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Environmental Protection Authority
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June 2004

Reports:

CONSERVATION AND LAND MANAGEMENT'S (CALM) FIRE MANAGEMENT POLICIES AND PRACTICES. A REPORT TO EPA. PERTH, WA. A. Hodgson. Fire Management Consultant.

FIRE REGIMES AND BIODIVERSITY CONSERVATION: A BRIEF REVIEW OF SCIENTIFIC LITERATURE WITH PARTICULAR EMPHASIS ON SOUTHWEST AUSTRALIAN STUDIES. Grant Wells, Stephen D. Hopper and Kingsley W. Dixon

AUDIT OF THREE OF DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT PRESCRIBED BURNS. URS Consultants

CONSERVATION AND LAND MANAGEMENT'S (CALM) FIRE MANAGEMENT POLICIES AND PRACTICES

A REPORT TO EPA. PERTH, WA.

BY

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Introduction.

I have been asked to analyse and provide advice and recommendations on aspects of CALM's fire management policies and practices. The full scope of the work and terms of reference are included in this Report as **Appendix 1.** In summary, this Report is to:

- provide advice on what compromises the key elements of current "best practice" fire management policy and practice for southern Australia and in particular South West Australian vegetative and climatic conditions in relation to prescribed burns and wildfire,
- compare this with CALM's current policies and practices; and
- make recommendations on changes that should be made for those CALM policies and practices to meet best practice standards.

In discussions with EPA it was agreed to delete Term of Reference 4 from the scope of the work. It was confirmed that this analysis is a "desk exercise" not requiring field proofing and that it should address some issues, outside the ambit of the Conservation and Land Management Act 1985, that impinge on CALM's ability to deliver "best practice" fire management. Because the analysis is a "desk exercise" it benchmarked processes rather than performance in the field.

The key elements of current "best practice" fire management against which CALM's current fire management is benchmarked are listed under Term of Reference 1. They were derived in the main from a review of fire management policies and strategies across southern Australia that endured or evolved through fire disasters, Inquiries and political change over several decades. I believe they are relevant today to fire management in most parts of southern Australia, including south-west West Australia. In this Report I present them using terminology applicable to south-west WA. Inquiries into fire management that were reviewed are listed in **Appendix 2.**

Definitions.

I give a specific meaning to a few key words used in this Report. They are:

Role. The part that an organization plays in society.
Policy. A decision rule for pursuing objectives.
Strategy. A general course of action to achieve one or more objectives. Syn.with **Practice.**
CALM Lands. A collective term for all lands, Crown and private, managed by CALM.

LIST OF RECOMMENDATIONS.

Recommendation 1.
The Fire and Emergency Services Authority of Western Australia Act 1998 be amended to provide for the preparation and review of a State Bushfire Plan, Bushfire Risk Management Plans and Bushfire Plans of Operation. (pages 4, 5, 12.)

Recommendation 2.
The Fire and Emergency Services Authority of Western Australia Act 1998 be amended to provide that at the request of the Police and Emergency Coordinator or at their own volition, the Executive Director CALM and the Executive Director Fire Services FESA may, by agreement, appoint an officer of one of the agencies to have the overall control of response activities in relation to any fire in any area and, in the absence of such agreement, the Coordinator may direct one of the Executive Directors to appoint an officer to have the overall control. (pages 6, 12.)

Recommendation 3.
The Conservation and Land Management Act 1984 be amended to provide that notwithstanding anything to the contrary in any other Act or law it shall be the duty of the Executive Director to carry out proper and sufficient work to manage fires to protect and sustain the health and biodiversity of ecosystems, regenerate disturbed or degraded ecosystems and to prevent and suppress unplanned fires on all CALM lands. (pages 6, 7, 12, 13.)

Recommendation 4.
The Conservation and Land Management Act 1984 be amended to provide that the Executive Director shall maintain an explicit and routine system, agreed to by the Auditor General, to record all planned and unplanned fires on all CALM lands. (page 9, 14.)

Recommendation 5.
CALM (i), initiate a program to identify the value the WA community is prepared to put on all assets, including intangible assets on CALM lands and (ii), develop and use methodology to balance the risk/costs/benefits of prescribed burning versus wildfires. (pages 9,10, 18, 19.)

Recommendation 6.
The Conservation and Land Management Act 1984 be amended to provide that the Minister consider the advice of the Executive Director, CALM before approving Plans involving fire management. (pages 13, 14.)

Recommendation 7.
CALM's fire management policies be expressed succinctly in the terms listed P2 to P8 inclusive under Term of Reference 1 in this Report. (pages 3, 4, 7, 8, 9, 10.)

Recommendation 8.
CALM's fire management strategies be expressed succinctly in the terms listed S 1 to S 15 inclusive under Term of Reference1 in this Report. (pages 10, 11, 17.)

Recommendation 9.
CALM initiate a research program to identify the spread and behaviour of fires caused by lightning, including their projected spread and behaviour after their spread was stopped or slowed by suppression actions. *(page 18.)*

THE REPORT

TERM OF REFERENCE 1.

" Provide advice on what would comprise the key elements of current "best practice" fire management policy and practice for southern Australia; and particularly South West Australian vegetative and climate conditions in relation to prescribed burns and wildfire."

The following policies and strategies are current key elements of "best practice" fire management for southern Australia; and particularly for *all rural lands* in CALM's Regions in south-west Western Australia. (Numbering is for the purpose of referencing in this Report and does not suggest order of importance.)

Summary of key elements of "best practice" fire management Policy.

P 1. Legislation that:

(i), requires preparation, approval and regular review of a State Bushfire Plan, Bushfire Risk Management Plans and Bushfire Plans of Operation for the prevention, mitigation and suppression of bushfires across *all rural and urban lands* in south-west WA and for post-fire community recovery,
(ii), requires CALM to operate within arrangements that ensures:

- **a single controller is in supreme charge of a fire event that involves multi-agency response, and**
- **seamless co-ordination and integration of resources responding to multi- agency fire events.**

(iii), assigns to CALM the role of a fire authority and the duty, notwithstanding anything to the contrary in any other Act or law, to carry out proper and sufficient work to manage fires to protect and sustain the health and biodiversity of ecosystems, regenerate disturbed or degraded ecosystems and to prevent and suppress unplanned fires on all CALM lands,

P 2. Where the dual objectives of protecting life and high value assets and protecting conservation values cannot both be achieved, management priority on CALM land shall be given to protection of life and high value assets.

P 3. CALM shall prepare Fire Management Plans for all CALM lands and integrate the Plans with WA Bushfire Risk Management Plans and WA Bushfire Plans of Operation.

P 4. CALM shall differentiate between unplanned fires that must be controlled and planned fires that are lit to achieve specified outcomes. The former include natural fires caused by lightning that occur at times when they threaten or may threaten biodiversity and other assets on CALM lands and lives and high value assets on adjoining lands. Planned fires include those lit to reduce fuel loads that increased as a consequence of controlling natural fires and fires lit to maintain the health and biodiversity of ecosystems or for regeneration of disturbed or degraded ecosystems.

P 5. CALM shall continually improve its knowledge base by conducting its own research and development programs in matters peculiar to its responsibilities and the technologies used to manage fire on CALM lands. It shall also support independent research relevant to bushfire management.

P 6. CALM shall maintain training programs for all personnel it employs likely to be involved in campaign fires and all similar personnel employed by other Government Agencies operating on its lands to:

- **meet relevant occupational health and safety standards,**
- **perform appropriate roles in fire management from base level to incident control of campaign fires,**
- **meet special requirements pertaining to its duty to conserve and protect ecosystems.**

Where appropriate, training programs shall be competency based and provide accreditation recognized by the Australasian Fire Authorities Council. (AFAC)

P 7. CALM shall maintain an explicit and routine system to record all fire events on its lands. The system and details recorded shall conform to standards agreed by the Auditor General and shall be made available for independent audit.

P 8. CALM shall identify all assets including intangible assets, on CALM lands in ways that reflect the value the community puts on them.

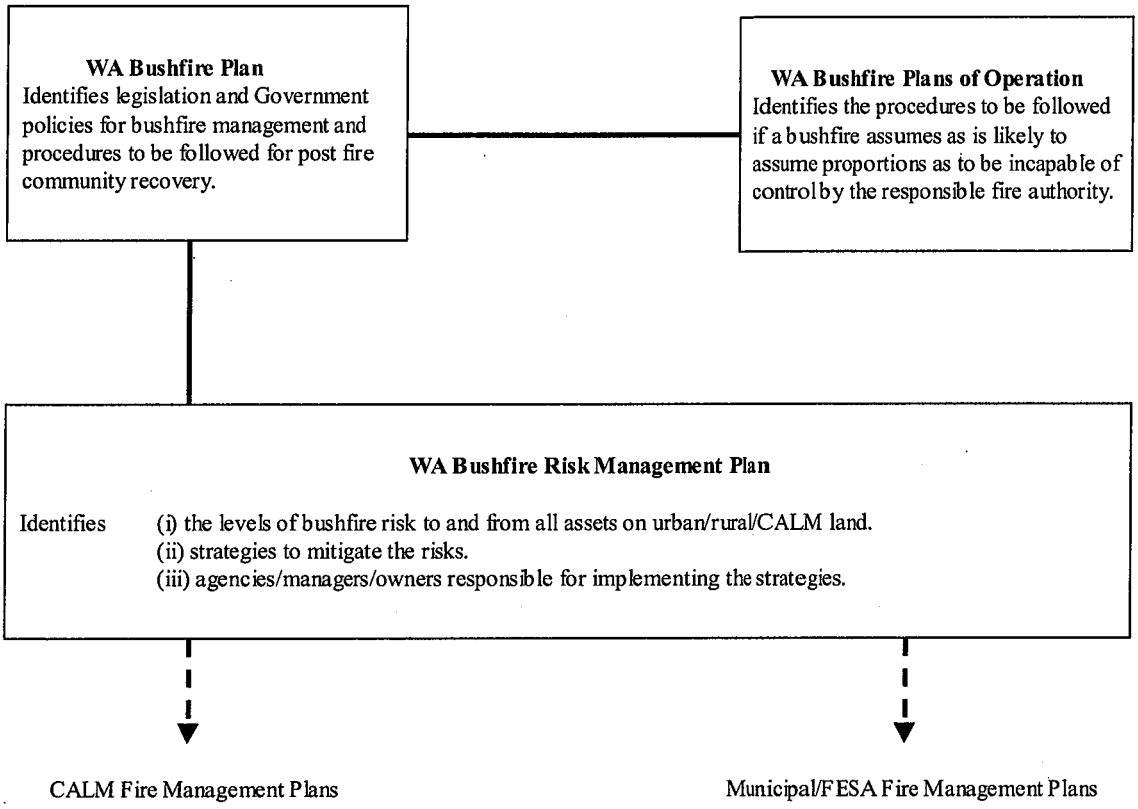
Rationale for the key elements of "best practice" policy.

P 1(i). State and regional bushfire planning.

Good legislation signals Parliament's intent to provide WA with "best practice" bushfire management and provides the administrative frameworks that allow policies to develop, objectives and outcomes to be identified and planned for and strategies to be applied. It also establishes the accountability of key players and by association, of the Government of the day. Even with the best will in the world, an agency such as CALM cannot deliver "best practice" fire management in isolation or in the absence of State and regional bushfire policies and management plans.

A State Bushfire Plan (WABP) identifies the hierarchy of legislation and policies that drive the administrative processes involved in preparation of Bushfire Risk Management Plans and Bushfire Plans of Operation. It also identifies the infrastructure, procedures and processes to be used in post-fire community recovery. A Bushfire Risk Management Plan (BRMP) identifies the levels of risk across all lands in the area to which it applies, the strategies to be implemented to manage the risks and the Agencies/owners/managers responsible for implementing the strategies. A Bushfire Plan of Operation (BPO) sets out the procedures to be followed if a bushfire assumes or is likely to assume proportions as to be incapable of control by the responsible fire authority.

Fig. showing hierarchy of Plans and purposes.



CALM has developed a comprehensive wildfire threat analysis Manual that is a BRMP for CALM lands. The Department of Planning and Infrastructure and the Fire and Emergency Services Authority of WA have jointly prepared a document titled Planning for Bush Fire Protection. That document is a good guide for identifying risks and how to minimise them in planning processes. It is not a BRMP. It is an aid, not a Plan that identifies and documents specific bushfire risks at specific places. Nor does it identify strategies to minimise the risks and the Agency/owner/managers responsible for managing the risks. It appears that there are no BRMP'S for *all rural and urban lands* in CALM's Regions in south-west WA. Since fire does not recognise jurisdictional boundaries an "overall" BRMP is essential to identify all bushfire risks, to and from assets, on all lands. The assets and activities associated with them are as diverse as power lines, road, rail and tele-communication systems, farms, mines, water catchments and storages and any number of tangible and intangible assets on CALM land The crucial point here is that legislation must require a body, largely independent of vested interests, e.g. Local Government, to drive a process that allows all the Agencies/owners/managers of assets a say in identifying the fire risk to their assets and the fire risk their assets pose to others. CALM's wildfire threat analysis Manual therefore, while excellent in itself, is deficient in that it appears to have been developed in isolation and without the benefit of a process that identifies all the risks across all rural and neighboring urban lands. **(Recommendation 1.)**

WESTPLAN-WILDFIRE prepared by the Fire and Emergency Services Authority and CALM on behalf of the State Emergency Management Committee is arguably an example of a good BPO. However it uses

a flawed procedure to ensure one individual is in supreme control of a fire event involving several agencies that is likely to fail when there is confusion or a dispute during a crisis. Circuit breaking legislation that specifies a procedure that is appropriate and effective in a worst- case scenario is needed to avoid confusion.

P 1(ii). Avoiding confusion.

South-West WA has combustible vegetation, weather patterns that cause the vegetation to dry every year and a history of ignitions coinciding with cyclonic winds. That the coincidence will occur again is certain. And WA is not immune to outbreaks of exotic disease and pests or terrorism by fire or other means. No single Agency can afford the resources to handle a full-scale fire or other emergency and a procedure driven by legislation is essential to provide a lead Agency with timely and appropriate support whenever a fire event has assumed or is likely to assume such proportions as to be incapable of control by the lead agency. Two or more bosses during an emergency are a recipe for disaster and lives, property and environmental values can be lost needlessly. Heads and Agencies will roll if that happens. (Watch the current ACT Coronial Inquiry) Memoranda of Understanding between Agencies are a poor substitute for legislation. They are not binding on the Agencies; they are not enforceable and will not stand up to judicial scrutiny following a disaster. A single effective multi-agency incident management system driven by legislation must be a mandatory requirement in WA to co-ordinate response to emergencies ranging in complexity from a traffic bingle to a terrorist attack. **(Recommendation 2.)**

P 1 (iii). CALM's role and duty.

CALM lands occupy a significant proportion of south-west WA and CALM is a key player in a holistic fire management system for the region. Vegetation and fire are inextricably linked and because CALM manages the vegetation it must manage fire on its lands. Vegetation on CALM lands is different in many ways from vegetation on most private land. It produces fuels comprising leaves, bark, sticks, branches and logs. Fire burning those fuels is not easy to extinguish with water even with chemicals added, and the fire edge is often inaccessible to ground tankers. Dry firefighting strategies using hand tools or machinery to make mineral earth barriers are essential for fighting fires in those fuels and the skills and technologies needed are therefore very different to those needed on private land where the bulk of the flammable vegetation is perennial or annual grass and is grazed or cropped. Grass fires are easily extinguished with water and most rural/volunteer fire services use water tankers as their primary and often only firefighting unit. CALM's obligation and responsibility to manage fire on its lands must not be passed either deliberately or by default to another Agency not having the tools, skills and experience gained through managing, on a daily basis, lands carrying native vegetation.

The consequence of allowing a Government Agency to default on its responsibility to deliver effective fire management on its own domain is to shift the burden of fire suppression onto volunteers. This leads inevitably to the fire suppression strategy that received much publicity during large fires in eastern States in recent years. The strategy concentrates maximum resources at or near the public land/private property interface and defends private assets by back burning and/or combating "ember attacks", often during severe weather conditions. The personnel are mostly volunteers and are dedicated, courageous and well equipped and trained for fighting fires in grassland. The strategy certainly reduced potential losses on private land during some recent firefights in eastern States when large forest fires moved onto private land. However the success of this strategy aimed solely at reducing potential losses on private land must not be allowed to obscure some facts. It failed in the ACT and at some places in Victoria in 2003. It can take days rather than hours to assemble the massed resources required to defend private property during

which time the fire spreads further on public land. The volunteers are often ill equipped and untrained for fighting forest fires and do not always recognise situations that are life threatening. The Coronial Inquiry into deaths of volunteer firefighters in a fire at Linton, Victoria in 1998 made that point clear. It places a heavy burden on volunteers and local communities, a burden that rightly belongs to the Agency managing the public land. And it pays scant attention to conservation and other values on the public land. The enormous damage done to ecosystems, soils and water catchments by those fires in some eastern States was unquestionably due to failed fire management programs on the public land. If further failures allow the strategy to become the norm for combating fires on public land there will be further loss of biodiversity, more soils will become hydrophobic or eroded and more water catchments and storages will be degraded.

Following the January 2003 fires in Victoria the "volunteer" fire service (Country Fire Authority) proposed that it take over the Fire Management Branch of the public land manager. (Dept. Sustainability and Environment). The Victorian Government Inquiry into the fires rejected the proposal saying of it: *"We believe the obligation and responsibility of public land managers to prevent and respond to fires on the land under their stewardship is better protected if the appropriate resources remain within DSE."* The McLeod Report into the Bushfires in the ACT in 2003 was critical of decisions to merge the bushfire expertise of land management agencies with ACT Bushfire Services. In summary, CALM must be a fire authority in its own right, it must be supported by good legislation, and it must be accountable for its actions or lack of actions.

Good fire management planning, policies and intent will not alone ensure that ecosystems will survive in their present form. Recent fire events in the eastern States caused massive environmental damage including irreversible changes to ecosystems on public lands in the iconic 'Man from Snowy River" country where *'pine-clad ridges raise their torn and rugged battlements on high"* (A B Patterson). Dr DH Ashton, an eminent forest botanist and ecologist with over 50 years of experience in the area, saw the effect of the fire recently and wrote: *"Therefore in this area there has been a major ecological consequence of the fires. A short forest dominated by Cypress pine will be replaced by open woodland of multi-stemmed White Box until such time as dispersal from unburnt Callitris succeeds in re-establishing the original stand. Given the severity of the site conditions this may take a very long time to achieve (if ever)".* This happened because someone failed to do the work on the ground needed to prevent the scale and intensity of the fires. Fuels that accumulated over decades where natural fires caused by lightning had been deliberately extinguished and little or nothing had been done to reduce the accumulating fuels by planned burning or any other means fed the fires. In those places the fires were feral, behaving in ways and causing effects alien to the natural processes that most ecosystems require for health, diversity and sustainability. The Agency managing the public land must have the unfettered duty to do the work and it must report to Parliament annually whether or not it has discharged its duty and if not, why not. If CALM does not have that duty, or fails to discharge it, vegetated landscapes in south-west WA may suffer damage in the next decade or so similar to that described above. **(Recommendation 3.)**

P 2.Priorities at the interface.

The interface between public land and private land (both rural and urban) poses special problems for fire managers. The Report of the Bushfire Review Committee following the 1983 Ash Wednesday fires in Victoria says of the problems: *"Communities, often commuter-orientated, have chosen to live cheek by jowl with an enormously hostile and dangerous environment. Often dwellings are left vacant by day as man and wife go out to work, or a wife and small children are left on their own. The risk to life and*

property does not end there. Other major factors are involved. They include, for instance that many such communities have no background of living in the bush and are generally unused to fending for themselves under fire conditions. Additionally, some of those with an interest in preserving the environment resist measures designed to remove hazards. However perhaps the worst of all, the fire fighting problem in these areas where high fuel levels and relatively crowded populations co-exist is probably the most difficult to manage".

