THE COLONG FOUNDATION FOR WILDERNESS LTD.

NSW Bushfire Inquiry

16 April 2020

Introduction

The Colong Foundation for Wilderness

The Colong Foundation is a community conservation organisation that campaigns for the protection and management of wilderness, national parks and other large natural areas. The organisation was founded in 1968 (as the Colong Committee) and has played a major role in many important conservation achievements over the past 52 years in NSW. Many of these achievements are now highly valued by the community and almost taken for granted. Yet they were only achieved by sustained and vigorous public action supported by forward-looking governments and government agencies. These achievements include:

- creation of the rainforest Border Ranges National Park;
- passage of the NSW Wilderness Act in 1987, the first of its kind in Australia;
- the listing of numerous areas under the Wilderness Act, now totalling over two million hectares;
- expansion of the national park system in the Blue Mountains and its culmination in the World Heritage listing of the million-hectare Greater Blue Mountains Area in 2000;

Colong Foundation's interest in bushfire

Fire management is a central concern in the management of large intact natural areas (i.e. wilderness), as fire is critical to the protection of both human and natural communities. The Colong Foundation believes that the over-riding objectives in managing the core of large natural areas should be the protection of biodiversity, geodiversity and ecosystems and the maintenance of natural processes. The corollary is that fire management for protecting human assets should mainly occur near the bushland margins where it can be more effective.

The 2019-20 bushfire season

Most of the areas in eastern NSW that the Colong Foundation has campaigned to protect over the past 50 years were impacted by the 2019-20 bushfires.

An indicative list of fire impacted wilderness includes Timbarra, Binghi, Washpool, Banyabba, Bundjalung, Bindery/Mann, Guy Fawkes, Chaelundi, Cathedral Rocks, Mt

Kaputar, Macleay Gorges, Werrikimbe, Mt Seaview, Limeburners, Wollemi, Yengo, Grose, Kanangra-Boyd, Nattai, Ettrema, Budawang, Buckenbowra, Deua, Brogo, Nadgee, Pilot, Bimberi, Goodradigbee and Bogong Peaks.

The value of wilderness

Wilderness in NSW is protected under the *Wilderness Act 1987*. A wilderness area is described in the Act thus:

- the area is, together with its plant and animal communities, in a state that has not been substantially modified by humans and their works or is capable of being restored to such a state,
- the area is of a sufficient size to make its maintenance in such a state feasible, and
- the area is capable of providing opportunities for solitude and appropriate self-reliant recreation.

By being protected from modification, including recreational and tourism developments, wilderness has the highest level of environmental protection under NSW law. The above characteristics make the conservation of natural values paramount in wilderness. The large size of wilderness areas helps to protect constituent biodiversity from outside impacts including human activities and invasive species. It should also help protect wilderness from environmentally damaging fire management programs.

The Colong Foundation regards wilderness as a place where nature has primacy, and can flourish in glorious diversity. Wilderness cradles a genetic storehouse of unimaginable wealth for future generations, as illustrated by the Wollemi Pine. Due to their size, diversity and the old growth they contain, wilderness areas provide the opportunity for ecosystems to adjust to the duress of climate change. Their soils and groundwater systems are more intact and so provide higher water yield and quality than disturbed catchments. Wilderness provides the opportunities for personal rediscovery through outdoor activities in a wild setting. Wilderness has inspired philosophers, and has given us art that enriches our lives. It grants effective preservation to Aboriginal heritage within its original setting.

Purpose of this submission

As a member of the Nature Conservation Council of NSW (NCC), the Colong Foundation's purpose in this submission is to both support the NCC submission and to emphasise some important issues of particular concern to the Colong Foundation.

Existing documents

We commend and support the following documents which cover many of the issues of concern:

- *Colong Foundation Bushfire Policy* (attachment A to this submission);

- NPWS (n.d., reprinted 2013). *Living with Fire in NSW National Parks, A strategy for managing bushfires in national parks and reserves 2012–2021* (attachment B to this submission);
- NSW Nature Conservation Council (2020). *Submission to the NSW Independent Inquiry Into the 2019-20 Bushfire Season* (already available to the Inquiry).

Term of Reference 1: ***The causes of, and factors contributing to, the frequency, intensity, timing and location of, bushfires in NSW in the 2019-20 bushfire season, including consideration of any role of weather, drought, climate change, fuel loads and human activity*****.**

Wilderness and fire

The evidence is that the majority of the NSW bushfires this season were caused by lightning, especially the larger fires. These included Bees Nest, Liberation Fire Trail, Gospers Mountain, Green Wattle Creek, Currowan, Dunns Road and Badja Forest Road. Some of these began in declared wilderness areas within national parks, while others were in state forest or private tenure.

It is self-evident that the largest bushfires will occur in the largest areas of bush, which in NSW are mostly national parks and wilderness areas. Lightning ignitions also tend to occur more in rugged mountain country, which is where most of our wilderness areas are.

Wilderness areas are not all bush ready to burn. Amongst regions of dry forest these areas also include significant areas of wetter forest types (rainforest and wet sclerophyll) that only burn under very severe fire conditions and therefore are more likely to act as fire inhibitors – and should be protected. Rugged wilderness areas also contain the topographic diversity and particular features that can impede fire and be used as natural barriers during suppression operations. These include deep gorges, moist southern slopes, clifflines, rocky areas and rivers.

Wilderness is not inherently more fire-prone than other bushland, but fires in wilderness are more difficult to access and extinguish due to remoteness and rugged topography. This fact highlights the need for a greater commitment to extinguishing remote fires when they are small. Rapid detection followed by a rapid and substantial response are essential. When remote fires grow too big for initial attack they often become very difficult to control.

Many remote fires were put out due to the combined efforts of the National Parks and Wildlife Service (NPWS) and Rural Fire Service (RFS) using aircraft and remote area firefighting teams (RAFT). But some were not, and grew much larger. Some remote lightning fires were not attacked at all in their early stages. These adverse outcomes were due to various combinations of a shortage of aircraft and RAFT, difficult weather/ground conditions and a lower priority given to fires when small.

Drought, weather and fuel loads

There is no evidence to support the notion that bushland fuel loads were higher this season than in previous seasons[1]. Scientists have emphasized that the key difference that produced the unprecedented scale of these fires was the extended drought and record high temperatures coupled with weather during the fires[2], [3]. These factors ensured that the fuel that existed was more cured, drier and more available to burn. This was expressed in many areas by trees and understory shrubs dying from the drought and extensive leaf-drop due to water stress.

Under the severe to catastrophic conditions experienced at times during the season, fires burnt through low fuel areas including almost bare paddocks and bush areas that had been burnt only a few years earlier. Fires also burnt through orchards, pine plantations and heavily logged forests.

ToR 1 Recommendations:

- Commit greater resourcing and higher priority to detecting and putting out remote fires as quickly as possible.
- Ensure a priority for fire management in wilderness is the protection of fire-inhibiting vegetation types and landscape features.
- Recognise that wilderness is not inherently more fire-prone than other bushland or land uses and that drought and weather were the primary drivers of the extreme fire season.

Term of Reference 2: ***The preparation and planning by agencies, government, other entities and the community for bushfires in NSW, including current laws, practices and strategies, and building standards and their application and effect.***

Fire mitigation and prescribed burning

A great deal of scientific literature and strategic thinking emphasises that the impact of bushfire on people needs to be managed mostly where that impact occurs, on the bushland interface. This is logical, risk-based, evidence-based and cost-effective.

While prescribed burning remote from settlement has a role in ecological management, its value in protecting people and their assets is minimal. If done for other reasons it can have negative ecological effects. Burning can also reduce fire-inhibiting vegetation and promote more fire-prone plant communities.

[1] NPWS has more than satisfied the state government targets for both 'area treated', with 103% of target achieved; and for 'properties protected' with 120% of the target achieved.
[2] Matthias M. Boer, Víctor Resco de Dios and Ross A. Bradstock, Unprecedented burn area of Australian mega forest fires, *Nature Climate Change,* 24 February, 2020.
[3] Rachel H Nolan, Matthias M Boer, Luke Collins, Victor Resco de Dias, Hamish Clarke, Meaghan Jenkins and Ross A Bradstock, Causes and Consequences of eastern Australia's 2019-20 season of mega-fires*, Global Change Biology,* 2020.

The protective value of burning increases the closer to settlement that burning is done. Hence strategic burning some distance from assets to assist containment strategies has some value, which was demonstrated in some instances in the recent fire season. However the most 'bang for the buck' is achieved when mitigation is done close to assets to eliminate or reduce the potential fire impact. Hectare-based targets are a nonsense as they do not measure protective benefit.

Prescribed burning, even close to houses, is widely recognised by fire agencies and scientists as useful but 'not a panacea'[4]. Another widely stated position is that the best mitigation that landowners can do is on their own property and immediately adjacent, because this is what will affect how well the property survives during a fire.

Prescribed burning does not stop fires, the purpose is to moderate fire behaviour to increase the chances of control and to reduce fire impacts. The limitations of prescribed burning in modifying fire impacts are well researched. Previous fire to reduce fuel is most useful in moderating fire behaviour in the first year or two[5]. In severe to catastrophic conditions any burn over two to three years in age will have little effect. Therefore it is partly an issue of probability: whether a wildfire occurs where a prescribed burn has recently been carried out. The recent fire season provides a large dataset to further assess these issues.

Prescribed burning also has major practical limitations. The RFS Commissioner has referred to smoke impacts and narrowing windows of the right conditions. Other issues are the difficulty of getting all the permissions from private landowners and the availability of RFS crews midweek. Burns near houses are complicated, tricky and expensive and they can be high risk. These and other reasons explain why most prescribed burning in NSW is done by NPWS away from human assets.

Burning is not the only method of attempted mitigation, however it's one of the actions that takes the least effort. More emphasis needs to be placed on land use planning, property management, building standards, vegetation management and other methods. If houses were managed so they couldn't burn then the risk to them wouldn't exist[6].

Grazing and logging

Substantial scientific evidence indicates that neither grazing nor logging offer useful reduction in bushfire intensity, despite these ideas being superficially logical to the lay person. On the other hand logging and grazing open up areas to increased fire risk from both arson and escaped fires lit to burn forest waste and promote 'green

[4] https://www.theguardian.com/australia-news/2020/jan/08/hazard-reduction-is-not-a-panacea-for-bushfire-risk-rfs-boss-says
https://www.abc.net.au/news/2020-01-07/fuel-reduction-burn-debate-rubbish-says-vic-fire-chief/11849522

[5] Analysis of fire severity maps of the Gospers Mountain, 3 Mile and other smaller fires in the Central Coast hinterland in 2019-20, shows containment being assisted in only the most recently treated areas (i.e. burnt in the last 18 months).

[6] Mick Harewood, February 2020, How Science, Diligence and Luck saved our Home.
Paul Whitington, February 2020, Forest Recovery newsletter.

pick'. Grazing and logging are being opportunistically promoted by those with a vested interest in grazing and logging, with no evidence to support the idea that they reduce fire risk[7, 8].

These practices do pose an enormous risk to the ecological integrity of wilderness, national parks and other areas set aside for conservation. They must be excluded. The Bees Nest wildfire in Guy Fawkes National Park, illustrates the case, as the park was heavily over grazed by emaciated feral horses during the recent drought but this did not stop this fire.

Role of NPWS

NPWS manages about 9% of NSW and most of the fire-prone bushland. Much of the NPWS land management time and budget is taken up with fire: planning and undertaking burns and other mitigation programs, liaising with communities and other agencies, fire planning, maintaining databases and other records and, every summer, putting out hundreds of fires. Fire and introduced species control are the two major land management programs undertaken by NPWS. This is because fire management is a legal requirement, because fire is a key factor in ecosystem and species management that can be manipulated, and fire also has huge implications for human communities bordering NPWS reserves.

The capacity and professional skills of NPWS in bushfire suppression are widely recognized within government and frequently praised by the RFS Commissioner as being critical to fire operations. NPWS undertakes most of the prescribed burning in NSW. In bushfire suppression, NPWS fills vital specialized niches, principally in RAFT, aerial attack, suppression strategy planning and incident control.

Every fire season, the recent one included, and with little public fanfare, NPWS puts out numerous on-park fires, especially remote ones, and assists with many off-park fires. They supply many of the best air attack supervisors in NSW, staff many IMT planning teams and fill many deputy incident controller roles.

As a large land manager, the role of NPWS in fire is critical. RFS is not a land manager, and fire management must be integrated with the greater task of managing the land.

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7 Stone, C., Hudak, A., Morgan, P. Forest (2003) Harvest Can Increase Subsequent Forest Fire Severity. Proceedings of the Second International Symposium on Fire Economics, Planning, and Policy: A Global View. p.525 General Technical Report PSW-GTR-208. US Forest Service.
Lindenmayer, D.B., Hobbs, R.J., Likens, G.E., Krebs, C.J. and Banks, S.C. (2011) Newly discovered landscape traps produce regime shifts in wet forests. Proceedings of the National Academy of Sciences, Vol. 108, No. 38, pp15887-15891.

8 The Victorian Alpine Grazing Taskforce following the 2003 fires determined that "grazing did not reduce blazing".
Williams, R.J., Wahren C., Bradstock, R.A. and Muller, W.J. (2006) 'Does alpine grazing reduce blazing? A landscape test of a widely held hypothesis'. Austral Ecology, Vol. 31, pp 925-936.

ToR 2 Recommendations:

- Greatly increase the emphasis on non-burning methods of bushfire risk reduction, including property management, building standards and land use zoning.
- Focus prescribed burning for asset protection close to assets and reject hectare-based targets.
- Reject grazing and logging as useful fire mitigation strategies and exclude them from conservation reserves.
- Retain the critical role of NPWS in fire management and suppression, and increase support and resourcing for this function within NPWS.

Term of Reference 3: ***Responses to bushfires, particularly measures to control the spread of the fires and to protect life, property and the environment, including:***

a. immediate management, including the issuing of public warnings

b. resourcing, coordination and deployment

c. equipment and communication systems.

Initial attack

In appropriate circumstances, 'natural' lightning fires in wilderness may be let burn, but not if they might reach settled areas or if they are part of the impact of climate change. Generally, most remote fires during the fire season should be suppressed. Rapid and effective initial attack is essential, but was found wanting in many cases this past fire season. Some of the largest and most destructive fires resulted from remote lightning strikes in declared wilderness that were not put out, including Gospers Mountain and Green wattle Creek fires in the Greater Blue Mountains World Heritage Area.

NPWS has been very successful in such operations, and did put out many remote fires in this last season, some with the assistance of RFS crews. However some remote operations were hampered because not enough aircraft and/or RAFT were available and because they were not given priority compared to other fires that were impacting houses. This strategic approach led to some fires becoming very large, burning many houses and requiring massive resources to control.

Suppression methods

Numerous official documents, policies and operational procedures exist to guide how bushfire suppression is *organised* in NSW. However guidelines on how to *do* bushfire suppression seem to be very scarce. There appears to be no effective review or assessment of how suppression strategies worked or didn't work, and alternatives. Certainly there is nothing that is publicly available.

A wide range of methods can be adopted for containing fires, including aerial attack with water or retardant, RAFT attack, aerial burning, construction of containment lines, clearing of vegetation, backburning, direct attack with tankers and defensive property protection. The methods used, in a section 44 or other large fire, are decided by the Incident Management Team, but in a manner that is opaque to outsiders and rarely reported to the public. Nor are the outcomes of any reviews or lessons that eventuate.

Strategic decisions are very complex and difficult, especially amid the scale, trauma and carnage of the recent fire season. However these factors make it even more imperative to have a more rigorous system in place for deciding how best to tackle a fire and fore reviewing operations after the event.

In the face of many adverse events and the lack of transparency, it is difficult to have confidence that the most effective and least damaging methods have been used in any operation, or that they have been thoroughly reviewed with 'lessons learned' identified and adopted.

Environmental impacts of suppression

Fire suppression activities in bushland areas can have impacts on environmental values including vegetation, wildlife, cultural heritage, land stability and water quality. It is even more important to avoid these impacts in wilderness areas and national parks.

The two objectives of putting the fire out and avoiding environmental impacts are not always equally achievable. However many instances of unnecessary impacts suggest that not enough attention is given to the environment. Examples include bulldozer swathes of excessive width or which were never likely to be needed, 'burning out' areas of bush that don't need to be burnt out and large-scale backburns that impact more bush and expand the fire with, sometimes, no strategic benefit in reducing property impacts. (It is acknowledged that just because an action was ineffective with hindsight does not prove it was unnecessary or inappropriate at the time. However the volume of such examples over many years, and the seriousness of some, suggests there is an issue to address).

On the evidence of events, it would seem that key planning documents such as national park plans of management, Reserve Fire Management Plans and District Bushfire Operations Plans are often overlooked. These plans contain provisions for protecting environmental values in the course of fire suppression, and are required to be observed. Both processes are mandated by the *Rural Fires Act*.

Protecting moist forest types

As stated above, moist forest types, especially in large bushland areas, are a fire inhibitor and fire control advantage. These areas need to be protected and if possible expanded to mitigate fire risk. However both prescribed burning and suppression methods like backburning and aerial ignition can 'eat away' at the edges of moist communities, or even burn through them altogether. Both situations will

tend to reduce the moist vegetation over time and replace it with more fire-prone vegetation types.

ToR 3 Recommendations:

- Expand aircraft and RAFT resources for attacking remote fires, and give these fires a high priority when they have potential to become larger, more difficult and more damaging.
- Increase transparency, monitoring, assessment and public reporting of bushfire suppression strategies and post-fire reviews.
- Ensure that environmental impacts are fully considered during bushfire operations through observance of mandatory plans and adequate assessment of suppression strategies.
- Make protection of moist forest types a priority in both bushfire suppression and mitigation.

Thank you for this opportunity to contribute to the NSW Independent Inquiry into the 2019-2020 bushfire season.

Yours sincerely,

Keith Muir
Director
The Colong Foundation for Wilderness Ltd

Attachment A

Colong Foundation Policy
Bush Fire management and Wilderness

Preamble

Bush fire management encompasses all bush fire policies and operations, including fire mitigation, ecological burning and fire suppression. Fire management in and affecting wilderness and other large bushland areas should protect wilderness values in a climate-changing world through the following principles and strategies.

Principles

i. Bush fire management (which by definition occurs in predominantly natural environments) is treated as one component of ecological management of bushland.

ii. The prime bush fire management objectives in and for wilderness are the minimisation of all biophysical impacts and the maintenance and restoration of wilderness integrity (natural values, natural processes and existing biodiversity).

iii. All fire management in wilderness is based upon principles of ecological sustainability and the best scientific knowledge.

iv. Fire management in wilderness is evidence-based but flexible and adaptive (recognising that knowledge is evolving and an ecological risk management approach may be necessary if knowledge is incomplete).

v. The principle performance criterion for fire management in wilderness is the maintenance of the majority of each vegetation community within its (scientifically determined) desirable limits of fire regime (frequency, intensity, timing and variability).

vi. The integrity of old growth forests, rainforests and other fire sensitive vegetation are protected from an increased risk of wildfire arising from inappropriate fire regimes and climate change.

