertaken by Forests Department/CALM scientists were fire effects on karri birds (15 yrs), southern jarrah upland plants (28 yrs and 15 yrs) and eastern jarrah plants (15 yrs).

Aspects of forest fire ecology currently the subject of active projects within the Science Division include:

- Fire regime effects on the structure and floristics of Jarrah forests (B. Ward, N. Burrows).
- The effect of fire on fruiting of fungi in Karri regrowth stands (R. Robinson).

- The effect of fire frequency on soil organic matter and bulk density in Jarrah and Karri forest (K. Whitford).

Other fire effects projects where data collection is complete and writing up is in progress or recently completed include:

- Effects of spring and autumn prescribed burns on small vertebrates in Jarrah forest at Batalling (A. Wayne).
- Prescribed burning and conservation of invertebrate communities in Jarrah forest at Batalling (I. Abbott, P. van Huerck).
- Invertebrate biodiversity in Tingle and other forests of the Walpole-Nornalup National Park in relation to time since fire (P. van Huerck).

A list of reports and papers relating to forest fire behaviour and ecology authored or co-authored by departmental staff since the 1997 reviews for the CRA follows at section 1.5. Whilst this shows an ongoing research effort, it also demonstrates the current limitations. There is a need for a greater emphasis on long term forest fire research, and for investigation of important ecosystems associated with forests that may have special requirements in relation to fire management (eg wetlands and riparian communities, organic soil communities, fringing vegetation around rock outcrops.). Whilst universities and institutions should be encouraged to undertake further fire ecology research, this is likely to be predominantly short term. The department can provide the continuity necessary for long term research and should take the lead in such studies.

The level of fire research is currently lower than it has been in then past. Fire research accounted for approximately 3% of the 2000-2001 Science Division expenditure (equivalent to slightly over 12% of the amount spent on fuel reduction burning in the same period, and approximately 4% of all fire related expenditure excluding actual suppression; See Appendix 2). Under half this amount was on fire effects studies.

Recommendation 1.1: Greater resources be allocated to long term fire effects research.

1.3 Fire Regimes

Few question that fire has long been a feature of south-west forest areas. The Mediterranean climate with long dry summers, flammable vegetation, and recurring ignition sources such as lightning, make fire inevitable. The vegetation has evolved with fire and demonstrates a range of vegetative and reproductive traits that enable plants to persist, and in some cases depend, on particular fire regimes, with fire being an essential disturbance for the perpetuation of some plant species (Bell et al, 1989; Pate & Hopper, 1994). A lack of Tuart regeneration has been attributed to a change in fire regime, with less frequent fire resulting in the establishment of dense Peppermint to the detriment of the Tuart (Ward 2000; Bradshaw 2000). Similar significant changes in vegetation and soils with long fire exclusion have been noted in Tasmanian wet sclerophyll forest (Ellis 1994).

Loss of biodiversity as a consequence of fire exclusion, and the need for a change in fire regime has also been noted on Fraser Island (Sinclair 2000).

There is ample historical evidence for fire including fossil deposits, carbon records, and in more recent times, historical journals. Whilst there is general agreement fire is a natural part of the ecosystems, there is less agreement on what are " appropriate" regimes.

Aboriginal people regularly used fire (eg Hallam 1975 & 1985) with consequent impact on the biota (Bowman 1998; Pyne 1991). Nyungar people applied a variety of fire regimes in their management of the land (Kelly 1999), both low intensity fires at very short (2 year) intervals, and hot fires at longer intervals to regenerate thickets.

Evidence from studies on Balga shows that in pre European times fire occurred in some areas at least three times in a decade (Ward & Sneeuwjagt 1999; Ward et al 2001). Burrows et al (1995) suggested from a dendrological analysis of stem damage of old Jarrah trees that there were frequent low intensity fires prior to European settlement with occasional high intensity fires. Following European settlement there were more frequent high intensity fires, which Burrows et al (op cit) suggested were probably associated with increased fuel levels as a result of logging and long periods of fire exclusion until the introduction of prescribed fuel reduction burning.

Gill et al (1997) reviewed the literature on fire for six periods (Pre 1855; 1855-1920; 1920-1953;1953-1960; 1960-61; 1961 to present) outlining the changes at various times post European settlement with differing attitudes towards fire, and noting some of the consequential effects.

Knowledge of past regimes can assist understanding of ecosystem development and function but is not in itself a necessarily appropriate basis for determining future regimes, both because of inherent uncertainties and changed circumstances.

A number of authors (eg Bradstock et al, 1995) have referred to the need for fire management to be flexible and continually take into account the history of fire. Species monitoring as a guide to prescribing fire provides the most effective way of avoiding plant extinctions. The use of relatively fire sensitive species as site indicators has been proposed as bio-indicators. After all species have flowered following a fire, a period of time is left for seed build up to occur before the site is considered safe from extinctions should it be burnt (Gill and Nicholls 1989, Burrows and Friend 1998).

Burrows et al (1999) propose the use of a range of indicators including climatic characteristics that affect fire proneness, evidence of historical fire regimes and specific biological attributes of key floral and faunal elements, to assist in determining appropriate regimes.

Adaptive management based on monitoring and ongoing research is recommended by a number of authors (including Gill and Bradstock, 1995).

An adaptive approach to fire management planning is recommended in section 7. To facilitate transfer of knowledge and ensure inclusion of the latest scientific knowledge in the planning process, relevant staff from Science Division should be involved in the planning process.

Recommendation 1.2: Relevant Science Division staff be directly involved in fire planning, including annual burn plan reviews.

1.4 Principles

Whilst there is a considerable body of knowledge pertaining to fire in south-west forests, such knowledge will always remain imperfect, even with continuing research efforts. To assist consistency and objectivity in planning in the face of uncertainty, it is useful to provide guiding principles that can be periodically revised based on the current state of knowledge.

- **Fire is inevitable in the forests of south-west Australia.** The combination of climate, vegetation and ignition sources ensures fires will occur. Management can influence the fire regime, but cannot exclude fire.
- **Fire is a naturally recurring disturbance that both kills and regenerates vegetation.**

- **The flora and fauna have evolved with fire.** Species show a range of adaptive traits that enable them to survive or prosper in a fire environment. Whilst few species are dependant on fire, many demonstrate positive flowering or regeneration response following fire and achieve a competitive advantage from particular fire events or regimes. The response of species is highly variable.
- **Fire is an important determinant of vegetation structure.** For example, periodic "hot" fires are required to regenerate thickets favoured by some fauna, followed by periods of fire exclusion. Low intensity fires are important in maintaining old growth karri forest (ie avoiding stand replacement fires), retaining large old Tingle (tree fall is much higher following more intense fires), and preserving examples of open coastal woodlands of Yate and peppermint.
- **There is no single fire regime that is best suited for all flora, fauna, and ecosystems.** Organisms have developed with a great variety of fire regimes, and thrive in different circumstances. A fire regime that enables one organism to gain competitive advantage will disfavour a competitor.
- **Environmental heterogeneity is recognised as one of the major driving forces in ecological systems** (Williams et al 1994).
- **Diversity and variability in fire regime at a landscape level helps maintain biodiversity.** Fire diversity provides the greatest opportunity that the requirements of the range of organisms present will be covered. Diversity in regime relates to the season, intensity and time between fires across the landscape. Variability refers to the uniformity (or lack of it) in the regime as it relates to any particular area. Both high intensity and very low intensity fires and fires in all seasons form part of such diversity.
- **Patchiness of burning is an important factor in providing heterogeneity at a local level.** It can allow organisms to persist on a site where fires are at a frequency that is close to the reproductive limits of the organism.
- **Fires burning under very dry conditions with moderate to high fuel accumulations leave few unburnt areas.** Widespread, high intensity fires will periodically remove most of this local patchiness from the landscape. If such fires occur too frequently they will result in local extinction, or loss over a long time period while re-colonisation takes place. Where fires are intense, much of the subsequent recolonisation is dependant on external recruitment. The larger the fire, the longer the process.
- **Fires burning under severe conditions with moderate to high fuel accumulations cannot be controlled.** Fires burning under such conditions spread rapidly, and have intensities exceeding the limits for suppression. Such fires will continue to spread unchecked until they either run into areas of lower fuels or weather conditions moderate to the extent that control is possible.
- **Isolated small fires can result in concentrated grazing of subsequent regeneration** by both insects and larger fauna This can markedly reduce the density of regeneration following fire.
- **Fire regime at a very local scale may be critical for the survival of some threatened species and ecological communities.**
- **The ecological impact of fire depends on extrinsic factors as much as fire itself,** in particular weather conditions both preceding and subsequent to the fire.

1.5 Recent Science Division Publications

Bibliography of publications relating to the behaviour and ecological effects of fire in south-west Australian forest and shrubland ecosystems authored and co-authored by staff of the Science Division, Department of Conservation and Land Management - January 1997 to July 2001

Source: Science Division website bibliography
http://calmweb.calm.wa.gov.au/drb/science/biblio/index.html

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2 Obtain legal advice on the Department's legal responsibility for fire management and wildfire protection

2.1 Summary

The Department may be liable under common law for damage or injury arising from fire on land that it manages. The extent of this liability depends on the circumstances in each case. However, in relation to government and government entities the Courts have tended to impose very exacting standards when determining whether the care exercised in a particular case was reasonable.

The Conservation and Land Management Act provides powers to certain officers in relation to fire (particularly with respect to forest land), but the Act does not specify any obligations with respect to fire management. Fire management is an implied requirement to meet the objectives of the Act and management plans prepared in accordance with the Act.

The Crown is not bound by the Bush Fires Act and the Fire Brigades Act, therefore, while certain departmental officers do have powers they may exercise, the Department does not have statutory obligations under these Acts. Actions authorised under these Acts may, however, impact on the Department's management of lands.

The Department should take a risk management approach in discharging its fire control responsibilities to minimise its potential liability.

2.2 Statutory Provisions

Four Acts have the potential to impact on the Department with respect to fire. The application of these Acts to the Department is outlined below, based on advice from the Crown Solicitor's Office, however until the provisions are tested in the Courts there remains some uncertainty.

2.2.1 Bush Fires Act 1954

The Bush Fires Act applies throughout the State, including urban areas and fire districts gazetted under the Fire Brigades Act 1942, however the provisions of the Bush Fires Act do not affect the provisions of the Fire Brigades Act or the Conservation and Land Management Act (Bush Fires Act S6).

The Bush Fires Act outlines both obligations with respect to fire and powers that may be exercised by various parties.

2.2.2 The Department's obligations

Legal advice received is that the Department/the Crown is generally not bound by the Bush Fires Act.

Until such time as it has been tested in Court, there will remain an element of uncertainty. However, while there is some uncertainty as to whether the Crown is bound by the Bush Fires Act, the advice received indicates the view most likely to be judicially adopted is that it is not so bound.

The relevant rule of statutory interpretation is the presumption that, in the absence of express words or necessary implication, statutes are not to be construed as binding the Crown. Some uncertainty was introduced in 1990, with the Court holding that whether the presumption against the Crown being bound by a statute applied in a particular case depended simply upon the proper interpretation of that statute having regard to the statute's subject matter, its purpose and policy, and the time it was enacted." [High Court decision Bropho vs Western Australia (1990) 171 CLR 1]

Advice received is that prior to the Bropho decision, the legal position was that the Bush Fires Act did not bind the Crown. Bropho has introduced an element of uncertainty as to whether the Crown is bound by the Act or perhaps by some of its provisions though, on balance, having regard as to when the Act was introduced, to various observations in Hansard which appear to assume the Crown was not bound, and to the presence of section 34 (which appears to have been drafted on the assumption that there was no statutory obligation for Crown land or reserves), the better view would seem to be that the Bush Fires Act does not bind the Crown.

Whilst the Department is not generally bound by the Bush Fires Act, s56 imposes a specific obligation on forest officers (amongst others) to demand the name and address of a person found committing an offence and provide details to the Local Authority.

2.2.2.1 Powers of other parties on lands managed by the Department

Although there is no obligation on the Department to act in accord with the Bush Fires Act, there is provision under the Act for other persons to take actions that may impact on land managed by the Department.

S39 of the Act provides wide-ranging powers for a bush fire control officer to take necessary steps to extinguish a fire. If a forest officer is present at a fire on or near Crown land he may take supreme control of the fire, and any bush fire personnel present come under his orders and direction (s45). The exercise of the powers under s39 by a bush fire control officer can thus be restricted on land managed by the Department.

S34 provides for neighbours to construct firebreaks and burn to reduce hazards on Crown land other than "forest land", unless there is in place a fire management plan approved by the Fire and Emergency Services Authority and a notice precluding exercise of the powers under s34 is published. Such notice may be subsequently varied or cancelled. It is the Crown Solicitor's view that it is incumbent on the Department to notify the Authority if the plan cannot be adhered to (see 2.3 Requirements under Common Law).

The powers under section 34 for various lands managed by the Department are summarised as follows:

- *State forest, timber reserves and freehold land held by the Executive Director* is included in the definition of 'forest land' in the Bush Fires Act and therefore the powers for others to enter and construct breaks cannot be exercised.

- *Other lands vested in the Conservation Commission* are subject to entry under s34 (if a FESA approved fire management plan is not in place).

- *Private land managed by the Department under CALM Act s16* is deemed to be the appropriate category of Crown land (except for dealings in that land). If the agreement is for the land to be managed as State forest neighbours cannot exercise powers under s34. In all other cases they could enter the land to establish breaks unless specifically excluded where a fire management plan has been approved by the Fire and Emergency Services Authority.

- *Crown lands managed under CALM Act s33(2)* remains Crown land subject to entry under s34.

- *Timber Sharefarms:* The Crown is not bound by the Bush Fires Act in respect to timber sharefarms established on private land (whether through agreements under CALM Act s34B or Forest Products Act Part 7), however the land remains private land, and the owner of the property remains bound. Therefore any plantation must comply with requirements such as a notice regarding firebreaks issued under s33 of the Bush Fires Act (or local laws under the Local Government Act as referred to under this section).

- *Regional Parks:* There are various tenures and agencies responsible for lands within Regional Parks. Whilst the Department has responsibility for preparing a coordinated management plan, the responsibilities remain with the owner/occupier/managing agencies for each parcel of land. The lands for which the Department has management responsibility are vested in the Conservation Commission, or are lands owned by the Western Australian Planning Commission and managed under CALM Act s16 agreement "for some other public purpose". It is therefore not deemed to be one of the categories of lands vested in the Conservation Commission, but as the land is owned by a Crown agency it would be considered Crown land for the purposes of the Bush Fires Act.

2.2.2.2 Special recognition for certain Departmental staff and lands under the Bush Fires Act

The Bush Fires Act gives special recognition to forest officers and "forest land". In general, it provides for powers to the Department on forest land equivalent to those of a local authority, and provides greater "over-riding" powers to forest officers in some circumstances.

Forest officers have all the powers of a bush fire control officer for fires burning on forest land (s39), and may take supreme control of a fire burning on or near Crown land (s45), in which case all bush fire control officers and other personnel at the fire come under the direction and control of the forest officer. Note that s45 is not restricted to forest land, but includes all categories of Crown land managed by the Department.

A forest officer may prohibit or postpone the lighting of a fire within 3 km of forest land, notwithstanding a permit has been issued, and may do so "to the exclusion of the exercise of those powers by a bush fire control officer or the local government" (s46).

Where there is forest land in the district, a local authority must consult with a forest officer if it proposes to vary the prohibited or restricted periods (s17 & s18).

The Act places restrictions and obligations for persons carrying on activities involving fire (including blasting) near forest land (s25, s27A, s27D) including requirements for notification and the activities being undertaken to the satisfaction of a forest officer.

A forest officer may enter land to extinguish a fire and may recover expenses (s28).

The Executive Director may direct neighbours of forest land to construct breaks or reduce hazards (s34).

2.2.3 Fire Brigades Act 1942

The Fire Brigades Act applies to all areas within fire districts declared under that Act, and overrides the provisions of the Bush Fires Act in those areas (see s6 Bush Fires Act) including powers of forest officers under the Bush Fires Act where these are in conflict.

Fire control is the responsibility of the Fire and Rescue Service within gazetted fire districts.

S33 (e) (i) provides for the Chief Officer or an authorised officer to direct an owner or occupier to abate a potential danger to life or property from fire. There is no provision for the Chief Officer or a third party to undertake work if the direction is not implemented. There are potential implications for Departmental lands if a direction were to be given, however in the absence of specific reference to the Act being binding on the Crown it is likely the Department is not so bound.

2.2.4 Fire and Emergency Services Authority of Western Australia Act 1998

The Fire and Emergency Services Authority is a body corporate with perpetual succession established under this Act. References to the previous Bush Fires Board under the Bush Fires Act now refer to the Authority.

The Authority has a board of management, whose membership includes the 3 chairmen of the consultative committees established under s22 of the Act:

(a) Bush Fire Service Consultative Committee;
(b) Fire and Rescue Service Consultative Committee; and
(c) State Emergency Service Consultative Committee.

The Bush Fires Act previously defined membership of the Bush Fires Board to include the Department. There is not a requirement under the FESA Act for the Department to be a member of either the Authority or a consultative committee.

The Department is currently represented on the Bush Fire Service Consultative Committee.

The FESA Act does not impose obligations on the Department.

S37 of the FESA Act protects the Crown and individuals from civil liability with respect to functions being carried out under the Bush Fires Act, Fire Brigades Act, and Fire and Emergency Services Act.

2.2.5 Conservation and Land Management Act 1984

The Department's obligations with respect to fire management are not explicit in the Conservation and Land Management Act.

There are only four sections in the Act that refer directly to fire, and these relate to powers and offences, not obligations on the Department. It is an offence to light fires that threaten forest produce (s104) and to burn on adjoining lands without notice to a forest officer (s105). A forest officer authorised by the Executive Director can enter any lease, licence or permit area to prevent or suppress fires (s120). A forest officer can call for assistance with fires on State forest or timber reserve (s135).

Fire management is implicit in carrying out the functions of the department. S33 is silent with respect to fire, but requires management to be in accord with management plans. Management plan objectives include protection of flora and fauna and maintenance and restoration of the natural environment (s56) (of which fire is a component). In the absence of a management plan "necessary operations" that can be carried out include works for the protection of persons, property, flora and fauna (s33A).

Thus whilst not specifically mentioned as an obligation under the Act, fire management is a necessary part of carrying out the department's functions under the Act.

2.2.6 Wildlife Conservation Act 1950, and Commonwealth Environment Protection and Biodiversity Conservation Act 1999

These Acts do not impose statutory responsibilities for fire management, but do impose requirements in relation to how fire management activities are conducted. It is an offence to take actions which significantly impact on threatened species (both Acts) and threatened ecological communities or matters of national environmental significance (under the Commonwealth legislation) without approval under the Act(s).

The Environment Protection and Biodiversity Conservation Act, and those provisions of the Wildlife Conservation Act relating to flora, are binding on the Crown.

2.3 Requirements under Common Law

Whether or not the Department may properly be described as an occupier within the meaning of the Occupiers' Liability Act in respect of any piece of land, its responsibilities are for all practical purposes determined in accordance with the ordinary principles of negligence.

Under the common law the Department falls under a duty to take all reasonable care to eliminate or minimise foreseeable risks of harm. It will be liable in negligence if a person or entity suffers injury or loss as a consequence of the Department's conduct where the Department cannot demonstrate that that conduct was reasonable.

The Department would be held liable for injury caused by fire which a departmental employee had negligently lit or negligently failed to control.

In circumstances where a fire has occurred, without negligence by the Department (such as through lightning strike), on land in respect of which the Department has statutory responsibilities, the existence of those responsibilities may of themselves give rise to a duty to take all reasonable steps to contain the fire. However, legal advice is that regard would have to be had to all the circumstances – including the nature of the land, the nature of the Department's function in relation to that land, and the extent to which the Department has by its conduct led others to assume that the Department has accepted responsibility for fire control on the land – to determine the nature and extent of the duty of care owed by the Department to those suffering injury or loss by reason of the escape of fire from departmental lands. Generally, it should be assumed by the Department that it does fall under an obligation to take all reasonable care to extinguish or control bush fire (however occurring) on its lands.

What is reasonable depends on the circumstances of each case. However, as is evidenced by the High Court's decision in *Nagle vs. Rottnest Island Authority* (in which the Authority was held liable for failing to erect a sign to warn of the risk of diving at The Basin at Rottnest Island), it is not uncommon for the Courts to impose upon government entities very high "reasonable" standards. This is particularly the case where the agency holds itself out as having special expertise, which is relied on by others.

There is currently a very high public expectation of the Department in relation to fire. The Department (and previously the Forests Department) are recognised as leaders in forest fire control. This expertise is reflected in legislation and government policy. The Bush Fires Act provides precedence of powers to forest officers, and the State Emergency Management Committee Policy Statement 7 (Western Australian Emergency Management Arrangements) identifies the Department as the Hazard Management Agency for departmental lands other than in a gazetted fire district, with responsibility for (amongst other things):

> *"...ensuring all emergency management activities pertaining to the prevention of, preparedness for, response to and recovery from a specific hazard are undertaken."*
> (Policy Statement 7, SEMC, December 1998)

The Department's actions in seeking protection under s34 of the Bush Fires Act in themselves have implications for the duty of care owed by the Department. To prevent inappropriate clearing/action on reserves other than forest land by persons exercising their right to construct firebreaks, the Department has generally applied to have its management plans recognised as fire management plans under s34 of the Bush Fires Act. The preparation of fire management plans in itself creates expectations. Where such plans are submitted to the Fire and Emergency Services Authority, there are clear expectations that the actions outlined will be followed.

Legal advice is that an entity submitting a fire management plan to the Fire and Emergency Services Authority is undertaking to the Authority not only that in its view the plan provides adequate fire protection in relation to the reserve but also that it has the resources and commitment necessary to ensure the plan is adhered to. The advice is that in the event that an entity formed the view that the plan in place no longer provided adequate fire protection in relation to the reserve or that it was unable to comply with the plan, the Authority should be immediately advised so that the notice precluding others entering the reserve to clear firebreaks or reduce fire hazards, can be cancelled or varied.

Non-compliance with the fire management plan in circumstances where the material conduct has caused or contributed to the injury or loss may well be regarded as constituting negligence.

2.4 Discussion

2.4.1 Interaction with Bush Fires Act

The Bush Fires Act has underpinned a partnership arrangement between Local Government, private property owners, and the Department of Conservation and Land Management (and its predecessor, the Forests Department) for fire control in the south-west of WA. Both the Forests Department and subsequently the Department had statutory representation on the Bush Fires Board, until its abolition and replacement with the Fire and Emergency Services Authority, with the introduction of the FESA Act in 1999.

Much of the current practice has evolved in the spirit of this partnership, and the recognition of the "privileged position" enjoyed by forest officers under the Bush Fires Act. With the amalgamation of the emergency services under the FESA Act there are new arrangements. The Department is not a member of the Fire and Emergency Services Authority (which has much wider interests than the previous Bush Fires Board) but is represented on the Bush Fire Service Consultative Committee. This is not however a statutory requirement. Should the Department cease to be represented on this Committee there would be less interaction and a greater potential for future misunderstandings and breakdown of the cooperative arrangements and conventions.

Although not bound by the Act, the Department has complied with the spirit of the Act, including in most cases seeking permits to burn for land other than "forest land", and applying for exemptions from the Bush Fires Board to burn during the Prohibited Period. The partial and inconsistent conforming to provisions of the Act has contributed to confusion as to whether the Act did bind the Department. FESA have suggested the Act be amended to bind the Crown, but this would lead to conflict in many areas, such as between the requirements of an occupier under the Bush Fires Act and the requirements where the land concerned is held for the purposes of its management in accordance with statutory requirements (such as land vested in the Conservation Commission).

The Department should continue to forge and maintain strong cooperative links with the brigade organisations and local government regarding fire control, for the mutual benefit of all. The Department needs to establish a consistent approach with respect to its voluntary acceptance of restrictions imposed under the Bush Fires Act, such as restrictions imposed on the lighting of fires under certain weather conditions and during the prohibited period, and in relation to permits. A demonstrated responsible approach in this regard will foster cooperative links, and also help reduce potential common law liability. The Department should consult with relevant authorities (FESA and local authorities as appropriate) and seek their concurrence to proposed action, but to avoid confusion regarding the application of the Act, should not seek permits or approvals not required by law.

Recommendation 2.1: The Department develop a consistent approach that complies with both the letter and the spirit of the Bush Fires Act. As the Department is not bound by the Act it should not seek permits or approval, but it should consult with and seek concurrence from FESA and local authorities in situations where private landholders require permits.

2.4.2 Public Expectation and Risk Management

There is no doubt the Department has a duty of care in relation to fire control. What constitutes the reasonable standard of conduct necessary to discharge that duty will vary with the circumstances, but it can be said that it will frequently be more difficult for the Department to satisfy that standard than it will be for the general landholder. This is because of:

- The Department's acknowledged expertise in relation to fire control;
- The Department's assumed resources;
- The demonstrated success of fire control strategies since 1961 having created an expectation that the community will be protected from forest fires; and
- The Department's high profile with respect to fire.

The higher the public expectation, the greater is the Department's potential liability. The Department can, through its actions, influence its potential liability, both directly through fire protection works undertaken, and indirectly through ensuring public expectations (at least in so far as that expectation is engendered by the Department) are based on a realistic assessment of the Department's capabilities and responsibilities, not on false perceptions. Some specific areas that need to be considered are:

2.4.2.1 State Emergency Management Arrangements

Under the Bush Fires Act local government has responsibility for bush fire protection in its local area, including a requirement to appoint fire control officers (s38). The Act provides over-riding powers to forest officers, but does not require that these be used.

S45 clearly states a forest officer **may** take supreme control of a fire burning on or near Crown land. This was specifically amended from "shall" in 1987, after the formation of the Department with its broader responsibilities. Notwithstanding this, State Emergency Management Committee Policy Statement 7 identifies the Department as being the agency responsible for hazard management on **all** departmental lands not in a gazetted fire district. According to Draft Revised Policy Statement 7 (SEMC, March 2001), this includes responsibility for:

"Ensuring all emergency management activities relating to the prevention of, preparedness for, response to and recovery from a specific hazard are undertaken."

These requirements are much greater than that expected of an individual occupier under the Bush Fires Act. If this statement is accepted without qualification, the Department's duty of care is also likely to be correspondingly greater, notwithstanding it has no statutory obligations. The Department clearly does not have the resources in many areas to fulfil the obligations imposed by this policy, and should make this abundantly clear.

Recommendation 2.2: The Department seek amendment to State Emergency Management Committee Policy Statement 7 to properly reflect the Department's statutory powers and responsibilities.

2.4.2.2 Subdivisions/Adjoining Developments

The Department's management (including fire management) has been promoted by some sales people as an advantage in cases of subdivisions on adjoining land. Such subdivisions not only have the potential to increase the values at risk in the event of wildfire, but simultaneously reduce the ability to undertake fuel management both directly (opposition from some) and indirectly (more difficult, costly, greater resources required, and additional constraints). In many cases such developments may be some distance from existing departmental resources. The reality may be quite different from the perceptions and expectations of purchasers/residents.

Whilst it can be argued that where a person builds or places assets in a fire prone environment he or she accepts a level of risk, and therefore ought not to be able to recover damages in the event that risk eventuates, it should not be assumed, particularly in view of the increasing preparedness of the Courts to impose liability on government, that the Department would not be exposed to claims in negligence if damage or injury consequential on a fire occurred. To reduce the potential liability to the Department it is important to ensure that the fire risks and hazards associated with natural areas and the Department's position are formally outlined to the local government and planning authorities prior to any approvals, and on an ongoing basis. It should be emphasised that the local government has ongoing responsibility for fire protection, as well as for planning approvals.

Clearly in many cases there is no attempt by the property owner or occupier, be it through ignorance or complacency or reliance on the Department, to provide for protection for their assets. In many cases the buildings have been placed as close as practicable to the adjoining natural areas managed by the Department, to maximise the benefit of the private land, and take advantage of the adjoining land. An example is a restaurant near Yallingup that has been built within a few metres of the boundary of a national park, within highly flammable vegetation, with no attempt to provide protection and because of its siting, no capacity to provide an effective fuel modified buffer between the building and the boundary.

The Fire and Emergency Services Authority is in the process of preparing planning guidelines for future subdivisions/developments. Whilst these address many of the key issues for new rural subdivisions, they rely on both those with statutory planning responsibilities both requiring and enforcing the provisions. If they fail to do so this may not diminish the potential liability to the Department in the event of damage or injury resulting from fire on lands managed by the Department..

Recommendation 2.3: The Department seek amendments to the Bush Fires Act such that prime responsibility for adequate fire protection clearly rests with the person(s) who establish vulnerable assets in fire prone areas.

Recommendation 2.4: The Department formally respond to all applications for development adjoining lands managed by the Department, outlining the potential fire risks and hazards, and emphasising the responsibility for ensuring adequate fire protection lies with local government.

2.4.2.3 Resources Allocation

The Department has limited resources. Allocation of these resources to meet broader statutory objectives should be viewed as a policy decision (eg fire vs weeds), in which the courts should not interfere, however if this results in inadequate resources for fire control the courts may view this as an operational matter, and find adversely. This is likely to be more so where there is a reduction in previous resource levels.

The Department's capabilities must be clearly communicated to the local governments (who have statutory responsibility for fire protection in their local area) to enable them to address the situation. Failure to do this would increase the Department's potential liability. This is particularly important where there are changed/changing circumstances such as any reduction in resources, or changes in land use either on or adjoining land managed by the Department that affect fire protection.

2.4.2.4 Additions to Estate managed by the Department

New areas to come under the Department's management may also be distant from existing resources, and the cost of establishing a local presence may be unwarranted or prohibitive.

The Department may in some cases undertake fire prevention work on a reserve, but unless the Department submits a fire management plan under s34, the situation remains largely unchanged. The local government remains responsible for fire protection. Notwithstanding this, there may be some expectation that responsibility for fires on such land may change with the change in management or tenure. It is important that the local government is formally advised of the situation.

2.4.2.5 Fire Management Plans

The Department needs to ensure it does not raise unrealistic public expectations through fire management plans.

Whether an application should be made for exemption under Bush Fires Act s34 needs to be carefully considered. If such a plan is approved and fully complied with it would assist in demonstrating actions taken to meet the duty of care were reasonable. Conversely, where such a plan is gazetted under s34 there is an obligation to comply with the plan, and failure to do so would increase potential liability in the event a fire from the reserve caused damage or injury. A lack of resources would not be an acceptable excuse.

Recommendation 2.5: The Department regularly communicates to local government the limitations on its contribution to fire protection in the local area, and immediately advises when there is any reduction or other factors that affect the effectiveness of fire protection.

3 Identify values of the south-west forest region land which the Department manages and undertake a consultative risk analysis, with the Output Directors, to determine the risk factors to be applied to the maintenance of those values

Any change in values caused by a fire event does not depend on whether it is a wildfire or a planned fire event, but on the innate nature of the ecosystem, intensity and extent of the fire, time of year for the fire event, and time elapsed since the last fire event. The impact of fire on the values identified can be analysed, irrespective of the fire cause. The risk associated with a prescribed fire event is generally more predictable than for unplanned fires because the conditions are planned to meet chosen outcomes.

A qualitative risk analysis matrix in line with the principles of AS/NZS 4360:1995 is presented for the Nature Conservation Output and the Parks and Visitor Services Output. A matrix for the forest production risks is presented under term of reference 4 (next section).

A deficiency of any risk analysis approach is that its focus is on the avoidance of adverse outcomes, rather than on enhancement of desired outcomes. In the case of perturbation by fire this tends to reinforce perceptions of fire as a "destroyer", rather than fire as a natural element of ecosystems and in some cases an important agent in the regeneration of species. Fire as a component of ecosystems is neither good nor bad *per se*, but is a recurring phenomenon that results in a range of responses.

Conventional risk analysis considers the likelihood of occurrence and the consequence of an event(s). The likelihood of a fire event is highly variable across the forest areas, and is dependent on weather, ignition sources, previous fire history/fuels, and the success of any suppression action that may be undertaken. For this reason it is difficult to apply a likelihood factor across the whole of the forest area to any matrix. The only likelihood that can be stated with confidence is that fire will inevitably occur. The nature, frequency and extent is dependent on the factors outlined above and can be influenced by management actions. Because of these uncertainties, the approach to developing the matrix is similar to that used by Seager (2001) where risk measures (in terms of consequence and likelihood) of risk associated with possible fire scenarios are considered in the matrix. The likelihood of the scenarios occurring can be estimated. For example the probability of a high intensity fire occurring in the majority of the forest in any one year is estimated to be generally greater than 0.01 (1:100) (see Section 9).

The high variability across the landscape makes a "whole of forest" risk analysis matrix for all values impossible. More detailed analysis requires a spatial analysis at a local level. To enable such analysis the parameters must be restated in a form that allows them to be identified on a map. The "Classification of Values for Spatial Analysis of Fire Management in South West Forest Areas of Western Australia" (at Table 3.6 in this section) provides a guide for mapping discreet values related to the risk matrix. The Table also provides a qualitative comparison of values, with the values within each group being of broadly similar importance in comparison with other groups.

This classification is a statement of the Department's priorities in relation to fire management. Much wider consultation is required to ensure the classification properly reflects a consensus view of the broader community's values.

Recommendation 3.1: The Department seek wider community input into the classification of values for fire management analysis.

3.1 Biodiversity Conservation Values

Different communities and species will respond in different ways to a given fire regime. A fire event or regime that favours one species or community may be detrimental to another. The matrices below outline general principles only. These need to be considered in a more detailed spatial analysis at a local level that considers the specific species/communities/values present.