Demographic changes continue in all States including WA and have increased the problems as more people choose to live in fire prone environments, and primary and secondary industries including some multi-million dollar enterprises, establish assets close to and sometimes on public lands. The potential for death and destruction by fire at the interface between public land and private property is enormous and no Agency will survive long if it fails to give priority to the protection of life and high value assets. The areas where this policy applies are identified in Bushfire Risk Management Plans. In WA they comprise a very small part of the total CALM lands estate and on those areas some conservation values may be sacrificed for a greater community benefit. In some places they may comprise a large proportion of a small discrete area and in those places special and costly strategies may be needed to minimise the loss of conservation values.

P 3. In-house planning.

Best practice requires that CALM is responsible for the preparation and review of Fire Management Plans for all CALM lands. FMP's include objectives for planned and unplanned fires and the holistic operational requirements for both. They may apply to a broad area, e.g. an administrative unit, a discrete area or they may be a sub-plan of another Plan, e.g., a Park plan of management. FMP's must mesh with land use Plans and WA Bushfire Risk Management Plans. And crucially, they must not be compromised by any other Agency.

P 4. Fire must be managed.

Ecosystems in south-west Western Australia are in many ways dependent on fire for regeneration and for the rejuvenation of ecological processes. The ecosystems existing today on CALM lands are not static. They evolved in response to climate change and changes in fire regimes over millennia. Prior to Aboriginal occupation, lightning caused the fires. The Aborigines changed the oldest regimes when they added their cultural and accidental fires to the landscape. European settlement caused further and abrupt changes when it extinguished Aboriginal burning and replaced it with fires lit deliberately to clear land, reduce vegetation perceived to be hazardous and to promote a "green pick" for domestic animals. European settlement also shrunk the ecosystems that existed prior to about 1826. Farms, houses, hamlets, towns, water storages, mines, cities and infrastructures obliterated what went before on large chunks of the landscape. These assets and the values associated with them are not compatible with uncontrolled and/or unplanned fires. Ecosystems and societies continue to change as fuels on CALM lands increase, assets and values on private lands increase and communities react to perceived threats to biodiversity, water supplies, air quality and lifestyles.

The option of totally excluding fire is impossible to achieve and illogical because most Australian ecosystems need fire for health and diversity. And the option to let nature take its course vanished when Europeans arrived in south-west WA. Fires caused by lightning still occur, but no longer have the luxury of spreading without conflicting with contemporary culture, lifestyles, assets, values and perceptions. And large intense fires cannot be controlled until they run out of fuel or the weather changes.

The only viable option is to manage fire by using it in ecosystems when and where it is needed to sustain or improve their health and biodiversity and excluding it when and where it has potential to degrade ecosystems and/or damage life and property. WA has the knowledge, skills and technologies to do this. A mind set within sections of the community that sees prescribed burning solely as a tool for production forestry or for protecting assets is an impediment to this option if it is allowed to sway Government policies and CALM's decision making. That mind set is out of step with current thinking of mainstream ecologists and environmentalists. They know that fire is necessary for the health and biodiversity of most ecosystems and that prescribed burning is an ecologically- conscious tool to achieve that objective and to mitigate the damaging effects of large intense wildfires. Even the Wilderness Society of USA, a long time opponent of any sort of manipulation of natural events, now accepts the mainstream thinking. Its spokesman said of recent fires in California, *"it's critically important we prioritize protecting homes and communities, but at the same time we need to restore fire to wild lands in a safe way through prescribed burns."*

P 5. Research and Development.

WA has benefited from the best forest fire research programs in the world. Those programs provided the science and technical know-how that underpinned forest and fire management for decades. WA also has an enormous amount of scientific knowledge about fire in its ecosystems. This knowledge and expertise must be continually updated and not lost, abandoned or ignored as the focus of land management changes to meet new challenges. In-house research is the quickest way to get findings translated into practice. It also runs the risk of bias, so needs to be supported by external independent research.

P 6.Training.

Safety of personnel in all work places must be a top priority for all managers. Competency based fire training improves the understanding by personnel of their roles in fire management and the efficiency with which personnel are deployed. It allows interchange of personnel across jurisdictional, State and national boundaries.

P 7. Accountability.

There must be sound systems in place to record, analyse and independently audit planned and unplanned fire events. Without these systems there is no reliable basis on which fire management policy and strategies can be adjusted in the light of new knowledge based on science and experience. Nor can poor performance be exposed in a timely way. Auditing should be done within CALM. It should also be done external to CALM within the Minister's portfolio and it must also be done external to both otherwise the process will not be seen as independent. The office of the Auditor General is seen as independent and should conduct external audits. **(Recommendation 4.)**

P 8. Value all Assets.

Ecosystems in south west WA are an asset that requires to be valued by the community in the same way that any other asset is provided with a value that guides its management and protection. The intrinsic values of wilderness, water catchments, biodiversity, cultural sites and the like are valued by the community as much, and often more, as are tangibles like saw logs and gravel and the community expects them to be protected. Assigning a value to both tangible and intangible assets provides a valid basis for

prioritising expenditure in accordance with community expectations rather than in response to episodic fire events. **(Recommendation 5.)**

Summary of key elements of "best practice" fire management Strategies/ Practices.

The following strategies are accepted widely by Agencies, including CALM, managing fire on public lands and also by managers of private forests.

S 1. Prepare for each administrative field area, and keep under constant review, Fire Management Plans. (FMP). FMPs shall include objectives for planned and unplanned fires and the holistic operational requirements for both. Objectives for planned fires shall include specific goals identified for the health of and biodiversity in ecosystems and the prescriptions required to manage such fires safely and effectively. Objectives for unplanned fires shall include effective pre-suppression, suppression and post- fire recovery and the operational requirements of each. Performance standards and an annual works program shall be part of each FMP.

S 2. Arrange for every FMP to be integrated with WA Bushfire Risk Management Plans and WA Bushfire Plans of Operation.

S 3. Maintain independently or where appropriate with co-operation of other agencies, an initial attack system that is rapid, aggressive and effective and with the capacity to control unplanned fires quickly. When an unplanned fire is not considered to be an immediate threat and initial attack is deferred, the occurrence of the fire and the reasons for deferring control action shall be recorded.

S 4. Maintain a fire detection system that gives timely warning of fires threatening CALM lands and adjoining lands.

S 5. Maintain a system of roads, fire trails, airfields and helipads for access and safety of personnel managing fires. The standard of access shall accommodate occupational health and safety expectations of volunteers that may use the access during fire emergencies.

S 6. Develop and use guidelines to manage smoke from planned burns to reduce atmospheric haze in Perth's airshed.

S 7. Develop and use guidelines, prescriptions and standard operating procedures to plan and conduct prescribed burning.

S 8. Conduct and participate in programs to minimize the occurrence of preventable fires.

S 9. Schedule staff training programs at all competency levels to achieve specific numbers of staff needed to manage planned fire programs and unplanned fires.

S 10. Organise the total resources of the Agency into an effective and efficient fire authority capable of combating simultaneous fires and integrating with other fire agencies in campaign fires.

S 11. Rehabilitate and restore disturbance and damage to areas damaged by fire operations.

S 12. Engage professionally trained teachers and journalists to improve community awareness and understanding of vegetation fires and best practice fire management based on science, experience and accountability.

S 13. Record, store and periodically analyse weather records necessary for calculation of indices used for research and prescriptions for planned burning.

S 15. Maintain formal liaison with fire authorities and land management agencies in other States.

Rationale.
In my experience, only two of the strategies listed above are accepted with reluctance by some Agencies. They are:

S 3. Recording deferred action.

Unplanned fires can occur at places and/or at times when it is not necessary for a number of reasons to mount a rapid and sometimes costly initial attack. On the other hand there are recorded instances of large and damaging fires that became so because initial attack was deferred when the fires were first detected. The requirement to record the occurrence of an unplanned fire and the reason for deferring action to control it worries some fire management staff. Personal judgment is involved in making the decision to defer and some feel that they are putting their reputation under too close scrutiny by having to record their decision. Most opinion is, and I agree, that better decisions are made when staff involved are required to record the fire and the reason why action to control it was deferred.

S 12. Communicating with the community.

"Best practice" fire management will not have community support if it is not understood and trusted by the community and it will not be allowed to happen if politicians believe it does not have community support. Few professionals within fire management Agencies have the training or acquired skills to communicate well with the many publics within the community including, and in particular, those in cities remote from field based fire managers. Professionally trained teachers and journalists are needed to help do that job. Fire managers do not always realise they need that help.

TERM OF REFERENCE 2.

"Provide advice on how this best practice would apply to the Department of CALM's Swan, South West and Warren regions, taking into account the range of ecosystems and climatic conditions in those regions."

The range of ecosystems and climatic conditions across CALM's three Regions does not in itself, pose a significant problem. The vegetation and climate parameters needed to apply "best practice" are well known and understood. The skills required to implement "best practice" are also well known and the technologies are available. With respect to prescribed burning, CALM's current strategies produce variable fire behaviour within each burn block. This is due to topography, variable fuel loads, diurnal fluctuations in fuel moisture content, fuel moisture differentials between aspects and because every

individual ignition within a block produces head fires, flank fires, junction zone fires and tail fires. And some areas within each block do not burn. This variability in fire behaviour plus unburnt areas, produces a mosaic of fire effects on the vegetation and hence contributes to biodiversity. CALM's strategies and technologies also allow the range of fire intensities within a block to be manipulated. Varying the timing and spacing of individual ignitions within a block does this. CALM therefore has a very flexible and effective tool for prescribed burning. It can achieve any one of several specified outcomes and is flexible enough to shift from one objective to another during the conduct of a burn if the need arises.

The larger the block the greater the variation in topography, moisture, and fuels and therefore the greater the potential for a burn to contribute to biodiversity. A downside is that the larger the block the greater the risk that fires will rekindle and exceed the prescribed intensity on parts of the block and/or escape control lines. CALM's current strategies usually use established roads and tracks as the boundary of blocks to be burnt. The roads and tracks are essential for safety of personnel, to allow ground crews onto the blocks and to confine the fires within the blocks. A significant problem will arise if CALM, as a result of changed priorities or new information, finds the need to confine fires to smaller blocks, specific landscape or ecological units or to exclude fires from small discrete areas within blocks. This may require new roads to be built and the cost and environmental impact of new roading will be considerable. The cost of prescribed burning escalates dramatically as the size of the blocks to be burnt decreases and any perceived need to reduce the size of blocks and/or build new access should be thoroughly examined and justified otherwise the increased costs will cripple prescribed burning programs.

A more serious impediment to applying "best practice" fire management is that CALM has no legislative support to manage fire to achieve one of its core objectives stated in its Corporate Plan as *" To protect, conserve and where necessary and possible, restore Western Australia's natural biodiversity"*. It may be that this situation arose because CALM inherited the legacy of its predecessor WA Forests Department, that for decades assumed the role of a fire authority and did the job so well that the community and successive Governments saw no need to change fire legislation. Recent legislation that created the Conservation Commission of WA and the Forests Products Commission did not address fire issues. Furthermore, the various statutes that should provide an interlocking framework for "best practice" fire management in WA are seriously flawed. Powers, roles, duties, obligations, accountabilities and responsibilities are not clear and sometimes ignored. Gaps are band-aided over with M'sOU that in law, are not binding on the parties and cannot be enforced. In summary, WA now has the situation where there is no overarching legislation that drives bushfire planning and risk assessment, no legislation that guarantees a single supreme controller of a multi-agency fire and CALM is a de-facto fire authority without legislative support to manage fire to achieve a core objective namely, biodiversity. In this circumstance, a future fire event that triggers a judicial Inquiry will expose the Government, Ministers, Agencies and key bureaucrats to the charge of failing to do what should have been obvious, namely, get the legislation and administrative guidelines right. The possibility that a future fire event causes social disruption and enormous damage to biodiversity must be contemplated. **(Recommendations 1, 2 and 3)**

TERM OF REFERENCE 3.

"On the basis of the above:

- *review CALM's current fire management policies and practices applying in its Swan, South West and Warren regions; and*
- *provide advice and recommendations on changes that should be made to meet best practice standards."*

Legislative issues.

(Advice with Recommendations on issues outside the ambit of the Conservation and Land Management Act 1984 is given in Terms of Reference 1 and 2.)

CALM does not have a clear and unequivocal duty in law to manage fire on lands that it manages. CALM's primary legal obligation comes from Section 28 of the Bush Fires Act 1954:

(1) (a) where a bushfire is burning on any land—
(i) at any time in any year during the restricted burning period; or
(ii) during the prohibited burning times,
and the bush fire is not part of the burning operations being carried out upon the land in accordance with the provisions of this Act, the occupier of the land shall forthwith, upon becoming aware of the bushfire, whether he has lit or caused the same to be lit or not, take all possible measures at his own expense to extinguish the fire.

This is an obligation to react to unplanned fires. The Conservation and Land Management Act 1984 confers some powers on some officers to take actions relating to fires considered to threaten CALM lands and fires lit illegally but does not specify a duty to manage fire pro-actively to meet one of its core objectives stated in its Corporate Plan as "To protect, conserve and where necessary and possible, restore Western Australia's natural biodiversity". The Wildlife Conservation Act 1950 makes CALM responsible for the conservation and protection of native flora and fauna on all land and water in WA but is silent on pro-active fire management. CALM's duty to manage unplanned and planned fires may be implied because fire management is inseparable from vegetation management. But good legislation must do better than leave things to be implied by whoever is making decisions at any particular time or in any political climate. The duty must be established by Parliament, it must be clear and unfettered and if amendment is thought necessary, it should be amended by Parliament.

Another legislative issue with potential to jeopardise best practice fire management on CALM lands is the process for approving fire management Plans. Most of the approved management Plans made available on the Department's naturebase web site for review are either out of date or have been overtaken by structural changes in the Agencies involved. That is understandable and is not of concern in this Report. But the legal process by which some of those Plans were developed and approved still applies and does not follow "best practice" planning for fire management. To illustrate the point, the Lane Poole Reserve Management Plan 1900-2000 describes the process as follows: "*The NPNCA* (now CCWA) *is responsible for the preparation of management plans for all land which is vested in it. These plans are prepared by CALM and issued by NPNCA* (now CCWA) *as draft plans for public comment. The NPNCA* (now

CCWA) *followed this procedure for the Lane Poole Reserve and submitted the plan, revised to take the public comment into account, to the Minister for the Environment for approval."*

CALM is the foremost Government authority on fire management on CALM lands and furthermore, CALM must manage fires on them. A process that requires or even allows CCWA to take a fire management Plan prepared by CALM, seek public comment on the Plan and amend the Plan in light of public comment and then seek the Minister's approval of the Plan is seriously flawed. It has potential to deny the Minister advice from CALM about changes made by CCWA based on comments from the public and for CALM to have to manage land in accord with a Plan that does not reflect best practice fire management policy or strategies. CALM staff explained to me that the process actually works differently and that CALM would be aware if a draft fire management Plan was amended by CCWA and would do something about it if the amendment were not acceptable to CALM. It would do so on the basis that there is a good working relationship between CALM, CCWA and the Minister. I accept that is the case in 2004, but it begs the question. Political climates, Governments, Agencies and individuals in them change over time and good working relationships cannot be guaranteed. This issue is too important to leave dormant. Legal processes with similar flaws have had serious consequences in other States recently and its significance should not be dismissed casually. **(Recommendation 6).**

CALM's Policies.

CALM's document titled Draft (Feb 2004) Fire Management Policy and was reviewed and benchmarked against "best practices" identified in this Report. The document reflects poorly on CALM. It is a statement **about** policy and does not identify specific policy or policies that drive strategies to achieve one or more objectives. At best the document is confusing. I hold the view that policies should be succinct and capable of standing alone without supporting explanation. Of course, in most cases policies will be presented with allied strategies, arrangements, supporting rationale and the like, but that does not justify why the public has to read an 8 page Government document and still not be sure what is or are CALM's fire management policy or policies. **(Recommendation 7)**

Furthermore, the first paragraph under **1. OBJECTIVE** puts protection of life and property secondary to protecting biodiversity. That is not "best practice' and conflicts with policy statement **(5. Policy)** in the document. The paragraph should be re- phrased to comply with "best practice" policy.

Policy 5.1 dot pt 9.also falls far short of "best practice". Audits by the Conservation Commission of WA are, and will be seen to be, internal audits within the Minister's portfolio. They are not independent of the Minister's portfolio. Whilst there is a place for internal audits within CALM and within the Minister's portfolio, they must not substitute for, or hide the need for external independent auditing. The office of the Auditor General will be seen to be independent and should conduct such Audits. It may be that CALM's system of collecting and recording information already conforms to standards acceptable to the Auditor General. That should be ascertained and if not, the advice of the Auditor General should be followed.

I also disagree with the rationale (Page 6, dot pt. 8) that areas from which fire is excluded "*provide an important benchmark against which the effects of other fire regimes can be evaluated*". Fire should be excluded from some ecosystems because they do not depend on fire for regeneration and health in the long term. Those areas are not the norm across all ecosystems in south-west WA and are not appropriate benchmarks for evaluating fire regimes in other ecosystems. If CALM intends that the rationale apply to areas within ecosystems that depend on fire for regeneration and health in the long term, fire excluded areas can be useful reference areas for science but they are not "control" areas for benchmarking other fire

regimes. All statistical analyses using fire excluded areas as a basis for the "null hypothesis" would show a significant result and are meaningless and misleading. The rationale should be deleted from the Document.

On planning issues, the Document is unclear and potentially confusing about planning processes and the hierarchy of plans for fire management. Terms used include "master burn plan", "prescribed burning plans", " plans prepared by the Department", "fire preparedness and fire response plans" and "fire management plans". There is no clear definition of what these plans are, how they relate to each other, how they are prepared and reviewed or how they are matched with Plans of other agencies. A policy document about Plans does not have to detail the content of Plans but it must state their purpose, objectives and any interlocking arrangements, legal and otherwise, with other Plans. Without this clear definition, most members of the community with an interest in management of public lands will not understand the fire management planning process and some will not trust it.

CALM's performance.

In this desk exercise I assessed CALM's prescribed burning program as follows. CALM's planned program of prescribed burning post 1996/97 is about 200,000 ha. or approx. 8% of the total estate per annum. The program started to decline in 1996/97 and the annual target has not been achieved in any year since then. It may be achieved in 2003/04. The accumulated shortfall totals about 450,000 ha. or about 18% of the total estate. Wildfires burnt about 137,000 ha. in 2002/03, well above the 10-year average of about 36,000 ha. Assuming (without verification) that the wildfires burnt some areas programmed for prescribed burning, it still leaves a significant area carrying fuels older, heavier and more hazardous than CALM believes is desirable. The shortfall equates to about a 2-year works program and this increases every year the target area is not achieved. Two questions arise from the analysis. One is, can CALM redress the shortfall and achieve its target program in the future? The other is, does CALM's current program benefit biodiversity on its lands or is it detrimental to biodiversity?

Documents made available suggest that the answer to the first question is that CALM is unlikely to make up the shortfall and will have difficulty maintaining the existing program in the immediate future. CALM lost 38% of its field based personnel between 1999 and 2001. Since then the number has increased but is still more than 20% below the 1999 figure. Downsizing to that extent so quickly must be expected to have a negative effect on planning for prescribed burning and the quantity and quality of burns. The recent decline in area of prescribed burning, co-incident with loss of staff suggests it is a reason for the decline. The negative effect on planning may not be apparent for some time because good planning must start years before the planned burns occur. Also, CALM's organisational structure suggests that fire management is no longer a core activity. Prescribed burning programs have to compete at the corporate level for resources in competition with all other programs. And at CALM's senior corporate level, the playing field appears unbalanced because the Director, Fire Management is not present and Regional Managers who implement prescribed burning programs are not accountable for outcomes to the Director, Fire Management. Unlike many other tasks CALM must undertake, safe and effective prescribed burning depends on "windows of opportunity" that often cannot be predicted well in advance, can appear or disappear overnight and can be few one year or many the next. The Director, Fire Management must have the clout to influence shifts in funds and resources as opportunities arise to do safe and effective burning. In some years the shift might be large and not appreciated or accepted by Directors of other programs.