Strategies

<u>Research</u>

vii. Increased research and analysis of:

- vegetation and fire history;
- fire ecology specific to landscapes and plant and animal communities;
- the effects and efficacy of fire management activities.

viii. Rapid and supported assimilation of knowledge into on-ground fire management policies and practice.

Fire mitigation

ix. Undertaking planned fires in wilderness areas for ecological reasons only, and protecting off-wilderness assets on off-wilderness lands.

x. Allowing wildfires in wilderness to burn in appropriate circumstances, e.g. expected fire area, intensity and timing is within ecologically-determined limits, risk to human life and property is manageable, suppression may cause more impact than the fire, fire origin is natural (lightning).

xi. Increased effort by state and local government to prevent urban expansion within the bushland interface adjoining a wilderness area (as these are often high fire danger areas).

Fire suppression

xii. Greatly increased investment in the development of expert fire strategists and pre-planned low impact fire control strategies (aimed at maintaining natural processes and biodiversity in the long term) for large bushland areas.

xiii. More concerted and consistent efforts to prevent illegal ignitions and to investigate and prosecute offenders, e.g. the permanent establishment of well-resourced bush fire arson investigation teams.

xiv. Increased efforts in early wildfire detection, particularly during bush-fire danger periods and in remote areas, to enable rapid detection, assessment and response.

xv. Rapid attack and close containment as the preferred suppression response to wildfires (when suppression is the objective – see clause xviii below), and ensuring that resources, capability and response times (for aerial suppression, Remote Area Fire Teams and other means) are adequate to support the highest possible success rate for such responses in remote bushland areas.

xvi. Ensuring that, if initial attack fails, ongoing ‘campaign’ fire suppression strategies affecting wilderness have as prime objectives the protection of natural values and the minimisation of environmental impacts, and that strategies are evidence-based on a detailed understanding of the ecology, history and behaviour of fire in the local landscape, as well as the successes and failures of past suppression efforts.

xvii. Ensuring that in large fire campaigns, knowledge, skills and resourcing are adequate to support ‘surgical’ and low-impact strategies (e.g. small tactical burns, use of natural containment lines and hand-tool lines, precision aerial burning and water-bombing) in preference to

strategies that may be higher impact and less precise (e.g large-scale backburns from hard containment lines).

xviii. Ensuring that 'let burn' is an approved and supported option for wildfires in wilderness under appropriate circumstances (see clause x above).

Physical intrusions in wilderness

xix. Using existing constructed containment lines within a wilderness for back burning only when they have been identified for such use in a pre-incident operations plan that has been subjected to public comment and review, and these lines are properly constructed to minimise damage to wilderness values.

xx. Avoiding the installation of containment lines by bulldozer during a section 44 bush fire emergency or other wildfires without prior consideration and approval in an open and transparent process.

xxi. Immediate closure and/or restoration of any new trails constructed or upgraded during fire suppression operations.

xxii. Removal and replacement of fire observation towers located in wilderness areas with other effective detection methods that do not impact upon wilderness values, such as more aerial surveillance.

Background

Wildfire frequency in eastern Australian wilderness areas has generally increased since white settlement and is likely to continue to do so due to climate change and continuing population growth. Wilderness and other large bushland areas can be a buffer against ecosystem shifts due to global climate change. Wilderness areas, covering just two per cent of New South Wales, may be the only places where natural ecological processes can be protected from intensive fire management for the protection of human life and property.

Fire management for wilderness should limit fire frequency in ways that mimic the pre-European and pre-global warming environment. This management would seek to restore and maintain wilderness integrity (natural processes and biodiversity).

Excessive burning can cause severe damage to rugged wilderness areas. When burnt, the ground cover that binds the soil is lost, leading to accelerated sheet erosion as the next rains strip away the thin soils and nutrients. Streams then fill with gravel and silt.

Too-frequent fires can also wipe out local wildlife populations, destroy the important and restricted old growth vegetation and lead to the replacement of existing vegetation communities with more fire-tolerant (and fire-prone) communities. Fire sensitive trees, such as *Eucalyptus oreades*, *E. deanei* or *E. dalrympleana*, or shrubby understorey species, such as Banksias and Allocasuarinas, can be lost from broad areas. Often it is these very oldest plants that provide most of the nesting and roosting places for birds, such as the Eastern Bristle-bird and a number of threatened microbat species. Fire that is too infrequent may have similar impacts for some communities.

The assertion that Australia's forest lands were once all some sort of grassland or open woodland and should be burnt more often to mirror Aboriginal burning practices is incorrect. Many types of forests and woodlands, particularly those containing long-lived shrubs, would not have been subject to frequent (less than ten-year) burns[(i)]. The evidence is in the biology of key species in this vegetation.

For some wilderness areas in NSW fire frequency is already well in excess of acceptable ecological limits (e.g. much of Wollemi). Many iconic wet old growth forests, such as the Coolangubra, greatly exceed the constructed ecological fire regime limits as currently conceived and the concept may not be appropriate for such forests. These forests are much more susceptible to fire than rainforests, and may need active protection from wildfire in a climate-changed world.

In these circumstances, effective fire-fighting in wilderness requires constant aerial and satellite surveillance (or alternatives) in bush fire danger periods to enable rapid detection and response. Such an approach is flexible and also eliminates the need for static fire observation towers in wilderness areas. To effectively tackle fires in remote areas while they are still small, more personnel need to be trained and supported as RAFT teams and as fire strategists. Although there has been much investment in recent years in road-based fire suppression capability, equivalent investment in remote area firefighting has been lacking.

Vigilant fire suppression in a climate-changed world would help to restore the natural variability of native vegetation age classes. It would also help to ensure rare old growth plant communities, including rainforests and tall eucalypt forests, and other fire sensitive species can be protected.

It is recognised, however, that even a well-resourced strategy of rapid aerial suppression backed up by RAFT is very unlikely to stop all intense wildfires. It is the ones that get away that can become very large wildfires and may prompt damaging control responses. Large wildfires, by definition, occur mostly in wilderness and other large bushland areas, which are mostly within national parks.

In the recent past most wildfires have burnt into parks, and not the other way around[(ii)]. For this reason broad-area planned burns of wilderness are a poor and ineffective way of controlling such external fires. In this context, additional fuel-reduction burns should be undertaken where they are most effective, and that is close to the assets being protected (eg. towns and rural districts[(iii)]). Further efforts to achieve an appropriate mosaic of patch burns on adjoining private land are necessary.

Letting wilderness burn may be a valid fire management strategy, when controlling the fire by burning from containment lines a long distance from the wildfire would be likely on balance to cause more area to be burnt, or when such a response may be ecologically appropriate.

Fire management of wilderness needs to be based on solid science and detailed ecological understanding at the local landscape level. Much more investment in both research and professional fire strategy skills is needed to ensure that fire management is responsive to the ecological needs of specific wilderness areas and ecological communities. There should be more comprehensive and rigorous mapping and analysis of fire areas, fire intensity and vegetation responses so that knowledge of

how particular communities function under different fire regimes is developed over time.

Decisions on the application of damaging suppression practices, such as construction of containment lines in wilderness areas and large-scale backburning, should be addressed in an open transparent manner during risk management planning, not during a fire crisis. In a fire emergency, bulldozers should not be allowed to scar the scenery and initiate erosion by cutting in poorly considered fire control lines on steep slopes. Hurriedly installed control lines often fail to contain a wildfire and cause more harm to the environment than either the wildfire or a well-designed and maintained fire trail. Use of constructed containment lines deep within a wilderness area to control wildfire can be dangerous to firefighters, as ground vehicle access is often slower than a hot wildfire and refuge areas and escape routes are limited.

Except for fire trails in perimeter areas, trails should be closed and rehabilitated to restore wilderness values, particularly those installed without due consideration during a fire emergency.

i Benson and Redpath, 1997, 'Nature of pre-European native vegetation in Australia, in Cunninghamia, Vol. 5(2).

ii Mr J P Henry, Deputy Fire Co-ordinator with the Bush Fire Council of NSW, 14-16 Sept, 1983, reported in the proceedings of the Ninth National Conference of the Australian Fire Protection Association.

iii Park Watch, March 1994, Vol 76

Attachment B

NSW GOVERNMENT
Office of Environment & Heritage
NSW National Parks & Wildlife Service

Living with Fire in NSW National Parks

A strategy for managing bushfires in national parks and reserves 2012–2021

NSW GOVERNMENT
Office of Environment & Heritage
NSW National Parks & Wildlife Service

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Foreword

Fire is an integral part of Australia's natural environment. New South Wales is one of the most bushfire prone areas on the globe. Almost every community has been touched in some way by bushfire and its aftermath.

Our climate, weather systems, vegetation and fuel characteristics and the rugged and remote terrain of parts of New South Wales are all particularly susceptible to the ignition and spread of fires. Each year thousands of bush and grass fires burn across the state. While many are planned for hazard reduction purposes and for achieving land management and ecological objectives, many fires are unplanned. Most unplanned fires are contained and extinguished by firefighters before they cause significant damage. However, during severe, extreme or catastrophic fire weather events, some bushfires can escalate to a size and severity well beyond our fire suppression capability and will often pose a serious threat to life and property. Inappropriate fire regimes, such as frequent fires, or absence of fire, can also pose a significant threat to our Aboriginal and historic heritage, threatened species, ecological communities, and landscape and catchment values.

We cannot bushfire proof our state. However, we can make sure the National Parks and Wildlife Service works alongside all government agencies, our communities and our national park neighbours to minimise the threat of bushfire where possible, and focus our efforts where it counts most. We can also bolster our firefighting resources and skills so that we are more ready than ever to respond quickly and efficiently to protect homes and communities, and stop the spread of fire where possible.

This Living with Fire Strategy is aimed at presenting a state-wide approach to the management of bushfires in our national parks and reserves over the next decade, consistent with NSW 2021 and in response to the social, economic and environmental drivers and current emerging threats we face. The strategy will be reviewed each year in order to revalidate its principles, objectives and strategies.

The Hon. Robyn Parker MP
Minister for the Environment
Minister for Heritage

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Preface

The NSW National Parks and Wildlife Service (NPWS), part of the Office of Environment and Heritage, is a state government agency within the Department of Premier and Cabinet, and is responsible to the NSW Minister for the Environment.

As a major land manager under the *National Parks and Wildlife Act 1974* and one of the four recognised fire authorities in NSW under the *Rural Fires Act 1997*, NPWS is committed to managing bushfire and its associated risks in partnership with other NSW fire authorities, the NSW Bush Fire Coordinating Committee (BFCC), and district bush fire management committees, adjoining land owners and the community to minimise the threats associated with severe bushfires and inappropriate fire regimes.

NPWS is also committed to maintaining biodiversity through the use of fire (ecological burning), and the protection and conservation of natural and cultural heritage values, including threatened species both on and off our national parks and reserves.

NPWS has adopted a comprehensive set of fire management policies and procedures to guide and direct its approach to managing fires in our national parks and reserves. Individual reserve fire management strategies have been prepared for all bushfire prone national parks and reserves and are a priority for completion in newly acquired parks and reserves.

These strategies describe how fire will be managed at a park and reserve level. NPWS also participates in the development of landscape-level bushfire risk management plans which are prepared in accordance with the Rural Fires Act and which incorporate park and reserve strategies. NPWS also employs and equips a substantial workforce which is fit, highly trained and experienced in fire management, and which specialises in dry and remote area firefighting techniques.

Bushfire risk factors are constantly changing. The population is growing and ageing and, every year, the number of people living in bushfire-prone areas increases. The climate is becoming warmer, and in many places it is also becoming drier. Large and intense bushfires, which have been more frequent in the first decade of the twenty-first century than in previous years, can threaten life, property, biodiversity and carry risk of injury to firefighters.

Managing bushfire impacts must also include monitoring sediment and nutrient loads in water catchments and managing smoke impacts on air quality, greenhouse gas emissions and wine production. In addition, native plants, animals and ecosystems are under increased pressure from a range of threatening processes, including habitat fragmentation, climate change, invasive species, land-use changes and altered fire regimes. A major challenge is finding the right balance in our approach to bushfire management which addresses each of these concerns.

Abbreviations

AFAC	Australasian Fire and Emergency Service Authorities Council
APZ	Asset Protection Zone
BAAT	Burnt Area Assessment Team
BFCC	Bush Fire Coordinating Committee
BFEAC	Bush Fire Environmental Assessment Code
BFMC	Bush Fire Management Committee
CERMB	Centre for Environmental Risk Management of Bushfires
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECC	Department of Environment and Climate Change
DECCW	Department of Environment, Climate Change and Water
EBMP	Enhanced Bushfire Management Program
FIMS	Fire and Incident Management Section
FMM	Fire Management Manual
ICS	Incident Control System
KPI	key performance indicator
LMZ	Land Management Zone
NPW Act	*National Parks and Wildlife Act 1974*
NPWS	National Parks and Wildlife Service
OEH	Office of Environment and Heritage, Department of Premier and Cabinet
OFH	overall fuel hazard
RART	Rapid Aerial Response Team
RF Act	*Rural Fires Act 1997*
RFMS	reserve fire management strategy
RFS	Rural Fire Service NSW
SFAZ	Strategic Fire Advantage Zone
SOI	Southern Oscillation Index

1 Introduction

The bushland and rangelands of New South Wales include a diverse range of landscapes in which fire has been a significant and recurring natural event. Bushfire regimes (the combined frequency, intensity, seasonality and spatial distribution of fires) have influenced and continue to influence the current distribution, diversity, structure and composition of our ecosystems. Human settlement into bushfire-prone areas and resultant changes to these natural fire regimes can pose a considerable threat to human life, property and to the natural and cultural values that are protected in our parks and reserves.

The NSW National Parks and Wildlife Service (NPWS) manages more than 860 terrestrial parks and reserves in seven categories (national parks, nature reserves, state conservation areas, karst conservation reserves, historic sites, regional parks and Aboriginal areas) covering more than 7 million hectares, approximately 9% of NSW. About 90% of the area of these parks and reserves is prone to bushfires and about 30% is declared wilderness. The area of parks and reserves managed by NPWS will continue to increase over the next 10 years.

Our national parks and reserves contain significant heritage values, including old growth forest, threatened plants and animals, wilderness, significant historic sites and Aboriginal places, as well some of the state's most popular tourism destinations. They are also places which provide clean drinking water, clean air, and which sequester carbon. The parks and reserves are surrounded by a mixture of land uses, including residential properties, critical infrastructure, such as dams and transmission lines, and agricultural enterprises.

In accordance with the *National Parks and Wildlife Act 1974* (NPW Act), NPWS is responsible for protecting and conserving natural and cultural heritage values in our national parks and reserves. Under the *Rural Fires Act 1997* (RF Act), NPWS is also responsible for taking 'practicable steps to prevent the occurrence of bushfires on, and to minimise the danger of, the spread of bushfires on or from', those parks and reserves.

In addressing these statutory obligations NPWS has adopted the following primary fire management objectives:

- to protect life, property and community assets from the adverse impacts of fire
- to develop and implement cooperative and coordinated fire management arrangements with other fire authorities, park and reserve neighbours and the community
- to manage fire regimes in reserves to maintain and enhance biodiversity
- to protect Aboriginal sites and places, historic places and culturally significant features from damage by fire
- to assist other fire agencies, land management authorities and landholders in developing fire management practices that contribute to conserving biodiversity and cultural heritage across the landscape.

These objectives are translated into fire management policies and procedures which apply to parks and reserves across the state and at a local level are implemented through specific reserve fire management strategies for each park and reserve.

This strategy provides a state-wide framework for fire management by NPWS. It identifies a vision and a set of management principles that NPWS strives to implement in managing fire and a strategic framework for achieving these goals over the next 10 years consistent with Goal 28 of *NSW 2021 – A plan to make NSW number one* (NSW Government 2011) (see below).

The strategy aims to integrate and better position NPWS's cooperative bushfire risk-management efforts to manage current and emerging bushfire risks.

It also seeks to integrate operational resources, research capacity, technology and innovation to achieve these outcomes and is supported by the NPWS Strategic Bushfire Research Statement which outlines the bushfire research priorities for NPWS (Appendix A).

This strategy seeks to balance the social, economic and environmental aspects of fires, for an integrated, balanced and comprehensive approach to bushfire management incorporating cooperative fire research, prevention, mitigation, preparedness, and response and recovery actions.

NSW 2021 – A Plan to Make NSW Number One

Goal 28: Ensure NSW is ready to deal with major emergencies and natural disasters.

Targets: By 2016, increase hazard reduction across NSW by increasing the:

- number of properties protected by hazard reduction works across all bushfire-prone land tenures by 20,000 per annum
- annual average area treated by hazard reduction activities by 45%.

Priority actions: Limit bushfire severity by:

- establishing annual bushfire hazard reduction works targets for land management agencies responsible for bushfire-prone lands consistent with the state target
- increasing the number and area of hazard reduction activities undertaken on national parks and reserves.

2 The context

2.1 Fire in NSW

In NSW, as in other parts of south-east Australia, climate, severe weather systems, seasonally flammable vegetation, topography, and recurring and sometimes multiple ignition sources, combine to create one of the most bushfire prone environments in the world. Grasslands and shrublands become flammable for varying periods each summer. In the understorey of eucalypt-dominated forests and woodlands, flammable shrubs, grasses and leaf litter accumulate in varying proportions. When these dry out sufficiently, they become fuel for bushfires. In eastern NSW, in seasons of average or higher rainfall, moist areas such as rainforest gullies, riparian zones and forests on sheltered aspects restrict the spread of fires to drier parts of the landscape. However, during droughts these normally moist areas can dry out, increasing the connectivity of flammable fuel in the landscape and creating the potential for very large bushfires. In the rangelands of western NSW, seasons of above average rainfall can give rise to prolific grass growth, which later cures in summer providing the fuel conditions needed for large rangeland fires.

The weather pattern in NSW periodically brings extremes in fire weather, and strong, hot and dry north-westerly winds that often contribute to extreme or catastrophic fire danger ratings. Along the sea-breeze moderated coastal fringe, such extremes in fire danger are less frequent than inland, but may often occur several times each year. In such weather conditions, bushfires develop and spread rapidly, with uncontained fires reaching intensities well beyond modern fire suppression limits, even in recently modified fuel areas. Periods of extreme fire danger are recurring natural events in NSW. They are certain to continue and are likely to be exacerbated by the effects of climate change over the next 10 years and beyond.

Lightning is a natural and seasonal source of fires, established in the Australian landscape for hundreds of thousands of years, even before the arrival of Aboriginal people. Natural fires, together with climate, landform and soils, have played a fundamental role in shaping the biodiversity of Australia's terrestrial ecosystems (Flannery 1994).