Fire frequency, intensity , size and time of year can all significantly influence the biological values. The risk factors associated with frequency, intensity and size are broadly defined and summarised in the three following tables. Whilst likelihood of the fire scenarios may relate in part to the time of year a fire occurs, other risk factors relating to the life cycle of individual species may be quite variable and are better considered at a local level.

Table 3.1: FIRE SCENARIO

	Frequency		
Intensity (After Cheney 1981)	**High** Interval between fires < juvenile period	**Medium** Interval between fires > 2x juvenile period	**Very Low** Interval between fires > period to senescence
Very High 7,000 – 70,000 kW/m Crown fires in most forests	**High Intensity High Frequency** Generally only applicable to long lived species such as over-storey (trees) High frequencies with low intervals (short juvenile periods) would not permit sufficient fuel accumulation for high intensity fires..	**High Intensity Medium Frequency**	**High Intensity Very Low Frequency**
Moderate/High 500–7,000 kW/m Complete crown scorch Defoliation in low forest	**Moderate Intensity High Frequency**	**Moderate Intensity Medium Frequency**	**Moderate Intensity Very Low Frequency**
Low Less than 500 kW/m	**Low Intensity High Frequency**	**Low Intensity Moderate Frequency**	**N/A** Fuel accumulations over long periods result in higher intensity fires

The juvenile period of the vascular plants has been used as a bio-indicator for fire frequency as suggested by Burrows et al (1998,1999). Whilst such indicators can be expected to relate to other components of the ecosystem, there may be cases where other organisms are identified as being more appropriate as a measure of fire interval for particular areas (e.g. threatened communities/species with specific requirements). These should be identified for that location when a spatial analysis is undertaken.

Table 3.2: LIKELY BURNT/UNBURNT MOSAIC

Intensity (After Cheney 1981)	Fire Size		
	Large > 2,000 hectares Re-colonisation from margins difficult. Re-introductions may be required.	**Medium** 10 – 2,000 hectares	**Small** < 10 hectares Small patches may be subject to intensive grazing pressure.
Very High 7,000 – 70,000 kw/m Crown fires in most forests	**Low patchiness.** Unburnt patches unlikely	**Nil** No unburnt areas likely	**Nil** No unburnt areas likely
Moderate/High 500 – 7,000 kw/m Complete crown scorch Defoliation in low forest	**Low – Moderate patchiness** Some unburnt patches likely	**Low patchiness** Few unburnt areas likely	**Nil** No unburnt areas likely
Low Less than 500 kw/m	**High patchiness**	**Moderate patchiness**	**Low patchiness**

The mosaic of burnt/unburnt within a fire area is affected by the size and intensity of the fire. High intensity fires require a major change in fuel conditions to not burn an area. Low intensity fires burning closer to the limits of conditions for sustainable spread are more likely to have high patchiness as moister or low fuels are encountered. The larger the area, the less uniform the conditions, and the greater the probability of patchiness.

3.2 Qualitative Risk Analysis

The risk classes indicated in the matrix in Table 3.3 are a measure of combination of likelihood of occurrence in the scenario and the significance of the consequence if it does. The probability of an event for a small area may be high, but the significance of the consequence overall may be low because of the small area involved. In other cases the converse may be the case; eg the probability of a small fire resulting in the extinction of a given species may be very low, more so where there is a high burnt/unburnt mosaic, but if that fire happens to be at the only known occurrence, the consequences would be very high. This type of detail is best considered in a spatial analysis that looks in details at the location of threatened species and ecological communities. Table 3.3 provides only a general risk profile.

Table 3.3: QUALITATIVE RISK ANALYSIS MATRIX – NATURE CONSERVATION OUTPUT

Possible Consequence	**Fire Scenario** (as per Table 1)																							
	High Intensity									**Moderate Intensity**									**Low Intensity**					
	High Frequency			**Medium Frequency**			**Very Low Frequency**			**High Frequency**			**Medium Frequency**			**Low Frequency**			**High Frequency**			**Medium Frequency**		
	Lgearea	**Med area**	**Sml area**	**Lge area**	**Med area**	**Sml area**	**Lge area**	**Med area**	**Sml area**	**Lge area**	**Mod area**	**Sml area**	**Lge area**	**Mod area**	**Sml area**	**Lge area**	**Mod area**	**Sml area**	**Lge area**	**Mod area**	**Sml area**	**Lge area**	**Mod area**	**Sml area**
Species/community extinction	*	*	*	H	S	L	H	H	L	M	L	L	L	L	L	H	H	S	L	M	L	L	L	L
Local extinctions	*	*	*	H	H	L	H	H	L	M	M	L	L	L	L	H	H	H	M	M	L	L	L	L
Permanent change in overstorey stand structure	H	H	S	L	L	L	H	H	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Permanent loss of old growth forest values	H	H	S	H	H	M	H	H	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Permanent change in understorey structure	*	*	*	L	L	L	H	H	L	H	S	M	L	L	L	M	M	L	H	S	L	L	L	L
Reductions in structural diversity and species richness at a regional scale	*	*	*	S	M	L	H	H	L	H	S	M	L	L	L	S	M	L	S	M	L	L	L	L
Reductions in structural diversity and species richness at a landscape scale	*	*	*	S	S	L	H	H	L	H	H	M	L	L	L	H	S	M	H	S	L	L	L	L
Reductions in structural diversity and species richness at a local scale	*	*	*	S	S	M	H	H	M	H	H	S	M	L	L	H	H	S	H	H	M	L	M	M

* Not applicable. High intensity/high frequency fires only apply to species with long juvenile periods (eg trees) (See Table 1)

H = High risk: Action required to reduce the risk.

S = Significant risk: Detailed analysis required. Action will be required in most instances to reduce the risk.

M = Moderate risk: Ongoing monitoring with follow up action as required.

L = Low risk: Monitoring only, no specific action required to reduce risk.

3.3 Visitor Values

Whilst fire regimes may impact on visitor values in the long term, the obvious effects of fires are immediately apparent. The risk matrix therefore considers scenarios based on short term responses to fires. Multiple fire scenarios are included as these dilute suppression efforts and the ability to organise evacuations if required.

Of necessity the matrix is in broad terms only. For example, whilst in a general sense there is a higher risk of loss of values such as the life of a visitor to the forest in large intense fires, the risks only exist if people are actually present. A more detailed analysis is required to consider the actual situation in specific areas.

Table 3.4: QUALITATIVE RISK ANALYSIS MATRIX – PARKS & VISITOR SERVICES OUTPUT

Possible	**Fire Scenario**					
Consequence	**Multiple large high intensity fires in visitor areas**	**Extensive high intensity fires in visitor areas**	**Small high intensity fires**	**Extensive moderate/low intensity fires, low mosaic**	**Extensive moderate/low intensity fire, high mosaic**	**Small fires**
Loss of life	High	Significant	Moderate	Low	Low	Low
Loss of cultural/heritage sites	High	Significant	Significant	Moderate	Low	Low
Loss of high value infrastructure	High	Significant	Significant	Moderate	Low	Low
Reduced landscape amenity unless an improved vista is created	Significant	Significant	Moderate	Moderate	Low	Low
Damage to recreation infrastructure	Significant	Significant	Moderate	Moderate	Low	Low

High risk: Action required to reduce the risk. Options include site closures, relocations and fire/fuel modification.
Significant risk: Detailed analysis required. Action will be required in most instances to reduce the risk.
Moderate risk: Ongoing monitoring with follow up action to reduce risks as required.
Low risk: Monitoring only, no specific action required to reduce risk.

3.4 Community Protection

As for visitor values the impacts of fires on community values are immediate and usually short lived. The fire scenarios considered in the matrix reflect this immediacy.

Table 3.5: QUALITATIVE RISK ANALYSIS MATRIX – COMMUNITY PROTECTION

Possible Consequence	Fire Scenario		
	Multiple high intensity fires	**High intensity fires**	**Low intensity fires**
Loss of life	High	Significant	Low
Disruption to essential services	Significant	Moderate	Low
Property loss	Significant	Moderate	Low
Smoke/public outcry	Low	Low	Moderate[1]

High risk: action required to reduce the risk.
Significant risk: detailed analysis required. Action will be required in most instances to reduce the risk.
Moderate risk: Ongoing monitoring with follow up action to reduce risks as required.
Low risk: Monitoring only, no specific action required to reduce risk.
[1]Based on current perceptions that prescribed fire events can be avoided or eliminated whereas uncontrolled fire events are not "caused" by managers.

Table 3.6: CLASSIFICATION OF VALUES FOR SPATIAL FIRE MANAGEMENT ANALYSIS IN SOUTH WEST FOREST AREAS OF WESTERN AUSTRALIA

NOTE: This classification does not address the type, location, or extent of actions that may be taken for either protection or enhancement of any values. A range of actions may be available (eg closure of sites to protect life, fuel management, buffers, etc). The appropriateness of given action(s) will depend on the particular circumstances, but any actions should aim at maximising benefits to multiple values. Where an analysis of the actions leads to conflicts between competing values arise, this table provides a guide to priorities. In doing so, care must be taken to ensure decisions are based on the importance of the values at risk, not the size they appear on a map. The colours noted are the recommended standard colours for mapping.

BIODIVERSITY CONSERVATION	VISITOR VALUES	FOREST PRODUCTION	COMMUNITY PROTECTION
GROUP 1 VALUES: (red) **Human Life - Areas where there is a significant threat of MULTIPLE FATALITIES in the event of wildfire.** Does not include sites where adequate refuge exists or relatively low numbers of people and good multiple access provide for reasonable egress/evacuation **Irreplaceable biological values.**			
• Only known occurrence of fire vulnerable threatened species or ecological community. Fire likely to result in extinction	• Camping areas with high fire season populations, restricted egress, no refuge area. (eg Murray Valley). Does NOT include areas where adequate refuge exists (eg beachside such as Hamelin Bay) or rapid escape/evacuation possible. • High visitation recreation sites with dead end access and no refuge.		• Settlements, rural residential and special rural subdivisions with native vegetation, poor access, no reticulated water. Does NOT include larger urban areas with maintained gardens, ovals and structures for refuge and therefore a low risk to life. • Hospitals and schools • Public buildings with daily use, access for suppression and evacuation poor.
GROUP 2 VALUES: (orange) **Very high biological values. Very high property/community impact. Some risk to life in event of fire**			
• Fire vulnerable* critically endangered and priority 1 species or ecological communities. Risk of extinction if burnt. • Only known occurrence of fire vulnerable priority 2 species. • Severely under-represented fire seral stages of communities with vulnerable species. • Severely under-represented structural types.	• Major recreation/tourist areas) with good access, but sheer numbers pose a risk to life in event of fire. (eg Tree Top Walk, Boranup and Gloucester national parks) • Popular long distance walk tracks & mountain bike trails • Fire vulnerable registered heritage sites • Fire vulnerable registered Aboriginal sites		• Essential utilities (regional power, water, gas supply) • Infrastructure posing significant environmental threat (eg bulk chemical storage). • Urban areas • Rural/residential and special rural subdivisions, poor access, reticulated, regular fuel modification. • Shopping centres • Commercial precincts • Public buildings with daily use access good, or weekly use access for suppression and evacuation poor.

BIODIVERSITY CONSERVATION	VISITOR VALUES	FOREST PRODUCTION	COMMUNITY PROTECTION
GROUP 3 VALUES: (yellow) **High biological, property values. Low risk to life**			
• Fire vulnerable* endangered, vulnerable and priority 2 species or ecological communities. • Long established (>15yrs) research/ monitoring plots and scientific reference areas to be kept fire free. • Area significant to the maintenance of overall structural diversity, species richness • Under-represented structural types eg old growth forest	• Old growth forest values	• Pine plantations >100ha 8-20 yrs old. • Consolidated Karri regrowth >1000ha, 5-30 yrs old	• Rural residential subdivisions, multiple access, reticulated, fuel modification.. • Public buildings, monthly use access good
GROUP 4 VALUES: (green).			
• Short term research/monitoring plots to be kept fire free • Threatened species habitats (no species known to be present). • Under-represented (whole of forest basis) fire seral stage • Areas of regionally significant species richness, structural diversity	• Significant infrastructure (value > $1m), low risk to life.	• Pine plantations <100ha 8-20 yrs old • Pine plantations >100ha <8 or >20 yrs old • Hardwood plantations >100ha • Consolidated Karri regrowth 250-1000ha, 5-30 yrs old • Consolidated Karri regrowth >1000ha, 30-50 yrs old • Consolidated Jarrah regrowth >250ha, 5-20 yrs old.	• Scattered houses. • Public utilities
GROUP 5 VALUES: (light brown)			
• Populations of fire vulnerable priority 3 species and ecological communities • Regionally under-represented seral stages. • Regionally under-represented structural types • Locally significant species, communities	• Fire vulnerable cultural/historical sites • Landscape values	• Other plantation areas.	• Harnessed catchments with erosion susceptible soils • Developed farmland

BIODIVERSITY CONSERVATION	VISITOR VALUES	FOREST PRODUCTION	COMMUNITY PROTECTION
GROUP 6 VALUES: (light blue)			
• Regionally significant fire vulnerable species or ecological communities • Priority 4 & 5 (conservation dependant) species or communities • Local structural diversity, species richness • .	• Recreation infrastructure		• Regional open space
GROUP 7 VALUES: (uncoloured)			
"Base" or "background values" including multiple use areas, wilderness areas and similar zones are not separately classified.			

Explanatory notes:

- **Fire Vulnerable**: Vulnerability for species and communities may depend on the stage of the species and recent fire history. For example, it is unlikely that a single fire event will be catastrophic to most plants, but it would render an obligate seeder vulnerable for a period till a sufficient seed store is re-established. A single fire event could be catastrophic to some fire sensitive highly restricted animals such as Gilbert's Potoroo, or to a threatened ecological community already under significant threat from weed invasion.

- **Species** in relation to threatened species includes subspecies and distinct populations determined by the Minister to be 'species'.

- For definitions of threatened species, threatened ecological communities, and priority species and ecological communities refer to Policy Statement 9 (Revised 2001)

- Fire seral stages are used in this classification as a measure of fire diversity.

4 Undertake a consultative risk analysis, involving the Forest Products Commission, of the impacts of fire on timber supply, to include advice from the Commission of the level of resource protection it is prepared to fund

4.1 Risk Assessment

The Forest Products Commission (FPC) has not independently undertaken a detailed business risk analysis to determine acceptable loss of supply. Such an analysis could include:

- Contractual obligations, hedging and insurance options;
- Direct and indirect financial impacts of loss of supply;
- Downstream impacts and obligations; and
- Identification of critical periods.

It is considered such a quantitative analysis is warranted to better assess the level of acceptable risk, but was beyond the time constraints for this review.

A qualitative risk assessment in accord with AS/NZS 4360:1995 guidelines is provided as a first step towards determining priorities for expenditure for fire management and protection of forest products. Consequences are considered in terms of death/damage to a range of timber stands, and differ according to the scarcity of the resource and replacement cost. Other consequences as outlined above, or the effect of events on the corporate image are not separately defined but are implied in assessing the level of consequence for the different losses.

Conventional risk analysis considers both the consequence and likelihood of occurrence. The likelihood of a fire event is highly variable across the forest areas, and is dependent on weather, ignition sources, previous fire history/fuels, and the success of any suppression action that may be undertaken. For this reason it is difficult to apply a likelihood factor across the whole of forest area to any matrix. The only likelihood that can be stated with confidence is that fire will inevitably occur. The nature, frequency and extent is dependent on the factors outlined above and can be influenced by management actions. Because of these uncertainties, the approach to developing the matrix is similar to that used by Seager (2000) where risk factors associated with possible fire scenarios are considered in the matrix. Fire scenarios represent the likelihood of those events resulting in the consequences listed, with decreasing likelihood from left to right (ie. it is far more likely that a large area of the critical stands would be burnt in an extreme fire event when fires are uncontrollable or when resources are stretched over multiple large fires than when there is a single local fire).

The risk analysis matrix provides only a broad overview of the consequences and likelihood. A more detailed spatial analysis is required to determine optimum action to reduce risks. The probability of loss of significant areas of a particular stand depends not only on the fire event, but will also vary with the spatial distribution. If the areas of concern are dispersed over a wide area it reduces the probability of a large proportion being involved in any non-fire event. The priorities outlined in the risk analysis are included in the "Classification of Values for Spatial Fire Management Analysis" (see previous term of reference) to facilitate more detailed analysis in a more detailed manner. This classification also indicates the weighting of forest production values in relation to other values impacted by fire/fire management actions.

The risk to the FPC's business is a combination of the likelihood of the areas being burnt and the consequences if they are. The risk has been broadly assessed in four classes in the risk analysis matrices. These have been prepared for plantations and native forest timber production separately, and are also shown combined in line with the relative weightings of the "Classification of Values".

4.2 Native Forests

In the following table the Karri regrowth classes shown are those of greatest significance to timber supply, and most susceptible to damage. Karri >50 years old (yo) can be salvage logged if killed. Jarrah >20yo is less likely to be killed in a fire, and is assumed to be of sufficient height to have a utilisable bole length below any crown damage resulting in malformation of the future stem.

Table 4.1: QUALITATIVE RISK ANALYSIS MATRIX – NATIVE FOREST TIMBER PRODUCTION AREAS

Possible Consequence			**Fire Scenarios**				
Forest stands killed/severely damaged			**Large high intensity fire**	**Multiple medium intensity fires**	**Single medium intensity fire**	**Multiple small fires**	**Single low intensity fire**
Karri	**Regrowth 5-30yo**	**>1000ha**	High	Significant	Moderate	Moderate	Low
Karri	**Regrowth 5-30yo**	**250-1000ha**	Significant	Significant	Moderate	Moderate	Low
Karri	**Regrowth 30-50yo**	**>1000ha**	High	Significant	Moderate	Low	Low
Jarrah	**Regrowth 5-20yo**	**>250ha**	High	Moderate	Moderate	Low	Low
Karri	**>50Yo**		Moderate	Low	Low	Low	Low
Jarrah	**>20yo**		Low	Low	Low	Low	Low

High Risk: Action required to reduce risk. Priority for fuel reduction to improve probability of success of suppression action.
Significant Risk: Detailed analysis required. Fuel reduction is likely to be required in most instances.
Moderate Risk: Further analysis required to determine action warranted. Reduction in risk desirable.
Low Risk: No additional pre-suppression works warranted. Suppression capacity maintained for other forest production values adequate. Salvage and insurance arrangements to be considered.

4.3 Plantations

For pine plantations the period 8-20yo is considered critical. Major investment in establishment and tending operations has been completed, the salvage potential following a fire would be negligible, and there would be a high cost in removal of killed stems for new site preparation. Pine plantations older than 20 will have salvage potential (and consequent less site preparation). Site preparation following fire in stands <8yo is low, and major expenditure in silvicultural tending has not yet occurred.

Table 4.2: QUALITATIVE RISK ANALYSIS MATRIX – PLANTATIONS

Possible Consequence Forest stands killed/severely damaged			**Fire Scenarios**				
			Large high intensity fires	**Multiple medium intensity fires**	**Single medium intensity fire**	**Multiple small fires**	**Single low intensity fire**
Pines	**8-20yo**	**>500ha**	High	High	Moderate	Low	Low
Pines	**8-20yo**	**100-500ha**	High	High	Significant	Moderate	Low
Pines	**>20yo**	**>500ha**	High	Significant	Moderate	Low	Low
Pines	**<8yo**	**>500ha**	High	Significant	Moderate	Low	Low
Pines	**8-20yo**	**<100ha**	Significant	Moderate	Moderate	Moderate	Low
Pines	**>20yo**	**100-500ha**	High	Moderate	Moderate	Low	Low
Pines	**<8yo**	**100-500ha**	Moderate	Moderate	Moderate	Low	Low
Bluegums		**>100ha**	Moderate	Moderate	Low	Low	Low
Pines	**>20yo**	**<100ha**	Moderate	Moderate	Low	Low	Low
Pines	**<8yo**	**<100ha**	Moderate	Low	Low	Low	Low
Bluegums		**<100ha**	Low	Low	Low	Low	Low

High Risk: Action required to reduce risk. Priority for fuel reduction to improve probability of success of suppression action.
Significant Risk: Detailed analysis required. Fuel reduction is likely to be required in most instances.
Moderate Risk: Further analysis required to determine action warranted. Reduction in risk desirable.
Low Risk: No additional pre-suppression works warranted. Suppression capacity maintained for other forest production values adequate. Salvage and insurance arrangements to be considered.

4.4 Combined Analysis matrix

Table 4.3: QUALITATIVE RISK ANALYSIS MATRIX – NATIVE FOREST TIMBER PRODUCTION AND PLANTATION AREAS

Possible Consequence			**Fire Scenarios**				
Forest stands killed/severely damaged			**Large high intensity fire**	**Multiple medium intensity fires**	**Single medium intensity fire**	**Multiple small fires**	**Single low intensity fire**
Pines	**8-20yo**	**>500ha**	High	High	Moderate	Low	Low
Pines	**8-20yo**	**100-500ha**	High	High	Significant	Moderate	Low
Karri	**Regrowth 5-30yo**	**>1000ha**	High	Significant	Moderate	Moderate	Low
Pines	**>20yo**	**>500ha**	High	Significant	Moderate	Low	Low
Pines	**<8yo**	**>500ha**	High	Significant	Moderate	Low	Low
Pines	**8-20yo**	**<100ha**	Significant	Moderate	Moderate	Moderate	Low
Pines	**>20yo**	**100-500ha**	High	Moderate	Moderate	Low	Low
Pines	**<8yo**	**100-500ha**	Moderate	Moderate	Moderate	Low	Low
Karri	**Regrowth 5-30yo**	**250-1000ha**	Significant	Significant	Moderate	Moderate	Low
Karri	**Regrowth 30 – 50yo**	**> 1000ha**	High	Significant	Moderate	Moderate	Low
Jarrah	**Regrowth 5-20yo**	**>250ha**	High	Moderate	Moderate	Low	Low
Bluegums		**>100ha**	Moderate	Moderate	Low	Low	Low
Pines	**>20yo**	**<100ha**	Moderate	Moderate	Low	Low	Low
Pines	**<8yo**	**<100ha**	Moderate	Low	Low	Low	Low
Karri	**>50yo**		Moderate	Low	Low	Low	Low
Bluegums		**<100ha**	Low	Low	Low	Low	Low
Jarrah	**>20yo**		Low	Low	Low	Low	Low

High Risk: Action required to reduce risk. Priority for fuel reduction to improve probability of success of suppression action.
Significant Risk: Detailed analysis required. Fuel reduction is likely to be required in most instances.
Moderate Risk: Further analysis required to determine action warranted. Reduction in risk desirable.
Low Risk: No additional pre-suppression works warranted. Suppression capacity maintained for other values adequate. Salvage and insurance arrangements to be considered.

4.5 Funding and Risk

The Forest Products Commission is facing declining revenues in line with reductions in the amount of timber harvested from native forest, and is unable to maintain the level of expenditure on fire protection incurred in the 2000-2001 financial year. As revenues decline further there will be pressure for further reductions in fire protection expenditure. The level of risk will thus be determined largely by the funds available, rather than any assessment of acceptable risk.

The qualitative risk analysis matrix provides guidance for determining priorities for application of the limited funds. It should be noted however, that the increase in risk of fire losses with reduction in expenditure is not linear. There are "fixed" costs associated with maintaining a fire protection service in terms of equipment, detection systems and a core level of trained fire fighters. Any reduction in expenditure will mainly affect fuel reduction. Effective suppression can only be undertaken at very much the lower end of the potential for forest fires. Intensity is directly related to fuel levels so while the cost of maintaining the suppression response remains unchanged, the likelihood of success is reduced (ie. because of the fixed costs, a reduction in fire protection expenditure invites a disproportionately larger risk of loss).

There are a number of options available to reduce risk, including fire protection measures such as firebreaks, fuel reduction, suppression response preparedness, as well as insurance, pre-planned salvage arrangements, and manipulation of contract periods. Some of these may have differing implications for the "hidden" consequential loss.

To determine the optimum response to risk a better definition of the consequences is required. Whilst losses of timber values due to an individual fire may be acceptable, this may in turn increase the value of the residual stands in terms of the ability to meet contractual obligations, or even sustain a long term viable timber supply. A business analysis should be undertaken to better define both the commercial consequences and any implications for Government.

Recommendation 4.1: The Forests Products Commission undertake a more detailed quantitative analysis to define the commercial consequences of fire loss.

4.6 Staff for Fire Control

The Forest Products Commission has indicated an interest in their staff remaining involved in fire control beyond 2005 on a "fee for service" basis for works not directly related to protection of timber supply. There are benefits to both the Department and the Commission from such ongoing involvement. The Department gains from access to skilled staff and the Commission both from a reduction in salary cost through recoup works, and a maintenance of the skills of their staff.

Under s59(1)(c)(ii) of the Forests Products Act 2000 the Commission is to include in the contract price for forest products from departmental land the cost of managing and protecting that land. Costs associated with training or involvement with fire management related to timber production areas, should continue to be borne directly by the Commission. Arrangements should be agreed for recoup of costs for assistance with fire management clearly not associated with State forest or the protection of timber supply.

Recommendation 4.2: Forests Products Commission be requested to ensure its staff maintain and acquire fire skills and experience through training and participation in burning.

4.7 Accountability

The Forest Products Commission requires greater transparency and accountability for fire management (including silvicultural burning) costs incurred on its behalf, including reporting against agreed criteria. This should be partly met through reporting improvements as a result of the implementation of ISO14001. Improved monitoring, accountability and reporting are common requirements and are further addressed under Term of Reference 8. "Develop a means of separately identifying timber protection, community protection values, and nature conservation values".

5 Provide advice on fire fighter safety as a part of the risk analysis

5.1 Introduction

The Department has a duty of care to its employees that includes "as far as practicable, provide and maintain a working environment in which employees are not exposed to hazards" (Occupational Safety and Health Act 1984). Fire is inherently hazardous. Whilst hazards can be mitigated in some circumstances, they cannot be eliminated. Provision of information, instructions, procedures, training and equipment all contribute to reducing the exposure of employees to such hazards

There have been 52 deaths of bush fire fighters and numerous injuries in Australia since 1980. The majority of deaths have been due to fire fighters being burnt following entrapment. There have been deaths of fire fighters in Western Australia, but no deaths of forest fire fighters. There have been a number of "near misses" resulting in injuries and fire fighting vehicles being burnt.

In an analysis of major burnover incidents since 1980, Paix (2000) attributed 14 of the 19 Australian incidents investigated, to sudden changes in, or an underestimation of, fire behaviour.

5.2 Forest Fire Fighter Safety - Fire Behaviour

As forest fuels accumulate, so does the potential killing power of a forest fire. Fire line intensity (the amount of radiant energy released per metre of fire line), a measure of this killing power, is a function of the rate of fire spread (speed of movement) and the quantity of fuel burnt. Both rate of spread and fuel accumulation are known to increase with time elapsed since the last fire.

The safest and most efficient and effective way to suppress forest fires is to work at the fire face removing new fuel from immediately in front of the flames (direct attack). Forest fires burning with an intensity of greater than about 2000 kW/m cannot be directly attacked. Direct attack is the safest method of fire fighting because fire fighters are always adjacent to burnt ground for refuge if weather, fuel or topographic fire conditions change unexpectedly. Parallel or indirect attack methods where fire fighters work at some distance (metres to kilometres) from the fire edge carry inherent risks of entrapment that have resulted in deaths of fire fighters elsewhere (eg Linton; Cheney et al 2000), and near misses in WA (eg Chittering Valley fire, February 1989, Smith, 1989).

Control of forest fires burning with an intensity exceeding about 3000 kW/m is generally not possible even with assistance from water bombers, notwithstanding that their use can assist "saves" of individual assets from fires of greater intensity by reducing the intensity of the fire at that point and allowing ground crews to take action to prevent specific assets from being damaged or destroyed as intense head or flank fires move past them. This can in itself create potentially hazardous situations if it encourages crews to enter dangerous situations where there is intense fire and no safe refuge if needed.

The behaviour (flame height, direction and speed of movement, amount and distance of spotting) of high intensity fires may be erratic and is less predictable than that of lower intensity fires, thus requiring more considered judgement and actions by firefighters. Current fire prediction models are largely based on slow moving, low intensity fires. Both the results of wildfire experience and recent research with Project Vesta (op cit) have demonstrated that rates of spread are severely underestimated by such models for higher intensity fires, by factors of 2 or more. Cheney et al (2000) have also highlighted that lines of fire of about 200m or greater do not pass through a prolonged acceleration or build up phase but can reach their full potential spread rate within moments. Thus a quiet flank or backing fire in heavy fuels can rapidly develop into a fast moving high intensity fire, creating a highly dangerous situation conducive to entrapment and burnover situations.

5.3 Fire Survivability

Estimates of the conditions that are survivable in the event of a burnover/entrapment vary. Survivability depends on the duration of the exposure and the protection available. Knight (1988) suggested a maximum air temperature of 100^0C and maximum body temperature rise of 2^0C as survivable, and Bond and Cheney (1986) suggested 15 minutes at 120^0C. These limits are readily exceeded if fire fighters are directly exposed to the radiation from high intensity forest fires. Early experiments simulating the effects of bushfire showed cars to be remarkably resistant to heat and able to provide effective protection from radiation for about 4 minutes after which they ignited (Cheney 1972). During this period the interior temperature remained relatively low until the interiors caught fire. Cheney suggested that 2000-3000 kW/m as the maximum intensity under which a fire tanker crew will survive in their vehicle. This may however be an underestimate as some bush fire fighters have survived in entrapments on narrow fire trails in heavy bush, where the intensity is likely to have been higher. However, the situations in which a vehicle can provide effective protection in a forest situation are limited to the lower end of the range of possible intensities. A forest fire with intensities 5000-10,000 kW/m may involve flame heights of more than 10 metres and take 3-6 minutes to pass (Bond and Cheney 1986). The surrounds may then remain hostile for another half hour as the larger fuels burn out. In extreme conditions forest fires may have intensities up to 100,000kW/m.

Increased periods between fire events result in greater fuel accumulations that pose potential threats to the safety of bush fire fighters through:

- Greater radiation from higher intensity fires reducing the probability of survival in the event of entrapment; and
- Greater risk of entrapment through a combination of a lack of experience/situational awareness, and potential for rapid and unexpected escalation in fire behaviour.

In recent years there has been less area burnt annually than in the period preceding the major fires in 1961 that sparked the Rodger Royal Commission recommendation for a major increase in the amount of prescribed burning in south west forests (see Section 7, figure 7.1 and 7.2). Without fire, forest fuels accumulate; initially rapidly so they can reach levels where forest fires burning under severe conditions burn with an intensity that makes them impossible to control. The majority of the forest areas now contain fuels in this state.

A map showing the potential intensity for fires burning under 95 percentile weather conditions under current fuel loads is included in Section 9.

Recommendation 5.1: The Department ensures all forest fire fighters, controllers and supervisors are trained to understand the potential fire behaviour changes with increased fuel loads, with an emphasis on avoiding entrapment situations.

5.4 Forest Fire Fighter Safety - Resource Impacts

Skills, experience and fitness all have a direct bearing on the safety of fire fighters. A permanent workforce provides greater stability to build a core of trained and experienced fire fighters, but such stability can result in a generally aging workforce. A balance is required between experience and fitness for optimum safety.

The trend over the past 2 decades has been for a reduction in the permanent workforce (eg Pemberton District employed 39 permanent forest workers in 1989 – in 2001 there were 14 supplemented by 11 seasonal/casual staff) with a consequent loss of experience, but an overall improvement in fitness. Lack of experience can be partly offset by training, but must be supplemented by working alongside experienced crew members. If seasonal staff return for several years they can attain a good level of experience, but the opportunities for this are limited in many areas, particularly in the south, both by the limited numbers available, and competition for other work (eg seasonal horticultural work). There are a number of employment factors that mitigate against regular seasonal workers, including uncertainties about continuity, and appointment by short term casual contracts with short breaks between that make persons ineligible for employment relief, housing loans, reduce the overall average income and make it difficult to establish a normal (by socially accepted standards) lifestyle. To improve experience and safety, alternatives that encourage seasonal workers to return should be investigated. Options may include permanent part time employment or other forms of guaranteed re-employment in successive years for at least a core period. Any employment contract for fire fighters should include fitness as a criterion for continued employment.

Recommendation 5.2: Employment contracts for seasonal employees be framed to encourage annual re-employment to increase the experience level and hence safety of seasonal fire crews.

Where there is a high turnover of seasonal staff there will be a high proportion of novices, placing greater responsibilities on the supervisor and increased safety risks for the crew. As a general rule it is recommended that not more than one third of a forest fire crew comprise inexperienced personnel, and should not exceed 50% even on "quiet" sectors (eg mop-up).

Recommendation 5.3: A level of experienced fire fighters be maintained to enable forest fire crews to include in their total numbers not more than one third inexperienced personnel who in turn must meet the basic fire fighter accreditation standard.

Possibly the greatest influence on the safety of fire fighters is the decisions of the incident managers and supervisors. Decisions on strategies and tactics not only dictate the success of the operation, but also the danger in which crews are placed. It is generally accepted that it requires a minimum of 10 years' intensive exposure to fire control and fire operations to develop the level of skills required for Level 3 Forest Fire Controllers and Planners. There has been an attrition of such high level fire staff to other organisations, and a number have transferred to the Forest Products Commission. Such experience cannot be replaced in the short term, and it is important that the FPC staff remain part of the fire organisation.