The emergence of the Forest Products Commission has not improved CALM's ability to manage fire on its lands and there are reasons why its ability to assist may be less in the future. The Commission is a

Government Authority with the role of harvesting on a sustained basis and selling forest products grown on CALM lands, in other words a commercial enterprise with a conservation conscience. It is required to pay an appropriate return (profit) to the State for that exploitation, to undertake an analysis of the risk from fire to its native timber production resources and to provide CALM with the funds CALM needs to control the risk to acceptable levels, so far as is reasonable and practicable. It appears that at this time, the Commission has not paid any money to CALM to manage the risk. The Commission can make a profit only if the revenue it gets from selling forest products exceeds cost of production and overheads. It has little control over the price it charges for its forest products because that is determined in the market place in competition with other suppliers of forest products. Competitiveness can be improved by cutting overheads, lowering operating costs by contracting and/or using strategies that are less labour intensive. That is likely to happen and if it does, CALM's ability to manage fire and fire risks will suffer.

The question of whether or not CALM's strategies are beneficial or detrimental to biodiversity is too important to dismiss with a trite answer like "nobody knows" or by over- generalising. If the question addressed a specific vegetation alliance the answer is probably known or easily found. Using an eastern State example to illustrate the point, and at the risk of oversimplification, science has established definitive information that Mountain Ash *(Euc.regnans)* grows in even-aged stands that regenerated after a major disturbance, usually a fire of high intensity that killed the parent trees. Initially, for the first 30 –50 years after the fire, the new forest has an understorey dominated by Acacias. As the forest matures the Acacias live out their life cycle and are replaced in the understorey by other genera. Mountain Ash does not produce enough seed for regeneration until it is about 30 years old and thereafter, not in every year. In the absence of intense fire, it lives out its life cycle in about 300+ years and other genera then dominate the forest. If an intense fire occurs before Mountain Ash is old enough to produce seed or later in a year of poor seed production, other genera will dominate the new forest. The optimum fire regime for this vegetation alliance is one intense fire after age 30, before senescence is too advanced and in a year when there is a good crop of seed. On the other hand, one intense fire before age 30 or in a poor seed year, or two intense fires within about 30 years or no intense fire for 300+ years would be detrimental to the alliance. Science has established definitive information for other vegetation alliances, including many in WA, that identify fire regimes optimum for their survival in the long term. Science has also identified optimum fire regimes for specific species of plants and animals and for specific management objectives, including mitigating the damaging effects of wildfires. Science also shows that a specific fire regime or prescribed burning program can benefit one ecological process and harm another. This latter point is one reason why there is so much robust debate about prescribed burning; it can be good or bad depending your point of view.

A problem with analysing CALM's current prescribed program in terms of its effects on biodiversity is that scientific studies, excellent as they are, are of limited help. They usually focus on a very small part of the whole and rarely address issues on the scale of landscapes where many varied and complex vegetation alliances exist and where people are part of the environment, have a right to be there and to be heard. CALM must work and deliver best practice fire management in that environment and often finds itself having to make decisions that cannot please all interested parties. More scientific research will improve everyone's understanding or the role of fire in ecosystems but it will never resolve conflicting views on specific issues. And the need for further research must not be a reason why prescribed burning programs should be scaled down pending new information.

There is considerable concern in WA that CALM's prescribed burning program is biased towards "fuel reduction burning" to mitigate the effects of wildfire and that it is detrimental to specific species of plants and animals and to biodiversity. There is little evidence based on science or experience that prescribed

burning has been detrimental to specific species or biodiversity and the concern seems to be based on a perception of something that might happen rather than on something that has happened. There is compelling evidence worldwide that prescribed burning programs, managed by people with experience and a range of skills and with a good knowledge of fire and natural history science, can maintain healthy and biodiversity ecosystems across landscapes. CALM's current prescribed burning program is biased towards mitigating the damaging effects of wildfires but the concern is not justified right now. The EPA and CALM's must not lose sight of the fact some of CALM's lands now carry vegetation residues that, because of fire suppression action, has not been recycled by natural fires caused by lightning. Those residues do not decompose quickly, and if they accumulate for many years they are a risk to natural ecological processes even if unburnt. There is compelling evidence that failure to modify those fuels dooms ecosystems to feral fires that reduce biodiversity, cause other serious environmental damage, not the least of which is water quality and quantity, plus social and economic damage. The decline in the amount of prescribed burning since about 1995, downsizing of CALM, relegation of fire management to a non-core activity, and creating a commercial agency to harvest and sell forest products, mirror events that started in the eastern States a decade earlier and were not redressed before feral fires in 2003 burnt 1 million hectares of parks and State forest in one conflagration in Victoria and a similar area elsewhere. In Victoria, 53% of the "treed" area (527,100 ha) impacted by those fires, was burnt by fires intense enough to severely scorch the tree crowns or burn them right off. And most of that damage occurred on only three days. That must be a wake up call for Western Australia.

CALM's strategies. (Recommendation 8.)

Calm's strategies and "tools of trade" were reviewed in detail and are without doubt, "best practice." The management of and presentation of all information pertaining to fire management at operation level warrants special comment. The information is assembled in a Fire Operations Manual and presented on CD disk containing more than 70 Fire Protection Instructions. They cover the full range of issues that field staff need at their fingertips to guide their day-to-day work. The Instructions can be amended, added to or deleted from, at any time and staff can access and retrieve information they need easily and quickly. It is in my experience, without peer. It contrasts with some other Fire Management Manuals seen recently that are not user friendly and remain current until the Departmental Head signs off on a revised edition of the whole Manual. Parts of those Manuals became obsolete long before they were reviewed and the new edition approved.

TERM OF REFERENCE 5

"Identify outstanding issues for research or improved knowledge that are necessary to provide the capacity to improve fire management policies and practice in south western Australia on an ongoing basis."

CALM currently conducts or sponsors more than 40 research projects related to fire effects and its management. As indicated before in this Report, WA has benefited from a strong commitment to fire research over many decades. That commitment still exists and the current program has no peer anywhere in the world. I found only two issues that are not directly addressed in the current programs where research or development of methodology may, in time, improve fire management.

One is that the role fires caused by lightning play in shaping ecosystems on CALM lands needs to be better understood. A research project is needed to record the projected path of every lightning caused fire from its detection to the time when, in the absence of suppression action, it would have stopped spreading. CALM has good information on vegetation types, fuel ages and loads and rates of fire spread for the full range of fluctuating weather and fuel moisture conditions needed for the study. Portable automatic weather recorders are available to record diurnal fluctuations in the weather at remote locations so there are no serious technical problems to overcome. There will be some logistic problems organising fieldwork during peak periods of lightning activity. **(Recommendation 9)**

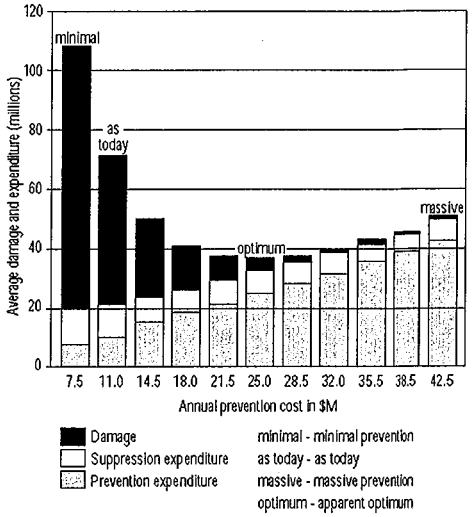
The other issue arises from the need to balance the risk/costs/benefits of prescribed burning and is dealt with next in Term or Reference 6.

TERM OF REFERENCE 6.

" Balance the risk/costs/benefits of prescribed burns versus wildfires".

I am of the opinion that CALM, together with all other Agencies responsible for managing public lands in Australia, is not in a position to balance the risk/costs/benefits of prescribed burns versus wildfires. But it is important that CALM does so. As stated earlier in this Report, ecosystems in south-west WA are an asset that requires to be valued by the community in the same way that any other asset is provided with a value that guides its management and protection. Until such time as CALM is able to put a monetary value on all assets, including intangible assets on its lands, financial support for conservation will continue to wax and wane in response to good and bad fire seasons. There is plenty of anecdotal evidence of prescribed burns reducing the spread and intensity of subsequent wildfires and hard evidence from "case histories". There is no good methodology currently available to translate that evidence into a cost/benefit analysis.

One analysis of forest fire management conducted in 1997 by economists in Victoria concluded, *"for every $1 spent of funding allocated to fire management, Victoria benefits by $22 in saving costs."* That analysis considered all facets of forest fire protection, not just prescribed burning, and made many assumptions along the way. Another model developed in Victoria in the 1990's is illustrated below. It used more than 50 years of fire history on public lands and shows the cumulative relationship between costs of fire prevention, fire suppression and damage. That model shows considerable promise and should be investigated.



Two things must be done before it is possible to know how to strike a balance between the risks/costs/ benefits of prescribed burns and wildfires. They are further work to develop a model that assesses the appropriate balance and importantly, CALM must put a value on its lands that reflect what the WA community is prepared to pay to sustain ecosystems in a healthy condition. **(Recommendation 5.)**

Appendix 1.

SCOPE OF WORK FOR
ANALYSIS OF FIRE MANAGEMENT POLICIES AND PRACTICES OF THE DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Using knowledge of recent fire research and findings from inquiries into recent major fires, including those in NSW, ACT and Victoria:

1 Provide advice on what would comprise the key elements of current 'best practice' fire management policy and practice for southern Australia; and particularly South West Australian vegetative and climatic conditions in relation to prescribed burns and wildfire.

2. Provide advice on how this best practice would apply to the Department of CALM's Swan, South West and Warren regions, taking into account the range of ecosystems and climatic conditions in those regions.

3. On the basis of the above:
   - review CALM's current fire management policies and practices applying in its Swan, South West and Warren regions; and
   - provide advice and recommendations on changes that should be made for those policies and practices to meet best practice standards.

4. Undertake a case study analysis of a recent wildfire event or events to determine the extent to which CALM policies and practices provide for adequate management of wildfires and their consequences in terms of biological, social and economic impacts.

5. Identify outstanding issues for research or improved knowledge that are necessary to provide the capacity to improve fire management policies and practice in south western Australia on an ongoing basis.

6. Balance the risks/costs/benefits of prescribed burns versus wildfires.

As part of this consultancy the contractor would be required to:

(a) prepare and submit a draft and final report to the EPA;
(b) provide a briefing to the EPA on the draft report;
(c) Meet with EPA and CALM staff to agree on an appropriate wildfire event to analyse; and
(d) be very familiar with recent fire inquiries into fire management in Australia.

Appendix 2.

Report of the Board of Inquiry into the Occurrence of Bush and Grass Fires in Victoria, 1977. ("Barber Inquiry")

Report of the Bushfire Review Committee on Bushfire Disaster Preparedness and Response in Victoria, Australia, following the Ash Wednesday Fires 16 February 1983. ("Miller Report").

Review of Vegetation-based Fire in Tasmania, 1993. ("Bale Report").

Report of the Fire Review Panel conducting a review of the CALM prescribed burning Policy and Practices And Wildfire Threat Analysis, 1994. ("Lewis Report").

Coronial Inquiry into the Linton Fire, Victoria 1998.

Inquiry into the Operational Response to the January Bushfires in the ACT 2003. (McLeod Report)

Report of the Inquiry into the 2002-2003 Victorian Bushfires. ("Esplin Report").

Report on Inquiry into 2001/2003 Bushfires, NSW Joint Select Committee.("Price Report").

A Nation Charred: Inquiry into the Recent Australian Bushfires, 2003. ("Nairn Inquiry").

Coronial Inquiry into the ACT fires—current. Daily summaries of proceedings.

FIRE REGIMES AND BIODIVERSITY CONSERVATION: A BRIEF REVIEW OF SCIENTIFIC LITERATURE WITH PARTICULAR EMPHASIS ON SOUTHWEST AUSTRALIAN STUDIES

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ABSTRACT

To assist the EPA in its review of fire management by the Department of Conservation and Land Management, this paper briefly reviews the published scientific literature pertaining to the impact of fire regimes on biodiversity conservation. With some exceptions, literature on this subject is primarily descriptive, short term and correlational; and often lacks sufficient definitional and experimental rigour for conclusive and predictive statements on hypotheses to be drawn. Consequently, alternative interpretations and conclusions are commonplace, and much remains to be investigated.

Understandably, no studies address the role of fire in maintaining and protecting all biodiversity. The literature is selective as to species and communities investigated, with a focus on some vascular plants and some vertebrates. The importance of sampling effects, replication issues and surrogacy have rarely been tested. Taxonomic impediments and cryptic life history stages such as resting or dormant propagules confound attempts to rigorously sample biota. A few descriptive studies where effects of more than a single fire have been documented show changes in the relative abundance of some plants and animals. Rigorous experimental science has been applied to hypotheses relating to life history attributes with obvious fire effects, such as the role of smoke and heat on germination of many vascular plants. Fire exclusion combined with predator control and experimental translocation have led to increased abundance of rare vertebrates such as Noisy Scrub Birds. However, trends in metapopulation dynamics under different fire regimes are known for few organisms, and even less has been documented about interactions between fire effects and those caused by other processes such as disease attack, predation, herbivory, salinity etc.

Much more research is required to approach an adequate understanding of fire regimes and biodiversity conservation. Two broad streams are recommended – (i) long term descriptive and correlational monitoring studies to generate hypotheses on the impact of fire scale, intensity, season and patchiness – monitoring sites need to be replicated frequently across southwest Australian landscapes to adequately sample rapid geographical turnover in less vagile organisms such as most vascular plants, land snails etc.; and (ii) rigorous experimental studies with adequate sampling, replication and controls to test hypotheses and develop predictive theory regarding fire regimes and biodiversity conservation. High priority should be given to test current hypotheses enumerated herein.

INTRODUCTION

To assist the EPA in its review of fire management by the Department of Conservation and Land Management, this paper briefly reviews the published scientific literature pertaining to the impact of fire regimes on biodiversity conservation. We focus on southwest Australian studies as requested in our terms of reference (Appendix A). The review is limited to edited books and peer-reviewed scientific journals. Time available (one month) did not allow for the voluminous grey literature on fire regimes and biodiversity conservation to be consulted and considered. However, we have drawn upon the collective reading of the two junior authors of the scientific literature over the past two decades in addition to the month of intensive review conducted by the senior author.

The review is broadly structured in line with headings and subject areas identified in the terms of reference (Appendix A). However, to enhance clarity, two subjects are first addressed: (i) definitional issues and (ii) descriptive v/s experimental studies.

DEFINITIONAL ISSUES

Biodiversity is the variety of life – the genes, species and communities of all living things. *Biodiversity conservation* is the process of minimising extinction of living things – genes, species and communities.

Fire regime is the frequency, interval, season, intensity, scale and patchiness of fire. *Prescribed burns* are those ignited for the application of planned fire regimes by land managers. *Wildfires* are those ignited by nonhuman causes or by humans in a manner not planned by land managers.

Much confusion and debate has been generated by the use of scientific terminology in nonspecialist literature regarding fire regimes and biodiversity conservation. For example, evolutionary terms relating to "adaptation" require rigorous testing and proof to be accurately invoked, including experimental demonstration of function, heritability, and natural selection, and application of phylogenetic tests (Hopper 2003).

Needless to say, few traits of Australian biota have been subject to such rigorous tests to demonstrate the existence of evolutionary adaptations to fire. Yet many authors, including scientists, use terms such as "fire-adapted" when discussing Australian biota, rather than neutral terms such as "fire tolerant". These logical leaps lead some readers/listeners to draw the conclusion that a "fire-adapted" biota should therefore be able to deal with any fire regime it is exposed to.

A classic example is the commonly observed fire response of plants resprouting from underground rootstocks. Many authors glibly cite resprouting as an adaptation to fire. Yet it may be an effect of fire, with entirely different evolutionary origins, rather than an adaptation, since multiple other causes could select for resprouting – grazing, flooding, freezing etc.

DESCRIPTIVE V/S EXPERIMENTAL STUDIES

The foregoing highlights a major confusion often evident even in refereed scientific papers - that between a correlation or effect established in a descriptive study v/s a causal link established through rigorous experimentation. Descriptive studies can establish pattern and correlation, and help formulation of causal hypotheses, but they cannot establish causation. The latter requires rigorous experimentation with adequate sampling, replication and controls to test hypotheses. A further logical trap occurs when conclusions are drawn from extrapolations beyond those reasonably inferred from evidence at hand.

To highlight this difference, take a controversial contemporary southwest Australian example – inferences on historical fire regimes made from fire-scar patterns on balgas (grasstrees – Lamont *et al.* 2003). It has been elegantly demonstrated that a correlation exists between a change in the number of fire scars on grasstrees and the approximate dates of a change from Aboriginal to predominant European land management in the southwest (Figure 1). Fire scars appear more frequently (averaging 3-5 years) between 1860 and 1900 than subsequently (averaging 8-10 years since the 1950s). Some authors extrapolate this correlation to the whole landscape in which the balgas sit, arguing that Aboriginals burnt country on average every 3-5 years Lamont *et al.* 2003).

However, the evidence does not allow concluding anything more than that that individual grasstrees were burnt more frequently prior to European land management than afterwards. On the descriptive evidence available, to extrapolate from individual grasstrees to the surrounding landscape is not warranted. There are significant reasons why caution should be applied in this case. Firstly, a number of plants associated with the balgas require longer fire return intervals than 3-5 years to build up an adequate seed supply for replacement (Burrrows and Wardell-Johnson 2003). How could they have persisted in the landscape if the balga fire scar intervals applied to whole landscapes?

Secondly, palynological data and charcoal in fossil deposits similarly suggest longer average intervals (Hassell and Dodson 2003).

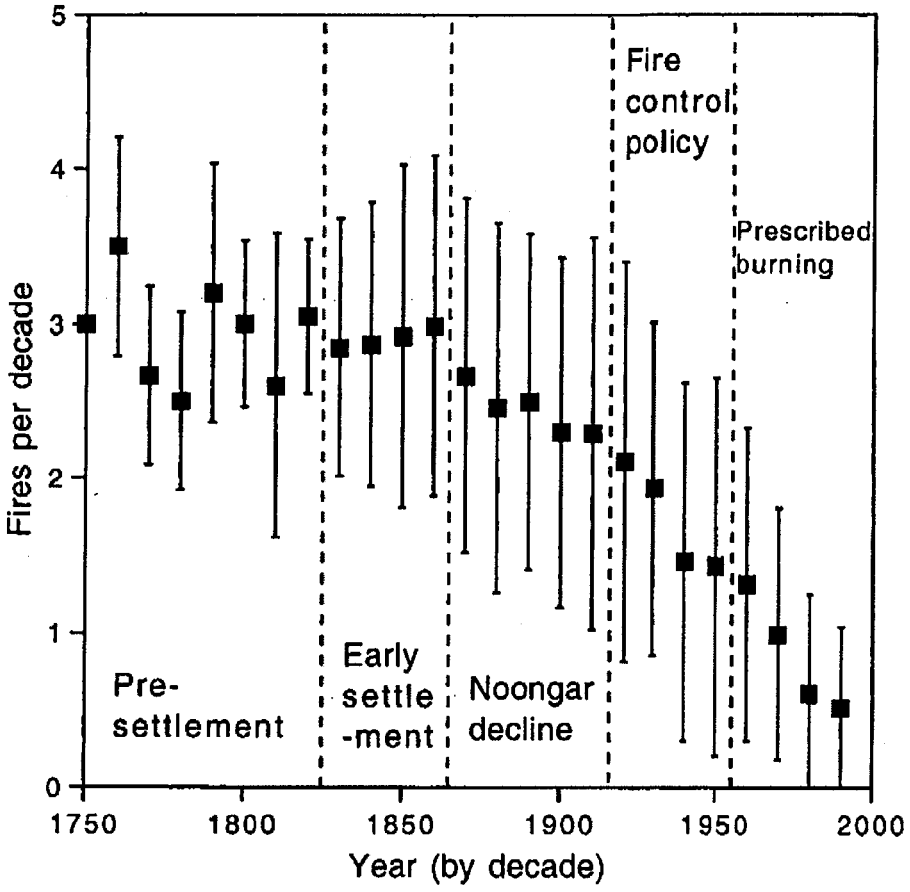

Figure 1: Mean number of fires per decade (± SD) for grasstrees at 50 sites scattered throughout the jarrah forest/woodland (Lamont *et al.* 2003).