Sources of fire ignition are either from lightning or from human causes close to areas of rapid urban expansion or access roads, and are more likely to occur on weekends during early spring to late summer (Bryant 2008). Periodically, ignitions caused by multiple lightning strikes will occur in remote or rugged areas and can overwhelm suppression capability. Deliberate and accidental human-caused fires often occur on or preceding days of very high or extreme fire danger and can quickly reach proportions beyond the limits of suppression.

2.2 Fire and people

The arrival of Aboriginal people in Australia commenced an interaction between humans, fire and the environment that has extended over at least the last 40 to 60 millennia, and has further influenced the distribution, structure and composition of ecosystems (Flannery 1994). For NSW, knowledge about traditional Aboriginal burning practices and their impacts is fragmentary, and assumptions about Aboriginal fire usage and impacts remain speculative. It is thought Aboriginal people learnt to use fire in the landscape to manipulate the timing, frequency, scale and intensity of fire occurrence (fire regimes), and as a result changed the species composition and structure of some ecosystems (Ellis et al. 2004). Aboriginal peoples' use of fire may have served a range of purposes, including the promotion of favoured food sources, and manipulation of vegetation cover and condition for improved hunting, safety and ease of travel through the landscape (Forest Fire Management Group 2007). When Europeans arrived in NSW in the late 18th century, they inhabited landscapes shaped and, in most cases, maintained by lightning and/or traditional Aboriginal burning induced fire regimes (Whelan et al. 2006).

In south-eastern Australia, European settlement brought dramatic changes to land-use systems and fire regimes, nowhere more so than in NSW. Through the 19th century, far-reaching land-use change, principally to agriculture, extended relatively rapidly from the coastal plains, through the major valley systems of the Great Divide and across the tablelands and plains of inland NSW. This land-use change brought extensive vegetation clearing and the introduction of livestock grazing and cropping, as well as pest animals and weeds, contributing to landscape scale changes to vegetation cover, structure and composition, animal habitats and watercourses. Land settlement also brought new and growing communities settled in villages, towns and cities. These growing communities, the infrastructure that links them and the rural enterprises that support them require protection from the impact of bushfire. For these important reasons, effective fire suppression has become a fundamental public safety management necessity across NSW.

The landscape condition changes that came with European settlement varied previous fire regimes. Some have proposed that in some landscapes, such as the woodlands and grasslands of inland NSW, historical fire frequency may have been reduced significantly. In other areas, principally near urban population centres, arson and careless fire use have resulted in more frequent high intensity summer fires. The evidence suggests a significant increase in fire frequency since 1800, followed by a slight reduction over the past 50 years.

2.3 Fire and communities

Many communities in NSW choose to live in bushland settings, in rural or semi-rural areas, or where urban areas abut or extend into bushland areas. The natural, aesthetic and amenity values of our bushland are highly valued, but these same values can pose a significant threat on days of extreme or catastrophic fire weather conditions. From time to time, bushfires burn at intensities beyond the limits of modern suppression capacity, impacting communities, infrastructure, rural assets and economies and natural resources. At their worst, these impacts involve loss of human life, extensive property and economic damage and social and environmental impacts. Such events are well documented in our history (Appendix B).

Today in NSW, fire-prone ecosystems, a fire-conducive climate, and vulnerable rural and urbanised communities all intersect to create levels of bushfire risk which are amongst the highest in the world. The need to protect our rural communities and those along the edges of our cities and towns from bushfires presents our communities, land managers and fire services with a great challenge.

2.4 Fire and the environment

Fire has been a recurring feature of Australian ecosystems over millions of years. As a result, ecosystems and their flora and fauna have evolved to reflect particular fire regimes which affect the functioning of ecosystems in numerous ways. For example, different fire regimes may alter vegetation structure, change animal habitat, affect fuel accumulation and alter nutrient and energy flows (Bradstock and Kenny 2003; Whelan et al. 2006). These in turn will affect plant and animal distribution, the spread of disease such as root rot fungus (*Phytophthora* spp.), changes in the composition of soil, and atmospheric carbon. A variety of fire regimes, including occasional intense crown fires and low intensity frequent fires, facilitates a diverse and rich mix of plants and animals, structural diversity in vegetation and habitat and promotion of more robust ecosystem structures and functions.

However, altering the fire regime beyond the evolutionary adapted thresholds can disrupt the functioning of those ecosystems, adversely affecting their health and diversity, and potentially leading to structural change and local extinction of some species and establishment of others; hence high frequency fire is listed as a key threatening process under the *Threatened Species Conservation Act 1995*. When planning fire management activities, NPWS uses biodiversity thresholds based on plant species functional types and life history to identify the domain of acceptable fire intervals within broad vegetation types (Kenny et al. 2004).

It is widely acknowledged that natural landscapes with a diversity of fire regimes have greater biological diversity and ecological resilience than landscapes with a low diversity of fire regimes (Bradstock et al. 1995; Bradstock and Kenny 2003; NSW Government 2004). NPWS and other land managers are faced with a complex challenge in managing fire regimes to maintain the health and resilience of these 'fire-adapted' ecosystems. A great variety of fire regimes is required in order to maintain ecosystem health and diversity in a landscape context. A most significant challenge for NPWS, and indeed all Australian land managers, is to maintain appropriate fire regime diversity in the long term while meeting other important land management objectives, including protection of life and property, infrastructure and environmental services. To facilitate this, ongoing research is essential to establish and maintain a current knowledge base and adaptive management approach for effective bushfire management (see section 5.6).

2.5 Fire and fuels

Fuel is one of the fundamental elements required to sustain a fire. While other factors, such as topography and weather, will greatly influence fire spread and intensity, fuel is the element most easily manipulated for fire management. Hence hazard reduction is about reducing the quantity and/or changing the structure of the available fuel.

Fuel is described and measured in layers. Fires generally start and develop in the surface layer (litter from fallen leaves and twigs) and near-surface layer (grasses and suspended litter). Ignition of elevated fuels (shrubs and saplings) will depend on the fire intensity and the continuity between the surface and elevated layers. Crown fires require continuity from these surface fuels through to the elevated or bark fuels, and usually occur under extreme fire weather conditions which have created intense ground fires. Crown fires usually release wind-borne embers which lead to dangerous spot fires ahead of the main fire front and ember attack on nearby properties.

The quantity of fuel (fuel load) at any place is determined by many factors including vegetation type, climate and productivity of the site, time and intensity of the last fire and recent weather events. Models of fuel accumulation over time follow a negative exponential curve, where fuel builds up rapidly for several years after a fire and then reaches a relatively steady state level. Recent research work is helping to improve our knowledge of fuel dynamics across the different NSW vegetation types (Watson 2011; Watson et al. 2012).

2.6 Fire and risk management

It is neither possible nor desirable to eliminate bushfires in NSW – they are inevitable across all fire-prone vegetation types. When high fuel loads, ignition sources and adverse weather inevitably coincide, wildfires will result. Modern fire management requires the assessment, measurement and mitigation of risks – to social, economic and environmental values. This creates an imperative to work closely with adjoining land managers, community groups and fire authorities to continually improve our understanding of bushfires, and to work together in managing the risks associated with living in a fire-prone environment (Bradstock and Kenny 2003; Whelan et al. 2006).

As the removal of hazards (fuel) is one of the key tools for reducing fire risks to both communities and environmental values, managing the risks associated with wildfires will entail improving community understanding and acceptance of the need to use prescribed fire appropriately on private and public lands.

It is important, however, to acknowledge that there will always be a high residual risk in some areas on days of catastrophic fire weather and that prescribed burning only temporarily reduces fuel loads.

Fire is an unusual disturbance in that it can be both a threat and a requirement for maintaining species richness in many ecosystems. When managing species and ecosystems, long periods of time between bushfires can be detrimental, just as high fire frequency can be harmful. Using prescribed fire appropriately (selecting the correct fire regime for the correct vegetation community) is therefore an important factor for land managers.

NPWS also manages a broad range of cultural heritage. NSW has a rich cultural heritage that forms an integral part of the contemporary landscape. The landscape encompasses many aspects of Aboriginal heritage, including Aboriginal sites and artefacts, natural landforms, sites of spiritual or ceremonial significance and native flora and fauna (totem species, bush foods and medicines). Other types of cultural heritage include historic structures, roads, modified landscapes and archaeological sites. Cultural heritage sites and artefacts may or may not be susceptible to fire and have different requirements in order to protect them from the impacts of fire. NPWS is committed to cultural heritage management principles and, where applicable, includes cultural heritage guidelines in all NPWS reserve fire management strategies.

Effective bushfire risk management requires a partnership between fire authorities and communities. This partnership must be based on understanding the role of fire in the environment, understanding and sharing responsibilities for managing risks (to people, the environment and cultural heritage), and maintaining strong collaboration between fire authorities, land managers and the community. Communities that have a better understanding of the behaviour and management of bushfires do not necessarily experience fewer fires or less property loss; however, they are more likely to have a better understanding of the impacts of bushfire and take appropriate measures to minimise the risk to life and property. It is therefore imperative for people living in bushfire-prone areas to understand the risks of bushfire and to make preparations accordingly.

3 Bushfires in NSW – long-term and recent trends

Due to a range of contributing factors, the risks associated with managing bushfire in national parks and reserves have been steadily rising.

- The number of people living in adjoining bushfire-prone areas has significantly increased (ABS 2010).
- Protected areas managed by NPWS have more than trebled since the 1970s (DECC 2008).
- Average annual rainfall in NSW has been declining over the past two decades, increasing the duration and severity of bushfire seasons (Hennessy et al. 2005). In addition, water demands have grown with increasing population size, highlighting the importance of protecting drinking water catchments from adverse bushfire regimes.
- Fire weather has been getting progressively worse over the past two decades (Hennessy et al. 2005; Lucas et al. 2007; DECCW 2010a) and it is likely that this trend will continue.
- The number of bushfires from human causes (accidental and deliberate) has been rising.
- The number of native plant and animal species, populations and communities listed as threatened, and which have been identified as vulnerable to adverse bushfire regimes, has been rising.
- The costs of bushfire and emergency management in NSW have been rising at unprecedented levels.

In response to these rising risk factors, NPWS and other NSW fire authorities have over the last 20 years been broadening approaches to bushfire risk management and improving risk management capacity.

3.1 NSW population

At both a national and a state level the population is both growing and ageing. Over the past 50 years the NSW population has increased by more than 3.2 million (ABS 2008). As a result, the number of people exposed to bushfire risks over that period has increased significantly, as the urban edge of major population centres has continued to grow outwards and into bushland-dominated environments. Also, new villages and towns have been established in satellite and greenfield suburbs, many of which are within or adjacent to bushfire-prone areas.

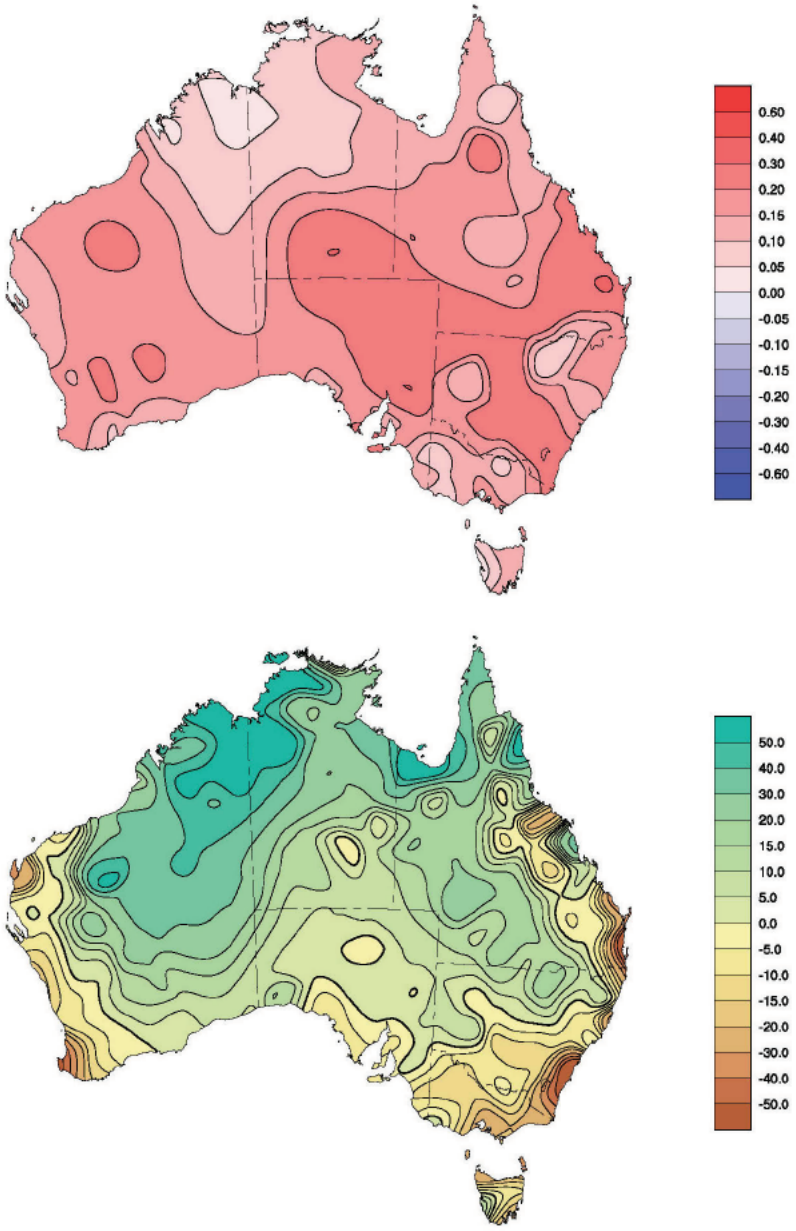
Continued strong growth in the NSW population is expected, with forecasts of about 1.2–1.4% pa, 8.12–8.22 million people by 2020 (BoM 2008). In addition, the growing popularity amongst the 'baby boomers' population of seeking a 'tree' or 'sea change' has created regions of high demand for residential development in peri-urban environments in regional NSW, placing increasing pressure on managers of adjoining public lands, including parks and reserves, in terms of managing the risk of bushfires.

3.2 Fire and weather

Although NSW has a very variable climate, recent climate and weather trend analyses undertaken by the Office of Environment and Heritage (OEH), the Bureau of Meteorology and CSIRO indicate worsening bushfire weather trends over the last 50 years in NSW (BoM 2009; Hennessy et al. 2005; Lucas et al. 2007; DECCW 2010a). This is particularly the case on the North Coast, Far South Coast and South West Slopes where reduced rainfall and increased temperatures overlap with relatively fire-prone vegetation communities in sclerophyll forest and shrubland ecosystems, thereby increasing the potential for large and damaging wildfires (Figure 1).

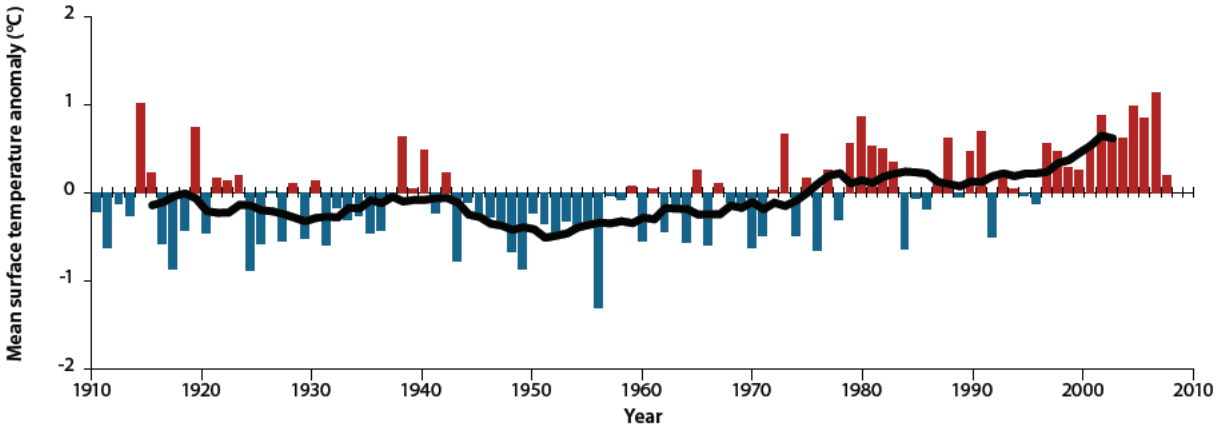
Climate trends over the last 100 years indicate an accelerating increase in average annual temperature in NSW (Figure 2). For example, during the 1950s to 1980s, the annual average temperature increased by 0.1°C per decade; since 1990 it has been about 0.5°C per decade.

Figure 1: Trend in mean temperature and rainfall 1960–2010 (°C/10 years)



Source: Bureau of Meteorology (product of National Climate Centre)

Figure 2: Annual mean temperature anomalies for NSW 1910–2007



Source: BoM (2008)

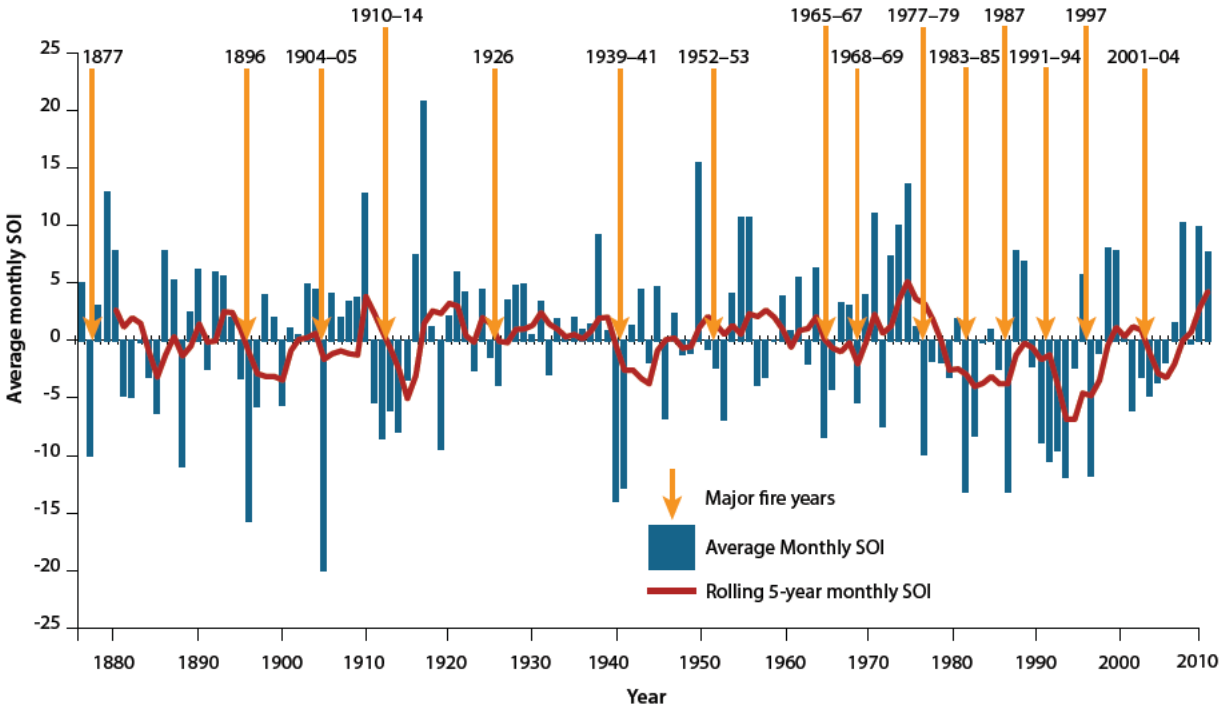
In NSW there appears to be a positive relationship between major bushfires and a negative Southern Oscillation Index (SOI), particularly so in the last 40 years (Figure 3). Sustained negative values of the SOI often indicate El Niño episodes. El Niño conditions generally result in below average rainfall over much of eastern Australia and a higher incidence and extent of bushfires. Conversely, a lower incidence and extent of major wildfires has been observed during positive SOI periods.