Fire resources inventories are operational documents prepared annually, but not archived so it is difficult to readily ascertain the extent of the change in the skills base, but for example, the 1992 RESIN (resources inventory) records for Kirup listed 13 staff. This included 2 type 3 and 2 type 2 Incident Controllers/Operations Officers. The 2001 "Redlining" database lists 8 staff, with 1 type 3 and one type 2. Whether such individual reduction affects fire fighter safety depends very much on the back up available from other areas, which in turn depends on maintaining an adequate overall level of experience. This requires long term planning and action to ensure suitable personnel acquire both training and experience.

Recommendation 5.4: Increased emphasis be placed on successional planning for key fire control staff.

Supplementing Departmental forest fire fighters with Bush Fire Brigades carries inherent risks. There is a vast difference in the type of fire fighting required for forest and grassland areas. Forest fires generally burn with a much higher intensity than is possible with grass fires. The majority of Bush Fire Brigade personnel do not have extensive experience in forest fire fighting and have limited knowledge about forest fire behaviour, situational awareness or local knowledge.

The use of inexperienced crews or crews of unknown experience places additional stress and responsibilities on supervisors and lack of familiarity with procedures can increase the risks of errors with potentially serious consequences. To reduce such risks, it is desirable that training of Bush Fire Brigade personnel and departmental personnel be integrated, so that similar standards and procedures are applied.

Recommendation 5.5: The Department cooperate with FESA and local government authorities to encourage a high level of forest fire training for brigades likely to be involved in forest fires.

5.5 Forest Fire Fighter Safety - Fire Fighter Demographics

Fire fighting can be a physically demanding task, and is often highly stressful for both the management teams and the field crews. A high level of physical fitness is required for the safety of both the individual and the crew. The Department's program of fire fighter fitness testing has helped avoid the loss of fire fighters through stress and heart failure as has happened elsewhere. The use of seasonal workers who must pass a fitness test helps to maintain an overall balance in the face of an otherwise aging workforce.

With changes in rural land use and rural communities there is a general increase in the average age of the population, with the younger people leaving to seek work in towns. As a consequence, in many Bush Fire Brigades their declining numbers of members are getting older.

Much of the machinery used in forest harvesting is well suited to forest fire suppression, and is an important component of the overall fire suppression resources. Many of the machine operators are trained and experienced in fire suppression. The amount of equipment available for fire suppression, and the number of contractors and experienced machine operators working in the forests is declining as harvesting of forest products is reduced. The use of machines from outside the forest, with operators with lesser forest fire experience, will increase the need for closer supervision by experienced personnel.

Recommendation 5.6: The Department consider the changes in the availability and experience of others involved with forest fire fighting when determining its resource and experience requirements for fire management in particular areas.

5.6 Forest Fire Fighter Safety – Training and Experience

The Department currently has some of the best-trained and most experienced forest fire fighters in Australia. Much of their competence is based on practical experience with fire, rather than classroom training. There is no substitute for such experience, but most has been gained through low intensity prescribed burning, or fire suppression in areas that have been subject to some fuel reduction in the past. Crews involved in regeneration burning have observed high intensity fire behaviour, but there is relatively little experience with suppression of high intensity wildfires in heavy fuels. Experience promotes situational awareness through an improved ability to recognise cues from the surrounding environment; lack of experience increases the risk to fire fighter safety.

The majority of deaths and burn injuries in bush fire fighting throughout the world have resulted from entrapment following rapid and unexpected escalations in fire behaviour. Great improvements in fire-fighter safety can be achieved if through prior planning and action both the "unexpected" and "fire behaviour" are reduced. Potential fire behaviour can be reduced through fuel reduction. The "unexpected" can be reduced through training, both of crews and supervisors, to increase their ability to recognise potentially lethal situations and so avoid them.

The Department currently provides a high standard of fire training via nationally accredited courses. Such training must be supplemented with fire ground experience. In the past, much of the training for both supervisors and fire crew was on the job training with mentoring being provided by experienced personnel. There is currently less mentoring because other agreed work priorities take precedence (over both mentoring and being mentored) and there are fewer people to assign to the work who have the requisite mix of fire knowledge and mentoring skills. Unless this is addressed the situation will compound, as there is a decline in the number of experienced personnel able to provide such mentoring.

Recommendation 5.7: The Department provide a formal mentoring program for fire as a requirement of a formal in-service program for all new field personnel.

An increasing trend is to provide management teams rather than individuals when resourcing a fire. This has significant advantages in efficiency through the familiarity of the team members with each other when working together to implement fire suppression systems and procedures. There may be benefits in also training teams as a whole, particularly where the teams include FPC staff and where otherwise the team work may deteriorate over time.

Whilst training standards are high, a number of people have expressed concerns that the current format can make it difficult for some to attend and suggested a more modular approach that allows training to be undertaken in shorter bursts (eg. 2 day instead of 5 day), may be beneficial. The time pressures that restrict the ability to attend training courses have also been cited as a major reason for people not attending burning operations where the theoretical training can be supplemented with practical experience. Practical experience is considered an essential component of training to maintain a safe work environment. An emphasis must be maintained on planning for, and then taking the necessary action to ensure, that the requisite number of people retain the minimum desirable level of fire fighting experience.

Recommendation 5.8: Training programs be implemented so as to facilitate both attendance and learning outcomes.

5.7 Fire Fighter Safety – Protective Equipment

The role of protective equipment in fire fighter safety is subsidiary to that of training and situational awareness. The best safety is to avoid critical situations in the first place. There are situations, however, where bush fire fighters will be caught in life threatening situations such as burnovers, where protective equipment can increase safety. A conundrum exists, however. The provision of some protective equipment that provides uncertain protection in some circumstances only may in fact reduce fire fighter safety if crew become lulled into a false sense of security by its provision.

The Department provides appropriate personal protective equipment based on research findings (eg Brotherhood et al 1990) and recommended best practice based on experience and collaboration with other agencies. It also has a good record in implementing the results of research in equipment design and specification.

The Department relies on the cabins of vehicles, supplemented by blankets, to provide refuge and protection from radiation in the event of a burnover. To date this has proven successful in several incidents, with no loss of life. Vehicle cabs are sufficient to accommodate the numbers of crew, and no separate crew protection or sprinkler systems are provided.

Sprinkler systems have assisted survival in some situations in entrapments in Australia, but they are demonstrably unsuccessful in circumstances such as high wind and limited water. They have the potential to provide a false sense of security.

The use of cabs for radiation shelter stems from Cheney's 1972 research that showed passenger vehicles remained a safe refuge until the interiors caught fire, when rapid increases in heat and smoke forced evacuation. Modern vehicles have changed considerably since that time, with much greater glass area, and much greater use of plastics, potentially reducing the time such vehicles may afford protection from the radiant heat of a forest fire before the build up in noxious fumes drive the occupants out of the burning vehicle. The extent of this requires further investigation. When vehicles used in fire fighting are replaced, preference should be given to vehicles that minimise the use of flammable plastics. Modification to the cabs or provision of crew shelters separate from the cab may be warranted if further investigation shows a significant reduction in the protection offered by modern vehicles.

Recommendation 5.9: The Department continue to monitor the development and effectiveness of crew protection systems and ensure best practice is implemented when replacing or upgrading fire fighting units.

6 Identify other outcomes the Department requires from its fire management activity

6.1 Public Image

Fire management is a highly visible activity undertaken by this Department. As such it is in a position to strongly influence public perceptions about the Department overall. Currently there is an ambivalence towards the Department's fire management practices, which are poorly understood by the media and the public. There is a positive response to the Department's professionalism in its fire suppression activities, but an adverse reaction to burning. A range of concerns are expressed and many of these relate to aesthetics (smoke, loss of wildflowers, unsightly black areas,)

It would be easy to respond to the "shiny fire engine syndrome" and reinforce the Department's image by taking advantage of the positive reaction to such images as water bombers and tankers heroically combating the flames. A major downside of this is that it reinforces the perceptions that fire is bad, and by inference so are the Department's burning activities.

Greater efforts are required to gain community support for the Department's fire management plans, so that the professional way in which they are implemented enhances the Department's reputation for environmental management and community care.

Recommendation 6.1: Appropriate market research be conducted into what key stakeholders and the wider community know, understand, and perceive concerning fire in the natural environment and fire management practices in Western Australia.

Recommendation 6.2: The Department implement a strategic communication and advocacy program that will develop key stakeholder and community awareness and understanding of the role of fire in the natural environment, and will assist in encouraging informed community discussion concerning fire management in the State's natural environment.

6.2 Emergency Response: ICS Teams

The Incident Control System introduced to Western Australia through this Department has wide application for emergency management and has now been widely adopted by emergency management agencies. The high standard of training in emergency response undertaken for fire is equally applicable to the management of other incidents such as oil spills and cetacean strandings. The broadest possible involvement of staff in incident management activities is desirable.

6.3 Peer Respect

There is considerable interaction with other departments and agencies through fire management. The manner in which this is conducted and the level of professional standards demonstrated will reflect on the Department's reputation within Government.

6.4 Leadership and Responsibility

Many of the organisational, management, and leadership skills required to successfully carry out fire management are equally applicable to management in the broader organisational context. Thus many of the skills developed as part of the extensive fire training programs have application across the organisation.

7 Identify short to medium term fire management plans and prescription

7.1 Current Plans – Brief Overview

Current plans have their roots in the Report of the Rodger Royal Commission in 1961 that recommended (in part) "the Forests Department make every endeavour to improve and extend the practice of control burning to ensure that the forests receive the maximum protection practicable consistent with silvicultural requirements." Planning has been based on the prime objective of reducing fuel loads so as to reduce the intensity of any subsequent wildfires. Burning of blocks of forest on a 6-8 year rotational basis was instigated in the 1960's. Whilst the perception remains that this is still the case today, the reality is far different, with few areas being burnt on a regular basis. The average fire interval now exceeds 10 years (Gill et al 1997), primarily as a result of external constraints and limited resources, and conscious efforts are made to vary the season of burning. There has been a shift to consider broader fire management requirements, but this has been hampered by conflicting views and a lack of clearly articulated biodiversity conservation fire management goals. The main focus has therefore remained on reducing fuels to aid wildfire suppression, with other requirements largely being viewed as constraints requiring modifications to the burning programs, rather than primary objectives.

Fire management planning is complex, and an extensive planning system has been developed to manage this. There are 33 separate steps identified in Fire Protection Instruction 1 (Master Burn Planning) commencing from 8 years prior to a planned burn to allow for the interaction of fire with other activities (eg dieback interpretation and demarcation). To better handle this complexity the use of GIS (ESRI's ArcView) has been introduced into the planning process. It has streamlined many tasks, improved integration, and facilitated new products such as the public information maps. Although this introduction has resulted in many improvements, it was implemented by adapting a hard copy "master burn plan" and has inherited many of the limitations of such hard copy systems. It was developed with "management units" (burning blocks and sub-units within the original burning blocks) that effectively established the pre-existing manual system in an electronic format. This does not take full advantage of the analytical power of the GIS platform to look at alternatives.

Despite some attempts by the Department's Fire Branch to arrange integrated planning meetings, communications have not been successful and planning is largely done by Branch staff and region/district fire coordinators in relative isolation, and often with only limited access to some information. Fire scientists or ecologists from Science Division have rarely been directly involved in the planning process.

The results of the fire planning process are passed on to the IOPS (Integrated Operational Planning System) custodian in Forest Management Branch. Because of the long lead times associated with the interaction of fire and dieback mapping prior to logging, any change in the planned program for either logging or fire may have serious repercussions for the other.

7.2 Fire Management Plans – A Revised Approach

An adaptive approach to fire management planning is recommended, utilising the modelling and analytical powers of GIS to fully incorporate fire ecology knowledge, to consider alternatives, and reviewing both the models and practices based on monitoring of outcomes.

Fire is an important management tool for both conservation and protection. Fires affect the structure and composition of both the understorey and overstorey, and reduce the amount of fuel. Conservation and fire protection objectives can often be achieved simultaneously. Any fire will reduce fuels, and so provide a fire protection benefit, but some fire regimes may be detrimental to biodiversity conservation.

Knowledge of fire ecology, although incomplete, can be summarised as *fire diversity promotes biodiversity.* It is proposed that fire planning firstly considers the managed fire regime that optimises fire-induced diversity at the landscape scale. The next stage should be to carry out a systematic risk analysis to determine what values are threatened by this regime, including the potential for wildfires to threaten conservation, life, property, and forest production values (see section 9). The fire management plan should then identify the measures necessary to reduce unacceptable risk to values.

A model for fire diversity is required. Knowledge of fire ecology should be used as a basis for determining the level and nature of fire diversity to promote biodiversity. The greatest information about the vital attributes and responses to fire of the biota relates to the vascular flora, and since plants are not mobile as are other organisms, it is proposed this group be used as an indicator or measure for determining a fire diversity model. It has been shown that many other groups of organisms generally (but not invariably) respond to fire regimes in a manner similar to the vascular flora with which they are associated. Use of flora to provide a measure of fire diversity would therefore appear reasonable, however available knowledge from other taxanomic groups (including mammals and birds) should be used when devising appropriate mosaic models, and the models refined in the light of new knowledge.

Notwithstanding a generalised model for attaining fire diversity, where there are specific requirements identified, as for threatened species/communities or to maintain or re-establish specific vegetation associations or habitat (such as Tuart or south coast woodlands with grassy understorey), these need to be considered separately.

An idealised fire age-class distribution model is of the form of a negative exponential function, which is the form expected under 'natural' ignition conditions (eg McCarthy and Gill 1997; Tolhurst 1999, 2000, Tolhurst and Friend 2001;). This assumes a constant hazard over the life of a community which, whilst not strictly correct, is a reasonable approximation. Tolhurst and Friend (2001) illustrate a comparison between distribution assuming different hazard functions varying over time, and a negative exponential function.

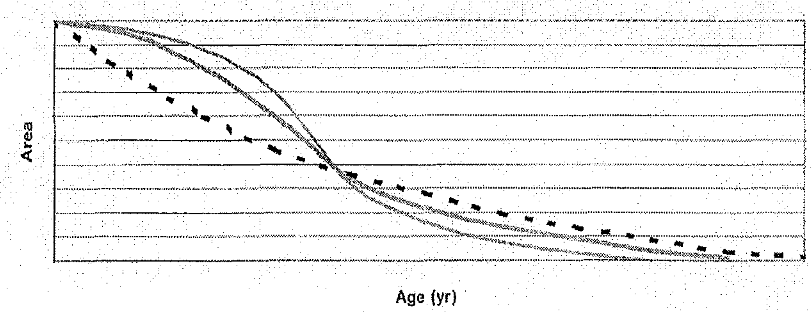


Figure 2. Area distribution with time since fire assuming different hazard functions. Dotted line represents a negative exponential distribution. (Adapted from Johnson & Van Wagner 1985)
(Reproduced from Tolhurst and Friend 2001)

Tolhurst (2000) has provided a method for setting the parameters for such a function using the vital attributes of key plant species. Burrows (2001b) has outlined how this might be applied in WA forests.

It is proposed that fire management aim to:

- Maintain seral stages of both overstorey and understorey components based on an idealised negative exponential distribution for each class at whole of forest, regional and landscape scales.
- Create a mosaic of burn ages from recently burnt to long unburnt, that includes patches burnt at different seasons and at different frequencies. Generally, granite outcrops and more mesic landscape elements, such as riparian zones, wetlands, some swamps, and valley floors, will contain relatively fire sensitive species, so should be burnt less frequently.
- For any given area, vary the interval between fire and the season burnt.
- Protect/enhance threatened species and ecological communities. Localised fire regimes will be applied based on the best available knowledge to protect/enhance these. This will automatically predetermine the seral stages for part of some vegetation units.
- Provide protection for visitors and visitor facilities, and provide for protection against loss or injury on adjoining lands from fires on lands managed by the Department. Just as specific regimes may need to be applied to protect/enhance threatened species, modified regimes (eg shorter rotation) may need to be applied to provide for an acceptable level of protection in some areas.

Where specific regimes are required to protect high value assets it may bias the distribution of seral stages. Areas adjoining such assets may over represent the "shorter period since last fire" classes locally, but the aim should be to maintain as much as possible the idealised structural distribution at the landscape scale. It is important that even where there is a priority for maintaining low fuel levels that the interval between fires and the season of burning are varied.

At the coarse (whole of block) scale at which past fire histories have been recorded it is currently meaningless to consider existing fire/structural distributions in relation to vegetation units such as the Mattiske and Havel (1998) units, suggested by Burrows (2001b). These are smaller than some of the areas that have been recorded as being burnt on a whole of block basis, notwithstanding it is well known that there are many unburnt areas within such blocks. Use of the Mattiske and Havel units should remain an objective for the future, as more accurate recording of burn boundaries and burn classes becomes available via the remote sensing tools currently being developed (eg Li Shu et al 2001). The continued development of such tools is considered essential if finer scale models are to be considered. In the interim, burn planning should aim for structural diversity, and at both a landscape and whole of forest scale units such as the Christensen fauna habitat types or the Bradshaw and Mattiske (1997) forest ecosystem types can provide a broad measure of fire distribution across these types.

Recommendation 7.1: The development of remote sensing and GIS tools to support fire management planning is continued.

An idealised time since fire/structural distribution model for each type should be prepared using the method outlined in the proposal by Burrows (Appendix 2) and the annual burns programmed to progress towards such a distribution. An outline of how analysis can be undertaken to support such planning is included under section 10 that addresses the term of reference: "Review the appropriateness of the landscape scale of current fire management practices".

It must be recognised that such an idealised model is unlikely to occur naturally in a landscape dissected by farms, roads and where fire is affected by suppression, nor is it likely to be achieved in practice, particularly when applied at a finer scale, as many different types may occur within the one fire/burn area. Nevertheless burn planning aimed towards such a model provides an approach that will tend to maximise the protection of diversity. It is intended that this approach be applied to both understorey and overstorey strata, although at vastly different time scales, and adapted in response to monitoring results.

Low intensity fires affect the life cycle of understorey species but are unlikely to kill overstorey species (trees). Trees have much longer juvenile periods and live much longer than most understorey species. The periods between fires that kill/regenerate trees must also be correspondingly higher. To maintain the structural distribution of fire sensitive overstorey (tree) species it is necessary to prevent too-frequent high intensity fires. Low intensity fires will need to be used to prevent extensive high intensity (stand replacement) fires and applied so as to also provide the desired structural diversity within the understorey.

To meet structural goals, there is no fixed rotation: the future burn program is based on the fire history, and must therefore be reviewed each year in light of the fire occurrences (both planned fire and wildfire) during the previous season. It is feasible that, if a sufficient mosaic is successfully established, different fuels within the same overall burn envelope may be prescribed to be burnt within one or two years of a previous burn in the same area.

A burn program based on achieving diversity may need to be modified to take into account specific requirements for asset or species/community protection, or operational constraints. It is pointless to develop a burn program that cannot be implemented.

Recommendation 7.2: An adaptive approach to burn planning is taken, based on fire diversity/structural models for vegetation units.

Fire management planning is guided by and should be in line with departmental policies. Although a much broader range of priorities was recognised with the introduction of the Wildfire Threat Analysis in the early 1990's, the Fire Management Policy (Policy Statement 19) was not revised. This is well overdue, and particularly in view of the recent changes in the Department, the policy should be revised.

Recommendation 7.3: Policy Statement 19, Fire Management Policy, be revised to more accurately reflect the values and intended practices of the Department.

7.3 Burn size

A mosaic of different burns can be achieved by distribution, both temporally and spatially, of individual burns or by patchiness within a burn envelope. Both have advantages and disadvantages.

Smaller burns generally have greater uniformity of fuel conditions. This aids in prescribing the type of fire desired, but the uniformity also means that there is little patchiness within the burn. As most of the area is burnt out there is a low risk of subsequent fire escape. The distribution of small burns in the landscape can be used to determine the distribution of the structural types, and theoretically, the idealised structural model for any given community could be achieved through a planned distribution of individual burns. In practice this is not feasible, both in relation to the resources and the environmental disturbance (associated with fireline construction) that would be required to achieve this.

The larger the burn envelope, the greater the variation in fuels, moisture and topography within the area and the greater the potential for creating mosaics within the burn envelope. The larger amounts of unburnt vegetation in such a mosaic mean there will be a greater risk of re-ignition and subsequent fire escape. The consequences of such an escape will depend to a large extent on the level and uniformity or otherwise of surrounding fuels. If a mosaic is established throughout the whole of the forest the potential for uncontrolled fire spread is much reduced. If however, large areas are long unburnt such escapes could cause significant adverse consequences.

A mosaic created without mineral earth boundaries (as within a large burn envelope) has advantages of reduced disturbance and reduced risk of weed or disease introduction. It does, however, carry increased risks that if conditions are not as forecast, large areas of a vegetation community planned to be excluded could be burnt in a single fire event, particularly if such areas are contiguous, such as along riparian zones.

Whilst both large and small burns carry their inherent risks, it is recommended that burn envelope size be maximised wherever possible (initially at least >5,000 – 10,000 ha), and that small burns be restricted to critical areas. Small burns require far greater resources per unit area, large numbers of burns cannot be achieved, and an inevitable result due to a lack of resources will be a distortion in fire age/structural classes away from the idealised model, increasing the risks to biodiversity. The consequent increase in fuel loads will result in more extensive, higher intensity and more uniform burns. Individual burn areas will increase; the mosaic of fuel ages/structure will decrease, as will distances from boundaries for re-colonisation of the areas. These risks are considered greater than the risks associated with a loss of a planned mosaic within a burn as a result of unforecast conditions or errors.

Implementation of a strategy of large burn envelopes that include a significant mosaic of unburnt vegetation carries with it an increased risk until such time as there is a greater mosaic of fuel ages across the forest. Currently there are large areas of forest with relatively uniform heavy fuels where such escapes would be difficult to control in adverse conditions.

Recommendation 7.4: The size of individual burn operations be maximised where possible, with the objectives to provide for diversity and a mosaic of burnt and unburnt patches within the boundaries of the overall burn envelope.

7.4 Prescriptions and practice

An individual burn will normally be planned to provide multiple benefits that could include structural diversity objectives and protection of visitor assets, timber values, specific species and neighbouring lands. These objectives should be agreed as part of an integrated planning process. It is essential that the reasons for the burn be clearly identified in the objectives, so that the burn can be prescribed correctly, and costs allocated appropriately.

Recommendations 7.5: Prescription objectives clearly identify both the reason(s) and intended outcomes for each burn.

Each prescription outlines the strategies to be achieved to meet the objectives, including prescribing the conditions under which the fire will be lit. The success or otherwise of the burn in meeting these objectives is dependant on how well this is done, and how well it is implemented. There have been occasions when sudden changes in the weather and similar unforseen events have required burns to be completed outside the prescription. Such occasional occurrences are unavoidable. There have also been suggestions that some burns have been carried out not fully in accord with the conditions prescribed, where for operational reasons (eg availability of aircraft) the decision has been made that the objectives could still be achieved. This is undesirable, as it increases the chance of errors because it negates one of the important benefits of preparing a prescription: that carefully considered decisions are made free from immediate operational pressures. To avoid this situation, the full range of conditions under which it is acceptable to burn to meet the desired objectives should be included in the prescription, with appropriate limitations.

Where objectives include the creation of mosaics based on vegetation classes, fuel sampling and monitoring of the conditions must be carried out in both the areas proposed to be burnt, and those vegetation types planned to be left largely unburnt to create the mosaic. This is particularly important to increase the likelihood of success where burns are proposed without mineral earth separation between burnt and unburnt areas.

Both in the overall planning and in the prescription detail, particular attention needs to be paid to the location of boundaries to facilitate getting a secure edge, especially if significant unburnt areas are to be retained. This is generally more readily achieved with larger burns where there is a greater opportunity to use catchment boundaries and less requirement to cross creeks.

7.5 Post burn monitoring

In order to adapt the future burn program in light of the recent fire history, and to measure the success of the prescription, post burn monitoring must be carried out. To enable this to be done in a consistent and cost effective manner, recent remote sensing research work should be progressed as quickly as possible.

Representative plots should be established to monitor the long-term effects of the fire regimes being applied to achieve the structural goals, so that these regimes may be modified if they are not achieving their goals or are resulting in unforeseen adverse consequences. It may be appropriate to include these as part of the FORESTCHECK monitoring system.

7.6 Isolated reserves

Whilst fire is one of the most important tools for management of natural areas, it is not always the most appropriate tool to maintain biodiversity and to protect values against wildfire. This may particularly be the case in small isolated reserves, as is recognised in Policy Statement 19. Factors that need to be considered include:

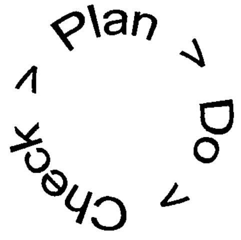
- Potential for weed invasion following a fire;
- The size of the reserve and relationship to other small reserves with similar vegetation/habitats; and
- Feasibility of other fire protection measures.

Most small reserves are currently not planned to be burnt, or are burnt only infrequently.

In many instances reserves will be too small to consider partial burning in an attempt to establish seral stages. It may be appropriate for structural diversity to be maintained across a group of reserves with similar vegetation/habitats. It may also be appropriate to use mechanical disturbance (eg. slashing/hoeing) both to modify fuels for fire protection reasons and to regenerate areas, although grazing pressures on small patches of regeneration may still be deleterious whether regenerated by fire or following mechanical disturbance.

7.7 Resources, Achievements and Adaptive Management

There are three phases to the planning/implementation cycle:



An essential component of the proposed fire management approach is that it is not locked into a particular set of circumstances or actions, but that the outcomes are monitored, reviewed in the light of contemporary knowledge, and the approach modified as required.

The ability to implement the plan is a critical consideration. The best plan in the world will not achieve intended outcomes if it is not or cannot be implemented. When planning, thought must be given to the resources available, and the operational effect of such factors as burn size, sequencing of burns in relation to other fuels, time of year, etc. The extent to which planned fire management activities have been achieved must be included as a component of an adaptive management approach, and the plan and/or available resources adjusted to enable the best balance of outcomes.

Much of current burning is undertaken to meet silvicultural requirements, and many burns have conservation objectives, but the objective of preventing the spread of uncontrollable wildfires remains a major part of fire management plans. Plans have incorporated numerous changes over time that have had the effect of imposing additional constraints on burning operations. The outcomes of these changes are clearly illustrated in the graphs from Gill et al (1997) shown in figure 7.1. Areas burnt are a proportion of total area, and thus reflect the trends independent of any changes in area due to changes in land tenure. Whilst these are for State forest and timber reserves only, the trends are applicable to all forested public land in the south west. The trend for less area being burnt has continued, with the current area burnt annually by prescribed burning being lower than at any time since the 1950's.

Fig. 2.12. Trends in the areas burnt (by prescribed and unplanned fires) per Julian year from 1922/23 as a proportion of the total area of State Forests and Timber Reserves (including softwood areas). Trend lines use 1969 as a data divide.

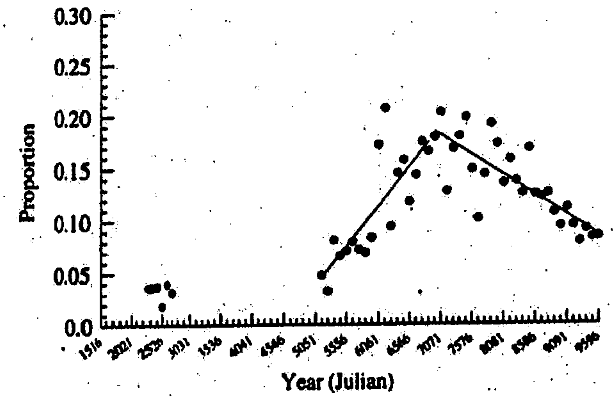


Fig. 2.13. The average apparent fire interval (fire cycle) for the forestry estate as a function of Julian year.

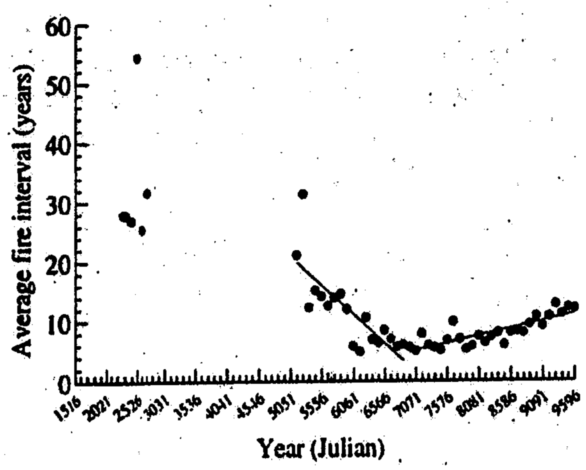
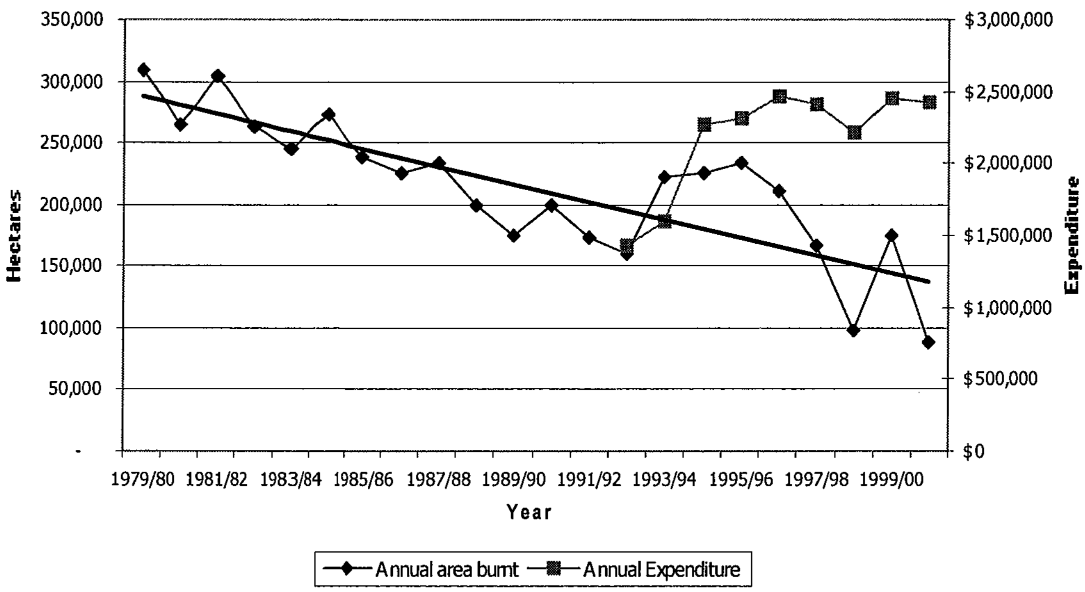


Figure 7.1 Historical Trends (Source: Gill (1997) p 45)

These outcomes shown by Gill et al are primarily a consequence of the additional resource requirements that have resulted from changes affecting the manner in which operations are carried out. This trend is illustrated in the following chart. Expenditure figures are in 2001 $ (CPI adjusted) and shown only from 1992/93 on, due to accounting changes at that time. Expenditure shown is for prescribed (fuel reduction) burning only, and does not include the increases in overall cost of burning due to the increased complexity of silvicultural burns.

Fig 7.2: PRESCRIBED BURNING IN FOREST REGIONS - AREA & COST (1979/80 to 2000/01)



Many of the changes that have contributed to the increased costs result from external factors affecting the fire management operation plans either directly or indirectly. These include response to concerns regarding smoke, localised pressures, and effects of timber harvesting plans, resulting in reduced size and increased complexity of burns. As less area is burnt, the fuel loadings adjacent to planned burns increase, further adding to the cost.

In applying an adaptive management model, the net effect of each change must be evaluated in terms of both the specific goal to be achieved by the change, and the effect of the change overall. The plan should then be modified to achieve the best possible outcome. The impact of change on the ability to achieve the outcomes without an accompanying change in resources (if required) must not be overlooked.

7.8 Smoke Management

Smoke management is an example both of how changes to meet one outcome can affect the overall result, and of how planning cannot be undertaken in isolation, but must be undertaken in collaboration with others to produce the best overall outcome (in this case the net public health/community safety/environmental and aesthetic outcomes.)

In past decades there were occasions when smoke in the metropolitan area was so thick that it threatened closure of Perth airport, and on one occasion, even shipping lanes. Long periods of heavy smoke over south-west towns were common. This is no longer acceptable to the community.

Collaboration between the Department and the Bureau of Meteorology has resulted in considerable advances in smoke trajectory modelling. This has been used in the planning of burns. An analysis of Department of Environmental Protection data since 1994 reveals that no smoke from prescribed burns has resulted in the National Environmental Protection Measure standard for Fine Particulates (PM^{10}) being exceeded in the Perth area. Reduced visibility as a result of haze from CALM burns has fallen from a regular occurrence to two or three incidents per year, and these do not exceed any PM (PM^{10}) standards (Sneeuwjagt and Higgs, 2000).

Despite this, whenever there is even a low level haze incident there is a public outcry, with adverse health effects (particularly on asthmatics) being claimed. There is little or no evidence that air pollution is a major precipitant of asthma at a public health level (Anderson 1999) and there is evidence to suggest that bushfire smoke does not have significant effects on health (Brotherhood et al 1990). A study undertaken prior to and during the 1994 Sydney bushfires (that produced smoke in Sydney suburbs for 9 days, 6 of which exceeded the PM^{10} standard) showed fewer attendances at hospitals for asthma during this period compared to the control period (Corbett 1994).