Thirdly, it has been known since the journals of Banks and Menzies in the 18th Century that Aboriginal people burnt individual grasstrees for cultural reasons, especially to promote resinous exudates for use as glues, conceal their body odour, hunt for animals nesting within the grasstree, signal other people, etc. Given the sophisticated knowledge of fire use evident among Aboriginal people, perhaps they were able to burn grasstrees regularly for the above cultural purposes without incinerating the surrounding landscape. Evidence is therefore needed to falsify the hypothesis that surrounding landscape did not burn at the same frequency as inferred from fire scars on grasstrees before it could be argued that the fire scar pattern reflects a landscape pattern in fire regime. This is a difficult hypothesis to test in southwest Australia given that traditional Aboriginal land management is no longer practised. In such circumstances, it would be reasonable to simply note an interesting correlation (balga fire scars decrease in frequency over the transition from Aboriginal to European land management) but draw no conclusions regarding historical burning of landscapes from the balga fire scar data.

This is an exemplary case where alternative hypotheses can be invoked to explain a correlational pattern described from nature – balga fire scar frequency directly reflects landscape-level fire regimes v/s targeted cultural burning of balgas occurred independent of landscape-level fire regimes. Critical experiments are needed to test the competing hypotheses and ascertain more probable causal relationships. As will be evident, most of the literature we have reviewed below is descriptive and correlational in relation to fire regimes and biodiversity conservation. We should exercise similar caution in their interpretation, and be especially careful about extrapolation, inferring causation and predicting from correlations untested through rigorous experiment.

Although in the minority, there have been experimental studies that provide a link between attributes of fires and biodiversity. For example, increased germination of native species occurs after a smoke presowing treatment (Dixon *et al.* 1995, Roche *et al.* 1997a,b, Tieu *et al.* 1999). Studies were undertaken following observations that seedlings of some native species established only following

fire. These correlational observations prompted the alternative hypotheses that either heat, smoke, ethylene or some other attrribute of fire causes germination. Subsequent experimentation in the laboratory and nursery has determined that both heat and smoke (Roche *et al.* 1997a,b, Tieu *et al.* 1999) can promote germination of seed of many plant taxa. These studies have identified that components of fire can cause a recruitment response from native species and therefore provide a link to fire effecting some components of biodiversity.

SCIENTIFIC EVIDENCE OF THE IMPACTS OF FIRE ON BIODIVERSITY

Scientific Evidence of a Long History of Fire in South-West Western Australia

Fire in southwest Australia predates human occupation (Aboriginal and European) by millions of years (Atahan and Dodson 2004; Hassell and Dodson 2003, Dodson 2001). A number of pre-human fire intervals have been estimated from charcoal records, including:

- Sediment cores from Fitzgerald River National Park of 30-100+ yr intervals operating 4.6-2.7 thousand years before present (Hassell and Dodson 2003);
- Return periods of 5-13 years during the Pliocene in south-west Western Australia (Atahan *et al.* 2004).

Human influence on fire regimes commenced c. 50, 000 years ago with the arrival of Aboriginals (Roberts *et al.*, 1990, 1994 in Atahan *et al.* 2004; Turney *et al.* 2001 in Hassell and Dodson 2003). A number of methods have been employed to estimate the impact of human ignition on the fire regime including charcoal records (Atahan and Dodson 2004; Hassell and Dodson 2003, Dodson 2001), fire scars on elements of the flora including grasstrees (Lamont *et al.* 2003) and tree species (Burrows *et al.* 1995), and observations from the written records of early European settlers and explorers (Abbott 2003, Dixon and Barrett 2003). Some of these studies have suggested that fire intervals decreased following Aboriginal occupancy (Abbott 2003, Burrows *et al.* 1995. Ward *et al.* 2001) including the observation that modern-day Aborigines in northern Australia burn some areas annually (Haynes 1985). However, Hassell and Dodson (2003) suggest that this was only the case for areas permanently occupied by Aborigines and intervals remained much longer in areas into which they rarely ventured including the area presently known as Fitzgerald River National Park where intervals of 30-100 years persisted. Wardell-Johnson *et al.* (2004) suggested that while fire frequency increased with the arrival of Aboriginals, intervals between intense fires in the jarrah forest was in the vicinity of 80yrs. Post-European settlement, the fire regime has been altered again both through use of fire (e.g. prescribed burns), displacement of Aboriginals, and fragmentation of the landscape by agricultural and urban infrastructure. Fire intervals evident on kwongan grasstree scars following the 1940's were of the order of c.10 years, wih a range 2-26 (Lamont *et al.* 2003). Life history studies of *Banksia* species indicate a range of 10-16 years in the kwongan (Yates *et al.* 2003) . In the jarrah forest, post-European fire intervals of 5-7 yrs have occurred on balgas since arrival of Europeans with a current mean interval c. 8 yrs (Lamont *et al.* 2003).

This long history of fire has promoted two important hypotheses:

i) components of the biota have evolved with and adapted to fire (Burrows and Wardell-Johnson 2003, Bowman 2003). However, as pointed out earlier in this text, Hopper (2003) contended that the term fire-tolerant, rather than fire-adapted, more appropriately describes present knowledge for most organisms as there are alternative hypotheses to the evolution of the 'fire-adaptative' traits such as resprouting and bradyspory. There are three fire–response traits which require further examination to determine whether they are a true adaptation to fire: smoke induced germination, life cycles of fire ephemerals and fire induced flowering (Hopper 2003).

and, ii) a return to a historical fire regime may benefit biodiversity conservation. A number of authors query both the purpose and capacity for a return to historical fire regimes. Abbott (2003) questioned the value and potential of returning to Aboriginal burning practices pointing out that "Noongars set fires for their own purposes, especially for generating an ongoing food supply, and not for biodiversity conservation." Similarly, Lamont *et al.* (2003) questioned the value of reverting to a past fire regime as there have been no studies to determine if such regimes are optimal for the conservation of species. Hobbs (2003) also questioned reversion to past practices suggesting that "when considering fire regimes in fragmented systems, it is important to do so in the context of the vastly altered landscapes and communities which currently exist". Regardless of these historical patterns, the considerable changes wrought by Europeans on the Australian landscape (e.g. clearing, exploitation, fragmentation, introduction of weeds and feral animals) make attempts to restore historical regimes both problematic

and arguably inappropriate (Wardell-Johnson *et al.* 2004). For example, fragmentation of the landscape and current legislation that makes burning during the summer months illegal are obstacles to reinstating Aboriginal burning strategies (Abbott 2003).

In short, it remains difficult to ascertain how frequently areas were burned historically, what effect this has had on the evolution of the biota and whether a return to a historic fire regime would facilitate biodiversity conservation.

Scientific Evidence of Impacts of Fire Regime on Biodiversity Conservation

A few descriptive studies where the effect of more than a single fire has been documented have shown changes in the relative abundance of some plants (Burrows and Wardell-Johnson 2003, Yates *et al.* 2003) and animals (van Heurck and Abbott 2003). For example, the frequency of *Acacia browniana* in jarrah forest in southwest Australia has been shown to differ between areas under different fire regimes including wildfire and prescribed burns (Figure 2). Note that the abundance of this shrub varies complexly even when prescribed burns occur in the same season, such as autumn.

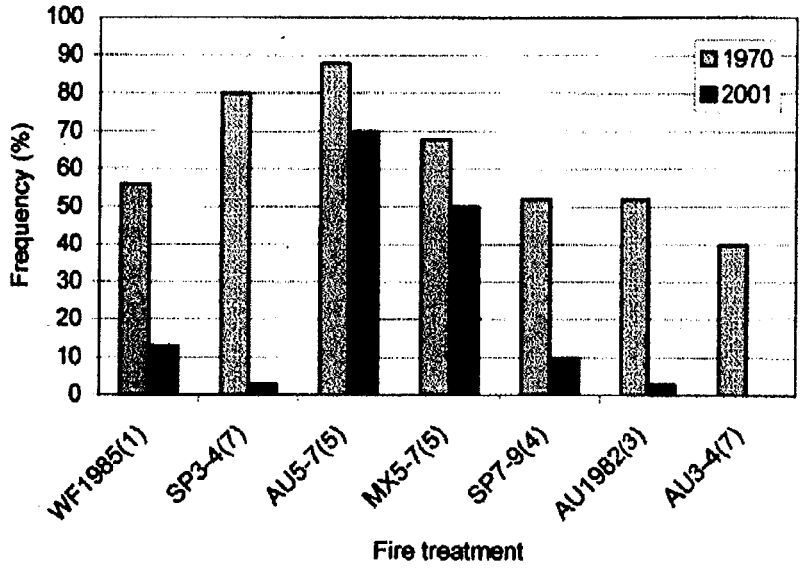

Figure 2: Changes in the frequency of occurrence of *Acacia browniana* (Mimosaceae) in sample plots in response to fire regimes over the period 1970-2001 in the Lindsay jarrah forest block west of Manjimup. Fire treatments over this period; WF1985 = a summer wildfire in 1985, SP3-4 = spring fire at 3-4 year intervals, AU5-7 = autumn fire at 5-7 year intervals, MX5-7 = fire various seasons at 5-7 year intervals, SP7-9 = spring fire at 7-9 year intervals, AU1982 = autumn fire in 1982, AU 3-4 = autumn fire at 3-4 year intervals. The number of fires experienced over the period 1970-2001 is shown in parentheses (Burrows and Wardell-Johnson 2003).

These results indicate that fire has the potential to alter biodiversity as it may result in changes to the abundance of some components of the biota. However, understandably there has been no empirical study which addresses the role of fire in maintaining and protecting all biodiversity as there are insurmountable impediments to this task including:

- Taxonomic restrictions: 5-10% of Australian fungi is named (Robinson and Bougher 2003), and it is probable that the current number of plant species in southwest Australia shall increase from c. 7500 to c. 8000 (Hopper 2003).
- Resource restrictions: there are an estimated 18 000 insect species in jarrah and karri forests (van Heurck and Abbott 2003), and an estimated 250 000 species of fungi in Australia (Robinson and Bougher 2003).

The large number of taxa alone prohibits monitoring for the effect of fire regimes on the entire biota. As such the literature is selective as to species and communities that have been investigated. A number of authors have noted a disparity in the knowledge on different components of the biota. Fire management is currently based on observations of too few taxa. Bamford and Roberts (2003)

contended that prescribed burning regimes were designed to maximise containment of wildfires but the variations, eg. spring v/s autumn burns, complete v/s mosaic burns, were largely designed from responses of vegetation, not fauna, to fire. "With very few exceptions we are not in a position to make predictions about fire responses or to select optimal fire regimes to maintain, for example, even a simple value like species richness for the frog or reptile fauna" (Bamford and Roberts 2003). Other authors have similarly identified disparities in the amount of information available on different components of the biota. For example "most studies have examined the impact of fire on small mammals and birds, very few studies have focussed on reptiles and/or amphibians (Friend and Wayne 2003)".

Difficulties in monitoring the biota are also compounded by sampling errors (Thomson *et al.* 2003, 2004), replication issues (Hobbs and Yates 2003)) and the fact that the use of surrogates (indicator species) has yet to be ratified as an effective measure of biodiversity conservation for other groups of organisms. For example, Landsberg and Crowley (2004) promoted flora as the most convenient indicators because plants reflect the physical environment, they are the primary target of many of the pressures acting on the landscape, and plants are relatively amenable to measurement. However, Andersen *et al.* (2004) contended that due to the overwhelming contribution of invertebrates to biodiversity, no monitoring program can be considered credible if invertebrates are not addressed.

Similarly, use of space-for-time approaches are commonplace in the literature (reviews in Abbott and Burrows 2003) but their veracity as surrogates for long term monitoring of the same sites subjected to variable fire regimes has yet to be tested to our knowledge.

At the current time, hypotheses for management of fire to conserve biodiversity are restricted to typically short-term correlational studies of selected components of the biota. No fire regime has been shown to conserve all biodiversity of a region, even at a local scale. Conversely, it is the opinion of many authors that no fire regime is optimal for all components of the biota (e.g. Burrows and Abbott 2003).

In summary, with some exceptions, literature on this subject is primarily descriptive, short term and correlational, and often lacks sufficient definitional and experimental rigour for conclusive and predictive statements on hypotheses to be drawn. Consequently, alternative interpretations and conclusions are commonplace, and much remains to be investigated.

Impact of Prescribed Burning on Biodiversity Conservation and Reduction of the Impact of Wildfire

In the terms of reference for this review (Appendix A) we were asked to identify in the literature scientific evidence of the impact of fire on biodiversity and to determine whether there are differences in impacts from prescribed burns and wildfire. No empirical study comparing the effects on biodiversity conservation of wildfire v/s prescribed burns was found during the review. However, it became evident that the real questions which require attention are not related to differences in wildfire and prescribed burning,. Rather, it is their combined effect on biodiversity and management implications that needs to be addressed.

Abbott and Burrows (1999) provided a map of an area in the south-west Western Australia indicating regions burnt by the Department for Conservation and Land Management (DCLM) in the ongoing prescribed burning program (Figure 3). A map of wildfires ignited as a result of lightning strikes (Figure 4 - Mc Caw and Hanstrum 2003) indicates that prescribed burning does not eliminate fire from non-human ignition sources. The presence of both types of fires within the one landscape also suggests that the fire regime of any area in the southwest is likely to include both prescribed burns and wildfire.

These results are supported by studies of fuel loads (Mc Caw and Hanstrum 2003, Grove and Malajczuk 1985) in areas that are prescribed burnt. Such studies suggest that in some ecosystems fine fuel loads may carry a wildfire unless burnt at intervals of 2-4 years or less. Grove and Malajczuk (1985) observed litter accumulation in 4 year post-fire *Eucalyptus diversicolor* (karri) forest to be equivalent to a stand which had remained unburnt for 36 years. The authors suggest that "periodic fuel reduction burning in *E. diversicolor* forest results in regular regeneration of the understorey and may explain the high rates of understorey biomass accumulation compared with other eucalypt forests in which fire is excluded". This result suggests that prescribed burning, even at short intervals of 4 years may not prevent wildfire. Mc Caw and Hanstrum (2003) observed fire to burn patches in areas of woodlands and shrublands in southwest Australia that had been burnt 3-5 years previously. Similarly Birk and Bridges (1989) identified that fine-fuel levels 2–4 years after fire were capable of carrying a

high-intensity fire in areas of *Eucalyptus pilularis* (blackbutt) forest in New South Wales that had been prescription burnt at 2 and 4-year intervals.

These results indicate that in the area studied, prescribed burns may offer some protection from wildfire but only if conducted on a frequent basis. Too frequent fire has been shown to result in a greater decrease in species diversity than too infrequent fire (Watson and Wardell-Johnson 2004) and it has been suggested that frequent fire may be the greatest threat to studied biota (e.g. Yates *et al.* 2003). It would seem, therefore, that if prescribed burning is to be conducted frequently enough to reduce wildfire risk then there is the potential to alter the biodiversity of a region.

Although sample sizes are low despite 60 years of data, records of wildfire and prescribed burns in native bushland in Kings Park suggest that a period of prescribed block burns at an interval of three years, or prescribed buffer strip burns, had little effect on reducing either the frequency or scale of wildfires (Figure 5 – KPBG 1995).

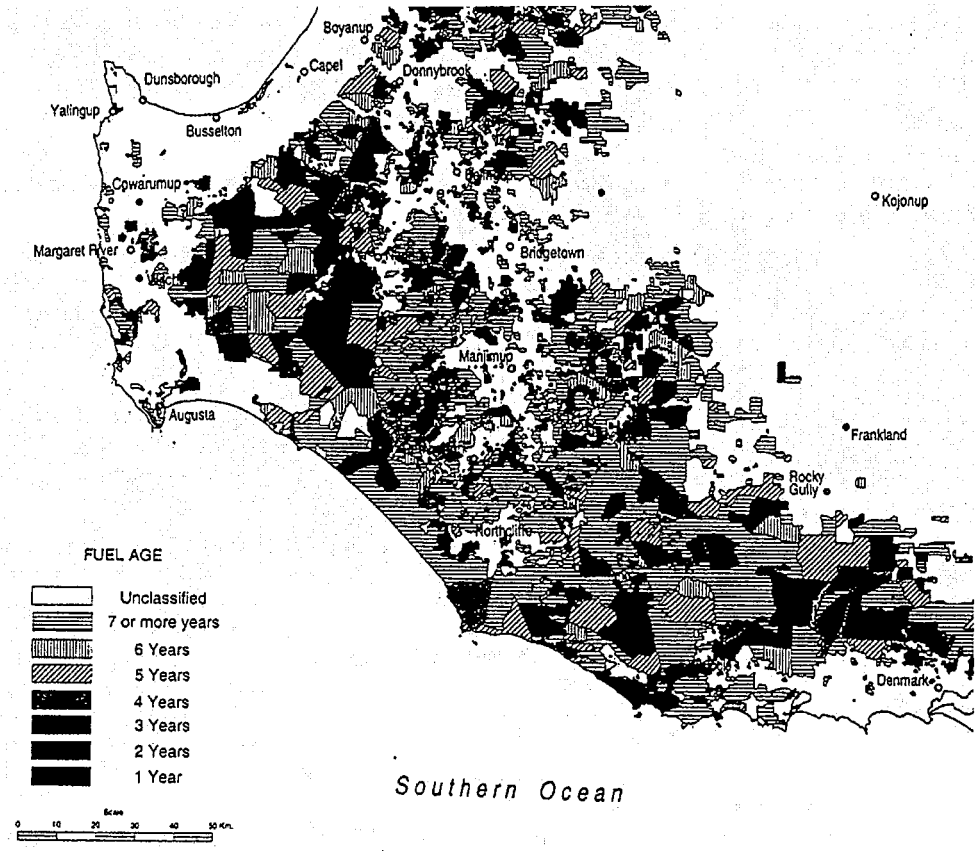

Figure 3: Prescribed burns in the southwest of Western Australia (Abbott and Burrows 1999).

In summary, there is evidence to suggest that prescribed burns may succeed or fail to reduce the incidence and severity of wildfire, depending upon local circumstances and the age of post-fire vegetation. Moreover, wildfire and prescribed burns co-occur. As such, in terms of scientific research, it is the impact of the fire regime (wildfire plus prescribed burns) on biodiversity conservation that requires investigation.

Does Fire Diversity Promote Biodiversity ?

The hypothesis that a mosaic of fire ages promotes biodiversity requires rigorous investigation. This hypothesis is promoted by several authors on the observation that some species become rare in the absence of fire and others rare with too frequent fire (e.g. Burrows and Abbott 2003, Burrows and Wardell-Johnson 2003). However, typically, the absence of species in systems is declared without due consideration to cryptic life stages of the organisms concerned.

Some researchers (Pyne 2003, Wardell-Johnson and Burrows 2003, Bamford and Roberts 2003, van Heurk and Abbott 2003, Robinson and Bougher 2003) hypothesise that species may become rare if fire is too infrequent. However, such hypotheses are often based on observations that frequently fail to

address the issue of cryptic life stages. The taxon deemed to have become reduced in abundance may actually be present but not as adult organisms. For example, Burrows and Wardell-Johnson (2003) observed that certain plant species are rare in long unburnt sites but their data do not falsify the hypothesis that viable seed of the species was present in the soil seed bank. Similarly, Robinson and Bougher (2003) noted that a high proportion of fungi observed in burnt areas were not present in unburnt areas. These observations are based on counts of fruiting bodies and as such did not ascertain whether fungal hyphae were present in the soil and simply not fruiting. At the other end of the scale, researchers have observed species to become rare with too frequent fire (e.g. Yates *et al.* 2003). However, again the presence of these species in cryptic life stages is rarely considered.