However, some of the most significant fire seasons on record have occurred following major La Niña episodes, where conditions generally result in above average rainfall over NSW. These major seasons have occurred in arid and semi-arid rangelands of western NSW where fuel dynamics and fire exhibit different patterns when compared to the forests of eastern NSW. In these rangelands, fire follows heavy rain, due to above-average growth of herbs and grasses and rapid curing of fuel in spring and summer, in contrast to forests where extended periods of drying are required as a prerequisite for major fires.

Also, a positive Indian Ocean Dipole (colder sea temperatures in the eastern Indian Ocean relative to the western Indian Ocean) has also been strongly linked to drought cycles and bushfire weather changes in NSW, especially when coinciding with a negative SOI.

These observations further inform our understanding of trends in climate and bushfire occurrence and extent in NSW.

Figure 3: Southern Oscillation Index and major bushfire occurrence in NSW 1876–2009



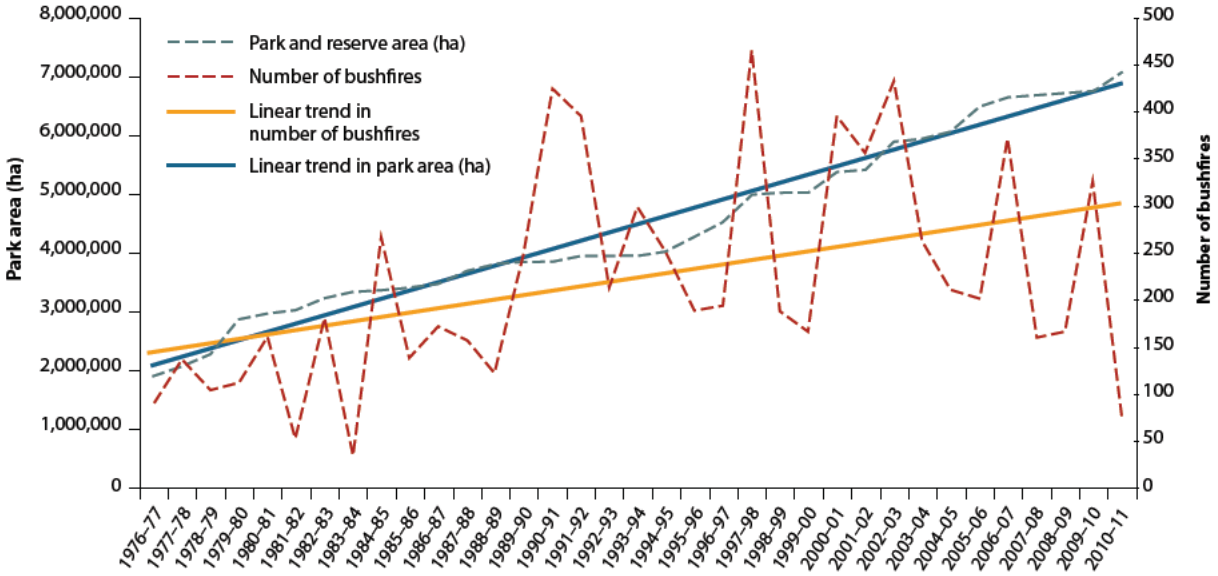
3.3 Fire and national parks

3.3.1 Bushfire occurrence trends

The area managed by NPWS has increased significantly over the last 30 years and NPWS fire management responsibilities have also consequently increased. The number of fires starting in or moving onto national parks and reserves has also increased in parallel with this trend (but not at the same rate – see Figure 4) and with changes that have occurred in both climate and local weather conditions. Years of highest ignition numbers and of area burnt on parks and reserves coincide with those years with adverse bushfire weather conditions.

It is likely that the differences in the area managed and bushfire numbers over the last 30 years have been influenced by the acquisition of a greater proportion of parks and reserves in the Central and Western divisions of NSW where wildfires are less frequently recorded. However, this may also be a reflection of the improvements in community education, regulation of arson and management of accidental ignitions in bushland areas when they are established and managed as protected areas.

Figure 4: Trend in total area of parks and reserves and annual number of wildfires 1976–2010



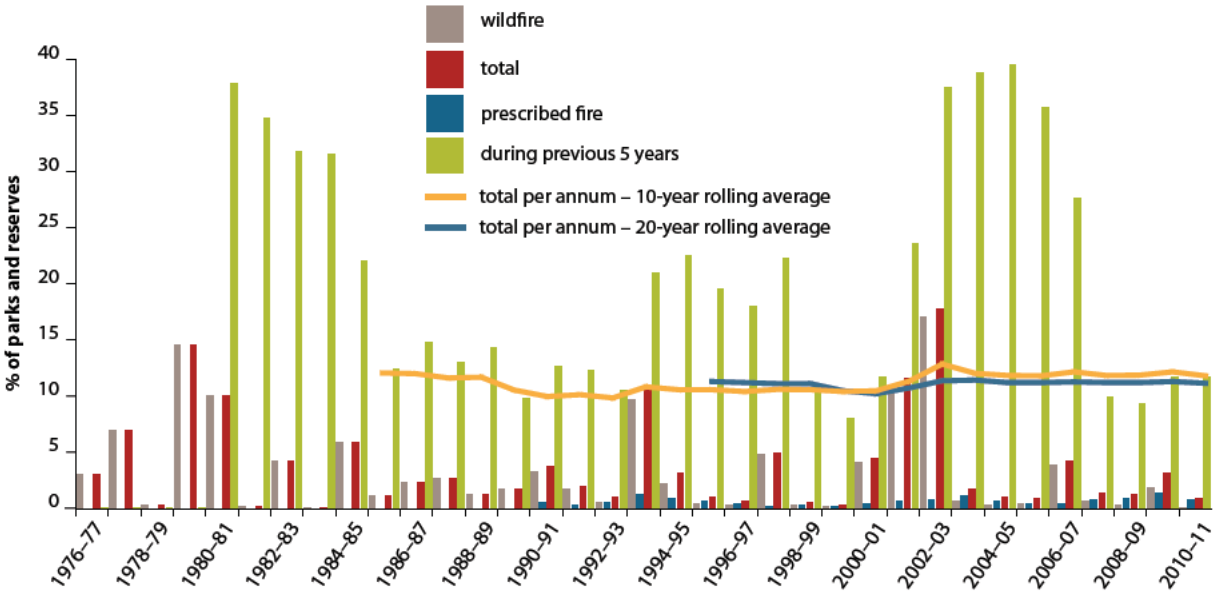
3.3.2 Area burnt by bushfires

Annual area burnt statistics for parks and reserves indicate that severe fire seasons have been more prevalent over the last 20 years (1990–2010). This trend has also been observed in the USA, where a large and sudden increase in wildfire activity in the mid-1980s has been noted with higher large-wildfire frequency, longer wildfire durations and longer wildfire seasons (Westerling et al. 2006).

The percentage of area burnt on parks and reserves over the last 20 years from both prescribed burns and from wildfires has averaged 3.6% per annum, or 3.8% over the last 10 years (Figure 5), or approximately 4% or 4.2% respectively if adjusted for bushfire-prone lands only. The average ratio of wildfire area to prescribed burning area over this period is about 5:1.

One of the major challenges over the next 10 years will be to decrease this ratio of area burnt from wildfire to prescribed burns, that is, to gain more management control over what gets burnt. This will be achieved through an enhanced strategic prescribed burning program, improved detection techniques and improved rapid response techniques for wildfires, thus giving NPWS greater control over the intensity, timing and location of fires. This also supports NPWS objectives of protection of life, property and community assets and management of fire regimes to maintain and enhance biodiversity (see section 5.5).

Figure 5: Percentage of area burnt on parks and reserves 1976–2010

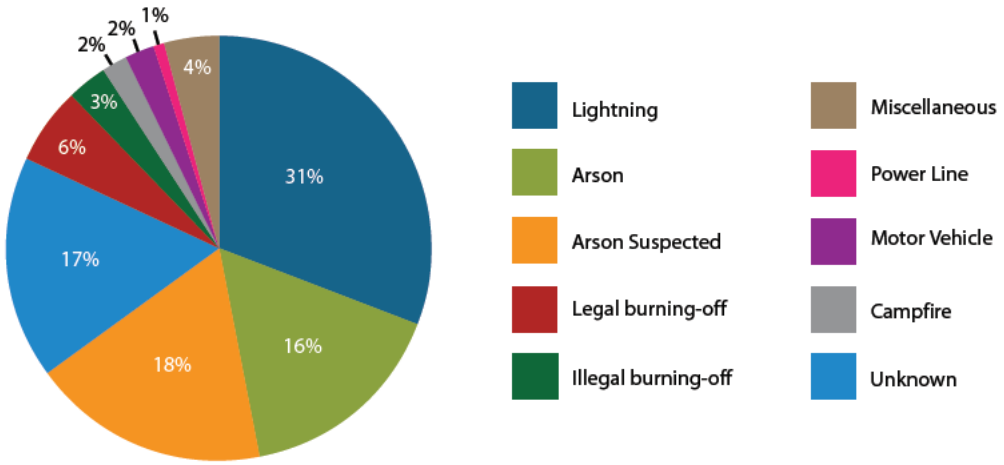


3.3.3 Causes of wildfires

Lightning is the predominant natural cause of ignitions on parks and reserves, representing about 30% of the total cause (Figure 6). This is especially the case in parks on the coastal ranges and western slopes and plains where more than 30–40 ignitions may start from just one dry storm. Increasing temperatures are expected to increase the number of lightning-caused wildfires. The benefits of a rapid response firefighting capability are obvious in these situations. The ability to quickly respond to multiple ignitions in remote areas greatly reduces the costs and impacts of these fires, which can burn tens of thousands of hectares.

In parks that are located in high population areas such as the Sydney Basin, arson (16%), suspected arson (18%), unknown causes (17%) and motor vehicle fires account for a much higher number of ignitions. Human-induced fires may constitute offences against the law and require formal and prompt investigation. These fires can threaten life and property, impact on biodiversity, incur major suppression costs, divert NPWS resources away from other functions and expose firefighters to unnecessary risk of injury, and therefore need to be carefully managed and reduced in frequency.

Figure 6: Cause of wildfire ignitions on parks and reserves 1995–2010 (n=2886)

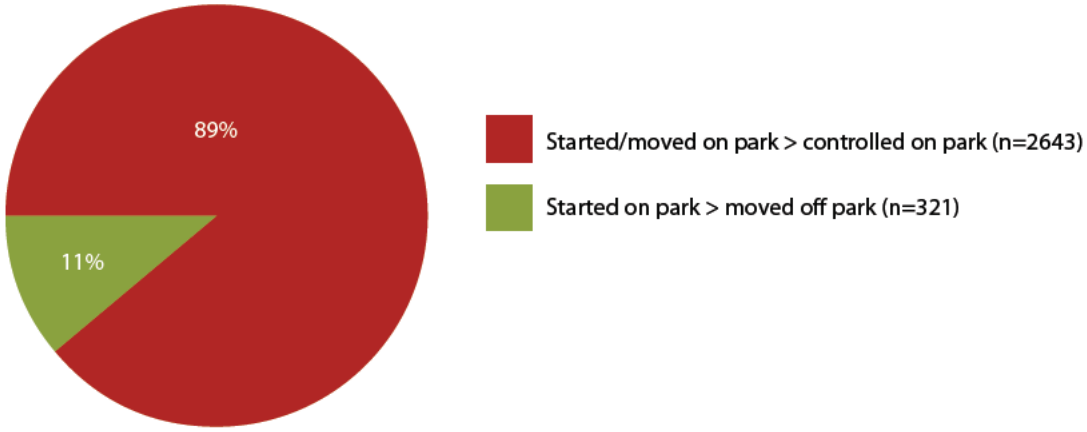


3.3.4 Origin of wildfires

The ability to prevent the spread of wildfires from parks and reserves to adjoining properties in accordance with the obligations for land managers under the RF Act is an important key performance measure. Preventing the escape of wildfires from managed properties, although virtually impossible under extreme fire weather situations, is nevertheless a useful indicator of the success of strategic hazard reduction programs and of detection and response capability.

Over the last 10 years, of the fires that started on NPWS-managed lands (or moved on to NPWS-managed land from neighbouring properties), 89% have been controlled on park (Figure 7). Of the wildfires that burn on parks and reserves, more than twice as many (25%) escape from neighbouring properties into parks and reserves than escape off park (11%). This is an impressive record for NPWS, particularly given the extent (56,000 km) and rugged and remote nature of the boundaries of parks and reserves. This can also be a very useful performance indicator of the effectiveness of detection, suppression and success of strategic hazard reduction programs.

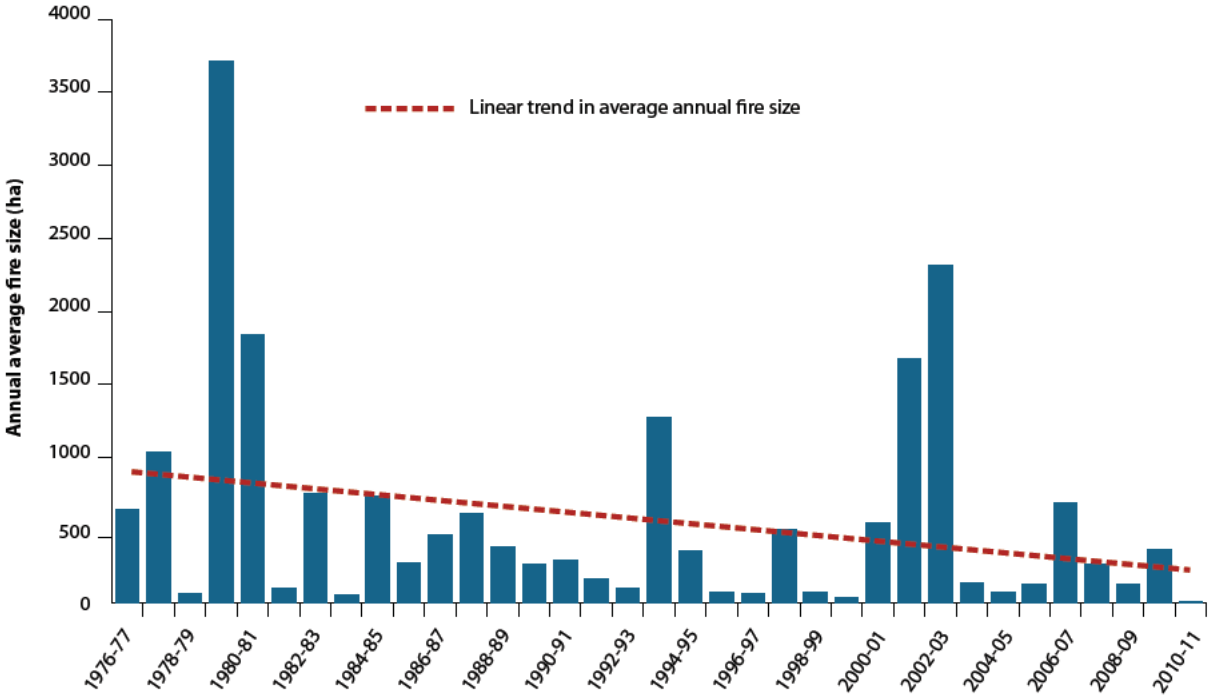
Figure 7: Origin of wildfire ignitions impacting parks and reserves 2000–10 (n=2964)



3.3.5 Size of bushfires

Despite climate change impacts, a weak but downward trend in the annual average size of wildfires on parks and reserves has occurred over the last 35 years and NPWS aims for this trend to continue (Figure 8). Improved bushfire detection and suppression effectiveness and more strategic fuel management within parks and reserves may be a contributing factor to this trend. Over the last 35 years, the average annual area burnt by wildfires on parks and reserves is approximately 144,000 ha. This reflects the remote and rugged terrain, including more than two million hectares of declared wilderness, in which NPWS undertakes the majority of its bushfire suppression activities.

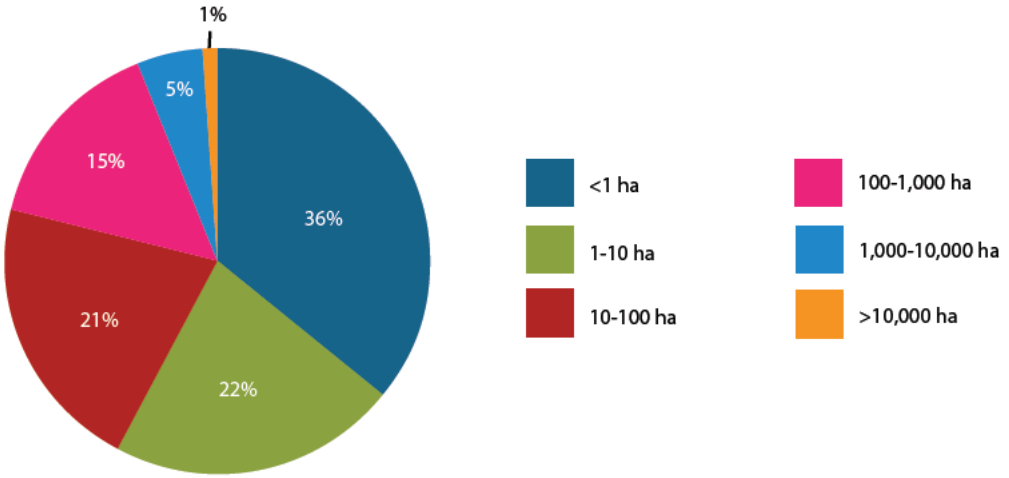
Figure 8: Trend in the average annual size of wildfires on parks and reserves 1976–2010



The size distribution of wildfires in any one year will vary according to weather patterns and the coincidence of ignitions on days of extreme bushfire weather, and to the capacity of land managers and fire services to quickly detect and safely contain ignitions. Average annual size of wildfires will be greatly influenced by the few very large fires that coincide with extreme weather conditions, therefore drought years will stand out in trends of fire history data (Figure 8). Hence, to account for annual seasonal differences arising from shifts in climate patterns, such as the SOI, trends in area burnt are measured as five- to 10-year rolling averages.