Under the Perth Air Quality Management Plan (DEP 2000) it is proposed that the DEP "Undertake a comparative risk assessment of mortality and morbidity influenced by smoke from prescribed burning and bushfire." This is welcomed, and should provide the basis for a better evaluation of net costs and benefits to both the community and environment of differing levels of smoke management.

Smoke is an inevitable product of both managed and wild fires. Fires of differing intensities and in different seasons may have differing effects on airshed quality. The environmental effects of the fires will vary, and there will certainly be different threats to firefighters, property and the community from the direct effects of the fires. Decisions on smoke management and fire management should not be taken in isolation, but should aim to provide the best overall result for the community as a whole. Involvement of other relevant agencies to develop jointly appropriate fire management strategies based on an analysis of all factors should provide opportunity for both optimising outcomes and gaining wider support for the implementation of resultant plans.

Recommendation 7.6: The Department, the Department of Health and the Department of Environmental Protection/Environmental Protection Authority be involved in determining a fire management strategy that provides for optimal overall outcomes.

7.9 Integrated Planning

In the past fire management planning was closely integrated with other operations, most significantly timber harvest and recreation planning, at a District and Regional level. New structures have been developed in the Department with greater emphasis on functional lines of control, and with more centralised forest planning. This has reduced the effectiveness of local integration, although the strong operational planning system for fire has continued to support the implementation of fire management activities.

Fire is not a core output for the Department, but is a function that crosses output boundaries. It both affects and is affected by other activities directed towards achieving output outcomes, and must be integrated with them. Past attempts at regional integrated burn planning meetings have not been successful, and Fire Branch staff and fire coordinators have largely done burn planning with only limited input from others. Whilst output leaders are required to sign off on proposed plans, there has been little ownership of the outcomes by them. Integrated planning has also been hampered by restrictions on the availability of some key data sets for fire planning due to concerns by the data custodians as to how the data will be used or transferred. Planning in isolation of the knowledge held by others is an invitation for errors and omissions.

A process to ensure greater integration of planning across outputs is required. The expertise devoted to planning in different areas must at some point be brought together so the areas of common interest can be supported and conflict can be resolved. This is not necessarily best undertaken by fire staff. There may be merit in Forest Management Branch being restructured to coordinate such integration of plans, but this must involve all stakeholders including the Parks and Visitor Services and Nature Conservation output representatives, and fire managers. It would also be advantageous for Science Division staff to be involved in planning meetings to facilitate consideration of the latest scientific knowledge in the planning process.

It is not suggested that the expertise for all functions reside in this restructured integrated operational planning branch or that it be responsible for all facets of planning. Fire Branch would remain responsible for providing expert input into the overall strategic plan, and for the detailed planning based on agreed, integrated objectives. Fire Branch would be responsible to ensure operational and safety aspects of fire planning, such as sequencing of burns to reduce the risk of escapes and to permit burning under more risky conditions with northerly winds for smoke management purposes, are fully covered in the planning process. Annual (at least) planning meetings would be required to review and agree on overall objectives and burn outputs.

Recommendation 7.7: A framework be established to integrate fire management with other plans.

8 Develop a means of separately identifying timber protection, community protection values, and nature conservation values

It is necessary to identify values according to program (or Output) to ensure that fire management costs associated with the protection/enhancement of such values are correctly ascribed. This review has identified that there are other factors at least as important that need to be addressed if greater accounting accuracy is to be achieved.

8.1 Identification of Values

Values that the Department manages have been identified earlier in this report as part of the term of reference 3 "Identify values of the south-west forest region land which the Department manages and undertake a consultative risk analysis, with the Output Directors, to determine the risk factors to be applied to the maintenance of those values".

Difficulties have been associated in the past, not so much with the identification of values, as with their proper recognition in objectives and prescriptions. Many values in relation to fire management were identified in the past through wildfire threat analyses undertaken in the early nineties, and others such as those associated with silvicultural burning have been self-evident from the reasons for conducting the operation.

Values have been identified but allocation of costs has been only poorly related to these. Whilst part of the reason for this lies in the accounting difficulties discussed below, it is also a consequence of a lack of specific fire management objectives related to the Output values.

As discussed in section 7.9, fire management activities cross Output boundaries. They pre-date the introduction of program (and subsequently Output) budgeting and because any one activity can result in outcomes in several Outputs, they do not fit comfortably within an Output budgeting framework. Fire management was focused almost entirely on protection from wildfires or use of fire for silvicultural purposes. Measurable objectives were described in terms of the fire outcome, for example scorch heights/amounts, and reduction of fuel loading below a specified level. The reasons for preventing damaging wildfires were usually considered self evident and not stated, or if they were, expressed generally as protection for life and property. The introduction of program/output budgeting altered the way costs were recorded, but did not change the basic objectives, (ie. both before and after the introduction of program budgeting, the objective remained the prevention of uncontrollable and damaging wildfires). Objectives were not reviewed in terms of the programs (ie. why prevent damaging wildfires; the program values involved), but continued to focus on the desired fire behaviour outcome.

This lack of clear objectives relating the task to the program values has contributed to a sometimes inconsistent and confused approach to cost allocation for fire management activities. For example, objectives for a prescribed burn have generally been phrased in terms of reducing fuels to specified levels (ie. the desired fire outcome) not in terms of the program values to be protected/enhanced. If the objectives are clearly stated in relation to program values (ie. the reasons for conducting the burn rather than just the desired fire outcome) it provides a sound basis for subsequent allocation of costs. Similarly a reassessment of other fire management activities (such as maintenance of access, equipment, detection etc,) in relation to program values should be undertaken.

Recommendation 8.1: Clear objectives for the protection/enhancement of values be agreed between representatives of the purchasers (Forest Products Commission and Output Directors) and providers (Regional Services fire representatives) during the planning process, and these form the basis for cost allocation.

8.2 Budgeting and Accounting Processes

Fire management is not a separate program in its own right. It is a component of the Department's core outputs of Nature Conservation and Parks and Visitor Services and provides protection for timber and community values. Although the annual program may remain reasonably constant, the contribution of an annual program to each of these components can vary markedly from year to year. Recurrent budget allocations for each program have not been varied annually to take account of this. This has resulted in a pseudo fire budget comprised of relatively fixed amounts from each program irrespective of the area where the work was to be carried out in a particular year

This inflexible approach to program budget allocation has contributed to inconsistencies in the recording of expenditure. In some cases costs have been debited according to the values being protected/enhanced (ie. the purpose for which the work was carried out), with an over expenditure in that budget being balanced by a corresponding under expenditure in the fire codes of the program where the budget was provided. In other cases expenditure has been recorded against the program where there was a budget, irrespective of the values being protected/enhanced by the work carried out. Whilst the overall expenditure on fire was correctly recorded, detailed analysis according to program can not be reliably undertaken.

To avoid the confusion that can arise from this budgeting process there must be provision for either greater flexibility in annual budgets between the programs to allow for correct budget allocation in the first place, or alternatively the fire program is budgeted for as a separate program.

Recommendation 8.2: The budget allocation process be amended to account for annual variations between outputs in fire activities.

A major impediment to accurate recording of expenditure is the way the current chart of accounts and financial system operates. An individual fire job carried out for a single clearly defined purpose on a single tenure can require up to 14 separate expenditure codes (most commonly 11) to account for salaries, wages, overtime, plant, etc.

Where a job such as a prescribed burn is carried out to achieve multiple objectives and should rightfully be costed against each of these, the numbers are multiplied accordingly. Thus for a prescribed burn which may be carried out to provide protection for fire sensitive regrowth areas, to provide protection for neighbouring assets and recreation areas, as well as to create a particular seral stage, there could be 44 separate expenditure codes. Reliable recording of expenditure in such circumstances is impossible.

In order to reduce account codes to a reasonable number it has been recommended practice to identify the priority reason for conducting the operation (program value) and to allocate costs for the task to this program. Whilst this may arguably balance out in time it is not a transparent process, and such a guideline blindly applied could lead to some gross distortions. For example, the most important value in a large prescribed burn area may only occupy a minuscule portion of that area and protection for that particular value may be far more economically provided in the immediate surrounds, but because it is by far the highest value in the burn area the whole cost gets allocated to that program. Such extreme examples are rare, but it is common for a benefit to be accrued by a number of programs from the one operation, but for all the costs to be attributed to just one. It would be far preferable to have a system that encourages allocations that accurately reflect the cost of individual jobs, not just a correct overall allocation.

To achieve this it is suggested that each fire related task be given a single account code that is then automatically reallocated, on a basis agreed for each specific job, to the relevant programs (via a "distribution set"). The percentage to be allocated to each program should be determined by agreement between the stakeholders. For prescribed burns this agreement should be reached when the objectives are set during the integrated planning meeting recommended under the planning section.

For wildfires the cost distribution will need to be carried out retrospectively.

For other fire related tasks (eg. water points, access, detection, detention) the distribution from year to year would generally remain constant but should be agreed between and periodically reviewed by the stakeholders.

Stakeholders include representatives of the Output Directors and the Forest Products Commission who are purchasing services, and from Regional Services Division (Fire Branch and field representatives), charged with delivering the service.

Recommendation 8.3: Accounting procedures be amended to provide for all costs to be debited to a single account for each fire related job, with automatic redistribution on a predetermined basis.

8.3 Other Cost Distortions

Fire management activities are seasonal but there are associated costs that must be borne throughout the year both in relation to staff and equipment. Where these resources cannot be efficiently used when not required for fire management they become an overhead cost to the organisation.

Equipment such as heavy duties, bulldozers and loaders, currently have a higher hire component, largely as a result of the expense of the specialised equipment and the relatively low use when spread across the year. Currently, the charges for the use of this equipment are applied equally to all jobs. This is a strong disincentive to use such equipment on non fire specialised tasks where external equipment can be hired at a much lower cost to that particular job (although at an additional cost overall to the Department). Ascribing the full cost of this specialised equipment to a non-fire job is not only a disincentive for its use but leads to distorted costings.

As the primary use of this equipment is for either fire suppression or prescribed burning the total fixed costs of this should be borne by these activities, with other activities where this equipment is used only being debited charges equivalent to external hire. In this manner the real cost of both the job and fire activities including wildfire suppression can be identified.

Recommendation 8.4: The fixed costs of specialised equipment such as heavy duties and fire fighting plant be separately identified and debited to wildfire suppression and burning.

Similar overheads may exist when using fire fighting staff during non fire periods if these people lack the skills to efficiently perform other tasks, or there is a lack of productive priority work in the "off" season. These are more difficult to quantify than the costs associated with plant and vehicles, and have been reduced through the reduction in permanent workforce and use of seasonal fire staff.

8.4 Community Protection

Many fire protection jobs are undertaken not primarily to protect or enhance the core departmental outputs (indeed in some cases to their detriment), but to provide protection against wildfires to broader community values including property on adjoining lands. Such community protection benefits may be an indirect consequence of an activity primarily undertaken for fire management of lands managed by the Department (eg. detection system that has as its focus forest lands, but can detect fires elsewhere), or incur a direct expense specifically to protect community values (eg. fuel reduction burn to protect an adjoining residential area). Almost all activities undertaken near the forest fringe have either a community benefit, or incur a greater cost because of the neighbouring land.

Previously the Forest Resources Management program was the only program that included an account (program 41) that enabled a number of these costs (planning/liaison, prescribed burning, suppression) to be separately identified where they were undertaken on State forest or timber reserves for the benefit of the neighbouring community with no direct benefit to the FRM program output.

This has not applied to other land tenures. Where land tenures have changed, these same jobs, are recorded as costs against the general Parks and Visitor Services or Nature Conservation outputs.

The extent to which cost of community protection should be a cost of doing business or be separately funded is arguable. In either case, the quantum of this should be clearly identified.

Recommendation 8.5: The costs of providing community protection be identified through the creation of a separate program or sub-programs within the core output programs.

9 Review the Wildfire Threat Analysis and provide advice on the incorporation of other values into the WTA or an appropriate similar tool. This review to include the provision of advice on a fire analysis system to identify areas in which fire is required for protection of values

9.1 Overview

- The Wildfire Threat Analysis (WTA) was conceived as an analytical tool to both identify and explain the appropriate actions to ameliorate threat from wildfires (Muller, 1993). It aimed to:
    - provide a framework to analyse the best available information on all factors contributing to the wildfire threat, and allow evaluation of alternative responses;
    - provide a standard and repeatable process such that consideration of the same data by different persons and/or at different times will identify similar situations;
    - permit objective comparisons between different areas with different problems and allow priorities to be readily determined;
    - support the clear and explicit explanation of the rationale behind fire management decisions; and
    - provide a rational basis for discussion and conflict resolution in the preparation of management plans.
- The WTA uses the best available models and information to underpin decision making, but recognises the limitations of both the models and the reliability of the data.
- There is no single index for wildfire threat. The WTA considers four groups of contributing factors: values at risk, risk of a fire starting, fire behaviour if fires do occur, and the capacity to respond with suppression action. Within each group the factors are related to each other and an index value for that group can be determined, but there is not a clearly definable relationship between the themes that would permit a single index to be determined with any credibility. Instead, the WTA product as introduced was a system of transparent map overlays for each of the themes with a base map identifying values. Density of hatching related to the severity classes within each theme. Density of the combined hatching gave a visual impression of where the greatest threat was likely to occur, and the contribution of each factor to the apparent threat could be readily identified..
- Although there is no single WTA index, single maps have subsequently been produced illustrating the overall threat without the underlying components (ie. the four major themes of values, risk, suppression response and fire behaviour). This was not originally intended, as it is essential to be able to view the factors that have contributed to an apparent high threat in order to draw any conclusions as to the best way to counter that threat. It is possible to get an apparent high value although there is little or no overall threat, if three of the factors are high and the fourth is very low or zero. For example, if there is a high risk of ignition in an area with high values, but located distant from any suppression forces, the overall rating will appear high, but if the fuels are very low (eg. area has just been burnt) there is actually little or no threat. It is emphasised that the WTA was conceived as an analytical tool to both determine the appropriate course of action to ameliorate threat and to be able to explain this. It should not be used as a stand-alone index. If it is easier to produce a combined map rather than produce the overlays, maps of the component themes should always accompany it.

- The component maps can be used individually to consider the effect of specific actions. They are also useful for analyses other than just planning to ameliorate wildfire threat. For example, identification of potential intensities, and the location and importance of values can support decisions when there are wildfires; intensity and structural maps can assist biodiversity planning.
- The WTA is an analysis framework that can be implemented manually on a hard copy map system, or via a GIS platform. It is onerous and time consuming to update the information manually. This is a major reason why the complete WTA for all forest areas that was undertaken in 1992/93 has not been updated or maintained in most areas. Much of the 1992/93 WTA was done manually, as an interim step and to collate data for the GIS implementation that was envisaged.
- Some work was initiated on the department's raster based GIS, Forest Management Information System (FMIS).
- Values map – an interim, values map was generated from data held within FMIS, based on the then endorsed "Classification of values for WTA". Not all values could be identified via the existing FMIS databases. For a values map to be maintained within a GIS additional themes needed to be created, based on the data manually collated. This was not done.
- Values themes – many of the values in the revised "Classification of Values for Spatial Fire Management Analysis" are available via existing databases, such as the DEFL (rare flora) database and can readily be imported into the ESRI environment currently being used for fire management planning. Other important asset databases such as RATIS (recreational database) do not currently have a spatial component. It is recommended that a values theme be maintained, based on access to relevant databases maintained by other custodians, supplemented by additional databases maintained by Fire Branch for those values not otherwise recorded. RATIS should be amended to include geographical coordinates for each site.
- Risks – the original risk classes were based on local knowledge. It is recommended that the fire cause and origins section of the actual fire history databases be used as a basis for risk as per the following maps (Maps 1 and 2).
- Suppression response – when the WTA was introduced broad suppression classes were mapped based on local knowledge of the area. It was anticipated that in the future network analysis could be undertaken based on the road networks and terrain classification. Unfortunately the data for the computer operational graphic (COG) maps have been developed in a Computer Aided Drafting (CAD) structure. The roads do not have any intelligent data associated with them that would allow network analysis in a GIS. Any classification of suppression response based on a radial distance from headquarters (see Map 5) is likely to be overly optimistic. Fires do not always originate adjacent to major roads and tracks, and the suppression response to the bulk of the area will be greater than implied by the circles.
- Fire behaviour – in 1993 fire behaviour was modelled within FMIS, using the then best available equations for fire behaviour in forests, grass and shrublands. Forest structure was modelled based on existing FMIS themes including stand type and cutting history. FMIS records also provided a broad area of fire history on which to base fuel accumulation. Where assumptions had to be made during the modelling, these were documented. Unfortunately the fire behaviour model was not amended when the structure of the underlying FMIS base themes was changed, and cannot now be used.
- Fire behaviour – as part of this review a fire behaviour modelling capability has been developed within the ESRI environment, using updated fire models for grass and heath, and Beck's equations for the Forest Fire Behaviour Tables. The more detailed modelling of the forest structure previously undertaken within FMIS was not available, and as a consequence more assumptions were made in preparing the fire behaviour maps in Section 9.3 (Maps 3

and 4). These are based on the best information available at the time of preparation. As fire intensity is an important measure of fire behaviour and fire effects, additional work to improve the model output is warranted. Areas which should be addressed include:

- Forest stand modelling: Structure is an important component in determining fire effects, fuel loads and wind ratios (the wind that reaches the fire compared with the wind in the open).
- Weather: The existing modelling has been done on weather records compiled in 1992 for weather stations located primarily at the work centres. In some cases these were based on a limited (10 years or so) period of records. Since that time there are many more records available to improve the reliability for the existing stations, and records have become available from additional remote stations. It is possible that in some cases weather records collected at a work centre are not representative of the bulk of the district. A review of available records should be undertaken to ensure that the best data set is used for fire behaviour calculations.
- Fuel age: Fuel accumulation rates have been modelled from the broad "year last burnt" classes in FMIS. These indicate when burning was last carried out within a block, but assume the whole block was uniformly burnt. It is known that this is not the case. As mentioned elsewhere, there is a potential for more accurate recording of burn boundaries and classes via remote sensing. As these data become available they should be incorporated into the model to replace the existing FMIS theme.

- Fire behaviour: Preliminary results from Project Vesta indicate that the current fire models used may under-predict rates of spread (and hence also intensity) by a factor of 2 or more under wildfire conditions. It is essential that the fire behaviour models be updated as soon as new equations become available. The latest and best available information should be incorporated at all times. Fire Branch should continually monitor the developments and update the models accordingly.
- The analytical tools of the WTA are equally applicable to analysing the potential impacts of any modelled fire scenario, including proposed planned burns. In reviewing the values classification in Section 3 it was deliberately broadened and titled "Classification Of Values For Spatial Fire Management Analysis", not just restricted to WTA. Nevertheless the WTA remains an appropriate tool to identify areas where fire is required to be used for the protection of values.
- Science Division should be encouraged to model fire effects based on the results of research so this information can be included in a spatial fire management analysis.

Recommendation 9.1: The Wildfire Threat Analysis be retained as an appropriate means of identifying where additional actions are required to provide fire protection.

Recommendation 9.2: The GIS analytical tools developed for the Wildfire Threat Analysis be maintained and further enhanced to support fire management planning and analysis.

Recommendation 9.3: Science and Nature Conservation Divisions investigate spatial models to incorporate research findings in fire management analyses.

9.2 Risk of Ignition

The following maps show, for the forest regions:

1. The incidence of all fires occurring within a 10 year period (Map 1); and
2. The locations and causes of all recorded fires affecting the Department (Map 2).

The 10 year fire incidence map illustrates that, in the absence of effective suppression, most of the lands managed by this Department will be affected by wildfire in a 10 year period. From this, and the headfire rate of spread map (Map 4), the probability of a fire of the intensities shown can be estimated. The fire behaviour maps (Map 3: Fireline Intensity and Map 4: Headfire Rate of Spread) are based on 95 percentile weather conditions (on average the severity of these weather conditions will be equalled or exceeded one day in every twenty during the fire season or about 9-10 times per fire season). If a random ignition pattern is assumed, the probability of a fire exceeding the intensities shown on the map in any one year is therefore 1:20 multiplied by 1:10. = 1:200. This is a likely underestimate of the likelihood of fires with such intensity occurring for two reasons:

- As indicated by the preliminary findings of Project Vesta, under wildfire conditions, the headfire rate of spread and hence fireline intensity may be at least two or more times that calculated from the present models. Thus the intensities mapped would be exceeded under conditions that occur far more frequently. This would require further modelling, but if the fires burn twice as hot, it is likely that any given intensity will be exceeded twice as often, and the equivalent return period (probability) would be around 1:100.
- Ignition pattern is not random, with at least one ignition risk (lightning strikes) being much more likely associated with weather patterns that result in the 95 percentile or more severe weather conditions (see Table 9.1).

TABLE 9.1: CAUSES OF FIRES

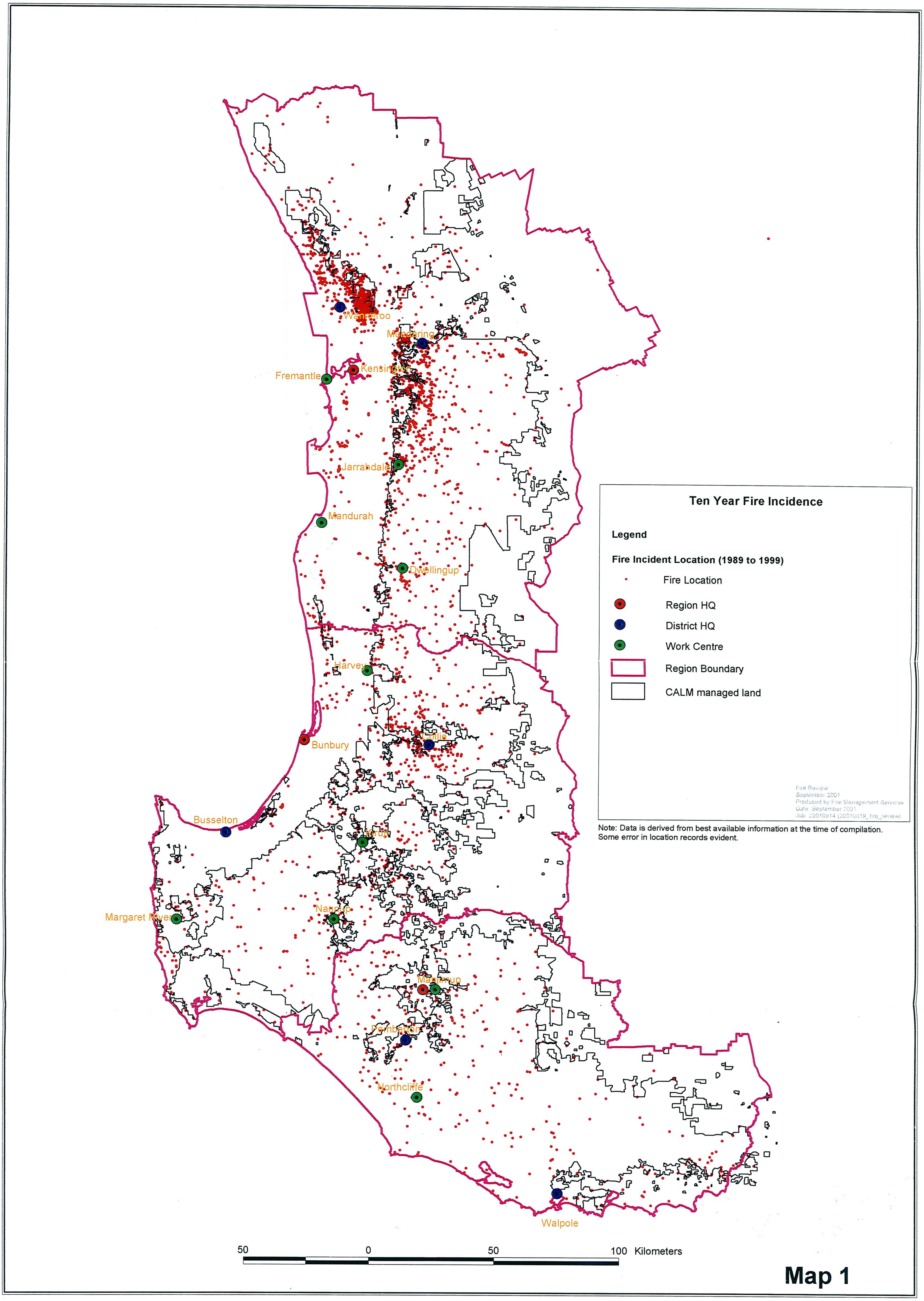
Cause	Percentage of all recorded fires			Percentage of fires with known cause		
	All Records 50/51:99/00	10 years 89/90:99/00	5 years 95/96:99/00	All Records 50/51:99/00	10 years 89/90:99/00	5 years 95/96:99/00
Deliberate	**42%**	**50%**	**48%**	**48%**	**57%**	**58%**
Accidental						
Escapes from CALM	8%	5%	4%	9%	5%	5%
Escapes from other land	12%	9%	8%	14%	10%	10%
Timber industry	3%	1%	1%	3%	1%	1%
Other industry	5%	4%	4%	5%	5%	5%
Recreational activities	7%	7%	6%	8%	8%	7%
Other misc. causes	4%	4%	5%	4%	5%	6%
Total accidental	**37%**	**30%**	**27%**	**43%**	**34%**	**33%**
Lightning	**7%**	**8%**	**7%**	**9%**	**9%**	**8%**
Unknown	**14%**	**14%**	**18%**			
Total	100%	102%	100%	100%	100%	100%
Number of recorded fires	8358	4654	1711	7214	4011	1395

The fire causes map (Map 2) and Table 9.1 illustrate that the vast majority of fires (91% of all fires for which a cause has been identified) are caused by human activity. Whilst lightning causes only 8% of fires overall (or 9 % of fires with known causes), this number can be highly variable in any one year and such fires can result in disproportionate difficulties for control.. As noted above, lightning is often associated with severe weather conditions. Lighting storms often result in multiple fires, often away from roads and tracks, therefore increasing the time and resources required for suppression.

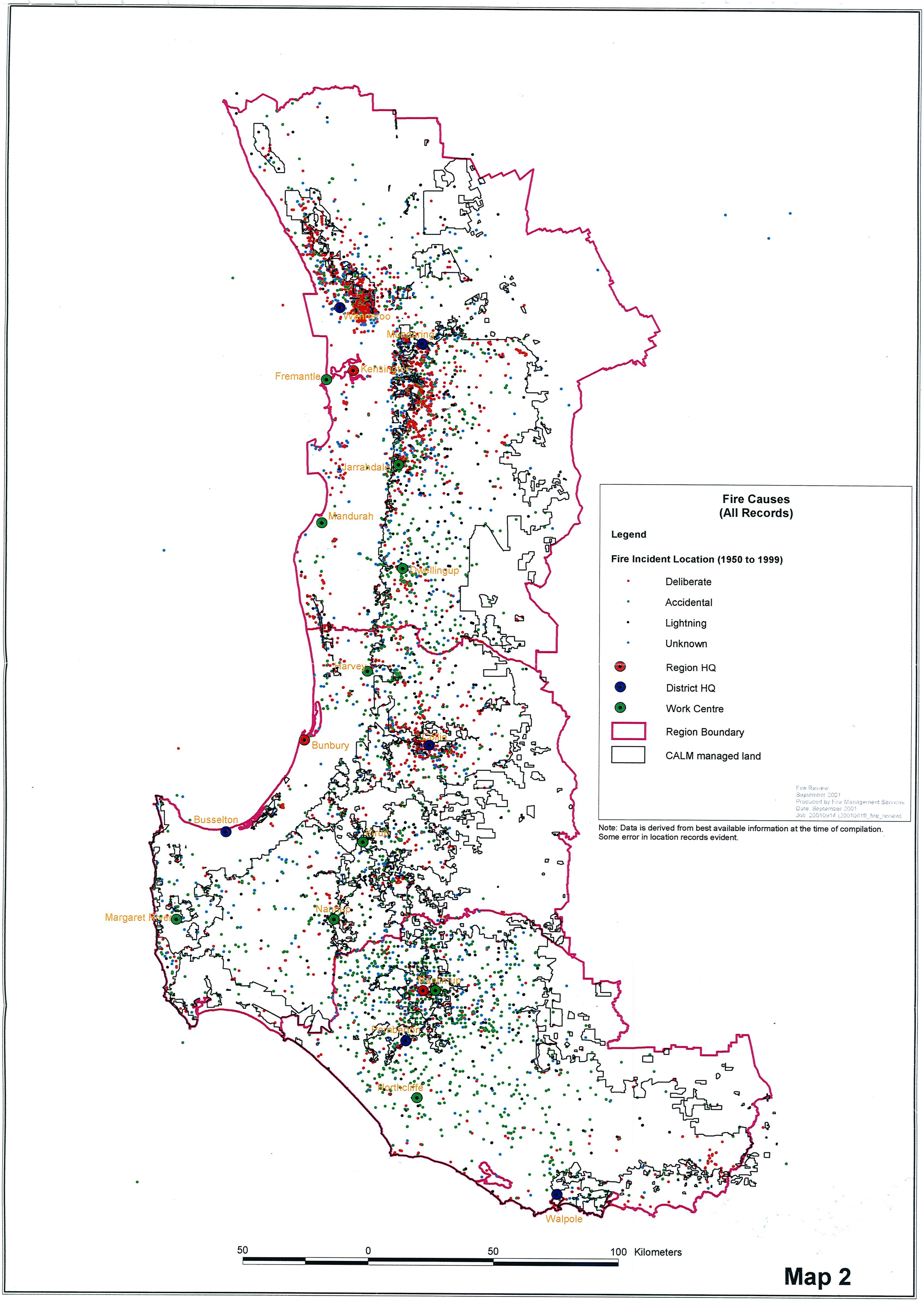
A disturbing number (up to 58% of fires where cause identified) have been deliberately lit.

Not surprisingly considering the risk associated with uncertain weather forecasts, the next highest identified cause is escapes from burning operations (23% of total), with 60% of these being from fires originating from lands not managed by the Department. The number of escapes from burning operations by the Department has decreased significantly in recent years to around half the long term average, reflecting in part both improved planning and execution, and less burning being carried out. Paradoxically, any reduction in escapes due to less burning being undertaken is likely to lead to an increase in future, as the risk of escape increases with increasing fuel loads.

It has been suggested that barbecues be banned as a means of reducing fire incidence. Open fires are already banned on days with severe weather conditions. Extending such bans may prevent some fires, but whilst escapes from barbecues attract attention, they account for only a small number of the overall fires, being included within the 6-8% of fires attributed to recreational users. It would appear more can be gained by concentrating efforts on the major causes of fires. Efforts to reduce the incidence of both deliberate and accidental fires should continue, including arson investigations and public awareness programs in conjunction with FESA.