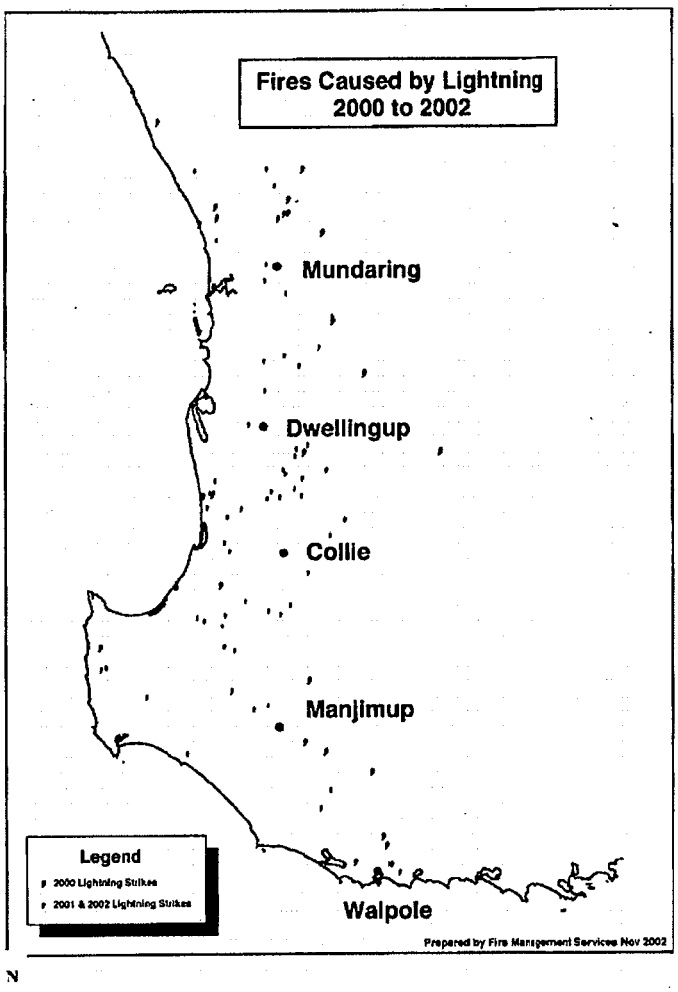

Figure 4: Patten of lightning-caused fires in forest areas of southwest Australia from June 2000-June 2002 (McCaw and Hanstrum 2003).

To determine whether fire is impacting on the presence/abundance of an organism it is necessary to ensure that the taxon is not present in some cryptic life stage. Few studies that discuss the impacts of fire have sufficiently addressed this issue.

Potential Value in the Conservation of Rare Species

Fire use or exclusion has been involved in the management of some rare species. For example, Smith 1985) suggested that fire exclusion combined with predator control have been primary influences in the increase in abundance of the Noisy Scrub Bird in southwest Australia. In contrast, use of prescribed burns as part of an integrated pest management program offers the potential to stimulate the threatened native *Pimelea spicata* populations while controlling bridal creeper (Willis *et al.* 2003).

Some authors consider that fire-sensitive taxa exhibit relictual distribution patterns in being confined to naturally less flammable sites including mesic areas, permanent waterbodies, rocky areas and offshore

islands (Burrows and Abbott 2003). These areas may require longer fire intervals than surrounding vegetation and special attention should be given to endemic components of the biota to ensure those species are conserved (Wardell-Johnson and Horwitz 2000). For example, Yates *et al.* (2003) concluded that there is a dearth of experimental studies to understand the complex relationship between fire and rarity in southwest WA. Fire response for the 327 rarest flora in Western Australia is known or inferred for just under two-thirds (209). However, of these, the greatest proportion are nonsprouters and thus may be particularly susceptible to fire regimes. Indeed fire sensitive taxa are known for all major habitats and dryland systems in the southwest.

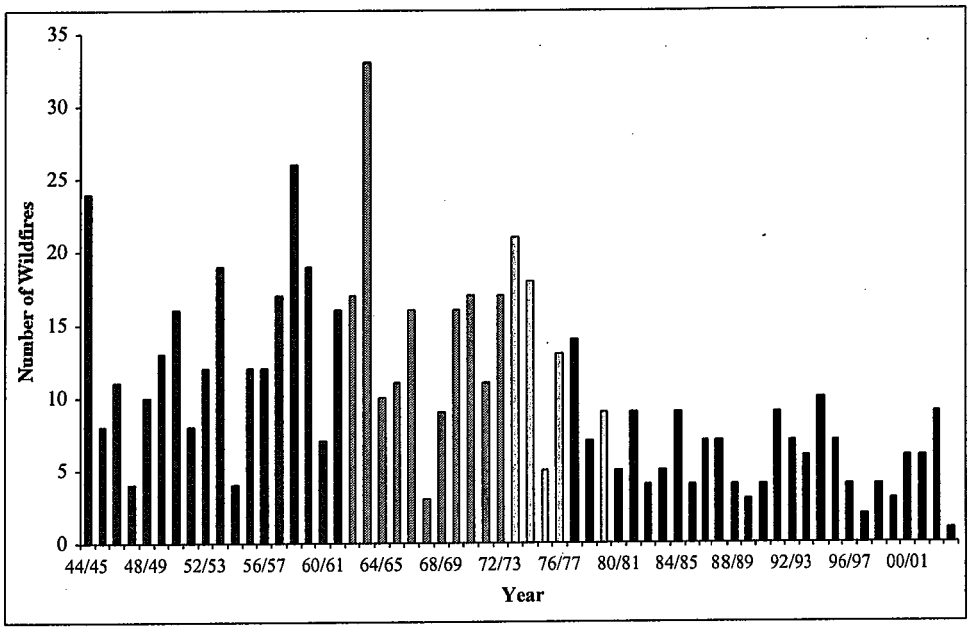

Figure 5: Number of wildfires in Kings Park over 60 years (1944-2004) under differing management regimes – prescribed block burning on a three year rotation (red), no burning (grey), buffer-strip burning (striped) and integrated management with no prescribed burning (black) Data updated from KPBG1995.

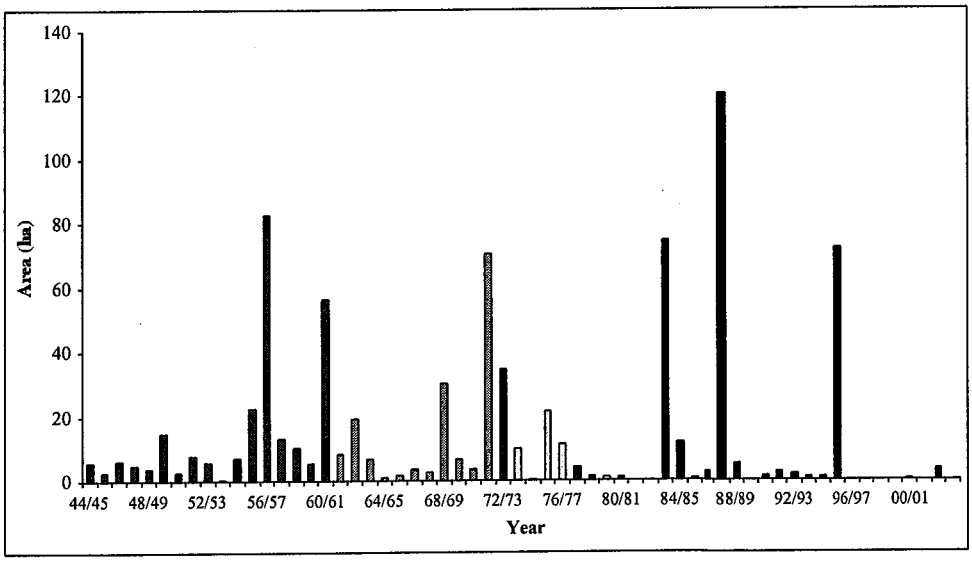

Figure 6: Total area burnt annually (hectares) by wildfire in Kings Park over 60 years (1944-2004) under differing management regimes – prescribed block burning on a three year rotation (red), no burning (grey), buffer strip burning (striped) and integrated management with no prescribed burning (black) Data updated from KPBG1995.

CURRENT LEVEL OF UNDERSTANDING AND OF FIRE MANAGEMENT AND AREAS FOR FUTURE RESEARCH.

"It is important at the outset to recognise that most of us are still settlers in a globally unique and changing environment in south-west WA. We have much to learn before sustainable land management, including the use of fire, is achieved" (Hopper 2003)." Perhaps the most poignant points that can be taken from the substantial amount of scientific research undertaken in recent decades, is "that patterns of post-fire succession can be diverse and complex" (Burrows and Abbott 2003), "we should expect different responses and biodiversity outcomes over short distances from the same fire regime" (Hopper 2003) and no one fire regime appears optimal for the persistence of all components of the biota (Bamford and Roberts 2003, Burbidge 2003, Robinson and Bougher 2003, van Heurck and Abbott 2003). Although some authors have provided guidelines for establishing fire regimes (Lamont *et al.* 2003, Burrows and Friend 1998 in Burrows and Wardell –Johnson 2003) all suggestions are restricted to monitoring a small component of the biota and therefore cannot be shown to be optimal for overall biodiversity conservation.

Research conducted to date on fire is insufficient to allow prescriptions to be made for fire regimes to maximise biodiversity conservation. Further studies are required before an adequate understanding of fire regimes and biodiversity conservation is attained. Two broad themes are recommended:

(i) long term descriptive and correlational monitoring studies to generate hypotheses on the impact of fire scale, intensity, season and patchiness – monitoring sites need to be replicated frequently across southwest Australian landscapes to adequately sample rapid geographical turnover in less vagile organisms such as most vascular plants, land snails etc. (Hopper 2003);

(ii) rigorous experimental studies with adequate sampling, replication and controls to test hypotheses and develop predictive theory regarding fire regimes and biodiversity conservation (e.g. Whelan and Main 1979; Hobbs 2003).

Fire and the Changing Ecosystem

Fire is too often considered in isolation, without references to other important factors that affect the ecosystem and also influence fuel distributions and hence fire characteristics. Consideration needs to be given to the complex ways other disturbances affect the incidence of fire, its impacts, and the ecosystem response to it (Hobbs 2003). Researchers need to consider interactions between disturbance regimes at local and global scales (Wardell-Johnson *et al.* 2004). For example, Western Australia's 1998 State of the Environment Report lists the salinisation of land and inland waters as the highest priority issue for the southwest (Wallace *et al.* 2004). As such future management of fire in the southwest may need to consider the added effects of salinity on biodiversity.

Invasive plant species are one of the most significant threats to natural areas particularly in agricultural and urban environments. The interaction between burning and weed invasion and subsequent influence on biodiversity requires consideration (e.g. KPBG 1995). The incidence of fire can enhance weed invasion, weeds may displace native perennials and weeds can increase fine fuel loads leading to more frequent and more intense fires (Hobbs 2003). Grazing pressures by herbivorous insects have a direct effect on recruitment of some plants depending on the scale of fire in Banksia woodland on the Swan Coastal Plain (Whelan and Main 1979). Consideration is also needed as to what effects perceived global warming will have on the fire regime and its effect on biodiversity and that this needs to be considered in determining appropriate regimes (Wardell-Johnson *et al.* 2004).

Species Specific Studies and Modelling of Biological Patterns

"Overall site-based studies highlighting biogeographic patterns, and critical factors of population decline in key indicator species are the most serious deficits in current understanding in Western Australia (Wardell-Johnson *et al.* 2004)". Understanding trends in populations of key species including such aspects as mortality and fecundity can provide predictors of the overall system health and are critical to risk assessment. However, Wallace *et al.* (2004) contend that "assessment of biodiversity status by direct observation of biota involves the understanding of processes at a range of scales for which data are generally unavailable". The authors suggest that a major challenge for monitoring is to demonstrate links between biodiversity and surrogates that can be monitored at the required scales. For example, remotely-sensed data could form the basis of the monitoring system where vegetation cover monitoring data will inform questions of biodiversity. An ongoing collaborative effort is required to develop understanding between cover responses and landscape

health, function and biodiversity (Wallace *et al.* 2004)". There are numerous monitoring programs being run throughout Western Australia for different purposes eg. vegetation change and salinity in the southwest (Wallace *et al.* 2004, pp 102-103). Ensuring these programs are integrated with data shared among researchers may assist in broadening the scope of current studies.

Understanding the effects of fire on biodiversity will require many more years of intensive monitoring. Lindenmeyer (1999) suggested that major changes are required to monitoring programs if this is to be achieved including:

- "identifying innovative ways to secure long-term funding that may be guaranteed beyond typical government and institutional timeframes";
- "education of funding bodies to ensure that they recognise that useful results may take a prolonged period to obtain and that monitoring is not a second-rate science."

Monitoring sites need to be replicated frequently across southwest Australian landscapes to adequately sample rapid geographical turnover in less vagile organisms such as most vascular plants, land snails etc. (Burrows and Wardell-Johnson 2003, Hopper 2003).

Key hypotheses for future research

Burrows and Abbott (2003, pp. 445-446) provided some 12 principles (hypotheses) for fire management in southwest Australia. Hopper (2003) proposed three others. Indeed, the literature is replete with hypotheses in need of future research, as a perusal of the review chapters in Abbott and Burrows (2003) reveals.

Which are most deserving and urgent? In terms of the subject of this review, we suggest that those studies of fire regimes that experimentally establish how to minimise the extinction of genes, species and ecosystems are the most critical.

A consideration of the foregoing in this light therefore enables identification of a number of hypotheses deserving of future research pertaining to fire regimes and biodiversity conservation, with special reference to southwest Australia. These hypotheses, in no particular order, include:

- Adaptations to fire are difficult to distinguish from those for coping with other disturbances;
- Impacts of fire regimes on biodiversity are complex and difficult to predict;
- The relative abundance of organisms may change with fire regime;
- Extinction of genes, species and communities due to fire regime is rare, especially compared with that following habitat destruction, weed and feral animal invasion, dieback disease and salinity;
- The interaction of fire regimes with other disturbances may pose a significant risk to biodiversity conservation;
- Some aspects of fire management have longer term impacts on biodiversity conservation than fire itself eg. bulldozing roads and fire breaks, burning spoil heaps;
- Genes, species and communities most threatened by fire regimes are those that are rare and highly localised in the landscape, especially in cool moist habitats or natural fire refuges eg.:
    1. wetlands (especially peat based)
    2. granite outcrops
    3. Stirling Range montane heath
    4. tingle forest
    5. Callitris forest on islands
    6. Kimberley vine thickets etc.;
- Fire regime diversity promotes biodiversity conservation.

Exploration of these and other hypotheses will assist managers in their quest to achieve biodiversity conservation through appropriate fire regimes. However, choices and priorities have to be made, as funding for science in fire and biodiversity research is limited. Ultimately the community should be involved in helping decide which components of biodiversity are most important to conduct research on first, and then how much effort should scientists place on research on fire regime effects in the context of all major impacts on biodiversity conservation. We see merit in such ongoing community involvement. Given present funding levels, an increased allocation for strategic scientific research on fire regimes and biodiversity conservation in southwest Australia seems warranted.

GENERAL CONCLUSIONS

- The fire regime may impact on biodiversity conservation as changes to the abundance of species have been demonstrated. However, documented extinction of genes, populations and communities are few and taxa predicted to be at threat from fire are typically rare species that are highly localised in refugial habitats in the landscape;
- In terms of scientific research, the combined impacts of prescribed burns and wildfire (the fire regime) on biodiversity conservation warrant attention, as it is difficult to disentangle the two kinds of fire at specific sites;
- Impacts of fire regimes on biodiversity are complex and difficult to predict. Two broad areas of research are required - correlational monitoring studies and rigorous experimental studies with adequate sampling, replication and controls to test hypotheses and develop predictive theory regarding fire regimes and biodiversity conservation, and aimed at testing hypotheses listed above;
- Given present funding levels, an increased allocation for strategic scientific research on fire regimes and biodiversity conservation in southwest Australia seems warranted.

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REFERENCES

Abbott, I. (2003) Aboriginal fire regimes in the south-west Western Australia: evidence from historical documents. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 119-146. Backhuys Publishers, Leiden, Netherlands.

Abbott, I. and Burrows, N. (1999) Biodiversity conservation in the forests and associated vegetation types of southwest Western Australia. Australian Forestry **62**(1), pp. 27-32.

Abbott, I. And Burrrows, N., eds (2003) *Fire in ecosystems of south-west Western Australia: impacts and management.* Backhuys Publishers, Leiden, Netherlands.

Andersen, A. N., Fisher, A., Hoffmann, B. D., Read, J. L. and Richards, R. (2004) Use of terrestrial invertebrates for biodiversity monitoring in Australian rangelands, with particular reference to ants. *Austral Ecology* **29**, pp 87-92.

Atahan, P., Dodson, J. R. and Itzstein-Davey, F. (2004) A fine-resolution pollen and charcoal record from Yallalie, south-western Australia. *Journal of Biogeography* **31** pp. 199-205.

Bamford, M. J. and Roberts, J. D. (2003). The impact of fire on frogs and reptiles in south-west Western Australia. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 349-361. Backhuys Publishers, Leiden, Netherlands.

Birk E. M. and Bridges R. G. (1989) Recurrent fires and fuel accumulation in even-aged blackbutt (*Eucalyptus pilularis*) forests. *Forest Ecology and Management* **29** pp 59-79.

Bowman, D. M. J. S. (2003) Australia landscape burning: a continental and evolutionary perspective. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 107-118. Backhuys Publishers, Leiden, Netherlands.

Burbidge, A. H. (2003). Birds and fire in the Mediterranean climate of south-west Western Australia. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 321-347. Backhuys Publishers, Leiden, Netherlands.

Burrows, N. D., Ward, B. and Robinson, A. D. (1995) Jarrah forest fire history from stem analysis and anthropological evidence. *Australian Forestry* **58** pp 7-16.

Burrows, N. and Abbott, I. (2003). Fire in south-west Western Australia: a synthesis of current knowledge, management implications and new research directions. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 437-452. Backhuys Publishers, Leiden, Netherlands.

Burrows, N. D. and Friend, G. (1998) Biological indicators of appropriate fire regimes in southwest Australian ecosystems. In: Prudent, T. and Brennan, L. (eds.), Fire in Ecosystem Management: Shifting the Paradigm from Suppression to Prescription, Tall Timbers Fire Ecology Conference Proceedings pp 413-421,Tall Timbers Research Station, Tallahassee.

Burrows, N. and Wardell-Johnson, G. (2003). Fire and plant interactions in forested ecosystems of south-west Western Australia. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 225-268. Backhuys Publishers, Leiden, Netherlands.

Dixon, K. W., Roche, S. and Pate, J. S. (1995) The promotive effect of smoke derived from burnt native vegetation on seed germination of Western Australian plants. *Oecologia* **101(2)** pp 185-192.

Dixon, K. and Barrett, R. (2003) Defining the role of fire in the south-west Western Australian plants. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 205-223. Backhuys Publishers, Leiden, Netherlands.

Dodson, J. R. (2001) Holocene vegetation change in the Mediterranean-type climate regions of Australia. *The Holocene* **11 (6)** pp. 673-680.

Friend, G. and Wayne, A. (2003). Relationships between mammals and fire on south-west Western Australian ecosystems: what we know and what we need to know. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 363-380. Backhuys Publishers, Leiden, Netherlands.

Grove, T. S. and Malajczuk, N. (1985) Biomass production by trees and understorey shrubs in an age-series of *Eucalyptus diversicolor* F. Muell. stands. *Forest Ecology and Management* **11** pp 59-74.

Hassell, C. W. (2000) Fire ecology studies in the Fitzgerald River National Park, Western Australia. PhD Thesis. University of Western Australia, Perth.

Hassell, C. W. and Dodson, J. R. (2003) The fire history of south-west Western Australia prior to European settlement in 1826-1829. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 71-85. Backhuys Publishers, Leiden, Netherlands.

Haynes, C. C. (1985) The pattern and ecology of munwag: traditional aboriginal fire regimes in north-central Arnhemland. *Proceedings of the Ecological society of Australia* **13** pp 203-214.