The proportion of wildfires managed in various size classes is a more useful indicator than average fire size for assessing effectiveness of detection and suppression capability. Since 2000, 79% of all wildfires on NPWS reserves have been contained to less than 100 ha in area (Figure 9).

Figure 9: Size class distribution of park bushfires 2000–2010 (n=2964)



4 A coordinated approach to bushfire management

4.1 Responsibilities

4.1.1 Scope and scale of NPWS bushfire management responsibilities

NPWS is responsible for the management of more than 860 national parks and reserves across NSW, covering an area of approximately seven million hectares, a land base that includes some of the most remote, rugged and bushfire-prone country in NSW. These areas have been reserved to conserve their natural and cultural values, including biodiversity, physical landscapes, Aboriginal sites, historic structures and recreational settings. The reserve system is expected to continue to increase over the next 10 years in accordance with the priorities identified in the *New South Wales National Parks Establishment Plan 2008* (DECC 2008).

The responsibilities of NPWS extend to the protection and conservation of natural and cultural heritage values across NSW, including Aboriginal sites, wildlife and threatened species. In NSW there are more than 1000 native species, populations and ecological communities listed as threatened with extinction. Of these, more than 400 species are identified as being threatened by altered bushfire regimes.

Fire management is one of the most important tasks in managing protected areas and biodiversity, and it is recognised that bushfire management must be fully integrated with other aspects of protected area management. It also needs to be integrated with bushfire management on adjacent lands, with planning undertaken at the landscape level (DECCW 2010b).

NPWS has statutory obligations for bushfire management. Under the RF Act, NPWS has responsibilities as both a public authority and a firefighting authority and has obligations for the responsible management of bushfires on parks and reserves and for cooperating with bushfire management on other lands in NSW. This includes the prevention of wildfires on NPWS reserves and minimisation of the danger of spread on or from NPWS land under Section 63 of the RF Act, the detection and suppression of wildfires on NPWS land and other tenures in conjunction with other agencies under Section 44 of the RF Act, and the implementation of risk management programs to protect life and property from wildfires.

4.1.2 Cross-tenure fire management

Fires do not recognise boundaries, and therefore we realise the importance of working closely with neighbours and local brigades in taking a broader landscape-based approach to bushfire management, with activities undertaken both on and off park based on jointly agreed priorities, consistent with local bush fire risk management plans. The NPWS approach includes:

- undertaking cooperative risk-planning and hazard-reduction activities with private landholders
- undertaking fire trail access planning and works with neighbours
- actively engaging with neighbours before, during and after the bushfire season.

4.1.3 Coordinated bushfire management

NSW has a very effective framework and structure for multi-agency cooperative bushfire management and planning, in which NPWS plays an active role along with NSW Rural Fire Service (RFS), Fire and Rescue NSW and Forests NSW. NPWS is also a long-standing member of the NSW Bush Fire Coordinating Committee (BFCC), which is responsible for coordinating a cross-section of government and non-government organisations with an interest in the prevention, mitigation and suppression of bushfires, and enabling these parties to develop and progress policies and procedures aimed at ensuring a coordinated approach to major issues. At a regional level, NPWS actively participates in most of the local bush fire management committees throughout NSW and is an important contributor to coordinated and cooperative bushfire planning and operations, and engages in joint training initiatives with other agencies.

NPWS is an active member of the Australasian Fire and Emergency Service Authorities Council (AFAC) and the Bushfire Cooperative Research Centre (CRC), and regularly provides resources to assist with wildfire suppression in other Australian states and territories and for joint international assignments, in accordance with formal cooperative agreements. NPWS is also engaged in a multi-state Burnt Area Assessment Team (BAAT) with ACT Parks, Conservation and Lands, and Parks and Wildlife Service Tasmania. BAAT facilitates a rapid and integrated post-fire rehabilitation and fire recovery assessment of an area to ensure that local land managers are provided with a report detailing fire impacts and areas that may need immediate remediation or further investigation.

NPWS is also involved in wildfire prevention strategies and operates within the joint agency Bushfire Arson Task Force that is represented by NPWS, NSW Police, RFS and Fire and Rescue NSW. NPWS works closely with these partner agencies to investigate fires on NPWS-managed land using appropriately trained and experienced staff, with responsibilities in assisting investigations and reporting to Strike Force Tronto, in accordance with the NSW Coroner's guidelines.

4.2 Capabilities

Given the extensive nature of national parks and reserves and the legislative responsibilities to manage the reserves for the protection of life and property and conservation values, NPWS has invested in developing:

- the coordination of all bushfire management activities by a newly established Fire and Incident Management Section, supported by bushfire ecologists within a Scientific Services Division and by regionally based bushfire management specialists and teams
- a hierarchy of bushfire management policies and procedures (this strategy; Fire Management Manual – FMM; branch and regional incident procedures; reserve fire management strategies and NPWS Bushfire Research Statement) to guide the approach taken with bushfire management in parks and reserves
- a well-trained, fit, accredited to national competency standards, and highly mobile firefighting force of around 1350 staff who are equipped to undertake various firefighting roles, including rapid response and remote area firefighting, and staff who specialise in incident management
- a well-maintained fleet of firefighting vehicles, comprising a large number of light 4WD (for example, Category 9 tankers) vehicles which are optimal for firefighting in rugged country, together with a specially outfitted helicopter fleet with well-trained and experienced pilots

- a government funded enhanced hazard reduction and rapid wildfire response program for 2011–16
- an extensive network of more than 37,600 km of park roads, fire trails and management trails
- bushfire prevention activities which include education and regulation programs on the use of fire in parks and reserves
- community engagement at a local level through programs such as RFS Hotspots and FireWise
- a risk-based level of preparedness of regional staff enabling early detection and safe and rapid response capability to bushfires
- cooperative arrangements (joint management plans and agreements) with adjoining states and territories and with other firefighting agencies and peak bodies.

4.2.1 Remote area firefighting

NPWS maintains dedicated aircraft and employs seasonal remote area firefighting crews in conjunction with RFS during the bushfire danger period to rapidly and safely respond to wildfires, especially in remote and difficult to access areas. The remote area firefighting capacity includes:

- conducting specific training for helicopter winching and hover exit for remote firefighters
- maintaining a fleet of specially equipped helicopters for remote area firefighting
- conducting fitness testing for all staff involved in on-ground fire management activities
- employing highly trained teams of remote area firefighters
- following the Joint Operational Protocol for Remote Area Firefighting.

As a result, nearly 80% of fires over the last 10 years have been contained to an area of less than 100 ha (Figure 9).

4.2.2 Hazard reduction activities

There is a strong commitment from NPWS to reduce the risk of potential damage from bushfires to park values and to neighbours. Addressing this requires a multi-faceted approach that includes appropriate planning principles, community education and fuel management. A standard bushfire management zoning system is used in all parks and reserves to identify the fire management intent for a specific area as follows:

- Asset Protection Zones (APZs): to protect human life, property and highly valued public assets and values
- Strategic Fire Advantage Zones (SFAZs): to provide strategic areas of fire protection advantage which will reduce the speed and intensity of wildfires, and reduce the potential for spot fire development. To aid containment of fires to existing management boundaries
- Land Management Zones (LMZs): to maximise the biodiversity value of ecosystems, to minimise the risk of extinction through inappropriate fire regimes, and to reduce the likelihood of the spread of fires.

Part of the fuel management approach includes conducting hazard reduction activities to reduce fuel on parks and reserves, with priority to APZs and SFAZs. Hazard reduction can include both prescribed burning and mechanical approaches, such as slashing and mowing to remove or reduce vegetation. The NPWS approach includes:

- undertaking annual reviews of reserve fire management strategies for all parks and reserves, each of which guides hazard reduction activities

- using a state-wide bushfire zoning system to help prioritise hazard reduction to reduce the risks to life and property while maintaining biodiversity values in the broader landscape
- using the Bush Fire Environmental Assessment Code (BFEAC – RFS 2006) for NSW, where applicable, to streamline the issuing of hazard reduction certificates with appropriate environmental conditions
- implementing a prioritised hazard reduction program in cooperation with bush fire management committees which is focused on areas of highest risk within APZs, most of which are on or, more usually, adjacent to park boundaries
- maintaining appropriate and diverse bushfire regimes through prescribed burns in order to maintain ecosystem structure and functioning in parks and reserves.

Since 2005, NPWS has regularly undertaken more than 50% of the total area of prescribed burning in NSW despite only managing about 25% of the state's bushfire-prone lands. For example, in 2009–10 NPWS carried out 60% of the total area of prescribed burning undertaken in NSW.

4.2.3 Incident management

NPWS will continue to maintain a high level of capacity in bushfire management, particularly in the areas of planning and responding to remote area fires, and in implementing a well planned, prioritised and strategic approach to its prescribed burning program. The NPWS approach includes:

- applying the Australasian Inter-service Incident Management System and related policies and procedures for managing bushfires, consistent with all other fire and emergency service agencies in Australia
- in conjunction with RFS, actively communicating with the public during incidents, including through community awareness programs, incident briefings, website information and letterbox drops
- preparing and implementing a biennial fire training plan and registered training organisation status to maintain staff competency and currency in bushfire management, including fire fitness testing
- developing and delivering role-specific bushfire training courses, such as for crew leaders, divisional commanders, air operations managers and air observers, in order to develop skilled operators with state of the art knowledge and capability
- actively participating in cooperative bushfire training with RFS, Fire and Rescue NSW and Forests NSW, including incident management and aviation training
- adopting a guarantee of service approach to regional bushfire management capability and equipment standards
- working cooperatively with NSW Police and participating in local emergency management committees and the State Emergency Management Committee
- establishing BAATs to enable rapid and integrated post-fire rehabilitation and fire recovery; each team provides local managers with a report detailing issues caused by fire and areas that may need immediate remediation or further investigation, and makes recommendations covering soils and erosion, flora, fauna, assets and infrastructure, and cultural heritage items.

5 The future: issues, challenges and risks

Over the past 50 years, the complexity of bushfire management has greatly increased. NSW now has more communities, infrastructure and businesses exposed to bushfire risks than at any other time in its history. The number of factors which need to be considered when planning and undertaking bushfire management has escalated greatly as knowledge about bushfires, their impacts and interactions with the environment has increased. Modern technologies and systems available for bushfire management have increased in sophistication, improving opportunities for performance improvement, but adding further technical capacity challenges. Bushfire management complexity is certain to continue escalating. A range of key future trends are expected to add further challenges to bushfire management for NPWS.

5.1 Population expansion in bushfire-prone areas

Almost one in three Australians lives in NSW. In June 2009, the NSW population reached 7.13 million and is expected to grow to more than 8 million by 2020. Population growth projections used by the NSW Government indicate that more than 70% of NSW's population growth will be in Sydney, mostly in the fire-prone western and southern growth areas. The fastest population growth rates, however, will be in coastal areas outside the major population centres (ABS 2008). The majority of NPWS parks and reserves are situated along the ranges and coast. Many of the coastal areas where the greatest residential and rural–residential growth is expected are in close proximity to large reserve areas, in many cases in the line of historical wildfire paths. These communities have a diverse range of expectations and experiences in relation to bushfire management. Key future growth areas in bushfire-prone regions include the Shoalhaven and South Coast, Hunter Valley and Central Coast, the Mid North Coast and in the Byron–Tweed area. The result will be a significant expansion of the rural–urban population exposed to bushfire impacts, and an expansion of the areas of NPWS-managed reserves requiring increased community protection. Increased ignitions have also been associated with rapid growth urban areas (NSW Government 2011).

5.2 Ageing population and increasing community vulnerability

The elderly and very young generally have significantly greater vulnerability to bushfires than those in other age groups. NSW has an ageing population: by 2051, those 65 years and over will have almost trebled to 2.36 million – more than one-quarter of the NSW population. Much of the growth in bushfire-prone areas of coastal NSW will be due to migration of older groups. The Mid North Coast is expected to have the highest proportion of the population aged 65 years or more in 2031 (35%). Other regions of coastal NSW will also have high proportions aged 65 years or more in 2031, all greater than 30% of their populations (ABS 2008). Over the same period, the loss of young adults from coastal towns to cities is projected to continue, suggesting a major shortfall in the recruitment of younger people to participate in volunteer bushfire and emergency organisations.

5.3 Climate change impacts

Current climate change modelling indicates changes in rainfall patterns across NSW (Figure 10). It is also likely that drought conditions will prevail for longer periods and more often. This means more of the landscape will be in a bushfire-conducive condition, and more often. Climatic conditions which contribute to large and intense bushfires (such as prolonged drought, low humidity, the number of days with high temperature and high wind speeds) are expected to increase (DECCW 2010a).

For example, modelling suggests that the number of very high and extreme bushfire danger days, the days on which high-impact wildfires burn, may increase by 4–25% by 2020, and by 15–70% by 2050 (Hennessy et al. 2005).

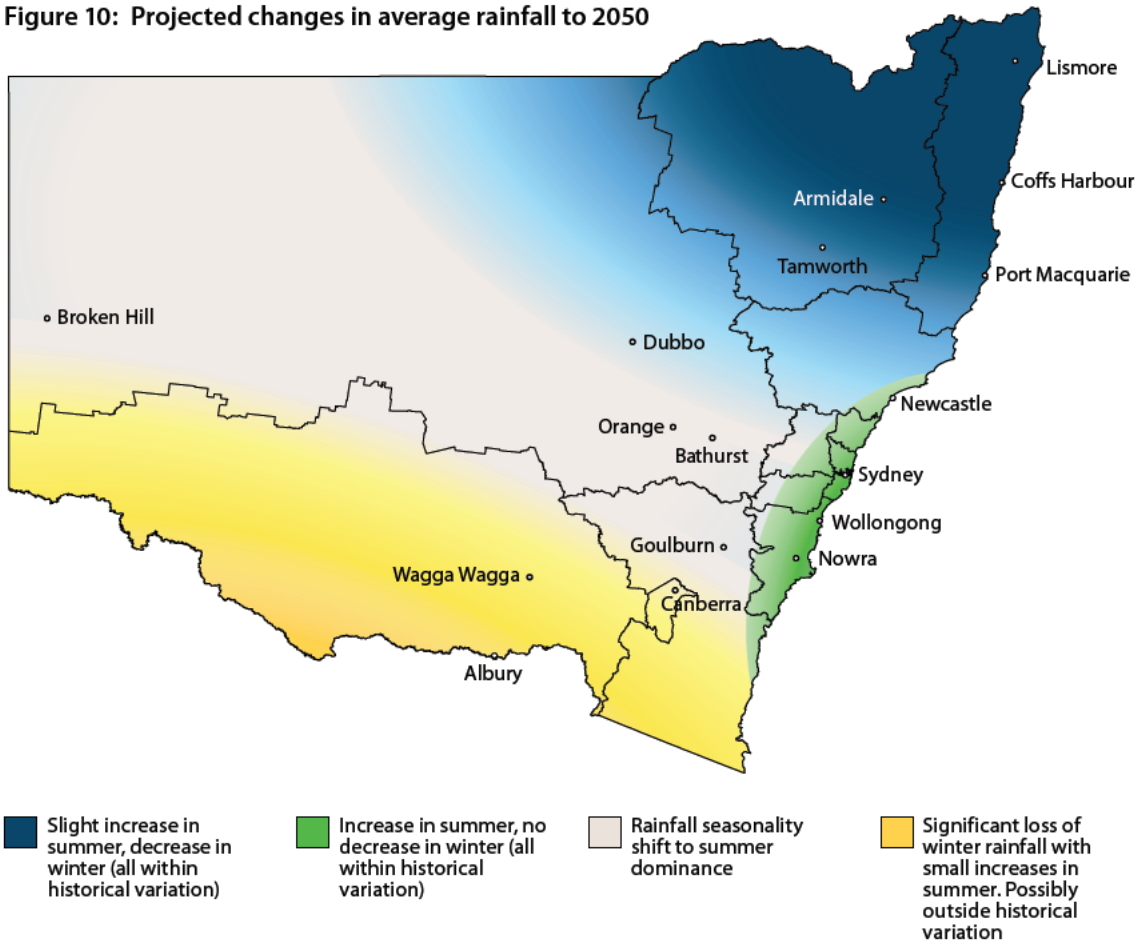
Therefore, over the remainder of this century, the incidence and severity of wildfires is likely to significantly increase in most bushland and rangeland areas, with the likely result that wildfire loss, damage and suppression costs will increase commensurately. More frequent, large, high-intensity wildfires will mean increased carbon emissions, a shift toward younger forests and, as a consequence, reduced carbon storage and greater water usage. Increased erosion and threats to water quality in forested water catchments may result, and increased threats to biodiversity from further bushfire regime shifts toward frequent, large and higher intensity wildfires are likely (DSE 2008). However, the return period of wildfires is likely to remain within the current domain of acceptable intervals for most vegetation classes (DECCW 2010a).

Many threatened species, populations and ecological communities are under pressure from a range of threats including habitat clearing and fragmentation, invasive animal impacts (for example predation, competition and habitat degradation), weed invasion, altered hydrology and altered bushfire regimes. Climate change impacts will add to, and potentially exacerbate, the range of pressures already adversely impacting on ecosystem function. Therefore, to increase the resilience of ecosystems to the added impacts of climate change, it will be important to effectively manage the range of other human-induced impacts, including inappropriate fire regimes.

In the future, larger and more intense wildfires are likely to impact areas that are traditionally less fire prone (wet forests and refuges such as canyons that in the past have been protected by their topography) with the potential to change forest structure and composition. Species that are highly sensitive to bushfire are likely to disappear, while those that depend on old or dead hollow-bearing trees and woody debris are likely to have less habitat. Small patches of bushfire-sensitive ecosystems in a matrix of extensive drier vegetation are most at risk. More extensive bushfire combined with drought stress is likely to decrease the flowering of plants such as banksias and eucalypts in dry forests and heaths, impacting on nectar-feeding animals.

Conversely, while a future climate may contain a higher incidence of drought and warmer days, leading to elevated fire danger, this may not result in an increase in burnt area across the state. As acknowledged in the *NSW Climate Impact Profile* (DECCW 2010a), there is a reasonable chance that these conditions may cause a decrease in fire in western NSW in the coming decades. In the longer term, this tendency could ultimately diminish fuel loads in the most productive ecosystems such as forests, with a resultant decline in fire. These speculative changes illustrate that fire is limited by differing factors in various ecosystems, and changes to these limitations need to be taken into account.