Wanneroo
Mundaring
Kensington
Fremantle
Jarrahdale
Mandurah
Dwellingup
Harvey
Collie
Bunbury
Busselton
Kirup
Nannup
Margaret River
Manjimup
Pemberton
Northcliffe
Walpole
Ten Year Fire Incidence
Legend
Fire Incident Location (1989 to 1999)
Fire Location
Region HQ
District HQ
Work Centre
Region Boundary
CALM managed land
Fire Review
September 2001
Produced by Fire Management Services
Date: September 2001
Job: 20010914 (20010919_fire_review)
Note: Data is derived from best available information at the time of compilation.
Some error in location records evident.
50
0
50
100 Kilometers

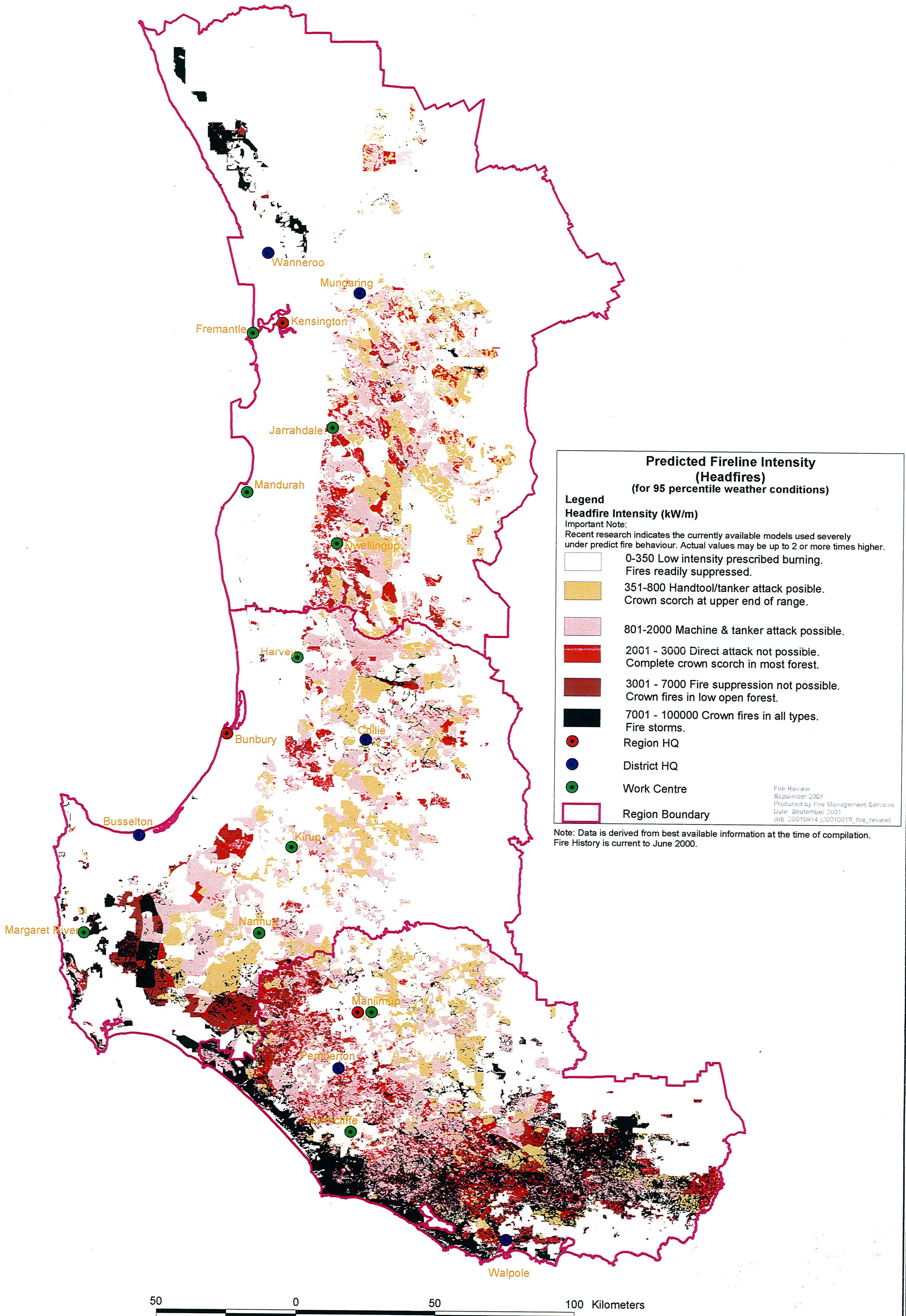
Map 1


Fire Causes
(All Records)
Legend
Fire Incident Location (1950 to 1999)
Deliberate
Accidental
Lightning
Unknown
Region HQ
District HQ
Work Centre
Region Boundary
CALM managed land
Note: Data is derived from best available information at the time of compilation.
Some error in location records evident.
Fremantle
Jarrahdale
Mandurah
Dwellingup
Harvey
Bunbury
Busselton
Northcliffe
Walpole
50
0
50
100 Kilometers
Map 2

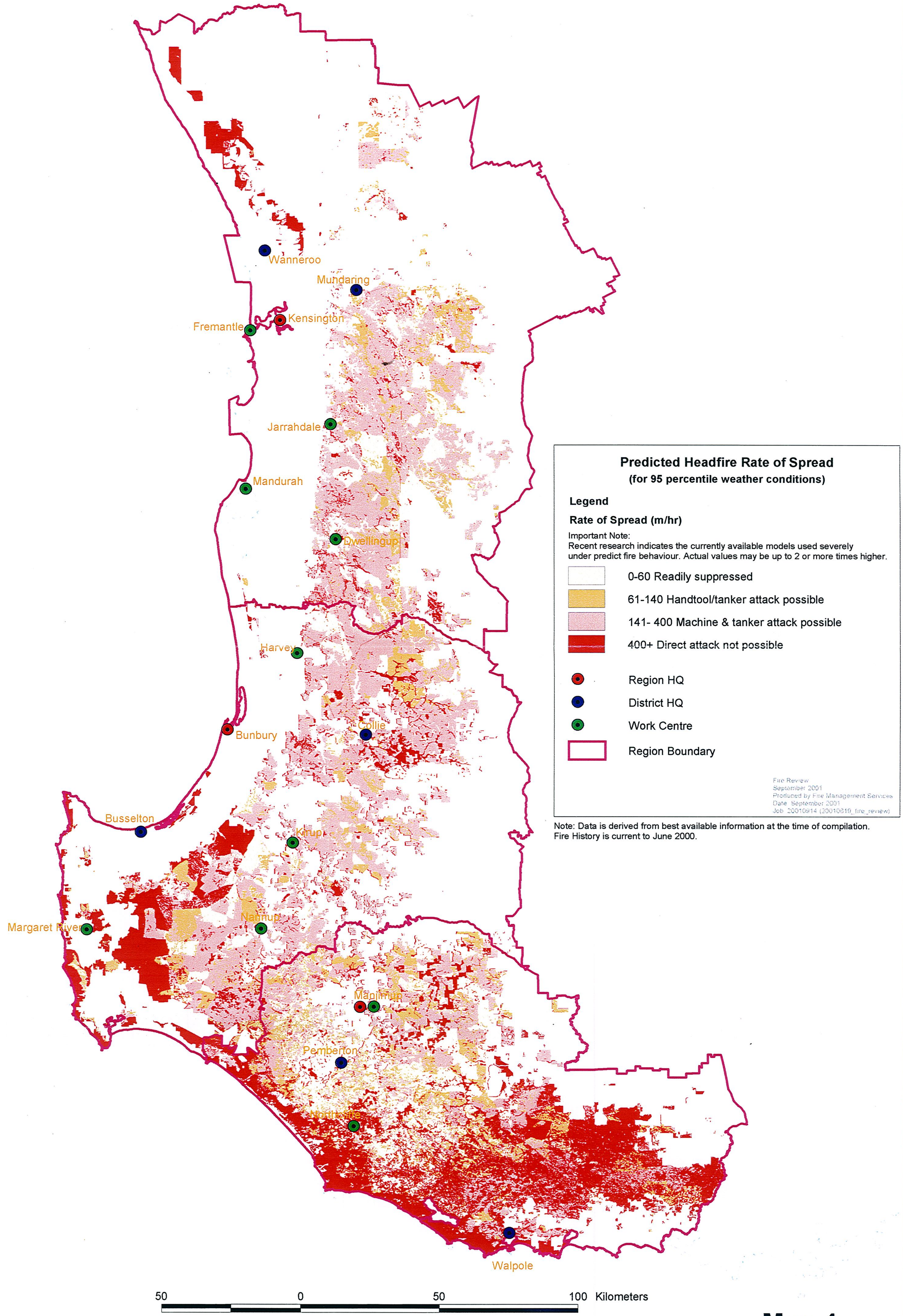
9.3 Fire Behaviour Maps

The fireline intensity (Map 3) and the head fire rate of spread (Map 4) maps are based on current fire models. These have been developed empirically from a large number of experimental fires, but carried out in a limited range of conditions. More recent research as part of Project Vesta indicates these models may severely under predict the rate of spread (and consequently also fireline intensity). under wildfire conditions . Actual rates of spread and fireline intensities may be two or more times greater than the predicted values shown.

Detailed modelling of the forest structure has not been undertaken in the preparation of these maps. Fires burning areas with more open structure as a result of logging or disease will be more influenced by wind and therefore have higher rates of spread/intensity.


Predicted Fireline Intensity
(Headfires)
(for 95 percentile weather conditions)
Legend
Headfire Intensity (kW/m)
Important Note:
Recent research indicates the currently available models used severely under predict fire behaviour. Actual values may be up to 2 or more times higher.
0-350 Low intensity prescribed burning. Fires readily suppressed.
351-800 Handtool/tanker attack posible. Crown scorch at upper end of range.
801-2000 Machine & tanker attack possible.
2001 - 3000 Direct attack not possible. Complete crown scorch in most forest.
3001 - 7000 Fire suppression not possible. Crown fires in low open forest.
7001 - 100000 Crown fires in all types. Fire storms.
Region HQ
District HQ
Work Centre
Region Boundary
Fire Review
September 2001
Produced by Fire Management Services
Date: September 2001
Note: Data is derived from best available information at the time of compilation.
Fire History is current to June 2000.
Wanneroo
Mundaring
Fremantle
Kensington
Jarrahdale
Mandurah
Dwellingup
Harvey
Bunbury
Collie
Busselton
Kirup
Margaret River
Nannup
Manjimup
Pemberton
Northcliffe
Walpole
50
0
50
100 Kilometers

Map 3


Predicted Headfire Rate of Spread
(for 95 percentile weather conditions)
Legend
Rate of Spread (m/hr)
Important Note:
Recent research indicates the currently available models used severely under predict fire behaviour. Actual values may be up to 2 or more times higher.
0-60 Readily suppressed
61-140 Handtool/tanker attack possible
141- 400 Machine & tanker attack possible
400+ Direct attack not possible
Region HQ
District HQ
Work Centre
Region Boundary
Fire Review
September 2001
Produced by Fire Management Services
Date September 2001
Job 20010914 (20010619_fire_review)
Note: Data is derived from best available information at the time of compilation.
Fire History is current to June 2000.
Wanneroo
Mundaring
Kensington
Fremantle
Jarrahdale
Mandurah
Dwellingup
Harvey
Bunbury
Collie
Busselton
Kirup
Margaret River
Nannup
Manjimup
Pemberton
Walpole
50
0
50
100 Kilometers

Map 4

9.4 Suppression Response

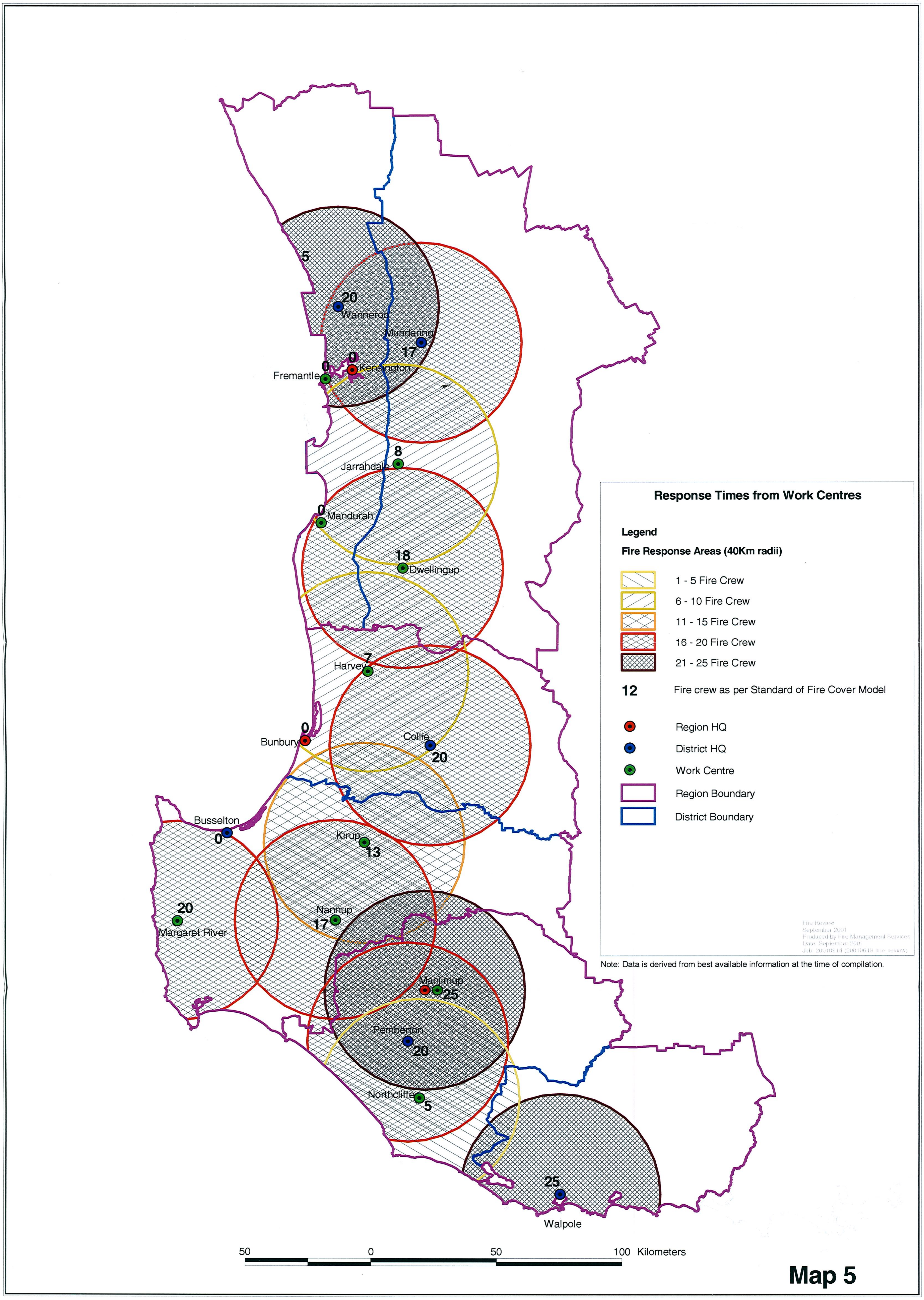
Suppression response depends largely on where forces are located at the time a fire occurs. This is unlikely to be the work centre during working hours when crews are in the field. If crews regularly work in the same area, these locations may be a reasonable basis for centering a response zone. If they work in different locations, it is better to use the work centre as being more representative overall. The work centre is also normally where crews would need to collect their fire units if fires occur after hours or on weekends. If units are kept at other locations, these should be the centroid.

Current digital map data do not store information on roads and tracks that would enable network analysis to be undertaken. In the absence of such network analysis capability, a forty kilometre radius was assumed by Fire Branch to be broadly and perhaps optimistically, representative of the areas where a fire could be attacked within an hour. Map 5 shows the forty kilometre radii from each work centre, and the number of fire crew indicated. The total numbers that could attend a fire within the time frame represented by the circles depends on the degree of overlap.

Whilst this provides an indication of the average response time, it can be misleading in terms of suppression capacity, as it assumes all resources are available for a single fire.

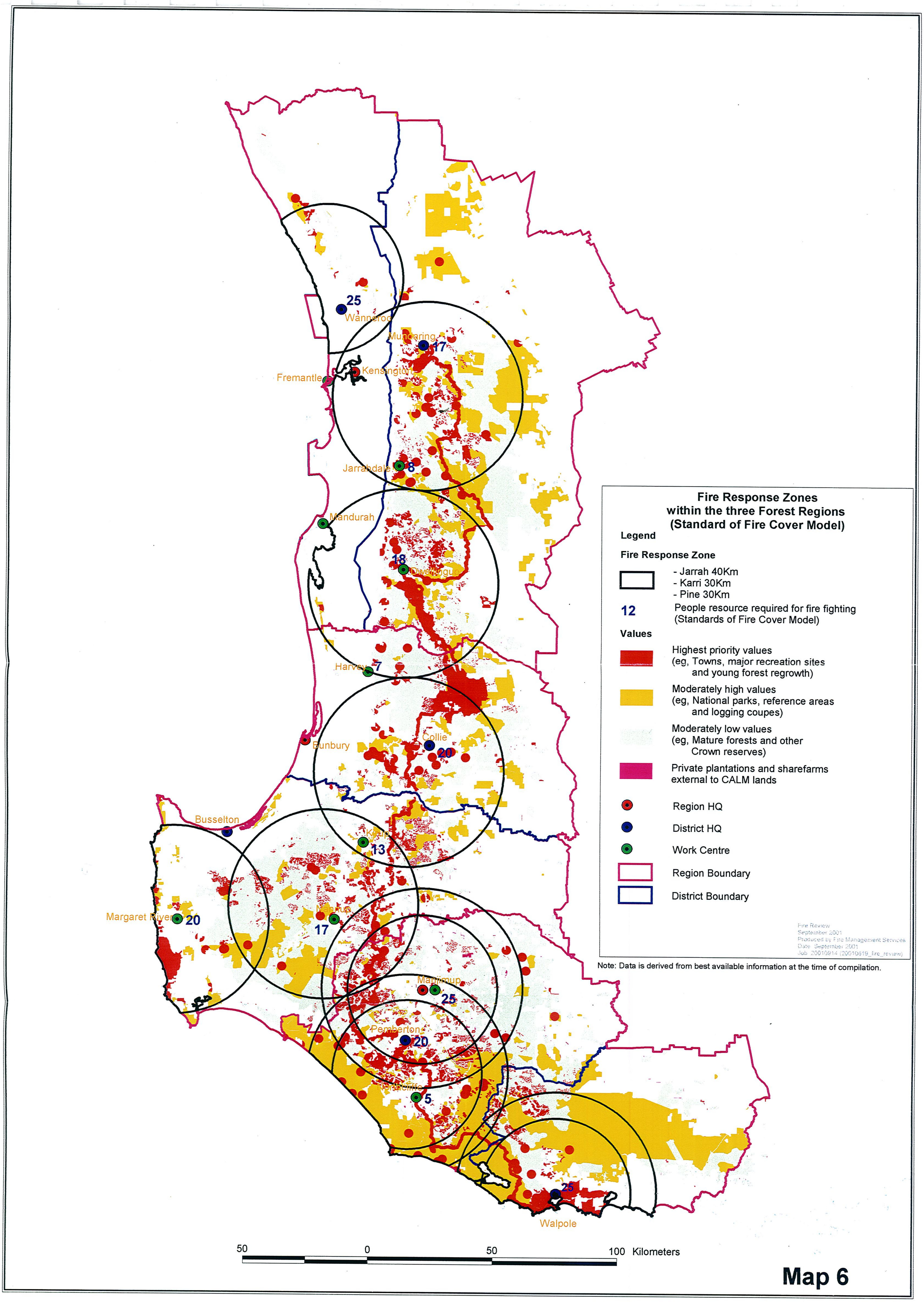
In determining the standards for fire cover model, Fire Branch has identified a number of response cells (Map 6: Fire Response Zones). These were broadly based to give coverage over the areas with the highest concentrations of values, and to determine the numbers required to be able to provide a first attack capability with resources from adjoining work centres. The centroid of the cells was weighted according to the numbers from each centre.

The response cells provide a useful planning tool to determine resource requirements if it is desired to be able to attack fires in all high value areas simultaneously, as it avoids "double counting" of resources. This approach uses the same principles as for the Response Time map (Map 5) , but provides different information to the response map. The response map shows that, even if resources are maintained at the Standards of Fire Cover (SFC) model levels, there are areas to which that level of response within one hour is not possible. It also highlights the importance of the distribution of work centres such as Nannup, Kirup and Jarrahdale in providing adequate spread of resources.



Note: Data is derived from best available information at the time of compilation.

Map 5


Fire Response Zones
within the three Forest Regions
(Standard of Fire Cover Model)
Legend
Fire Response Zone
- Jarrah 40Km
- Karri 30Km
- Pine 30Km
12
People resource required for fire fighting
(Standards of Fire Cover Model)
Values
Highest priority values
(eg, Towns, major recreation sites
and young forest regrowth)
Moderately high values
(eg, National parks, reference areas
and logging coupes)
Moderately low values
(eg, Mature forests and other
Crown reserves)
Private plantations and sharefarms
external to CALM lands
Region HQ
District HQ
Work Centre
Region Boundary
District Boundary
Fire Review
September 2001
Produced by Fire Management Services
Date: September 2001
Job: 20010914 (20010619_fire_review)
Note: Data is derived from best available information at the time of compilation.
Wanneroo
25
Mundaring
17
Fremantle
Kensington
Jarrahdale
8
Mandurah
18
Harvey
7
Bunbury
Collie
20
Busselton
13
Margaret River
20
17
Manjimup
25
Pemberton
20
5
25
Walpole
50
0
50
100
Kilometers
Map 6

10 Review the appropriateness of the landscape scale of current fire management practices.

10.1 Landscape

Landscape units have been variously defined but are generally accepted to be at a scale sufficient to encompass functioning ecosystems. Pen (1997) has defined "natural resource zones" based on Beard's (1981) natural regions combined with water drainage basins and the 1100 mm, 700 mm and 500 mm rainfall isohyets. These may be a suitable landscape unit and have the advantage of being consistent with other work. Burrows (2001b) has suggested the use of the Christensen faunal units as landscape units

10.2 Biodiversity and Asset Protection

As previously mentioned, current burn records have not been recorded at a sufficiently detailed scale to permit a quantitative analysis of fire distribution at a vegetation unit level. An indication of fire distribution can, however, be obtained from an analysis of the distribution within the Bradshaw and Mattiske (1997) RFA forest ecosystem classes or the Christensen Land System/Landscape Classification units at either a whole of forest or regional scale, and provide an initial basis for planning.

There is a range of fire intensities within the burnt areas recorded, ranging from broadscale low intensity burns, to very high intensity Karri regeneration burns. Between these extremes there have been fires prescribed at different intensities for silvicultural reasons, and a range of wildfire intensities. Intensity of burns/fires has not been recorded, so it is not possible to analyse the distribution of these. In an idealised model these would also follow a negative exponential function (see section 7.2) with long intervals between high intensity (stand replacement) fires reflecting the long juvenile periods of the overstorey species, with the highest frequency being for low intensity fires on Jarrah uplands. If appropriate means of reliably detecting intensity classes via remote sensing techniques can be established, this information should be included in future spatial databases. Development work currently underway on this is promising (G Behn, F Metcalfe, Li Shu: pers comm.).

It is only in recent years that season of a burn/fire has been recorded. There are insufficient data on which to carry out an analysis. There has, however, been a conscious effort to vary the season of burn following the guidelines of spring, spring , autumn, where possible.

The initial impression from reviewing the distribution of time since fire within each of both the Bradshaw and Mattiske RFA classes and Christensen classes is one of reasonable distribution of burn classes (Figures 10.1-10.5). This distribution, combined with the knowledge that the areas burnt include variety in both season and intensity, appears to indicate a satisfactory distribution of fire regimes. A closer examination shows that only very few classes approach a negative exponential distribution as outlined in Section 7. Even these show under representation of younger stages (see the figures following each of Figures 10.1 to 10.5).

The fire diversity is closest to a negative exponential model in the main upland Jarrah forests where there has been more burning done. As can be seen from both the Christensen fire age distribution graphs for the Southern Forest Region and the RFA vegetation classes containing Karri, and also from the fire intensity map in Section 9, there is a poor distribution in much of the southern forest area with a disproportionately low area burnt in recent years This region is currently at great risk of extensive high intensity fires. If these occur biodiversity will be diminished.

Because of the coarse nature of recording areas burnt previously referred to in section 7, the analysis of the Christensen classes may under represent the actual distribution, as within each recorded burn boundary there are unburnt areas that would increase the patch distribution at a landscape scale.

The coarseness of burnt area records is well illustrated by reference to class 21 (Estuaries/Open Water) in Fig 10.2, that shows some areas of water burnt. This has come about through past practices of recording everything within the external boundary of a fire area being burnt, due to the inability to obtain accurate recording at a reasonable cost. This highlights the importance for future planning and monitoring, of the development of remote sensing methods into operational methods that will provide accurate , low cost identification of burnt area classes.

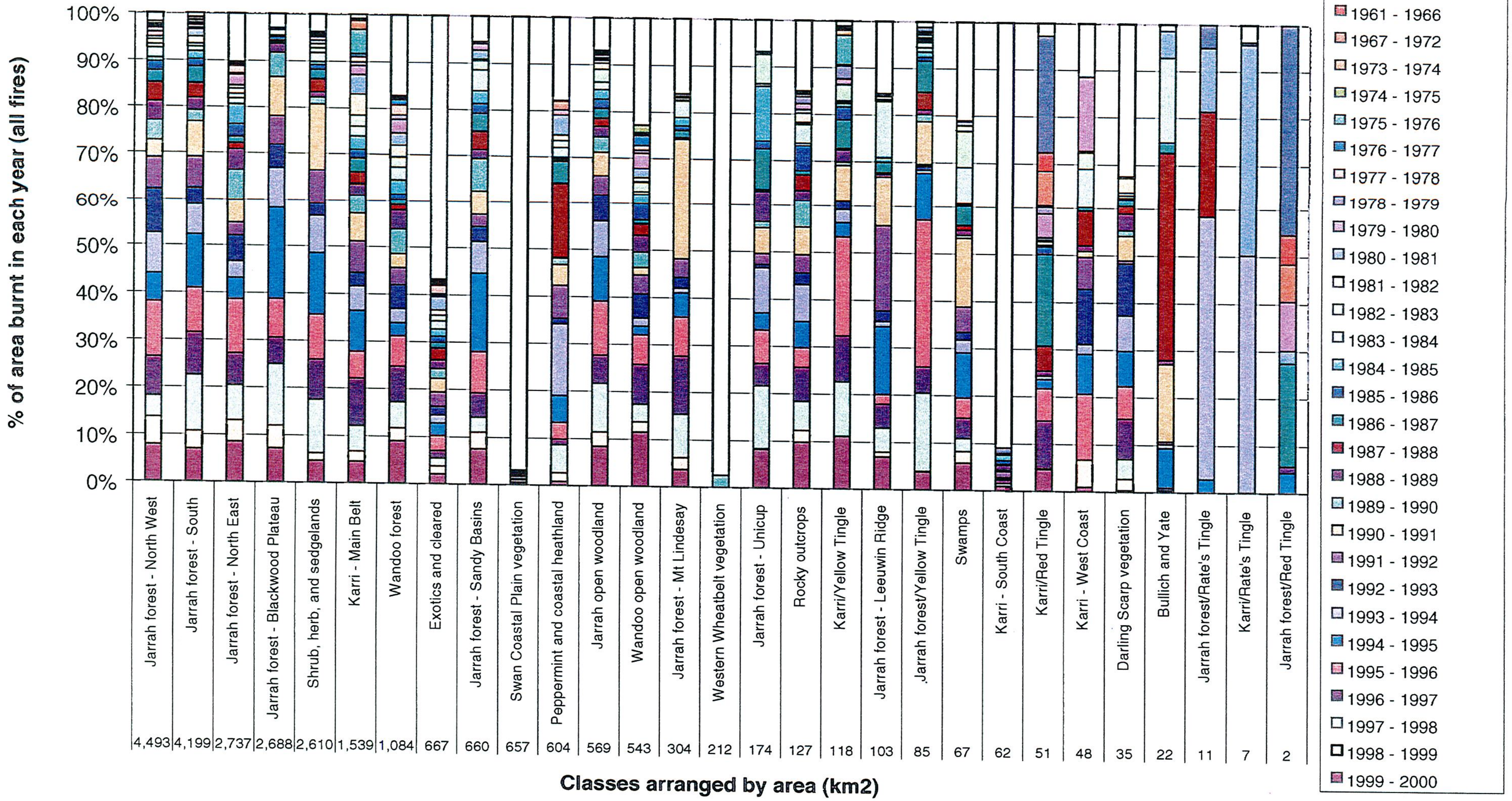
Although it cannot be confirmed with a fine scale analysis it would appear that current practices are appropriate for the maintenance of diversity where sufficiently extensively applied, as in the northern forests. There is insufficient information available at a fine scale to be conclusive, but there is no evidence that past burning practices have been detrimental at that scale. The analysis however, clearly demonstrates that for some areas (and particularly the southern forests) the extent of the burning has not been sufficient to achieve a fire distribution corresponding to the idealised model suggested.

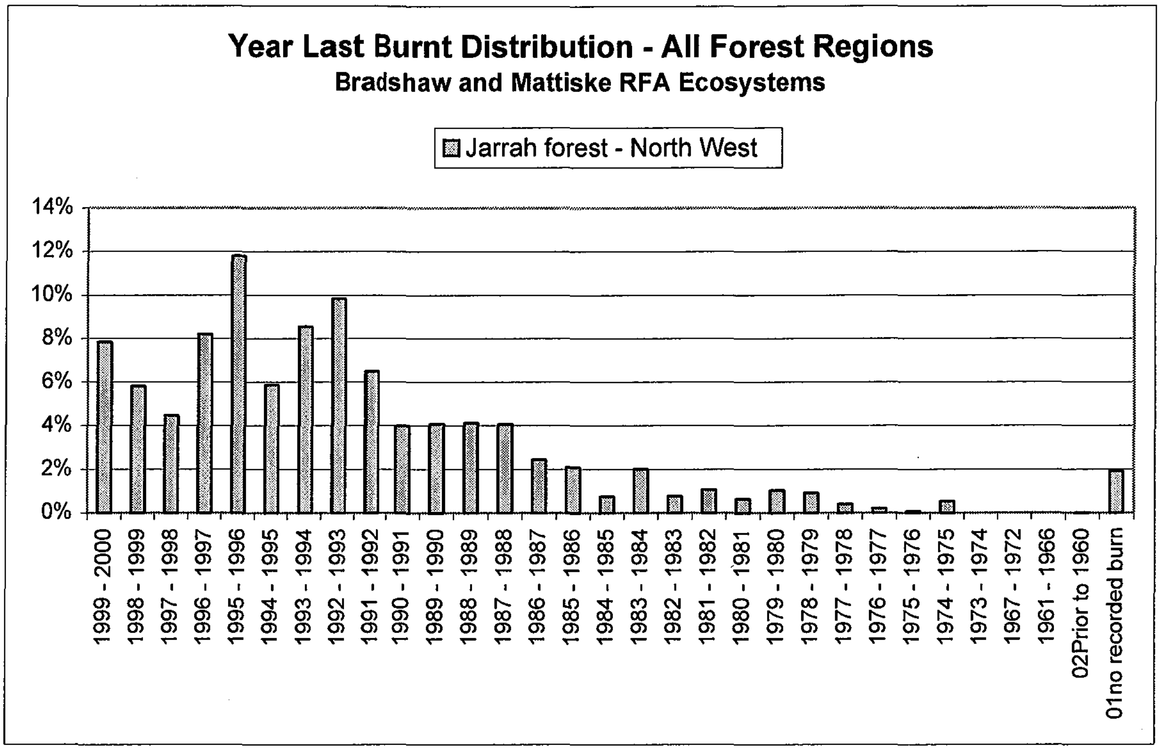
The potential for spread of high intensity (uncontrollable) wildfires threatens life, property and forest values as well as biodiversity conservation.

Recommendation 10.1: Remote sensing/GIS analysis techniques be further developed and implemented to monitor fire distribution.

Recommendation 10.2: Resources and appropriate techniques be applied to enable sufficient prescribed fire to be applied to maintain an overall fire diversity (including wildfire) as near as practicable to the fire distribution models.