Hobbs, R. (2003). How fire regimes interact with other forms of ecosystem disturbance and modification. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 421-436. Backhuys Publishers, Leiden, Netherlands.

Hobbs, R. J. and Yates, C. J. (2003) Turner Review No. 7 Impacts of ecological fragmentation on plant populations: generalising the idiosyncratic. *Australian Journal of Botany* **51** pp 471-488.

Hopper, S. D. (2003) An evolutionary perspective on south-west Western Australian landscapes, biodiversity and fire: a review and management implications. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 9-35. Backhuys Publishers, Leiden, Netherlands.

KPBG (1995) Kings Park Bushland Management Plan pp 63. Kings Park and Botanic Garden, Perth, Western Australia.

Lamont, B. B., Ward, D. J., Eldridge, J., Korczynskyi, D., Colangelo, W. I., Fordham, C., Clements, E. and Whittkuhn, R. (2003) Believing the Balga: a new method for gauging the fire history of vegetation using grasstrees.. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 147-169. Backhuys Publishers, Leiden, Netherlands.

Landsberg, J. and Crowley, G. (2004) Monitoring rangeland diversity: Plants as indicators. *Austral Ecology* **29**, pp 59-77.

Lindenmeyer, D. B. (1999) Future directions for biodiversity conservation in managed forests: indicator species, impact studies and monitoring programs. *Forest Ecology and Management* **115** pp 277-287.

McCaw, L. and Hanstrum, B. (2003) Fire environment of Mediterranean south-west Western Australia. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 87-106. Backhuys Publishers, Leiden, Netherlands.

Pyne, S. J. (2003) Fire's lucky country. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 1-8. Backhuys Publishers, Leiden, Netherlands.

Roberts, R. G., Jones, R. and Smith, M. A. (1990) Thermoluminescence dating of a 50, 00-year-old human occupation site in northern Australia. *Nature*, **345** pp 153-156.

Roberts, R. G., Jones, R., Spooner, N. A., Head, M. J., Murray, A. S. Smith, M. A. (1994) The human colonizaton of Australia: optical dates of 53, 000 and 60, 000 years bracket human arrival at Deaf Adder Gorge, Northern territory. *Quaternary Science Reviews* **13** pp 575-583.

Robinson, R. M. and Bougher, N. L. (2003).The response of fungi to fire in jarrah (*Eucalyptus marginata*) and karri (*Eucalyptus diversicolor*) forests of south-west Western Australia. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 269-289. Backhuys Publishers, Leiden, Netherlands.

Roche, S., Dixon, K. W. and Pate, J. S. (1997a) Seed ageing and smoke: partner cues in the amelioration of seed dormancy in selected Australian native species. *Australian Journal of Botany* **45** pp 783-815.

Roche, S., Koch, J. M. and Dixon, K. W. (1997b) Smoke enhanced germination for mine rehabilitation in the southwest of Western Australia. *Restoration Ecology* **5(3)** pp 191-203.

Thompson, G. G., Withers, P. C., Pianka, E. R. and Thompson, S. A. (2003) Assessing biodiversity with species accumulation curves; inventories of small reptiles by pit-trapping in Western Australia. *Austral Ecology* **28** pp 361-383.

Thompson, S. A. and Thompson, G. G. (2004) Adequacy of rehabilitation monitoring practices in the Western Australian mining industry. *Ecological Management and Restoration* **5(1)** pp .

Tieu, A., Dixon, K. W., Sivasithamparam, K., Plummer, J. A. and Sieler, I. M. (1999) Germination of four native Western Australian plants using plant-derived smoke. *Australian Journal of Botany* **47** pp 207-219.

Turney, C. S. M., Bird, M. I., Fifield, L. K., Roberts, R. G., Smith, M., Dortch, C. E., Grun, R., Lawson, E., Ayliffe, L. K., Miller, G. H., Dortch, J. and Cresswell, R. G. (2001) Early human occupation at Devils Lair, southwestern Australia, 50, 000 years ago. *Quaternary Research* **55** pp 3-13.

van Heurck, P. and Abbott, I. (2003).Fire and terrestrial invertebrates in south-west Western Australia. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 291-319. Backhuys Publishers, Leiden, Netherlands.

Wallace, J. F., Caccetta, P. A. and Kiiveri, H. T. (2004) Recent developments in analysis of spatial and temporal data for landscape qualities and monitoring. *Austral Ecology* **29**, pp 100-107.

Ward, D. J., Lamont, B. B. and Burrows, C. L. (2001) Grasstrees reveal contrasting fire regimes in eucalypt forest before and after European settlement of southwestern Australia. *Forest Ecology and Management* **150** pp 323-329.

Wardell-Johnson and Horwitz (2000) The recognition of heterogeneity and restricted endemism in the management of forested ecosystems in south-western Australia. *Australian Forestry* **63**(3), pp. 218-225.

Wardell-Johnson, G., Calver, M. Saunders, D., Conroy, S. and Jones, B. (2004) Why the integration of demographic and site-based studies of disturbance is essential for the conservation of jarrah forest fauna. ***journal???

Watson, P. and Wardell-Johnson, G. (2004) Fire frequency and time-since-fire effects on the open-forest and woodland flora of Girraween National Park, south-east Queensland, Australia. *Austral Ecology* **29** 225-236.

Whelan, R.J. and Main, A.R. (1979) Insect grazing and post-fire plant succession in south-west Australian woodland. *Australian Journal of Ecology* **4** pp. 387-398.

Willis, A., McKay, R., Vranjic, J. A., Kilby, M. J. and Groves, R. H. (2003) Comparative seed ecology of the endangered shrub, *Pimelea spicata* and a threatening weed, Bridal Creeper: Smoke, heat and other fire-related germination cues. *Ecological Management and Restoration* **4(1)** pp. 55-65.

Yates, C. J., Abbott, I., Hopper, S., D. and Coates, D. J. (2003). Fire a s a determinant of rarity in the south-west Western Australian global biodiversity hotspot. *In: Fire in ecosystems of south-west Western Australia: impacts and management.* (eds I. Abbott and N. Burrows) pp 395-420. Backhuys Publishers, Leiden, Netherlands.

Yates, C. J., Hopper, S. D., Brown, A. and van Leeuwin S. (2003) Impact of two wildfires on endemic granite outcrop vegetation in Western Australia. *Journal of Vegetation Science* **14** pp. 185-194.

APPENDIX A

Review Scope

- Identify the role of fire in maintaining and protecting biodiversity. This will include:
  - beneficial effects from prescribed burns, and the extent to which these are influenced by factors such as scale, frequency, seasonality and intensity.
  - adverse impacts from prescribed burns, and the extent to which these are influenced by factors such as scale, frequency, seasonality and intensity.
  - the effects of wildfire on biodiversity, and
  - whether the effects of wildfire are significantly different from those from prescribed burns
- Provide advice on the current understanding of fire management practices which promotes biodiversity protection, including the value of prescribed burns in reducing the impacts of wildfires.
- Comment on the level of understanding and identify gaps in information that need to be filled to improve our knowledge of fire effects on biodiversity through research, monitoring and data gathering.

Review Focus

- The review is to be limited to books and peer reviewed scientific journals including material accepted for publication awaiting printing.
- There is to be no personal interview component in the review, however, leading publicists on the subject may be approached to provide references they believe relevant.
- Publications included in the report shall be selected through a process of ranking according to scientific rigour utilising a system currently employed by the University of Western Australia and upon the advice of leading biodiversity and fire researchers.
- Studies conducted in the South West portion of Western Australia are to be given priority, however, other relevant Australian and international research material may be included.

2 June, 2004
Project No. 20857-044/596-F6413.2

Environmental Protection Authority
Level 9
141 St. Georges Terrace
Perth WA 6000

Attention: Mr. D. Betts
Project Manager

Dear Doug,

Subject: Audit of three of Department of Conservation and Land Management prescribed burns

1. Introduction

We are pleased to present the findings of our audit of three prescribed burns conducted by the Department of Conservation and Land Management (CALM). Our audit comprised the following activities:

- A visit to the CALM office at Kensington to gain an overview of the prescribed burn planning process;
- Interviews with CALM operational personnel regarding the objectives, planning, implementation and follow up of the three prescribed burns selected by the Environmental Protection Agency (EPA);
- Review of documentation relating to the three prescribed burns; and
- Field inspections of the sites of the three prescribed burns. During field inspections, the auditor inspected a sample of locations throughout the burn.

The scope of the audit was limited to the operational planning, implementation and follow-up of the burns, and excluded the assessment of biodiversity impacts and regional planning, through which the locations for the application of prescribed burns are selected. Following the submission of a draft of this audit report, further information was made available by CALM, which has been incorporated into this report.

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The prescribed burns selected by EPA for the audit were as shown in Table 1.

Table 1: Prescribed burns audited

Burn Name as used in this report	Burn Number	Size of Burn	CALM District	Date of Burn (core ignition)
"High Hill Road"	415585a	2521 ha	Swan Coastal District	5 October 2003
"Cornwall"	W007	2948 ha	Wellington District	10 November 2002
"Bramley"	BS031	1227 ha	Blackwood District	28 November 2003

Lists of personnel interviewed and documents reviewed are contained in Attachments A and B respectively.

2. Findings

The findings of the audit are presented in the following sections. In general, the burns largely met their set Objectives and Standards. URS considers that the most significant of the Objectives and Standards not achieved is:

- An unburnt pocket along a creek line on the edge of Cornwall, which is thought to have resulted in a wildfire of around 45 hectares. This result was despite aerial surveillance reportedly occurring up to three times per day in the days following the burn. There were no significant ecological or property values identified by CALM in the area impacted by the wildfire.

During the audit it was found that there were some records that were missing from files, usually records from the day of the burn, such as burn diaries that contain important information about the fire behaviour and actions taken during burning. Discussions with the Regional Fire Co-ordinator, South West Region, indicated that this issue had already been identified by CALM, as he mentioned a plan to initiate the use of carbon copy diaries.

Many records were also found to be incomplete, usually a document not having been authorised, or signed to verify that data had been checked.

It is good practice to ensure records of activities are complete and to manage records so that they can be easily retrieved. Failure to manage records appropriately could have

implications such as increasing the difficulty of CALM being able to demonstrate appropriate management in the event of legal or community action.

The specifics of these and other issues that arose during the audit are discussed further in this section.

2.1 Operational Planning

Burn prescriptions were developed for each burn, once the Objectives and Standards had been determined. It is understood from discussions with CALM personnel that Objectives for each burn were developed as part of the regional planning process, during which the values (ecological and life/property) are periodically assessed and prioritised. In general, burn prescriptions were found to have been developed in accordance with CALM's internal standards (Fire Operations Manual). Cases of incomplete records were evident across all three burns.

2.1.1 Public Consultation

Public consultation was carried out in a variety of ways and to varying extents across the three burns audited, according to CALM's knowledge about the level of interest in each burn by the stakeholders. For all burns, maps were available at local CALM offices for viewing by the public, and local Bush Fire Advisory Committees were briefed. CALM personnel interviewed during the audit indicated that a public notice is generally placed in the local paper, except in some areas, where historically there has been no interest from the public.

High Hill Road – the Assistant Fire Protection Officer stated that each season's burn programme is presented to the Bush Fire Advisory Committee at meetings, which Shire representatives and other interested parties can attend. A public notice was not placed in the local newspaper for the High Hill Road burn, as there had been no interest from the public when this was done in the past.

Cornwall – the District Fire Co-ordinator reported that the Cornwall burn was presented to the local Shire fire control officers as part of the burn programme for that season. There were no issues raised regarding the Cornwall burn. The Shire was again notified several days prior to the burn being conducted. The Environmental Officer from Worsley Alumina was also briefed of the intention to conduct the burn, and no issues of concern were raised.

Bramley – considerable additional public consultation and notification appears to have been carried out prior to conducting the Bramley burn, including:

- two rounds of letters to notify neighbours of the intention to conduct the burn;

- a public notice in the local newspaper, including possible disruption to the Ten Mile Brook walk trail;
- a briefing of the Leeuwin Naturaliste National Park Advisory Committee;
- a briefing of the Shire of Augusta Margaret River Bush Fire Advisory Committee;
- a briefing of the Busselton/Dunsborough Environment Centre;
- consultation with the Margaret River Tourist Centre regarding the possible disruption to Ten Mile Brook walk trail.

URS considers that the general approach to public consultation is appropriate. We suggest that the assumption that there will be no interest in prescribed burning in an area because there has been no interest in the past, be reviewed periodically, as it may lead to missed opportunities for consultation. Local residents can change over time and gain increased awareness and interest in fires and burning through incidents such as the Canberra wildfires.

2.1.2 Fuel Assessment

Fuel assessments for all burns appear to have been conducted in accordance with CALM's internal standards with the following minor exception:

Cornwall – one figure in a sample of Available Fuel weights was detected as incorrect. The magnitude of the error was immaterial to the prescription result and was isolated to the Cornwall burn. It appears that the error was a result of misreading of one of the tables in *Forest Fire Behaviour Tables for Western Australia*, however since it was not a systematic error, and the person involved was reported to be quite experienced in prescription planning, it does not appear to be the result of inadequate training or supervision. It was reported by several CALM personnel interviewed that the prescription calculations are reviewed by a more senior fire management officer to ensure that the data is giving a result as expected for that area. It was found during the audit however, that the calculation forms had not been signed off as checked by an appropriate person. URS considers it is good practice to both check a sample of critical calculations, and also to ensure that the paperwork is complete to record that the data has been checked.

Available fuel levels and years when last burnt were reported as:

- High Hill Road: 6.0-10.0 tonnes/ha, year last burnt 1991;
- Cornwall: 11.0-18.3 tonnes/ha, year last burn 1993; and
- Bramley: 12.5-19.0 tonnes/ha, year last burnt 1991.

All fuel figures were found to have been transcribed correctly in the documentation.

2.1.3 Pre-burn Checks and Notifications

A standard CALM Burn Prescription Checklist was completed for each burn, which included such checks as fuel assessments, maps and signs required during burning, dieback management, flora and fauna searches and notification required. Subsequently a CALM Nature Conservation Branch representative had authorised each of the burns to proceed as planned, with specifications for the management of a Noisy Scrub Bird potential habitat area in Cornwall and Brushtail possum habitat along Margaret River in Bramley.

As part of CALM's standard operations, appropriate CALM personnel representing each of Nature Conservation, Recreation, Hardwood Operations, and CALMfire, as well as the District Manager, are required to authorise each burn. All burns were authorised by the District Manager, however there were some instances where individual representatives did not provide signatures and comments. These instances are discussed below under "Records".

2.1.4 Prescription calculations

Prescription calculations were developed in accordance with CALM's internal standards, and the input of local knowledge, with no detected exceptions other than those related to authorisations and record keeping, as discussed below.

2.1.5 Records

There are many instances of incomplete records across the three burns, as follows:

High Hill Road

- The Recreation section of CLM386 was not completed and signed by a Recreation representative. Discussions with the Assistant Fire Control Officer indicated that this issue is not likely to be significant as CALM's records show that there are no recreational users of the area. However, similar situations with Cornwall and Bramley were managed by having the respective specialist make comment and sign the form to confirm that there were no issues. This may highlight an inconsistency across the organisation in the requirement of input from specialists.
- The Pre-Burn Checklist (CLM32) was not initialled to record that specified checks were carried out prior to lighting. A sample of these checks suggested that the actions were likely to have been carried out, but not recorded as such.
- The Pre-Burn Checklist (CLM32) was not dated by the District Manager.

- There were no signatures on the Fuel Assessment Records (CLM871) to record who had compiled them or to confirm that they had been checked.
- The copy of the Burn Prescription (CLM873) audited was not signed by either the Regional Manager or the CALMfire Manager.

Cornwall

- There were no signatures on the Fuel Assessment Records (CLM871) to record who had compiled them or to confirm that they had been checked.

Bramley

- There are comments, but no signature by the Recreation representative on the District managers Prescribed Burn Planning Checklist (CLM386). Also, the District Manager had not confirmed through the form whether all issues raised had been incorporated into the Burn Prescription. URS' audit findings however indicated that the issues had been addressed.
- There are no signatures on the Fuel Assessment Records (CLM871) to confirm that they had been checked.
- The Aerial Burn Flight Plan Checklist had not been signed to record checking of the plan. If the lack of signature indicates that the plans had not been checked, there could have been errors or omissions in the plans that could have impacted on the burn, however there was no evidence found during the audit to suggest there were errors or omissions in the plans.

2.1.6 Potential implications of findings for Operational Planning

The following are some potential implications of the audit findings, however no evidence was found during the audit to indicate that these issues had impacted on planning or implementation of the burns audited.

- Failure to challenge the assumption that there will be no interest in a burn programme in an area may result in loss of opportunity for public consultation where interest levels have changed either through increased awareness or new residents in the area.
- Failure to keep records of public consultation, such as minutes of meetings, may impact on CALM's ability to demonstrate that appropriate public consultation has occurred in the event of legal or community action.
- Failure to verify data in the prescriptions has the potential to lead to the incorporation of incorrect information and the development of an inappropriate burn prescription.

- Failure to gain authorisations by the appropriate designated personnel may lead to the loss of opportunity to incorporate important relevant information into the prescription.
- Failure to maintain complete records may limit the organisation's ability to demonstrate appropriate management in the case of legal or community action.

2.1.7 Suggestions for improvement to Operational Planning

Greater effort to ensure that:

- documentation is authorised by the appropriate personnel;
- records of meetings are produced
- all documentation is filed appropriately to ensure records of burns are complete and readily accessible.

2.2 Implementation of the burns

In general, the burns were conducted under conditions similar to those prescribed. In some cases the auditor relied on field observations of burn results for this information, as records of actual conditions were not always available during the audit. There was considerable reliance on the experience of personnel managing the burn to interpret whether the weather conditions were appropriate on and throughout the day of the burn. This practice carries an element of risk if people with insufficient experience were to be managing a burn with inadequate supervision. No evidence was found during the audit however, to indicate that this was the case.

The scope of this audit excluded a review of the adequacy of training and competency assessment systems, and given the importance of having competent personnel involved in burning operations, it would be considered good practice that CALM conducts periodic reviews of its training and competency systems.

2.2.1 Day of burn conditions

For all burns, field inspections during the audit indicated that actual conditions were similar to those prescribed, although records were not available to verify this in all cases. Actual wind speeds and temperatures were not measured using instruments on the days of the burns. Instead, readings were taken from fire towers and converted to ground speed by conversion factors developed by CALM. To assist with determining whether the weather conditions were appropriate, fire behaviour was observed from the aircraft and reported to the person managing the burn. Fire behaviour was described as "normal" for all burns. URS considers that hand-held instruments for measuring weather conditions may provide more accurate current weather data, including variations over the burn area,

however audit findings did not indicate that current methods have led to issues in the implementation of the burns audited.

High Hill Road

The Burn Prescription form states that "maximum wind strengths normally used are 15km/hr, for prescribed burns", however winds of up to 25km/hr were prescribed for and predicted the day before the burn. The burn resulted in two "hop-overs" (areas outside the burn boundary caught alight) on the lee side of the burn. They were suppressed by personnel present on site and impacted areas of around 1.5 hectares and less than 0.5 hectares respectively. There were no special values identified on the impacted land at the time of planning that specifically required protection from fire. This outcome is considered by CALM to be acceptable and quite common. In cases where personnel additional to those already deployed are required to suppress a hop-over, it is then classified as a wildfire. URS considers that this outcome is acceptable considering the large programme of burns and the limited occurrence of ideal climatic conditions. From field observations during the audit, it would appear that the fire intensity was still very mild and the burn objectives were achieved.

Cornwall

No records of actual or forecast weather conditions were available during the audit. From field observations during the audit it would appear that this burn, too, was very mild and no hop-overs were reported on the day of the burn.

Bramley

Field inspections and review of documentation indicated that the conditions were similar to those prescribed, however no records of the weather conditions on the day of the burn were available during the audit. It is understood that no hop-overs occurred during the day of the burn (28 November, 2003), however the diary entries indicated that at least one small one occurred afterwards, during mop-up (6 December, 2003). The area impacted by the hop-over was not recorded in post-burn documentation, and it is still unclear, after reviewing documentation and discussing with CALM personnel, where the hop-over actually occurred.