Figure 10: Projected changes in average rainfall to 2050



Source: DECCW (2010a)

5.4 Long-term impacts of past fire management practices

Past land and bushfire management practices have had a significant impact on fire regimes. Wildfire trends in NSW over recent decades indicate an increase in the number and size of large wildfires in prolonged drought-affected seasons. Analyses of similar bushfire trends in Victoria, Canada and the USA have linked these trends with improved bushfire suppression effectiveness and declining use of fire for land management. The success of past prevention and suppression efforts in restricting the area burnt by low to moderate intensity wildfires in mild and average fire seasons gives rise to more extensive areas with high fuel accumulation and connectivity in the landscape. This has the unintended consequence of increasing the potential for more severe wildfires during drought. When wildfires start in drought-affected seasons and are subject to adverse fire weather, large destructive wildfires will result that are very difficult and costly to contain. From a life and property perspective this has the consequence of placing people and homes at extreme risk during these times. From an ecological perspective, this may have the effect of reducing the variety of fire regimes or producing inappropriate fire regimes.

5.5 Managing the future fire mix

The primary fire management objectives for NPWS include managing the risk of wildfire impacts to life and property and managing fire regimes to maintain and enhance biodiversity. Given that land and fire management practices are already under pressure in the face of present wildfire risk levels, and due to the potential increase in the threat of wildfires due to climate change, some changes to current land and fire management practice will be necessary if these escalating risks are to be managed.

In order to manage escalating risks to these objectives a combination of strategic prescribed burning and rapid response to wildfires will be used. Over the last 20 years the average ratio of area burnt by wildfire to prescribed burns on NPWS lands is about 5:1. Over the next 10 years NPWS aims to decrease the area burnt on park from wildfires relative to the area burnt from prescribed burning, and to continue to reduce the average size of wildfires.

By strategically implementing prescribed burning, NPWS can meet its legislative drivers and plan where, when and how to use fire to achieve its management objectives and at what cost, thus giving NPWS greater control over the intensity, timing, location and costs associated with fire management. Using the state-wide bushfire zoning system and its reserve fire management strategies, NPWS will prioritise hazard reduction activities in APZs and SFAZs to reduce the risks to life and property and to provide strategic areas of fire protection to aid containment, while maintaining biodiversity values and thresholds in LMZs which make up 90% of the parks and reserves. Where the variety of fire regimes is reduced, intervention with prescribed burning can be used, particularly in dry forest, woodland and native grassland ecosystems, to increase variation in vegetation structure and seral stages, to improve habitat variety and biodiversity outcomes.

By using improved detection techniques and implementing an enhanced rapid response program, NPWS can react quickly to ignitions in parks and reserves and manage them accordingly.

If prescribed burning is planned strategically, to link other recently burnt areas or naturally less flammable areas and align with fire trail networks and areas of mechanical fuel reduction, there will be improved opportunities to contain or reduce the extent of drought season wildfires in the future.

5.6 Bushfire research priorities

Historically, key advances in Australia's fire management capacity have been underpinned by high quality, scientific and operational bushfire research. NPWS plays an active role in fire research which targets understanding of how native flora and fauna respond to fire, and how to minimise the extinction risks of species sensitive to particular patterns or regimes of fire while balancing this with the protection of life and property in and adjacent to the reserve system. Research is carried out by scientists and other personnel throughout the organisation, and through various collaborative projects with external organisations such as universities, on the behaviour, management and impact of fires. NPWS and OEH scientists also participate as invited members of a number of research and management committees, specialist panels and highly respected international research teams.

Through sponsorship and collaboration with the Centre for Environmental Risk Management of Bushfires (CERMB) at the University of Wollongong, the Bushfire CRC and other research institutions where appropriate, NPWS in collaboration with the RFS, Forests NSW and Fire and Rescue NSW is encouraging and facilitating research on fire regimes and climate change, developing a better understanding of how fire regimes respond to differing management scenarios and environmental variation (terrain, weather, vegetation), understanding how and why fuels differ across time and space, understanding and applying Aboriginal cultural burning practices with Aboriginal communities, and investigating the use of prescribed fire to mitigate emissions and improve carbon sequestration potential in Australian ecosystems.

An important consideration over the next 10 years will be maintaining the momentum that has been established through these jointly commissioned research projects and translating acquired knowledge into practice. This research mission has been translated into seven major research priorities for NPWS which are contained in the Bushfire Research Statement. The primary mechanism for achieving these research priorities will be through the OEH Knowledge Strategy, a strategic approach to research which identifies priority knowledge areas and aligns science and research with management, policy and legislative objectives.

Bushfire Research Statement – major research priorities:

1. fuel characteristics and accumulation rates for different vegetation formations and age classes
2. impacts of bushfire regimes on natural heritage values
3. effects of bushfire regimes on ecosystem processes and natural resources
4. effects of climate change on bushfire regimes and biodiversity
5. impacts of bushfire regimes on Aboriginal and historic heritage values
6. bushfire risk assessment and fire behaviour modelling
7. bushfire suppression effectiveness.

Source: NPWS (2010); Appendix A

6 Fire management vision, objectives and principles

Vision

NPWS is leading in fire management for conserving biodiversity and cultural heritage, and fighting fires cooperatively with other fire authorities to protect life and property.

Objectives

NPWS fire management objectives are to:

1. protect life, property and community assets from the adverse impacts of fire
2. develop and implement cooperative and coordinated fire management arrangements with other fire authorities, reserve neighbours and the community
3. manage fire regimes to maintain and enhance biodiversity values
4. protect Aboriginal sites and places, historic places and culturally significant features known to exist in NSW from damage by fire
5. assist other fire agencies, land management authorities, landholders and Aboriginal communities to develop fire management practices that contribute to conserving biodiversity and cultural heritage across the landscape.

NPWS priorities over the next 10 years fall under four key themes

1. enhancing fire management capacity
2. applying a risk management, best practice approach
3. building and sharing fire management knowledge
4. collaborating with partners and the community.

Fire management principles

- **Public safety** – This is the highest priority in all NPWS bushfire management activities, and includes the safety of firefighters.
- **Cooperation** – Managing the risks associated with bushfires is a shared responsibility. NPWS will continue to work cooperatively with other fire authorities and land managers to reduce the risk of damage from inappropriate fire regimes.
- **Sustainability** – NPWS bushfire management activities will aim to be environmentally friendly, ecologically sustainable and consistent with national park and reserve management objectives.
- **Culturally appropriate practice** – NPWS fire management activities will aim to protect cultural and heritage values and will engage with local communities.
- **Landscape approach** – NPWS will integrate its prevention, preparedness, and response and recovery programs on parks and reserves with similar programs across a broader landscape.
- **Innovation and evaluation** – Innovation and program reviews are essential tools to ensure continuous improvement of bushfire management policies and practice. NPWS will encourage innovation and review of its approach to fire management.
- **Adaptive management** – Best available knowledge will underpin the use of fire and fire regimes by NPWS. Adaptive fire management (learning by doing and monitoring) will be practiced.

7 Fire management strategies, actions and key performance indicators

This section identifies four key themes which form the basis for developing fire management strategies and actions and measuring the agency's performance.

1. Enhancing fire management capacity

- Fire management capacity, including personnel, equipment, technology and infrastructure, needs to be maintained and enhanced to manage bushfires, and meet future fire management challenges.

2. Applying a risk management approach

- Levels of bushfire risk to life and property, biodiversity, and cultural heritage vary within and between landscapes and ecosystems, in response to a range of factors.
- Fire risk varies as seasonal conditions change and fires and land management activities alter fuel quantity and structure in the landscape over time.
- A comprehensive and integrated range of controls (such as planning controls, fire prevention, awareness, mitigation, preparedness, response and recovery) is required for managing risk.

3. Best practice through building and sharing fire management knowledge

- Sound fire management policies, risk management planning, operations programs and procedures should be based on best available knowledge.
- Scientific research is necessary to continuously improve our understanding of: the effects of varying fire regimes on plants and animals, ecosystems, cultural heritage and natural resources; the factors contributing to fire behaviour; the most cost effective fire management practices.
- The sharing of knowledge gained from research and operational practice is central to NPWS aspirations as a 'learning organisation'.

4. Collaborating with partners and the community

- Coordination, cooperation and collaborative partnerships with communities, other fire authorities and other stakeholders are vital to cost-effectively manage wildfire risks and impacts.
- Wildfires are inevitable and do not recognise borders and boundaries and the factors influencing wildfire risks and impacts cross a range of physical, natural, and social science disciplines, and therefore effective bushfire risk management involves a coordinated contribution from everyone.

Within the four key themes, a number of strategies, actions and deliverables have been identified with associated key performance indicators (KPIs). NPWS will report annually on our performance against these measures. These reflect NPWS efforts to ensure that our approach to bushfire management is measurable, aspirational, accountable and conducive to continuous improvement and adaptive management. These strategies and the accompanying KPIs have been developed on the basis of current knowledge and will be reviewed over time in consultation with the National Parks and Wildlife Advisory Council.

Performance measures marked with an asterisk have been jointly developed between NSW and ACT land management agencies responsible for fire management under each agency's jurisdictional obligations. These agencies are NSW NPWS, Forests NSW and ACT Parks and Conservation Service. KPIs in italics will have reporting mechanisms developed over time as relevant data and business systems to support strategies are implemented.

Note: All deliverables and KPIs are measured at state level. A five-year rolling average will be used where appropriate to take account of variable factors, such as long-term weather patterns.

7.1 ENHANCING FIRE MANAGEMENT CAPACITY

Initiative 7.1: NPWS is structured and organised to meet its statutory bushfire management responsibilities.

Strategies	Action	Deliverable
Total capacity Fire management capacity is maintained to ensure that bushfires are controlled safely and damage/loss to life, property, environment values and cultural heritage is minimised.	Complete pre-season readiness activities, i.e. annual fire preparedness days, task-based assessments, fire-crew rostering and procurement of aircraft and equipment prior to the start of fire season [Annual]. Undertake annual review and report on the 2011–16 Enhanced Bushfire Management Program (EBMP).	Review and report on achievements under EBMP [annual review and report June 30; program review and report June 2015]. All NPWS regions identify the full range of fire management activities within their regional operations plans. All identified NPWS positions are filled with competent, current, fit and equipped firefighters or incident management team (IMT) members.
Personnel Field firefighting capacity is maintained to implement bushfire management. A NPWS Fire and Incident Management Section (FIMS) is maintained to develop, support and coordinate bushfire management and aviation policies, procedures and programs and coordinate state-wide incident responses.	Undertake regional fire management operations [Field]. Centrally support planning and coordination of bushfire management [FIMS].	FIMS is established, operates and is reviewed against its approved annual operational plan [31 July]. NPWS maintains IMT and firefighting roles to the minimum standard required under 'Level of Service – Fire Mitigation and Suppression'.
Equipment Fire equipment (such as personal protective equipment, vehicles, tools) is maintained to enable personnel to undertake fire management operations. Effective fire information systems are developed and maintained to improve and support fire management capacity to enhance information sharing and interoperability across government within a whole of government framework.	Complete pre-season readiness activities to ensure fire equipment meets requirements [Annual]. Implement Fire Information Systems Strategic Plan to deliver improved and enhanced fire information systems.	Fire management information systems are reviewed and updated [30 June] and audited [every three years].
Infrastructure Infrastructure is developed and maintained to support bushfire management.	Inspect and maintain essential and important road/fire trail network Inspect and maintain other fire management infrastructure (such as radio system, dams, hydrants, tanks, fire-spotting towers).	All essential and important management trails maintained to BFCC standard. Number of fire management assets by class inspected and maintained in accordance with cyclic maintenance and/or operational plans [>95% by 30 June].

These strategies and actions will be measured against the following KPIs:

Results	Measures (KPIs)
NPWS has overall capacity to manage fire.	% of all fires starting on-park which are controlled within the park boundary [>90%]. Annual average fire size [<400 ha per fire]. *% of wildfires contained within the first shift.** % of roles that are filled with fire management personnel with current competency.* *% of fire management personnel who hold required currencies in their designated role.** *% of all known cultural heritage sites damaged by fire each year [from debriefs, <1%].*
NPWS has competent fire management personnel to manage fire.	
NPWS has the equipment and systems required to manage fire.	
NPWS has the appropriate infrastructure to manage fire.	*To be developed.*

7.2 APPLYING A RISK MANAGEMENT APPROACH

Initiative 7.2: NPWS enhances its bushfire risk and adaptive management practices and incorporates risk management principles into its fire management activities.

Strategies	Action	Deliverable
Planning – framework An adaptive management framework is maintained for bushfire management which includes a contemporary state-wide strategy for bushfire management on parks and reserves (*Living with Fire Strategy*), a bushfire management code of practice (FMM), and reserve fire management strategies (RFMSs).	Undertake strategic reviews of fire management policies and procedures taking account of debriefs, audits and lessons learnt [Annual].	Annual review of FMM [30 June for review; 31 July for adoption]. Annual review of *Living with Fire Strategy* and research plan [30 June].
Planning – risk planning RFMSs are prepared for all parks and reserves and will be regularly reviewed and revised as required. These strategies are prepared within the state-wide bushfire risk management framework and inform annual hazard reduction works programs. Bushfire management activities are incorporated within the OEH corporate risk assessment and audit plan processes.	Review RFMSs and revise where required [Annual]. Incorporate RFMSs into bushfire risk management plans. Comply with recommendations of bushfire risk management plan audits where relevant. Identify bushfire risks within the corporate risk system and audit program.	
Prevention – wildfires Wildfires are minimised through effective strategic fuel management programs, stakeholder and community education and instilling an agency lessons-learnt culture. Fires starting on or spreading onto parks and reserves which are suspected arson are reported to NSW Police and investigated.	Implement strategic fuel management program to reduce the risk of unplanned fire ignitions [see biodiversity and fuel management below]. Incorporate lessons learnt from performance evaluations and fire debriefs into RFMS review and regional operational plan development [Annual]. Report suspicious or known arson bushfires to NSW Police/RFS. Participate in cooperative bushfire arson prevention programs.	All suspected arson caused wildfires reported to NSW Police/RFS.

These strategies and actions will be measured against the following KPIs:

Results	Measures (KPIs)
NPWS fire management practices evolve and improve in response to previous experiences and lessons learnt.	*To be developed.*
NPWS implements RFMSs to facilitate hazard reduction planning and operational response for each reserve.	% of reserves (> 3 months old) covered by an approved RFMS [100%]. % of hazard reduction program planned and scheduled annually [>150% of targets by FMZ approved and scheduled]. *% of fires impacting fire excluded areas.**
NPWS reduces the incidence of unplanned fires on parks.	Number of wildfires.* Number of human-caused wildfires [<1 event per 50,000 ha managed]. *% of prescribed burns which escape planned boundaries [<1%].**

7.2 APPLYING A RISK MANAGEMENT APPROACH

Initiative 7.2 (continued): NPWS enhances its bushfire risk and adaptive management practices and incorporates risk management principles into its fire management activities.

Strategies	Action	Deliverable
Prevention – biodiversity and fuel management Biodiversity is maintained through the use of vegetation biodiversity thresholds, targeted threatened species management and integrated weed management where appropriate. APZs, SFAZs and LMZs are maintained in accordance with FMM standards, and RFMS works schedule. **APZ characteristics:** Management practices should aim to have fuel levels maintained within the overall fuel hazard (OFH) low to moderate range. **SFAZ characteristics:** Management practices should aim to achieve mosaic fuel reduction patterns so that the majority of the SFAZ has an OFH of high or below. **LMZ characteristics:** Management practices should be appropriate to achieve land management objective, for example protecting heritage or mosaic burning.	Maintain the five-year rolling average of annual area treated and burnt (by both hazard reduction and wildfire) on parks and reserves within acceptable/ historical range [3–5%]. Enhance five-year rolling average of annual area treated on parks and reserves by hazard reduction to meet NSW 2021 targets and priority actions [>135,000 ha/yr and >800 activities/yr]. Implement strategic prescribed burning program and rapid response capability to decrease the area burnt on park from bushfires relative to the area burnt from prescribed burning.	Total annual area of park and reserve burnt per annum [3–5%]. Total average area and number of hazard reduction activities [>135,000 ha, >800 activities].
Preparedness Fire management personnel, equipment and infrastructure are maintained and checked through various pre-season readiness activities to ensure that bushfires are controlled safely and damage/loss to life, property, environmental values and cultural heritage are minimised.	Review relevant incident procedure and operating guidelines [Annual] Complete pre-season readiness activities: annual fire preparedness days, task-based assessments, fire-crew rostering and procurement of aircraft and equipment prior to the start of fire season [Annual]. Undertake regional fire management operations [Field]. Complete pre-season readiness activities to ensure fire equipment meets requirements [Annual]. Maintain essential and important road/fire trail network trafficability.	All NPWS state, branch and regional incident procedures reviewed and finalised [31 July]. All regions conduct annual fire preparedness training, equipment checks and task-based assessments in accordance with NPWS procedures [30 September]. All essential and important management trails maintained to BFCC standard.

These strategies and actions will be measured against the following KPIs:

Results	Measures (KPIs)
NPWS delivers the objectives of the RFMS.	% of APZs treated to meet objectives [>90%]. % of SFAZs treated to meet objectives [>70%] % of vegetation formations in LMZs within fire management prescription [<35% underburnt; >50% within biodiversity threshold; <35% overburnt].* *% of prescribed burn objectives met [>95%].** *% of fires impacting fire excluded areas.** % of all fires starting on-park which are controlled within the park boundary [>90%].
NPWS has overall pre-wildfire season capacity to manage fire.	*% of fire management personnel who hold required currencies in their designated role.**

7.2 APPLYING A RISK MANAGEMENT APPROACH

Initiative 7.2 (continued): NPWS enhances its bushfire risk and adaptive management practices and incorporates risk management principles into its fire management activities.

Strategies	Action	Deliverable
Response Fire response action is initiated in accordance with operational incident procedures.		
Recovery Recovery planning to restore environmental damage arising from high-impact fires is completed.	Maintain capacity and participation in interagency BAATs.	Joint agency BAATs identified [Team members and roles identified].
Performance evaluation A structured system of internal reporting against performance measures is used to feed back into the fire management framework to achieve adaptive management.	Prepare and summarise an annual fire performance report in the agency's annual report [Annual].	Annual review and report against NPWS *Living with Fire Strategy* KPI's [31 July].