Fig 10.1 Bradshaw and Mattiske RFA Ecosystems - Year Last Burnt (All Forest Regions)




Year Last Burnt Distribution - All Forest Regions
Bradshaw and Mattiske RFA Ecosystems
Jarrah forest - North West
14%
12%
10%
8%
6%
4%
2%
0%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
1995 - 1996
1994 - 1995
1993 - 1994
1992 - 1993
1991 - 1992
1990 - 1991
1989 - 1990
1988 - 1989
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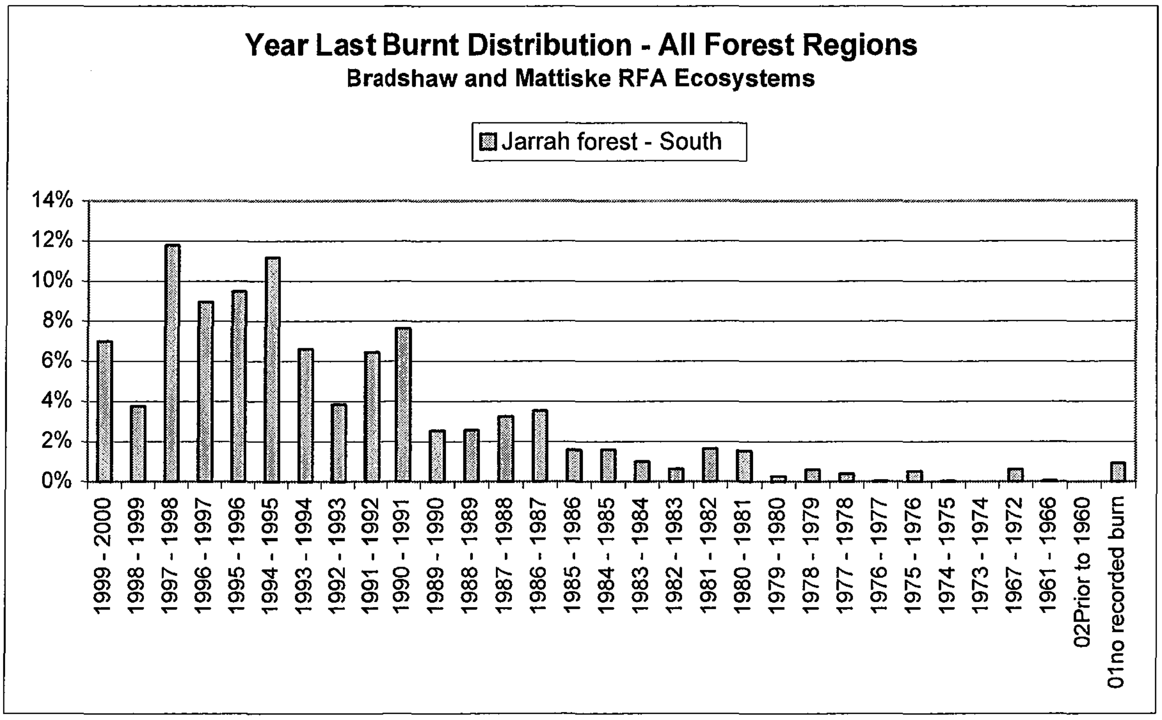
1985 - 1986
1984 - 1985
1983 - 1984
1982 - 1983
1981 - 1982
1980 - 1981
1979 - 1980
1978 - 1979
1977 - 1978
1976 - 1977
1975 - 1976
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02Prior to 1960
01no recorded burn


Year Last Burnt Distribution - All Forest Regions
Bradshaw and Mattiske RFA Ecosystems
Jarrah forest - South
14%
12%
10%
8%
6%
4%
2%
0%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
1995 - 1996
1994 - 1995
1993 - 1994
1992 - 1993
1991 - 1992
1990 - 1991
1989 - 1990
1988 - 1989
1987 - 1988
1986 - 1987
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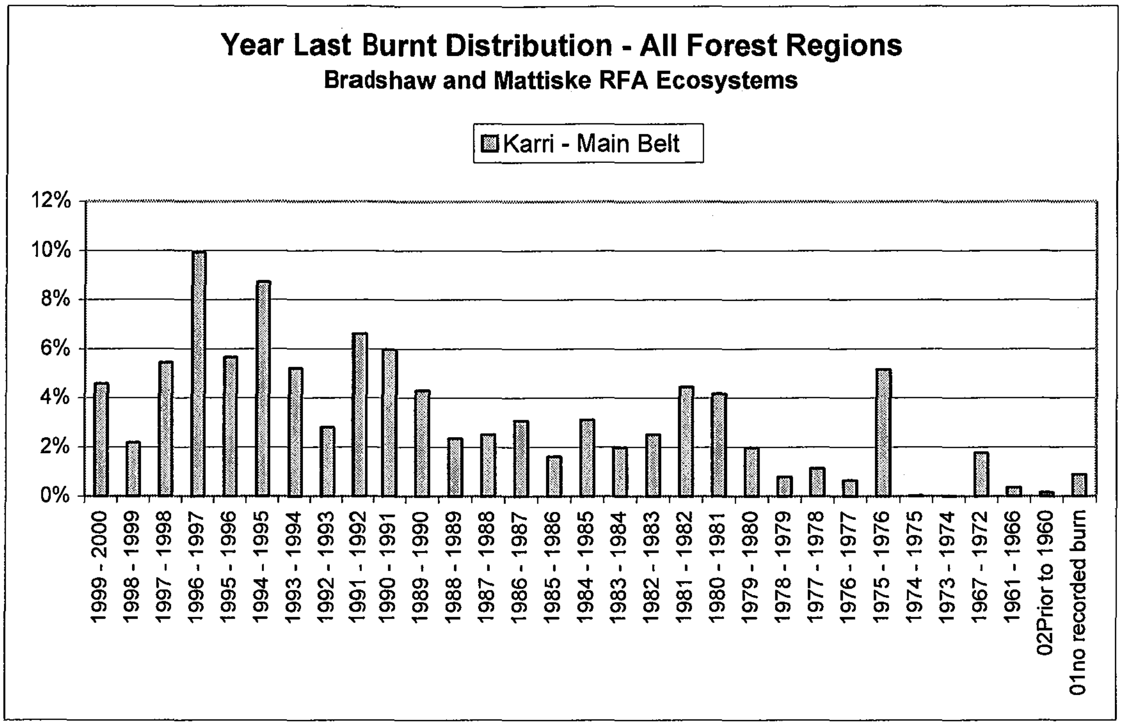
1983 - 1984
1982 - 1983
1981 - 1982
1980 - 1981
1979 - 1980
1978 - 1979
1977 - 1978
1976 - 1977
1975 - 1976
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02Prior to 1960
01no recorded burn


Year Last Burnt Distribution - All Forest Regions
Bradshaw and Mattiske RFA Ecosystems
Karri - Main Belt
12%
10%
8%
6%
4%
2%
0%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
1995 - 1996
1994 - 1995
1993 - 1994
1992 - 1993
1991 - 1992
1990 - 1991
1989 - 1990
1988 - 1989
1987 - 1988
1986 - 1987
1985 - 1986
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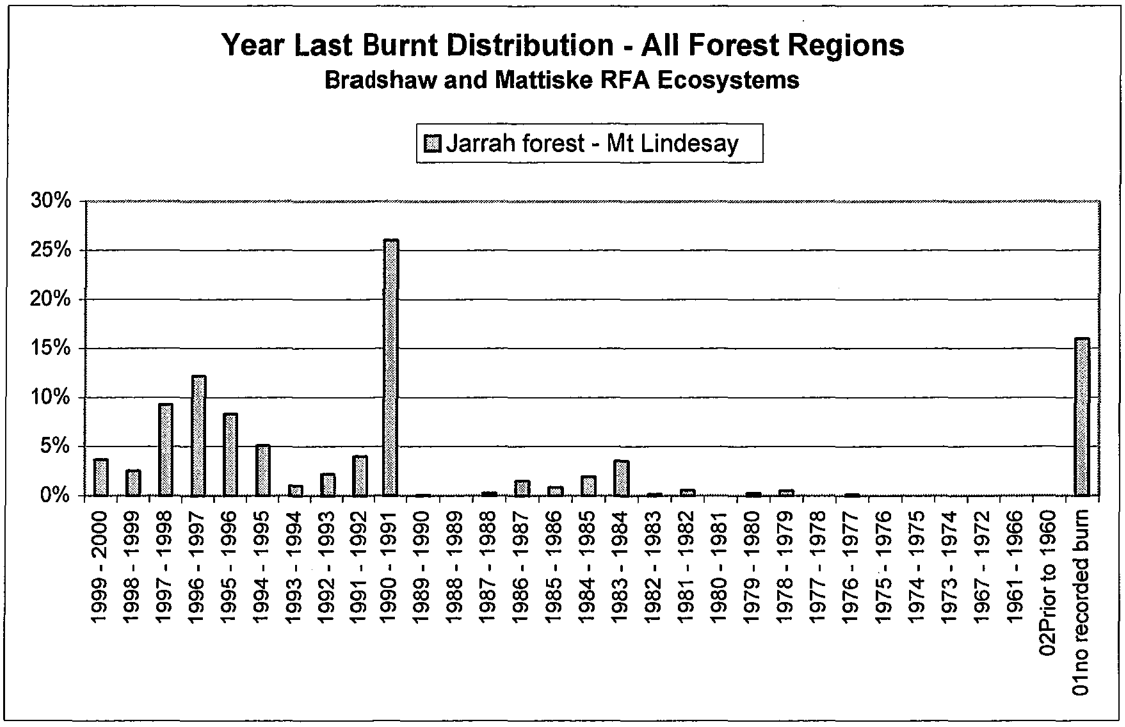
1982 - 1983
1981 - 1982
1980 - 1981
1979 - 1980
1978 - 1979
1977 - 1978
1976 - 1977
1975 - 1976
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02Prior to 1960
01no recorded burn


Year Last Burnt Distribution - All Forest Regions
Bradshaw and Mattiske RFA Ecosystems
Jarrah forest - Mt Lindesay
30%
25%
20%
15%
10%
5%
0%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
1995 - 1996
1994 - 1995
1993 - 1994
1992 - 1993
1991 - 1992
1990 - 1991
1989 - 1990
1988 - 1989
1987 - 1988
1986 - 1987
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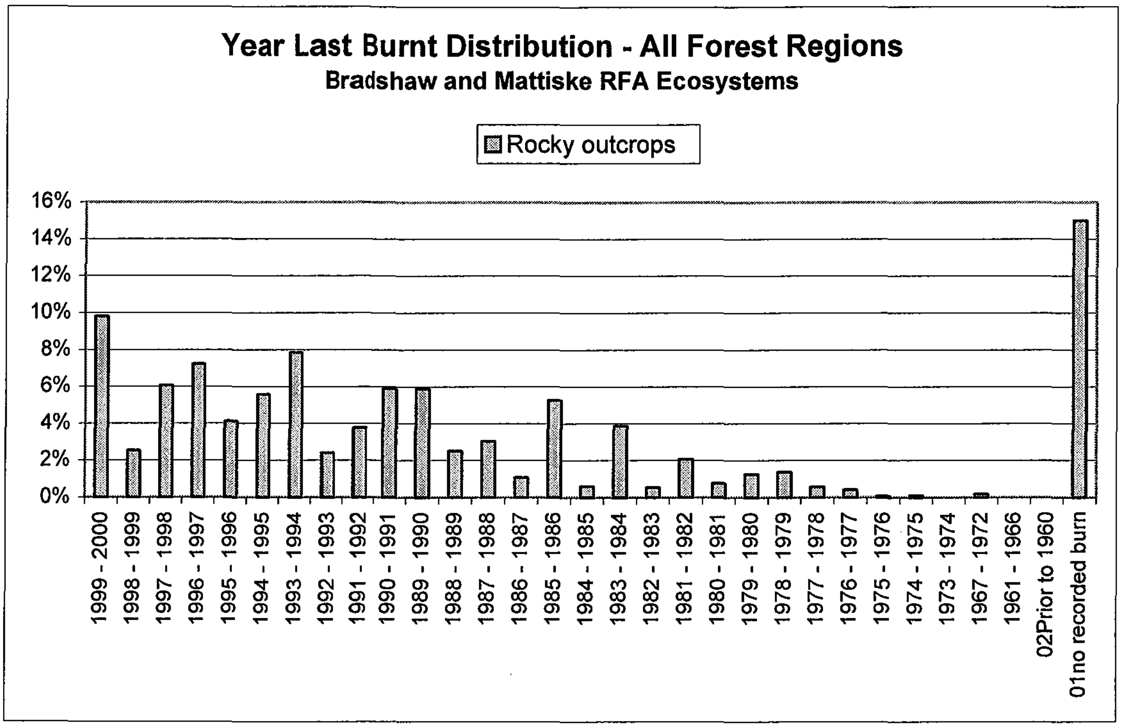
1982 - 1983
1981 - 1982
1980 - 1981
1979 - 1980
1978 - 1979
1977 - 1978
1976 - 1977
1975 - 1976
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02Prior to 1960
01no recorded burn


Year Last Burnt Distribution - All Forest Regions
Bradshaw and Mattiske RFA Ecosystems
Rocky outcrops
16%
14%
12%
10%
8%
6%
4%
2%
0%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
1995 - 1996
1994 - 1995
1993 - 1994
1992 - 1993
1991 - 1992
1990 - 1991
1989 - 1990
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1987 - 1988
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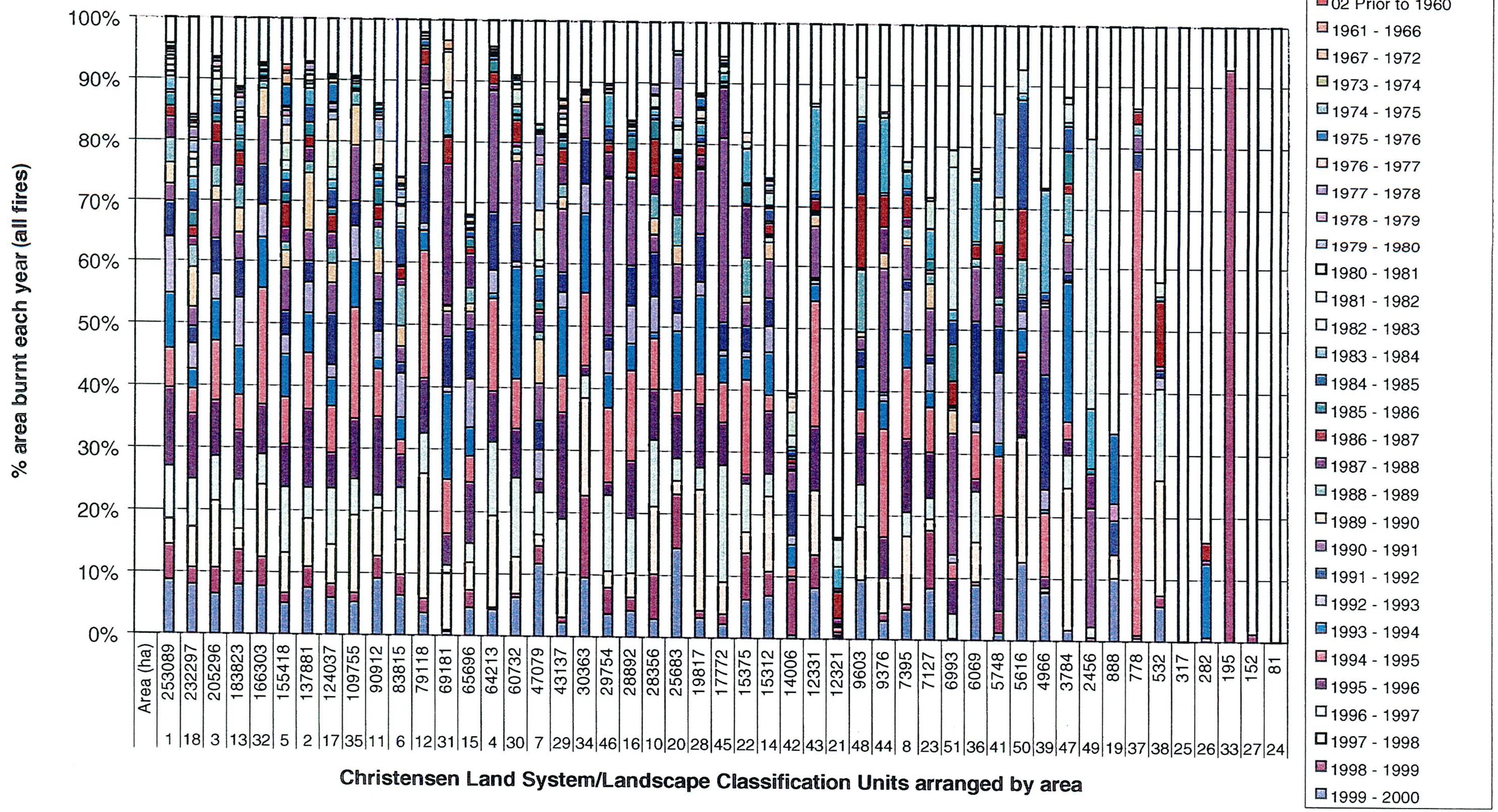
1984 - 1985
1983 - 1984
1982 - 1983
1981 - 1982
1980 - 1981
1979 - 1980
1978 - 1979
1977 - 1978
1976 - 1977
1975 - 1976
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02Prior to 1960
01no recorded burn

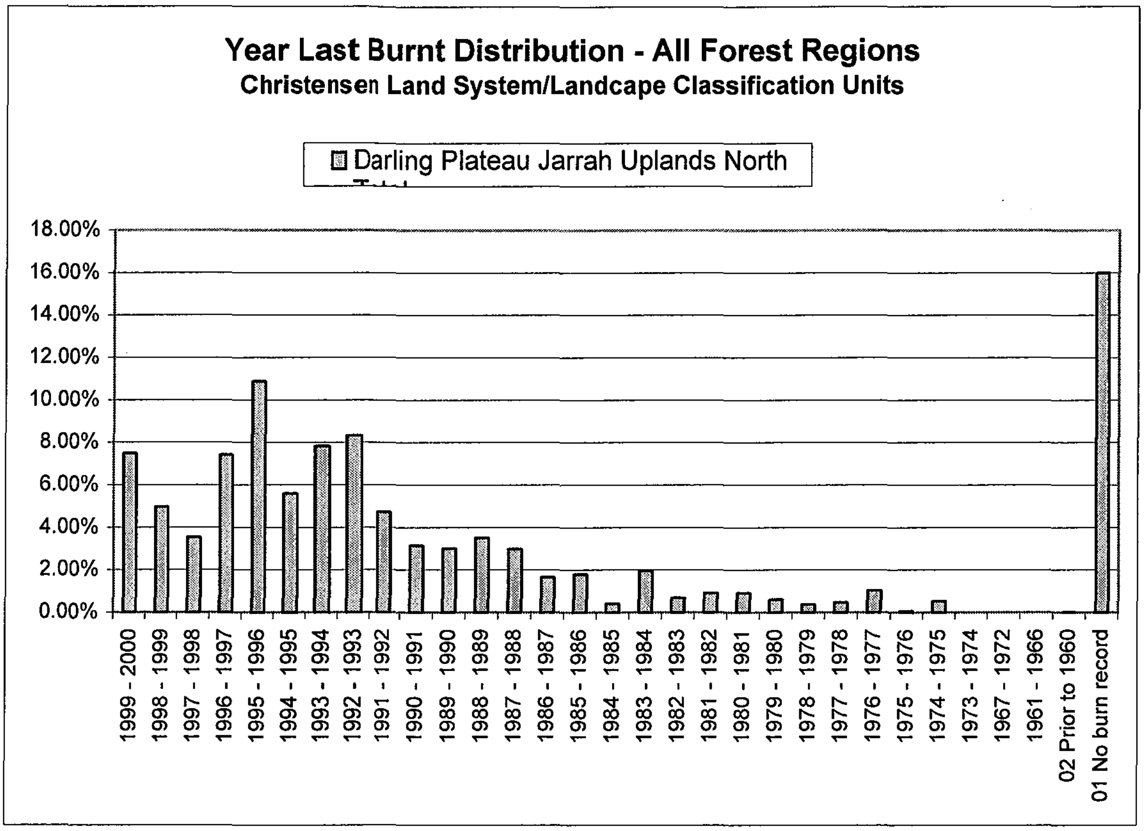
CHRISTENSEN FAUNAL CLASSIFICATION UNITS (for use with following figures)

UNIT	DESCRIPTION	
	LAND SYSTEM	LANDSCAPE UNIT
1	Darling Plateau	Jarrah Uplands North
2	Darling Plateau	Jarrah Uplands East
3	Darling Plateau	Jarrah Uplands South
4	Darling Plateau	Jarrah Uplands South East
5	Darling Plateau	Karri Uplands
6	Darling Plateau	Wandoo Uplands
7	Darling Plateau	Powder Bark Uplands
8	Darling Plateau	Scarp
9	Darling Plateau	Depression/Swamps North
10	Darling Plateau	Depressions/Swamps South
11	Darling Plateau	Depressions/Swamps East
12	Darling Plateau	Depressions/Swamps South East
13	Darling Plateau	Jarrah Valleys North
14	Darling Plateau	Jarrah Valleys East
15	Darling Plateau	Jarrah Valleys South
16	Darling Plateau	Jarrah Valleys South East
17	Darling Plateau	Karri Valleys
18	Darling Plateau	Wandoo Valleys
19	Darling Plateau	Powder Bark Valleys
20	Darling Plateau	Granite Outcrops
21	Various Systems	Estuaries / Open Water
22	Collie Plain	Uplands
23	Collie Plain	Depressions/Swamps
24	Dandaragan Plateau	Uplands
25	Dandaragan Plateau	Valleys
26	Swan Coastal Plain	Uplands

UNIT	DESCRIPTION	
	LAND SYSTEM	LANDSCAPE UNIT
27	Swan Coastal Plain	Valleys
28	Southern Plains	Jarrah
29	Southern Plains	Karri
30	Southern Plains	Heath/Sedgeland
31	South Coast Dunes	South Coast Dunes
32	Blackwood Plateau	Jarrah Uplands
33	Blackwood Plateau	Karri Uplands
34	Blackwood Plateau	Depressions / Swamps
35	Blackwood Plateau	Valleys
36	Margaret River Plateau	Jarrah Uplands
37	Margaret River Plateau	Karri Uplands
38	Margaret River Plateau	Jarrah Valleys
39	Margaret River Plateau	Karri Valleys
40	Leeuwin Naturaliste Coast	Jarrah
41	Leeuwin Naturaliste Coast	Karri
42	Leeuwin Naturaliste Coast	Coast Heath
43	Scott Coastal Plain	Uplands
44	Scott Coastal Plain	Valleys / Swamps
45	Redmond	Uplands
46	Redmond	Valleys
47	Unicup	Jarrah Uplands
48	Unicup	Wandoo Uplands
49	Unicup	Jarrah Valleys
50	Unicup	Wandoo Valleys
51	Unicup	Scrubland
52	Swan Coastal Plain	Coastal Dunes

Fig 10.2: Christensen Classification Units - Year Last Burnt (All Forest Regions)




Year Last Burnt Distribution - All Forest Regions
Christensen Land System/Landcape Classification Units
Darling Plateau Jarrah Uplands North
18.00%
16.00%
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
1995 - 1996
1994 - 1995
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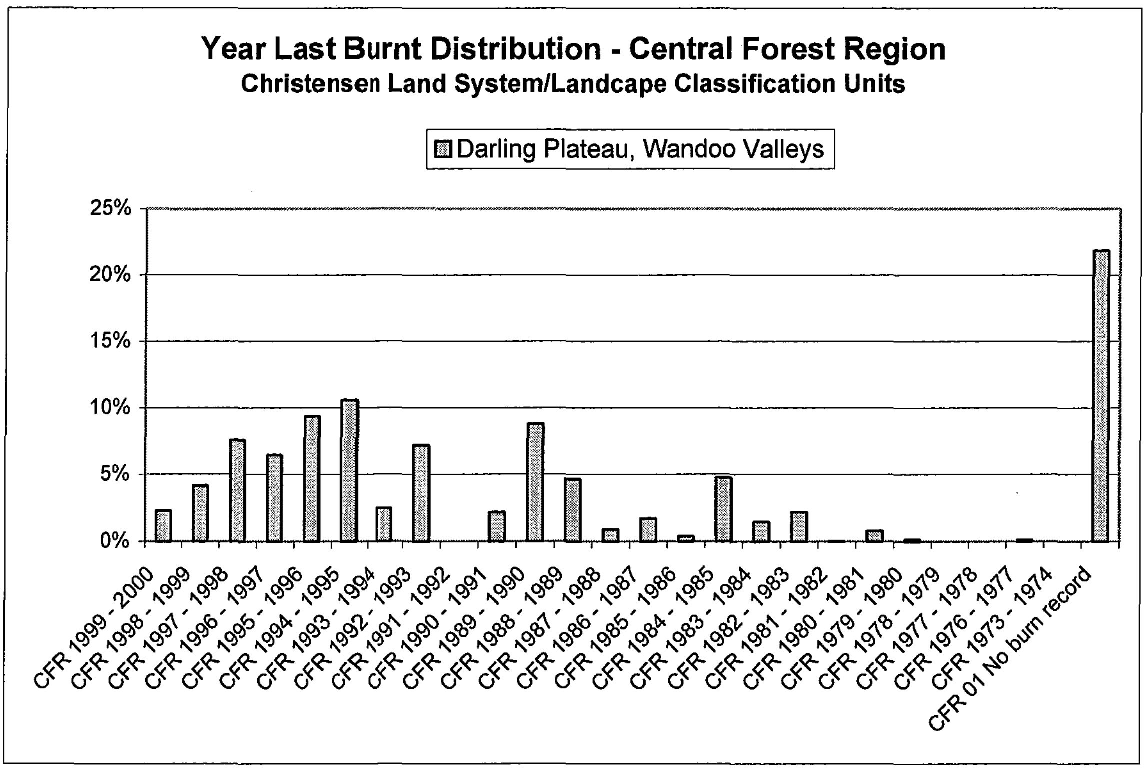
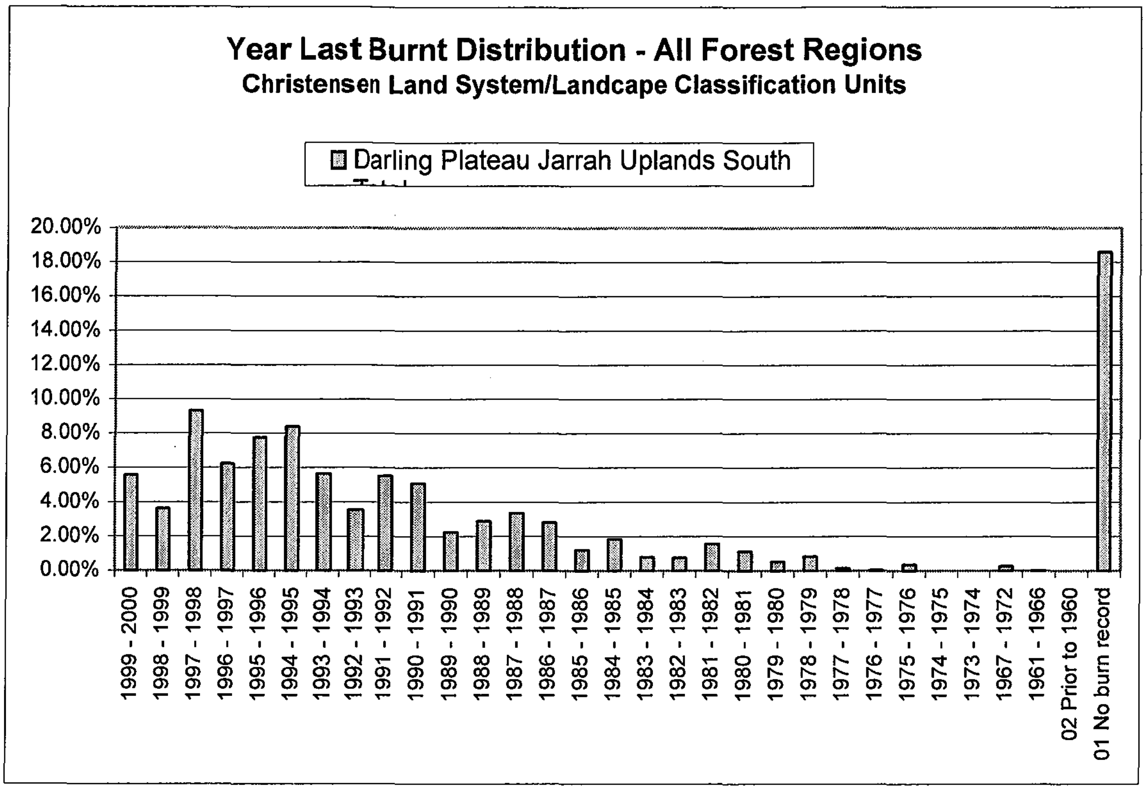
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02 Prior to 1960
01 No burn record


Year Last Burnt Distribution - Central Forest Region
Christensen Land System/Landcape Classification Units
Darling Plateau, Wandoo Valleys
25%
20%
15%
10%
5%
0%
CFR 1999 - 2000
CFR 1998 - 1999
CFR 1997 - 1998
CFR 1996 - 1997
CFR 1995 - 1996
CFR 1994 - 1995
CFR 1993 - 1994
CFR 1992 - 1993
CFR 1991 - 1992
CFR 1990 - 1991
CFR 1989 - 1990
CFR 1988 - 1989
CFR 1987 - 1988
CFR 1986 - 1987
CFR 1985 - 1986
CFR 1984 - 1985
CFR 1983 - 1984
CFR 1982 - 1983
CFR 1981 - 1982
CFR 1980 - 1981
CFR 1979 - 1980
CFR 1978 - 1979
CFR 1977 - 1978
CFR 1976 - 1977
CFR 1973 - 1974
CFR 01 No burn record


Year Last Burnt Distribution - All Forest Regions
Christensen Land System/Landcape Classification Units
Darling Plateau Jarrah Uplands South
20.00%
18.00%
16.00%
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
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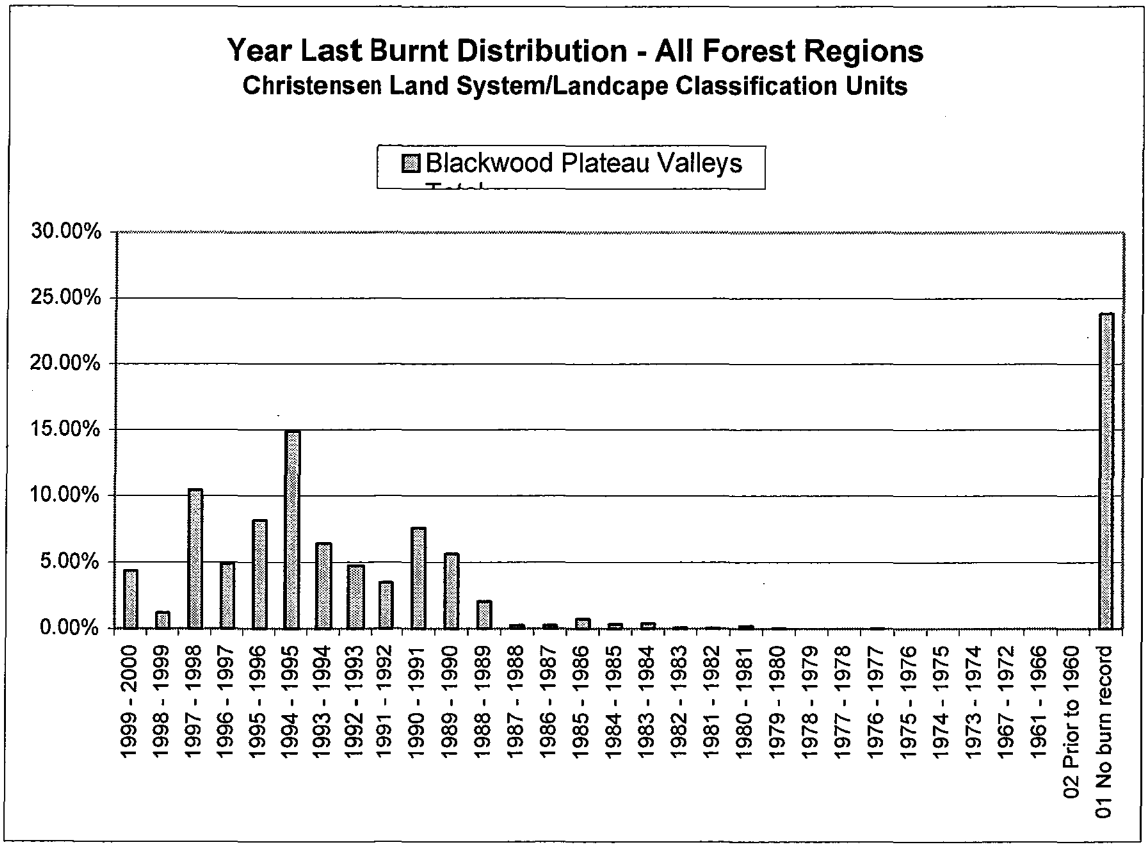
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02 Prior to 1960
01 No burn record


Year Last Burnt Distribution - All Forest Regions
Christensen Land System/Landcape Classification Units
Blackwood Plateau Valleys
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
1995 - 1996
1994 - 1995
1993 - 1994
1992 - 1993
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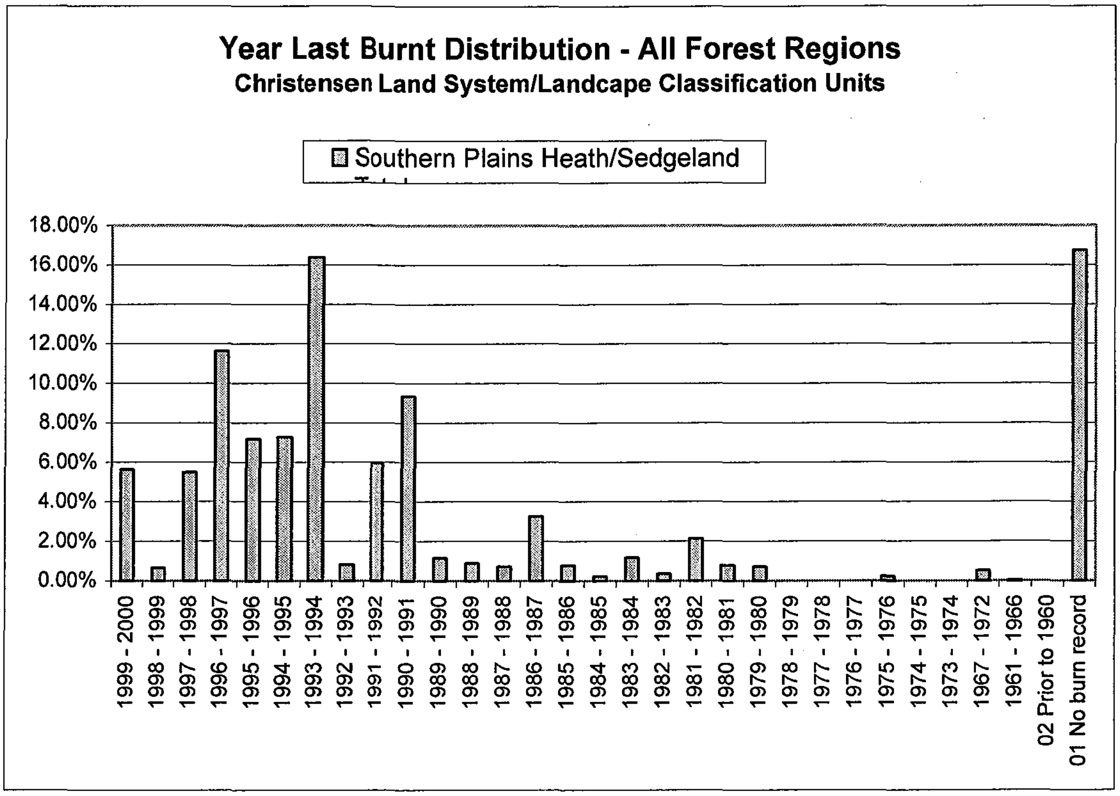
1977 - 1978
1976 - 1977
1975 - 1976
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02 Prior to 1960
01 No burn record