2.2.2 Records

High Hill Road

- The copy of the Operations Officers Day of Burn Checklist (FPI35) audited had not been completed or signed. Discussion with CALM personnel indicated that the form had been completed, however was subsequently misplaced.

Cornwall

- The Operations Officer's Day of Burn Checklist audited had not been signed. CALM personnel interviewed indicated that the checklist had probably been used, however it is common that field records are missing from files.

- Weather forecasts, actual weather conditions and fire behaviour were not included in the burn log book or the burn file that was audited. Documentation indicated that a spot weather forecast was used to override the readings of the nearest weather station, however the spot forecast was not available during the audit.

Bramley

- The Controllers Day of Burn Checklist (FPI35) has not been signed.

- A burn diary entry for the day of the burn was not available for audit.

2.2.3 Potential implications of findings for Burn Implementation

The following are some potential implications of the audit findings, however no evidence was found during the audit to indicate that these implications have occurred.

- The use of the statement on the Burn Prescription form which states "maximum wind strengths normally used are 15km/hr, for prescribed burns" when burns are considered safe by CALM personnel, and are being conducted, in conditions of higher wind speeds, exposes CALM to an element of risk in potentially having difficulty demonstrating adherence to internal procedures, should the need arise in the future.

- Failure to complete the Operations Officers Day of Burn Checklist may result in the omission of an important action during the burn that may affect its outcome.

- Incomplete records, such as the lack of records of site weather conditions, may also limit CALM's ability to demonstrate appropriate management in the event of legal or community action.

- Reliance on extrapolations of fire tower readings for ground wind speeds may lead to unexpected wind and fire behaviour if the accepted conversion factor is not appropriate for a particular burn due, for example, to local topographic conditions.

- Reliance on individuals to interpret conditions during a burn, such as estimating wind speeds and recognising "normal" fire behaviour may expose CALM to an element of risk, *if* training and competency assessment systems are not adequately developed or implemented. It should be noted that training and competency assessment were not reviewed as part of this audit.

2.2.4 Suggestions for Improvement to Burn Implementation

- In terms of assisting CALM to demonstrate due diligence, should they be required to, the wind strength statement on the Burn Prescription form should be reviewed to ensure that an appropriate and realistic speed is stated, so that it can be complied with.

- Greater effort should be made to ensure records are complete. Cultural change to this effect could be initiated through incorporating explanation of the reasons for and importance of keeping records into fire training courses.

- Increased emphasis should be applied to ensuring the appropriate personnel have authorised and had input into the burn. Cultural change to this effect could be initiated through the development of an internal programme whereby a sample is checked periodically by an independent person.

- It may be work investigating the use of hand-held instruments for measuring local ground wind speed, particularly on sites a considerable distance from the nearest fire tower.

- A review of training and competency systems for fire personnel should be conducted, if it is not already being addressed, to ensure risk is minimised.

2.3 Outcomes

2.3.1 Objectives and Standards of the burns

The Manager CALMfire reported that for each burn, there are primary and secondary objectives, which arise out of the regional planning process and drive the prescriptions for each burn, the primary objective having the greater influence over the burn prescription. A set of Standards is also defined for each burn, which are more quantifiable than Objectives, and which the burn aims to meet.

From review of the documentation of the three burns audited, the primary and secondary objectives were only apparent to the auditor for one burn (Bramley), as various versions of the prescription forms had been used, and completed slightly differently for each of the burns. For Cornwall there were two Objectives listed and for High Hill Road there were six Objectives listed, neither of which nominated primary or secondary Objectives. The Manager CALMfire was able to identify the primary Objective for each of these burns from prior knowledge of the burns. It is understood that the Objectives of the burns are as follows:

High Hill Road

Primary Objective – Protect softwood plantations from major fire runs.

Secondary Objectives

1. Maintain and enhance biodiversity and its interactions through the use of prescribed fire.
2. Initiate water recharge through the use of prescribed fire as a management tool.
3. Protect forest ecological values from the impacts of severe wildfire.
4. Protect softwood plantation from major fire runs.
5. Develop a low fuel strategic buffer that will limit the spread of intense wildfires and provide protection to fire-fighters and other departmental values, state and commonwealth infrastructure
6. Reduce fuels to less than 2 tonnes/ha over 70% of burn area.

Cornwall

Primary Objective - To provide and maintain a suitable habitat for the Noisy Scrub Bird by providing a burn exclusion area and providing a fuel reduced buffer surrounding the exclusion area.

Secondary Objective – To provide strategic protection against wildfire damage through the creation of low fuel buffers to protect Worsley Alumina infrastructure and surrounding community values, by way of a fuel reduction burn.

Bramley

Primary Objective – to provide protection from wildfire damage to surrounding community values and assets, including neighbouring farms, vineyards and Margaret plantation, by the application of fire under prescribed conditions to reduce the quantity of combustible material.

Secondary Objective – to protect, maintain and enhance ecological values and biodiversity processes within the Bramley state Forest by the application of a low intensity, slow moving prescribed burn that will provide a mosaic of burnt (70-90%) and unburnt (10-30%) patches.

Achievement of Objectives and Standards

Each burn prescription specifies a set of Objectives and a set of Standards that are to be achieved. Achievement of all Objectives was assessed by CALM as "good" on a scale of "good", "fair" or "poor". Achievement of the Standards was not recorded separately, but taken into account in the assessment of achievement of the Objectives.

URS assessed the achievement of each Objective and Standard individually, due to the inconsistent use of the categories among the burns audited (e.g. High Hill Road and Bramley included burnt/unburnt percentages as Objectives, whereas Cornwall included burnt/unburnt percentages as a Standard).

Of the total of 26 Objectives and Standards across the three burns, 21 are considered by URS to have been met, one is considered to have been substantially met, three were not met, and there was no evidence to indicate whether or not one had been met (water recharge).

Detailed findings for the stated Objectives and Standards for each of the burns are included as Attachment C. A summary of achievement of Objectives and Standards is presented below in Table 1. Each symbol in the Achievement and Outcomes column represents one Objective or Standard from the combined Objectives and Standards the three burns. There were some instances where a burn had more than one Objective or Standard of each category (hence the inconsistent number of symbols amongst the categories).

Table 1: Summary of achievement of Objectives and Standards

Type of Objective or Standard	Achievement and Outcomes	Comments
Achievement of fuel reduction to a stated proportion and level	✓✓×	×Technically, based on Landsat imagery analysis that is still under development, Bramley underachieved fuel reduction by 4%. URS does not however consider that this is a significant shortfall given the precision of the analysis.
Maintenance/enhancement of biodiversity/ecological values	✓✓✓✓	Based on subjective assessment of protection offered from wildfire and achievement of specific actions. Biodiversity studies were not conducted as part of this audit.
Protection of man-made assets	✓✓✓✓	Based on subjective assessment of protection offered from wildfire.
Scorch height	✓✓✓✓	No documented post-burn measurement data available. Based on field observations.
Burn contained within designated boundaries	✓✓×	× relates to 2 small (<2ha) fires outside the burn boundary. Objective technically not met, but considered acceptable by URS. (The Bramley Objective was specific to the exclusion area, which URS understands was not impacted by hop-overs).
No unburnt pockets on edges of burns	✓✓×	× relates to an unburnt creek line on edge of Cornwall burn. 45ha wildfire thought to have escaped from this point and reported 5 days later, despite regular surveillance.
Vehicles to stay on existing tracks	✓	Based on field observations during audit.
Mop up to meet internal standards	✓✓⊙	⊙ relates to lack of vertical clearance on firebreak (walking track) adjacent to Margaret River, retained for aesthetic reasons. No adverse outcomes, successful balancing of competing objectives.
Increase of water yield	?	No feedback has been gained nor is expected (due to complexity of factors and interactions that contribute to aquifer levels) from Watercorp as to the success of this strategy for High Hill Road burn.

✓ Objective or Standard has been achieved

× Objective or Standard has not been achieved

⊙ Objective or Standard has been substantially achieved

? It is not known wither the Objective or Standard has been achieved

Discussion of the main issues

Achievement of fuel reduction to a stated proportion and level

No physical measurement of post-burn fuel levels or distribution of fuels across the burn areas are carried out as part of general practice by CALM. Instead, achievement of burnt area is estimated. It is labour intensive to take field measurements and difficult to interpret aerial photographs through the overstorey of the trees. It is, therefore, difficult to confidently assess the proportions burnt and unburnt and may not add much value to the current practice of viewing the areas from the air soon after burning and estimating the percentage burnt. Currently, observations made during post-burn flights are not mapped unless unburnt areas are greater than 20 hectares in size. This flight may be an opportunity to map some of the smaller unburnt areas to help with the estimate of burnt/unburnt areas.

Field observations during the audit indicated that litter, trash and dry shrub fuels have generally been reduced to a very low levels.

CALM's Manager of CALMfire reported that CALM is currently developing a method of assessing the fire intensity and spatial distribution across the burn area using interpretation of Landsat satellite imagery. The process has been assessed by CALM as having around 80% - 90% reliability in delineating burnt and unburnt areas.

CALM's stated Objectives, and outcomes achieved as indicated by Landsat imagery interpretation, are shown in Table 3.

Table 3: Target and actual % burnt for each burn audited

Burn	Target % burnt	Actual % burnt (Landsat)
High Hill Road	70%	94%
Cornwall	60-90%	79%
Bramley	70-90%	66%

High Hill Road achieved greater fuel reduction than its target of 70%, however considering the primary objective of the burn was to provide strategic fire protection for plantation assets in the area, this outcome is satisfactory. Technically, based on Landsat imagery analysis, Bramley does not meet its Standard, however in URS' opinion, 4% does not represent a significant shortfall taking into consideration the accuracy of the image interpretation.

Maintenance/enhancement of biodiversity/ecological values

Biodiversity studies were not carried out by URS as part of this audit as it is beyond the scope of this audit. The principle used by CALM is that biodiversity is enhanced by the creation and maintenance of mosaics of different vegetation types and ages, and that there are three levels of mosaic:

1. Landscape level (prescribed burn areas interspersed with unburnt areas across the landscape);
2. Burn level (burn exclusion zones within a prescribed burn area); and
3. Within a burn (varying levels of intensity of fire within the burn area creating a mosaic of species and ages of vegetation).

In URS' opinion, a mosaic of vegetation ages appears to have been achieved within each burn, through variation in fire intensity across the burn area, however species diversity was not assessed as part of this audit, nor was the extent to which the mosaic was represented on various parts of the landscape within the burn area.

Discussions with the Manager CALMfire indicated that multi-disciplinary meetings are held after each burn programme in each district or region to assess the achievement of objectives, including issues that the Nature Conservation group has had input into. Minutes of one post-burn meeting were sighted, however minutes of meetings for the three burns audited were not available. It would be beneficial to keep records of such meetings, as a record that the burns have been finalised and all follow-up actions completed.

Protection of man-made assets

In URS' opinion, the three burns audited should offer temporary (around 4 to 5 years) protection to assets in the area by limiting the rate of spread of wildfires, depending on the direction from which a future wildfire approaches. However, it should be noted that the level of protection will always depend on the conditions under which the wildfire is burning, and so protection from all wildfires cannot be guaranteed.

Scorch height

Scorch was negligible to mild in all three burns, and all Objectives and Standards relating to scorch height (to protect aesthetic values), were achieved.

Burn contained within designated boundaries

Hop-overs (burn escapes to outside the designated burn boundary) occurred during the High Hill Road and Bramley burns, and were reported to have been contained to small areas, 1.5 hectares at the most, and additional resources were not required to assist with suppression. In URS' opinion, considering the difficulties in predicting all fire behaviour,

and CALM's practice of continuously monitoring burn boundaries during burns, hop-overs contained to around one hectare are an acceptable outcome, where it is identified that there are no special ecological values or assets in the area. Technically however, the objective has not been met for High Hill Road, as there were two hop-overs during the burn. The objective was met for Bramley, as the specific objective for that burn was that there were to be no hop-overs into the burn exclusion area, and while hop-overs were reported, it is not clear where the hop-over actually occurred. During the audit, those parts of the exclusion area sampled for inspection showed no signs of having been burnt by a hop-over.

No unburnt pockets on edges of burns

High Hill Road and Bramley met their objectives relating to unburnt pockets, however Cornwall did not. Discussions with CALM personnel and field observations indicated that it is possible that there was an unburnt creek line running to the eastern boundary of Cornwell, which could have been the cause of a wildfire (Serial No. 8) that was reported on 15 November 2002 (five days after the prescribed burn). Discussions with CALM personnel and review of CALM documentation indicated that patrol and mop-up were carried out on the two days following the burn, and CALM personnel reported that aerial surveillance was carried out up to three times per day over the following three days until the wildfire was detected. A review of weather conditions during the five days after the burn indicated that the weather had warmed considerably, which would have decreased the moisture content in the unburnt creek line.

It is sometimes not possible to achieve effective fuel reduction along creek lines due to the high moisture content, however early detection of wildfire may help to minimise the final size of the wildfire, and ensuring that regular surveillance is undertaken along boundaries where it is known that effective fuel reduction has not been achieved, maximises that chance of early detection. In this instance, CALM appears to have carried out regular surveillance to achieve early detection. In the absence of records of surveillance and an incident investigation, it is difficult to further identify and isolate the factors that have contributed to the wildfire, and therefore what could be done differently in the future. CALM personnel interviewed reported that it is standard practice to investigate only those incidents that involve high value assets or ecological values. It is good practice however, to investigate "near misses" such as this incident, which, if it happened elsewhere could have involved high value assets or ecological values.

Vehicles to stay on existing tracks

No newly formed tracks or associated damage were evident during the audit.

Mop-up to meet internal standards

The burns appeared to have met the internal standard for mop-up (FPI 24), with the exception of Bramley, which substantially met the Standard. Discussions with CALM

personnel and observations during the audit suggested that mop-up had been conducted according to FPI 24, except for the requirement that firebreaks have a five metre vertical clearance ("*clear a mineral earth break of at least 1m wide (wider if scrub fuels necessitate it) with a 5m vertical clearance free from overhanging scrub and flammable material*" (FPI 24, Mopup and security standards, p1)). This was due to the requirement that the walking track along the Margaret River be retained intact for aesthetic purposes. Other firebreaks were clear of debris and no unburnt pockets within 100m of the edge were noted. URS considers that this was a case of successful balancing of competing objectives and that there were no adverse outcomes.

Increase in water yield

No feedback has been gained nor is expected (due to complexity of factors and interactions that contribute to aquifer levels) from Watercorp as to the success of this strategy for High Hill Road burn.

2.3.2 Potential Implications for Burn Outcomes

- Failure to map observations made from the aircraft after burning, during the period in which Landsat analysis is still being assessed and implemented, results in CALM missing an opportunity to add to its records of the burn.
- The inconsistent use of the terms Objectives and Standards, and the inconsistent use of Primary and Secondary Objectives across CALM Districts results in difficulties in identifying the Primary Objectives and therefore assessing whether they have been met. As the Objectives form the basis for the prescription preparation and are also used for briefing burn crews on the purpose of each burn, it would be prudent to ensure that the Objectives, and the order of their priority, are very clear.

2.3.3 Suggestions for Improvement

- Until another method of assessment is fully proven and implemented, such as Landsat imagery analysis, mapping of observations made from aircraft after the burn should be trialled to determine usefulness.
- The current Burn Prescription form should be used for all prescribed burns, to ensure that Primary and Secondary Objectives are clearly defined, as the current form prompts the user to define both Objectives. A system of document control should be implemented to ensure that all personnel have access to the current versions of documents.

2.4 Follow up after burning

Follow up after burning was brief for the burns audited, however discussions with the Manager CALMfire indicated that multi-disciplinary meetings are held after each burn programme in each district or region to assess the achievement of objectives, including issues requiring special protection measures, such as recreational, biodiversity or timber production values. Examples of follow up actions for one burning programme were sighted, however similar documentation for the burns audited was not available. This could be due to the relatively low level of complexity of the burns audited and the types of issues involved. All three burns audited had no follow-up actions other than inspections. The Burn Prescription forms were signed off as each inspection was completed.

Discussions with CALM personnel indicated that the burn areas were aerially viewed in the days following the burns to identify any large (>20 hectares) unburnt areas. All burns were reported as not having any large unburnt pockets remaining.

High Hill Road

Daily checks of burn boundaries for one week were signed-off on the Burn Record (CLM 873) as having occurred, by the District Fire Co-ordinator on 5 November, 2003.

Cornwall

No additional work was noted as being required. The Burn Record was signed on 18 November, 2002 (after the wildfire had been detected and suppressed) to verify that the final ground inspection had been completed, and that there were no areas of scorch greater than one hectare, no large unburnt pockets, and that boundaries had been mopped up and were secure.

Bramley

No additional work was noted as being required. The Burn Record was signed on 11 February, 2004 to verify that the final ground inspection had been completed, and that there were no areas of scorch greater than one hectare, no large unburnt pockets, and that boundaries had been mopped up and were secure.

2.4.1 Potential implications for follow-up after burning

- A lack of records of systematic reviews of burn programmes by a multi-disciplinary team, which includes *all* burns, could have the potential to lead to an omission of an important action.

2.4.2 Suggestions for Improvement

- Record and retain the minutes of meetings of multi-disciplinary team review of burn programmes, and include all of the burns in that programme.

2.5 Overall Conclusions

In general, CALM has been very successful in executing the burns to achieve reduction in fuel loads to the targeted levels, while causing minimal damage to retained vegetation. All three burns appear to have been conducted under mild conditions, and scorch levels were negligible to minimal.

The incidence of hop-overs is difficult to eliminate, and CALM manages their detection and suppression through allocating crews to various sectors of the boundary, which they patrol during the burn. This practice has enabled the successful suppression of hop-overs in the sample of three burns audited.

21 out of 26 objectives were met from the three burns, only one of which has had a discernable negative impact to date (wildfire escape from Cornwall). Improvements could be made by ensuring that all Districts have access to the current versions of forms (e.g. the Burn Prescription form) and that there is common understanding of the use and purpose of the Primary Objective.

The introduction of a method of remote sensing (Landsat imagery analysis), which has been in development by CALM since 2001 should significantly contribute to improving CALMs ability to assess and map the burnt/unburnt mosaic, if financially and technically acceptable.

Planning and implementation appeared to have been conducted according to internal standards, however the absence of some authorisations did not leave a sound auditable trail. Observations and discussions during the audit suggested that this was largely a "house-keeping" issue, rather than a lack of regard for an appropriate approval process.

The quality of record keeping could be improved greatly through the completion of the appropriate authorisations and filing documentation appropriately. This issue is considered important to ensure that all appropriate information is incorporated into the burn prescriptions and that appropriate management can be demonstrated.