These strategies and actions will be measured against the following KPIs:

Results	Measures (KPIs)
NPWS contains wildfires to as small an area as possible.	Annual average fire size [<400 ha per fire]. Average size of inappropriate fire contained [ha].* *% wildfires contained within the first shift.** % of all fires starting on-park which are controlled within the park boundary [>90%].
NPWS responds rapidly to put out high risk fires.	Time from report of fire to NPWS to initial Rapid Aerial Response Team (RART) response action to be within acceptable timeframe [>90% of fires responded to in <30 min]. % of bushfires involving RART operations managed to acceptable size [>80% to <10 ha].
NPWS is involved in recovery planning.	*To be developed.*
NPWS fire management practices evolve and improve in response to previous experiences and lessons learnt.	*To be developed.*

7.3 BEST PRACTICE IS ACHEIVED THROUGH BUILDING AND SHARING FIRE MANAGEMENT KNOWLEDGE

Initiative 7.3: NPWS plays an active and leading role in fire management research, in collaboration with other research institutions, to continually improve fire management knowledge. NPWS has effective systems in place to share fire management knowledge and to learn from research and operational practice.

Strategies	Action	Deliverable
Research Research programs are undertaken and/or supported consistent with the attached NPWS Bushfire Research Statement (Appendix A), within the OEH Knowledge Strategy framework.	Implement the NPWS Bushfire Research Statement (Appendix A). Establish and implement bushfire research agreements with universities, communities and industry partners such as the University of Wollongong (CERMB) and the Bushfire CRC. Attend industry-relevant events and report on better practices identified.	Number of published papers, presentations and events attended relating to NPWS fire management practices [Number by category].
Monitoring A fire monitoring program, including preparation of guidelines, tools and data capture methods, is developed and implemented to allow NPWS to actively accrue information on fire impacts and the impacts and success of fire management actions.	Implement EBMP monitoring plan. Complete post burn reports for all prescribed burns.	All area burnt mapped within 14 days of completion. All pre- and post-burn fuel assessments captured.
Evaluation and review A systematic approach to reviewing fire management performance is developed. A framework for tracking the implementation of actions that correct and/or improve current practices is developed. A fire management lessons-learnt culture is implemented.	Incorporate lessons learnt from performance evaluations and fire debriefs into RFMS review and regional operational plan development [Annual]. Incorporate lessons learnt from, for example, fire debriefs and research into the FMM review [Annual]. Incorporate lessons learnt into agency training programs and procedures.	Fire debriefs are conducted for all wildfires on parks and reserves.
Knowledge dissemination and sharing A knowledge dissemination and sharing framework is established and implemented to test and share knowledge gained from research and operational practice.	Develop knowledge dissemination and sharing framework. Communicate fire research and science information to the broader fire management community and stakeholders through a variety of established channels as identified in the framework.	Examples of adaptive management provided in annual fire management report [Number].

These strategies and actions will be measured against the following KPIs:

Results	Measures (KPIs)
NPWS is systematic and thorough in finding and capturing information which is applied in planning and operations to achieve better practice.	*To be developed.*
	% of prescribed burn objectives met.* *% of fires impacting fire-excluded areas.**
	*% of prescribed burns which escape planned boundaries [<1%].**
	To be developed.

7.4 COLLABORATING WITH PARTNERS AND THE COMMUNITY

Initiative 7.4: NPWS continues to strengthen partnerships with local communities, land managers, fire authorities and government departments to improve community understanding of the role of fire in the environment and increase shared responsibility for bushfire risk management.

Strategies	Action	Deliverable
Other fire agencies and partners A high level of commitment and participation at local, state and national levels in fire and emergency management is maintained through: • fire forums • local cooperative arrangements • state and national coordination.	Participate and contribute to international, national, state-wide and local workshops and leadership programs (for example AFAC, forest fire management group (FFMG), BFCC, BFMC and Bushfire CRC). Contribute to the development of national, state-wide and local policies and procedures.	Contribution to BFCC and AFAC and Bushfire CRC [Annual summary of contribution]. Contribution to all bushfire management committees [Number of committees where NPWS is active].
Community Community bushfire awareness programs are contributed to and supported to increase community understanding of the role of fire in the environment and to enhance community resilience. Collaborative partnerships and projects that support capacity building and knowledge exchange with local and Aboriginal communities and stakeholders are developed and maintained. A Community Engagement Strategy for fire management is developed and implemented.	Review and update external web site and printed material [Annual]. Participate in Aboriginal and local partnerships and projects (such as Hotspots, Fire Sticks, FireWise). Implement Community Engagement Strategy.	Contribution to Nature Conservation Council (NCC)/RFS Hotspots and Firesticks programs [person days]. Community engagement strategy developed and reported against annually [developed by June 2012].

These strategies and actions will be measured against the following KPIs:

Results	Measures (KPIs)
NPWS works with other fire agencies to manage fire in NSW, and our partners invite and value our input (and vice versa).	Number of joint agency operations [Classified by agency and activity type]. Number and value of joint research projects [Number and value].
NPWS works with the community to manage fire in NSW.	*To be developed.*

Glossary

The following definitions are taken from the AFAC Bushfire Glossary and include terminology specific to NPWS operations.

Term	Definition
Anthropogenic	Caused by human beings.
Assets	Anything valued by people which includes houses, crops, forests and, in many cases, the environment.
Asset Protection Zone	An area surrounding a residential or other significant asset, managed to reduce the bushfire hazard to an acceptable level. The width of an APZ will vary depending on slope and construction type.
Burnt area	Area burnt by fire (also see treated area).
Bushfire	A general term used to describe a fire in vegetation.
Bushfire-prone lands	A bushfire-prone area is land that can support a bushfire or is likely to be subject to bushfire attack.
El Niño	The extensive warming of the central and eastern Pacific Ocean that leads to a major shift in weather patterns. In Australia, particularly eastern Australia, El Niño periods are associated with an increased probability of drier conditions.
Fire excluded area	An area where the fire management objective is to not have planned or unplanned burning, even if it is as small as a single habitat tree.
Firefighter	Any employee, volunteer or agent of any fire agency who occupies, or is designated to undertake, a role for the purpose of fire suppression.
Firefighting operations	Any work or activity directly associated with control of fire.
Fire management	All activities associated with the management of fire-prone land, including the use of fire to meet land management goals and objectives.
Fire Management Manual	A compendium of policy and procedural information necessary for NPWS to achieve its fire management objectives (DECCW 2010b).
Fuel management	Modification of fuels by prescribed burning or other means.
Greenfield suburbs	Previously undeveloped land generally on city fringes used to create suburbs with low density housing.
Hazard reduction (activities or program)	Activities or programs that modify fuels by prescribed burning or other means. Also referred to as fuel management.
Inappropriate fire	A fire that is on agency-managed land that the agency did not make a decision to ignite or let burn.
Land management zone	An area managed to meet relevant land management objectives.
Peri-urban	Between the outer suburbs and the countryside; peri-urban areas tend to have a higher concentration of individual houses and less public transport.
Prescribed burn	A fire used for prescribed burning.

Prescribed burning	The controlled application of fire under specified environmental conditions to a predetermined area and at the time, intensity, and rate of spread required to attain planned resource management objectives. It is undertaken in specified environmental conditions.
Prescribed fire	Any fire ignited by management actions to meet specific objectives. A written, approved burn plan must exist, and approving agency requirements (where applicable) must be met, prior to ignition.
Reserve fire management strategy	A document that details the desirable fire management regimes and objectives for a NPWS reserve. It assesses bushfire threats within the area, the type and nature of natural and cultural heritage, assets and other facilities within the reserve and includes guidelines for any suppression activities or hazard reduction work to be undertaken within that area.
Risk	The exposure to the possibility of such factors as economic or financial loss or gain, physical damage, injury or delay, as a consequence of pursuing a particular course of action. The concept of risk has two elements: the likelihood of something happening, and the consequences if it happens (AS4360).
Strategic fire advantage zone	An area managed to provide strategic areas of fire protection advantage which may reduce the speed and intensity of bushfires and reduce the potential for spot fire development, and to aid containment of bushfires to existing management boundaries.
Treated area	The area over which a prescribed burn or hazard reduction was conducted; includes unburnt patchiness in the treatment area.
Wildfire	An unplanned vegetation fire, including grass, forest and scrub fires.

Appendix A: NPWS Bushfire Research Statement

Background

Effective and efficient bushfire management for the protection of life and property and for natural and cultural heritage conservation is of paramount importance. It is one of the most important tasks facing OEH in managing protected areas. The task is made more complex by issues such as fragmentation of natural landscapes, weeds and pest animals, climate change impacts and fire regimes on biodiversity, and the juxtaposition of populated and natural areas.

The management of bushfires is a critical component of land management across the NSW landscape. Under the RF Act OEH is both a fire authority and a public authority and, as a result, is responsible for the prevention and control of bushfires on all land under its management. This includes regulating fire use, detection and suppression of wildfires and the implementation of risk mitigation programs to better protect life and property from fires. OEH also integrates its bushfire management programs with adjoining land managers.

OEH's primary bushfire management responsibilities are to:

- protect life, property and community assets from the adverse impacts of bushfires
- develop and implement cooperative and coordinated bushfire management arrangements with other fire authorities, reserve neighbours and the community
- manage bushfire regimes in reserves to maintain and enhance biodiversity
- protect Aboriginal sites and places, historic places and culturally significant features known to exist in NSW from damage by bushfires
- assist other fire management agencies, land management authorities and landholders in developing bushfire management practices to conserve biodiversity and cultural heritage across the landscape.

As the leading environmental and conservation agency in NSW, OEH is responsible for protecting natural resources such as vegetation, soil, water and air; conserving nature, including biodiversity, habitats and landscapes; and protecting significant Aboriginal, social, historic and scientific values. OEH is also responsible for fostering public appreciation, understanding and enjoyment of nature and cultural heritage and their conservation. For example, OEH coordinates the NSW Government's Biodiversity Strategy (DECCW 2010c), which commits all government agencies to working towards conserving biodiversity; the strategy focuses on conservation on both public and private land, and promotes partnerships between government and local communities.

Threatened species in NSW are protected by the *Threatened Species Conservation Act 1995*, which is administered by OEH. The key tasks include developing recovery actions for threatened species, managing threats to biodiversity, certification of environmental planning instruments, and developing BioBanking, an innovative market approach to biodiversity conservation. The threatened species Priorities Action Statement identifies key actions to recover threatened species, some of which relate to fire research.

OEH manages a large network of protected areas such as national parks and nature reserves, as well as supporting other conservation options for land. The reserve system aims to:

- protect the full range of habitats and ecosystems, plant and animal species, and significant geological features and landforms found across the state
- protect the largest and most diverse collection of cultural heritage on public land, including places, objects and features of significance to Aboriginal people, as well as rural, vernacular and working heritage
- protect other important areas, such as places of scenic beauty, landscapes and natural features of significance, wilderness areas, wild rivers, water catchments, popular places for nature-based recreation, and icons and sites of national significance.

Within its primary goal of conserving natural and cultural values across the landscape, OEH has the following objectives:

- to arrest the decline in biodiversity across NSW
- to build an integrated protected area system consisting of national parks, reserves and other public and private land managed for conservation
- to work with Aboriginal communities to conserve and protect objects, places and landscapes of Aboriginal cultural significance
- to support Aboriginal people in the practice and promotion of their culture
- to conserve and protect nature and cultural heritage in terrestrial and marine reserves, and in botanic gardens
- to actively manage key pressures on the reserve system
- to provide opportunities for visitors to enjoy national parks, reserves and botanic gardens, and to build community support for conservation.

The NPW Act states that NPWS is to conduct such scientific research as the Chief Executive considers necessary for, or in connection with, the preservation, protection, management and use of every national park, historic site, state conservation area, regional park, nature reserve, karst conservation reserve and Aboriginal area, and such scientific research as the Chief Executive considers necessary for, or in connection with, the preservation, protection and care of fauna and the protection of native plants and other flora, either separately or in conjunction with other persons or bodies. Under the NPW Act, each park and reserve type contains a management principle which encourages appropriate research and monitoring.

In addition, Section 72 of the NPW Act states that each plan of management prepared for a park and reserves is to consider 'the encouragement of appropriate research into natural and cultural features and processes, including threatening processes'.

Bushfire research structure

Ongoing research is essential to establish and maintain a knowledge base and adaptive management approach for effective bushfire management. It is also necessary to ensure that the bushfire regimes in reserves are appropriate for the long-term persistence of communities, species and populations of native plants and animals, the protection and conservation of cultural heritage, and for staff and visitor safety and enjoyment.
OEH currently supports bushfire research through the following main avenues:

- a specialist Bushfire Ecology Unit in the Scientific Services Division that investigates the ecological and environmental impacts of bushfires
- financial support in partnership with RFS for the Centre for Environmental Risk Management of Bushfires at the University of Wollongong;
- as a stakeholder and member of the Bushfire CRC
- various bushfire research projects carried out by other parts of OEH
- cooperative projects with, and logistical support to, universities and other institutions undertaking bushfire-related research.

A strategic bushfire research statement

It is timely to consider and generate a statement of OEH bushfire research priorities given the large and decentralised nature of OEH, the many people within the agency and outside with an interest or involvement in bushfire research, and the changing landscape, climate, and understanding of bushfire ecology and management systems. This statement of priorities can be used to prioritise and encourage cooperative research and to assist in allocation of OEH resources.

The Science Statement describes the drivers, values and approaches that guide OEH's science directions; the Knowledge Strategy sets the strategic directions for science and research and requires priority areas for knowledge acquisition in OEH. Current knowledge areas for which strategies are being developed are rivers, wetlands and groundwater; biodiversity, and culture and heritage. Fire plays a critical role in at least two of these priority areas.

NPWS's mission for bushfire research is:

> *To work collaboratively with research partners to acquire, apply and communicate knowledge relating to the protection of life and property and the conservation of significant natural and cultural heritage values.*

This mission has been translated into seven major research priorities, each with a set of research questions.

Key OEH Research Priorities

1. Quantifying fuel characteristics and accumulation rates for different vegetation formations and age classes.

Understanding fuel accumulation rates, fuel type loadings and fuel structure in different vegetation formations and classes is very important for bushfire risk assessment, prioritisation of hazard reduction programs and for real-time fire behaviour predictions. Further structured work in this area is vitally important in order to feed into various bushfire behaviour and risk assessment models, such as *Planning for Bushfire Protection* (RFS 2006) and *Phoenix RapidFire* (Tolhurst et al.).

There is also a need to validate rapid assessment techniques for fuel hazard assessment, such as overall fuel hazard assessment and photo guides, for example Project Vesta (CSIRO 2008), and to investigate remote sensing techniques for assessing fuel condition.

Research priorities

- What are the fuel characteristics and accumulation rates for the different vegetation formations in NSW, with priority given to those most bushfire prone?
- What are the differences in fuel characteristics and accumulation rates in NSW vegetation formations (different vegetation classes), and what is the significance of these differences in terms of fire behaviour?
- What are the most cost effective remote sensing techniques for assessing fuel characteristics?
- What is the reliability of the various rapid assessment techniques, such as OFH scores in assessing fuel hazard in NSW vegetation formations?

- What is the most cost-effective methodology (for example, GIS and data warehouse) for assessing, storing and accessing fuel characteristics for the different vegetation formations in NSW?

Outcomes

- increased understanding of fuel type loadings and structure within and between vegetation formations
- improved ability to schedule prescribed burns in order to maintain fuel loads at desired levels
- improved ability to assess relative bushfire potential for prioritising hazard reduction programs
- improved predictions of real time fire spread and intensities for safe and effective fire suppression and community warnings
- increased confidence in the use of rapid assessment techniques for fuel hazard assessment
- better methods for storing, improving reliability and sharing information and knowledge on fuel characteristics of vegetation formations and classes.

2. Impacts of bushfire regimes on biodiversity values

Bushfire regimes have the potential to transform vegetation types, to cause rapid and dramatic change to vegetation structure, to impact on species richness and to cause the local extinction or senescence of threatened species. Some bushfire regimes can also lead to the colonisation of pest animals and weeds in protected areas or can help reduce such infestations.

Comprehensive bushfire environmental assessment guidelines have been developed in NSW (RFS 2006). The guidelines provide standard conditions to be used in approving hazard reduction activities which relate to biodiversity and other values. In particular, guidelines have been developed to cover the protection of threatened species and of ecosystems (fire regimes and fire interval thresholds), and standards relating to minimising the impacts of smoke, soil erosion and stability, and weeds, and for the protection of riparian buffers, Aboriginal heritage, other cultural heritage values, and significant environmental protection areas. These guidelines are based on best available knowledge which is scant and often extrapolated from other areas. The management of fire in bushland areas, including national parks and nature reserves, is based on these guidelines. The guidelines would benefit from focused research and regular review.

Research priorities

- What are the ideal bushfire regimes to promote recovery of threatened species, critical habitats, endangered ecological communities and endangered populations?
- What are the life cycle and vital attributes of those species which are currently absent or poorly known from the NSW Flora Fire Response Database and Fauna Fire Response Database (NPWS 2003), particularly the threatened species?
- What is the extent of any geographical or biophysical variations in species' life cycles and vital attributes?

- What is the relationship between species (flora and fauna) richness and structural composition of vegetation formations under different bushfire regimes?
- What are the impacts of various fire regimes on specialised flora and fauna habitat values, such as tree hollows and logs, and peat bogs?
- What minimal impact techniques might be most cost effective in restoring critical habitats and endangered ecological communities after major fires?
- What is the effect of bushfire regimes on the survival of threatened plant and animal species, endangered populations and endangered ecological communities?
- What are the impacts of various bushfire regimes on feral predator population size and predation rates, particularly on threatened species?
- What are the impacts of various bushfires regimes on increased herbivory of threatened species?
- What is the importance of long unburnt sites for conserving biodiversity and habitats?

Outcomes are improved guidelines for assessing and minimising the impacts of hazard reduction and wildfire suppression activities on threatened species and other significant fauna, endangered ecological communities and endangered populations.

3. Effects of bushfire regimes on ecosystem processes and natural resources

Bushfire regimes are the combination of fire frequency, fire intensity, season of occurrence and spatial distribution of bushfires as they affect a particular ecosystem. Bushfire regimes will impact on ecosystem processes and function and natural resources in different ways. It is important to understand these differences when planning for catchment protection and natural resource conservation.

Research priorities

- What is the impact of bushfire regimes on soil formations and on erosion and sedimentation rates, especially in drinking water catchments?
- What is the effect of bushfire regimes on water flows (quantity and quality), especially in drinking water catchments?
- What is the impact of bushfire regimes on nutrient cycling and the carbon cycle?
- How can smoke impacts from bushfires, such as the volume of particulate emissions and smoke plume behaviour, be minimised under different fire weather and behaviour conditions?
- What minimal impact techniques might be most cost effective in protecting drinking water catchments from impacts arising from major wildfires?
- How can fire regimes be used to assist in weed and pest animal management?