Year Last Burnt Distribution - All Forest Regions
Christensen Land System/Landcape Classification Units
Southern Plains Heath/Sedgeland
18.00%
16.00%
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
1995 - 1996
1994 - 1995
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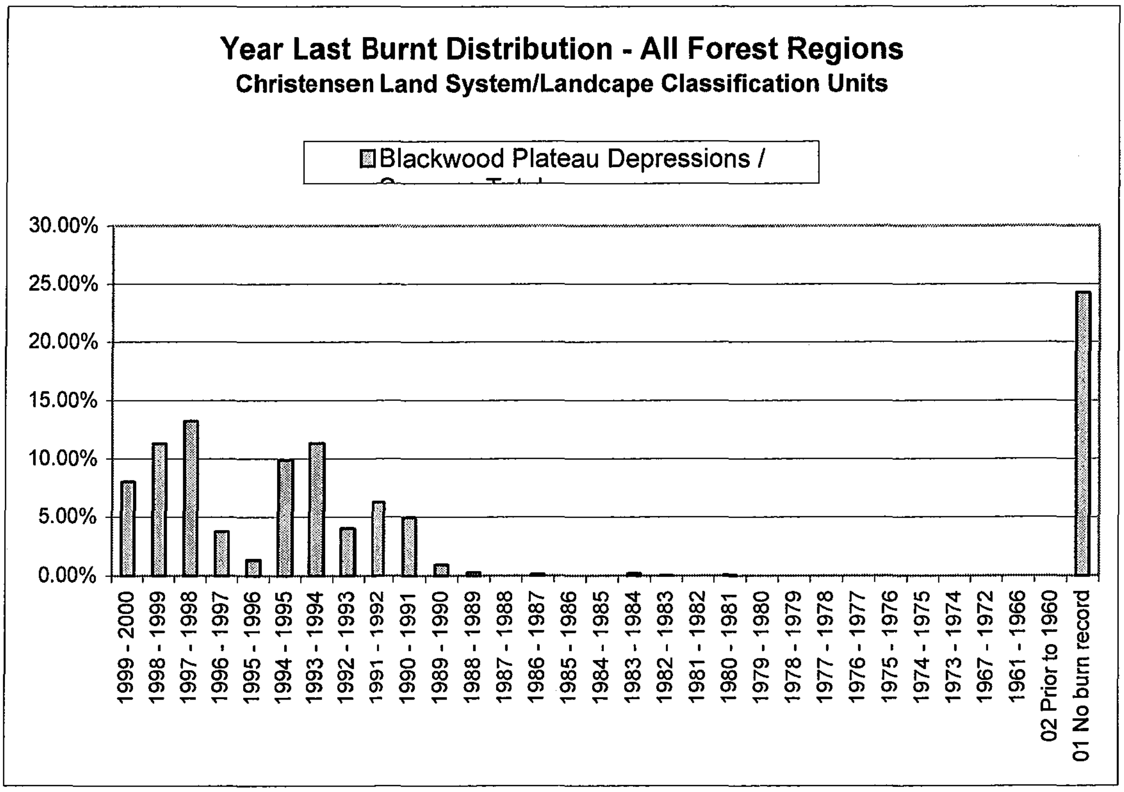
1981 - 1982
1980 - 1981
1979 - 1980
1978 - 1979
1977 - 1978
1976 - 1977
1975 - 1976
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02 Prior to 1960
01 No burn record


Year Last Burnt Distribution - All Forest Regions
Christensen Land System/Landcape Classification Units
Blackwood Plateau Depressions /
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
1999 - 2000
1998 - 1999
1997 - 1998
1996 - 1997
1995 - 1996
1994 - 1995
1993 - 1994
1992 - 1993
1991 - 1992
1990 - 1991
1989 - 1990
1988 - 1989
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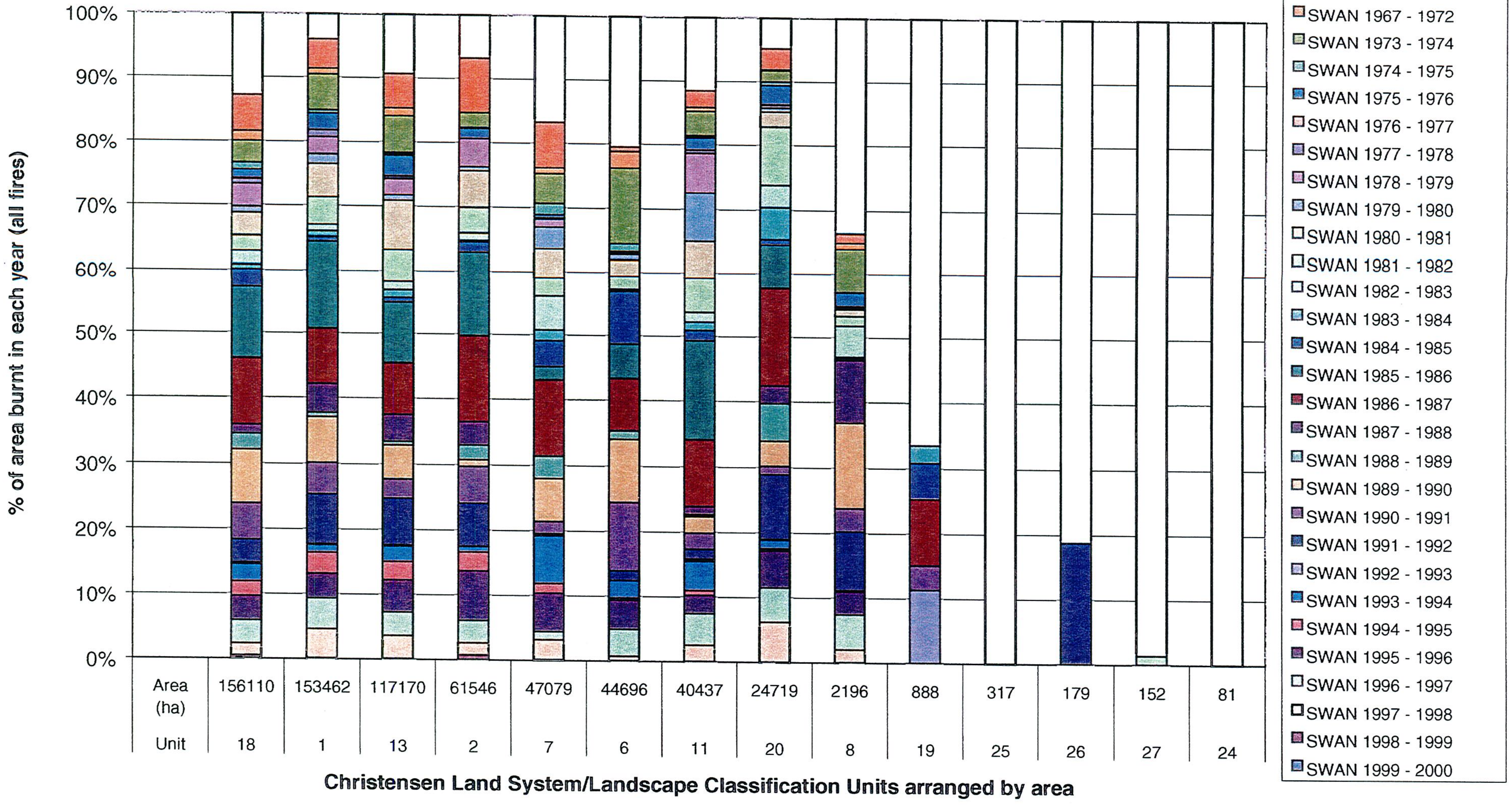
1982 - 1983
1981 - 1982
1980 - 1981
1979 - 1980
1978 - 1979
1977 - 1978
1976 - 1977
1975 - 1976
1974 - 1975
1973 - 1974
1967 - 1972
1961 - 1966
02 Prior to 1960
01 No burn record

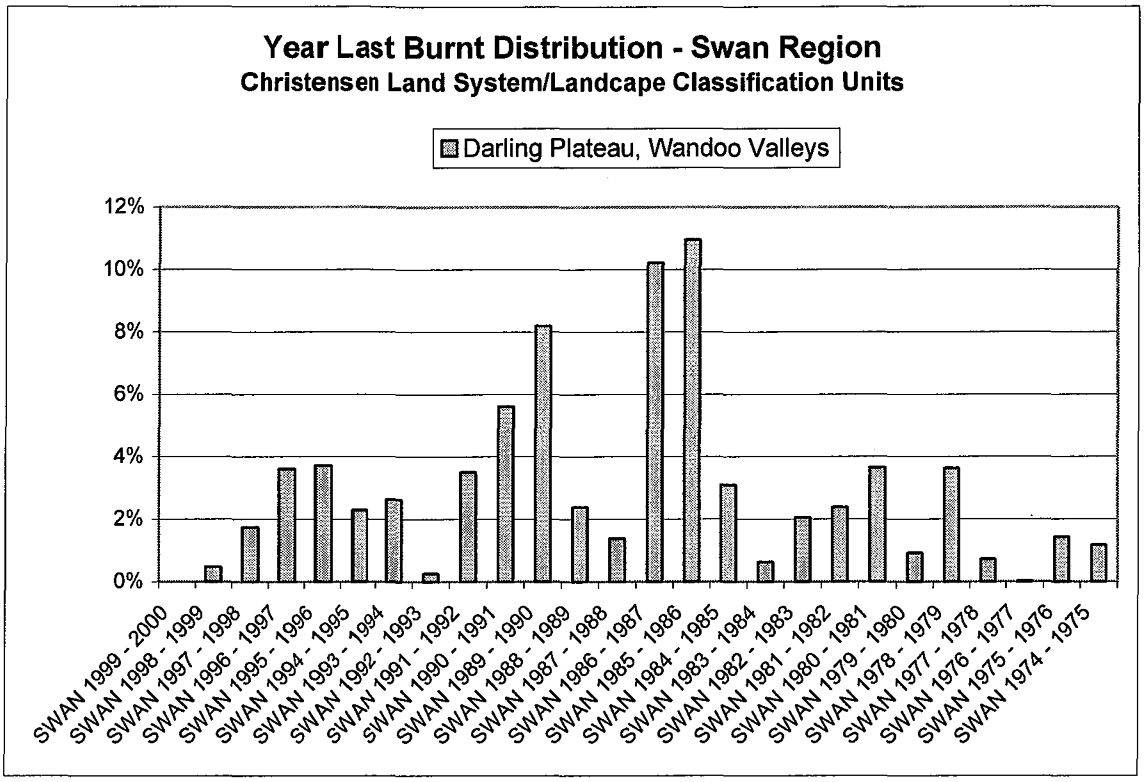
CHRISTENSEN FAUNAL CLASSIFICATION UNITS (for use with following figures)

UNIT	DESCRIPTION	
	LAND SYSTEM	LANDSCAPE UNIT
1	Darling Plateau	Jarrah Uplands North
2	Darling Plateau	Jarrah Uplands East
3	Darling Plateau	Jarrah Uplands South
4	Darling Plateau	Jarrah Uplands South East
5	Darling Plateau	Karri Uplands
6	Darling Plateau	Wandoo Uplands
7	Darling Plateau	Powder Bark Uplands
8	Darling Plateau	Scarp
9	Darling Plateau	Depression/Swamps North
10	Darling Plateau	Depressions/Swamps South
11	Darling Plateau	Depressions/Swamps East
12	Darling Plateau	Depressions/Swamps South East
13	Darling Plateau	Jarrah Valleys North
14	Darling Plateau	Jarrah Valleys East
15	Darling Plateau	Jarrah Valleys South
16	Darling Plateau	Jarrah Valleys South East
17	Darling Plateau	Karri Valleys
18	Darling Plateau	Wandoo Valleys
19	Darling Plateau	Powder Bark Valleys
20	Darling Plateau	Granite Outcrops
21	Various Systems	Estuaries / Open Water
22	Collie Plain	Uplands
23	Collie Plain	Depressions/Swamps
24	Dandaragan Plateau	Uplands
25	Dandaragan Plateau	Valleys
26	Swan Coastal Plain	Uplands

UNIT	DESCRIPTION	
	LAND SYSTEM	LANDSCAPE UNIT
27	Swan Coastal Plain	Valleys
28	Southern Plains	Jarrah
29	Southern Plains	Karri
30	Southern Plains	Heath/Sedgeland
31	South Coast Dunes	South Coast Dunes
32	Blackwood Plateau	Jarrah Uplands
33	Blackwood Plateau	Karri Uplands
34	Blackwood Plateau	Depressions / Swamps
35	Blackwood Plateau	Valleys
36	Margaret River Plateau	Jarrah Uplands
37	Margaret River Plateau	Karri Uplands
38	Margaret River Plateau	Jarrah Valleys
39	Margaret River Plateau	Karri Valleys
40	Leeuwin Naturaliste Coast	Jarrah
41	Leeuwin Naturaliste Coast	Karri
42	Leeuwin Naturaliste Coast	Coast Heath
43	Scott Coastal Plain	Uplands
44	Scott Coastal Plain	Valleys / Swamps
45	Redmond	Uplands
46	Redmond	Valleys
47	Unicup	Jarrah Uplands
48	Unicup	Wandoo Uplands
49	Unicup	Jarrah Valleys
50	Unicup	Wandoo Valleys
51	Unicup	Scrubland
52	Swan Coastal Plain	Coastal Dunes

Fig 10.3: Christensen Classification Units - Year Last Burnt (Swan Region)




Year Last Burnt Distribution - Swan Region
Christensen Land System/Landcape Classification Units
Darling Plateau, Wandoo Valleys
12%
10%
8%
6%
4%
2%
0%
SWAN 1999 - 2000
SWAN 1998 - 1999
SWAN 1997 - 1998
SWAN 1996 - 1997
SWAN 1995 - 1996
SWAN 1994 - 1995
SWAN 1993 - 1994
SWAN 1992 - 1993
SWAN 1991 - 1992
SWAN 1990 - 1991
SWAN 1989 - 1990
SWAN 1988 - 1989
SWAN 1987 - 1988
SWAN 1986 - 1987
SWAN 1985 - 1986
SWAN 1984 - 1985
SWAN 1983 - 1984
SWAN 1982 - 1983
SWAN 1981 - 1982
SWAN 1980 - 1981
SWAN 1979 - 1980
SWAN 1978 - 1979
SWAN 1977 - 1978
SWAN 1976 - 1977
SWAN 1975 - 1976
SWAN 1974 - 1975

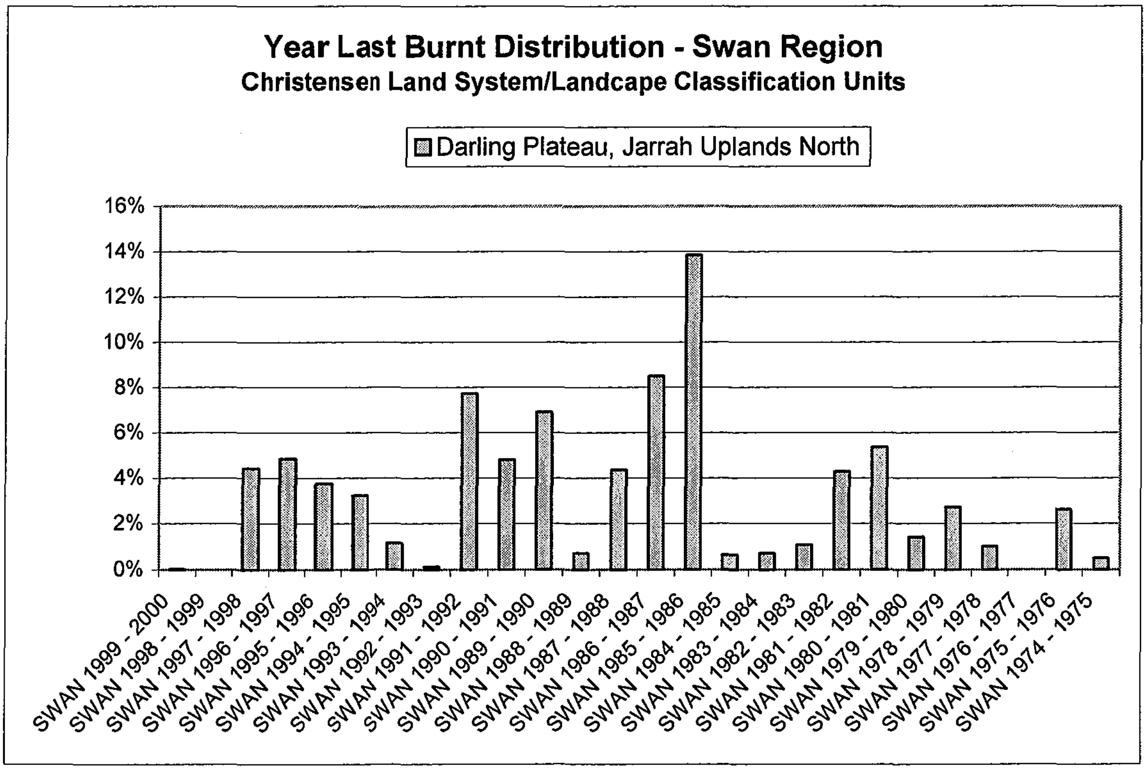
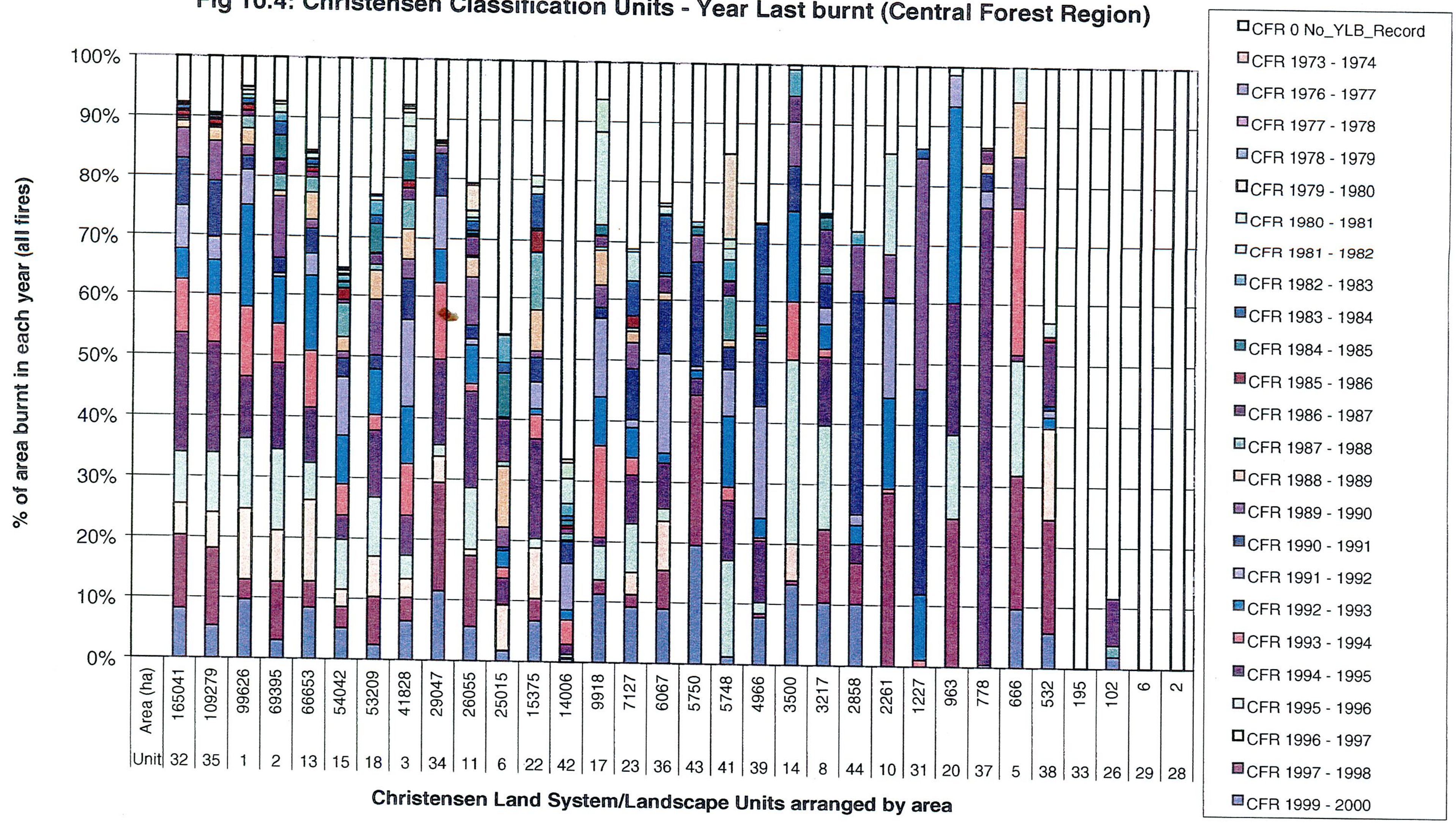
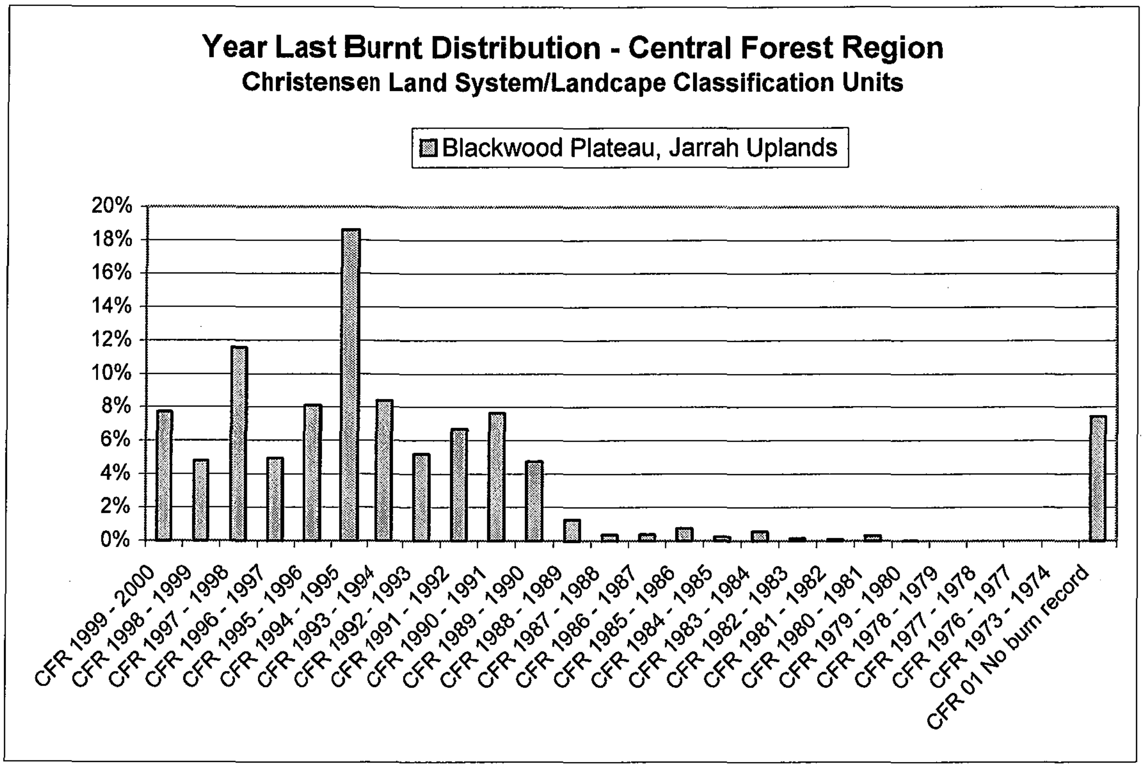

Year Last Burnt Distribution - Swan Region
Christensen Land System/Landcape Classification Units
Darling Plateau, Jarrah Uplands North
16%
14%
12%
10%
8%
6%
4%
2%
0%
SWAN 1999 - 2000
SWAN 1998 - 1999
SWAN 1997 - 1998
SWAN 1996 - 1997
SWAN 1995 - 1996
SWAN 1994 - 1995
SWAN 1993 - 1994
SWAN 1992 - 1993
SWAN 1991 - 1992
SWAN 1990 - 1991
SWAN 1989 - 1990
SWAN 1988 - 1989
SWAN 1987 - 1988
SWAN 1986 - 1987
SWAN 1985 - 1986
SWAN 1984 - 1985
SWAN 1983 - 1984
SWAN 1982 - 1983
SWAN 1981 - 1982
SWAN 1980 - 1981
SWAN 1979 - 1980
SWAN 1978 - 1979
SWAN 1977 - 1978
SWAN 1976 - 1977
SWAN 1975 - 1976
SWAN 1974 - 1975

Fig 10.4: Christensen Classification Units - Year Last burnt (Central Forest Region)




Year Last Burnt Distribution - Central Forest Region
Christensen Land System/Landcape Classification Units
Blackwood Plateau, Jarrah Uplands
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
CFR 1999 - 2000
CFR 1998 - 1999
CFR 1997 - 1998
CFR 1996 - 1997
CFR 1995 - 1996
CFR 1994 - 1995
CFR 1993 - 1994
CFR 1992 - 1993
CFR 1991 - 1992
CFR 1990 - 1991
CFR 1989 - 1990
CFR 1988 - 1989
CFR 1987 - 1988
CFR 1986 - 1987
CFR 1985 - 1986
CFR 1984 - 1985
CFR 1983 - 1984
CFR 1982 - 1983
CFR 1981 - 1982
CFR 1980 - 1981
CFR 1979 - 1980
CFR 1978 - 1979
CFR 1977 - 1978
CFR 1976 - 1977
CFR 1973 - 1974
CFR 01 No burn record

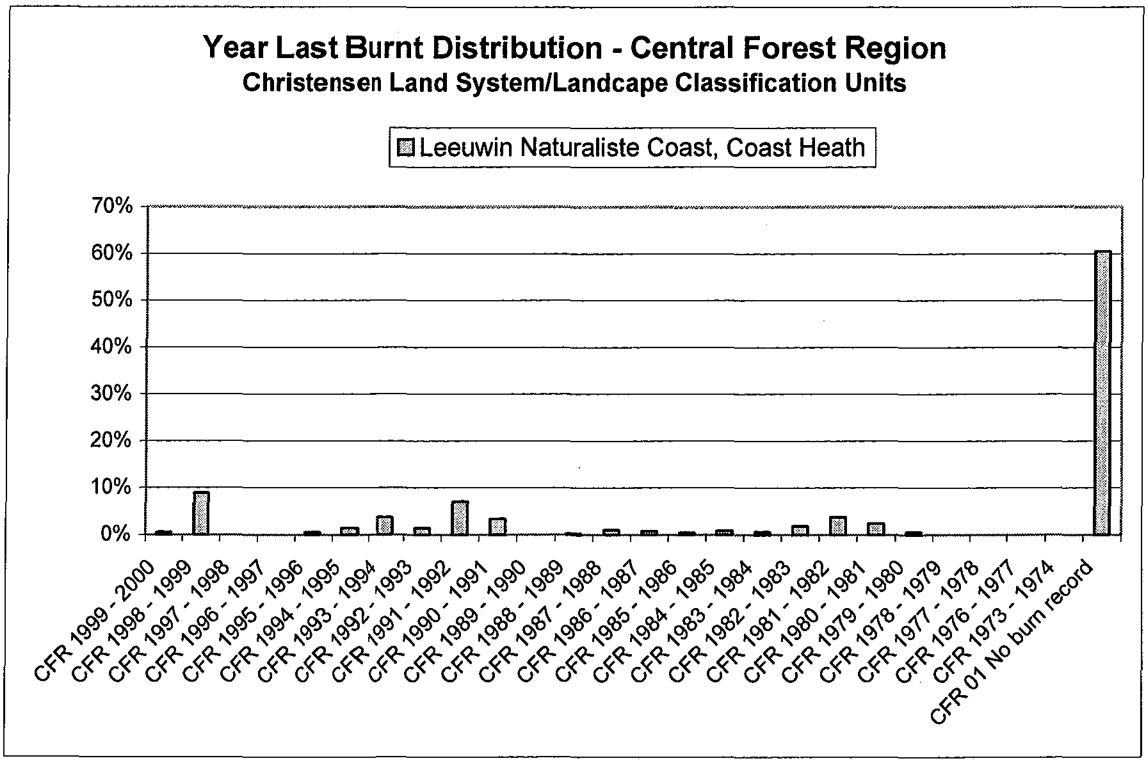
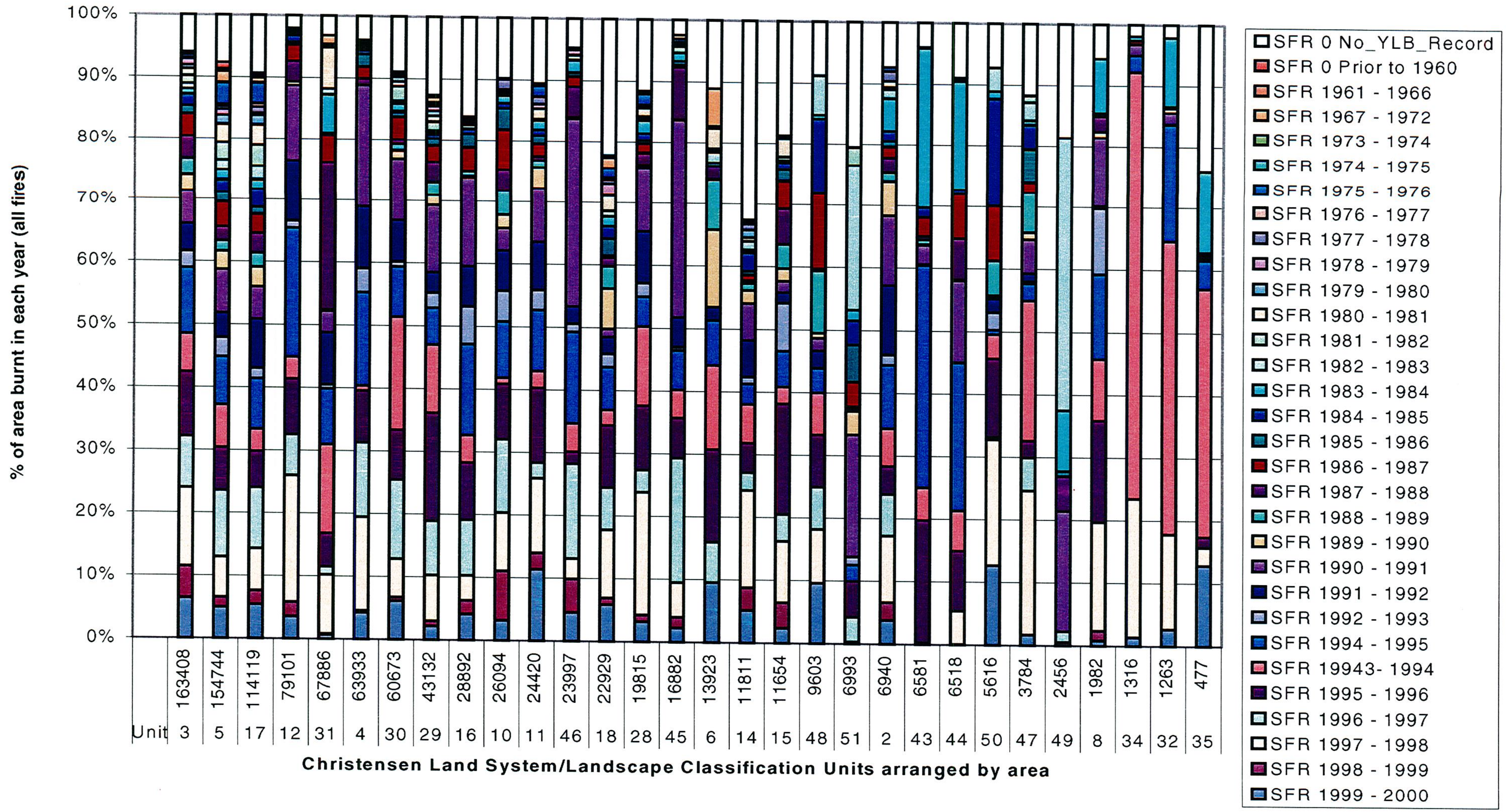
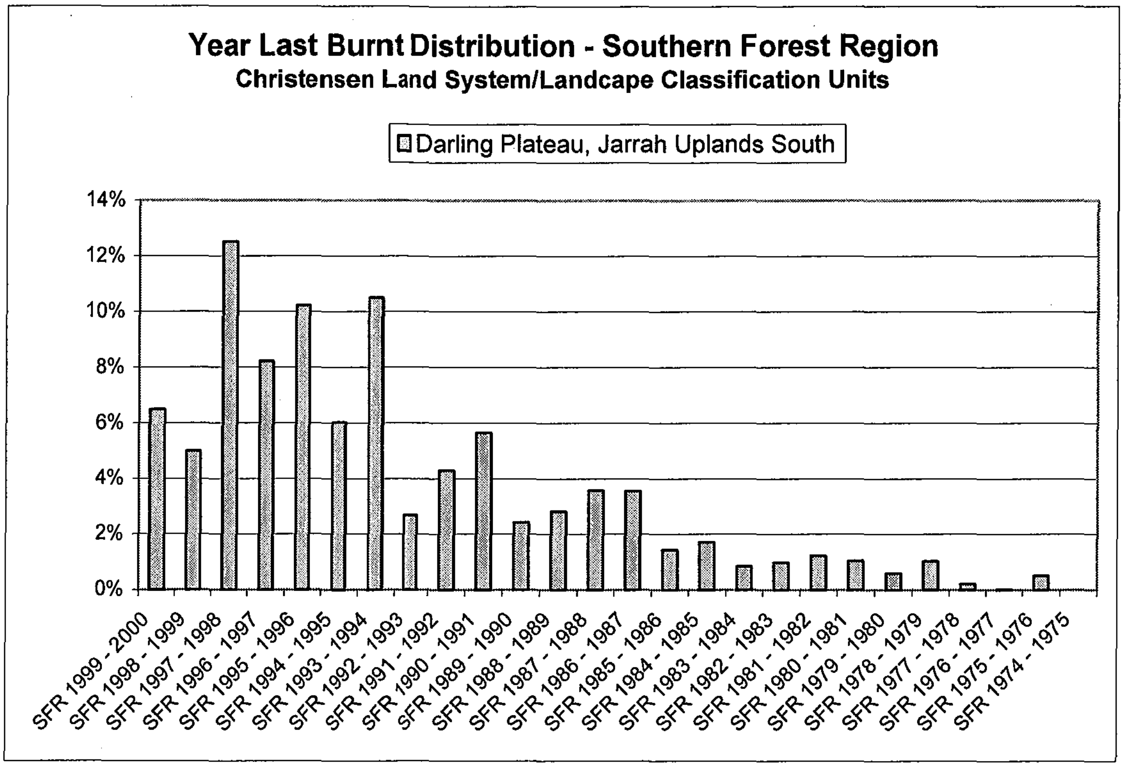