Yours sincerely,
URS AUSTRALIA PTY LTD

Jodie Mason
Senior Environmental Scientist

Donna Pershke
Principal Systems and Sustainability

Attachment A
List of documentation reviewed

High Hill Road 415585a (Swan Coastal District)

Burn Prescription Folder, including:

- Burn Prescription Checklist
- District managers Prescribed Burn Confirmation Checklist
- Burn Prescription form CLM 873 (1997)
- Pre-burn Checklist
- Fuel Assessment Summary
- Fuel Assessment Records
- Day of burn diary
- Burn notifications
- Fire weather for the day of burn
- Fuel age maps
- Briefing notes
- Public map

Additional documentation

- Email regarding sign management plan requirements (7/4/2004, from Brian Inglis)

Cornwall W007 (Wellington District)

Burn Prescription Folder, including:

- Burn Prescription Checklist
- District managers Prescribed Burn Confirmation Checklist
- Burn Prescription form CLM 873 (1997)
- Pre-burn Checklist
- Fuel Assessment Summary
- Rating system for prescribed burning
- Controllers day of burn checklist
- Sign management form
- Map of Noisy Scrub Bird potential habitat

Attachment A
List of documentation reviewed

- Fuel Assessment Record
- Helicopter Landing pad form
- Fuel age maps
- Public map
- Operation Officers Day of Burn checklist
- Email regarding foxglove sites from Paul de Tores and Rob Turner (22//2/2002)
- Email regarding protection of PS plots from David Swain to Greg Strelein, Frank Colyer (7/3/2002)

Additional documentation

- Collie office log book, 10/11/2002, 11/11/2002
- Mopup and Security Standards (FPI24)
- Fire System: Annual Summary of Wildfires CLM434 (8/7/2003)
- Measurement of Forest Fuel Quantity (FPI23)
- Fire Operations Manual Instructions, chapter 7
- Certification of Prescribed Burns (FPI26)
- Fire Weather 11-16/11/2002

Bramley BS031 (Blackwood District)

Burn Prescription Folder, including:

- Burn Prescription Checklist
- District managers Prescribed Burn Confirmation Checklist
- Burn Prescription form CLM 873 (2002)
- Pre-burn Checklist
- Fuel Assessment Summary
- Controllers day of burn checklist
- Sign management form
- operations maps
- Burn notification forms

Attachment A
List of documentation reviewed

- Fuel Assessment Records
- Outcome of DIA website search and file search at DIA, Perth
- Dieback hygiene map
- Helicopter Landing pad form
- Aerial burn flight plan checklist
- Rating system for prescribed burning
- Public map
- Operation Officers Day of Burn checklist
- Letter from S&J Properties to CALM regarding property protection during burning
- Non-indigenous cultural heritage site CALMweb search results
- Heritage Council of WA seach results
- Australian Heritage Places inventory
- Register of Aboriginal sites 3/7/2003
- Apiary site permit detail record

Additional documentation

- Burn diaries 27/11/2003, 4-7/12/2003
- Daily moisture content record sheet (Northern Jarrah), Nov/Dec 2003
- Witchcliffe SDI (BOM)
- Daily log, Kirup, 28/11/03
- Edging, FPI40
- Fauna survey results
- Letter from CALM to Shire of Augusta-Margaret River re inclusion of road reserves in burn
- South west Region Public Consultation/Information Program for Spring 2002 Burn Season
- Public consultation – Bramley BS031 Prescribed Burn
- Roadside signage and safety at burns and wildfires, FPI64

Attachment A
List of documentation reviewed

- Patrol of burns and wildfires, FPI25
- Phytophthora cinnamomi Management plan
- Copy of Augusta-Margaret River Mail public notice of intent to burn
- Letter from Shire of Augusta-Margaret River to CALM re inclusion of road reserves in burn
- Blackwood District Autumn 2004 Burning Achievements (05/05/04)
- Report on Quokka surveys of proposed burn areas, Blackwood district, Autumn 2004
- Memo from Marika Maxwell, Rob Turner, Greg Voigt to Greg Mair, District Manager, re Draft Nature Conservation/FMS 2003 Spring Burn Fauna Survey Results, Burn recommendations and strategies 18/09/2003
- Burn issues for discussion and detailed actions/outcomes 2/09/03

Attachment B
List of personnel interviewed

Rick Sneeuwjagt – Manager CALMfire

Femina Metcalfe – Information and Technology Co-ordinator

John Tillman – Regional Fire Co-ordinator, South West Region

Mark Barendrecht – Regional Fire Assistant

Mike Cantelo – Perth District Fire Co-ordinator

Brian Inglis – Fire Protection Officer, Swan Coastal District

Rob Turner – Acting Fire Co-ordinator, Blackwood District

Mike Fielden – District Fire Co-ordinator, Wellington District

Attachment C
Table of Objectives and Standards

Objectives and Standards	Audit findings
High Hill Road, date of burn 5 October 2003	
Objectives	
1. (Primary Objective) Protect softwood plantations from major fire runs.	A review of maps in the Wanneroo CALM office and observations of the reduction in fuel levels due to the burn indicated that the burn was strategically located to offer temporary (around 4 to 5 years) protection to softwood plantations to the west of the burn by limiting the rate of spread of wildfires approaching from the east. CALM personnel reported that a wildfire that was burning to the north-east of the burn on 10/10/2003 (5 days after the prescribed burn), burnt in a south-westerly direction until it reached the eastern boundary of the prescribed burn area, where its intensity was reduced by the reduced fuel levels, thus enabling it to be controlled. Observations made during the audit supported this report. The burn could also offer temporary protection to other plantations in the area, depending on the direction from which a future wildfire approaches. In URS' opinion, this prescribed burn meets the general Objective of providing protection from wildfire. It should be noted however that the level of protection will always depend on the conditions under which the wildfire is burning and therefore cannot guarantee protection from every wildfire.
2. Initiate water recharge through the use of prescribed fire as a management tool	CALM personnel reported that Watercorp has made a general request that more extensive burning be done in the area in order to increase groundwater recharge. However, there has been no feedback from Watercorp to CALM to verify whether the increased water yield has been achieved, and feedback is not expected by CALM, due to the complexity of factors and interactions that contribute to aquifer levels. It is not known whether this Objective has been achieved.
3. Protect forest ecological values from the impacts of severe wildfire	A review of maps in the Wanneroo CALM office and observations of the reduction in fuel levels due to the burn indicated that the burn should offer temporary (around 4 to 5 years) protection to the Yeal Nature Reserve and various adjacent Proposed Reserves from fires approaching from the east by

Objectives and Standards	Audit findings
	limiting their rate of spread. In URS' opinion, this prescribed burn meets the general Objective of providing protection from wildfire. It should be noted however that the level of protection will always depend on the conditions under which the wildfire is burning and therefore cannot guarantee protection from every wildfire. No studies of ecological values were conducted as part of the scope of this audit.
4. Maintain and enhance biodiversity and its interactions through the use of prescribed fire	Biodiversity studies, or assessment of the adequacy of CALM's incorporation of biodiversity in burn planning, were not carried out by URS as part of this audit as these are beyond the scope of this audit. CALM personnel reported that CALM's Nature Conservation group reviews the effects of fire on flora and fauna, however there is generally no feedback from them for each burn, and there has been no assessment or feedback for this burn. The Manager CALMfire reported that follow-up actions by the Nature Conservation group are generally confined to those burns for which issues have been raised during burn planning. No issues were raised during burn planning for this burn. The principle used by CALM is that biodiversity is enhanced by the creation and maintenance of mosaics of different vegetation types and ages, and that there are three levels of mosaic: at a landscape level (prescribed burn areas interspersed with unburnt areas across the landscape); at a burn level (burn exclusion zones within a prescribed burn area); and within a burn (varying levels of intensity of fire within the burn area creating a mosaic of species and ages of vegetation). In URS' opinion, this burn has achieved this Objective in the sense that a mosaic of vegetation appears to have been created/maintained, particularly at the landscape and burn level. We cannot comment on the effectiveness of this measure in achieving biodiversity outcomes.
5. Develop a low fuel strategic buffer that will limit the spread of intense wildfires and provide protection to fire-fighters and other departmental values, state and commonwealth infrastructure	A review of maps in the Wanneroo CALM office and observations of the reduction in fuel levels due to the burn indicated that the burn should offer temporary (around 4 to 5 years) protection to the Pinjar Gas Turbine Station by limiting the rate of spread of wildfires approaching from the north-east

Objectives and Standards	Audit findings
	limiting the rate of spread of wildfires approaching from the north-east direction. Similarly it should offer temporary (around 4 to 5 years) protection to other infrastructure and people (such as fire fighters) in the area by reducing the intensity of fire in the prescribed burn area. In URS' opinion, this prescribed burn meets the general Objective of providing protection from wildfire. It should be noted however that the level of protection will always depend on the conditions under which the wildfire is burning and therefore cannot guarantee protection from every wildfire.
6. Reduce fuels to less than 2 tonnes/ha over 70% of burn area	CALM's Manager of CALMfire reported that CALM is currently developing a method of assessing the fire intensity and spatial distribution across the burn area using interpretation of Landsat satellite imagery. The process has been assessed by CALM as having around 80% - 90% reliability in delineating burnt and unburnt areas. Analysis of images indicated that fuels had been reduced on 94% of the burn area. Field observations during the audit indicated that litter, trash and dry shrub fuels have generally been reduced to a very low level. Field observations also suggested that the distribution of fuel reduction over the burn area has been widespread, and no substantial unburnt areas were observed. In URS' opinion, based on estimates from field observations during the audit and landsat imagery analysis, this burn meets this Objective.
Standards	
1. Burn scorch height may exceed 5m	The conditions prescribed for the burn were intended to limit the scorch height to seven metres. Field observations during the audit indicated that scorch height was generally below two to three metres. In URS' opinion this burn has met this Standard.
2. Standard mop up required	CALM personnel reported that standard mop-up procedures were followed after the burn. There was no evidence during the audit to suggest that this was not the case. Firebreaks were clear of debris and no unburnt pockets within 100m of the edge were noted. In URS' opinion, this burn has met this Standard.

Attachment C
Table of Objectives and Standards

Objectives and Standards	Audit findings
3. No unburnt pockets within 50m of burn edge greater than 20 X 20m	The field inspection during the audit suggested that there were no unburnt pockets within 50m of the burn edge greater than 20 X 20m. In URS' opinion, this burn has met this Standard.
4. Burn to remain within designated boundaries	Two "hop-overs" (burn escapes to outside the designated burn boundary) occurred during the burn, one to the north and one to the east of the burn. The northern hop-over burnt an area of around 1.5 hectares, and the eastern one burnt an area of less than 1 hectare. According to CALM's protocols, a hop-over is not classified as an "escape" or "wildfire" unless additional resources are called in to assist with suppression. In URS' opinion, considering the difficulties in predicting all fire behaviour, and CALM's practice of continuously monitoring burn boundaries during burns, these hop-overs are an acceptable outcome, however, technically the Standard has not been met.
5. Stags and dangerous limbs to be mopped up and made safe	There was no evidence from field observations during the audit to suggest that this Standard was not met at the time of mop up. In URS' opinion, this burn has met this Standard.
6. Vehicles to remain on existing tracks	During the site visit, there was no obvious evidence of vehicles having left the existing tracks. The location of the northern hop-over was even difficult to find, as there were no obvious tracks where the grader/loader had left the firebreak to clear a break around the hop-over. In URS' opinion, this burn has met this Standard.
Cornwall, date of burn 10 November 2002	
Objectives	
1. (Primary Objective) Provide and maintain a suitable habitat for the Noisy Scrub Bird by providing a burn exclusion area and providing a fuel reduced buffer surrounding the exclusion area.	Field observations made during the audit indicated that the burn exclusion area remained unburnt, and that the southern and eastern boundaries of the exclusion area have been fuel reduced. The western and northern boundaries of the exclusion zone were not fuel reduced at the same time as the burn being audited, however, the fuel age of the adjacent forest to the north and west of the burn

Objectives and Standards	Audit findings
	exclusion area were shown on a fuel age map to be one and three years old respectively. In URS' opinion, this objective has been met, as the exclusion zone has been surrounded by a fuel reduced buffer, developed strategically over the past three years.
2. Provide strategic protection against wildfire damage through the creation of low fuel buffers to protect Worsley Alumina infrastructure and surrounding community values, by way of a fuel reduction burn	The Worsley conveyor runs through the eastern portion of the burn area. URS considers that the burn should offer temporary (around 4 to 5 years) protection to that section of the conveyor within the burn boundary. Similarly it should offer temporary (around 4 to 5 years) protection to other community values in the area by reducing the intensity of fire in the prescribed burn area. In URS' opinion, this prescribed burn meets the general Objective of providing protection from wildfire. It should be noted however that the level of protection will always depend on the conditions under which the wildfire is burning and therefore cannot guarantee protection from every wildfire.
Standards	
1. Reduce fuels to 2-3 tonnes/ha over 60-90% of the burn area	It was reported by CALM personnel that soon after the burn, the spotter pilot viewed the burn area from the aircraft and reported that there were no substantial unburnt pockets. Field observations during the audit indicated that litter, trash and dry shrub fuels have generally been reduced to a very low level in the burnt areas. Unburnt areas were observed during the field visit, mainly along streams and drainage lines. CALM's Manager of CALMfire reported that CALM is currently developing a method of assessing the fire intensity and spatial distribution across the burn area using interpretation of Landsat satellite imagery. The process has been assessed by CALM as having around 80% - 90% reliability in delineating burnt and unburnt areas. Analysis of images indicated that fuels had been reduced on 79% of the burn area. In URS' opinion, based on estimates from field observations during the audit

Objectives and Standards	Audit findings
	and Landsat imagery analysis, this burn meets this Standard.
2. No unburnt pockets >3ha are to remain within 300m of any edge	Comments as above (1). Discussions with CALM personnel and field observations indicated that it is possible that there was an unburnt creek line running to the eastern boundary, which could have been the cause of a wildfire (Serial No. 8) that was reported on 15 November 2002 (five days after the prescribed burn). The fire reportedly burnt 44.5 hectares. Discussions with CALM personnel and review of CALM documentation indicated that patrol and mop-up were carried out on the two days following the burn, and that aerial surveillance was carried out up to three times per day over the following three days until the wildfire was detected. A review of weather conditions during the five days after the burn indicated that the weather had warmed considerably, which would have lowered the moisture content in the unburnt creek line. It is not known by URS whether or not the unburnt area is greater than three hectares in size, however URS understands that the intent of the Standard is to minimise risk of escapes from burn edges. In URS' opinion, the intent of this Standard has not been met. It is sometimes not possible to achieve effective fuel reduction along creek lines due to the high moisture content, however the early detection of wildfire may help to minimise the final size of the wildfire, and ensuring that regular surveillance is undertaken along boundaries where it is known that effective fuel reduction has not been achieved, maximises that chance of early detection. In this instance, CALM appears to have carried out regular surveillance to achieve early detection. In the absence of surveillance documentation and an incident investigation, it is difficult to further identify the factors that contributed to the wildfire.
3. Minimise scorch to <6m along Collie Tallanalla and Harvey Quandanning Roads	The conditions prescribed for the burn were intended to limit the scorch height to 6 metres. Field observations during the audit indicated that the intensity of the burn was quite low – small (~>1ha) areas unburnt, large fuel still in place, and very few epicormic shoots, even despite the substantial areas of regrowth. Negligible scorch was observed throughout the burn area, including along Collie

Objectives and Standards	Audit findings
	Tallanalla and Harvey Quandanning Roads, thereby minimising the visual impact of the burn. In URS' opinion, this burn has met this Standard.
4. All unintended out breaks of fire inside the exclusion area are to be suppressed immediately and kept to <1ha	Discussions with CALM personnel, review of CALM documentation and field inspections indicated that there were no unintended out breaks of fire inside the exclusion zone during the period of or following the burn.
Bramley, date of burn 28 November 2003	
Objectives	
1. (Primary Objective) Provide protection from wildfire damage to surrounding community values and assets, including neighbouring farms, vineyards and Margaret plantation, by the application of fire under prescribed conditions to reduce the quantity of combustible material.	Review of maps and the site visit during the audit indicated that the burn is strategically positioned adjacent to the town of Margaret River. It should act to provide protection against wildfire approaching from the north-east, by limiting the rate of spread. The burn has been effective in reducing the quantity of combustible material, and should limit the rate of spread of most wildfires entering the burn area for the next 4 to 5 years. Similarly it should offer temporary (around 4 to 5 years) protection to the many other community values and assets in the Margaret River area by reducing the intensity of fire in the prescribed burn area. In URS' opinion, this prescribed burn meets the general Objective of providing protection from wildfire. It should be noted however that the level of protection will always depend on the conditions under which the wildfire is burning and therefore cannot guarantee protection from every wildfire.
2. Protect, maintain and enhance ecological values and biodiversity processes within the Bramley State Forest by the application of low intensity, slow moving prescribed burn that will provide a mosaic of burnt (70-90%) and unburnt (10-30%) patches	Performance against the biodiversity aspect of this Objective was not assessed, as biodiversity studies were beyond the scope of the audit. Review of CALM documentation indicated that CALM's Nature Conservation group has authorised the burn, specifying a low intensity burn for along the edge of the Margaret River, to protect brush-tail possum habitat. Field observations during the audit indicated that the low intensity had been achieved. The principle used by CALM is that biodiversity is enhanced by the creation and maintenance of mosaics of different vegetation types and ages, and that

Attachment C
Table of Objectives and Standards

Objectives and Standards	Audit findings
	there are three levels of mosaic: at a landscape level (prescribed burn areas interspersed with unburnt areas across the landscape); at a burn level (burn exclusion zones within a prescribed burn area); and within a burn (varying levels of intensity of fire within the burn area creating a mosaic of species and ages of vegetation). In URS' opinion, this burn has achieved this Objective in the sense that a mosaic of vegetation has been created/maintained. We cannot comment on the effectiveness of this measure in achieving biodiversity outcomes.
Standards	
1. Reduce accumulated fuels <2 tonnes/ha in Jarrah/Marri by applying a slow moving prescribed fire that will provide a mosaic of burnt (70-90%) and unburnt (10-30%) patches	Field observations during the audit indicated however that litter, trash and dry shrub fuels have generally been reduced to a very low level. Field observations also suggested that the distribution of fuel reduction over the burn area has been widespread, with some small areas unburnt, and mainly located in streams and drainage lines. No substantial unburnt areas were observed. In URS' opinion, based on estimates from field observations, this burn has met this Standard. CALM's Manager of CALMfire reported that CALM is currently developing a method of assessing the fire intensity and spatial distribution across the burn area using interpretation of Landsat satellite imagery. The process has been assessed by CALM as having around 80% - 90% reliability in delineating burnt and unburnt areas. Analysis of images indicated that fuels had been reduced on 66% of the burn area, slightly less than the target 70-90%. Technically, based on Landsat imagery analysis, this burn does not meet this Standard, however in URS' opinion, 4% does not represent a significant shortfall taking into consideration the accuracy of the image interpretation.
2. Scorch to the upper forest canopy not to exceed 30% of the burn area	Field observations during the audit indicated that the maximum scorch height was around four metres. Some scorch to the parts of the upper canopy was evident on slopes where the fire intensity would be expected to be higher than the burn average, however this area is estimated to be limited to one to two

Attachment C
Table of Objectives and Standards

Objectives and Standards	Audit findings
	hectares within a burn area of 1207 hectares. In URS' opinion, based on estimates from field observations, this burn has met this Standard.
3. Scorch not to exceed 5 metres adjacent to Osmington Road	The conditions prescribed for the burn were intended to limit the scorch height to six metres, however field observations during the audit indicated that scorch height did not exceed four metres throughout the burn area. CALM personnel reported that the small portions of the burn adjacent to Osmington Road were excluded from the core lighting due to their small areas, difficult boundaries, and the fact that they had already recently been fuel-reduced around the edges. Observations during audit indicated that the scorch along Osmington road from the edge burning was negligible. In URS' opinion, based on field observations, this burn has met this Standard.
4. No unburnt pockets to exceed 15 ha in size and no unburnt pockets to exceed 2 ha within 100m of boundary	During the field inspection at the time of the audit, no large unburnt pockets were observed, and no unburnt pockets greater than two hectares in size within 100 metres of the boundary were observed. In URS' opinion, based on estimates from field observations, this burn has met this Standard.
5. Burn will meet mop-up standards as per FPI 24	Discussions with CALM personnel and observations during the audit suggested that mop-up had been conducted according to FPI 24, except for the requirement that firebreaks have a five metre vertical clearance. This was due to the requirement that the walking track along the Margaret River be retained intact for aesthetic purposes. Other firebreaks were clear of debris and no unburnt pockets within 100m of the edge were noted. In URS' opinion, based on discussions with CALM personnel and field observations, this burn has substantially met this Standard.

Objectives and Standards	Audit findings
6. Ensure the fire exclusion area is not burnt	At least one hop-over was reported during mop-up in the days following the burn, however after review of the documentation and discussions with CALM personnel, it is not clear to URS where the hop-over actually occurred. No parts of the exclusion zone sampled for inspection were observed to have been burnt by a hop-over. In URS' opinion, based on field observations, this burn has met this Standard.