Outcomes

- improved understanding of impacts of bushfire regimes on ecosystem functioning and processes particularly related to pest and weed species impacts
- improved operational guidelines for minimising the impact of hazard reduction and wildfire suppression activities on natural resources, such as drinking water catchments and urban air catchments.

4. Effects of climate change on bushfire regimes and biodiversity

Current climate change modelling indicates changes in rainfall and temperature patterns across NSW. It is also likely that drought conditions will prevail for longer periods and more often. This means that more of the landscape will be in a bushfire-conducive condition, and more often. Climatic conditions which contribute to large and intense bushfires (such as prolonged drought, low humidity, the number of days with high temperature and high wind speeds) are expected to increase. For example, modelling suggests that the number of very high and extreme bushfire danger days, the days on which high-impact wildfires burn, may increase by 4–25% by 2020, and by 15–70% by 2050.

Research priorities

- What changes to regional fire weather patterns and bushfire risk may arise as a result of anticipated climate change impacts, and how can these be best managed?
- What is the expected impact of climate change and elevated CO_2 on fuel loads and fuel characteristics?
- What changes to ignition rates and distribution may arise as a result of climate change, for example, fires started by lightning?
- How can the past be used to better explain the future? The use of palaeoecological studies will help to better understand bushfire history of catchment areas and impacts on biodiversity with a focus on those catchments which are vulnerable to climate change impacts, for example Australian Alps, wetlands and rainforest areas.

Outcomes

Improved understanding of climate change and climate change impacts on fire regimes, bushfire behaviour and carbon sequestration at a regional level and the impacts of consequent changed fire regimes on fuel accumulation and distribution and on ecological communities and habitats in order to be better prepared to detect and respond to wildfires, to minimise net atmospheric greenhouse gas emissions and to conserve significant ecosystems.

5. Impacts of bushfire regimes on Aboriginal and historic heritage values

Bushfires can have an adverse impact on the conservation and preservation of cultural sites. A bushfire can destroy archaeologically important Aboriginal sites such as scarred or carved trees and, surprisingly, can damage rock engravings – intense heat can cause exfoliation of the outer rock layers on sandstone rock outcrops and in turn damage rock art.

Bushfires may also damage various items of historical or architectural importance, including homesteads, outbuildings and related developments, surveyor–explorer trees, old mine buildings, convict stockade sites and bridges. High intensity bushfires are likely to be much more important in this regard than low intensity bushfires. Strategic hazard reduction which is designed to reduce the intensity of bushfires near these sites will have a positive impact on cultural sites and objects provided adequate steps are taken to ensure that items are not damaged by the burn.

Research priorities

- What impacts do various fire regimes have on rock types and lithic plant communities, and what impacts might be expected on associated Aboriginal rock art and in what circumstances?
- What are the impacts of bushfire smoke on Aboriginal rock art, and what steps can be taken to minimise these impacts?
- What asset protection guidelines are appropriate for various cultural heritage sites and places?
- What information exists on Aboriginal traditional practices and stories regarding the use of fire, and where and how is this knowledge best applied?

Outcomes

Increased participation of Aboriginal people in shaping fire management practices in order to build employment opportunities and enliven cultural practices and to better understand the impacts of fire regimes on Aboriginal sites in order to improve guidelines for their protection.

6. Bushfire risk assessment and fire behaviour modelling

Vegetation and fire history can be used to model fuel characteristics if appropriate research can reliably be used to establish such a relationship. Fuel characteristics, terrain (slope and aspect) and current or standard weather information (drought condition, temperature, humidity and wind speed and direction) can be incorporated into a model which predicts either real time or potential fire behaviour (rate of spread, intensity and spotting distance). When used in conjunction with a fire spread model, relative assessments of bushfire risk and bushfire spread can be made over large areas. This is particularly useful in planning wildfire suppression strategies, for firefighter safety, community safety and warnings, for determining priorities for hazard reduction programs and for urban and park planning. However, such systems are heavily reliant on constant testing of data and the reliability of fire behaviour models. A systematic approach to ongoing testing and validation is required.

Research priorities

- What is the reliability of various bushfire behaviour models in different landscapes and fire danger rating scenarios, and how can they be improved?
- How can information on bushfire behaviour best be characterised, captured, stored and presented to assist in real time and predictive fire spread and fire potential maps and in evaluating various bushfire behaviour models?
- What is the current distribution of bushfire regimes in NSW and how can they best be characterised, standardised and monitored?
- What are the guiding principles to be used in establishing a network of long-term ecological research sites?
- What is the effectiveness of various hazard reduction programs on wildfire behaviour and reduction of risk to life, property and other values?

Outcomes

An improved understanding of the impacts of various fire regimes on ecological communities, the effect of hazard reduction on fire behaviour and more importantly the establishment of a reliable system for monitoring and building knowledge about the effects of fire, fuel accumulation and fire behaviour under various scenarios.

7. Bushfire suppression effectiveness

The safe and cost-effective control of bushfires is an important fire management goal above all others. Because of the global value of such research work, much of the work in this area will be collaborative and more likely to be undertaken on a national basis, with OEH contributing as appropriate.

However, there are some questions which are particularly relevant to agencies responsible for fire management in remote and rugged landscapes, and it is these questions which will be actively pursued by OEH.

Research priorities

- What are the fire break construction rates for different ground crew configurations and for various types of machinery in different landscapes?
- What are the decision rules for the cost-effective use of different types of aircraft in different landscapes and fire danger rating scenarios?
- What remote bushfire detection techniques are most cost-effective?
- What are the patterns of wildfire ignitions in protected areas, and can they be reliably predicted?
- What decision rules should apply for the cost-effective use of fire retardants in different landscapes?

Outcomes

Accumulation of information which can be easily translated into useable and reliable operational data which can assist with establishing methods of cost-effective firefighting and improved firefighter safety.

Governance arrangements

For this research statement to be useful, a governance framework and budget will need to be established to provide accountability and transparency in the promotion of the research priorities and for the accumulation and application of fire management knowledge. A number of groups and divisions in OEH have an interest in this area of research, and a collaborative approach with other land managers, fire authorities and non-government and community groups is proposed in order to maximise cost effectiveness.

Interpretation, dissemination and integration of knowledge of bushfires is critical to the successful adaptive management of bushfires. There is already much knowledge about bushfire management, bushfire planning and the effect of bushfire on biodiversity. However, one of our greatest challenges is the timely uptake and translation of research findings to policy, operational plans and operations. In undertaking research projects aimed at answering the questions listed above it will be very important to regularly communicate with all stakeholders during the course of the research, rather than just at the end. Good communication planning will need to be included in research briefs in order to achieve the most beneficial result for OEH and for the community.

Actions

- The NPWS Fire Management Advisory Committee, or a subcommittee, will be established as the knowledge team for the fire management thematic area within NPWS.
- This research statement will be reviewed annually by the NPWS Fire Management Advisory Committee in collaboration with the Parks and Wildlife Directors Group, the National Parks and Wildlife Advisory Council, the Science Sub-committee of the OEH Executive and targeted NSW Bush Fire Coordinating Committee members.
- An annual implementation plan and report will be prepared to encourage research on the priority questions identified in this research statement.
- Partnerships consistent with the priorities in this research statement will be maintained and funded with the Bushfire CRC and the University of Wollongong Centre for Environmental Risks of Bushfires over the next five years in conjunction with RFS and other fire authorities and land managers.
- OEH will provide direction and feedback to researchers, to communicate findings and best practice with and between staff and the community and to facilitate the translation of research findings into policy, planning and operations. OEH will continue to support the AFAC, RFS and the Nature Conservation Council in these endeavours.
- This research statement and other useful information will be placed on the OEH intranet and OEH website.

Appendix B: Major bushfires in NSW

From a risk perspective, bushfires can be capricious and unpredictable natural hazards. Major losses have been attributed to bushfires in NSW since about 1851, sometimes causing major loss of life, property damage and predominantly short-term impacts on environmental values. The following table identifies some of the worst wildfires in NSW since the mid-1920s.

Fire season, area and regions burnt	Life, property and environmental impacts
2002–03 1,464,000 ha Greater Sydney; Hunter; Northern NSW; Central tablelands; Southern Tablelands; Monaro Alpine; Illawarra; South Coast	3 people killed; 86 houses destroyed; 3400 stock killed. Major impacts also in Canberra (4 lives, 488 houses) and north-eastern Victoria. Fires burnt 75% of Kosciuszko National Park with significant impacts on alpine ash forests, snowgum woodlands and alpine ecosystems, including significant soil losses and initial species decline. The fires which burnt in the ACT caused significant damage to Canberra's water catchment requiring $3.5 million expenditure on catchment repair and stabilisation, and $50 million for upgrades to water treatment facilities to deal with the increased sediment loads.
2001–02 744,000 ha Greater Sydney; Hunter; North Coast; Mid North Coast; Northern Tablelands; Central Tablelands	109 houses destroyed; 6000 stock killed; damage estimated at $75 million. Extensive and severe fire impacts across a high proportion of Sydney's water catchments. Large intense fire impacts in conservation reserves in the Blue Mountains, Wollemi/Hunter region, North Coast and Royal National Park (re-burnt after large fires in 1994).
1997–98 >500,000 ha Hunter; Blue Mountains; Shoalhaven; Pilliga; Sydney	3 people killed; 10 houses destroyed. Large areas of the Pilliga burnt with large impacts on koala colonies, mallee fowl and other fauna. Large fires also affecting water catchment areas south of Sydney.
1993–94 >800,000 ha North and South coasts; Hunter; numerous Sydney peri-urban areas	4 people killed; 206 houses and 80 other premises destroyed. Fires in Royal National Park and the Grose Valley resulted from arson, re-burning areas already extensively burnt in 1987–88, with adverse biodiversity impacts. Large areas of coastal forest and heath communities on the north coast burnt.
1991–92 Sydney and Central Coast peri-urban areas	2 people killed; 14 houses destroyed.
1990–91 >280,000 ha Riverina; Sydney; Central Coast	8 houses destroyed; 176,000 sheep and 200 cattle killed; extensive rural infrastructure damage. Large fires in south-western NSW had broadscale impacts on western vegetation communities, including river red gum forests and woodlands.

Fire season, area and regions burnt	Life, property and environmental impacts
1987–88 180,000 ha Kosciuszko National Park; Sydney; western NSW	4 people killed. Fires in south-eastern part of Kosciuszko National Park, Sydney (Penrith and Sutherland), and western NSW (Bethungra, Yanco, Wellington).
1986 10,000 ha Mount Kaputar National Park	
1984–85 3,500,000 ha Western Division	5 people, 40,000 stock killed; extensive rural infrastructure damage ($40 million). Very large fires burned around 3.5 million hectares in semi-arid western NSW with widespread mortality including from starvation and predation after the fires. Fires were fuelled by prolific grass following good rainfall seasons.
1982–83 60,000 ha Blue Mountains; Sutherland; southern NSW	3 people killed; $12 million of pine forest destroyed.
1979–80 >1,000,000 ha South Coast; Goulburn; Mudgee; peri-urban Sydney	9 people killed; 5 volunteers killed at Waterfall, Royal National Park; 14 houses destroyed in Warringah. Large high-intensity fires on the south coast, particularly near Eden, caused severe damage across large areas. Fires in the vicinity of Eden killed extensive areas of young regrowth forests, from the ranges to the coast. Major fires near Sydney including at Warringah, Wyee, Sutherland and the Southern Highlands.
1978–79 >50,000 ha Southern Highlands; South West Slopes	5 houses destroyed; heavy stock losses.
1977–78 54,000 ha Blue Mountains	3 people killed; 49 buildings destroyed.
1976–77 74,000 ha Hornsby; Blue Mountains	3 houses destroyed.
1974–75 4,500,000 ha Western Division from Bourke to Balranald	6 people killed; 50,000 stock lost; more than 10,000 km of fencing destroyed. Extensive areas of mallee and western eucalypt woodlands, grasslands and shrublands burnt with widespread fauna mortality including from starvation and predation after the fires. Fires were fuelled by prolific grass following good rainfall seasons.
1972–73 300,000 ha Kosciuszko National Park; Eden; Queanbeyan; Burrinjuck Dam	

Fire season, area and regions burnt	Life, property and environmental impacts
1969–70 280,000ha Roto; Riverina	1 person killed.
1968–69 >2,000,000 ha Coast and ranges near Sydney, Blue Mountains and Illawarra	14 people killed; about 160 homes and buildings destroyed. Much of the coastal and nearby ranges in the south and the north of the state were burnt in severe drought conditions. Extensive areas of moist sclerophyll forests killed by high intensity fires, with significant impacts on coastal koala populations and other forest-dwelling fauna.
1964–65 530,000 ha Snowy Mountains; Southern Tablelands; Nowra; Sydney	5 people killed; houses, farms and forests damaged.
1957–58 >2,000,000 ha Blue Mountains, particularly around Leura	5 people killed; 158 houses, businesses, shops, schools, churches and a hospital damaged.
1951–52 >4,000,000 ha Inland and southern NSW; Newcastle	11 people killed; 85 homes destroyed; widespread rural damage with major impacts around Wagga Wagga and Newcastle. Extensive areas of western forest and woodland burnt and major fires in the Pilliga. These fires had significant impacts on semi-arid ground-dwelling mammal populations, including bilbies.
1944 Blue Mountains; Hornsby; Sutherland; Cessnock; Gosford	2 people killed near Lochinvar; 150 buildings destroyed, including more than 20 homes, shops, kiosks and lookouts in the Blue Mountains, homes at Cowan, seven in Gosford, four in Riverstone, and seven in Windsor. Extensive bushland, crops and state forest damaged.
1938–40 >2,400,000 ha The Riverina near Griffith; Yass; Canberra	13 people killed; more than 400 buildings destroyed. Serious bushfires in mountainous regions in the south of the state; the worst fires in the history of Canberra; thousands of acres of valuable timber, crops and pasture destroyed.
1926–27 >2,000,000 ha North Coast; Newcastle area; Canberra; Albury; Dubbo; Griffith	8 people killed.

Source: Adapted from various sources, including Ellis et al. (2004)

References

ABS (2008) *Australian Demographic Statistics December 2008*. Australian Bureau of Statistics. www.abs.gov.au/AUSSTATS

ABS (2010) *3218.0 Regional Population Growth, Australia 2008-09*. Australian Bureau of Statistics www.abs.gov.au/AUSSTATS

BoM (2008) Bureau of Meteorology. www.bom.gov.au/cgi-bin/climate/change/timeseries.cgi?variable=tmean&region=nsw&season=0112

BoM (2009) *Recent and Historical Climate Maps*. Bureau of Meteorology. www.bom.gov.au/climate/

Bradstock R and Kenny B (2003) An application of plant functional types to fire management in a conservation reserve in south-eastern Australia, *Journal of Vegetation Science* 14: 345–54

Bradstock R, Keith D, and Auld T (1995) Fire and conservation: imperatives and constraints on managing for biodiversity, pp. 323–33, in Bradstock R, Auld T, Keith D, Kingsford R, Lunney D and Sivertsen D (eds), *Conserving biodiversity: threats and solutions*, Surrey Beatty and Sons, Sydney

Bryant C (2008) Deliberately lit vegetation fires in Australia, *Trends and Issues in Crime and Criminal Justice* No. 350. Australian Institute of Criminology

COAG (2012) *National Bushfire Management Policy Statement for Forests and Rangelands*. Forest Fire Management Group, Council of Australian Governments

CSIRO (2008) Project Vesta: Fire in Dry Eucalypt Forest, Fuel Structure, Fuel Dynamics and Fire Behaviour, CSIRO Publishing, Melbourne

DECC (2008) *New South Wales National Parks Establishment Plan*. Department of Environment and Climate Change NSW, Sydney. www.environment.nsw.gov.au/protectedareas/npestabplan.htm

DECCW (2010a) *NSW Climate Impact Profile: The impacts of climate change on the biophysical environment of New South Wales*. Department of Environment, Climate Change and Water NSW www.environment.nsw.gov.au/resources/climatechange/10171climateimpactprof.pdf

DECCW (2010b) *Fire Management Manual*. Department of Environment, Climate Change and Water NSW

DECCW (2010c) *Draft NSW Biodiversity Strategy 2010–2015*. Department of Environment, Climate Change and Water NSW

DSE (2008) *Living With Fire: Victoria's Bushfire Strategy*. Department of Sustainability and Environment, Melbourne

Ellis S, Kanowski P and Whelan R (2004) *National Inquiry on Bushfire Mitigation and Management*. Commonwealth of Australia, Canberra

Flannery T (1994) *The Future Eaters: An Ecological History of the Australasian Lands and People*. Grove Press

Forest Fire Management Group (2007) *The place of fire in the Australian environment*. Commonwealth of Australia, Canberra

Hennessy K, Lucas C, Nicholls N, Bathols J, Suppiah R and Ricketts J (2005) *Climate change impacts on fire-weather in south-east Australia*. CSIRO, Canberra

Kenny B, Sutherland E, Tasker E and Bradstock R (2004) *Guidelines for Ecologically Sustainable Fire Management*. NSW National Parks and Wildlife Service

Lucas C, Hennessy, K, Mills G and Bathols J (2007) *Bushfire Weather in Southeast Australia: Recent Trends and Projected Climate Change Impacts*. Bushfire Cooperative Research Centre, Melbourne

NPWS (2003) *NSW Flora and Threatened Fauna Fire Response Database*. NSW National Parks and Wildlife Service

NPWS (2010) *NPWS Bushfire Research Statement – Bushfire research priorities for NPWS*. NSW National Parks and Wildlife Service

NSW Government (2004) *Guidelines for Ecologically Sustainable Fire Management*. NSW Government, Sydney

NSW Government (2011) *NSW 2021 – A Plan to Make NSW Number One*. NSW Department of Premier and Cabinet. www.2021.nsw.gov.au/

RFS (2006) *Bush Fire Environmental Assessment Code for New South Wales*. Rural Fire Service NSW

RFS (2006) *Planning for Bushfire Protection*. Rural Fire Service NSW

Tolhurst K, Chong D and Duff T, *Phoenix RapidFire – a bushfire simulator and risk assessment decision support tool*. Bushfire Cooperative Research Centre

Watson P (2011) *Fuel load dynamics in NSW vegetation. Part 1: Forests and grassy woodlands*. Centre for Environmental Risk Management of Bushfires, University of Wollongong

Watson P, Penman S and Horsey B (2012) Data from the UoW fuel hazard study, by vegetation type and time-since-fire. Centre for Environmental Risk Management of Bushfires, University of Wollongong

Westerling AL, Hidalgo HG, Cayan DR and Swetnam TW (2006) Warming and earlier spring increase western US Forest Wildfire Activity, *Science* 313, 940–3

Whelan R, Kanowski P, Gill M and Andersen A (2006) *Living in a land of fire*, article prepared for the 2006 Australia State of the Environment Committee, Department of Environment and Heritage, Canberra

www.environment.nsw.gov.au