Year Last Burnt Distribution - Central Forest Region
Christensen Land System/Landcape Classification Units
Leeuwin Naturaliste Coast, Coast Heath
70%
60%
50%
40%
30%
20%
10%
0%
CFR 1999 - 2000
CFR 1998 - 1999
CFR 1997 - 1998
CFR 1996 - 1997
CFR 1995 - 1996
CFR 1994 - 1995
CFR 1993 - 1994
CFR 1992 - 1993
CFR 1991 - 1992
CFR 1990 - 1991
CFR 1989 - 1990
CFR 1988 - 1989
CFR 1987 - 1988
CFR 1986 - 1987
CFR 1985 - 1986
CFR 1984 - 1985
CFR 1983 - 1984
CFR 1982 - 1983
CFR 1981 - 1982
CFR 1980 - 1981
CFR 1979 - 1980
CFR 1978 - 1979
CFR 1977 - 1978
CFR 1976 - 1977
CFR 1973 - 1974
CFR 01 No burn record

Fig 10.5: Christensen Classification Units - Year last burnt (Southern Forest Region)




Year Last Burnt Distribution - Southern Forest Region
Christensen Land System/Landcape Classification Units
Darling Plateau, Jarrah Uplands South
14%
12%
10%
8%
6%
4%
2%
0%
SFR 1999 - 2000
SFR 1998 - 1999
SFR 1997 - 1998
SFR 1996 - 1997
SFR 1995 - 1996
SFR 1994 - 1995
SFR 1993 - 1994
SFR 1992 - 1993
SFR 1991 - 1992
SFR 1990 - 1991
SFR 1989 - 1990
SFR 1988 - 1989
SFR 1987 - 1988
SFR 1986 - 1987
SFR 1985 - 1986
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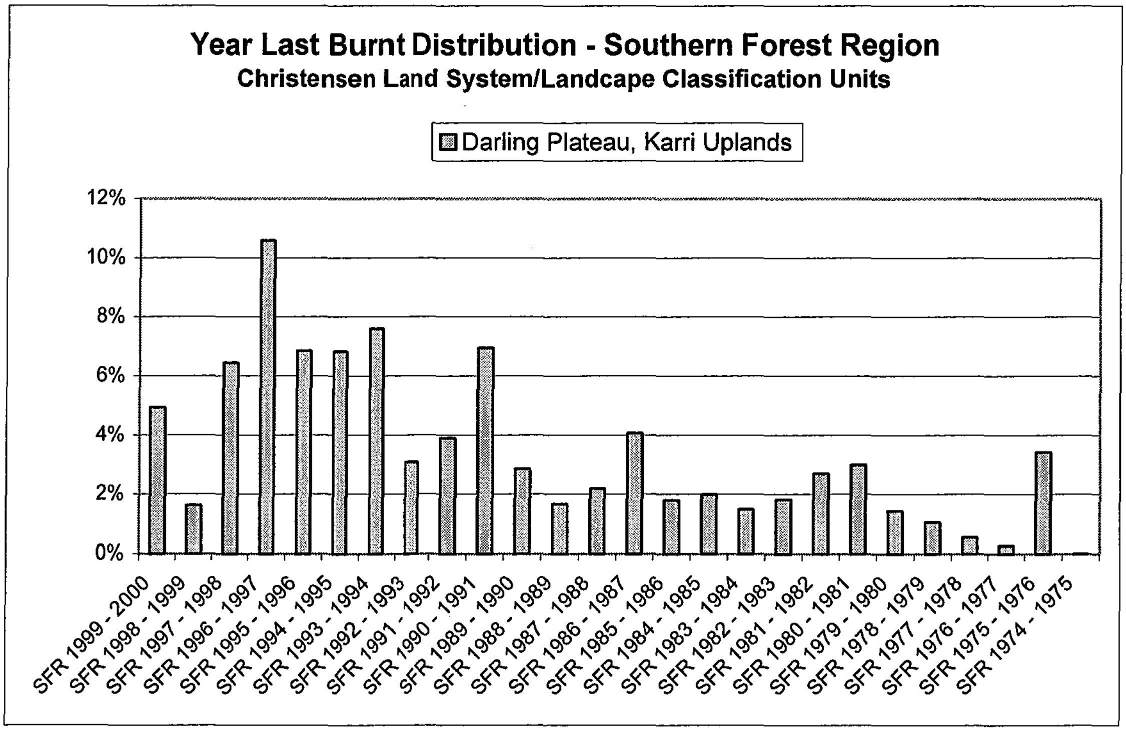
SFR 1983 - 1984
SFR 1982 - 1983
SFR 1981 - 1982
SFR 1980 - 1981
SFR 1979 - 1980
SFR 1978 - 1979
SFR 1977 - 1978
SFR 1976 - 1977
SFR 1975 - 1976
SFR 1974 - 1975


Year Last Burnt Distribution - Southern Forest Region
Christensen Land System/Landcape Classification Units
Darling Plateau, Karri Uplands
12%
10%
8%
6%
4%
2%
0%
SFR 1999 - 2000
SFR 1998 - 1999
SFR 1997 - 1998
SFR 1996 - 1997
SFR 1995 - 1996
SFR 1994 - 1995
SFR 1993 - 1994
SFR 1992 - 1993
SFR 1991 - 1992
SFR 1990 - 1991
SFR 1989 - 1990
SFR 1988 - 1989
SFR 1987 - 1988
SFR 1986 - 1987
SFR 1985 - 1986
SFR 1984 - 1985
SFR 1983 - 1984
SFR 1982 - 1983
SFR 1981 - 1982
SFR 1980 - 1981
SFR 1979 - 1980
SFR 1978 - 1979
SFR 1977 - 1978
SFR 1976 - 1977
SFR 1975 - 1976
SFR 1974 - 1975

11 Suggest a method of weighting the maintenance of the Department's current fire management program against the implementation of its statutory obligations

There are two aspects to weighting outcomes against obligations:

- Achieving a balance between fire management and other activities the Department must undertake to meet its statutory obligations; and
- Process and performance measures.

11.1 Achieving a Balance

As outlined in Section 2, the Department does not have statutory obligations for fire protection, but is liable under the common law for damage arising from fire on land that it manages. The Department has statutory obligations to provide for recreational use in various classes of land it manages, a statutory duty of care to its staff, and common law responsibilities relating to the safety of visitors. It also has obligations and responsibilities related to the protection of forests for timber supply.

Fire management is critical to achieving the Department's statutory obligations for protection of flora and fauna, and maintenance and restoration of the natural environment. Fire diversity promotes biodiversity. Long periods of fire exclusion from large areas will ultimately result in extensive high intensity fires, which will reduce biodiversity. Other threatening processes such as weed invasion and predation by feral animals can also have highly significant impacts on biodiversity.

To achieve a balance between the competing demands for limited resources, a risk management approach to comparing the likelihood and consequences of different events is recommended as a means of weighting the different programs. The classification of values outlined in Section 3, whilst developed for fire, can be used as a framework for considering other factors such as ferals, weeds and the provision of visitor facilities. Quite obviously, if a course of action (or inaction) leads to the high probability of an event (fire, ferals, etc) that could result in extinction of a species or community, then the risk is high, irrespective of the vector. Similarly the consequences of proceeding or not proceeding with a recreation program, of developing or closing areas to visitors, etc. can be assessed on a similar framework.

There has been some development of a risk management approach in relation to fire. It recognises that fire is inevitable, but that consequences depend on the fire regime, which can be influenced by a range of management actions. Both qualitative (see section 3) and more quantitative (see section 9) assessments can be undertaken. A similar risk management approach needs to be undertaken for other activities, to provide a basis for comparison. It is suggested that a semi-qualitative approach be taken, using the "Classification of Values" as a framework for comparing economic and less tangible values. Probabilities of events should preferably be calculated from statistical data, or peer reviewed "expert systems" where this is not possible. Such an approach would provide transparency and efficiency in resource allocation.

Recommendation 11.1: A risk management approach be implemented for all activities to provide weightings for allocation of resources to meet a range of obligations.

11.2 Process and Performance Measures

Implementation of an ISO standard can provide measures of process performance. Financial efficiency in achieving outcomes is often used as at least part of a measure of performance. Standards should be developed for all processes/outcomes.

A measure widely applied within fire protection services is the Standards of Fire Cover (SFC). SFC is a term commonly used to describe the overall level of fire protection services that agencies provide to meet established benchmarks or standards. This approach has been used by Fire Branch to recommend the numbers of fire fighters, incident control staff, and support staff required in the forest regions. The recommended standards for the numbers of required firefighters and staff was based on:

- Capacity to provide initial attack;
- Ability to staff large fires; and
- Capacity to undertake prescribed burning.

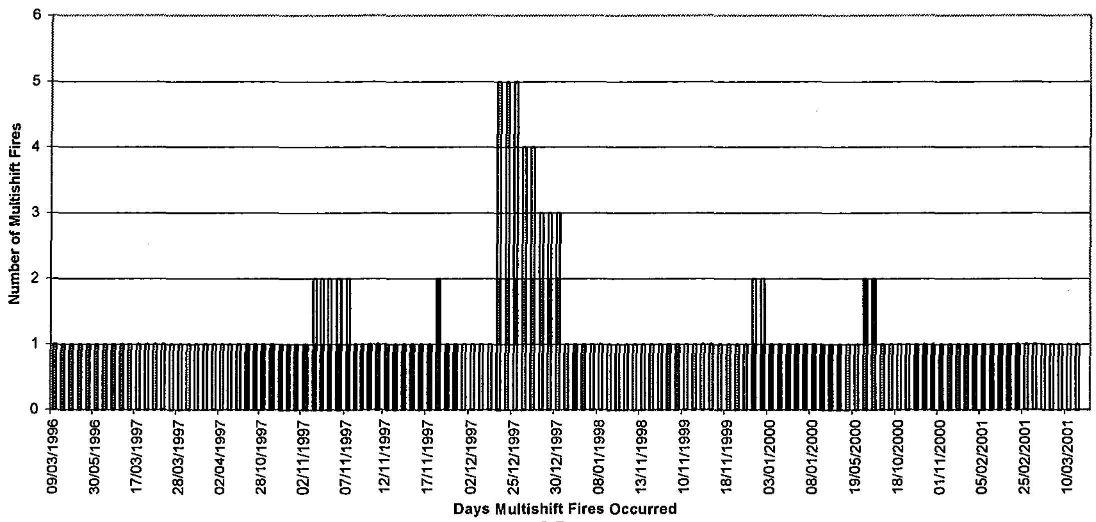
The workforce requirements to meet the standards were determined from the despatch tables (recommended resources to be despatched to forest fires under varying conditions) published in the Forest Fire Behaviour Tables (Sneeuwjagt and Peet, 1979, 1985, 1998).

The basis for the standards of fire cover has been re-examined during the course of this review.

Initial Attack Standard: As outlined in section 9, Fire Branch has identified "response cells" for initial attack. The numbers required within each cell are based on the despatch tables in the Forest Fire Behaviour Tables, and have been validated through experience. The number of fire crew and the need for their distribution has a sound basis (see section 9 maps) if the objective is to be able to attack a fire in each response cell concurrently.

A one hour first attack capability will reduce the likelihood of large fires, but will not guarantee success. Large fires will occur, especially when numerous fires occur concurrently. There is a significant jump in the resources required to staff a multi-shift fire, and logic would dictate that the costs would increase markedly. Attempts to determine the economic efficiency of different levels of readiness were frustrated by a lack of reliable data, due to past changes in accounting practices, and problems with invalid data records.

Large Fire Standard: The SFC model is based on the ability to staff one large (multishift) fire in each of the three forest regions. The multi shift fires that occurred in the period 1996-2001 are shown on the following chart.



Two multi shift fires have occurred simultaneously at least once each year, and five at the one time on one occasion. The occurrence of such events is closely tied to conditions, and could be expected to increase if the fuel levels increase. If resources are inadequate, the duration of the fires is extended. This exacerbates the resource requirements, as crews are required to replace those needing rest for both safety and Award reasons. Planning to retain a workforce for three short-term multi shift fires would therefore appear reasonable, recognising that this will be inadequate when extended fires occur.

Burning Requirements: To meet an initial attack capacity whilst maintaining a skeleton mop up/patrol crew at any "live" burn requires additional personnel during the burning period. The 1994 model has identified the need for each "response cell", but as the burning period in the northern and southern forests overlap for only a short period, the total numbers can be reduced if the work force can be transferred.

The fire model identifies an overall requirement for 131 fire control staff, 220 fire fighters for initial attack only, 288 for three large fires, and 280 for initial attack plus burning. In addition support staff are required for large fire situations.

A reduction in either trained fire fighters or fire control staff implies an acceptance of a higher level of risk, and does not necessarily result in any cost savings if the consequences are larger fires. Unfortunately the lack of sufficient data to provide reliable trends did not permit a proper economic analysis to ascertain the optimum level for either fire suppression readiness, or the level of fuel reduction burning

12 Implement a Communication Strategy for the Review

This term of reference was unclear, as the implementation of a strategy to communicate the findings of the review cannot be undertaken until after its completion, and is a decision for the Executive Director who has commissioned the review. It was clarified by the steering committee that implementation during the review related to the consultation strategy.

As part of this review internal consultation was undertaken with people from the following sections of the Department:

- Corporate Executive (Executive Director, Acting Director Sustainable Forest Management, Acting Director Nature Conservation, Director Parks and Visitor Services, Director Regional Services, Director Western Australian Threatened Species and Communities Unit, Director Science Division);
- Science Division;
- Fire Branch;
- Nature Conservation and Parks and Visitor Services Output Leaders and Fire Coordinators in the three forest regions;
- District and Regional Parks staff;
- Overseers and fire crew;
- People Services Branch;
- Risk management section;
- Management audit section.

This involved face to face discussions with more than 70 people from within the Department and the Forest Products Commission. Additional consultation was undertaken by telephone.

Information about the review was also presented at Fire Coordinators meetings and the Annual Fire Coordinators Seminar. Input to the review was invited at these meetings and via the Email network.

Advice was obtained from the Crown Solicitor's Office in relation to section 2 of this report.

To promote further discussion, it is suggested that following endorsement by the Corporate Executive, the findings of this review (along with any desired caveats) be made widely available within the Department to promote further discussion. This should include:

- The author to present findings to staff from the three forest regions, Nature Conservation, Parks and Visitor Services, Science and Sustainable Forest Management Divisions, Fire Branch, and other interested staff;
- The author to discuss relevant sections with staff from Corporate Services Division;
- Hard copies of the report to be distributed to all Divisions, Regions, Branches, the Forest Districts, and the Department's library; and
- Publishing the report on the CALMWeb.

Recommendation 12.1: This report on the Review of Fire Operations be made widely available to departmental staff, including through publishing on CALMWeb.

13 Identify the human resource issues associated with implementing possible fire management models

13.1 Personal Factors

Fire control is a difficult and stressful activity. Many qualified staff are avoiding involvement because of this, and some have retired from fire activity on stress related medical grounds. Being able to withdraw from involvement with fire duties has been quoted as a reason for some staff electing to transfer to the Forest Products Commission.

Contributory factors to people avoiding or seeking to reduce involvement with fire include:

- The "Linton Factor". Staff are concerned at the possibility of being involved in coronial inquiries and potential personal liability in the event of deaths. The recent Linton Coronial Inquiry in Victoria has heightened such concerns.

- External confrontation. During the Regional Forest Agreement process many staff suffered great stress from the verbal abuse received whilst attempting to carry out their job. Some staff have indicated that they do not wish to face further confrontation over fire related issues.

- Internal conflict. Fire suppression requires decisive leadership: management of emergencies by committee consensus is potentially disastrous. This decisiveness is seen by some when expressed in non-emergency situations as aggressiveness, unwillingness to consider other views, and a source of conflict some wish to avoid.

- Family stress. The load on individuals has increased with reducing numbers of both staff and fire crew. Examples were quoted where individuals had been on duty/at fires/burning for 7 weekends out of 8. According to some staff, the rostered one weekend off in four "never happens". The inability to plan ahead to have a weekend off with family places considerable stress on relationships. Several persons at all levels mentioned avoidance mechanisms including the use of telephone answering machines to screen calls, and seeking doctor's certificates when the stress mounted to unacceptable levels.

- Increasing difficulty of the task. More complex burns, heavier adjoining fuels, greater risk and greater criticism from all areas both internal and external (smoke over Perth, ash on cauliflowers, burning all the wildflowers, etc).

- Reduced burn preparation and reduced resources lead to increased risk, and increased stress.

- Pressures of other work make it difficult for staff to attend necessary training and fire operations activities. There is more work pressure at most levels due to the increased demands and reduced staff. This lack of time makes mentoring difficult to achieve, and increases the pressure on individuals.

Fire activities involve inherent risks. If something goes wrong, those involved are usually criticised, but insufficiently acknowledged for their achievements: good outcomes are expected. The reaction to accidental smoke over Perth, and late changes to burn programs (notwithstanding that considerable planning and preparation may already have been undertaken) contribute to a perception that the fire programs are not well understood or fully supported by senior management or government. From a career perspective there is little incentive for persons to become involved with fire, and its associated risks. Past recognition of the importance and difficulty associated with fire management operations has waned, lesser importance has been placed on fire experience in the selection criteria for senior field positions including District Manager, and risk avoidance is seen as a more successful career strategy by some junior staff.

Fire is an essential activity for natural land management, and the development by staff of knowledge and skills related to fire, and involvement in fire management activities, should be strongly encouraged.

13.2 Awards/Allowances

There are some perceptions that the current system for payments encourages over-servicing. Although this may be the case for one or two individuals there is no evidence that this is generally the case. On the contrary, the reluctance for people to get involved with fire would indicate that the financial rewards are a poor incentive. However, unsubstantiated allegations that fire management decisions (eg. how long to mop-up, who to send to a fire, etc) are influenced by the financial returns to individuals are damaging to both the individual and the Department, and consideration should be given to procedures and payments that increase transparency and reduce such perceptions.

The average payment to staff in the forest regions who were involved in fire related work outside normal working hours (duty officer and availability allowances, fire suppression overtime, and burning overtime) was 15% additional to normal salary. This is significant in terms of both income for individuals, and as an indication of the quantum of fire related work required outside normal working hours.

A small number (20 of the 561 persons who received payment for fire related duties) received significantly more: 40% or more additional to their normal salary. These staff all work in the Swan Region, where the incidence of fires is greatest. Seven of the twenty did not work the full year, and therefore the fire payments are disproportionately high percentage of their total salary. Wildfire-associated costs accounted for over 94% of these payments, and prescribed burning overtime less than 6%, reflecting the high number of fires, particularly in the Perth District.

Perceived inequitable treatment can led to frustration. Many staff outside the fire area work considerable overtime that is unpaid, albeit in doing so they may have a choice not available to rostered fire staff. There are however direct inequities within the fire system. There are differences between the fire service provisions in different awards, and there are inconsistencies in the way they are implemented, including both how the workload and level of experience is spread.

In one District a small number of staff received the bulk of the payments (and did the bulk of the fire work). These staff complained of being overworked, and yet other staff in the same District felt that they had not been optimally involved. Clearly better management is required in this instance.

Inequities in the payments and conditions include

1. Differences in rates between awards for similar work/disabilities, for example those under the AWU Award are paid at a higher rate for availability than are those employed under the Public Service Award.

2. Duty Officer rates are based on the defined minimum level of responsibility required for the role, and an average time required to be spent on routine duties. This is both variable between areas, and has changed over time with changes in staff structures and systems. Rates do not

relate to the classification of the officers on duty, who are frequently classified much higher than the minimum classification on which the rates are based, and do not reflect the varying levels of expertise brought to the task.

3. The current system for overtime payments provides for those working under the most severe fire conditions (day shift) to be paid less than those operating on night shift where penalty rates apply throughout.

Award restructuring, at least as regards to fire service provisions, is highly desirable to reduce inequities, to recognise the particular nature of the tasks, and to encourage participation but discourage over-servicing (or the perception of such). Areas that should be further explored include:

- Uniform fire service conditions for all staff and employees.
- Shift work/rosters to include weekend work and replace duty officer overtime payments.
- Means to ensure minimum periods free from any duties, including weekend periods.
- Possibilities for shift work system to address point 3 above, where normal hours plus a shiftwork loading can be worked for any part of the 24 hour cycle and additional penalty rates only apply after the normal hours have been worked.
- All time worked on fire suppression or burning operations be paid at a special flat rate (eg. 150% ordinary time). This would recognises the additional load and stress associated with such work (which applies irrespective of whether the fire operation is during or outside normal working hours), and also:
  - o enable burning operations to be scheduled for optimum efficiency independent of penalty rate considerations
  - o remove opportunity for suggestions of scheduling/over-servicing to take advantage of higher penalty rates.

The above were raised during consultation for this review, and there was a wide range of opinions expressed. Time did not permit follow up of these areas as part of this review.

Recommendation 13.1: Fire service provisions be given a priority for award alignment, to develop uniform and equitable provisions that reflect the duties performed.

13.3 Staff Resources

There is a need to maintain sufficient skilled fire management staff for both incident management and fireline supervision. In addition a large number of staff are required to fill specialist and support roles, particularly in large fire situations. There are more departmental staff in the south-west than required for fire management, many of whom already have the majority of the skills required as part of their normal duties, but they are not all involved/available for fire roles. Some additional training is required both in individual skills and in working as part of a team. This is currently difficult because even if staff are willing, involvement with fire management (including training) interferes with their other duties and their Managers may be reluctant for this to happen. Even should they be supportive, there is currently no provision in the service provider agreements for this. Fire operations, and particularly the peak demands of an emergency response, are episodic events. Whilst a core of specialist staff are required, it is cost prohibitive to maintain the number of staff required for operations dedicated purely to fire roles. An efficient fire organisation must be based on utilising multi-skilled personnel. To achieve this:

- Staff selection procedures should include skills required for roles in the fire organisation in the selection criteria for all field based positions in the forest regions. Such skills need not be limited to fireline roles, but should include skills identified as essential for support roles.
- A role in the fire organisation should be included in all duty statements and job descriptions for such staff.
- Service provider agreements must include provision for training/maintenance of skills for the relevant fire roles for all field staff.
- Fire emergency response must be given priority over normal works programs
- Regular works programming must include sufficient flexibility to respond to the fire management needs where these are dictated by weather conditions and cannot be tightly planned in advance.

Recommendation 13.2: Fire management be identified as part of the duties of all departmental staff in the forest regions, and relevant skills base be maintained.

14 Miscellaneous

During the course of the review a there were a number of items encountered that did not fit within the terms of reference, but were considered worthy of recording.

14.1 Use of Web Forms

The implementation of the burning program is supported by a detailed system of planning calendars, checklists, and operational instructions. These are largely manual, and many of the procedures are repetitious. This could be considerably streamlined if established in an electronic format, with links from the planning calendar to the necessary guidelines, forms, templates for notification letters, etc. Updates would also be facilitated.

The use of web based input forms would also reduce multiple recording, and with well-designed error trapping could reduce errors in corporate and operational archived data. Care must be taken that the form-filling requirement does not become more important than achieving the outcome, and the system must be designed in conjunction with both the field users and the data custodians. Significant improvements in both productivity and accuracy are, however, possible, particularly where it eliminates multiple transfer of information from form to form before final entry into a database.

Accurate recording is essential for subsequent analysis. Numerous errors became evident during analysis for this review. Errors are compounded when separate data sets are combined. For example, recording errors in two separate data sets resulted in a very high proportion (the majority for at least one class) of invalid or incomplete records when these data sets were combined on a unique field. In this case errors included incorrect and inconsistent allocation of the unique field in the two data sets, transposition of figures in dates, etc. Well-designed entry forms can largely eliminate this source of error.

Recommendation 14.1: Consideration be given to greater use of the internal web to facilitate operational planning and to improve accuracy of recording data.

14.2 Access to and Maintenance of Spatial Data Sets

There are numerous spatial databases in the department, maintained by different centres for a range of purposes on four different GIS platforms (FMIS; MapInfo; ESRI (ArcView & ArcInfo); ER Mapper) and the MicroStation CAD. Whilst there are differences in the data structures between the GIS platforms, data can generally be readily exchanged between them. MicroStation has advantages for cartographic design, but has greater difficulties with attributing any data and has limited value (primarily as a backdrop picture) for GIS applications and analysis.

In addition to corporate data sets, there are individual sets maintained locally. Standards for data sets may vary according to intended use, with the accuracy of some field data needing to be verified before being included into a corporate data set, and some never reaching this standard. Nevertheless, planning should be based on the **best available** information, including that which may not meet cartographic standards. Just as there is an interim list for possibly threatened species (i.e. the "priority" flora and fauna lists), it would appear useful to record all available data sets and develop procedures to exchange this information.

There are restrictions on access to some data sets for general use (eg the rare flora and fauna databases, logging plans) for reasons of confidentiality. Difficulties with access have contributed to local data sets being maintained for operational reasons. Such data sets may contain more up to date key planning information (albeit maintained at a lower data collection or cartographic accuracy standard) than does the corporate data set. Unless there is a system for regular update, there are dangers in operating from duplicate data sets, or using "snapshots" from data sets. To minimise the need for duplicate sets being maintained, restrictions on access should be reduced wherever possible. Information is of limited use to the Department if it is not used in support of our management operations.

14.3 Introduction of New Technology

Concern regarding the introduction of new technology was expressed by a number of people. The principal areas of concern were:

- Lack of consultation with people in districts and regions who are intended to either be users of the systems, or provide data or other inputs to maintain them. Some systems are perceived to have been developed purely to meet a need remote from the field, without consideration of either the needs of the field users, or the way it would impact on operations. Systems imposed with little or no net benefit to the field are resented as just being additional work. Unless there is a clear benefit, the inputs expected are likely to fail, or be unreliable.

- Poor support for newly introduced technology. Whilst the value of systems may be acknowledged, introduction with inadequate training and support can result in significant extra workload and frustration, and poor acceptance of the system.

Training for some personnel is being undertaken through field staff working with the GIS section within Fire Branch. This increases the level of expertise, and enables wider support by these individuals to other staff. To gain maximum benefit of both new technology and such acquired expertise, the formal training for intended users, and/or any self-help guides required, should be clearly identified before and accompany the introduction of new technology.

Appendix 1

TERMS OF REFERENCE

Review of Fire Operations in Forest Regions

Initial Terms of Reference

Terms of reference for the Project Officer's brief were to -

- Synthesise current research knowledge related to fire.
- Obtain legal advice to identify the Department's legal responsibility for fire management and wildfire protection.
- Identify values of the south-west forest region land which the Department manages and undertake a consultative risk analysis, with the Output Directors, to determine the risk factors to be applied to the maintenance of those value.
- Undertake a consultative risk analysis, involving the Forest Products Commission, of the impacts of fire on timber supply, to include advice from the Commission of the level of resource protection it is prepared to fund.
- Provide advice on firefighter safety as a part of the risk analysis.
- Identify other outcomes the Department requires from its fire management activity.
- Identify short to medium term fire management plans and prescription.
- Develop a means of separately identifying timber protection, community protection values, and nature conservation values.
- Review the Wildfire Threat Analysis and provide advice on the incorporation of other values into the WTA or an appropriate similar tool. This review to include the provision of advice on a fire analysis system to identify areas in which fire is required for protection of values.
- Review the appropriateness of the landscape scale of current fire management practices.
- Suggest a method of weighting the maintenance of the Department's current fire management program against the implementation of its statutory obligations.
- Implement a communication strategy for the review.

Term of reference subsequently added

- Identify the human resource issues associated with implementing possible fire management models.

Appendix 2

Summary of Fire Expenditure 2000-2001

Table 1: Summary of Fire Operations Expenditure

Activity	Expenditure
Planning / Liaison	$ 1,559,867.89
Water Points	$ 123,658.74
Training	$ 464,451.59
F/Breaks	$ 635,164.79
Prescribed Burning	$ 2,427,108.80
Detection	$ 885,242.98
Detention	$ 869,340.82
Hazard Reduction	$ 115,013.68
Weather	$ 75,672.23
Fire Equipment	$ 374,985.65
Silvics Burn	$ 1,082.34
Silvics/Regen Burning	$ 879,282.21
Sub Total	**$ 8,410,871.72**
Wildfire	$ 5,790,678.43
Total Fire Expenditure	**$14,201,550.15**

Table 2: Science Division Fire Expenditure 2000/2001: Summary and Comparison

	Total	% Science Total	% Fire (Excl Wildfire)	% prescribed burning
Fire Behaviour Expenditure	$117,025	1.13%	1.55%	4.82%
Fire Ecology Expenditure	$177,527	1.71%	2.36%	7.31%
Total Fire Research	**$ 294,552**	**2.84%**	**3.91%**	**12.14%**
Science Division Total Exp.	$10,366,447			

Appendix 3

Calculation of the idealised fire age class distribution for a Forest Landscape Unit (FLU)

Neil Burrows (August 2001)
(Adapted from Tolhurst 2000)

Determining the ideal fire cycle, or range and distribution of post-fire seral stages (fire intervals) within a particular vegetation complex, habitat type or landscape unit is an important strategy for achieving the objective of biodiversity conservation.

It is important in affecting structural diversity, habitat diversity and in determining the likely presence/absence of plant and animal species. For example, if the minimum fire interval is less than the juvenile period of the slowest maturing, fire sensitive plant species, then that species (key fire response indicator) is likely to decline. This sets the minimum or lower tolerable fire interval.

At the other end of the spectrum, we need to ensure vegetation is burnt before some plant species reach the end of their life cycle, lose the capacity to regenerate following fire, and become extinct. We know that species that are relatively short lived, are obligate seeders and store seed in woody capsules (serotinous) are particularly vulnerable to long periods of fire exclusion (key fire response indicators). These species have no capacity to store seed on site once the parent plant has died and the seed has been shed – the seed of these species, if it does not regenerate, deteriorates rapidly once shed.

Our knowledge of the life histories of plant taxa is incomplete, but we have some information for some species. FIREBASE and WABIOTA are good sources of information. We can gather more information by seeking out data/observations from other people or by a field inspection of some longer unburnt areas. For example, we know that *Melaleuca viminea*, a fire sensitive, serotinous species that occupies broad valley floors in the eastern jarrah forest, commences flowering at about age 6-8 years and lives for about 50 years. Therefore, the appropriate upper and lower interfire period for this vegetation complex is about 8-50 years.

Before attempting to define the idealised (fire) age class distribution for a vegetation type or complex, we must define the *fire cycle*. Tolhurst (2000). defines this as "*the period of time within which an area equal to the total area of the vegetation unit will be burnt*". If patterns of ignitions and fire spread were random, then it is likely that some areas would be burnt more than once within a fire cycle and some areas would remain unburnt within the fire cycle. Tolhurst defines the length of the *fire cycle* as the mid-point between the upper and lower tolerable interfire period, e.g., for broad valley floors dominated by *M. viminea*, the fire cycle would be about 30 years.

The ideal fire age class distribution for a particular vegetation type is not likely to be found in nature. A widely accepted model, or guide to this distribution is the negative exponential distribution (see Tolhurst 2000, M. Gill pers. comm.). Tolhurst provides a means of defining the shape of this distribution. This is done by first determining the starting and finishing areas in the distribution and then using exponential regression model to determine the parameters of the curve by joining these two limits.

Definitions (Tolhurst 2000):

(a) Total area of a ***vegetation community*** within a defined ***landscape unit***. I propose that unless we have better descriptions (higher resolution of vegetation types) that we recognise the Christensen Fauna Habitat Types as landscape units (re-name them ***Forest Landscape Units***) – they make biological sense and are at about the right scale. I also propose that we use the ***vegetation complexes of Mattiske and Havel (1998)*** to represent ***vegetation communities***.

(m) Maximum tolerable interfire period to maintain all species (e.g., 50 yrs for *M. viminea*).
(p) Planning period to be used for group size in age class distribution histogram (e.g., 2 yrs – ie, in age class distribution, age classes are at 2 yr intervals).
(b) Duration of fire cycle (e.g., 30 yrs for *M. viminea*)

Calculations (Tolhurst 2000):

1) Area to be burnt in the first planning period: F = p x a/c
2) Area to be burned in the final planning period: L = p(c/mxa/m)
3) Decay constant **(k)** and coefficient **(b)** of the exponential equation describing the age class distribution of the veg. These calculated using an exponential regression analysis tool and the two data points: F at time p/2, and L at time m. (This can be done in Excel).

Once theses parameters have been determined, the area (a) for each time interval (t) between time zero and the maximum tolerable fire interval can be calculated using the equation:

4) $a_t = b \exp^{-(kt)}$

No area should be available for reburning until it has passed the minimum tolerable fire frequency for the community as determined by the juvenile period of the slowest maturing, serotinous species (the key fire response indicator).

The age class distribution should be truncated at the maximum tolerable fire interval for the community as determined by the longevity of the shortest lived, serotinous species.

I suggest we take a couple of examples within a Conservation Landscape Unit and do a desk-top calculation and mapping exercise to map the "ideal" fire age class distribution for a particular vegetation complex. In most cases, we are likely to get a variety of veg complexes within a burn boundary, so the planning/process gets a little more complicated.

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